Public Input No. 207-NFPA 70-2019 [Global Input]

"no less than"
change to
"not less than"

Statement of Problem and Substantiation for Public Input

The term "no less than" is used approximately 6 times in the NEC.
The term "not less than" is used approximately 881 times in the NEC.

Reason for the global change is for consistency, and to comply with the style manual. The "no less than's" can be found in:

Definitions, Overcurrent Protective Device, Branch-Circuit.
240.21(B)(4)(9)
430.109(F)
600.32(A)(4) [appears twice in this section]
691.1

Submitter Information Verification

Submitter Full Name: Nick Sasso
Organization: Clark County Building and Fire
Street Address:
City:
State:
Zip:
Submittal Date: Thu Dec 26 19:34:36 EST 2019
Committee: NEC-P01

Copyright Assignment

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Public Input No. 259-NFPA 70-2020 [Global Input]

"unless permitted by..." or "unless permitted by Article..."
change to
"unless permitted in..."

Statement of Problem and Substantiation for Public Input

Basically this is just clean up language, and to be in accordance with section 4.1.2 of the style manual. Let's pick one or the other. I believe that the correct language should be "unless permitted in..."

The unless permitted by's are located in:

300.13(A)

348.20(A)

356.20(A)

411.5(B)

625.46

626.26

725.136(A)

760.136(A)

The unless permitted in's are located in

225.30

230.2

348.20

356.20

411.5(B)

625.46

626.26

725.136(A)

760.136(A)

Submitter Information Verification

Submitter Full Name: Nick Sasso
Organization: Clark County Building and Fire
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jan 08 14:31:09 EST 2020
Committee: NEC-P01

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Public Input No. 276-NFPA 70-2020 [Global Input]

(capable of being) locked in the open position

to

(capable of being) lockable open

Statement of Problem and Substantiation for Public Input

There are approximately 21 references to, "capable of being locked in the open position..."
and
there are approximately 26 references to, "capable of being lockable open..."

Let's pick one. Reason for change is consistency throughout NEC

Submitter Information Verification

Submitter Full Name: Nick Sasso
Organization: Clark County Building and Fire
Street Address:
City:
State:
Zip:
Submittal Date: Sat Jan 11 17:27:37 EST 2020
Committee: NEC-P01

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Public Input No. 277-NFPA 70-2020 [Global Input]

(capable of being) lockable open

change to

(capable of being) locked in the open position

Statement of Problem and Substantiation for Public Input

There are approximately 26 references to, "capable of being lockable open..."

and

there are approximately 21 references to, "capable of being locked in the open position..."

Let's pick one. Reason for change is consistency throughout NEC. Personally, I prefer "capable of being locked in the open position."

Submitter Information Verification

Submitter Full Name: Nick Sasso
Organization: Clark County Building and Fire
Street Address:
City:
State:
Zip:
Submittal Date: Sat Jan 11 17:33:21 EST 2020
Committee: NEC-P01

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Public Input No. 368-NFPA 70-2020 [Global Input]

Please provide page headers with the appropriate identifiers to make use of the code less confusing.

Example 1:	Chapter 1 Article 100 - Definitions - PART III - Haz Locs
Example 2:	110.31 Article 110 - Reqs for Electrical Installations -Part III - OVER 1000 VOLTS nom
Example 3:	Annex C- Tables Informative Annex C - Table C-3 (FMC) cont.

Statement of Problem and Substantiation for Public Input

Earlier versions of the document included shorthand page headers that greatly improved user ease of finding the correct code sections. As written now the document is confusing with important distinctions hard to ferret out. For example the sections that are limited in application to certain voltages or locations may run for pages but the transition to that distinction is hard to find, and any page after the initial distinguishing information is not notated in any way to indicate that a limitation of scope applies.. Identifiers such as Part III Over 1000 volts is not prominently distinguished in the body of the text and is not reflected in the page heading on latter pages, leading to much confusion when using the document in the field. (Earlier versions also had the PART III or similar transitions prominently bold to make finding them easier.) Please accept my apology if this is submitted in the incorrect format or to the incorrect panel or group. This would appear to be a style request more than a code request but I did not find any public input option for style or page headers.

Submitter Information Verification

Submitter Full Name: Joe Kunkel
Organization: NU Electric Co
Street Address:
City:
State:
Zip:
Submittal Date: Sun Jan 26 12:24:46 EST 2020
Committee: NEC-P01

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Public Input No. 454-NFPA 70-2020 [Global Input]

Type your content here: I would like to see one of the two things I have listed happen; either put all definitions in article 100 no matter how many times the term is used throughout the NEC or keep the NEC at the current format limiting article 100 for definitions of terms used more than twice in the NEC and using xxx.2 for definitions that are only used in that particular article. Do not use xxx.2 for anything besides definitions. Currently if an article does not contain any definitions, xxx.2 is used for anything. Example; 90.2 SCOPE, 110.2 APPROVAL, 200.2 GENERAL, plus many other articles, although this change would not in essence save lifes, it would add consistincey to the NEC, ...

Statement of Problem and Substantiation for Public Input

This would add consistency to the NEC,

Submitter Information Verification

Submitter Full Name: Ray Pritchett
Organization: NJATC
Affiliation: Evansville Electrical Training Center IBEW Local 16
Street Address:
City:
State:
Zip:
Submittal Date: Sun Feb 09 22:55:07 EST 2020
Committee: NEC-P01

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Public Input No. 2989-NFPA 70-2020 [Global Input]

Regarding the division of NEC Articles into “Parts”;

Where "Parts" are used to sub-divide NEC Articles by topic, it is proposed to amend the Part description text with a set of brackets that enclose the span of paragraph numbers that is encompassed by the respective Part category.

For example, NEC Chapter 2, Article 210, Part III.

This "Part" text string is represented as;

Part III. Over 1000 Volts

The proposal is to revise this "Part" text string to;

Part III. Over 1000 Volts (210.50-.70)

And, to do the same for all "Parts" of all NEC Articles.

Statement of Problem and Substantiation for Public Input

BASIS FOR CODE REVISION: to facilitate quicker more efficient code searches by providing a context clue via association of the paragraphs that are correlated to the "Part" sub-category. Page-by-page code searches that miss seeing the keyword "Part" somewhere on the page, could now be less prone to such erroneous mis-associations

Submitter Information Verification

Submitter Full Name: John Blissett
Organization: Bernhard TME
Street Address:
City:
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Submittal Date: Thu Sep 03 19:32:38 EDT 2020
Committee: NEC-P01

Copyright Assignment

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Public Input No. 3013-NFPA 70-2020 [Global Input]

Move all definitions in the code to Article 100, arrange them in alphabetical order and without any subdivisions.

Statement of Problem and Substantiation for Public Input

The National Electrical Code has definitions in multiple parts in Article 100 and many definitions scattered through out the code many of them in the .2 section of the articles.
Most of the other standards under NFPA have their definitions in one location and this will allow the NEC the same requirement. The Revisions to the NEC Style require all the definitions to be moved to Article 100.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 03 21:41:22 EDT 2020
Committee: NEC-P01

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Public Input No. 3141-NFPA 70-2020 [Global Input]

Move all definitions in current (2020) NEC text to Article 100. Insert those definitions in alphabetical order. For definitions that apply in only one article, the article number in parentheses shall follow the definition. The CMP responsible for the definition shall be identified in parentheses at the end of the definition following any extract or article information.

Type your content here ...

Statement of Problem and Substantiation for Public Input

This revision provides a more usable code by providing a uniform process to find definitions. Users are currently required to look in multiple locations to determine if a term is defined. Other NFPA codes and standards utilize a single location for all definitions.

Submitter Information Verification

Submitter Full Name: Donald Cook
Organization: Shelby County Department of De
Affiliation: Self
Street Address:
City:
State:
Zip:
Submittal Date: Sat Sep 05 15:11:40 EDT 2020
Committee: NEC-P01

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Public Input No. 3327-NFPA 70-2020 [Global Input]

Review the revisions to the new NEC Style Manual and make changes to comply with the Style Manual.

Statement of Problem and Substantiation for Public Input

The NEC Style Manual has been revised and every code making panel needs to review the manual and make changes to their code articles to comply with the Style Manual revisions.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 07:31:11 EDT 2020
Committee: NEC-P01

Public Input No. 3328-NFPA 70-2020 [Global Input]

Review the Articles with multiple parts to comply with the revisions made to the NEC Style Manual. Make changes based on the Style Manual revisions.

Statement of Problem and Substantiation for Public Input

Section 2.1.4 was revised by adding the last two sentences. Where an article contains multiple parts and includes general installation requirements, such requirements shall be located in the first part titled “Part I. General”. Part titles shall be descriptive and as concise as possible.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 07:34:42 EDT 2020
Committee: NEC-P01

Public Input No. 3329-NFPA 70-2020 [Global Input]

Revise the Definition Title Structure to comply with the NEC Style Manual.

Statement of Problem and Substantiation for Public Input

Review the Style Manual Revisions in 2.2.2.3 Definition Title Structure. Definitions that have sub-parts shall be listed alphabetically by the base term, with a comma and then the modifying descriptor.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 07:36:42 EDT 2020
Committee: NEC-P01

Public Input No. 3330-NFPA 70-2020 [Global Input]

Verify that all exceptions are written in completed sentences.

Statement of Problem and Substantiation for Public Input

The NEC Style Manual requires that all exceptions are written as complete sentences in accordance with 3.1.4.1.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 07:40:56 EDT 2020
Committee: NEC-P01

Public Input No. 3331-NFPA 70-2020 [Global Input]

Revise the definitions in Article 100 to include an acronym, as desired, for subsequent use in the NEC without having to state the term.

Statement of Problem and Substantiation for Public Input

The permitted use of acronyms in the NEC has changed with the Style Manual revisions in 3.2.3. When a term is defined in Article 100 and includes an acronym, that acronym is permitted to be used elsewhere through out the code.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 07:43:12 EDT 2020
Committee: NEC-P01

Public Input No. 3332-NFPA 70-2020 [Global Input]

Review the structure of all Informational Notes to comply with the revised NEC Style Manual.

Statement of Problem and Substantiation for Public Input

Sections 3.1.3.1 and 4.1.3 of the revised NEC Style Manual includes designed structure for references in Informational Notes.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 07:48:58 EDT 2020
Committee: NEC-P01

Public Input No. 3333-NFPA 70-2020 [Global Input]

Review all references to articles or parts of articles to comply with the Style Manual.

Statement of Problem and Substantiation for Public Input

Section 4.1.4 References to a Part Within an Article. Except for Article 100, references shall not be made to an entire article. References to parts within articles shall be permitted.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 07:50:17 EDT 2020
Committee: NEC-P01

Public Input No. 3335-NFPA 70-2020 [Global Input]

Review the use of Parts within an article and the section number for parts of an article.

Statement of Problem and Substantiation for Public Input

The code panels need to review the sections under their purview to comply with the revisions made to the NEC Style Manual. 2.4.2.1 Parts. If an article is subdivided into parts, it is recommended that the section numbering within each part start with the next decade as a minimum to allow for future growth. New or significantly reorganized articles shall follow this numbering convention. Where an article has multiple parts, Part I. shall be titled “General”.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 08:02:00 EDT 2020
Committee: NEC-P01

Public Input No. 3336-NFPA 70-2020 [Global Input]

More than one informational note in a section or subdivision shall be consectutively numbered.

Statement of Problem and Substantiation for Public Input

The numbering of informational notes need to comply with the changes made to the revised Style Manual.
2.4.3. Numbering Informational Notes. If there are two or more informational notes in a definition, section or subdivision, consecutive numbering of the informational notes shall only occur in that definition, section or subdivision.

Submitter Information Verification

Submitter Full Name: David Williams
Organization: Delta Charter Township
Street Address:
City:
State:
Zip:
Submittal Date: Tue Sep 08 08:10:27 EDT 2020
Committee: NEC-P01

Public Input No. 3490-NFPA 70-2020 [Global Input]

100 Definitions

Defined terminology associated with Manufacture and Construction activities.

1. **The term "Construction" shall be defined as the process of deploying product or installation of a device, material, or item of equipment in accordance to its designated purpose. An owner or owner's agent (e.g. contractor) implements construction at a specific worksite location for either a permanent installation, or a temporary application as permitted by code. Installation shall comply with manufacturer terms and ratings unless permitted otherwise in this code. All code delegated responsibilities for testing, marking, labeling, identification, documentation, etc., which are not the clear accomplished responsibility of the manufacture production process, shall be the due diligence responsibility of those involved with the construction process, unless approved otherwise by the authority having jurisdiction.**

Informational Note: construction applications include, but are not limited to, activities associated with activities involved with: install, field installed, field applied, field tested, field assembled, field evaluation, field wiring, field marking, field conversion, and field labeled.

2. **The term "Fabricated" shall be defined to apply to equipment or an assembly that is neither necessarily listed nor mass-produced. For example, custom equipment, a custom assembly, or equipment that is altered from its original listing. Fabrication may occur in whole or part onsite or offsite. Component parts and materials may be listed, or may be required to be listed by this code or by the authority having jurisdiction. Generally, where fabricated products are permitted by this code, code compliant product qualification shall be by a Field Evaluation Body, where duties typically include: product testing, marking, labeling, identification, standards compliance, product documentation and instructions sufficient for the safe operation appropriate per the application criteria. Fabricated applications also include reconditioned equipment and retrofit equipment, as permitted by this code, wherever equipment is functionally restored to other than conformance to the original manufacturer's equipment ratings and life cycle projections. Fabricated equipment and systems that encompass, in part or whole, any associated construction activities and elements, shall absorb the associated due diligence responsibilities involved, except as approved otherwise by the authority having jurisdiction.**

Informational Note: fabrication applications generally include, but are not limited to, activities associated with pre-fabricated equipment and systems: electrical system assemblies, mechanical system assemblies, and modular building assemblies. Where the assembly is listed as a unit, then the manufacture application responsibilities apply.

3. **The term "Pre-fabricated" shall be defined to apply to those fabricated equipment assembly activities that occur at a site other than the permanent installation location.**

4. **The term "Manufacture" shall be defined as the factory assembly of a product, characteristically mass produced and distributed. Examples include: equipment, wire, devices, material, and compounds. The manufacture process includes production activities including: factory testing, marking, labeling, identification; NRTL Listing where applicable; standards compliance, product document publication for sales and designer specifications including those used for: shipping, install, field**

testing, owner use, and maintenance. By definition, final assembly or other in-field activites of a product at its permanently installed location will not constitute an aspect of manufacture, unless performed by the manufacturer.

Informational Note 1: applications where a product's permanent or temporary installation occurs at a point-of-use location under direct supervision of the manufacturer, the requirement duties of both the manufacture process(es) and associated construction process shall be the responsibility of the manufacturer, except as approved otherwise by the authority having jurisdiction.

Informational Note 2: manufacture applications shall include modular equipment, where an assemblage of different products has been hybridized into a singular unit, when the unitized equipment is listed. Where the unitized equipment is not listed as a unit, then the fabricated application responsibilities apply.

Statement of Problem and Substantiation for Public Input

BASIS FOR CODE REVISION:
The term "construction" is used throughout NEC in reference to code requirements that are aimed at typically different segments of industry, which only occasionally overlap each other's general task sets. Product construction during manufacture is one application, versus product install during site construction. The code text describes both contexts as construction. Where practicable, it would improve functional clarity in code text requirements to employ distinct construction-like terms wherever reasonable and appropriate. The terms and definitions proposed are suggestions; to serve as a basis to move this discussion and consensus forward.
Where code requirements clearly intend compliance fulfillment to be about the product's activities prior to leaving the factory, distinct terminology can communicate this with added clarity. Similarly, where code compliance fulfillment clearly applies to the implementation of a product, as regards its permanent installation, a distinctly defined term for 'construction' will yield improved comprehension as to intended context. A third distinct category can also be established by definition that encompasses fabrication, to serve to encompass custom fabrication assemblies, reconditioned equipment, and retrofits.
Applications where the code responsibility can fall into gray areas for accountability between the three, can be attended to by a default assignment of responsibility. This explicit clarity helps ensure that enforceable code compliance responsibilities are clearly stated. Allowance for an exception, per AHJ acceptance, provides a mechanism to formally transfer an obligation of responsibility.
Where the code speaks to putting an identifying mark, or information, or color onto a cable or item of equipment, it more often refers to those which would intend to be understood as the responsibility of the manufacturer. The following two sets of code citations illustrate where the manufacturer is to provide a mark or color (first set) versus where the installer is to provide a mark or color. The third set of code citations is where it is intuitively apparent that either the manufacturer or installer could either be involved (or both involved) in providing a mark or color on the electrical equipment.
Example requirements for manufacturer marks or color include but are not necessarily limited to; 110.14(D), 110.28, 200.4(B), 200.6, 200.7, 200.9, 200.10(B), 200.10(D), 215.12(A), 215.12(B), 225.30(A)(7), 230.46, 230.66(A), 230.70(B), 230.77, 240.50(C), 240.81, 240.82, 240.83(A&B), 240.83(D), 240.85, 250.28(B), 250.110 Ex3, 250.119, 250.119(A), 250.119(B), 250.119(C), 250.126, 250.28(B), 250.112, 250.114, 250.119, 250.126, 300.11(B)(1), 300.11(B)(2), 310.3(D), Table 310.4(A), 310.6(ABC), 310.8(C)&(D), 310.10(C), 310.10(D), 311.14, 311.16(A), 311.16(B)(1&2)), 311.16(B4&C), 311.32, 314.16(C)(2), 322.56(B), 322.120(C), 336.120, 338.120, 368.12(E), 386.70, 388.70, 406.3(D), 406.3(E), 406.10(B), 406.13 (A-D), 409.110, 430.52(C)(5), 500.8, 501.5, 501.17, 501.105(B)(1), 501.130(A)(1, 502.6, 502.130(B)(1), 502.130(B)(2), 503.130(A), 504.80(C), 505.8, 505.20(B&C), 505.22, 505.26, 506.9(C)(1), 506.9(C)(2), 506.9(D), 517.18(A), 517.19(A), 517.61(C)(2), 530.21(B), 530.22(B), 545.22(A), 551.77(A), 552.10(B)(3), 552.10(E)(2), 555.8, 555.33(B)(2), 600.23(F), 600.33(A)(3), 600.33(A)(4), 690.12(C), 690.51, 694.22(A), 700.10(A), 705.12(D), 705.20, 706.15(C), 708.10(A)(2), 712.37, 725.3(P), 725.179, 760.3(O), 760.30, 760.176(G), 760.179(G)(1), 770.179, 800.182, 805.179, 820.179, 830.90(A)(2), 830.179(C&D), 840.170(B), and 840.170(E).
Example requirements for the installer to do the marks or color indications include but are not necessarily limited to; 200.4(B), 200.6, 210.5(C)(1), 210.5(C)(2), 210.12, 215.12(A), 215.12(C)(1), 215.12(C)(2), 225.30(B), 225.38(C), 225.52(D&E), 230.72(A), 300.5(D)(3), Table 300.50, 310.6(ABC), 311.14, 406.3(E),

406.10(B), 408.3(E)(2), 408.3(F)(1), 408.3(F)(2), 408.3(F)(3), 408.3(F)(4), 408.3(F)(5), 517.18(A), 517.19(A), 517.160(A)(5), 530.21(B), 530.22(B), 547.9(A)(10, 550.33(A), 552.43(C), 620.53, 620.55, 647.4(C), 647.7(A)(4), 668.21(C), 690.54, 690.55, 700.10(A), 712.25, 712.55, 725.124, 760.30, and 770.179(F).

Example requirements for either the manufacturer and/or the installer to do the marks or color indications include but are not necessarily limited to; 230.56, 250.21(C), 250.167(C), 408.3(E)(1), 409.102(B), 430.97(B), 430.109(A)(6), 430.109(E), 517.31(C)(1), 517.31(E), 517.42(E), 520.44(C)(3), 520.54(C), 520.54(J)(1), 520.54(K), 530.21(B), 530.22(B), 550.10(I), 690.1, 690.31(B)(1), 690.31(D)(2), 770.179(G), 805.90(A)(2), and 805.170(A).

As regards reconditioned equipment and retrofit equipment, the code is in its developing infancy as regards code requirements for marks, as they are few, yet likely to grow in upcoming code cycles. Having distinct groups for manufacture, installation, and fabrication also serves to help make obvious, the places in code that similar code requirements between them may be missing but warranted.

Similar to the topic above for equipment marks between manufacture, installation, and fabrication, are topics for labels and signage which are beyond marks.

In NEC Chapter 3,4 and 7 the term “manufacture specifications” can substituted for “construction specifications”. And in NEC Chapter 5 and 6, where specifications have other terminology variations based on product qualities, “manufacture specifications” can be used with such term descriptors for NEC consistency to augment transparency when a code specification is intended to apply to manufacture apart from installation criterion.

Another example benefit from having a distinction between manufacture, installation, and fabrication are for the code required documentation and whom is to provide it. Such as; instructions for shipping, install, or maintenance, versus installer instructions for operation sequence, equipment ratings guidance or site-specific diagnostic protocols.

Where an entity assumes multiple roles of manufacture, installation, and/or fabrication, they are intended to assume the respective responsibilities. And, what those responsibilities are will have improved certainty, when there are improvements to distinctions of terminology and nomenclature. Inspections and commissioning processes will similarly be improved for the same basis of improved enforceable clarity.

SIDEBAR: a supplemental suggestion, in the earnest of minimizing code text where practicable, is to utilize a letter or symbol icon, for use in NEC margins, that correlates to each of the three definitions for, manufacture, versus fabricated, versus construction. For example, a symbol icon for manufacturer (e.g. Hex Note enclosing an 'M'), versus those affiliated with the product install construction process (e.g. Hex Note with 'C'), versus the symbol for the fabrication process (e.g. Hex Note with 'F'). One example of benefit of deploying a symbolic nomenclature is the topic of labels, signage, and markings; which are often able to be grouped by: manufacturer, fabricated, or installer. Each instance in code for label, mark, or sign can include one or more of these three symbols in the margin alongside the code text without adding pages to the code. A raised bar of label and signage compliance is likely the result, plus an improved ease and capacity for enforcement by way of inspection or commissioning.

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Public Input No. 4390-NFPA 70-2020 [Global Input]

When an Article has Parts the revised Style Manual requires the following in 2.1.4.

Part titles shall be descriptive and as concise as possible.

Example:

Part I. General

Part II. Installation

Part III. Construction

Statement of Problem and Substantiation for Public Input

The revised Style Manual requires Article Part titles to be descriptive and concise as possible and provides examples for the code panels to use.

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Public Input No. 4707-NFPA 70-2020 [Global Input]

Globally revise the use of term "Listed", and revise use of the term "Labeled"

To distinguish the NRTL (testing lab) context for the term "labeled" and "listed" from other NEC context uses of these words in all their forms; label, labels, labeling and labeled, it recommended to apply capitalization to the word "Labeled" and "Listed" when intended for this particular context of a testing organization. Capitalization as proper nouns will make this context more readily recognizable.

For additional distinctive clarity for this context of these terms 'listed' and "labeled", apply them with their "NRTL" modifier; and deploy "NRTL Listed" and "NRTL Labeled" throughout the Code text. Of course, all variants formed for grammatical correctness would also be amended and capitalized, such as "NRTL Listing" and "NRTL Label" etc.

In the definitions, it is appropriate to associate NRTL to "Nationally Recognized Testing Laboratory", which is generally the type of testing agency. Any other testing agency, where approved by an AHJ, is allowed. It is also appropriate to include a reference to the industry standard organization that acknowledged to govern this industry acceptance standard for each NRTL, the Occupational Safety and Health Administration (OSHA). With OSHA acknowledged as the official agency, it becomes a Code-legitimized reference, able to facilitate any follow-up enquiries regarding code compliance. To help facilitate back-checks has never been more suitable than in this age of ever-increasing pirating of product and other pretenders to suitability.

Wherever the term 'Labeled' is used as part of 'NRTL Listed and Labeled', it shall refer to the equipment mounted labeling that is pertinent to all of the equipment item's application-specific Listing(s) and shall include the equipment ratings.

Wherever the term 'Marked' is used as part of 'NRTL Listed and Marked' or 'NRTL Listed and Labeled and Marked', 'marked' shall refer to the marking or labeling that is associated with the Listing and shall include the specific qualification of use mentioned in code. E.g. listed and labeled and marked as being suitable for use as service equipment.

Statement of Problem and Substantiation for Public Input

BASIS FOR CODE REVISION:

The term 'Listing' and 'Listed' will be capitalized and treated as a proper noun; short for 'NRLT Listing' and 'NRTL Listed'. The term 'Labeled' will also be capitalized as a proper noun when used to indicate 'NRTL Labeled' or 'Manufacturer Labeled' as regards the manufacturer's terms of use for the equipment. NFPA codes does not capitalize these three terms generally so they are indistinguishable from the other contexts for a list or label. Manufacturer terms of use regarding labeling can include ratings, Listing types, or other declarations of compliance to particular industry standards.

There Code text of NEC 110.3, Part (C) may have intended for equipment generally to be Listed, but technically it is not ever stated. All that is stated is the terms for who will do the testing and evaluation as regards a Listing.

The Occupational Safety and Health Administration (OSHA) is the official agency that recognizes qualified testing laboratories, of which there are 23 approved labs to date. OSHA confirms that NEC's "electrical" sub-distinction of labs in NEC 110.3, Part (C) doesn't formally exist as an industry recognized group. The 'electrical' testing laboratory distinction is an obscure reference used in two other places in the NEC [90.7,

490.48(A)], but not in the NEC's other (14) references of a testing laboratory. Underwriter Laboratories (UL) is the only distinct NRTL lab whose standards are cited in the NEC and there are hundreds of UL citations (see. NEC Informative Annex A). One relevant ATS example is cited in NEC; UL1008 for transfer switches up to 600V. And one relevant ATS example is not cited in NEC; UL1008A for 750V-46kV ATSs. Whether another NRTL lab other than UL may qualify NEC's intent as an "electrical lab" is unknown. The NEC requirements are functional without the "electrical" sub-distinction, and so this likely warrants deletion of "electrical" in an upcoming NEC code revision.

Though these code articles infer an expectation that an ATS shall be used, an ATS is not overtly mandated as required. Only when an ATS is used, then definitive code requirements apply, like a Listing for emergency use.

NEC Article 705 applies to Interconnected Power Production Sources that parallel with the normal source, which is typically the utility supplied power source. There is an incongruence of code due to what NEC 705 allows. That is whenever the 705 code language is interpreted as an absolute permission due to the omission of disallowances of use as an essential-class power system. The code requirement variance compared to similar applications is a risk, because it then grants an emergency power distribution topology absolution because the code language allows it. NEC Article 705 has no requirements for equipment to be Listed for any aspect.

NEC 705 applies to distribution gear that interconnects normal power (e.g. utility) with an alternate source of power (e.g. generator). The 705 distribution gear may serve in place of an automatic transfer switch because the code does not disallow that use. Yet code does not require it be listed for emergency use, nor does it even require the automated switching mechanisms to be electrically operated and mechanically held. The NEC 705 gear has latitude to have more than two sources and more than one load. The function of NEC 705 gear may be no less critical but it is more susceptible to dysfunction than an ATS. It is arguably more important even than any single automatic transfer switch as it can perform the duty of multiple transfer switches or be the power source to many ATSs. It is like using a string to support a chain. This example illustrates how language of one NEC article (705) can permit use of a power distribution topology that is inconsistent to all other instances of code text regarding transfer switching of emergency power, which would otherwise be fairly consistent.

Application Specific Code Requirements

A summary of code findings on power source selection for emergency applications is as follows;

1. FOR ALL CODIFIED POWER SYSTEM TYPES OTHER THAN NORMAL: An ATS shall be NRTL Listed for Emergency Use (and also identified for Standby Use). Exceptions are:

A. Optional Standby Power System (NEC 702; other Listing requirements may apply)

B. Fire Pump (NEC 695; other Listing applies)

C. Interconnected Power Production Sources (NEC 705)

D. Medium Voltage (see caveats below)

2. MEDIUM VOLTAGE CAVEATS:

A. NFPA 99 indicates an ATS <600V must be Listed for the purpose. No mention of requirements for other voltages >600V. Allowance for ATS >600V to not be Listed is one logical inference.

B. NFPA 110 states MV transfer of central plant or mechanical equipment is allowed using electrically interlocked medium voltage circuit breakers; but the equipment branch MV transfer switch is not to include life safety (LS), emergency (RE), or critical branch (CR) loads. By mention of critical branch this code regards healthcare but is not correlated by any healthcare code; neither by NFPA 99 nor by NEC 517. Allowance by Listing omission may be logically inferred for power system types not mentioned; SEPSS (NFPA 111), RSPSS (NEC 701), EQ (NEC 517), FPPSS (NEC 695), FCPSS (NEC 692), and EPSS (NFPA 110). Note that an MV transfer equipment is not disallowed for LS, RE, or CR if the MV switch is separated from mechanical loads. Also, there is no disallowance to separate loads if the MV ATS is Listed.

C. NFPA 70 (NEC) does not mandate a Listing requirement specific to distribution gear generally, including medium voltage (MV) equipment. NEC makes no mention of MV ATSs, nor provides any specific exemption for an MV ATS. That paralleling gear has no Listing requirement at all would apparently extend to MV types of paralleling gear.

3. FOR FIRE PUMP APPLICATIONS: A fire pump's local ATS and/or controller shall be NRTL Listed for electric motor-driven fire pump service. Other transfer equipment upstream of a fire pump ATS does not qualify it as a fire pump ATS also; so only the lower level ATS must meet these 'Fire Pump ATS' requirements.

4. GENERAL REQUIREMENTS: NRTL Listing types compound for each condition of use that applies; 'emergency', 'wet location', etc; whenever the NRTL Listed Use is an available product offering. An ATS must be NRTL Listed for all of the load types to be served. Field labeling by a Field Evaluation Body is an alternate compliance path for a Listing requirement generally, except where a Listing is overtly stated as the only compliance path such as for an ATS and select other NEC applications.

5. OPTIONAL STANDBY APPLICATIONS: Transfer equipment shall be NRTL 'Listed as Transfer Equipment' wherever supplemental circuit protection devices (CPD) are integral to the transfer equipment. No other Listing requirements apply for Optional Standby transfer equipment.

6. INTERCONNECTED POWER PRODUCTION SOURCES are a recognized transfer switch application apart from an ATS. NEC 705 scope only applies to multiple sources if the normal source (e.g. utility) is one of the sources. Where field labeling is provided, the NEC does not mandate any requirement for a Listing of any kind. Even if it is Listed, NEC doesn't require the gear to be NRTL 'Listed as Transfer Equipment' (as CPD optional standby transfer equipment must do), nor 'Listed for Emergency Use' (as all other emergency power transfer equipment must do). Where NEC 705 is applied to critical grade topologies, NEC suffers a glaring omission for any code-required NRTL type validation for a failsafe style of integrity, suitable for essential-class loads.

7. PARALLELING GEAR for automatic transfer switching of multiple sources (apart from an Article 705 type system) has no code article that governs its performance requirements. Only if the paralleling gear is connected to a normal (utility) source must it then comply with NEC 705. But even then the 705 requirements are not up to the usual code standards for critical or emergency gear and so it does not impose any failsafe standard for integrity including associated Listings.

Ironically, NEC 110.3(B) does state (by omission) that only the Listed or Labeled equipment needs to be used in accordance with the equipment manufacturer's instructions. Because the NEC makes no similar requirement of equipment that is not Listed nor Labeled, this equipment category escapes the stipulation to comply with the manufacturer's terms of use. This however is recognizable as nonsense, and an intonation of NEC intent must be interpolated.

NEC 110.3, Part (C) fails to identify that multiple Listings may be required for a product, and that one Listing may not be adequate. An individual separate Listing for each specific category of use is required whenever such Listing categories apply to the conditions of the equipment use.

NEC 110.3, Part (C) also fails to identify NEC's own exemptions for its general requirement that everything be Listed, and whether there are terms for when these exceptions are permitted or disallowed. One category is custom fabricated equipment, of which certain field assemblies may qualify as hybrid sub-category. One other category is equipment that has been reconditioned, refurbished or remanufactured. One final category is non-Listed equipment where NEC has outlined the specific terms of permitted use based on application. The problems arising from potential distinctions of allowances for non-Listed equipment is much more pronounced when the inconsistencies of Listing requirements by specific application are attempted to be put into a proper context (more on this in Chapter 8).

A best practice default for equipment selection is to choose a Listed product whenever one is available, and include each Listing application type that applies. Only when a Listed product cannot meet the design requirement should an alternative be considered; such as a custom fabricated product. Even then, such non-Listed applications shall be responsibly managed to best show coherence to all other code intent toward trustworthy integrity of; the components, the assembly work, and the resultant functionality. And where NEC outlines terms for use specific to "non-Listed" equipment (as done in Chapter 8), it shall be considered an acceptable form of compliance.

The NEC variations of terminology for Listed and for Labeled is diverse but the reason for this inconsistency is not always evident. The numeral in parenthesis is the number of occurrences found for each term in the NEC.

SIDEBAR: As the deadline for 2020 Public Comment is impending, the values and citations from here forward were not back-checked to 2020 NEC from the v2017 they were derived from .

1. Listed (1715), Listing (247), List (9)
2. Approved (473), Approving (2), Approval (44)
3. Labeled (65), Labeling (30), Labels (57), Label (55), Field Labeled (3), clearly Labeled (1)
4. Identified (2), Identifying (35), Identify (41)
5. Marked (647), Marking (555), Mark (31), Marks (3)
6. " Listed for" (332)
7. "Listed and Labeled" (21)
8. "Listed and Labeled for" (2)
9. "Listed or Labeled" (6)
10. "Listed, Labeled, and identified" (18)
11. "Listed, Labeled, or identified" (1)
12. "Prominently Labeled" (2)
13. "Listed, Labeled, and marked" (1)
14. "Listed and Labeled or field identified" (1)

Situation specific NEC requirements for equipment to be "Listed" vary case-by-case, whether by code article, or by site application type, or by equipment category. The way the requirements varied indicate that either code intent is not always consistent, or that the manner in which NEC requirements are written are a mixed bag of inconsistencies. In actuality, it is both.

The code citations below are selected to indicate general requirements and the requirements specific to switch transfer of emergency power sources. Other unrelated code citations are included to illustrate how the code may show consistency and how it shows inconsistency.

1. Listing Requirements by NEC Article

Every material item used for Trailer Parks (NEC 552), RVs (NEC 551), and mobile homes (NEC 550) must be Listed. But not a thing is mandated as needing to be Listed for hospitals (NEC 517), floating buildings (NEC 553), and certain other applications in NEC such as; Cablebus (370), Multioutlet Assemblies (380), Underfloor Raceways (390), Concealed Knob and Tube Wiring (394), Open Wiring on Insulators (398), Outdoor Overhead Conductors Over 1000V (399), Flexible Cords and Flexible Cables (400; though only nearly nil), Fixture Wires (402), Industrial Control Panels (409), Fixed Industrial Heating Equipment (455), Capacitors (460), Resistors and Reactors (470), Equipment Over 1000V (490), Integrated Electrical Systems (685), Interconnected Power Production Sources (705; aka paralleling gear), Circuits and Equipment Under 50V (720), and Energy Management Systems (750).

2. Listing Requirements by Equipment Category

For other NEC articles, the requirements for Listed equipment amounts to an honorable mention of oddities in bits and pieces; not because those bits are especially significant, or associated with criticality. NEC will

mention a Listing requirement for the parenthetically consequential 1% and miss the more essential 99%. Switchgear (408) requires that insulated conductors are Listed, but NEC invokes no other requirements of anything else to do with switchgear to be Listed. There are times that NEC chapters or paragraphs only apply technically for any equipment which is Unlisted.

Most all raceways and cabling, but one, are required to be Listed from the 300 series articles of NEC. But at many points amongst the other code articles, only the fittings are indicated as needing to be Listed. The singular 300-series article for cablebus that was inadvertently skipped, is likely an oversight.

3. Listing Requirements by Application Type

Some aspects of Listings are meant to apply categorically, like a Wet Location Listing for any equipment in wet locations; but NEC consistency is sporadic and omissions prolific where they should apply. This inconsistency is similar to the requirements mentioned for sun exposure considerations.

At some points of code there are common applications with common importance factors but they are treated with uncommon requirements.

4. Observations of Inconsistent and Irrelevant Text

The terminologies for similar types of Listings has aspects of inconsistency, such as the five different terms used for an ATS to be Listed for Emergency Use. The verbiage variations could infer that these refined differences in text vary for good reason (with potentially varying requirements), but under scrutiny they do not.

There are code sentences that are superfluous because the Listing requirement for a subcomponent item being mentioned was already imposed generally at some other NEC article prior. Such as for particular conduit fittings to be Listed. To make matters worse, the requirements at one location in code doesn't always match the other location.

Other code text is a waste of language as the statement is redundant unto itself. Such as stating that use of equipment is okay if the Listing says it's okay. Or employing a double-negative to state that equipment is not to be used in a way that the Listing doesn't say is okay. As a side issue, such statements infer that there are "Listing Instructions" to follow for each Listing type. That such instructions exist and are published respective to Listing types is not affirmed to be an industry accepted understanding. How is it proposed that such reference materials are to be captured with consistent integrity by electrical system designers?

At times one or two specifications or features of the Listing itself, are mentioned with the NEC code text. But the exclusion of the other Listing features beckons follow-up questions as to why a partial redundant mention is relevant for some features of the Listing but not the others.

Some NEC text has inferences that a Listing requirement exists without an actual requirement of a Listing ever being stated overtly, only as an inference that the requirement already exists. Conditional statements employing logical grouping sometimes miss clear meaning due to commas missing at relevant points of the sentence.

The benefit that the above comments hope to achieve is in universal applications of Listing requirements as a categorical default wherever practicable, with caveats to follow as to exceptions or specialty additions, such that taken together, the Code edits would amount to less text and simpler forms of clarity. It would be an aide, perhaps suited to Chapter 9 indexes if nowhere else, to have a running list of all potential types of Listings that may be suited to electrical applications governed by NEC. Of course, such a reference list would be subject to on-going updates, but to see them all is perhaps the opportune way to know them.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4586-NFPA 70-2020 [Definition: Labeled.]	similar topic
Public Input No. 4591-NFPA 70-2020 [Definition: Listed.]	similar topic

Public Input No. 4619-NFPA 70-2020 [Section No. 110.3(B)]	similar topic
Public Input No. 4624-NFPA 70-2020 [Section No. 110.3(C)]	similar topic

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Public Input No. 1888-NFPA 70-2020 [New Part after I.]

TITLE OF NEW CONTENT

Likely to Become Energized: Materials or equipment having a high probability of having voltage applied due to failure of insulation

Statement of Problem and Substantiation for Public Input

This PI introduces a definition for the term "likely to become energized" which is used in various articles throughout the Code such as: 250, 422, 430, 680, 682, and 694. In my experience the term is misunderstood by industry. Additionally the term is vague as to when installers and AHJ's must be concerned with the likelihood of being energized. What determines this likelihood? Annex B of the NFPA Style Manual states: "likely to become energized -- failure of insulation on." Using that as a reference is the basis of the proposed definition with this PI.

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

TITLE OF NEW CONTENT

Likely to become energized. Normally non-current carrying conductive materials enclosing insulated conductor(s), where the conductor(s) are operating at above ground potential in normal operation, and a failure of insulation, connector or termination may energize the conductive material.

Statement of Problem and Substantiation for Public Input

The term "likely to become energized" is used in at least 26 places in the NEC, yet there is no definition or guidance as to when this should be applied. Numerous safety requirements rely on this condition in order to be implemented. There are widely varying interpretations as to the meaning of the terms; a search of electrical "chat" forums will quickly verify how much discrepancy there is. Something so basic and important should not be left to interpretation and inconsistent application of the requirements. The NEC Style Manual contains a definition, but that is inadequate or incomplete and offers no guidance: likely to become energized -- failure of insulation on

A term that is used so widely and that other requirements depend on needs to be better defined. It is well past time for the NEC to offer guidance on this.

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Public Input No. 4337-NFPA 70-2020 [Global Input]

Many diverse undefined terminologies are used to invoke some manner of required approval from an AHJ. It may benefit the clarity of intent to either consolidate the use of terminologies or to define their distinctions in respect to each other, or to do some combination of both.

Statement of Problem and Substantiation for Public Input

BASIS FOR CODE REVISION
Here are examples of the diverse types of AHJ approval requirements in code;
1. Approved means; 215.12(C)(1), 215.12(C)(2), 230.24, 230.30(A&B), 230.40, 230.50(B), 230.51, 230.53, 240.5(B)(1) , 240.21(B)(2&3), 240.67(A), 250.6(B) 250.68(C)(2), 250.70 (4), 250.94 exception (3), 300.4(H), 300.5, 300.5(F), 300.5(K), 300.6(A)(2), 300.6(A)(2), 300.6(A)(3), 300.6(C)(1), 300.6(C)(2), 300.11(C), 300.15, 300.19(B&C), 300.21, 300.25, 300.50(C).
2. Acceptable to AHJ; 500.8(A), 505.9, 506.9(A).
3. Made available if requested by AHJ; 110.31(A)(3), 110.70, 215.5, 225.56(A) 399.30(A), 399.30(B), 691.6, 691.7, 691.8, 691.9.
4. Made available to AHJ; 110.41, 230.95(C), 240.67(C), 240.87(C) 490.48(A), 517.17(D), 590.6(B)(2), 645.27.
5. Given to AHJ prior to energization; 225.56(B).
6. If Adopted by Local AHJ; 220.12(B), 225.22, 225.36.
7. Preventative Maintenance Plan Required by AHJ; 708.6 (A-E)
8. Initial/Periodic Witness Test by AHJ; 700.3(A), 700.3(D), 708.6 (A-E).

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Public Input No. 4460-NFPA 70-2020 [New Definition after Definition: Lighting Track (Track Ligh...]

Likely to Become Energized

Conductive material that could become energized due to electric insulation failure. (CMP 5)

Statement of Problem and Substantiation for Public Input

Add a definition for Likely to Become Energized to Article 100. That phrase is used 25 times in the NEC, only 7 of which are in Article 250. It is described in Annex B of the NEC Style Manual as "likely to become energized -- failure of insulation on", unfortunately most NEC users do not read the NEC style manual. No offense intended to the NEC Style Manual Authors, but it is not nearly as exciting to read as the NEC. Many other terms in Annex B are defined in Article 100. There is a very important distinction between what can become energized compared to what is likely to become energized. I get many questions about what that phrase means in the NEC such as if it is metal then is it likely to become energized. Yes, if it is in contact with or contains energized conductors. The responsibility for this definition should be given to CMP 5.

Submitter Information Verification

Submitter Full Name: Paul Dobrowsky
Organization: Innovative Technology Services
Street Address:
City:
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Zip:
Submittal Date: Thu Sep 10 13:28:46 EDT 2020
Committee: NEC-P01

Copyright Assignment

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

Public Input No. 260-NFPA 70-2020 [Global Input]

rebar

to

reinforcing bar

Statement of Problem and Substantiation for Public Input

Reason for global change is consistency and proper terminology. Current terminology in Article 250 is very inconsistent:

250.50 Exception uses the proper terminology, “steel reinforcing bars.”
250.52(A)(3)(1) uses the proper terminology, “steel reinforcing bars.”
250.53(C) uses the improper term, “rebar.”
250.68(C)(3) uses the improper term, “rebar.”

To reiterate my previous explanation to the panel, the term “rebar” is short for reinforcing bar, and it borderlines on slang. 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…”

All the model building codes reference the American Concrete Institute (ACI) 318 for concrete reinforcement. ACI in section 3.5 calls it “steel reinforcement.”
In addition, ASTM A615 / A615M, Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement uses the proper term.

Rebar should be changed to “reinforcing bar,” and in the instance of 250.53(C), the full terminology “Steel reinforcing bar” should be used.
In 250.68(C)(3), the term “rebar” is repeated seven (7) times. Many of these references could even be changed to simply say, “the extension.” For example for c:
c. {The extension} shall not be used as a conductor to interconnect the electrodes of grounding electrode systems.

Submitter Information Verification

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Submittal Date: Wed Jan 08 18:27:56 EST 2020
Committee: NEC-P05

Public Input No. 389-NFPA 70-2020 [Global Input]

Change Grounding Electrode conductor and Grounding Electrode to Grounded electrode and Grounded Electrode conductor

Statement of Problem and Substantiation for Public Input

this would put the terminology in line with the grounded conductor. the "ED" is sinoinimus with past tense or present statuses as it relates to its function. "ING" is something that has yet to happen such as the function of equipment Grounding conductor when a fault occurs it is grounding the fault back to the source

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: Master Electrician
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Submittal Date: Thu Jan 30 11:52:19 EST 2020
Committee: NEC-P05

Public Input No. 1434-NFPA 70-2020 [Definition: Bonded (Bonding).]

Bonded (Bonding).

~~Connected to establish electrical continuity and conductivity.~~

A metallic path that is mechanically sound enough to reliably provide electrical continuity between metallic objects, with the purpose of eliminating dangerous differences of potential (CMP-5)

Statement of Problem and Substantiation for Public Input

The 2017 definition is "Connected to establish electrical continuity and conductivity." The 2020 revision kept this definition. And that is a shame. I don't think this definition is, well, definitive. What do they mean by "electrical continuity" and how does that differ from conductivity? Can you have a chunk of 4 gage wire that is electrically continuous but not conductive? Or conductive but not electrically continuous? Puzzling....

I like an earlier definition better, so here it is: "The permanent joining of metallic parts to form an electrically conductive path that ensures electrical continuity and the capacity to conduct safely any current likely to be imposed." The reason for the newer definition is it's presumably simpler. People were questioning how they were supposed to know how much current was likely to be imposed. This new definition just gave them something different to question.

My proposal solves the problem created by the previous solution to the definition.

Submitter Information Verification

Submitter Full Name: Mark Lamendola
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Submittal Date: Wed Jun 03 18:28:40 EDT 2020
Committee: NEC-P05

Public Input No. 325-NFPA 70-2020 [Definition: Bonding Conductor or Jumper.]

Bonding Conductor or Jumper.

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

Statement of Problem and Substantiation for Public Input

The term "reliable" is vague and unenforceable. It does not comply with the NEC Style Manual:
Paragraph 1.3 Regulatory Adoption
Because the NEC is intended to be suitable for adoption as a regulatory document, it is important that it contain clearly stated mandatory requirements in the Code text.

Paragraph 3.2.1 Unenforceable Terms
The NEC shall not contain references or requirements that are unenforceable or vague.

Submitter Information Verification

Submitter Full Name: Vincent Della Croce
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City:
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Zip:
Submittal Date: Tue Jan 21 11:19:59 EST 2020
Committee: NEC-P05

Public Input No. 1392-NFPA 70-2020 [Definition: Bonding Jumper, Main.]

Bonding Jumper, Main.

The connection between the grounded circuit conductor and the equipment grounding conductor, or the supply-side bonding jumper, or both, at ~~the service.~~ service equipment and supply-side disconnecting means permitted by 230.82. (CMP-5)

Statement of Problem and Substantiation for Public Input

In the 2020 NEC, CMP 5 added the requirements for supply-side disconnecting means [250.25] to require the supply-side disconnect [230.82] to be bonded the grounded conductor to the EGC, in accordance with 250.24. So, the definition of a Main Bonding Jumper should include the supply-side disconnect requirement. In addition 230.7 contains rules related to service conductors, but since supply-side conductors (supply-side of service equipment) is not considered service conductors then this rule does not apply. Also the rule on bonding metal parts per 250.92 do not apply to supply-side conductors, since they are not service conductors.
Currently there is not term for supply-side conductors, so we have a black hole that needs to be fixed.

Submitter Information Verification

Submitter Full Name: Mike Holt
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Submittal Date: Tue Jun 02 10:43:10 EDT 2020
Committee: NEC-P05

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

Bonding Jumper, ~~Main~~ Service .

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 Input

The word main is non-descriptive within the NEC. The word service is defined and better describes the location of the bonding jumper. By it's own definition the bonding jumper is at the service. This is also consistent with the term Bonding Jumper, System.

Submitter Information Verification

Submitter Full Name: Beau Burton
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City:
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Submittal Date: Wed Jun 03 14:49:38 EDT 2020
Committee: NEC-P05

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

Bonding Jumper, Supply-Side.

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 Input

Currently, the only code section providing any possible clarity on what constitutes a SSBJ is 250.30(A)(2) and only pertains to a SSBJ used in a separately derived system.
The Article 100 definition of a SSBJ defines its purpose but not its material.

Submitter Information Verification

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Submittal Date: Thu Sep 03 16:09:25 EDT 2020
Committee: NEC-P05

Public Input No. 3413-NFPA 70-2020 [Definition: Bonding Jumper, Supply-Side.]

Bonding ~~Jumper~~ Conductor , Supply-Side (Supply-Side Bonding Conductor) (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 Input

Change the term to match the definition. We have used the term Supply-Side Bonding Jumper and the term jumper normally would indicate a connection or a short conductor. The SSBC can be a conductor routed from a transformer to the first disconnecting of a separately derived system. This conductor is not really a jumper as the previous term alluded to and this change will correct the terminology used for the Supply-Side Bonding Conductor (SSBC).

There will be multiple Public Inputs submitted to change the various sections where the term is used.

Submitter Information Verification

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Submittal Date: Tue Sep 08 14:15:33 EDT 2020
Committee: NEC-P05

Public Input No. 940-NFPA 70-2020 [Definition: Effective Ground-Fault Current Path.]

~~Effective~~ Ground-Fault Current Path. , Effective

An intentionally constructed, low-impedance electrically conductive path designed and intended to carry current under ground-fault conditions 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 Input

The placement with in Article 100 leaves this definition isolated from the term Effective Ground Fault Current Path. By changing the way the term is written it will be placed below Effective Ground Fault Current Path. This placement will make it easier for the code user to know that there is a difference between the two terms. This rewritten title of the term is consistent with other terms in Article 100 such as Accessible, Bonding Jumper, Branch Circuit, Cable, Conductor and a few more similarly grouped terms.

Submitter Information Verification

Submitter Full Name: Beau Burton
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City:
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Submittal Date: Mon May 04 13:25:29 EDT 2020
Committee: NEC-P05

Public Input No. 360-NFPA 70-2020 [Definition: Ground Fault.]

Ground Fault Condition (Ground Fault) .

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 Input

This change is clearer and better aligns with the changes to the 2020 NEC resulting from the PIs submitted by the Fault Current Working Group under the Correlating Committee

Submitter Information Verification

Submitter Full Name: Timothy Crnko
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Submittal Date: Thu Jan 23 14:16:38 EST 2020
Committee: NEC-P05

Public Input No. 1730-NFPA 70-2020 [Definition: Ground-Fault Current Path.]

Ground-Fault Current Path.

~~An electrically conductive~~ A path from the point of a ground fault on a wiring system through normally non–current-carrying conductors, grounded conductors, equipment, or the earth to the electrical supply source. (CMP-5)

Informational Note: Examples of ground-fault current paths are any combination of equipment grounding conductors, metallic raceways, metallic cable sheaths, electrical equipment, and any other electrically conductive material such as metal, water, and gas piping; steel framing members; stucco mesh; metal ducting; reinforcing steel; shields of communications cables; grounded conductors; and the earth itself.

Statement of Problem and Substantiation for Public Input

Please remove “electrically conductive” from the definition since it adds no value and can be confusing because the Earth is included in the definition. The ground-fault current path is a path; it doesn't need to be identified as “electrically conductive.”

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
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City:
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Zip:
Submittal Date: Thu Jun 25 16:04:56 EDT 2020
Committee: NEC-P05

Public Input No. 2270-NFPA 70-2020 [Definition: Ground-Fault Current Path.]

Ground-Fault Current Path.

An electrically conductive path from the point of a ground fault on a wiring system through normally non–current-carrying conductors, grounded conductors, equipment, or the earth to the electrical supply source. (CMP-5)

Informational Note: Examples of ground-fault current paths are any combination of equipment grounding conductors of both metallic and wire type , metallic raceways, metallic cable sheaths, electrical equipment, and any other electrically conductive material such as metal, water, and gas piping; steel framing members; stucco mesh; metal ducting; reinforcing steel; shields of communications cables; grounded conductors; and the earth itself.

Statement of Problem and Substantiation for Public Input

Proposed addition to the informational note will remind installers, inspectors, and maintenance workers that the equipment grounding conductor (EGC) can be of a wire type installation of conductors but also included metallic raceways and cable jackets of varying types as found in 250.118..

Submitter Information Verification

Submitter Full Name: Gary Beckstrand
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Submittal Date: Thu Aug 13 08:21:23 EDT 2020
Committee: NEC-P05

Public Input No. 1883-NFPA 70-2020 [Definition: Grounded Conductor.]

Grounded Conductor.

A ~~system or~~ circuit conductor that is intentionally grounded. (CMP-5)

Informational Note: Although an equipment grounding conductor is grounded, it is not considered a grounded conductor.

Statement of Problem and Substantiation for Public Input

The term "System Conductor" is used 12 times in the 2020 NEC and the usage is confined to Articles 100 and 250. In each instance of usage, it is describing a grounded conductor and in 11 of the 12 instances it is part of the term "Grounded System Conductor". The term "Circuit Conductor" is used 81 times throughout the 2020 NEC. The term "Grounded Circuit Conductor" is used 43 times throughout the 2020 NEC and 10 times in Article 250.

In Articles 100 and 250, it is not clear that there is a difference between a "Grounded System Conductor" and a "Grounded Circuit Conductor", these terms appear to be used interchangeably.

If it is not the intent that these terms be used interchangeably:

- Definitions should be provided as proposed in PIs 1881-NFPA 70-2020 and 1882-NFPA 70-2020 to delineate the unique features of a "System Conductor" versus those of a "Circuit Conductor“

- PIs 1883-NFPA 70-2020 , 1906-NFPA 70-2020 , 1892-NFPA 70-2020 , 1893-NFPA 70-2020 , 1904-NFPA 70-2020 , and 1905-NFPA 70-2020 should be disregarded

If it is the intent that the two terms are to be used interchangeably:

- All instances of "System Conductor" should be changed to "Circuit Conductor“

- PIs 1883-NFPA 70-2020 , 1906-NFPA 70-2020 , 1892-NFPA 70-2020 , 1893-NFPA 70-2020 , 1904-NFPA 70-2020 , and 1905-NFPA 70-2020 should be accepted to change instances of “system conductor” to “circuit conductor”

- PI 1881-NFPA 70-2020 may be helpful in this scenario to clarify the meaning of the term ”Circuit Conductor”

- Replacing all instances of "Circuit Conductor“ with "System Conductor" and defining the term "System Conductor" would accomplish the same goal. "Circuit Conductor“ is presently more used throughout the NEC, so the proposal above requires a smaller number of revisions.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1881-NFPA 70-2020 [New Definition after Definition: Conductor, Bare.]	
Public Input No. 1882-NFPA 70-2020 [New Definition after Definition: Conductor, Insulated.]	
Public Input No. 1893-NFPA 70-2020 [Section No. 250.84]	
Public Input No. 1904-NFPA 70-2020 [Section No. 250.187(C)]	
Public Input No. 1905-NFPA 70-2020 [Section No. 250.34(C)]	

Public Input No. 1906-NFPA 70-2020 [Section No. 250.36(B)]

Public Input No. 1892-NFPA 70-2020 [Section No. 250.80]

Public Input No. 1881-NFPA 70-2020 [New Definition after Definition: Conductor, Bare.]

Public Input No. 1882-NFPA 70-2020 [New Definition after Definition: Conductor, Insulated.]

Public Input No. 1892-NFPA 70-2020 [Section No. 250.80]

Public Input No. 1893-NFPA 70-2020 [Section No. 250.84]

Public Input No. 1904-NFPA 70-2020 [Section No. 250.187(C)]

Public Input No. 1905-NFPA 70-2020 [Section No. 250.34(C)]

Public Input No. 1906-NFPA 70-2020 [Section No. 250.36(B)]

Submitter Information Verification

Submitter Full Name: John Cowans
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Submittal Date: Mon Jul 13 15:59:06 EDT 2020
Committee: NEC-P05

Public Input No. 1757-NFPA 70-2020 [Definition: Grounding Conductor, Equipment (EGC).]

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 usually 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 Input

Isolated grounds are permitted, and when these insulated grounding conductors are present the purpose of bonding local metal is handled by the other grounding means. Adding this one word reflects this.

Submitter Information Verification

Submitter Full Name: David Shapiro
Organization: Safety First Electrical
Street Address:
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Submittal Date: Sat Jun 27 21:24:32 EDT 2020
Committee: NEC-P05

Public Input No. 286-NFPA 70-2020 [Definition: Grounding Conductor, Equipment (EGC).]

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 when permitted, the main bonding jumper, system bonding jumper 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 Input

The equipment grounding conductor is allowed to connect directly to the grounded conductor in only a few instances. It will most likely be connected to a main or system bonding jumper which in turn connects to the grounded conductor.

Submitter Information Verification

Submitter Full Name: Mason Flanagan
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Submittal Date: Tue Jan 14 21:19:30 EST 2020
Committee: NEC-P05

Public Input No. 4647-NFPA 70-2020 [Definition: Separately Derived System.]

Separately Derived System.

An electrical ~~source~~ 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 Input

The present definition is frequently misunderstood because the word "source" is not defined in the NEC so it has been incorrectly considered as the supply (primary) to a transformer. The requirements in 250.30 apply to systems that are not directly interconnected to other power systems. Typically, the connection is referring to the output of the power system such as the generator output, output battery connections, transformer secondary, etc. The primary side of a transformer can be from a non-separately derived system but if the secondary is not connected to another system the secondary (output) is separately derived. The intent of this PI is to make the wording clear to the user but not to make any technical change of how it should be applied.

Submitter Information Verification

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Submittal Date: Thu Sep 10 16:15:48 EDT 2020
Committee: NEC-P05

Public Input No. 2038-NFPA 70-2020 [New Definition after Definition: Neutral Conductor.]

Neutral Conductor, Common

A neutral conductor used in a circuit with two or more ungrounded conductors where there is no votlage potential between the ungrounded conductors.

Statement of Problem and Substantiation for Public Input

The term "common neutral" is used in at least two code articles and is a term that is not well understood by many code users. This is is a neutral conductor, but one that is used with two or more ungrounded conductors of the same phase. Since the ungrounded conductors are of the same phase, there is no voltage potential between those ungrounded conductors. This means that the currents are additive on the common neutral conductor. The code user must understand this in order to correctly size a common neutral conductor.

Submitter Information Verification

Submitter Full Name: Don Ganiere
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Street Address:
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Submittal Date: Sun Jul 26 13:01:01 EDT 2020
Committee: NEC-P05

Public Input No. 2634-NFPA 70-2020 [New Definition after Definition: Nonlinear Load.]

Nonseparately Derived System.

An electrical source, other than a service, having a direct electrical connection to circuit conductors of any other electrical source other than those established by grounding and bonding connections.

Statement of Problem and Substantiation for Public Input

The term nonsparately derived system is used in Article 250.35(B) and 702.7(C) and partially defined in Informational Note No. 1 in 250.30. In addition all of the power source connections under the purview of Article 705 would be nonseparately derived systems. Defining the term in Article 100 will provide clarity on what is a nonseparately derived system vs. what is a separately derived system.

Submitter Information Verification

Submitter Full Name: Brian Baughman
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City:
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Submittal Date: Wed Aug 26 09:45:13 EDT 2020
Committee: NEC-P05

Public Input No. 2272-NFPA 70-2020 [Section No. 200.2(A)]

(A) Insulation.

The grounded conductor insulation , if

~~insulated~~
present , shall

~~have insulation that is~~
either:

(1)

~~suitable, other than color, for any ungrounded conductor of the same circuit for systems of 1000 volts~~
for solidly grounded power systems of 1000 volts or less,

~~or~~
and for impedance grounded neutral systems of over

~~1000 volts, or~~
1000 volts, the grounded neutral shall have similar conductor insulation properties, other than insulation color, to the ungrounded conductor of the same circuit.

OR (2)

~~rated not less than 600 volts~~
for solidly grounded

~~neutral~~
power systems of over

~~1000 volts as described in~~
1000 volts, the grounded neutral shall be rated not less than 600 volts.

Informational Note: see 250.184

~~(A).~~
and 225.4.

Statement of Problem and Substantiation for Public Input

1) The numerical list should be broken out to separate numbered sentences for clarity, as consistent to paragraph formatting of all other NEC.
2) Part (1) doesn't explain the context meant by the term "suitable", so suggestion is to revise for clarity.

Submitter Information Verification

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Submittal Date:	Thu Aug 13 10:08:04 EDT 2020
Committee:	NEC-P05

Public Input No. 753-NFPA 70-2020 [Section No. 200.2(A)]

(A) Insulation.

The grounded conductor, if insulated, shall have insulation that is (1) suitable, other than color, for any ungrounded conductor of the same circuit for systems of 1000 volts or less, or ~~impedance grounded neutral systems of over 1000 volts, or~~ (2) rated not less than 600 volts for solidly grounded neutral systems of over 1000 volts as described in 250.184(A).

Statement of Problem and Substantiation for Public Input

This is companion public input to rename the 'grounded' conductor, of an impedance grounded system, to 'system impedance conductor.' As such, this conductor would no longer be subject to the requirements of Article 200. It is non intuitive to think of a conductor that is at a 277 volt potential (480 volt system in a ground-fault condition) to be "grounded."

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 743-NFPA 70-2020 [New Section after 250.1]	New definition for conductor
Public Input No. 744-NFPA 70-2020 [Section No. 250.24(C)(4)]	rename 'grounded conductor' to 'system impedance conductor'
Public Input No. 745-NFPA 70-2020 [Section No. 250.30(A)(3)]	rename 'grounded conductor' to 'system impedance conductor'
Public Input No. 749-NFPA 70-2020 [Section No. 250.36(B)]	rename 'grounded conductor' to 'system impedance conductor'
Public Input No. 750-NFPA 70-2020 [Section No. 250.36(D)]	rename 'grounded conductor' to 'system impedance conductor'
Public Input No. 746-NFPA 70-2020 [Section No. 250.187(A)]	rename 'grounded conductor' to 'system impedance conductor'
Public Input No. 747-NFPA 70-2020 [Section No. 250.187(B)]	rename 'grounded conductor' to 'system impedance conductor'
Public Input No. 748-NFPA 70-2020 [Section No. 250.187(C)]	rename 'grounded conductor' to 'system impedance conductor'

Submitter Information Verification

Submitter Full Name: Eric Stromberg
Organization: Los Alamos National Laboratory
Affiliation: Self
Street Address:
City:
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Submittal Date: Sun Mar 22 19:04:26 EDT 2020
Committee: NEC-P05

Public Input No. 2214-NFPA 70-2020 [Section No. 200.3]

200.3 Connection to Grounded System.

Grounded conductors of premises wiring systems shall be electrically connected to the supply system grounded conductor to ensure a common, continuous grounded system. For the purpose of this section, *electrically connected* shall mean making a direct electrical connection capable of carrying current, as distinguished from induced currents. Grounded conductor connections through electrical equipment within the premise wiring system shall not be connected in a manor that creates parallel paths between the grounded conductors across different sets of branch circuit or feeder conductors.

Exception: Listed interactive inverters identified for use in distributed resource generation systems such as photovoltaic and fuel cell power systems shall be permitted to be connected to premises wiring without a grounded conductor if the connected premises wiring or utility system includes a grounded conductor.

Additional Proposed Changes

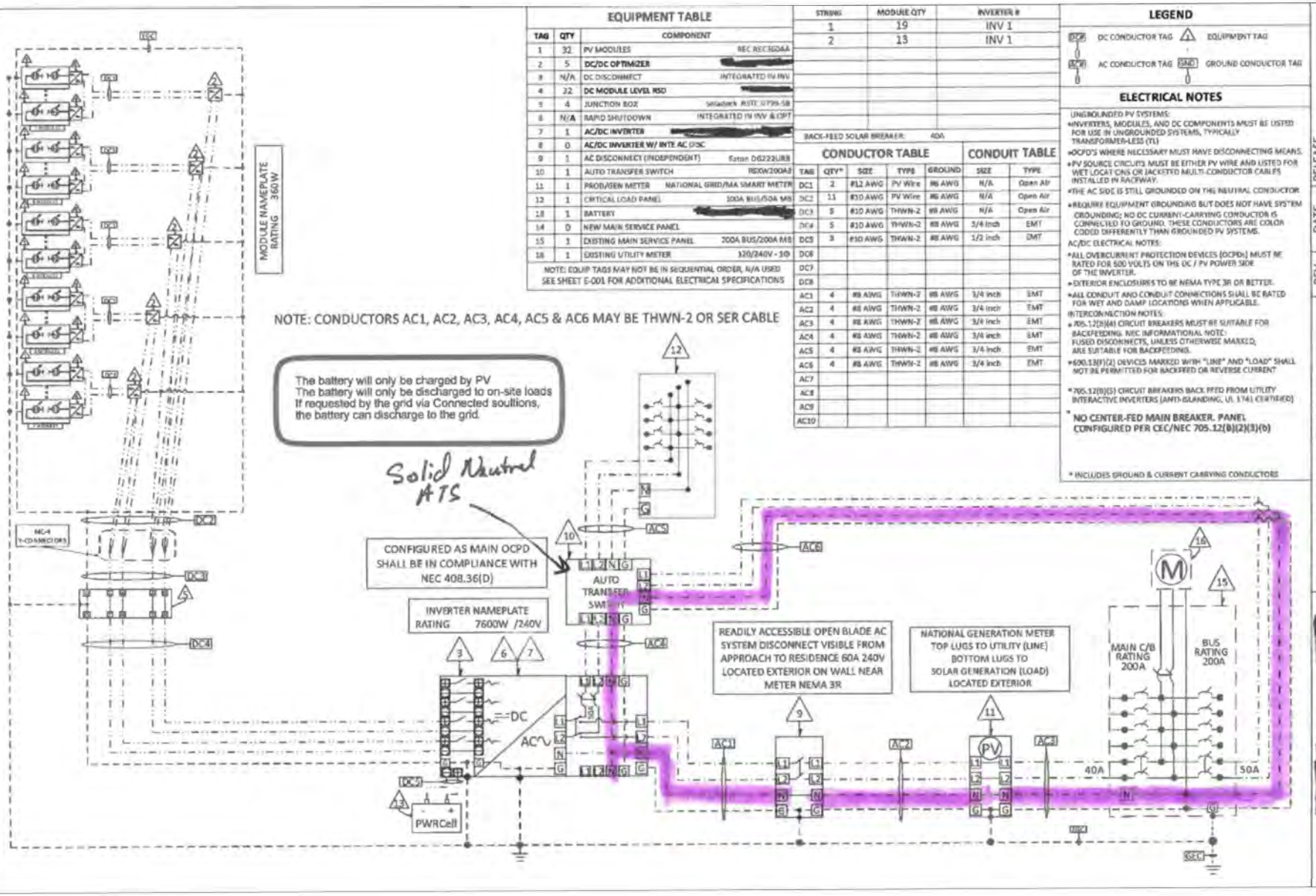
File Name	Description	Approved
Paralleled_Neutral_Path.pdf	One-line diagram highlighting an unintended paralleled path on the grounded conductor	

Statement of Problem and Substantiation for Public Input

With the increased installation of distributed generation with ac-coupled and dc-coupled multimode systems, there are potential scenarios where the connection of the associated equipment can create a paralleled path on a grounded conductors on the separate feeders between all of the associated equipment. The NEC is technically silent on this issue as no code article specifically prohibits the creation of this type of parallel path. The proposed language would add clarity to the code in Article 200.3 that these types of parallel paths are prohibited,

Submitter Information Verification

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Affiliation: Myself
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 11 10:31:05 EDT 2020
Committee: NEC-P05



EQUIPMENT TABLE

TAG	QTY	COMPONENT	
1	32	PV MODULES	REC REC360AA
2	5	DC/DC OPTIMIZER	[redacted]
3	N/A	DC DISCONNECT	INTEGRATED IN INV
4	32	DC MODULE LEVEL RSD	[redacted]
5	4	JUNCTION BOX	Ideal Tek PATE 3799-SB
6	N/A	RAPID SHUTDOWN	INTEGRATED IN INV & OPT
7	1	AC/DC INVERTER	[redacted]
8	0	AC/DC INVERTER W/ INTE AC DISC	
9	1	AC DISCONNECT (INDEPENDENT)	Eaton DG222URB
10	1	AUTO TRANSFER SWITCH	RSW200A2
11	1	PROD/GEN METER	NATIONAL GRID/MA SMART METER
12	1	CRITICAL LOAD PANEL	100A BUS/50A MB
13	1	BATTERY	[redacted]
14	0	NEW MAIN SERVICE PANEL	
15	1	EXISTING MAIN SERVICE PANEL	200A BUS/200A MB
16	1	EXISTING UTILITY METER	120/240V - 1Ø

NOTE: EQUIP TAGS MAY NOT BE IN SEQUENTIAL ORDER, N/A USED
SEE SHEET E-001 FOR ADDITIONAL ELECTRICAL SPECIFICATIONS

STRING	MODULE QTY	INVERTER #
1	19	INV 1
2	13	INV 1

BACK-FEED SOLAR BREAKER: 40A

CONDUCTOR TABLE / CONDUIT TABLE

TAG	QTY*	SIZE	TYPE	GROUND	CONDUIT SIZE	CONDUIT TYPE
DC1	2	#12 AWG	PV Wire	#6 AWG	N/A	Open Air
DC2	11	#10 AWG	PV Wire	#6 AWG	N/A	Open Air
DC3	5	#10 AWG	THWN-2	#8 AWG	N/A	Open Air
DC4	5	#10 AWG	THWN-2	#8 AWG	3/4 inch	EMT
DC5	3	#10 AWG	THWN-2	#8 AWG	1/2 inch	EMT
DC6						
DC7						
DC8						
AC1	4	#8 AWG	THWN-2	#8 AWG	3/4 inch	EMT
AC2	4	#8 AWG	THWN-2	#8 AWG	3/4 inch	EMT
AC3	4	#8 AWG	THWN-2	#8 AWG	3/4 inch	EMT
AC4	4	#8 AWG	THWN-2	#8 AWG	3/4 inch	EMT
AC5	4	#8 AWG	THWN-2	#8 AWG	3/4 inch	EMT
AC6	4	#8 AWG	THWN-2	#8 AWG	3/4 inch	EMT
AC7						
AC8						
AC9						
AC10						

LEGEND

DC# DC CONDUCTOR TAG — EQUIPMENT TAG

AC# AC CONDUCTOR TAG — GND GROUND CONDUCTOR TAG

ELECTRICAL NOTES

UNGROUNDED PV SYSTEMS:
- INVERTERS, MODULES, AND DC COMPONENTS MUST BE LISTED FOR USE IN UNGROUNDED SYSTEMS, TYPICALLY TRANSFORMER-LESS (TL)
- OCPD'S WHERE NECESSARY MUST HAVE DISCONNECTING MEANS.
- PV SOURCE CIRCUITS MUST BE EITHER PV WIRE AND LISTED FOR WET LOCATIONS OR JACKETED MULTI-CONDUCTOR CABLES INSTALLED IN RACEWAY.
- THE AC SIDE IS STILL GROUNDED ON THE NEUTRAL CONDUCTOR
- REQUIRE EQUIPMENT GROUNDING BUT DOES NOT HAVE SYSTEM GROUNDING; NO DC CURRENT-CARRYING CONDUCTOR IS CONNECTED TO GROUND. THESE CONDUCTORS ARE COLOR CODED DIFFERENTLY THAN GROUNDED PV SYSTEMS.

AC/DC ELECTRICAL NOTES:
- ALL OVERCURRENT PROTECTION DEVICES (OCPDs) MUST BE RATED FOR 600 VOLTS ON THE DC / PV POWER SIDE OF THE INVERTER.
- EXTERIOR ENCLOSURES TO BE NEMA TYPE 3R OR BETTER.
- ALL CONDUIT AND CONDUIT CONNECTIONS SHALL BE RATED FOR WET AND DAMP LOCATIONS WHEN APPLICABLE.

INTERCONNECTION NOTES:
- 705.12(B)(4) CIRCUIT BREAKERS MUST BE SUITABLE FOR BACKFEEDING. NEC INFORMATIONAL NOTE: FUSED DISCONNECTS, UNLESS OTHERWISE MARKED, ARE SUITABLE FOR BACKFEEDING.
- 690.13(F)(2) DEVICES MARKED WITH "LINE" AND "LOAD" SHALL NOT BE PERMITTED FOR BACKFEED OR REVERSE CURRENT
- 705.12(B)(5) CIRCUIT BREAKERS BACK FED FROM UTILITY INTERACTIVE INVERTERS (ANTI-ISLANDING, UL 1741 CERTIFIED)
- **NO CENTER-FED MAIN BREAKER. PANEL CONFIGURED PER CEC/NEC 705.12(B)(2)(3)(b)**

* INCLUDES GROUND & CURRENT CARRYING CONDUCTORS

REV	DATE	RELEASE
	06/25/2020	SUBMIT FOR PERMIT

11.520 kW PHOTOVOLTAIC PLANS

E-003

THREE LINE DIAGRAM

APN

Public Input No. 3742-NFPA 70-2020 [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*.

Exception: For column-width paneldboards, a common neutral shall be permitted for multiple branch circuits shall be permitted in accordance with 300.3(B)(4).

Statement of Problem and Substantiation for Public Input

The practice described in 300.3(B)(3) is a violation of this section as it uses one large neutral conductor for an entire panelboard of branch circuits.

Submitter Information Verification

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Submittal Date: Wed Sep 09 11:37:22 EDT 2020
Committee: NEC-P05

Public Input No. 2370-NFPA 70-2020 [Section No. 200.6]

200.6 Means of Identifying Grounded Conductors.

Informational Note: see 210.5, 215.12, 250.119, 455.6 (B), and 517.160(A) (5) for conductor identification and posting requirements that may apply.

(A) Sizes 6 AWG or Smaller.

An insulated grounded conductor of 6 AWG or smaller shall be identified by one of the following means:

(1) The insulated conductor shall have a continuous white outer finish.

(2) The insulated conductor shall have a continuous gray outer finish.

(3) The insulated conductor shall have three continuous white or gray stripes along the conductor's entire length on other than green insulation.

(4) Insulated conductors that have their outer covering finished to show a white or gray color but have colored tracer threads in the braid identifying the source of manufacture are acceptable means of identification.

(5) A single-conductor, sunlight-resistant, outdoor-rated cable used as a solidly grounded conductor in photovoltaic power systems, as permitted by 690.41, shall be identified at the time of installation by markings at terminations in accordance with 200.6(A)(1) through (A)(4).

(6) The grounded conductor of a mineral-insulated, metal-sheathed cable (Type MI) shall be identified at the time of installation by distinctive marking at its terminations.

(7) Fixture wire shall comply with the requirements for grounded conductor identification as specified in 402.8.

(8) For aerial cable, the identification shall comply with one of the methods in 200.6(A)(1) through (A)(5), or by means of a ridge located on the exterior of the cable so as to identify it.

(B) Sizes 4 AWG or Larger.

An insulated grounded conductor 4 AWG or larger shall be identified by one of the following means:

(1) A continuous white outer finish.

(2) A continuous gray outer finish.

(3) Three continuous white or gray stripes along the conductor's entire length on other than green insulation.

(4) At the time of installation, by a distinctive white or gray marking at its terminations. This marking shall encircle the conductor or insulation.

(C) Flexible Cords.

An insulated conductor that is intended for use as a grounded conductor, where contained within a flexible cord, shall be identified by a white or gray outer finish or by methods permitted by 400.22.

(D) Grounded Conductors of Different Systems.

Where grounded conductors of different systems are installed in the same raceway, cable, box, auxiliary gutter, or other type of enclosure, each grounded conductor shall be identified by system. Identification that distinguishes each system grounded conductor shall be permitted by one of the following means:

(1) One system grounded conductor shall have an outer covering conforming to 200.6(A) or (B).

(2) The grounded conductor(s) of other systems shall have a different outer covering conforming to 200.6(A) or 200.6(B) or by an outer covering of white or gray with a readily distinguishable colored stripe other than green running along the insulation.

(3) Other and different means of identification allowed by 200.6(A) or (B) shall distinguish each system grounded conductor.

The means of identification shall be documented in a manner that is readily available or shall be permanently posted where the conductors of different systems originate.

(E) Grounded Conductors of Multiconductor Cables.

The insulated grounded conductor(s) in a multiconductor cable shall be identified by a continuous white or gray outer finish or by three continuous white or gray stripes on other than green insulation along its entire length. For conductors that are 4 AWG or larger in cables, identification of the grounded conductor shall be permitted to comply with 200.6(B). For multiconductor flat cable with conductors that are 4 AWG or larger, an external ridge shall be permitted to identify the grounded conductor.

Exception No. 1: Conductors within multiconductor cables shall be permitted to be re-identified at their terminations at the time of installation by a distinctive white or gray marking or other equally effective means.

Exception No. 2: The grounded conductor of a multiconductor varnished-cloth-insulated cable shall be permitted to be identified at its terminations at the time of installation by a distinctive white marking or other equally effective means.

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 Input

The code has other conductor identification and posting requirements on the topic of facility-wide consistency of conductor marking by voltage system and by phase. A portion of these other codes likely always apply to this application of 200.6. And, each of the separate code requirements on this topic should correlate each other to facilitate consistency across a facility; 200.6 [grounded phase conductors], 210.5 [branch conductors], 215.12 [feeder conductors], 250.119 [equipment grounding conductors], 455.6(B) for conductors of manufactured phases, and 517.160(A)(5) [Isolated Power Systems].

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2368-NFPA 70-2020 [Section No. 455.6(B)]	similar issue and edit
Public Input No. 2371-NFPA 70-2020 [Section No. 210.5]	similar issue and edit
Public Input No. 2372-NFPA 70-2020 [Section No. 215.12]	similar issue and edit
Public Input No. 2373-NFPA 70-2020 [Section No. 250.119]	similar issue and edit
Public Input No. 2374-NFPA 70-2020 [Section No. 517.160(A)(5)]	similar issue and edit
Public Input No. 2368-NFPA 70-2020 [Section No. 455.6(B)]	
Public Input No. 2371-NFPA 70-2020 [Section No. 210.5]	
Public Input No. 2372-NFPA 70-2020 [Section No. 215.12]	

Public Input No. 2373-NFPA 70-2020 [Section No. 250.119]
Public Input No. 2374-NFPA 70-2020 [Section No. 517.160(A)(5)]

Submitter Information Verification

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Submittal Date: Tue Aug 18 10:36:54 EDT 2020
Committee: NEC-P05

Public Input No. 2718-NFPA 70-2020 [Section No. 200.6(A)]

(A) Sizes ~~6 AWG~~ 10 AWG or Smaller.

An insulated grounded conductor of ~~6 AWG~~ 10 AWG or smaller shall be identified by one of the following means:

(1) The insulated conductor shall have a continuous white outer finish.

(2) The insulated conductor shall have a continuous gray outer finish.

(3) The insulated conductor shall have three continuous white or gray stripes along the conductor's entire length on other than green insulation.

(4) Insulated conductors that have their outer covering finished to show a white or gray color but have colored tracer threads in the braid identifying the source of manufacture are acceptable means of identification.

(5) A single-conductor, sunlight-resistant, outdoor-rated cable used as a solidly grounded conductor in photovoltaic power systems, as permitted by 690.41, shall be identified at the time of installation by markings at terminations in accordance with 200.6(A)(1) through (A)(4).

(6) The grounded conductor of a mineral-insulated, metal-sheathed cable (Type MI) shall be identified at the time of installation by distinctive marking at its terminations.

(7) Fixture wire shall comply with the requirements for grounded conductor identification as specified in 402.8.

(8) For aerial cable, the identification shall comply with one of the methods in 200.6(A)(1) through (A)(5), or by means of a ridge located on the exterior of the cable so as to identify it.

Statement of Problem and Substantiation for Public Input

Changing the size from 6 AWG to 10 AWG will clear up a long standing code violations of the wrong size conductor being re-identified, the standard size wire that has a color other that black is number 10 AWG. This results in a number 8 AWG black conductor being re-identified instead of the correct colored wire being installed in the first place.
It is time for the code language to change that aligns with what is being installed in the field simply because it is what is most readily available to the electrician.
When you look at section 210.5 (C)(1) which is branch circuits that are supplied from more than one Nominal voltage System the branch circuits are allowed to be re-identified by marking tape with no size limitation and I think that the same should apply now to 200.6(A)

Submitter Information Verification

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Submittal Date: Sat Aug 29 13:41:26 EDT 2020

Committee: NEC-P05

Public Input No. 2709-NFPA 70-2020 [Section No. 200.6(B)]

(B) Sizes 4 AWG or Larger.

An insulated grounded conductor 4 AWG or larger shall be identified by one of the following means:

(1) ~~A continuous~~ The insulated conductor shall have a continuous white outer finish.

(2) ~~A continuous~~ The insulated conductor shall have a continuous gray outer finish.

(3) ~~Three~~ The insulated conductor shall have three continuous white or gray stripes along the conductor's entire length on other than green insulation.

(4) ~~At~~ The insulated conductor shall at the time of installation, be identified by a distinctive white or gray marking at its terminations. This marking shall encircle the conductor or insulation.

Statement of Problem and Substantiation for Public Input

This language will make it consistent with 200.6(A)

Submitter Information Verification

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Submittal Date: Sat Aug 29 08:28:39 EDT 2020
Committee: NEC-P05

Public Input No. 2273-NFPA 70-2020 [Section No. 200.6(D)]

(D) Grounded Conductors of Different Systems.

Where grounded conductors of different voltage systems are installed in the same raceway, cable, box, auxiliary gutter, or other type of enclosure, each grounded conductor shall be identified by voltage system. Identification that distinguishes each

~~system~~

grounded conductor by voltage system shall be permitted by

~~one~~

any combination of the following means:

~~One system~~

(1) The grounded conductor (s) of each distinct voltage system shall have

~~an~~

its own distinct outer insulation covering conforming to 200.6(A) or 200.6 (B).

(2) The grounded conductor(s) of

~~other systems shall have a different outer covering conforming to 200.6(A) or 200.6(B) or by an outer~~

each distinct voltage system shall have an outer insulation covering of white or gray with a readily distinguishable colored stripe other than green running along the insulation.

- ~~Other and different means of identification allowed by 200.6(A) or (B) shall distinguish each system grounded conductor.~~

The means of identification shall be documented in a manner that is readily available or shall be permanently posted where the conductors of different systems originate.

Informational Note: see 210.5(C)(1) Branch Circuits Supplied from More Than One Nominal Voltage System.

Informational Note: see 215.12(C)(1) Feeders Supplied from More Than One Nominal Voltage System.

Statement of Problem and Substantiation for Public Input

1) Clarify "different systems" to mean "different voltage systems", as compared to "different power system types", or "different equipment system types", or other potential interpretations for different

systems.
2) Simplify verbiage by consolidating intent of subparagraph 1, 3, and the first half of 2. The intent being that any distinction offered by compliance to 200.6(A) or (B) is permitted in part or whole of any identification scheme.
3) Include an informational note that correlates the requirement for neutral distinctions by voltage system to the phase conductor distinctions required for differing voltage systems; 210.5(C)(1).

Submitter Information Verification

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Submittal Date: Thu Aug 13 10:29:18 EDT 2020
Committee: NEC-P05

Public Input No. 497-NFPA 70-2020 [Section No. 200.6(D)]

(D)_ Grounded Conductors of Different Systems.

Where grounded conductors of different systems are installed ~~in~~ within the same ~~raceway, cable, box, auxiliary gutter, or other type of enclosure,~~ premises, each grounded conductor shall be identified by system. Identification that distinguishes each system grounded conductor shall be permitted by one of the following means:

(1) One system grounded conductor shall have an outer covering conforming to 200.6(A) or (B).

(2) The grounded conductor(s) of other systems shall have a different outer covering conforming to 200.6(A) or 200.6(B) or by an outer covering of white or gray with a readily distinguishable colored stripe other than green running along the insulation.

(3) Other and different means of identification allowed by 200.6(A) or (B) shall distinguish each system grounded conductor.

The means of identification shall be documented in a manner that is readily available or shall be permanently posted where the conductors of different systems originate.

Statement of Problem and Substantiation for Public Input

This will put Section 200.6 (D) in line with 210.5 (C)(1) as well as 215.12(C)(1). It will also remove any confusion of when we have to use different methods to identify the Grounded conductor. This will also correlate with other sections that use the term "premises" when describing when we are required to identify ungrounded conductors of different voltage systems.

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Committee: NEC-P05

Public Input No. 1001-NFPA 70-2020 [Section No. 200.7]

200.7 Use of Insulation of a White or Gray Color or with Three Continuous White or Gray Stripes.

(A) General.

The following shall be used only for the grounded circuit conductor, unless otherwise permitted in 200.7(B) and (~~C~~ D):

(1) A conductor with continuous white or gray covering

(2) A conductor with three continuous white or gray stripes on other than green insulation

(3) A marking of white or gray color at the termination

(B) Circuits of Less Than 50 Volts.

A conductor with white or gray color insulation or three continuous white stripes or having a marking of white or gray at the termination for circuits of less than 50 volts shall be required to be grounded only as required by 250.20(A).

(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 (1) and (2).

(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 one conductor identified by a white or gray outer finish or three continuous white or gray stripes, or by any other means permitted by 400.22, that is used for connecting an appliance or equipment permitted by 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.

(D) Main Bonding Jumpers and System Bonding Jumpers.

The use of insulation that is white or gray or that has three continuous white or gray stripes shall be permitted to be used for main bonding jumpers or system bonding jumpers.

Additional Proposed Changes

File Name	Description	Approved
System_Bonding_Jumper.JPG	White system bonding jumper	

Statement of Problem and Substantiation for Public Input

First let me point out the limitations of Terraview would not let me change the indent or the font for newly proposed Section D to the correct type. Now to my Public Input. What color can a system

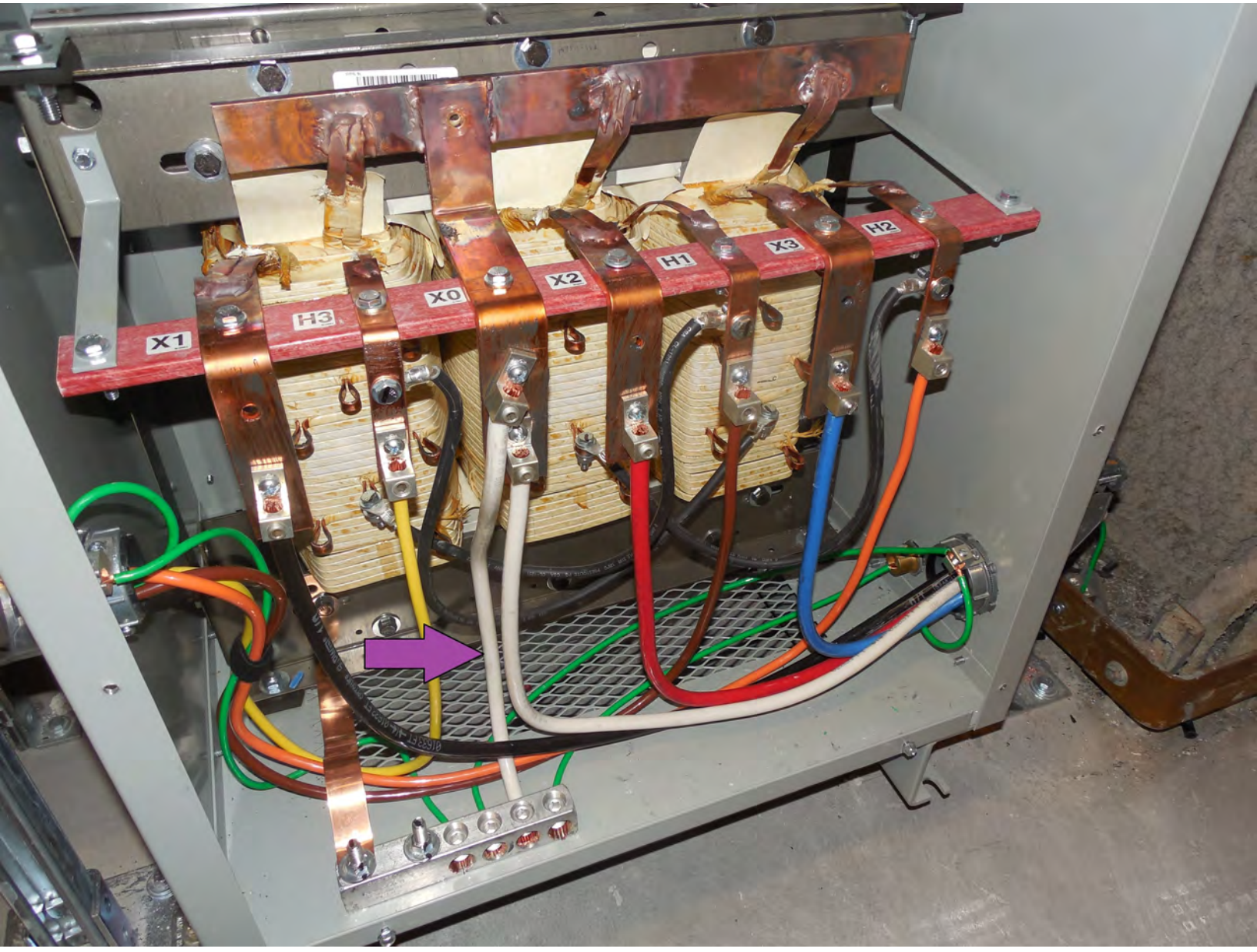
bonding jumper or main bonding jumper be? There is presently no Code rule specifically covering these conductors. Can they be green? Section 250.119 does not specifically permit or prohibit the use of green insulation, so I will be submitting a companion proposal to that section as well. Can a system bonding jumper such as the one in the photo I've provided be black, red, blue, brown, orange or yellow? Actually yes they can! Section 310.6(C) requires ungrounded conductors to be " finished to be clearly distinguishable from grounded and equipment grounding conductors", but makes no mention of system bonding conductors or main bonding jumpers. This means that the system bonding conductor CAN be the same color as any UNGROUNDED conductor! I will be submitting a companion proposal to that Section too. Can a system bonding jumper or main bonding jumper be white or gray? No, they cannot! The present wording in 200.7 does not permit the use of white or gray insulation since neither a system bonding jumper nor a main bonding jumper are a grounded CIRCUIT conductor. Using white or gray for these conductors will not result in a negative impact on safety due to the location and generally short length of conductor involved. I've worded this rule to be "permissive" rather than mandatory since my companion proposal for 250.119 will contain wording "permitting" the use of green for these bonding jumpers too.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1002-NFPA 70-2020 [Section No. 250.119]	
Public Input No. 1003-NFPA 70-2020 [Section No. 310.6(B)]	
Public Input No. 1004-NFPA 70-2020 [Section No. 310.6(C)]	

Submitter Information Verification

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Submittal Date: Fri May 08 08:12:37 EDT 2020
Committee: NEC-P05


X1
H3
X0
X2
H1
X3
H2

Public Input No. 2453-NFPA 70-2020 [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 (1) and (2).

(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 reidentify the entire length of the exposed conductor, and 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 one conductor identified by a white or gray outer finish or three continuous white or gray stripes, or by any other means permitted by 400.22, that is used for connecting an appliance or equipment permitted by 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 Input

The additional text will add clarity to the identification of a white or gray conductor being reidentified to be utilized as an ungrounded conductor in a cable type wiring method. The concern is some installers reidentify the entire visible length of the conductor within an outlet or switch box and some installers will only provide a thin marking and is then difficult to determine if the conductor is used as a grounded or an ungrounded conductor. There are now nonmetallic and armored type cables with separate grounded conductors within the cable assembly for each ungrounded conductor (14-4 or 12-4 cables), the method to identify which grounded conductor is to be used with the red or the black ungrounded conductor is typically done by having a red or black stripe on the white insulation. With the additional language to clarify the entire length of the conductor must be reidentified, as well as the present text of encircling of the conductor insulation, this will add clarity to this Code section and to the intended use of the conductor. Again, while some installers reidentify the white or gray for the entire visible length within switch boxes, other installers are not, the additional text will provide consistency with the expectations on identifying these conductors. This additional text will assist the AHJ in requiring better reidentification of these conductors

Submitter Information Verification

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Submittal Date: Sun Aug 23 08:00:45 EDT 2020
Committee: NEC-P05

Public Input No. 2274-NFPA 70-2020 [Section No. 200.10(A)]

(A) Device Terminals.

All devices

~~, excluding panelboards, provided with terminals for the attachment of conductors and intended for connection to more than one side of the circuit shall have~~

and equipment having conductor terminations for both the source side and the return side of a circuit, excluding power supply circuits in distribution gear, shall have their terminals properly marked for identification, unless the electrical connection of the terminal intended to be connected to the grounded conductor is clearly evident.

Exception:

Terminal identification shall not be required for devices that have a normal current rating of over 30 amperes, other than polarized attachment plugs and polarized receptacles for attachment plugs as required in 200.10(B) .

Statement of Problem and Substantiation for Public Input

It is unclear though unlikely whether panelboards are being characterized as devices, or equally unclear if there is meant to be a reference to the devices within panelboards. It appears appropriate to exclude all distribution equipment generally for their power circuits. Yet not exclude electronics, communications, controls or other component device circuits that may be integral to the power distribution equipment.

Submitter Information Verification

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Submittal Date: Thu Aug 13 11:50:41 EDT 2020
Committee: NEC-P05

Public Input No. 3815-NFPA 70-2020 [New Section after 200.11]

TITLE OF NEW CONTENT

See Attached Word Document for Changes

Additional Proposed Changes

File Name	Description	Approved
Article_205_PI.docx	Revise Article 200 and Add New Article 205.	

Statement of Problem and Substantiation for Public Input

This Public Input is submitted on behalf of a Correlating Committee Long-Range Task Group consisting of Robert Osborne (Chair), Paul Barnhart, Lou Grahor, David Temple, Donny Cook, Dean Hunter, Mike Querry, Roger McDaniel, Dave Burns, Rod Belisle, and Kevin Rogers. This Public Input, along with other companion Public Inputs, was developed with the goal of improving usability and providing a platform to increase the focus on requirements associated with Medium or High Voltage.

Installations, including campus-wide distribution systems, microgrids, alternative energy installations, etc., are covered by the Scope of the NEC®; however, requirements for conductors, equipment, and raceways used in applications operating in systems rated over 1000 volts are treated as an “after-thought” in how they are arranged in the document and covered by Technical Committees. In many cases, the “over 1000 volts” requirements exist in a dedicated “Part” within the Article – such is the case with existing Article 300. In other cases, similar products are handled in two separate Articles, such as with “switchgear”, with equipment rated 1000 volts and below addressed in Article 408, and equipment rated over 1000 volts addressed in Article 490. In addition to these two approaches, there are Articles where the “over 1000 volts” is intermingled with the “under 1000 volt” requirements, such as the case with Article 225. In many of these cases, the information for over 1000 volts is very limited (for example, Article 240, has only 3 Sections in the Part dedicated to requirements for over 1000 volts).

This Task Group’s initial task was to establish a demarcation for what can be referred to as Medium or High Voltage. The recommendation has been to establish this threshold as being equipment rated over 1000 Vac, 1500 Vdc.

Using these limits, the Task Group then set out to identify a structure to better align requirements, improve consistency in approach, improve usability, and create the opportunity for a Code Making Panel to have an increased focus on higher voltage applications.

The new proposed Article 205 would address the grounded conductor(s) installations in systems over 1000 volts ac, and 1500 volts dc. The code text that applied to over 1000 volt systems was extracted from Article 200.

Note: There are other Public Inputs being submitted that address restructuring, and these are identified as “Companion Public Inputs”. A reference to 250.184(A) will need to be reviewed and correlated with any changes to Article 250.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3728-NFPA 70-2020 [Global Input]	Companion Public Input (Articles 245 and 495)

Public Input No. 3765-NFPA 70-2020 [New Section after 250.194(B)]	Companion Public Input (Article 255)
Public Input No. 3772-NFPA 70-2020 [New Section after 110.79]	Companion Public Input (Article 115)
Public Input No. 3819-NFPA 70-2020 [Global Input]	Companion Public Input (Article 235)
Public Input No. 3827-NFPA 70-2020 [Global Input]	Companion Public Input (Article 305)
Public Input No. 3838-NFPA 70-2020 [Section No. 690.31(A)]	Companion Public Input (Section 690.31(A))
Public Input No. 3846-NFPA 70-2020 [Section No. 694.30(A)]	Companion Public Input (Section 694.30(A))
Public Input No. 3849-NFPA 70-2020 [New Part after IV.]	Companion Public Input (Section 706.30)
Public Input No. 3728-NFPA 70-2020 [Global Input]	
Public Input No. 3765-NFPA 70-2020 [New Section after 250.194(B)]	
Public Input No. 3772-NFPA 70-2020 [New Section after 110.79]	
Public Input No. 3819-NFPA 70-2020 [Global Input]	
Public Input No. 3827-NFPA 70-2020 [Global Input]	
Public Input No. 3838-NFPA 70-2020 [Section No. 690.31(A)]	
Public Input No. 3846-NFPA 70-2020 [Section No. 694.30(A)]	
Public Input No. 3849-NFPA 70-2020 [New Part after IV.]	

Submitter Information Verification

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Submittal Date: Wed Sep 09 13:25:36 EDT 2020
Committee: NEC-P05

Substantiation:

This Public Input is submitted on behalf of a Correlating Committee Long-Range Task Group consisting of Robert Osborne (Chair), Paul Barnhart, Lou Grahor, David Temple, Donny Cook, Dean Hunter, Mike Querry, Roger McDaniel, Dave Burns, Rod Belisle, and Kevin Rogers. This Public Input, along with other companion Public Inputs, was developed with the goal of improving usability and providing a platform to increase the focus on requirements associated with Medium or High Voltage.

Installations, including campus-wide distribution systems, microgrids, alternative energy installations, etc., are covered by the Scope of the NEC®; however, requirements for conductors, equipment, and raceways used in applications operating in systems rated over 1000 volts are treated as an "after-thought" in how they are arranged in the document and covered by Technical Committees. In many cases, the "over 1000 volts" requirements exist in a dedicated "Part" within the Article – such is the case with existing Article 300. In other cases, similar products are handled in two separate Articles, such as with "switchgear", with equipment rated 1000 volts and below addressed in Article 408, and equipment rated over 1000 volts addressed in Article 490. In addition to these two approaches, there are Articles where the "over 1000 volts" is intermingled with the "under 1000 volt" requirements, such as the case with Article 225. In many of these cases, the information for over 1000 volts is very limited (for example, Article 240, has only 3 Sections in the Part dedicated to requirements for over 1000 volts).

This Task Group's initial task was to establish a demarcation for what can be referred to as Medium or High Voltage. The recommendation has been to establish this threshold as being equipment rated over 1000 Vac, 1500 Vdc.

Using these limits, the Task Group then set out to identify a structure to better align requirements, improve consistency in approach, improve usability, and create the opportunity for a Code Making Panel to have an increased focus on higher voltage applications.

The new proposed Article 205 would address the grounded conductor(s) installations in systems over 1000 volts ac, and 1500 volts dc. The code text that applied to over 1000 volt systems was extracted from Article 200.

Note: There are other Public Inputs being submitted that address restructuring, and these are identified as "Companion Public Inputs". A reference to 250.184(A) will need to be reviewed and correlated with any changes to Article 250.

Proposed Changes

Change to Article 200:

200.2 General. Grounded conductors shall comply with 200.2(A) and (B).

(A) Insulation. The grounded conductor, if insulated, shall have insulation that is ~~(1)~~ suitable, other than color, for any ungrounded conductor of the same circuit for systems of 1000 volts or less. ~~, or impedance grounded neutral systems of over 1000 volts, or (2) rated not less than 600 volts for solidly grounded neutral systems of over 1000 volts as described in 250.184(A).~~

Addition of New Article 205:

ARTICLE 205 Use and Identification of Grounded Conductors for Systems Over 1000 Volts ac, or 1500 Volts dc.

205.1 Scope.
This article covers requirements for the use and identification of grounded conductors for systems rated over 1000 volts ac, 1500 volts dc, nominal. This article provides requirements for the following:

(1) Identification of terminals
(2) Grounded conductors in premises wiring systems
(3) Identification of grounded conductors

Informational Note: See Article 100 for definitions of *Grounded Conductor, Equipment Grounding Conductor,* and *Grounding Electrode Conductor*.

205.2 General.
Grounded conductors shall comply with 205.2(A) and (B).

205.2(A) Insulation.
The grounded conductor, if insulated, shall have insulation that is (1) suitable, other than color, for any ungrounded conductor of the same circuit for systems rated over 1000 volts ac or 1500 volts dc, or impedance grounded neutral systems of over 1000 volts, or (2) rated not less than 600 volts for solidly grounded neutral systems of over 1000 volts as described in 250.184(A).

205.2(B) Continuity.
The continuity of a grounded conductor shall not depend on a connection to a metallic enclosure, raceway, or cable armor.

205.3 Connection to Grounded System.
Grounded conductors of premise wiring systems shall be electrically connected to the supply system grounded conductor to ensure a common, continuous grounded system. For the purpose of this section, *electrically connected* shall mean making a direct electrical connection capable of carrying current, as distinguished from induced currents.

Exception: Listed interactive inverters identified for use in distributed resource generation systems such as photovoltaic and fuel cell power systems shall be permitted to be connected to premises wiring without a grounded conductor if the connected premises wiring or utility system includes a grounded conductor.

205.6 Means of Identifying Grounded Conductors.

205.6(A) Sizes 6 AWG or Smaller.
An insulated grounded conductor of 6 AWG or smaller shall be identified by one of the following means:

(1) The insulated conductor shall have a continuous white outer finish.

(2) The insulated conductor shall have a continuous gray outer finish.
(3) The insulated conductor shall have three continuous white or gray stripes along the conductor's entire length on other than green insulation.
(4) Insulated conductors that have their outer covering finished to show a white or gray color but have colored tracer threads in the braid identifying the source of manufacture are acceptable means of identification.
(5) A single-conductor, sunlight-resistant, outdoor-rated cable used as a solidly grounded conductor in photovoltaic power systems, as permitted by 690.41, shall be identified at the time of installation by markings at terminations in accordance with 205.6(A)(1) through (A)(4).
(6) The grounded conductor of a mineral-insulated, metal-sheathed cable (Type MI) shall be identified at the time of installation by distinctive marking at its terminations.
(7) For aerial cable, the identification shall comply with one of the methods in 205.6(A(1) through(A)(5), or by means of a ridge located on the exterior of the cable so as to identify it.

205.6(B) Sizes 4 AWG or Larger.
An insulated grounded conductor 4 AWG or larger shall be identified by one of the following means:

(1) A continuous white outer finish.
(2) A continuous gray outer finish.
(3) Three continuous white or gray stripes along the conductor's entire length on other than green insulation
(4) At the time of installation, by a distinctive white or gray marking at its terminations. This marking shall encircle the conductor or insulation.

205.6(C) Flexible Cords.
An insulated conductor that is intended for use as a grounded conductor, where contained within a flexible cord, shall be identified by a white or gray outer finish or by methods permitted by 400.22.

205.6(D) Grounded Conductors of Different Systems.
Where grounded conductors of different systems are installed in the same raceway, cable, box, auxiliary gutter, or other type of enclosure, each grounded conductor shall be identified by system. Identification that distinguishes each system grounded conductor shall be permitted by one of the following means:

(1) One system grounded conductor shall have an outer covering conforming to 205.6(A) or (B).
(2) The grounded conductor(s) of other systems shall have a different outer covering conforming to 205.6(A) or 205.6(B) or by an outer covering of white or gray with a readily distinguishable colored stripe other than green running along the insulation.
(3) Other and different means of identification allowed by 205.6(A) or (B) shall distinguish each system grounded conductor.

The means of identification shall be documented in a manner that is readily available or shall be permanently posted where the conductors of different systems originate.

205.6(E) Grounded Conductors of Multiconductor Cables.
The insulated grounded conductor(s) in a multiconductor cable shall be identified by a continuous white or gray outer finish or by three continuous white or gray stripes on other than green insulation along its entire length. For conductors that are 4 AWG or larger in cables, identification of the grounded conductor shall be permitted to comply with 205.6(B). For multiconductor flat cable with conductors that are 4 AWG or larger, an external ridge shall be permitted to identify the grounded conductor.

Exception No. 1: Conductors within multiconductor cables shall be permitted to be re-identified at their terminations at the time of installation by a distinctive white or gray marking or other equally effective means.

Exception No. 2: The grounded conductor of a multiconductor varnished-cloth-insulated cable shall be permitted to be identified at its terminations at the time of installation by a distinctive white marking or other equally effective means.

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.

205.7 Means of Identification of Terminals.

In devices or utilization equipment with polarized connections, identification of terminals to which a grounded conductor is to be connected shall be substantially white or silver in color. The identification of other terminals shall be of a readily distinguishable different color.

Exception: Where the conditions of maintenance and supervision ensure that only qualified persons service the installations, terminals for grounded conductors shall be permitted to be permanently identified at the time of installation by a distinctive white marking or other equally effective means.

205.8 Identification of Device Terminals.

All devices, excluding panelboards, provided with terminals for the attachment of conductors and intended for connection to more than one side of the circuit shall have terminals properly marked for identification, unless the electrical connection of the terminal intended to be connected to the grounded conductor is clearly evident.

Exception: Terminal identification shall not be required for devices that have a normal current rating of over 30 amperes, other than polarized attachment plugs and polarized receptacles for attachment plugs as required in 200.10(B).

205.9 Polarity of Connections.

No grounded conductor shall be attached to any terminal or lead so as to reverse the designated polarity.

Public Input No. 1085-NFPA 70-2020 [New Section after 250.1]

250.2 Definition

Objectionable current.

Current flow resulting from grounding or bonding connections which are not required by this Code.

Additional Proposed Changes

File Name	Description	Approved
3E8222E2-1156-4724-B1DB-BFEE594EB032.jpeg	Neutral current flowing on metal underground water pipe.	

Statement of Problem and Substantiation for Public Input

This definition is needed to clarify which currents are “objectionable” and which are not. Current flow that results from grounding or bonding connections that are “permitted” but not “required” by Code can be remedied by the methods specified in 250.6(B). On the other hand, current flow that results from grounding or bonding connections that are “required” by this Code, cannot be remedied since these connections are required. One example of this includes metal underground water piping systems that are bonded to service neutrals for use as grounding electrodes in multiple buildings supplied from the same utility transformer. In this case, the common metal underground water piping system will act as a parallel neutral since it is bonded to the neutral in multiple locations. In fact, it would defy all known laws of physics and electron current flow if electrons did NOT flow on this water pipe. See photo I’ve provided showing water pipe carrying a portion of the neutral current. There was 18.5-amps of current flowing simultaneously on the service neutral conductor with 7.3 amps flowing on the GEC and water pipe. Another example is a service wired in a metal raceway between the meter socket and the service disconnect. Section 250.92 requires each enclosure to be bonded to the neutral, resulting in the enclosures and raceways providing a parallel path for neutral current. These bonding connections are required, so removing them is not an option. If bonding or grounding connections are “required”, and these connections result in current flow on metal piping, raceways or enclosures, there are really no alterations that can be done to prevent this current flow. This definition will help installers and Code users decipher rules that have long been difficult to figure out. Current flow resulting from required grounding or bonding connections cannot be considered “objectionable” if these connections are “required”.

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Committee: NEC-P05


IDEAL
61-766
MAX MIN
INRUSH
True RMS
APO
AC
7.39
A
COM
VΩHz
CAT. IV 600V
CAT. III 1000V
MAX
1000V
750V~
OFF

Public Input No. 743-NFPA 70-2020 [New Section after 250.1]

TITLE OF NEW CONTENT

250.2 Definitions

System Impedance Conductor The conductor, in a resistance grounded system, that connects the neutral point of the transformer or generator to its connection point to the grounding impedance.

Statement of Problem and Substantiation for Public Input

In a 480/277 volt high resistance grounded system, the conductor that connects the neutral point of the system to the high side of the grounding impedance will be at a potential of 277 volts when the system is in a ground fault condition. This is precisely why neutrals are not allowed in the system such that no line to neutral loads are supplied. Currently, the Code refers to this as a 'grounded' conductor. It is non-intuitive for a grounded conductor to be at a voltage of 277 volts. Of course, in a non ground-faulted condition, the conductor will be at zero volts. This conductor is also referenced in 250.24, 250.30, and 250.187. There are companion proposals to change the wording in these sections.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 744-NFPA 70-2020 [Section No. 250.24(C)(4)]	
Public Input No. 745-NFPA 70-2020 [Section No. 250.30(A)(3)]	
Public Input No. 746-NFPA 70-2020 [Section No. 250.187(A)]	
Public Input No. 747-NFPA 70-2020 [Section No. 250.187(B)]	
Public Input No. 748-NFPA 70-2020 [Section No. 250.187(C)]	
Public Input No. 749-NFPA 70-2020 [Section No. 250.36(B)]	
Public Input No. 750-NFPA 70-2020 [Section No. 250.36(D)]	
Public Input No. 752-NFPA 70-2020 [Section No. 250.36(G)]	
Public Input No. 753-NFPA 70-2020 [Section No. 200.2(A)]	

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Public Input No. 3300-NFPA 70-2020 [Section No. 250.1]

250.1 Scope.

This article covers general requirements for grounding and bonding of electrical installations, and the specific requirements in (1) through (6).

(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

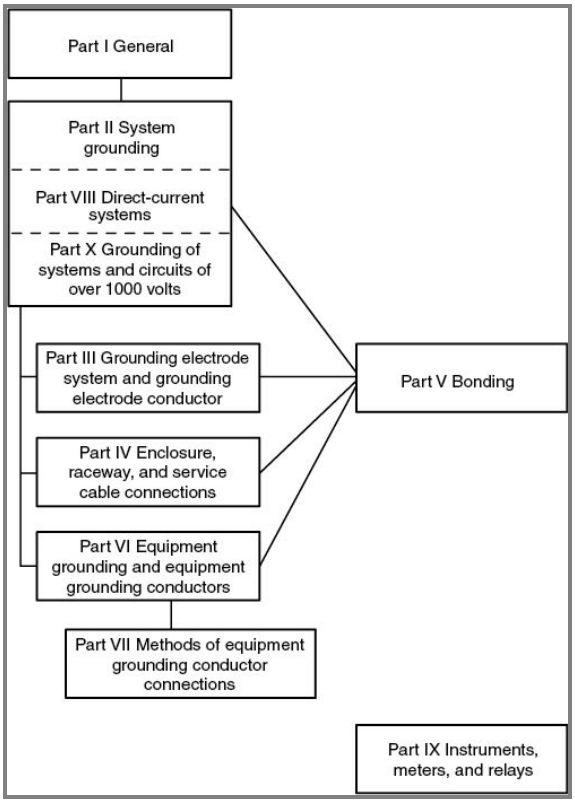
(5) Methods of grounding and bonding

(6) Conditions under which guards, isolation, or insulation may be substituted for grounding

Informational Note 1 : See Figure 250.1 for information on the organization of Article 250 covering grounding and bonding requirements.

Informational Note 2: See IEEE 3003.2 Recommended Practice for Equipment Grounding and Bonding in Industrial and Commercial Power Systems for additional information

Figure 250.1 Grounding and Bonding.



Statement of Problem and Substantiation for Public Input

This is another slice of updated content from the legacy "Red Book" IEEE 141, "Gray Book: IEEE 241 and IEEE 142 "Green Book" into the new IEEE 3000 Standards Collection. This new standard is part of a larger project to revise and reorganize the technical content of the 13 existing IEEE Color Books.

Benefits of the project include, but are not limited to: 1) the elimination of duplicate material that now exists in the various color books, 2) the
speeding up of the revision process by allowing Color Book content to be reviewed, edited and balloted in smaller segments, and 3) to accommodate more modern, efficient and cost effective physical publishing/distribution methodologies (i.e., the elimination of large and expensive to produce books.

From the project prospectus:

"The grounding and bonding of equipment in industrial and commercial power systems is covered in this recommended practice. The interconnection and grounding of the non-electrical metallic elements of a system is covered first. This is followed by a discussion of the objectives of equipment grounding and bonding, including minimizing electric shock hazard to personnel, providing adequate current carrying capability for ground faults, and ensuring the timely operation of overcurrent protection."

https://standards.ieee.org/standard/3003_2-2014.html

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Committee:	NEC-P05

Public Input No. 3805-NFPA 70-2020 [Section No. 250.1]

250.1 Scope.

This article covers general requirements for grounding and bonding of electrical installations, and the specific requirements in (1) through (6).

(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

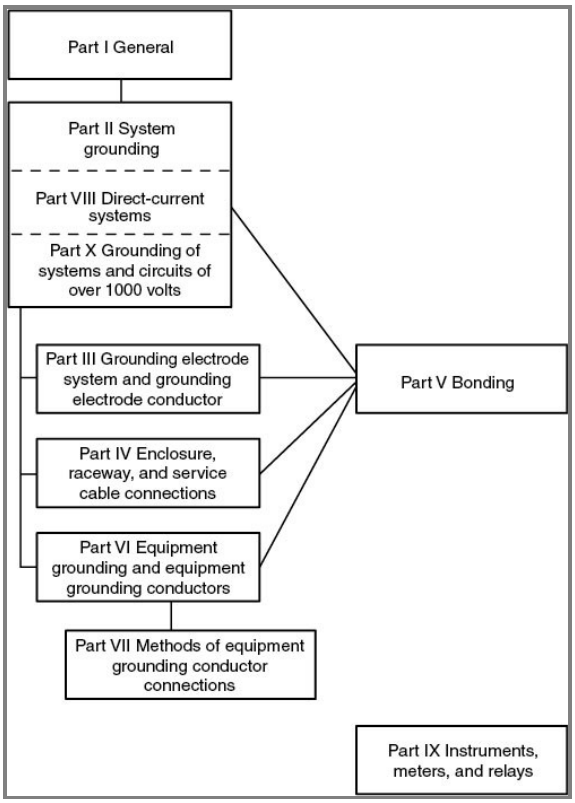
(4) Types and sizes of grounding and bonding conductors and electrodes

(5) Methods of grounding and bonding

(6) Conditions under which guards, isolation, or insulation may be substituted for grounding

Informational Note: See Figure 250.1 for information on the organization of ~~Article 250~~ this article covering grounding and bonding requirements.

Figure 250.1 Grounding and Bonding.



Statement of Problem and Substantiation for Public Input

Section 4.1.4 of the 2020 NEC(r) Style Manual prohibits references to entire articles with the exception of Article 100. The reference to Article 250 can be changed to "this article" to comply.

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Public Input No. 3807-NFPA 70-2020 [Section No. 250.4 [Excluding any Sub-Sections]]

The following general requirements identify what grounding and bonding of electrical systems are required to accomplish. The prescriptive methods contained in ~~Article 250~~ this article shall be followed to comply with the performance requirements of this section.

Statement of Problem and Substantiation for Public Input

Section 4.1.4 of the 2020 NEC(r) Style Manual prohibits references to entire articles with the exception of Article 100. The reference to Article 250 can be changed to "this article" to comply.

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Public Input No. 1064-NFPA 70-2020 [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) ~~Temporary~~ Currents Not Classified as Objectionable Currents.

Temporary currents resulting from abnormal conditions, such as ground faults, and currents resulting from required grounding or 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 Ground Currents.

Where isolation of objectionable dc ground currents from cathodic protection systems is required, a listed ac coupling/dc isolating device shall be permitted in the equipment grounding conductor path to provide an effective return path for ac ground-fault current while blocking dc current.

Statement of Problem and Substantiation for Public Input

Quite simply, grounding and bonding accomplish different objectives and both of them can create objectionable currents. Both grounding and bonding are covered by Article 250, but presently bonding is completely disregarded when it comes to objectionable current. I don't believe the intent of this rule is to purposely exclude bonding connections from this rule. In fact, bonding connections are much more likely to create objectionable currents than are grounding connections to earth. This revision is needed to make it clear that bonding connections should also be arranged to prevent objectionable currents. Revisions are also needed to clarify what currents are not considered objectionable. For example, metal enclosures and metal raceways at services are required to be bonded to the grounded conductor. These connections will result in the metal raceway between a meter and the service disconnect, to act as a conductor in parallel with the grounded conductor. Can this be considered objectionable current when these connections are REQUIRED to be made? I don't see how one could argue that point if the connections are required. Or another example may be neutral current flowing on an underground metal water piping electrode system for a building fed with multiple feeders as

specified in 225.30 or multiple services as specified in 230.2. This could easily result in neutral current flowing on the metal water piping system. But, can this be considered “objectionable current” if these bonding and grounding connections are REQUIRED to be made? I don’t think so. This revision will help clarify which currents are objectionable.

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Public Input No. 296-NFPA 70-2020 [Section No. 250.6(B)]

(B) Alterations to Stop Objectionable Current.

If the use of multiple grounding connections results in objectionable current and the requirements of 250.24 (A) (5), 250. 4(A), 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 connections.

(2) Change the locations of the grounding connections.

(3) Interrupt the continuity of the conductor or conductive path causing the objectionable current.

(4) Take other suitable remedial and approved action.

Statement of Problem and Substantiation for Public Input

the problem is when installing genset that are bonded to the neutral and frame you see objective currents. the way 250.6 is written you could remove other EGC. By not stating the general rule in 250.4 it could be glossed over, missing this important information which is to follow the prescriptive methods mention in 250. Just going to section 250.4 (A) (5) or 250.6 (B) (4) one of the important prescriptive methods overlooked is section 250.24(A) (5)

250.4 states in part: The prescriptive methods contained in Article 250 shall be followed to comply with the performance requirements of this section.

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Public Input No. 297-NFPA 70-2020 [Section No. 250.6(E)]

(E) Isolation of Objectionable Direct-Current ~~Ground Currents~~ from cathodic protection systems .

Where isolation of objectionable ~~dc ground~~ direct currents from a cathodic protection systems is required, a listed ~~ac coupling/dc isolating~~ isolation device shall be permitted in the equipment grounding conductor path to provide an effective return path for ac ground-fault current while blocking ~~dc current~~ the flow of direct currents .

Additional Proposed Changes

File Name	Description	Approved
decoupler.PNG	isolation device	

Statement of Problem and Substantiation for Public Input

the title is not stating the correct issue and is confusing. The issue is dc that is produced by a rectifier in an underground cathodic protective system. Isolators used to provide ac grounding and dc blocking for cathodic protection system are listed in the UL white book (VZQO) and are called Isolators. this is what the section should state.

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Solid-state decouplers are widely used in the energy industry. But many people don't understand what they are, how they function and the many ways in which they can be used. This article will arm you with a basic understanding of them – in layman's terms.

A decoupler simultaneously performs two electrical functions: DC isolation and AC grounding. This seems like a conundrum: how can something be electrically isolated and safely grounded at the same time? The easiest way to understand how a decoupler works is via an example of its most common use: a buried pipeline.

It can be helpful to think of a decoupler as a filter, which handles four different scenarios:

Cathodic Protection: Cathodic Protection (CP) systems are often necessary to prevent galvanic corrosion of a pipeline or other metallic structure. A CP system provides corrosion protection by applying a low voltage negative DC bias to the structure. However, required safety grounding systems connected to the structure short this CP current to ground and can compromise the efficiency of the CP system. Under normal circumstances, the decoupler functions to isolate or block the flow of DC current (cathodic protection) to other equipment or grounding material, thereby eliminating any negative influence on your CP system caused by neighboring equipment or grounding materials. Yet the decoupler also provides safety grounding protection from AC faults and lightning.

AC fault protection: AC fault current generated by a failure of nearby equipment is a safety hazard. This AC current can be transmitted via the pipeline, endangering nearby workers or causing damage to your pipeline. When an AC fault occurs, the decoupler instantly conducts fault current to ground, carrying AC current away from the pipeline and providing instant protection.

Lightning protection: When a lightning strike occurs, it can present a safety hazard to personnel and pose a risk to the pipeline. The decoupler behaves in the same way as it does during an AC fault. It safely channels the high-voltage DC current of the lightning to ground, protecting nearby workers. As soon as this event has ended, the decoupler automatically switches back to its DC isolation/cathodic protection role.

Mitigation of induced AC current: Many pipelines are buried along a shared right-of-way with high-voltage power lines, which induce AC current in the pipeline. This is not only a safety hazard to workers, but can also cause corrosion issues. Decouplers such as the PCR or SSD are designed to continuously conduct induced AC

Public Input No. 1460-NFPA 70-2020 [Section No. 250.8(A)]

(A) Permitted Methods.

Equipment grounding conductors, grounding electrode conductors, and bonding jumpers shall be connected by one or more of the following means that is identified or listed for the connection :

(1) Listed pressure connectors

(2) Terminal bars

(3) Pressure connectors listed as grounding and bonding equipment

(4) Exothermic welding process

(5) Machine screw-type fasteners that engage not less than two threads or are secured with a nut

(6) Thread-forming machine screws that engage not less than two threads in the enclosure

(7) Connections that are part of a listed assembly

(8) Other listed means

Statement of Problem and Substantiation for Public Input

The additional words are important and needed because all of the methods in the list are not appropriate or suitable for connecting all conductors. For example, as found in list item (5), "Machine screw-type fasteners that engage not less than two threads or are secured with a nut" are not suitable for connecting a 250 kcmil grounding electrode conductors.
The word identified is selected because some of the methods are not listed because they are considered hardware. Yet, the method that is not listed can meet the requirement of being Identified which is defined in Article as "Recognizable as suitable for the specific purpose, function, use, environment, application, and so forth, where described in a particular Code requirement."

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Public Input No. 1251-NFPA 70-2020 [Section No. 250.8(B)]

(B) Methods Not Permitted.

~~Connection~~ Connections, connection devices, or fittings that depend solely on solder shall not be used. Connections, connection devices, or fittings that depend on the brazing process shall be approved for the purpose.

Statement of Problem and Substantiation for Public Input

Pin brazing is common with cathodic protection grounding connections. Since brazing is performed at a relatively low temperature as compared with exothermic welding, it should only be allowed where it is approved for the purpose.

The American Welding Society (AWS) defines brazing as a process which involves a filler metal which has a liquidus above 450°C (842°F). Soldering involves filler metals with a liquidus of 450°C or below.

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Public Input No. 1308-NFPA 70-2020 [Section No. 250.12]

250.12 ~~Clean Surfaces.~~ Surface Conductivity

Nonconductive coatings (such as paint, lacquer, and enamel) ~~on equipment to be grounded or bonded shall be~~ shall be removed from threads and other contact surfaces to ensure good electrical continuity ~~or shall be connected by means of fittings designed so as to make such removal unnecessary~~ . Fittings and connections that avoid compromising or reducing the integrity of such coatings and finishes may also be utilized .

Statement of Problem and Substantiation for Public Input

The primary issue with 250.12 is that it does not make sense as written, reproduced below; "Nonconductive coatings (such as paint, lacquer, and enamel) on equipment to be grounded or bonded shall be removed from threads and other contact surfaces to ensure good electrical continuity or shall be connected by means of fittings designed so as to make such removal unnecessary."

The subject "nonconductive coatings on equipment to be grounded or bonded" is applicable until "OR SHALL BE CONNECTED BY[...]". Because it is one continuous sentence, it must be rewritten to make sense. The section is again reproduced below with the first clause omitted to exemplify the issue: "Nonconductive coatings [...] shall be connected by means of fittings designed so as to make such removal unnecessary."

In addition to correcting this fundamental problem, the revision also omits unnecessary wording to more clearly convey the code content,

The title was also changed because "Clean Surfaces" is vague and unspecific and easily misconstrued to mean surfaces that are free of contaminants, rather than intentional coatings. "Surface Conductivity" is more descriptive and specific to the corresponding code.

Submitter Information Verification

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Submittal Date: Sun May 31 11:06:24 EDT 2020
Committee: NEC-P05

Public Input No. 1437-NFPA 70-2020 [Section No. 250.20(B)]

(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) Where the system can be grounded so that the maximum voltage to ground on the ungrounded conductors does not exceed 150 volts

(2) Where the system is 3-phase, 4-wire, wye connected in which the neutral conductor is used as a circuit conductor

(3) Where 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-2018, *Standard for Electrical Safety in the Workplace*, high impedance grounding is an effective tool to reduce arc flash hazards.

Statement of Problem and Substantiation for Public Input

There is no difference between premises wiring and premises wiring systems the mean the same thing and therefore redundant.

Submitter Information Verification

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Submittal Date: Thu Jun 04 12:14:04 EDT 2020
Committee: NEC-P05

Public Input No. 3263-NFPA 70-2020 [Section No. 250.21(A)]

(A) General.

The following ac systems of 50 volts to 1000 volts shall be permitted to be grounded but shall not be required to be grounded:

(1) Electrical systems used exclusively to supply industrial electric furnaces for melting, refining, tempering, and the like

(2) Separately derived systems used exclusively for rectifiers that supply only adjustable-speed industrial drives

(3) Separately derived systems supplied by transformers that have a primary voltage rating of 1000 volts or less if all the following conditions are met:

(4) The system is used exclusively for control circuits.

(5) The conditions of maintenance and supervision ensure that only qualified persons service the installation.

(6) Continuity of control power is required.

(7) Other systems that are not required to be grounded in accordance with the requirements of 250.20(B)

(8) Portable, vehicle and trailer mounted generators installed in accordance with the requirements of 250.34

Statement of Problem and Substantiation for Public Input

Missing from the list is the portable/trailer generator AC system,

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Committee: NEC-P05

Public Input No. 4058-NFPA 70-2020 [Section No. 250.21(A)]

(A) General.

The following ac systems of 50 volts to 1000 volts shall be permitted to be grounded but shall not be required to be grounded:

(1) Electrical systems used exclusively to supply industrial electric furnaces for melting, refining, tempering, and the like

(2) Separately derived systems used exclusively for rectifiers that supply only adjustable-speed industrial drives

(3) Separately derived systems supplied by transformers that have a primary voltage rating of 1000 volts or less if all the following conditions are met:

(4) The system is used exclusively for control circuits.

(5) The conditions of maintenance and supervision ensure that only qualified persons service the installation.

(6) Continuity of control power is required.

(7) Other systems that are not required to be grounded in accordance ~~with the requirements of~~ with 250.20(B)

Statement of Problem and Substantiation for Public Input

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

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Submittal Date: Wed Sep 09 19:36:20 EDT 2020
Committee: NEC-P05

Public Input No. 1040-NFPA 70-2020 [Section No. 250.22]

250.22 Circuits Not to Be Grounded.

The following circuits shall not be grounded:

(1) Circuits for electric cranes operating over combustible fibers in Class III locations, as provided in 503.155

(2) Circuits in health care facilities as provided in 517.61 and 517.160

(3) Circuits for equipment within electrolytic cell line working zones as provided in Article 668

(4) Secondary circuits of lighting systems as provided in 411.6(A)(1)

(5) Secondary circuits of lighting systems as provided in 680.23(A)(2)

(6) Class 2 load side circuits for suspended ceiling low-voltage power grid distribution systems as provided in 393.60(B)

Statement of Problem and Substantiation for Public Input

250.22(4) is being misinterpreted by NRTL's as applying to all low voltage lighting systems, not just those covered by article 411. Article 411 low voltage lighting systems have a relatively high power limitation of 1500VA, often utilize bare conductors, and are often installed in wet locations. The secondary circuit grounding prohibition of 411.6(A) is appropriate for such systems.

However, with the appearance of new lighting technologies such as LED's and Power over Ethernet (PoE) and similar distribution systems, there are now low voltage lighting systems that use Class 2 secondary circuits. These systems comply with the power limits of 725.121 and Table 11(B). A secondary circuit grounding prohibition is not necessary or appropriate for such Class 2 circuits. This change is contained in my PI 1050.

The existing wording of 250.22(4) needs to correlated with new wording of PI 1050 if that PI is accepted.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1050-NFPA 70-2020 [Section No. 411.6(A)]	Correlates this PI 1040 with PI 1050
Public Input No. 1050-NFPA 70-2020 [Section No. 411.6(A)]	

Submitter Information Verification

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Submittal Date: Tue May 12 16:38:36 EDT 2020
Committee: NEC-P05

Public Input No. 3809-NFPA 70-2020 [Section No. 250.22]

250.22 Circuits Not to Be Grounded.

The following circuits shall not be grounded:

(1) Circuits for electric cranes operating over combustible fibers in Class III locations, as provided in 503.155

(2) Circuits in health care facilities as provided in 517.61 and 517.160

(3) Circuits for equipment within electrolytic cell line working zones as provided in ~~Article~~ 668.1

(4) Secondary circuits of lighting systems as provided in 411.6(A)

(5) Secondary circuits of lighting systems as provided in 680.23(A)(2)

(6) Class 2 load side circuits for suspended ceiling low-voltage power grid distribution systems as provided in 393.60(B)

Statement of Problem and Substantiation for Public Input

Section 4.1.4 of the 2020 NEC(r) Style Manual prohibits references to entire articles with the exception of Article 100. It is proposed to point the user to the scope of the relevant article instead, or the CMP may wish it revise to a specific part of Article 668 if necessary.

Submitter Information Verification

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Committee: NEC-P05

Public Input No. 1463-NFPA 70-2020 [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~~ service in accordance with 250.24(A)(1) through (A)(~~5~~ 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~~ , ~~including the~~ 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.

Where 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 high-impedance grounded neutral systems. The system shall meet the requirements of 250.36.

(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.

Where 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.

(~~5~~ 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.

(~~B~~ 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: Where 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 neutral systems shall be permitted to be connected as provided in 250.36 and 250.187.

(~~C~~ D) Grounded Conductor Brought to Service Equipment.

Where 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(C)(1) through (C)(4).

Exception: Where 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) ~~Parallel~~ Conductors in Two or More Raceways or Cables that are Connected in Parallel .

If the ungrounded service-entrance conductors are ~~installed in~~ connected in parallel in two or more raceways or cables, the grounded conductor shall also be installed in each raceway or cable and shall be connected in parallel. The size of the grounded conductor in each raceway or cable shall be based on the total circular mil area of the parallel ungrounded conductors in the raceway or cable, as indicated in 250.24(C)(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) High Impedance.

The grounded conductor on a high-impedance grounded neutral system shall be ~~grounded in~~ connected in accordance with 250.36.

(~~D~~ E) Grounding Electrode Conductor.

A grounding electrode conductor shall be used to connect the equipment grounding conductors, the service-equipment enclosures, and, where 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.

High-impedance grounded neutral system connections shall be made as covered in 250.36.

(~~E~~ 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.

Statement of Problem and Substantiation for Public Input

For 250.24(A), it seems the sentence is not grammatically correct with the phrase "at each service" set off in commas. 250.24(A)(5) is not a permitted connection of the grounded service conductor and thus should not be included in this list.
For (A)(1), this is intended to be an editorial change and not substantive. The present sentence does not read correctly as it exists.
Existing 250.24(A)(5) is renumbered as 250.24(B) as it must stand alone as it is not a permitted connection of the grounded service conductor.
The following main paragraphs are renumbered accordingly.
For existing 250.24(C)(2), proposed to change to 250.24(D)(2), the language is proposed to be revised for technical accuracy.
For existing 250.24(C)(4), proposed to change to 250.24(D)(4), An editorial improvement is proposed.

Submitter Information Verification

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Submittal Date: Fri Jun 05 23:15:18 EDT 2020
Committee: NEC-P05

Public Input No. 119-NFPA 70-2019 [Section No. 250.24(A)(1)]

(1) General.

The grounding electrode conductor connection shall be permitted to be made at any accessible point from the load end of the overhead service conductors, service drop, underground service conductors, or service lateral to, including 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.

Statement of Problem and Substantiation for Public Input

Section 250.24(A) already mandates that a connection to a grounding electrode conductor is required. The present wording in Section 250.24(A)(1) can easily be interpreted that a GEC connection must be made at EVERY(any) accessible point from the load end of the overhead or underground service conductors, service drop, service lateral to, including the grounded terminal or bus in the service disconnect. I certainly don't believe the intent of 250.24(A)(1) is to require a GEC connection at EVERY accessible point! The revision I proposed is simply to clarify that any of the locations are PERMITTED, but not all of the locations are REQUIRED to have this GEC connection.

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Submittal Date: Wed Nov 20 09:17:22 EST 2019
Committee: NEC-P05

Public Input No. 2266-NFPA 70-2020 [Section No. 250.24(A)(1)]

(1) General.

The grounding electrode conductor connection shall be made at each service disconnecting means and connected to the grounded conductor and main bonding jumper.

Exception: The grounding electrode conductor shall be permitted to be made at any accessible point from the load end of the overhead service conductors, service drop, underground service conductors, or service lateral to, including 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.

Statement of Problem and Substantiation for Public Input

It is a common practice to connect the grounding electrode conductor (GEC) at the same location in the service disconnecting means enclosure where the grounded conductor and the main bonding jumper are installed. Installing the EGC at any accessible point from the from the load end of the overhead service conductors, service drop, underground service conductors, or service lateral to, including the terminal or bus to which the grounded service conductor is connected at the service disconnecting means can be problematic. Installing the EGC at the service point of an overhead supply is inconvenient for installation and inspection but is still accessible. Installing the EGC in a meter socket requires contacting the utility to gain access to the connection of testing and inspection. Again, inconvenient but still accessible. Requiring the connection of all three conductors at the service disconnection means provides constancy for installers, inspectors, and maintenance personnel. Moving the last part of the sentence of the existing text to an exception will still allow for connecting at the EGC at other locations when installation conditions warrant such connection locations.

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Submittal Date: Wed Aug 12 16:01:55 EDT 2020
Committee: NEC-P05

Public Input No. 744-NFPA 70-2020 [Section No. 250.24(C)(4)]

(4) High Impedance.

The ~~grounded conductor~~ system impedance conductor on a high-impedance grounded neutral system shall ~~be grounded in~~ be in accordance with 250.36.

Statement of Problem and Substantiation for Public Input

This is part of a series of public inputs to rename the 'grounded' conductor, of an impedance grounded system, to 'system impedance conductor.'

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 743-NFPA 70-2020 [New Section after 250.1]	250.2 is the definition for this conductor
Public Input No. 745-NFPA 70-2020 [Section No. 250.30(A)(3)]	
Public Input No. 749-NFPA 70-2020 [Section No. 250.36(B)]	
Public Input No. 750-NFPA 70-2020 [Section No. 250.36(D)]	
Public Input No. 753-NFPA 70-2020 [Section No. 200.2(A)]	

Submitter Information Verification

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Submittal Date: Sun Mar 22 13:03:03 EDT 2020
Committee: NEC-P05

Public Input No. 1464-NFPA 70-2020 [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 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(E).

Statement of Problem and Substantiation for Public Input

The word "Service should be added to the title of this section to clarify the application of the contained rules.

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Submittal Date: Fri Jun 05 23:40:50 EDT 2020
Committee: NEC-P05

Public Input No. 4287-NFPA 70-2020 [Section No. 250.25]

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

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

This language was accepted by CMP 4 for the 2020 NEC but was removed by actions taken at the NFPA annual meeting. The biggest concern that was expressed is that CMP 5 should be the committee that addresses language regarding grounding and bonding. This language was reviewed and accepted by representatives all across the alternative energy community. This language makes the requirements clear and will be of great assistance to the enforcement community.

Submitter Information Verification

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Submittal Date:	Thu Sep 10 09:25:27 EDT 2020
Committee:	NEC-P05

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

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

The grounding of systems connected on the supply side of the service disconnect, as permitted in 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(E).

Statement of Problem and Substantiation for Public Input

The change to the title better reflects the application of not just grounding but bonding as well. The addition of the word "of" clearly separates the system from grounding system.

Submitter Information Verification

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Submittal Date: Tue Apr 21 12:52:27 EDT 2020
Committee: NEC-P05

Public Input No. 2660-NFPA 70-2020 [Section No. 250.26]

250.26 Conductor to Be Grounded — Alternating-Current Systems.

~~For grounded~~ If an ac premises wiring ~~systems~~ system is grounded , the conductor to be grounded shall be ~~as specified in the following~~ :

(1) Single-phase, 2-wire — one conductor

(2) Single-phase, 3-wire — the neutral conductor

(3) Multiphase systems having one wire common to all phases — the neutral conductor

(4) Multiphase systems where one phase is grounded — that phase conductor

(5) Multiphase systems in which one phase is used as in (2) — the neutral conductor

Statement of Problem and Substantiation for Public Input

Changing the statement to a conditional one by using "If" corrects the usage to the NEC Style Manual and makes it clear that the requirements in this section apply if the system is grounded, whether it is required to be grounded or is done so voluntarily. In addition the phrase "as specified in the following" is unnecessary for proper application and enforcement.

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Submittal Date: Thu Aug 27 15:24:14 EDT 2020
Committee: NEC-P05

Public Input No. 1612-NFPA 70-2020 [Section No. 250.28]

250.28 Main Bonding Jumper and System Bonding Jumper.

For a grounded system, main bonding jumpers and system bonding jumpers shall be installed as follows:

(A) Material.

Main bonding jumpers and system bonding jumpers shall be of copper, aluminum, copper-clad aluminum, or other corrosion-resistant material. A main bonding jumper and a system bonding jumper shall be a wire, bus, screw, or similar suitable conductor. Where of the wire-type, the main and system bonding jumper shall comply with 250.119.

(B) Construction.

Where a main bonding jumper or a system bonding jumper is a screw only, the screw shall be identified with a green finish that shall be visible with the screw installed.

(C) Attachment.

Main bonding jumpers and system bonding jumpers shall be connected in the manner specified in 250.8.

(D) Size.

Main bonding jumpers and system bonding jumpers shall be sized in accordance with 250.28(D)(1) through (D)(3).

(1) General.

Main bonding jumpers and system bonding jumpers shall not be smaller than specified in Table 250.102(C)(1).

(2) Main Bonding Jumper for Service with More Than One Enclosure.

If a service consists of more than a single enclosure as permitted in 230.71(B), the main bonding jumper for each enclosure shall be sized in accordance with 250.28(D)(1) based on the largest ungrounded service conductor serving that enclosure.

(3) Separately Derived System with More Than One Enclosure.

Where a separately derived system supplies more than a single enclosure, the system bonding jumper for each enclosure shall be sized in accordance with 250.28(D)(1) based on the largest ungrounded feeder conductor serving that enclosure, or a single system bonding jumper shall be installed at the source and sized in accordance with 250.28(D)(1) based on the equivalent size of the largest supply conductor determined by the largest sum of the areas of the corresponding conductors of each set.

Statement of Problem and Substantiation for Public Input

Adding the reference to 250.119 will require the system and main bonding jumpers of the wire-type to have green insulation, green covering, or be bare.

Submitter Information Verification

Submitter Full Name: Mike Holt
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Submittal Date:	Wed Jun 24 12:48:15 EDT 2020
Committee:	NEC-P05

Public Input No. 1469-NFPA 70-2020 [Section No. 250.28(C)]

(C) Attachment.

Main bonding jumpers and system bonding jumpers shall be connected ~~in the manner specified in~~ by one or more of the methods in 250.8 that is suitable for the material of the bonding jumper and the enclosure .

Statement of Problem and Substantiation for Public Input

Not all of the connection methods that are included in 250.8 are suitable for all the types on main or system bonding jumpers.
This revision will ensure the NEC requires that a suitable method will be used.

Submitter Information Verification

Submitter Full Name: Phil Simmons
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Submittal Date: Sat Jun 06 18:51:24 EDT 2020
Committee: NEC-P05

Public Input No. 1750-NFPA 70-2020 [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 considered 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 where 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 neutral system grounding connections shall be made as specified in 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) *Parallel Conductors in Two or More Raceways.* If the ungrounded conductors are installed in parallel in two or more raceways, the grounded conductor shall also be installed in parallel. The size of the grounded conductor in each raceway shall be based on the total circular mil area of the parallel derived ungrounded conductors in the raceway as indicated in 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 grounded conductor of an impedance grounded neutral 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~~ systems located indoors. Separately derived systems located outdoors shall use a grounding electrode 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:

(2) A conductor of the wire type not smaller than 3/0 AWG copper or 250 kcmil aluminum

(3) A metal water pipe that complies with 250.68(C)(1)

(4) The metal structural frame of the building or structure that complies 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

(e) *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.

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

(7) A connector listed as grounding and bonding equipment.

(8) Listed connections to aluminum or copper busbars not smaller than 6 mm thick × 50 mm wide (1/4 in. thick × 2 in. wide) and of sufficient length to accommodate the number of terminations necessary for the installation. If aluminum busbars are used, the installation shall also comply with 250.64(A) .

(9) 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 compliance with 250.50. In addition, the installation shall comply 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 comply with 250.36 or 250.187, as applicable.

Statement of Problem and Substantiation for Public Input

Edits for clarity.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
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Zip:
Submittal Date: Thu Jun 25 20:20:51 EDT 2020
Committee: NEC-P05

Public Input No. 1207-NFPA 70-2020 [Section No. 250.30(A)(1)]

(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).

There is a tremendous amount of requirements packed into 250.30 (A) (1). Reformatting the requirements of this article into list format will improve readability and application.

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.

Statement of Problem and Substantiation for Public Input

There is a tremendous amount of requirements packed into 250.30 (A) (1). Reformatting the requirements of this article into list format will improve readability and application.

The NEC has improved significantly in large part due to improved formatting and readability. This change will continue the trend of making the NEC an easier to document for inspectors, installers and others.

Submitter Information Verification

Submitter Full Name: Gary Hein
Organization: Submission is independent of employer.
Street Address:
City:
State:
Zip:
Submittal Date: Sat May 23 07:45:02 EDT 2020
Committee: NEC-P05

Public Input No. 1471-NFPA 70-2020 [Section No. 250.30(A)(1)]

(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~~ the largest of that required by 220.61 or Table 250.102(C)(1) 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.

Statement of Problem and Substantiation for Public Input

The changes proposed are primarily editorial in nature but will add clarity to the sizing of the grounded conductor that is permitted to be used as the grounded conductor as well as the supply-side-bonding jumper. Section 220.61 for sizing the grounded conductor is existing so the reference to that section does not impose new requirements. Table 250.102(C)(1) is also existing and should be included in this rule to clarify the minimum size of the grounded conductor.

Submitter Information Verification

Submitter Full Name: Phil Simmons

Organization:	Simmons Electrical Services
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Submittal Date:	Sat Jun 06 19:04:10 EDT 2020
Committee:	NEC-P05

Public Input No. 1611-NFPA 70-2020 [Section No. 250.30(A)(1)]

(1) System Bonding Jumper.

An unspliced system bonding jumper shall comply with 250.28(A) through (D) and 250 .119. 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.

Statement of Problem and Substantiation for Public Input

Adding the reference to 250.119 will require the system bonding jumper to be either green insulation or covering or bare.

Submitter Information Verification

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Submittal Date:	Wed Jun 24 12:44:26 EDT 2020
Committee:	NEC-P05

Public Input No. 993-NFPA 70-2020 [Section No. 250.30(A)(2)]

(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:

~~A~~
(a) supply-side bonding jumper of the wire type shall comply with 250.102(C) , based on the size of the derived ungrounded conductors.

(b) 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.

Statement of Problem and Substantiation for Public Input

There is actually no change to the section other than changing the numbers after 250.30(A)(2) "subnumbers" (1) and (2) to lower-case letters (a) and (b).
So those articles would now be 250.30(A)(2)(a) and 250.30(A)(2)(b).

If one takes a quick look at sections 250.30(A)(1) and 250.30(A)(3), it becomes apparent that proper style is to have a lower-case letter after the number and not another number.

We need to comply with the style manual, and be consistent throughout the NEC with how we number and letter the various code articles.
This is the reason for the proposed change.

Submitter Information Verification

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Submittal Date: Thu May 07 11:03:55 EDT 2020
Committee: NEC-P05

Public Input No. 1472-NFPA 70-2020 [Section No. 250.30(A)(3)]

(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) *Parallel Conductors in Two or More Raceways or Cables* . If the ungrounded conductors are ~~installed in~~ connected in parallel in two or more raceways or cables , ~~the grounded~~ a grounded conductor shall also be installed in each raceway or cable and shall be connected in parallel. The size of the grounded conductor in each raceway or cable shall be based on the total circular mil area of the parallel derived ungrounded conductors in the raceway or cable as indicated in 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 grounded conductor of an impedance grounded neutral system shall be installed in accordance with 250.36 or 250.187, as applicable.

Statement of Problem and Substantiation for Public Input

This rule applies equally to installations that are made with cables so "cables" is added where needed. The wording is revised about connecting conductors in parallel rather than installing them in parallel to be consistent with that in 250.122(F).

Submitter Information Verification

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Submittal Date: Sat Jun 06 19:17:03 EDT 2020
Committee: NEC-P05

Public Input No. 745-NFPA 70-2020 [Section No. 250.30(A)(3)]

(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) *Parallel Conductors in Two or More Raceways.* If the ungrounded conductors are installed in parallel in two or more raceways, the grounded conductor shall also be installed in parallel. The size of the grounded conductor in each raceway shall be based on the total circular mil area of the parallel derived ungrounded conductors in the raceway as indicated in 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 ~~grounded conductor~~ system impedance conductor of an impedance grounded neutral system shall be installed in accordance with 250.36 or 250.187, as applicable.

Statement of Problem and Substantiation for Public Input

This is a part of a series of public inputs to change 'grounded conductor' to 'system impedance conductor' in impedance grounded systems.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 743-NFPA 70-2020 [New Section after 250.1]	definition for this conductor
Public Input No. 744-NFPA 70-2020 [Section No. 250.24(C)(4)]	same conductor in a service
Public Input No. 749-NFPA 70-2020 [Section No. 250.36(B)]	
Public Input No. 750-NFPA 70-2020 [Section No. 250.36(D)]	
Public Input No. 753-NFPA 70-2020 [Section No. 200.2(A)]	

Submitter Information Verification

Submitter Full Name: Eric Stromberg
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Submittal Date: Sun Mar 22 13:13:39 EDT 2020

Committee: NEC-P05

Public Input No. 1049-NFPA 70-2020 [Section No. 250.30(A)(6)]

(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:

(2) A conductor of the wire type not smaller than 3/0 AWG copper or 250 kcmil aluminum

(3) A metal water pipe that complies with 250.68(C)(1)

(4) The metal structural frame of the building or structure that complies 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

(e) *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.

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

(7) A connector listed as grounding and bonding equipment that is made for the purpose of connecting and bonding multiple service equipment or separately derived systems' grounding electrode conductors . _____ Information Note: The Intersystem Bond Terminal Device of 250.94 is for communications intersystem bonding and is not suitable for service or separately derived system grounding electrode conductor tap connections.

(8) Listed connections to aluminum or copper busbars not smaller than 6 mm thick × 50 mm wide (**1**/**4** in. thick × 2 in. wide) and of sufficient length to accommodate the number of terminations necessary for the installation. If aluminum busbars are used, the installation shall also comply with 250.64(A) .

(9) 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.

Statement of Problem and Substantiation for Public Input

This has room to be elaborated on as proposed. A 250.95 Intersystem Bond Terminal Device meets the description as stated in 2020's 250.30A6c1 other than it's title 'Bonding for Communication Systems. The new language helps prevent a misapplication of an IBTD which I have seen.

Submitter Information Verification

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Committee: NEC-P05

Public Input No. 1480-NFPA 70-2020 [Section No. 250.30 [Excluding any Sub-Sections]]

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 a utility powered premises wiring system shall be considered as a single separately derived system at the common point of connection and shall be installed ~~in accordance with~~ ~~250.30~~ . as a separately derived system.

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 where 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.

Statement of Problem and Substantiation for Public Input

when multiple SDS are installed,/ the grounding of the system is already establish at the common point of connection. So when it supplies a premises wiring system it must be installed as a separately derived system otherwise the two system grounding connection will create a parallel path.

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Committee: NEC-P05

Public Input No. 1633-NFPA 70-2020 [Section No. 250.32(A)]

(A) Grounding Electrode.

A building(s) or structure(s) supplied by a feeder(s) or branch circuit(s) shall have a grounding electrode system and grounding electrode conductor installed in accordance with Part III of Article 250. Where there is no existing grounding electrode, the grounding electrode(s) required in 250.50 shall be installed.

Exception: A grounding electrode system and grounding electrode conductor shall not be required where only a single branch circuit, including a multiwire branch circuit, supplies the building or structure and the branch circuit includes an equipment grounding conductor for grounding the normally non–current-carrying metal parts of equipment.

Statement of Problem and Substantiation for Public Input

Add the word "conductor" and 'grounding electrode system' so that the rule makes sense. I submitted a PI for 2020 to add the requirement to have a GEC to (A), so the exception to follow through with the change made in 2020 NEC.

Submitter Information Verification

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Committee: NEC-P05

Public Input No. 2345-NFPA 70-2020 [Section No. 250.32(A)]

(A) Grounding Electrode.

A building(s) or structure(s) supplied by a feeder(s) or branch circuit(s) shall have a grounding electrode system and grounding electrode conductor installed in accordance with Part III of Article 250. Where ~~there is no existing grounding electrode, the grounding electrode(s) required in 250.50 shall be installed~~ none of the grounding electrodes specified in 250.52(A)(1), (A)(2), (A)(3) or (A)(8) are present one or more of the grounding electrodes in specified in 250.52(A)(4) through (A)(7) shall be installed and used .

Exception: A grounding electrode shall not be required where only a single branch circuit, including a multiwire branch circuit, supplies the building or structure and the branch circuit includes an equipment grounding conductor for grounding the normally non–current-carrying metal parts of equipment.

Statement of Problem and Substantiation for Public Input

This section has not been revised for many cycles and should be updated to correlate with the revisions made to 250.50 over the years. Additionally, what is an “existing grounding electrode?” Those that have years of experience with the NEC know it is a grounding electrode that generally exists due to construction. An argument could be made that just the reference to having a grounding electrode system in accordance with Part III of Article 250 is all that is necessary in this section. The proposed revision was chosen over that choice as most likely the feeder or branch circuit to a building(s) or other structure(s) is being installed after the original building or other structure is built and, therefore, it is more likely to have a grounding electrode in accordance with 250.52(A)(8) present. The proposed wording is also consistent with what is already in 250.50. The exception remains and is unchanged by this public input.

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Committee: NEC-P05

Public Input No. 123-NFPA 70-2019 [Section No. 250.34(C)]

(C) Grounded Conductor Bonding.

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

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

(2) a grounding-type receptacle is mounted on the generator or frame

(3) a terminal or receptacle that is identified for equipment grounding purposes is mounted on the generator or frame

The system conductor that is connected to the generator frame shall be not smaller than required by 250 .102(C) but shall not be required to be larger than the ungrounded conductor.

Informational Note: ~~For grounding portable generators supplying fixed wiring systems, see 250.30 .~~ See 250.30 for grounding and bonding portable generators that supply fixed wiring systems.

Additional Proposed Changes

File Name	Description	Approved
445-20_GFCI.jpg	Operation of GFCI Receptacles with and without bonded neutral.	

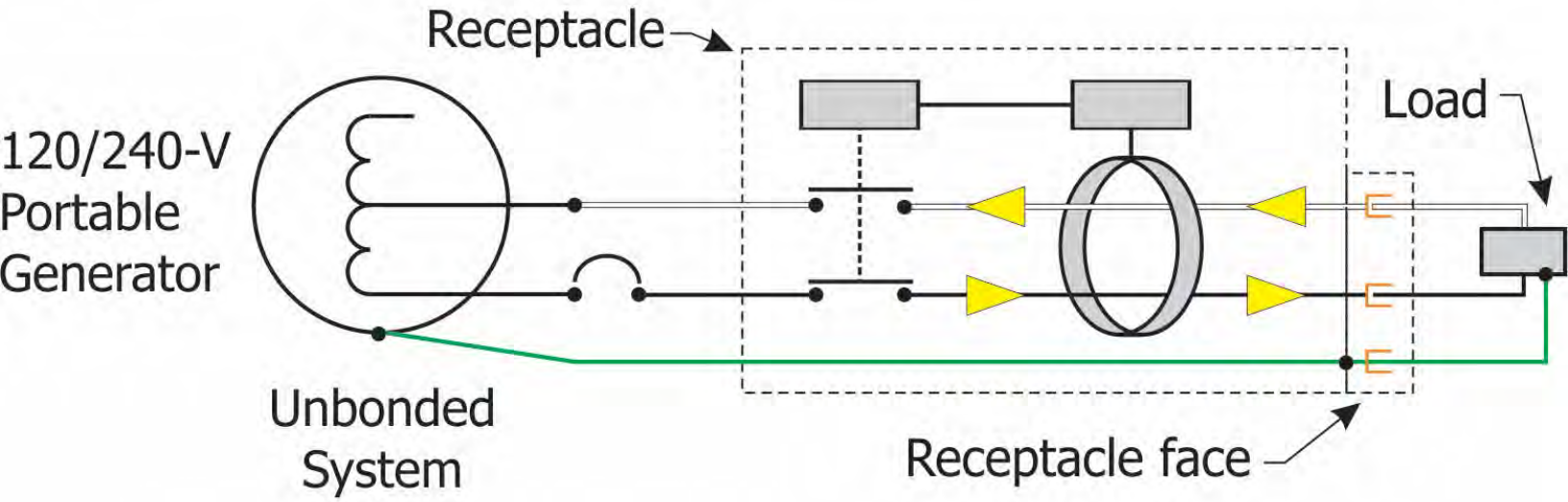
Statement of Problem and Substantiation for Public Input

1. CMP-5 is responsible for requirements for when electrical systems are required to be bonded and/or grounded. Thus, the safety provisions of this Public Input must be incorporated in this section.
2. It is vital that a reliable ground-fault return path be provided to ensure the safe operation of circuit protective devices.
3. The existing 250.34(C) requires that the neutral be bonded to the frame of the generator if the generator is a component of a separately derived system. It must also require that a ground-fault return path be provided if grounding type receptacles are provided on the generator.
4. It is common to see 15, 20 and 30-amp grounding type receptacles installed on these portable generators without a ground-fault return path. As a result, ground-fault protection cannot function even though it is indicated by the receptacles.
5. If a portable or vehicle-mounted or trailer-mounted generator is used in a stand-alone function and supplies electrical loads only through receptacles that are mounted on the generator, it is supplying "Premises Wiring" as defined in Article 100. Note that the definition of "Premises Wiring" includes "(b) wiring from and including the power source to the outlets where there is no service point." A portable generator used is a stand-alone function will not have a "service point" as defined but yet supplies "Premises Wiring". See also the Informational Note that follows the definition of Premises Wiring" which includes "generators".
6. It can be argued successfully in court that the rules in 250.21 require that the electrical system produced by a portable generator be grounded. As a separately derived system, the rules in 250.30 apply.
7. This Public Input must be accepted to simplify these requirements and clearly require the neutral be bonded to the frame of a portable-type generator for safety. If the neutral is not connected to the frame, a GFCI cannot provide the protection indicated and ground fault current cannot return to the source.
8. It is common for portable generators to be manufactured with grounding type receptacles as well as terminals such as or similar to Cam-Locks to connect power cords. The neutral needs to be bonded to the frame so these identified terminals are effective.

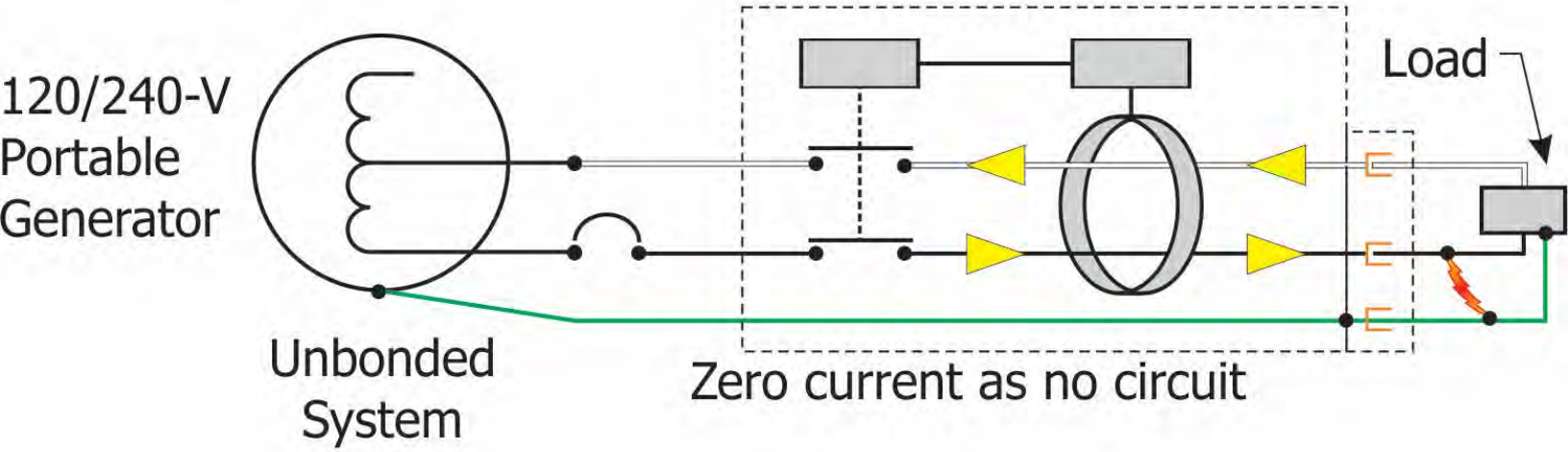
Submitter Information Verification

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Committee: NEC-P05

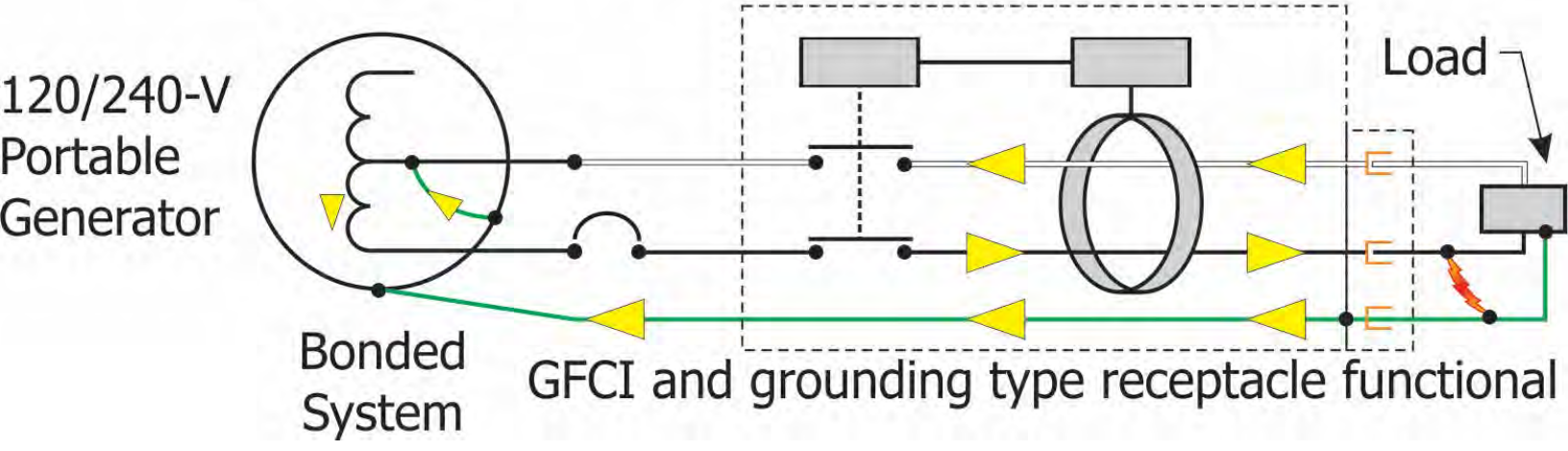
Normal System Operation with GFCI Receptacle



Operation with One System Conductor Faulted



Operation with One System Conductor Faulted



Public Input No. 1905-NFPA 70-2020 [Section No. 250.34(C)]

(C) Grounded Conductor Bonding.

A ~~system~~ circuit conductor that is required to be grounded by 250.26 shall be connected to the generator frame where the generator is a component of a separately derived system.

Informational Note: For grounding portable generators supplying fixed wiring systems, see 250.30.

Statement of Problem and Substantiation for Public Input

The term "System Conductor" is used 12 times in the 2020 NEC and the usage is confined to Articles 100 and 250. In each instance of usage, it is describing a grounded conductor and in 11 of the 12 instances it is part of the term "Grounded System Conductor". The term "Circuit Conductor" is used 81 times throughout the 2020 NEC. The term "Grounded Circuit Conductor" is used 43 times throughout the 2020 NEC and 10 times in Article 250.

In Articles 100 and 250, it is not clear that there is a difference between a "Grounded System Conductor" and a "Grounded Circuit Conductor", these terms appear to be used interchangeably.

If it is not the intent that these terms be used interchangeably:

- Definitions should be provided as proposed in PIs 1881-NFPA 70-2020 and 1882-NFPA 70-2020 to delineate the unique features of a "System Conductor" versus those of a "Circuit Conductor“

- PIs 1883-NFPA 70-2020 , 1906-NFPA 70-2020 , 1892-NFPA 70-2020 , 1893-NFPA 70-2020 , 1904-NFPA 70-2020 , and 1905-NFPA 70-2020 should be disregarded

If it is the intent that the two terms are to be used interchangeably:

- All instances of "System Conductor" should be changed to "Circuit Conductor“

- PIs 1883-NFPA 70-2020 , 1906-NFPA 70-2020 , 1892-NFPA 70-2020 , 1893-NFPA 70-2020 , 1904-NFPA 70-2020 , and 1905-NFPA 70-2020 should be accepted to change instances of “system conductor” to “circuit conductor”

- PI 1881-NFPA 70-2020 may be helpful in this scenario to clarify the meaning of the term ”Circuit Conductor”

- Replacing all instances of "Circuit Conductor“ with "System Conductor" and defining the term "System Conductor" would accomplish the same goal. "Circuit Conductor“ is presently more used throughout the NEC, so the proposal above requires a smaller number of revisions.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1881-NFPA 70-2020 [New Definition after Definition: Conductor, Bare.]	
Public Input No. 1882-NFPA 70-2020 [New Definition after Definition: Conductor, Insulated.]	
Public Input No. 1883-NFPA 70-2020 [Definition: Grounded Conductor.]	
Public Input No. 1893-NFPA 70-2020 [Section No. 250.84]	

Public Input No. 1904-NFPA 70-2020 [Section No. 250.187(C)]

Public Input No. 1906-NFPA 70-2020 [Section No. 250.36(B)]

Public Input No. 1892-NFPA 70-2020 [Section No. 250.80]

Public Input No. 1881-NFPA 70-2020 [New Definition after Definition: Conductor, Bare.]

Public Input No. 1882-NFPA 70-2020 [New Definition after Definition: Conductor, Insulated.]

Public Input No. 1883-NFPA 70-2020 [Definition: Grounded Conductor.]

Public Input No. 1892-NFPA 70-2020 [Section No. 250.80]

Public Input No. 1893-NFPA 70-2020 [Section No. 250.84]

Public Input No. 1904-NFPA 70-2020 [Section No. 250.187(C)]

Public Input No. 1906-NFPA 70-2020 [Section No. 250.36(B)]

Submitter Information Verification

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Committee: NEC-P05

Public Input No. 600-NFPA 70-2020 [Section No. 250.35(B)]

(B) Nonseparately Derived System. _ Generators installed as nonseparately derived systems shall be grounded in accordance with 250.35(B)(1) or (B)(2).

(1) Overcurrent Protection Not Provided. _ If the generator is installed as a nonseparately derived system, and overcurrent protection is not integral with the generator assembly, a supply-side bonding jumper shall be installed between the generator equipment grounding terminal and the equipment grounding terminal, bar, or bus of the disconnecting mean(s). It shall be sized in accordance with 250.102(C) based on the size of the conductors supplied by the generator.

(2) Overcurrent Protection Provided. If the generator is installed as a nonseparately derived system, and overcurrent protection is integral with the generator assembly, an equipment grounding conductor shall be installed between the generator equipment grounding terminal and the equipment grounding terminal of the downstream distribution equipment or transfer equipment. It shall be sized in accordance with 250.122 based on the rating of the generator overcurrent protection device.

Statement of Problem and Substantiation for Public Input

Article 230.35 clearly states how to ground a permanently installed separately derived system generator and nonseparately derived system generator that does not have integral overcurrent protection. Article 250.35 should also state the grounding requirements for nonseparately derived system generators that are equipped with integral overcurrent protection. The proposed change provides guidance that a properly sized equipment grounding conductor has to be installed between the generator and the downstream distribution equipment (feeder tap OCPD's) or transfer equipment.

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Committee: NEC-P05

Public Input No. 1965-NFPA 70-2020 [Section No. 250.36]

250.36 High-Impedance Grounded Neutral Systems.

High-impedance grounded neutral systems in which a grounding impedance, usually a resistor, limits the ground-fault current to a low value shall be permitted for 3-phase ac systems ~~of 480 volts~~ up 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.

High-impedance grounded neutral systems shall comply with 250.36(A) through (G).

Informational Note: According to Annex O of *NFPA 70E*-2018, *Standard for Electrical Safety in the Workplace*, high-impedance grounding is an effective tool to reduce arc flash hazards.

(A) Location.

The grounding impedance shall be installed between the grounding electrode conductor and the system neutral point. If a neutral point is not available, the grounding impedance shall be installed between the grounding electrode conductor and the neutral point derived from a grounding transformer.

(B) Conductor Insulation and Ampacity.

The grounded system conductor from the neutral point of the transformer or generator to its connection point to the grounding impedance shall be fully insulated.

The grounded system conductor shall have an ampacity of not less than the maximum current rating of the grounding impedance but in no case shall the grounded system conductor be smaller than 8 AWG copper or 6 AWG aluminum or copper-clad aluminum.

(C) System Grounding Connection.

The system shall not be connected to ground except through the grounding impedance.

Informational Note: The impedance is normally selected to limit the ground-fault current to a value slightly greater than or equal to the capacitive charging current of the system. This value of impedance will also limit transient overvoltages to safe values. For guidance, refer to criteria for limiting transient overvoltages in ANSI/IEEE 142-2007, *Recommended Practice for Grounding of Industrial and Commercial Power Systems*.

(D) Conductor Routing.

The conductor connecting the neutral point of the transformer or generator to the grounding impedance shall be permitted to be installed in a separate raceway from the ungrounded conductors. It shall not be required to run this conductor with the phase conductors to the first system disconnecting means or overcurrent device.

(E) Equipment Bonding Jumper.

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

(F) Grounding Electrode Conductor Connection Location.

For services or separately derived systems, the grounding electrode conductor shall be connected at any point from the grounded side of the grounding impedance to the equipment grounding connection at the service equipment or the first system disconnecting means of a separately derived system.

(G) Equipment Bonding Jumper Size.

The equipment bonding jumper shall be sized in accordance with (1) or (2) as follows:

(1) If the grounding electrode conductor connection is made at the grounding impedance, the equipment 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 bonding jumper shall be sized the same as the neutral conductor in 250.36(B).

Statement of Problem and Substantiation for Public Input

Many older industrial facilities currently operate using 240 volt secondary delta connected transformers. Ground faults on these systems can create a danger to operating personnel and equipment can experience overvoltages caused by the ground faults. High-impedance grounded systems eliminate most arc-flash dangers and minimize equipment overvoltages during ground faults. This protection should be extended to these lower voltage systems. While some industrial facilities are upgrading to 480Y/277V wye secondaries, this takes time and providing similar protection to the rest of the facility provides consistent protection across the facility. In addition, with the development and growth of micro-grids, many of these systems will be operating below 480 volts and this protection should be extended to these new technologies. The three restrictions listed would still be enforced. CSA Standard C22.2 No. 295-15, Section 4.9.1, which covers neutral grounding assemblies, is for systems rated 750V line to neutral or less and does not have a low limit. This change to NFPA 70 250.36 would allow manufacturers to use the same designs below 480 volts for both the U.S. and Canadian markets.

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Committee: NEC-P05

Public Input No. 1906-NFPA 70-2020 [Section No. 250.36(B)]

(B) Conductor Insulation and Ampacity.

The grounded ~~system~~ circuit conductor from the neutral point of the transformer or generator to its connection point to the grounding impedance shall be fully insulated.

The grounded ~~system~~ circuit conductor shall have an ampacity of not less than the maximum current rating of the grounding impedance but in no case shall the grounded ~~system~~ circuit conductor be smaller than 8 AWG copper or 6 AWG aluminum or copper-clad aluminum.

Statement of Problem and Substantiation for Public Input

The term "System Conductor" is used 12 times in the 2020 NEC and the usage is confined to Articles 100 and 250. In each instance of usage, it is describing a grounded conductor and in 11 of the 12 instances it is part of the term "Grounded System Conductor". The term "Circuit Conductor" is used 81 times throughout the 2020 NEC. The term "Grounded Circuit Conductor" is used 43 times throughout the 2020 NEC and 10 times in Article 250.

In Articles 100 and 250, it is not clear that there is a difference between a "Grounded System Conductor" and a "Grounded Circuit Conductor", these terms appear to be used interchangeably.

If it is not the intent that these terms be used interchangeably:

- Definitions should be provided as proposed in PIs 1881-NFPA 70-2020 and 1882-NFPA 70-2020 to delineate the unique features of a "System Conductor" versus those of a "Circuit Conductor“

- PIs 1883-NFPA 70-2020 , 1906-NFPA 70-2020 , 1892-NFPA 70-2020 , 1893-NFPA 70-2020 , 1904-NFPA 70-2020 , and 1905-NFPA 70-2020 should be disregarded

If it is the intent that the two terms are to be used interchangeably:

- All instances of "System Conductor" should be changed to "Circuit Conductor“

- PIs 1883-NFPA 70-2020 , 1906-NFPA 70-2020 , 1892-NFPA 70-2020 , 1893-NFPA 70-2020 , 1904-NFPA 70-2020 , and 1905-NFPA 70-2020 should be accepted to change instances of “system conductor” to “circuit conductor”

- PI 1881-NFPA 70-2020 may be helpful in this scenario to clarify the meaning of the term ”Circuit Conductor”

- Replacing all instances of "Circuit Conductor“ with "System Conductor" and defining the term "System Conductor" would accomplish the same goal. "Circuit Conductor“ is presently more used throughout the NEC, so the proposal above requires a smaller number of revisions.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1881-NFPA 70-2020 [New Definition after Definition: Conductor, Bare.]	
Public Input No. 1882-NFPA 70-2020 [New Definition after Definition: Conductor, Insulated.]	
Public Input No. 1883-NFPA 70-2020 [Definition: Grounded Conductor.]	
Public Input No. 1893-NFPA 70-2020 [Section No. 250.84]	

Public Input No. 1904-NFPA 70-2020 [Section No. 250.187(C)]

Public Input No. 1905-NFPA 70-2020 [Section No. 250.34(C)]

Public Input No. 1892-NFPA 70-2020 [Section No. 250.80]

Public Input No. 1881-NFPA 70-2020 [New Definition after Definition: Conductor, Bare.]

Public Input No. 1882-NFPA 70-2020 [New Definition after Definition: Conductor, Insulated.]

Public Input No. 1883-NFPA 70-2020 [Definition: Grounded Conductor.]

Public Input No. 1892-NFPA 70-2020 [Section No. 250.80]

Public Input No. 1893-NFPA 70-2020 [Section No. 250.84]

Public Input No. 1904-NFPA 70-2020 [Section No. 250.187(C)]

Public Input No. 1905-NFPA 70-2020 [Section No. 250.34(C)]

Submitter Information Verification

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Submittal Date: Tue Jul 14 15:57:28 EDT 2020
Committee: NEC-P05

Public Input No. 4708-NFPA 70-2020 [Section No. 250.36(B)]

(B) Conductor Insulation and Ampacity.

The grounded system conductor from the neutral point of the transformer or generator to its connection point to the grounding impedance shall be fully insulated.

~~The~~

For grounded system conductors installed external to enclosures, the grounded system conductor shall not be smaller than 8 AWG copper or 6 AWG aluminum or copper-clad aluminum. For grounded system conductors connected between multiple enclosures, the grounded system conductors shall not be smaller than 8 AWG copper or 6 AWG aluminum or copper-clad aluminum. For those sections of grounded system conductors installed in labeled and listed enclosures, the grounded system conductor shall have an ampacity of not less than the maximum current rating of the grounding impedance

~~but in no case shall~~

where both ends of the grounded system conductor are terminated within the enclosure. The termination points shall be

~~smaller than 8 AWG copper or 6 AWG~~

sized for connecting to external grounded system conductors per the applicable standard for the enclosure being used. Grounded system conductors passing through any enclosure without termination shall not be smaller than 8 AWG copper or 6 AWG aluminum or copper-clad aluminum.

Statement of Problem and Substantiation for Public Input

The first and second sentences maintain the original code requirements for grounded system conductors outside of enclosures. For conductors placed inside labeled and listed enclosures for internal wiring terminated at both ends within the enclosure, only wires protected by the enclosure will be allowed to be smaller than 8 AWG for copper conductors and 6 AWG for aluminum and copper-clad aluminum. Typical guidance for the termination of wires internal to enclosures is provided in UL 891, Switchboards. Section 8.4.8 provides the requirements for High-impedance neutral grounded systems. A change to 8.4.8.6 to allow cables less than 8 AWG in switchboards has been submitted through UL CSDS. Additionally, this change will harmonize 250.36(B) with CSA C22.2 No. 295-15, Sections 4.5.2 and 4.7.1. Labeled and listed enclosures will provide the necessary protection for the grounded system conductor. A grounded system conductor passing through an enclosure of any type without termination must still be the same size as the external conductors.

Submitter Information Verification

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Submittal Date: Fri Sep 11 12:05:55 EDT 2020
Committee: NEC-P05

Public Input No. 749-NFPA 70-2020 [Section No. 250.36(B)]

(B)– System Impedance Conductor Insulation and Ampacity.

~~The grounded system~~ The system impedance conductor from the neutral point of the transformer or generator to its connection point to the grounding impedance shall be fully insulated.

~~The grounded system~~ The system impedance conductor shall have an ampacity of not less than the maximum current rating of the grounding impedance but in no case shall the ~~grounded~~ system impedance conductor be smaller than 8 AWG copper or 6 AWG aluminum or copper-clad aluminum.

Statement of Problem and Substantiation for Public Input

This is part of a series of public inputs to rename the 'grounded' conductor, of an impedance grounded system, to 'system impedance conductor.'

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 743-NFPA 70-2020 [New Section after 250.1]	new definition for system impedance conductor
Public Input No. 744-NFPA 70-2020 [Section No. 250.24(C)(4)]	
Public Input No. 745-NFPA 70-2020 [Section No. 250.30(A)(3)]	
Public Input No. 746-NFPA 70-2020 [Section No. 250.187(A)]	
Public Input No. 747-NFPA 70-2020 [Section No. 250.187(B)]	
Public Input No. 748-NFPA 70-2020 [Section No. 250.187(C)]	
Public Input No. 750-NFPA 70-2020 [Section No. 250.36(D)]	
Public Input No. 753-NFPA 70-2020 [Section No. 200.2(A)]	

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Submittal Date: Sun Mar 22 18:01:58 EDT 2020
Committee: NEC-P05

Public Input No. 2620-NFPA 70-2020 [Section No. 250.36(C)]

(C) System Grounding Connection.

The system shall not be connected to ground except through the grounding impedance.

Informational Note: The impedance is normally selected to limit the ground-fault current to a value slightly greater than or equal to the capacitive charging current of the system. This value of impedance will also limit transient overvoltages to safe values. For guidance, refer to criteria for limiting transient overvoltages in ~~ANSI/~~ **IEEE** ~~142-2007,~~ ~~Recommended~~ **3003.1-2019 R** ***ecommended*** ***Practice for*** ***System*** ***Grounding of Industrial and Commercial Power Systems*** **.**

Statement of Problem and Substantiation for Public Input

IEEE 3003.1 is the title that replaces the IEEE 142, the so-called Green Book. From the 3003.1 scope statement: "Discussed in this recommended practice is the system grounding of industrial and commercial power systems. The recommended practices in this document are intended to provide explanations of how electrical systems operate. It can also be an aid to all engineers responsible for the electrical design of industrial and commercial power systems."

Here is the link for complete information:

https://standards.ieee.org/standard/3003_1-2019.html

Note a related title on equipment grounding which the committee may choose to reference to another section in Article 250 -- IEEE 3002.2-2014:

https://standards.ieee.org/standard/3003_2-2014.html

Submitter Information Verification

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Submittal Date:	Wed Aug 26 08:29:10 EDT 2020
Committee:	NEC-P05

Public Input No. 3309-NFPA 70-2020 [Section No. 250.36(C)]

(C) System Grounding Connection.

The system shall not be connected to ground except through the grounding impedance.

Informational Note: The impedance is normally selected to limit the ground-fault current to a value slightly greater than or equal to the capacitive charging current of the system. This value of impedance will also limit transient overvoltages to safe values. For guidance, refer to criteria for limiting transient overvoltages in ~~ANSI/IEEE 142-2007,~~ IEEE 3003.1 IEEE Recommended Practice for System Grounding of Industrial and Commercial Power Systems ~~.~~

Statement of Problem and Substantiation for Public Input

This is another slice of updated content from the legacy Color Books now mapping into the IEEE 3000 Standards Collection. From the project prospectus:

"Discussed in this recommended practice is the system grounding of industrial and commercial power systems. The recommended practices in this document are intended to provide explanations of how electrical systems operate. It can also be an aid to all engineers responsible for the electrical design of industrial and commercial power systems."

https://standards.ieee.org/standard/3003_1-2019.html

IEEE's Industrial Applications Society has determined a need for reorganizing the IEEE's Color Books Series, 13 books that currently cover various topics that fall under the purview of the Industrial and Commercial Power Industry. This comprehensive initiative, driven by the volunteer leadership of I&CPS, acknowledges that the continued and long-term maintenance of IEEE's Color Books has been affected by significant attrition due to declining volunteer resources, the complexity involved in updating each book, and content duplication among the books. The existing content will be integrated into a newly proposed structure by technical topics that will allow for easy updating, more streamlined content, and elimination of duplicative material.
[Note: This purpose will not be included in the document]

This new standard is part of a larger project to revise and reorganize the technical content of the 13 existing IEEE Color Books. Benefits of the project include, but are not limited to:

1) the elimination of duplicate material that now exists in the various color books,
2) the speeding up of the revision process by allowing Color Book content to be reviewed, edited and balloted in smaller segments,
3) to accommodate more modern, efficient and cost effective physical publishing/distribution methodologies (i.e., the elimination of large and expensive to produce books).

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Affiliation:	IEEE Education & Healthcare Facility Electrotechnology Committee
Street Address:	
City:	
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Submittal Date:	Mon Sep 07 16:52:09 EDT 2020
Committee:	NEC-P05

Public Input No. 750-NFPA 70-2020 [Section No. 250.36(D)]

(D)– System Impedance Conductor Routing.

The ~~conductor connecting the neutral point of the transformer or generator to the grounding impedance~~ system impedance conductor shall be permitted to be installed in a separate raceway from the ungrounded conductors. It shall not be required to run this conductor with the phase conductors to the first system disconnecting means or overcurrent device.

Statement of Problem and Substantiation for Public Input

This is part of a series of public inputs to rename the 'grounded' conductor, of an impedance grounded system, to 'system impedance conductor.'

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 743-NFPA 70-2020 [New Section after 250.1]	
Public Input No. 744-NFPA 70-2020 [Section No. 250.24(C)(4)]	
Public Input No. 745-NFPA 70-2020 [Section No. 250.30(A)(3)]	
Public Input No. 746-NFPA 70-2020 [Section No. 250.187(A)]	
Public Input No. 747-NFPA 70-2020 [Section No. 250.187(B)]	
Public Input No. 748-NFPA 70-2020 [Section No. 250.187(C)]	
Public Input No. 749-NFPA 70-2020 [Section No. 250.36(B)]	
Public Input No. 753-NFPA 70-2020 [Section No. 200.2(A)]	

Submitter Information Verification

Submitter Full Name: Eric Stromberg
Organization: Los Alamos National Laboratory
Affiliation: Self
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City:
State:
Zip:
Submittal Date: Sun Mar 22 18:10:37 EDT 2020
Committee: NEC-P05

Public Input No. 751-NFPA 70-2020 [Section No. 250.36(E)]

(E) ~~Equipment Bonding~~ Supply-Side Bonding Jumper.

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

Statement of Problem and Substantiation for Public Input

250.36(E) is currently titled "Equipment Bonding Jumper." The Article 100 definition of "Bonding Jumper, Equipment" is "The connection between two or more portions of the equipment grounding conductor. The jumper in 250.36 does not connect parts of the EGC. It is on the supply side and connects the grounded side of the system impedance to the enclosure/raceway/effective-ground-fault-current-path of the system.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 752-NFPA 70-2020 [Section No. 250.36(G)]	

Submitter Information Verification

Submitter Full Name: Eric Stromberg
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Submittal Date: Sun Mar 22 18:21:16 EDT 2020
Committee: NEC-P05

Public Input No. 752-NFPA 70-2020 [Section No. 250.36(G)]

(G) ~~Equipment Bonding~~ Supply-Side Bonding Jumper Size.

The ~~equipment~~ supply-side bonding jumper shall be sized in accordance with (1) or (2) as follows:

(1) If the grounding electrode conductor connection is made at the grounding impedance, the ~~equipment~~ supply-side 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 bonding~~ supply-side bonding jumper shall be sized the same as the ~~neutral conductor~~ system impedance conductor in 250.36(B).

Statement of Problem and Substantiation for Public Input

This is a companion public input to change "equipment bonding jumper" to "supply-side bonding jumper" in order to align with the definitions in Article 100. Also, in the current section, there is a reference to "neutral" conductor although there is no neutral conductor in the system. This is also a companion public input to introduce the definition of a "system impedance conductor."

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 743-NFPA 70-2020 [New Section after 250.1]	Definition of conductor from neutral point to resistor
Public Input No. 751-NFPA 70-2020 [Section No. 250.36(E)]	Change from 'equipment bonding jumper' to 'supply side bonding jumper'

Submitter Information Verification

Submitter Full Name: Eric Stromberg
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Affiliation: Self
Street Address:
City:
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Submittal Date: Sun Mar 22 18:49:10 EDT 2020
Committee: NEC-P05

Public Input No. 1505-NFPA 70-2020 [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. Where 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. In other than dwelling units, Grounding electrode conductors shall be identified by tag or other means where they terminate

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

Additional Proposed Changes

File Name	Description	Approved
.1591828841815		
10.msg	ground bar photo	

Statement of Problem and Substantiation for Public Input

We see ground bars on many commercial jobs with as many as 6-8 conductors some the same size some different sizes. It would be little effort and good practice to label each electrode conductor. some may have 2 labels IE.. water pipe and building steel

Submitter Information Verification

Submitter Full Name: James Dorsey
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City:
State:
Zip:
Submittal Date: Wed Jun 10 18:34:03 EDT 2020
Committee: NEC-P05

Public Input No. 2671-NFPA 70-2020 [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. Where 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. Two or more grounding electrodes that are bonded together shall be considered a single grounding electrode system.

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

Statement of Problem and Substantiation for Public Input

This PI is intended to be editorial in nature rather than substantive.
The sentence from 250.53(B) is being relocated here as this is the appropriate site for it.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2672-NFPA 70-2020 [Section No. 250.53(B)]	

Submitter Information Verification

Submitter Full Name: Phil Simmons
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City:
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Submittal Date: Thu Aug 27 18:18:30 EDT 2020
Committee: NEC-P05

Public Input No. 261-NFPA 70-2020 [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 (1) or (2):

(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; or

(2) Bare copper conductor not smaller than 4 AWG

~~Metallic~~ 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 Input

The NEC style manual considers the term "metallic" as possibly unenforceable and vague, and recommends using the term "metal" instead. In this case, I believe "metal" is the proper term.

Submitter Information Verification

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City:
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Zip:
Submittal Date: Wed Jan 08 19:52:05 EST 2020
Committee: NEC-P05

Public Input No. 3415-NFPA 70-2020 [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 (1) or (2):

(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; or

(2) Bare copper conductor not smaller than 4 AWG

Metallic components shall be encased by at least 50 mm (2 in.) of concrete and shall be located horizontally within that portion of a concrete exterior perimeter foundation or footing of a building or structure that is in direct contact with the earth or within exterior 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 Input

The concrete encased electrode relies on the moisture of the earth to provide a low resistant connection. This should take place only in the exterior perimeter of the building or structure. The IAEI is aware of an installation where they stated they were going to connect to the concrete encased electrode on the interior footings. Currently, the Code does not prohibit connecting to a footing over 100 feet from the exterior footings. CMP-5 has had discussions regarding the installation of the concrete encased electrodes and that they should be included in the requirements to the exterior perimeter footings. The weight of the building to the exterior footings should be a major component of the concrete encased grounding electrode system.

Submitter Information Verification

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City:
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Submittal Date: Tue Sep 08 14:20:12 EDT 2020
Committee: NEC-P05

Public Input No. 3421-NFPA 70-2020 [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 (1) or (2):

(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; or

(2) Bare copper conductor not smaller than 4 AWG

Metallic 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.Direct contact with the earth shall not include concrete separated by insulation, vapor barriers, films or similar items. 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 Input

The current informational note is not enforceable as an Informational Note. By moving the wording from the informational note to the Code text will provide a requirement that is enforceable.

Submitter Information Verification

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Submittal Date: Tue Sep 08 14:25:07 EDT 2020
Committee: NEC-P05

Public Input No. 4499-NFPA 70-2020 [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 continuous concrete, hoizontal or vertical, encasing either (1) or (2):

(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; or

(2) ~~Bare~~ A 20 foot lenght of bare copper conductor not smaller than 4 AWG

Metallic 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 Input

The definition of "electrode" from Article 100 and under CMP-5 responsibility states "A conducting object through which a direct connection to earth is established". In the case of a concrete encased electrode the "conducting object" that is direct contact with the earth is the concrete, not the rebar or copper wire encased in the concrete. The overall concrete encased electrode is a system to provide that connection to earth (the concrete) and to provide a means to connect to the electrical system (the rebar or copper wire).

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 concreate (rebar or wire) should be placed about 2 inches above the base of the concrete foundation footing.

There seems to be great confusion in application of the concrete encased electrode, especially since the vertical aspect was introduced several cycles back. Many seem to equate the rebar or copper wire as the main part of the electrode and it just happens to have concrete encasement. This in not what the studies cited show. For example, short pier foundations that may only be 5 feet deep and contain 4 each 5-foot rebars are being considered as a concrete encased electrode because "there is 20 feet of rebar encased the concrete". There is no evidence or study to back that up. Taken the "nth" degree one could take 20 1-foot lengths of 1/2 inch rebar bundled up with tie wires and encase in a block of concrete 16 inches by 16 inches and call that a concrete encased electrode. The proposed language clarifies that what is needed is 20 feet of concrete, horizontally or vertically, in contact with the earth

and that concrete contains rebar or wire along that entire length for connection of the electrical system to the length and volume of concrete in the earth. The main text establishes the 20 feet of concrete requirement and the sub (1) and (2) clarify that the length of concrete must include rebar in one or more pieces or copper wire.

Submitter Information Verification

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Submittal Date: Thu Sep 10 14:19:02 EDT 2020
Committee: NEC-P05

Public Input No. 915-NFPA 70-2020 [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 (1) or (2):

(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; or

(2) Bare copper conductor not smaller than 4 AWG

Metallic components shall be encased by at least 50 mm (2 in.) of ~~concrete and~~ 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~~ The maximum distance from electrode through the concrete to earth shall be 600? mm (24? in.). 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 Input

I was unable to find a maximum. I am not sure what the maximum should be, but I am sure that laying 20 ft of bare copper in the top of a 10 foot wall although it meets the 2" minimum would not be an adequate ground because of all of that concrete between the electrode and the earth. I was the engineer asked a question from a crew when they forgot to lay the bare copper ground when rebar was being prepared, so they just laid it on top of the network of rebar. It was epoxy rebar because of the corrosive environment of the area, so it was not a good conductor to make a good ground through the structure. We were just relying on the copper. Laying it on top met the rules for the ufer ground because it would be in at least 2" of concrete, but it would be about 36" away from any earth. I had them re-run the copper and weave it through the bottom layer of rebar. It makes sense to me that there is a limit on how much concrete there is between electrode and earth.

Submitter Information Verification

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Zip:
Submittal Date: Thu Apr 30 12:21:38 EDT 2020
Committee: NEC-P05

Public Input No. 2459-NFPA 70-2020 [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 or copper-clad steel conductor not smaller than 2 AWG.

Additional Proposed Changes

File Name	Description	Approved
TD002391.doc	UL467 Short Circuit & UL 486A-486B Mechanical Sequence Tests	
CCS_Corrosion_paper_Rev2.pdf	Corrosion Study Grade 40 CCS 50 Year Louisville	
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 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 and 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 or ground ring material elevates the protection of an electrical installation in two ways: 1) the GEC or ground ring can better withstand fusing during ultra-high A/Hz lightning strikes (see connector and fusing discussions below); 2) the GEC or ground ring 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 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. This type of application relates to the demands typical of ground ring conductors. 40CCS can be exothermically welded per IEEE Standard 80. 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 GE and 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 GE and 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 grounding electrode or 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.

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 Inputs for This Document

Related Input	Relationship
Public Input No. 2462-NFPA 70-2020 [Section No. 250.62]	Copper-Clad Steel Grounding Conductors
Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]	Copper-Clad Steel Grounding Conductors
Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]	

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
Affiliation: American Bimetallic Association
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 23 08:59:47 EDT 2020

Committee: NEC-P05

Testing done for the safety of our valued customer.

Global Circulation Laboratory Test Report

For Global Distribution

UL467 SHORT CIRCUIT & UL 486A-486B MECHANICAL SEQUENCE TESTS

YGHP29C2, YGHC2C2, YGHC26C26, YGHP34C29, YGHC29C29, YGHP34C34, YGHC34C34 HYTAP™ Connectors
YGL2C2, YGL29C29, YGL34C34 HYGRID™ Connectors
YGA4C2N, YGHA272N, YGA282N, YGHA302N HYLUG™ Connectors

5/8" and 3/4"Copper Clad Steel Ground Rod, #4AWG Solid, 4/0AWG Stranded, 7#7, and 19#8 COPPERWELD® 40% IACS Copper Clad Steel Conductors

PAT750XT-18V PATRIOT® Tool
with
UC, UO, U28RT, U29RT, U32RT, U997, PU998, and U1011 Die Sets

TD002391 REV B

Requested by / Date:	***Authorized by / Date:***	***Completed by / Date:***
C. Gandhi 12-Dec-2014	R Robicheau 12-Dec-2014	R Charpentier 06-Apr-2015
Engineering Approval / Date:	***Marketing Approval / Date:***	***Laboratory Approval / Date:***
R.Roman 20-Aug-2020	J Hogan 20-Aug-2020	R Charpentier 20-Aug-2020

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

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ENGINEERING COMMENTS: 4
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TEST EQUIPMENT : 5

Burndy LLC 47 East Industrial Park Dr.
Manchester / New Hampshire / 03109
Tel: 603 647 5000 Fax: 603 647 5205

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

PURPOSE OF TEST:

To determine if the Burndy HYTAP™, HYGRID™, and HYLUG™ Connectors can meet the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST REQUESTED:

UL486A-486B Mechanical Sequence
UL467 Short Time Current

TEST RESULTS:

Connector	Cable 1	Cable 2	Die	# of crimps	Securness	Pull	Short Time Current		
					Pass / Fail	Average Pull (lb)	Pass / Fail	Current (Amps)	Time (s)
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	U997	1	Pass	1021.3	Pass	1600	6
YGL2C2	#4 Solid CCS	#4 Solid CCS	U-O	1	Pass	1451.8	Pass	1600	6
YGHC2C2	#4 Solid CCS	#4 Solid CCS	U-C	1	Pass	1544.0	Pass	1600	6
YGA4C2N	#4 Solid CCS	n/a	U4CRT	1	Pass	814.0	Pass	1600	6
YGL29C29	7#7 STR CCS	7#7 STR CCS	U997	1	Pass	1643.2	Pass	4600	9
YGHC26C26	7#7 STRCCS	7#7 STR CCS	U-O	1	Pass	1239.4	Pass	4600	9
YGHA272N	7#7 STRCCS	n/a	U29RT	2	Pass	1574.0	Pass	4600	9
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PU998	1	Pass	1789.8	Pass	6100	9
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1849.8	Pass	6100	9
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1779.1	Pass	6100	9
YGA282N	4/0 AWG CCS	n/a	U28RT	2	Pass	2489.3	Pass	6100	9
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	U1011	3	Pass	2126.8	Pass	9000	9
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	U1011	3	Pass	2380.0	Pass	9000	9
YGL34C34	19#8 STRCCS	19#8 STR CCS	U1011	3	Pass	3158.3	Pass	9000	9
YGHC34C34	19#8 STR CCS	19#8 STR CCS	U1011	3	Pass	3812.1	Pass	9000	9
YGHA302N	19#8 STR CCS	n/a	U32RT	2	Pass	4792.2	Pass	9000	9

Burndy LLC 47 East Industrial Park Dr.
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TD002391

Global Circulation Laboratory Test Report

For Global Distribution

CONCLUSIONS:

All samples tested met the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST PROCEDURES

The table below shows the connector / conductor combinations tested.

Connector	Cable 1	Cable 2	Tool	Die	# of Crimps
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	PAT750	U997	1
YGL2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-O	1
YGHC2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-C	1
YGA4C2N	#4 Solid CCS	n/a	PAT750	U4CRT	1
YGL29C29	7#7 STR CCS	7#7 STR CCS	PAT750	U997	1
YGHC26C26	7#7 STR CCS	7#7 STR CCS	PAT750	U-O	1
YGHA272N	7#7 STR CCS	n/a	PAT750	U997	2
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PAT750	PU998	1
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGA282N	4/0 AWG CCS	n/a	PAT750	U997	2
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	PAT750	U1011	3
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	PAT750	U1011	3
YGL34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHC34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHA302N	19#8 STR CCS	n/a	PAT750	U32RT	2

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TD002391

Global Circulation Laboratory Test Report

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All conductors were cut to twenty four (24) inch lengths.
All ground rod was pre-crimped with the appropriate pre-crimp die
5/8in Rod UPRECRIMP58
3/4in Rod UPRECRIMP34

Mechanical Sequence
Four samples of each set were secured to the Secureness tester, the height; weight and bushing size were as specified in UL486A-486B Table 26. Samples were rotated for thirty minutes at 9rpm. Samples were then subjected to a 1-minute pull to the value specified in UL486A-486B Table 27 and then to failure.

Short Time Current
Test samples were assembled in a series loop configuration then attached to a current controller as shown below. The test current and duration are listed below. After completion of the test, electrical continuity was checked with a digital multi-meter.

Test current values were derived from the equation Annex C of IEEE Std 837-2002. The diameter of the conductor(s) were measured and the cross-sectional area of the conductors was calculated.

Conductor	***Current Value (A)***	***Duration (sec)***
#4AWG Solid COPPERWELD® 40% IACS CCS	1600	6
4/0AWG 19 strand COPPERWELD® 40% IACS CCS,	6100	9
7#7 stranded COPPERWELD® 40% IACS CCS	4600	9
19#8 stranded COPPERWELD® 40% IACS CCS	9000	9

TEST EQUIPMENT LIST:

MANUFACTURER	MODEL	DESCRIPTION	SERIAL #	RANGE
FLUKE	79 III	DMM	70591301 (Rene)	AUTO
OHIO SEMITRONICS		CURRENT TRANSDUCER	NA	15000:5
SATEC	T5000	TABLE TOP	2038	5000 lbs
VIRTECH	NA	HIGH CURRENT	NA	12V / 12000A
MITUTOYO	505-675	DIAL CALIPER	08914565 (Rene)	6"

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CORROSION ON BURIED COPPER CLAD STEEL



Cece Syarif

Global Application Engineer

&

Anthony Hale

Manager, Utility Products, North America

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For more information, contact sales@copperweld.com.
The results and conclusions obtained from studies done by Copperweld are only applicable to Copper Clad Steel manufactured by Copperweld. Due to proprietary process used to produce the wire, the findings cannot be superimposed on any other copper-clad steel conductor.

254 Cotton Mill Rd, Fayetteville, TN 37334. Tel. (931) 433 – 7177

July 26, 2011

This paper compiles several studies and analysis regarding the corrosion performance of buried Copperweld® Copper-Clad-Steel (CCS) conductors. These range from the early 1900's with the invention of Copperweld® through the present day with studies performed by independent parties as well as Copperweld Company in-house testing. The purpose is to present the available information so that prospective users of Copperweld® CCS wire and strand can evaluate the corrosion resistance and expected performance within their specific application and area. Copperweld uses oxygen free copper in the manufacture of Copperweld® wire and strand. The copper surface of CCS is expected to oxidize and turn color ranging from green (patination) to brown and black the same as any solid copper wire or strand when exposed to environmental stimuli. Corrosion on exposed steel at the cut tip or end of the wire is also expected. The question to be answered is if the corrosion on either material or the interface between the copper and steel (galvanic reaction) will result in degradation of the wire as to make it unsuitable for use as a grounding conductor.

The oldest known underground corrosion study of bimetallic material was performed in the early 1900s[1]. This study focused on the corrosion behavior of Copperweld® CCS underground rod as well as other materials such as Copper and galvanized steel ground rod. The National Bureau of Standards (NBS) conducted an extensive underground corrosion study that involves 36,500 specimens which include 333 varieties of ferrous, nonferrous, and protective coating materials buried in 128 test locations throughout U.S in 1910 - 1955.

The study summarizes the service life of a ground rod as following:

10 mils copper coating – acceptable for service life up to 40 years

13 mils copper coating – acceptable for service life up to 50 years

Similarly, the Naval Civil Engineering Laboratory in collaboration with the National Association of Corrosion Engineers conducted a 7-year program of testing metal rods for electrical grounding to determine the galvanic corrosion effect. The three metals tested were stainless clad steel, copper-bonded steel (CCS), and galvanized steel. The result on the ⅝" CCS ground rod was as expected. The copper surface of the CCS was

virtually free of corrosion and the steel core has corroded at the tip approximately 2 inches down the length of the rod.

Copperweld Corporation is the inventor and sole manufacturer of Copperweld® Copper-bonded ground rods and Copperweld® wire and strand since 1915. The corrosion behavior of a Copperweld® ground rod is similar to the corrosion on Copperweld® wire and strand conductor. Both materials consist of copper permanently bonded to a steel core. All Copperweld® 40% CCS has a copper thickness of 10% of the overall diameter. For example, Copperweld® 4THOUGHT™ has a configuration of 19 strands of 0.1055 inch wires. It means that each strand has a copper thickness of 10.55 mils. Based on the NBS study, 4THOUGHT™ will have at least a minimum service life of 40 years.

Copperweld has also conducted a 5-year study of buried bare 21% conductivity (copper thickness is 3% of the diameter) Copperweld® CCS in 10 different soil conditions in association with Southwest Research Institute[2]. The study reported 100% surface oxidation and various degrees of deterioration of the steel core as expected after 5 years. The exposed steel on the tip of the wire rusted and formed "scab", as shown in Figure 1. The rust appeared to "seal-off" the un-oxidized material from the corrosive medium. The maximum depth of corrosion was 70% of the wire diameter.



Figure 1: Example of Underground Corrosion of Copper Clad Steel

Although the copper surface oxidation was heavy, the samples showed no signs of pits or holes in the copper cladding. The copper thickness of a severely oxidized 5-year sample showed no discernable difference when compared to an un-oxidized control sample that was not subjected to the corrosive environment. The mechanical and resistance testing

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resulted in negligible differences between 5-year samples and the control samples. Thus, the oxidation had no discernable impact on the strength or electrical performance of the wire.

An accelerated corrosion study based on ASTM B117 was conducted on bare CCS and solid Copper wires to evaluate copper surface corrosion. The wires were exposed to salt fog spray for 504 hours. As a result, corrosion on the CCS copper surface showed no significant difference as compared to the corrosion of copper wire.



(a) Copper Clad Steel (b) Copper

Figure 2: Patination of Copper Surface after 504 hours exposure to Salt Fog Spray

In February 2011, three separate sample strands of Copper Clad Steel were un-earthed and cut out from a substation built in Louisville, KY. The conductors were 40% conductivity, Low Carbon Steel, Dead Soft Annealed, 7 No. 5 (231,613 circular mil) and were installed in 1962.

Table 1: Physical properties of the three strands of Copperweld® conductor that had been buried underground for 48 years in a Kentucky substation

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			Strand 1	Strand 2	Strand 3
Conductor Type			40% Low Carbon Annealed		
Conductor Size			7 No. 5		
Cross Section Area		in^2	0.1819	0.1819	0.1819
Diameter of Single end		*inch*	0.1819	0.1819	0.1819
Diameter of Conductor		*inch*	0.5457	0.5457	0.5457
Copper Thickness	Min	*inch*	0.0142	0.0114	0.0134
	Max	*inch*	0.0213	0.0209	0.01975
% Concentricity			83.30%	77.30%	83.90%
Depth of corrosion	Min	*inch*	0.004	0.028	0.111
	Max	*inch*	0.781	0.859	0.484

The 1962 conductors were manufactured by Copperweld with a nominal copper thickness of 10% of its diameter. Figure 3 shows the copper thickness ranges from 11.4 – 21.3 mils and the concentricity of the conductor averaged at 81.5%. Current manufacturing improvements yield concentricity of copper thickness above 85%.

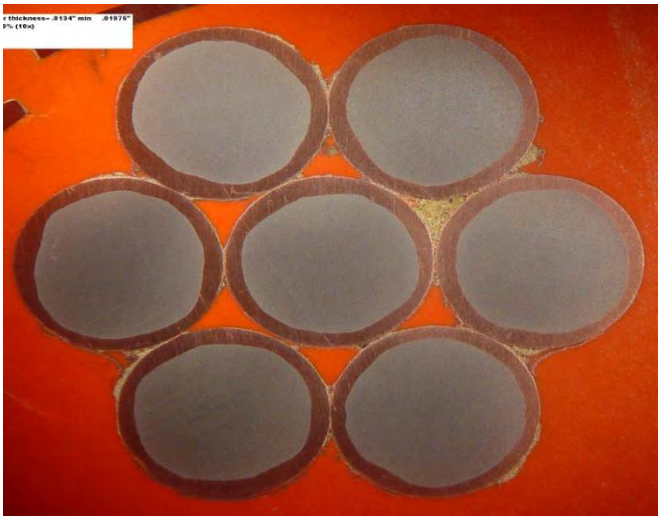


Figure 3: Copperweld® 40% LC DSA 7 No. 5 manufactured in 1962

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Figure 4a shows no visible corrosion observed other than oxidation and patination on the copper surface. At the ends of the wires, the corrosion occurred in the form of steel rust. The maximum depth of the corrosion is 0.859 inch with an average of 0.382 inch, as shown in Figure 4b.



Figure 4a: There is no visible corrosion between the copper and steel on all wires obtained from the substation in Kentucky.



Figure 4b: Corrosion occurred at the ends of the wires. Maximum penetration depth is 0.859 inch.

From all the corrosion studies above, there have not been reported or observed any galvanic corrosion at the interface of copper and steel. The process of cladding for

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Copperweld® ensures a metallurgical bond between the two metals. That metallurgical bond prevents any moisture from penetrating between the two metals precluding the corrosion process. Any propagation of corrosion on an area of exposed steel averages two times the diameter of the wire then stops. The corrosion rate of the copper surface is equivalent to that observed on standard solid copper wire and strand. Based on the results of these studies, it can be summarized that CCS can be expected to have a 50 plus year service life as buried grounding conductors.

REFERENCES:

1. Rempe, Chris. 7 July 2003. "A Technical Report on the Service Life of Ground Rod Electrodes".
2. Fox, Dustin, Belado, Chris, and Brossia, Sean. 23 September 2009. "The Effect of Corrosion on Tracer Wire with a Copper Clad Steel Center Conductor".

Powertech

Report ID: PL-03027 REP1
Revision: 0 Issued: 2020-04-15

Copper and CCS Wire Withstand Current and Fusing Current Tests

Copperweld Bimetallics, LLC



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REPORT OF PERFORMANCE

CLIENT	Copperweld Bimetallics,LLC. 5141 Virginia Way, Suite 410 Brentwood, TN, United States 37027
TEST OBJECTS	Copper Clad Steel (CCS) Wires Manufacturer: Copperweld Bimetallics,LLC. Types: Scorpius Prototypes Part Nos.: 61 x 072 7 x 080 Condition: New Copper Conductor Manufacturer: Encore Wire Types: #4/0 AWG (19 strand) CU #6 AWG (single strand) CU Condition: New
TESTED BY	Powertech Labs Inc. 12388 - 88th Ave, Surrey, BC Canada V3W 7R7 www.powertechlabs.com
TEST DATE	2020-01-24 to 2020-01-25
TEST SPECIFICATION	Client Specified, with reference to IEEE Std 80-2013 and IEEE Std 837-2014

Powertech Labs Inc. does not accept any liability for any damages resulting from the use of this report. The results relate only to the item tested, and it is the responsibility of the manufacturer to maintain conformity of any object having the same designations. Information regarding the estimated measurement uncertainty is available upon request. The test report shall not be reproduced except in full, without written approval of Powertech Labs Inc.

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1 INTRODUCTION

At the request of Copperweld Bimetallics,LLC., withstand current and fusing current tests were performed on standard copper and copper clad steel (CCS) wires in accordance with specifications and procedures provided by the client. Reference was made to IEEE Std 80-2013 and IEEE Std 837-2014 as guides for determining current levels and durations for the tests.

The High Power Lab is accredited by the Standards Council of Canada to ISO 17025 for short-circuit testing.

2 TEST OBJECT INFORMATION

The test objects were identified by the client as follows:

Copper Clad Steel Wires (CCS)

Manufacturer:	Copperweld Bimetallics,LLC.
Types:	Scorpius Prototypes
Part Nos.:	61 x 072
	7 x 080
Condition:	New

Copper Conductor

Manufacturer:	Encore Wire
Types:	4/0 AWG (19 strand) CU
	#6 AWG (single strand) CU
Condition:	New

Conductor sample diameters and dc resistance values were measured by the laboratory before testing, as presented in Table 1.

3 GENERAL INFORMATION

3.1 Purpose

The purpose of the tests is to identify the current limits at short durations for standard copper and Copperweld CCS grounding wire products, and to determine if these products meet the applicable requirements of the referenced Standards.

3.2 Witnesses

Name	Company
Jeff Jordan	Copperweld Bimetallics,LLC.
Lora Aboulmouna	Copperweld Bimetallics,LLC.
Jason Smolko	Copperweld Bimetallics,LLC.
Ryan Hale	Copperweld Bimetallics,LLC.

3.3 Tests Performed

Test Standards/Specifications:

Withstand current tests were performed as requested by the client, with reference to the following Standards to determine the test levels:

IEEE Std 80-2013, Table 6 – Specification for the ultimate current carrying capacity of copper grounding cables using symmetrical current.

IEEE Std 837-2014, Clause 7.2 and Table 3 – Electromagnetic force (EMF) test

4 SHORT-CIRCUIT CURRENT TESTS

General Information:

Standard	Client's Specification, with reference to IEEE Std 80-2013 and IEEE Std 837-2014
Test Dates	2020-01-24 to 2020-01-25
Test Leader	Chris Morton

Environmental Conditions:

Ambient temperature	(7 – 9) °C
Relative Humidity	(95 – 99) %

Test Conditions:

Samples were tested in a covered test cell which was open on one side to the outdoor ambient conditions. During each test, one sample was connected horizontally between the laboratory source bus and ground bus, at a bus spacing of 48 inches, as shown in Figures 30 through 33. The samples were terminated using Burndy mechanical connectors, as shown in Figures 34 and 35. The length of each wire sample was the minimum length required to span the distance between the buses, and each sample was at approximately right angles (90°) to both the source and ground bus. Each sample was suspended in free air approximately 46 inches above the floor of the test cell. The temperature of the sample at the start of each test was the natural outdoor ambient temperature of the laboratory, except for tests performed to IEEE 837, where the sample was allowed to cool to less than 100 °C before the second shot.

All tests were performed at a power frequency of 60 Hz using the test circuit shown in Figure 1. Current was initiated by energizing a current limited source that was calibrated to provide the target current through the circuit. The rms current, current symmetry and duration of each test were specified by the client.

The test current was measured using a 300 kA_{peak} rated Rogowski coil (Powertech ID № 39444). The expanded uncertainty of the current measuring system is estimated as 2% (k=2).

Test Results:

The results of the tests are provided in Tables 2 through 5. Current and voltage waveforms for each test are provided in Figures 2 through 29.

The Encore #4/0 AWG Cu wire did not withstand the I^2t calculated from the current and duration specified in IEEE 80, Table 6, for a 500 ms duration (44 kA_{rms}). It was capable of carrying a maximum of 92% of this I^2t value without fusing.

The Encore #4/0 AWG Cu wire did not withstand the EMF current specified in IEEE 837, Table 3 (47 kA_{rms}). It was capable of carrying a maximum of 91% of this current value without failing.

The Copperweld Scorpius CCS 61 x 072 conductor exceeded the 500 ms rms withstand current requirement of IEEE 80, Table 6, and met the EMF current requirements of IEEE 837, Table 3, for a 4/0 conductor.

For the #6 AWG Cu conductor size the Standards did not have current values specified, so these were calculated using Equation (45) from IEEE 80 and Equation (C.1) from IEEE 837. The calculations are presented in Appendix D.

Both the Copperweld Scorpius CCS 7 x 080 conductor and the Encore #6 AWG Cu conductor met the 500 ms rms withstand current requirement of IEEE 80, Table 6 (5.29 kA_{rms}), and the EMF current requirements of IEEE 837, Table 3 (5.81 kA_{rms}), for a #6 AWG Cu conductor.

APPENDIX A – FUSING CURRENT TEST CIRCUIT AND DATA

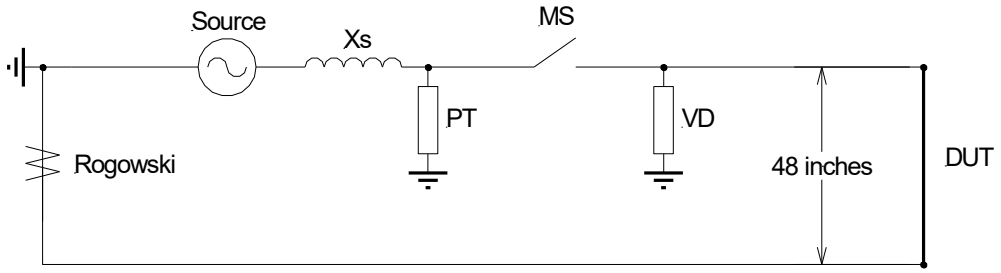


Figure 1: Test circuit schematic for all tests.

Notes:

1. X_S – Source current limiting reactance
2. MS – Making Switch
3. VD – Voltage measurement
4. Rogowski – Current measurement
5. DUT – Device Under Test

Table 1: Strand diameter and dc resistance measurements of sample conductors.

Wire Sample No.	Type	Strand Diameter [1] (in)		Conductor Diameter	Dc Resistance at 20°C
#		1	2	(in)	(μΩ/ft)
1	Encore Wire, 4/0 AWG, 19 strand CU	0.122	0.079	0.492	4.28
2	Encore Wire, 4/0 AWG, 19 strand CU	0.118	0.080	0.501	4.10
3	Encore Wire, 4/0 AWG, 19 strand CU	0.109	0.074	0.495	4.23
4	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.075	0.498	3.98
5	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.079	0.489	4.43
6	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.075	0.490	4.17
7	Encore Wire, 4/0 AWG, 19 strand CU	0.101	0.075	0.489	4.18
8	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.074	0.491	4.15
9	Encore Wire, 4/0 AWG, 19 strand CU	0.106	0.082	0.490	3.97
10	Encore Wire, 4/0 AWG, 19 strand CU	0.105	0.079	0.493	3.73
11	Scorpius 61 x 072 CCS	0.056	---	0.646	6.83
12	Scorpius 61 x 072 CCS	0.058	---	0.649	6.60
13	Scorpius 61 x 072 CCS	0.068	---	0.641	6.60
14	Scorpius 61 x 072 CCS	0.056	---	0.639	6.73
15	Scorpius 61 x 072 CCS	0.067	---	0.646	6.62
16	Scorpius 61 x 072 CCS	0.059	---	0.630	6.53
17	Scorpius 61 x 072 CCS	0.056	---	0.642	6.73
18	Scorpius 61 x 072 CCS	0.067	---	0.637	6.62
19	Scorpius 61 x 072 CCS	0.064	---	0.641	6.85
20	Scorpius 61 x 072 CCS	0.059	---	0.633	6.83
21	Encore Wire, #6 AWG, single strand CU	0.152	---	0.152	33.3
22	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
23	Encore Wire, #6 AWG, single strand CU	0.158	---	0.158	33.2
24	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.4
25	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.3
26	Encore Wire, #6 AWG, single strand CU	0.148	---	0.148	33.6
27	Encore Wire, #6 AWG, single strand CU	0.155	---	0.155	33.3
28	Encore Wire, #6 AWG, single strand CU	0.146	---	0.146	33.1
29	Encore Wire, #6 AWG, single strand CU	0.153	---	0.153	33.2
30	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
31	Scorpius 7 x 080 CCS	0.072	---	0.215	46.3
32	Scorpius 7 x 080 CCS	0.069	---	0.226	45.9
33	Scorpius 7 x 080 CCS	0.065	---	0.220	46.2
34	Scorpius 7 x 080 CCS	0.071	---	0.218	46.4
35	Scorpius 7 x 080 CCS	0.073	---	0.212	46.1
36	Scorpius 7 x 080 CCS	0.065	---	0.216	46.3
37	Scorpius 7 x 080 CCS	0.070	---	0.211	46.1

Note:

[1] Encore 4/0 AWG CU conductor had two sizes of strands, all remaining conductors had one size of strands. Strand and conductor diameters were measured using a digital caliper with a resolution of 0.001 in.

Table 2: Summary of tests on Encore 4/0 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
1	1	Run to fusing	3.85	41.7	60.0	530	923	2	Y
2	2	Withstand	3.85	41.8	62.5	509	889	3	N
3-1	3	EMF (IEEE 837)	4.24	48.0	130	262	826	4	N
3-2	3	EMF (IEEE 837)	4.26	48.0	130	127	503	5	Y
4	4	EMF (IEEE 837)	4.25	48.0	130	260	823	6	Y
5-1	5	EMF (IEEE 837)	4.20	47.4	129	262	808	7	N
5-2	5	EMF (IEEE 837)	4.19	47.4	128	9.9	77	8	Y
6-1	6	EMF (IEEE 837)	3.93	42.6	116	263	662	9	N
6-2	6	EMF (IEEE 837)	3.91	42.6	116	262	654	10	N

Table 3: Summary of tests on Copperweld Scorpius 61 x 072 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
7	11	Run to fusing	3.84	41.7	59.6	673	1173	11	Y
8	12	Run to fusing	4.25	48.1	69.8	500	1157	12	Y
9	13	Run to fusing	4.21	47.5	68.9	508	1150	13	Y
10	14	Withstand	4.09	46.2	66.2	508	1089	14	N
11-1	15	EMF (IEEE 837)	4.21	47.6	129	262	803	15	N
11-2	15	EMF (IEEE 837)	4.20	47.7	129	262	803	16	N
12-1	16	EMF (IEEE 837)	4.21	47.6	129	254	784	17	N
12-2	16	EMF (IEEE 837)	4.19	47.4	128	254	767	18	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

Table 4: Summary of tests on Encore #6 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
13	21	Run to fusing	3.90	5.18	7.36	607	16.3	19	Y
14	23	Run to fusing	3.90	5.18	7.57	600	16.1	20	Y
15	24	Run to fusing	4.27	5.68	8.15	500	16.1	21	Y
16-1	25	EMF (IEEE 837)	3.77	5.86	16.2	262	13.9	22	N
16-2	25	EMF (IEEE 837)	3.77	5.86	16.1	262	13.9	23	N

Table 5: Summary of tests on Copperweld Scorpius 7 x 080 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
17	31	Withstand	3.88	5.16	7.44	858	22.9	24	N
18	32	Run to fusing	3.89	5.16	7.43	908	24.2	25	Y
19	33	Run to fusing	4.48	7.00	10.3	493	24.1	26	Y
20	34	Run to fusing	4.41	6.91	10.2	502	23.9	27	Y
21-1	35	EMF (IEEE 837)	3.81	5.91	16.3	262	14.0	28	N
21-2	35	EMF (IEEE 837)	3.80	5.92	16.2	262	13.8	29	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

APPENDIX B – WAVEFORMS

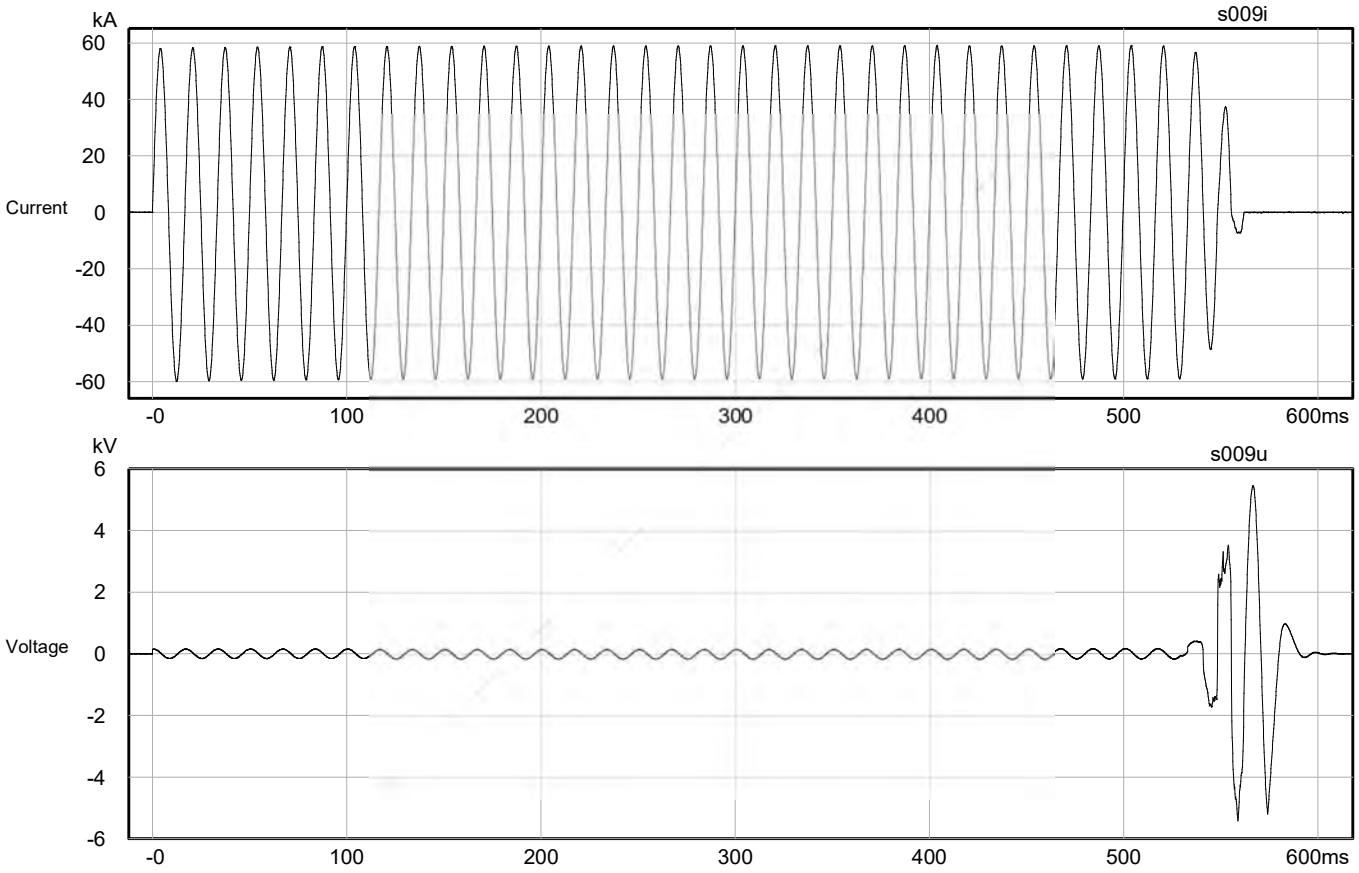


Figure 2: Waveforms for Test #1, Encore 4/0 AWG Sample 1.

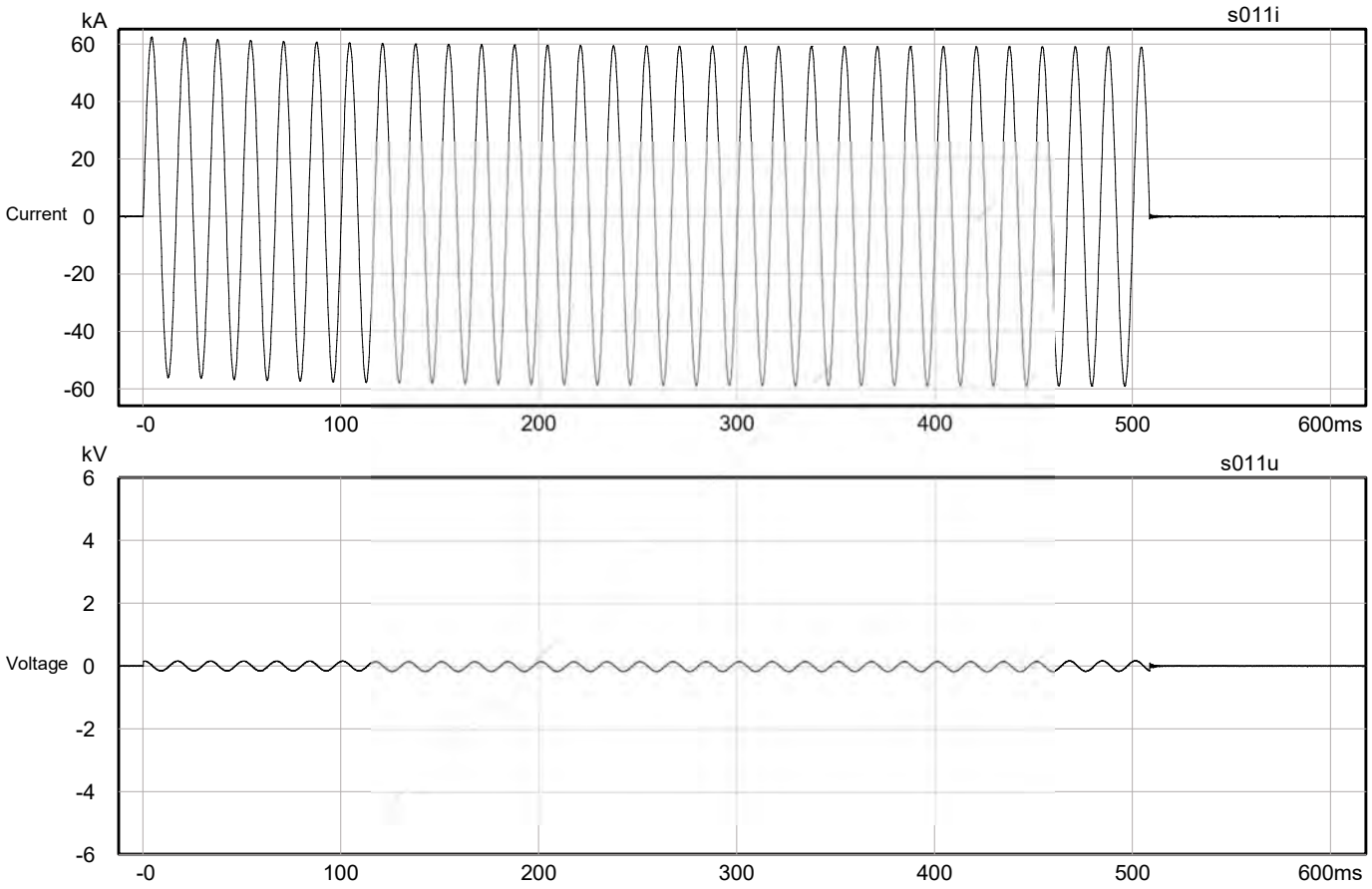


Figure 3: Waveforms for Test #2, Encore 4/0 AWG Sample 2.

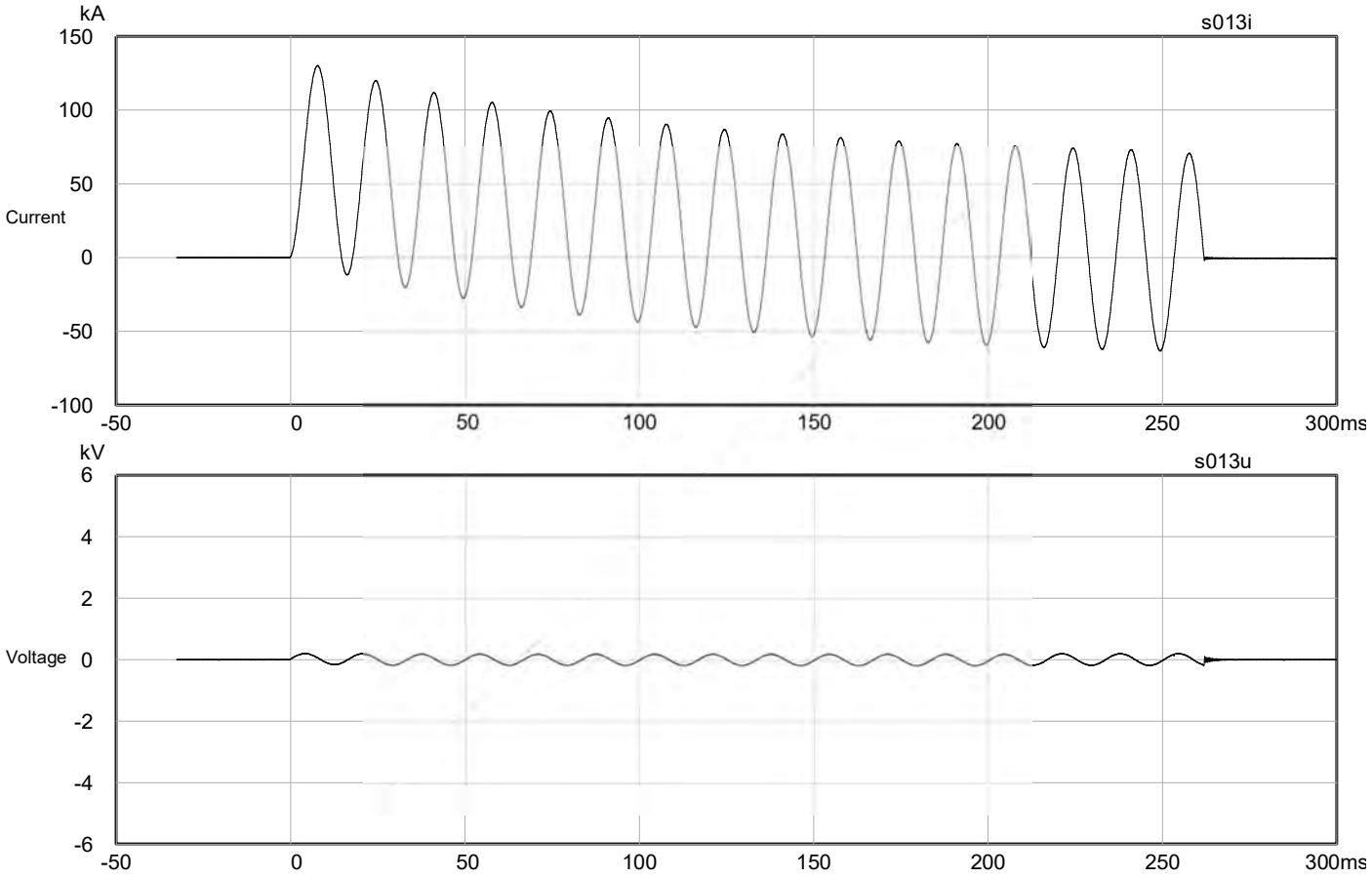


Figure 4: Waveforms for Test #3-1, Encore 4/0 AWG Sample 3.

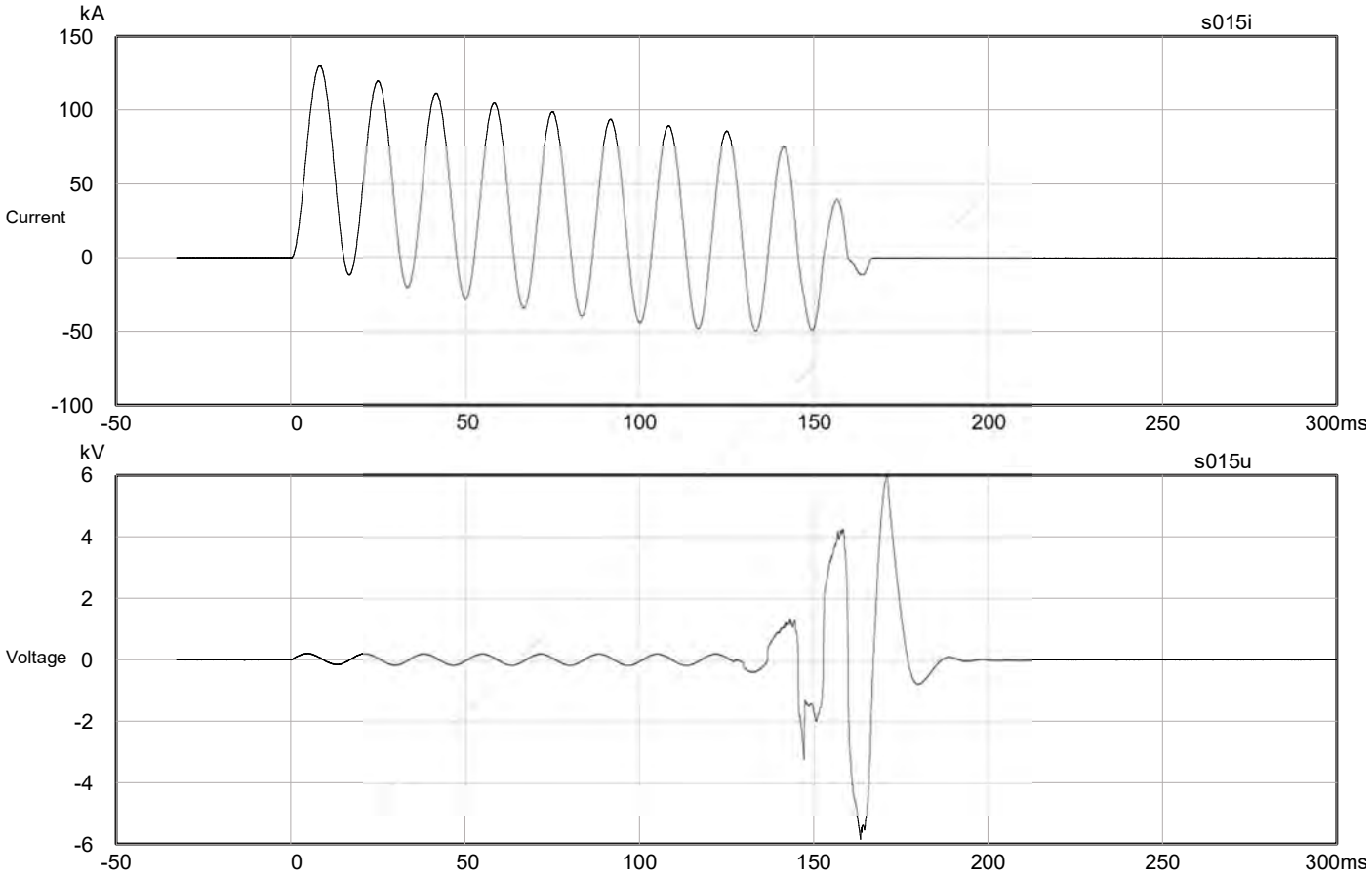


Figure 5: Waveforms for Test #3-2, Encore 4/0 AWG Sample 3.

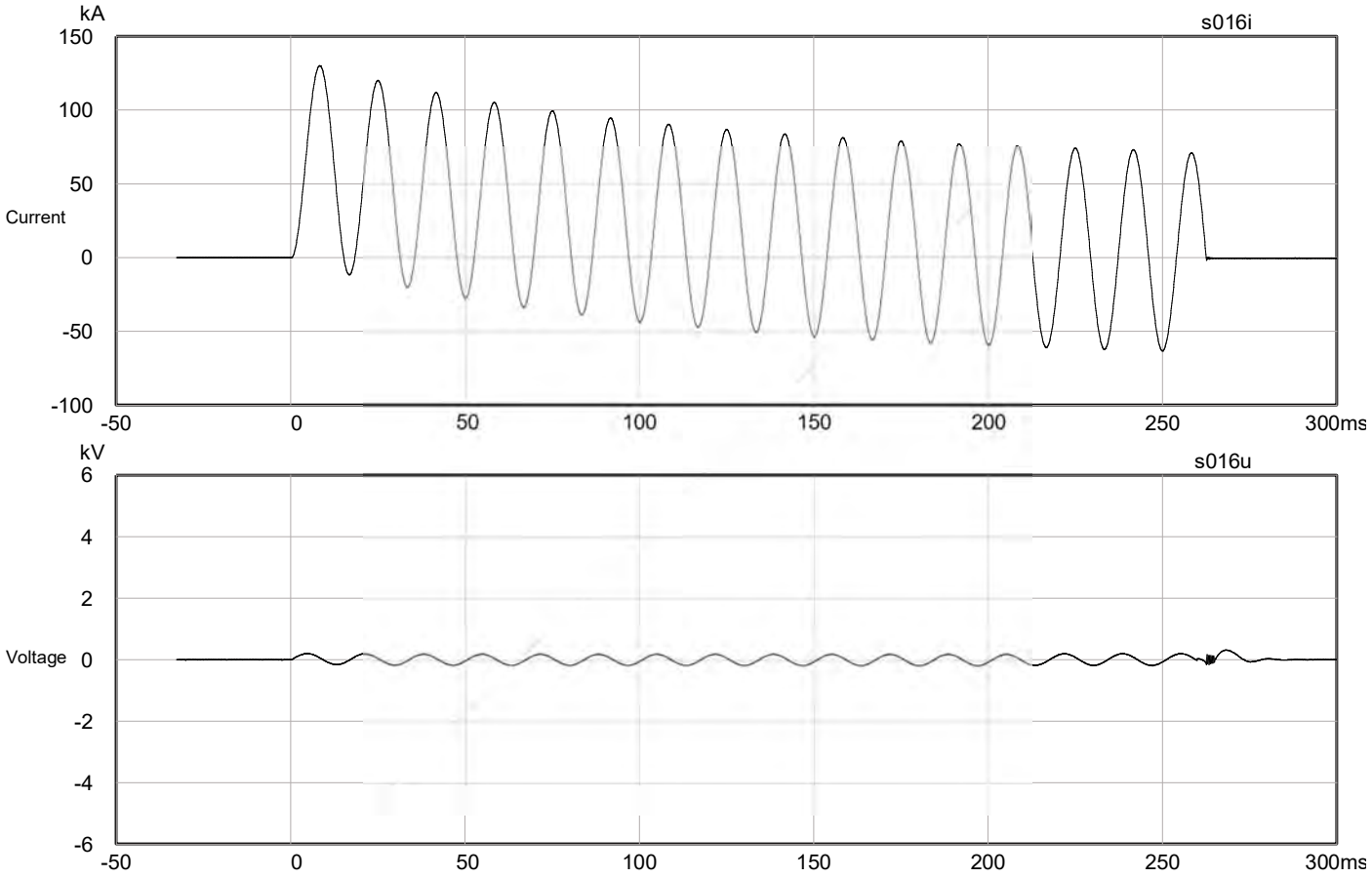


Figure 6: Waveforms for Test #4, Encore 4/0 AWG Sample 4.

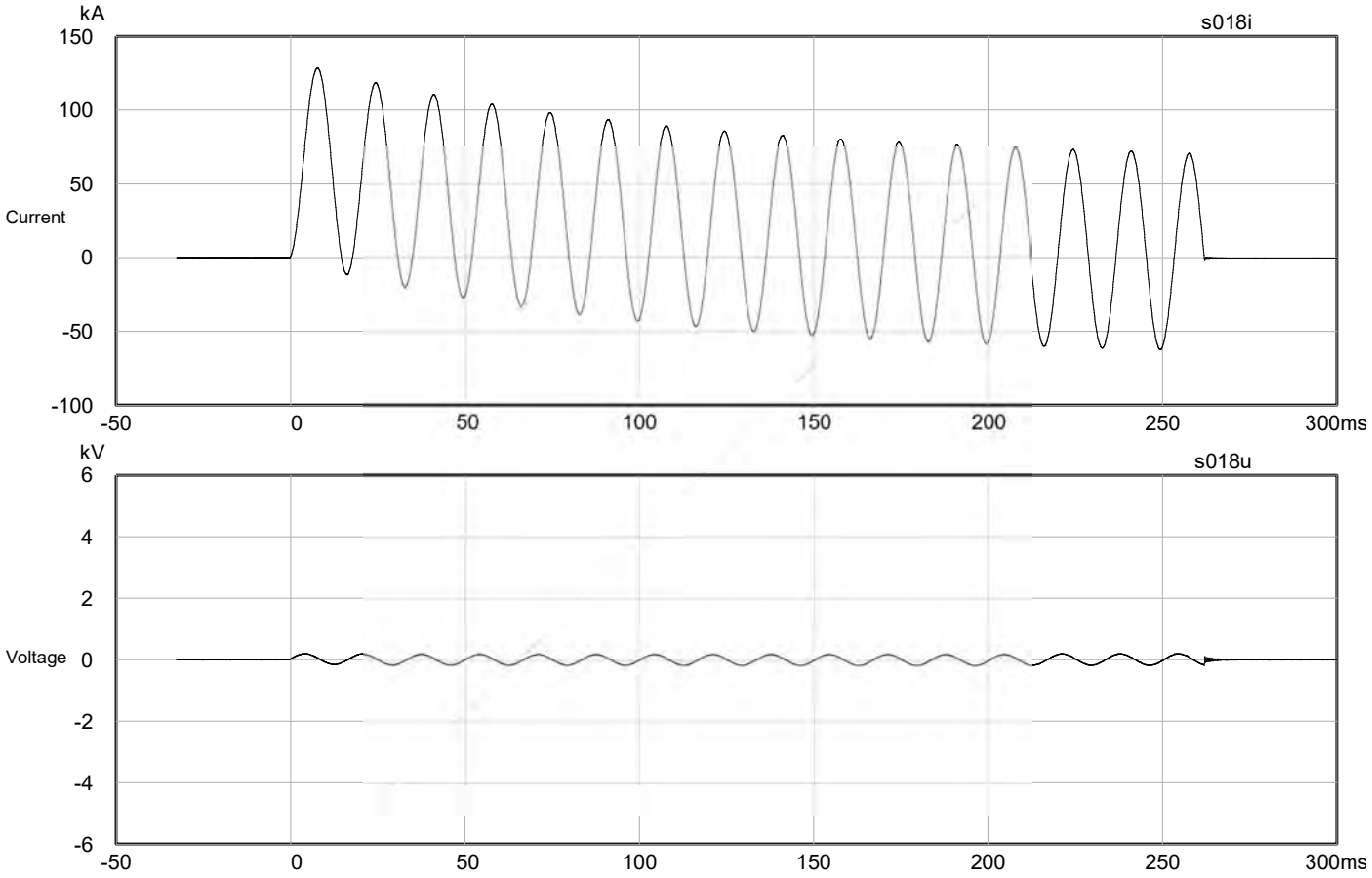


Figure 7: Waveforms for Test #5-1, Encore 4/0 AWG Sample 5.

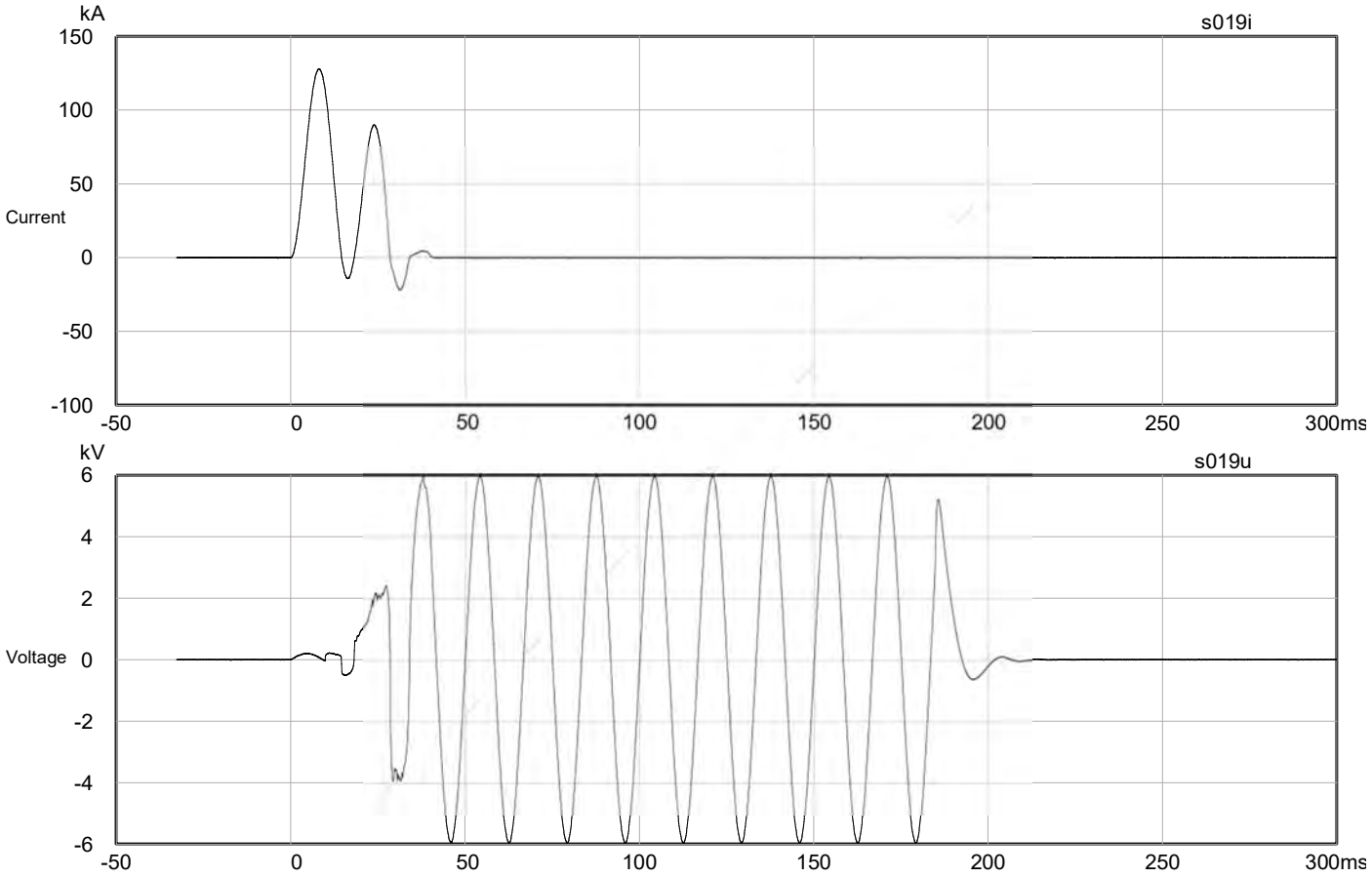


Figure 8: Waveforms for Test #5-2, Encore 4/0 AWG Sample 5.

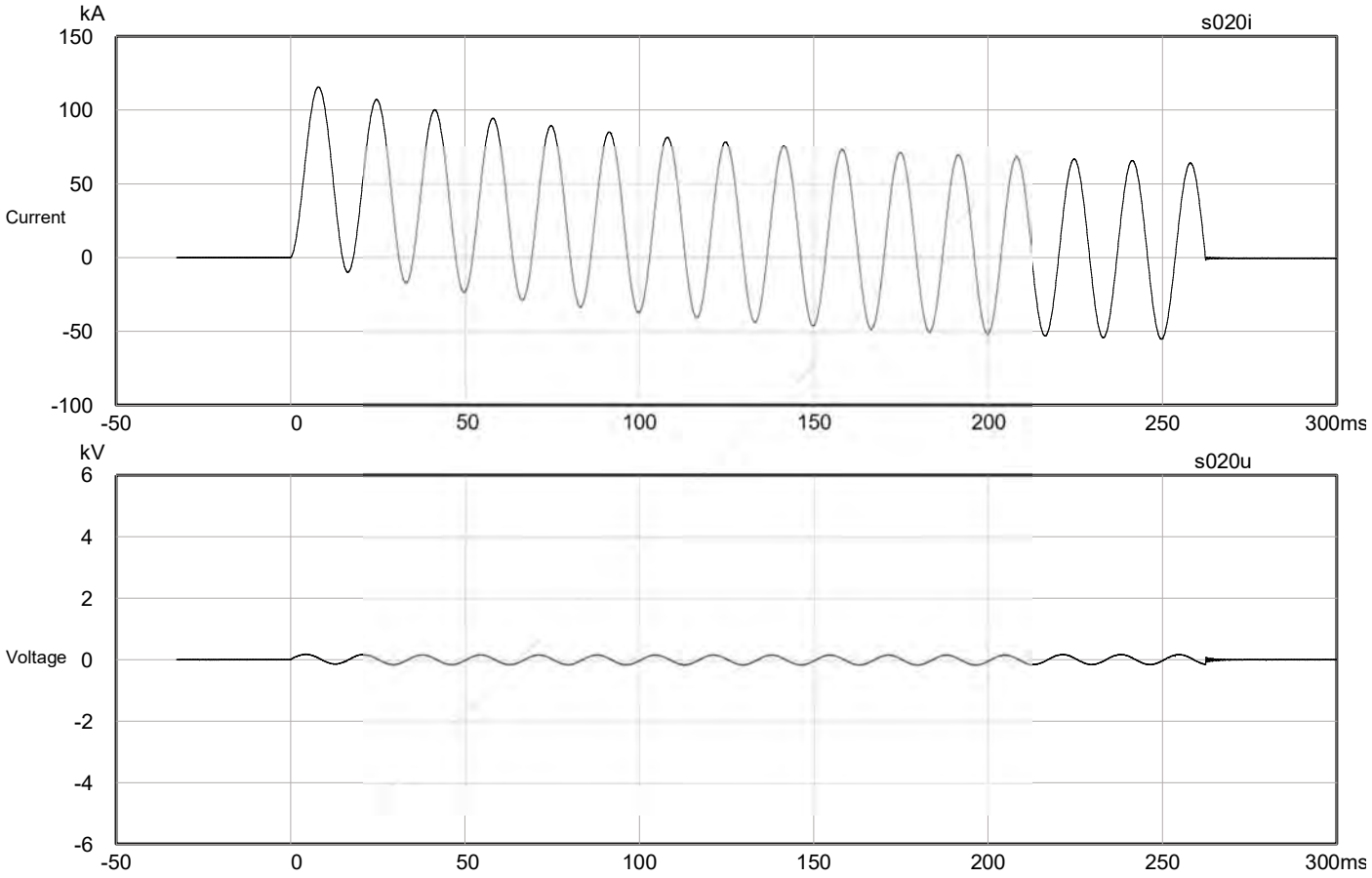


Figure 9: Waveforms for Test #6-1, Encore 4/0 AWG Sample 6.

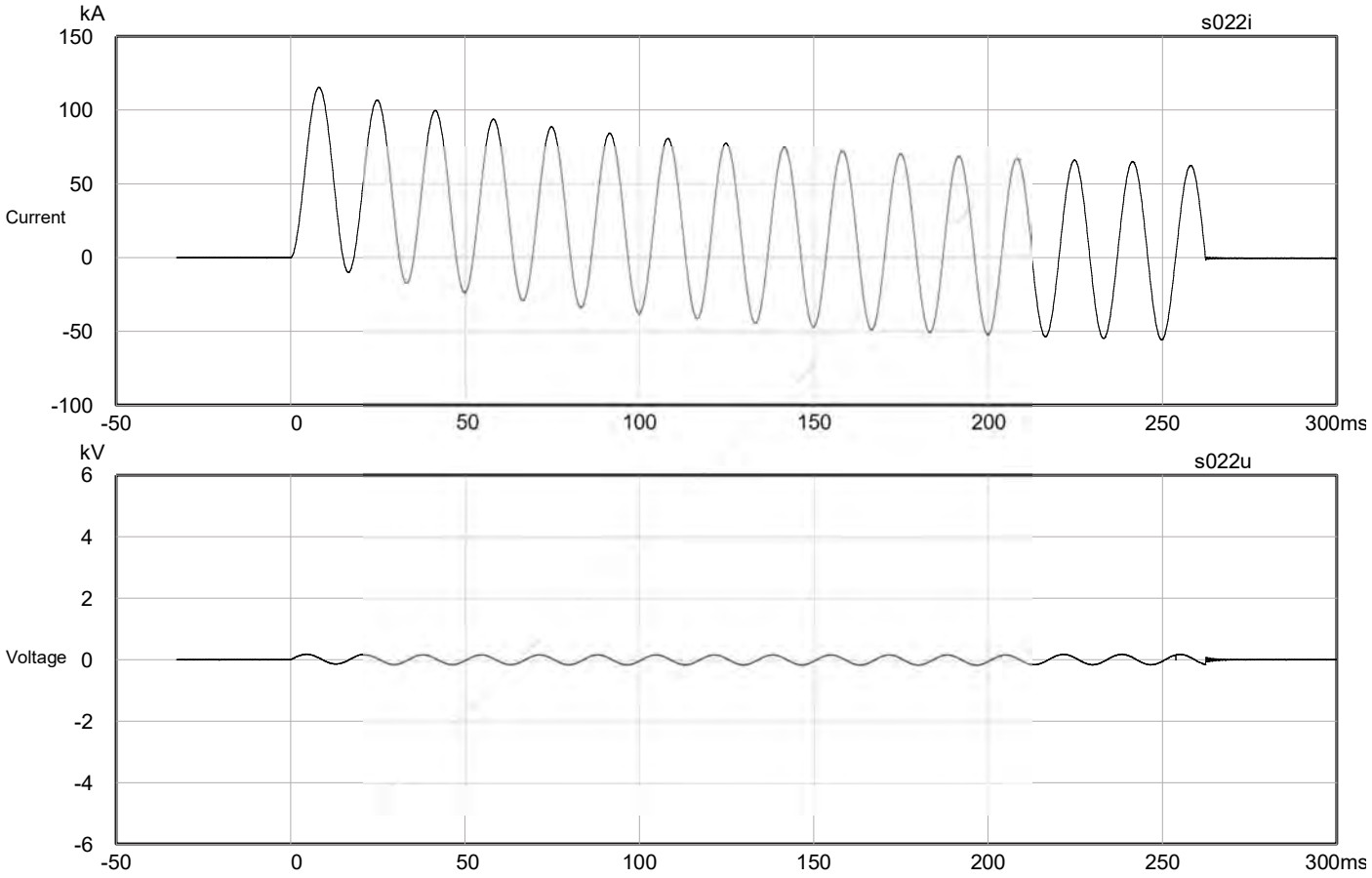


Figure 10: Waveforms for Test #6-2, Encore 4/0 AWG Sample 6.

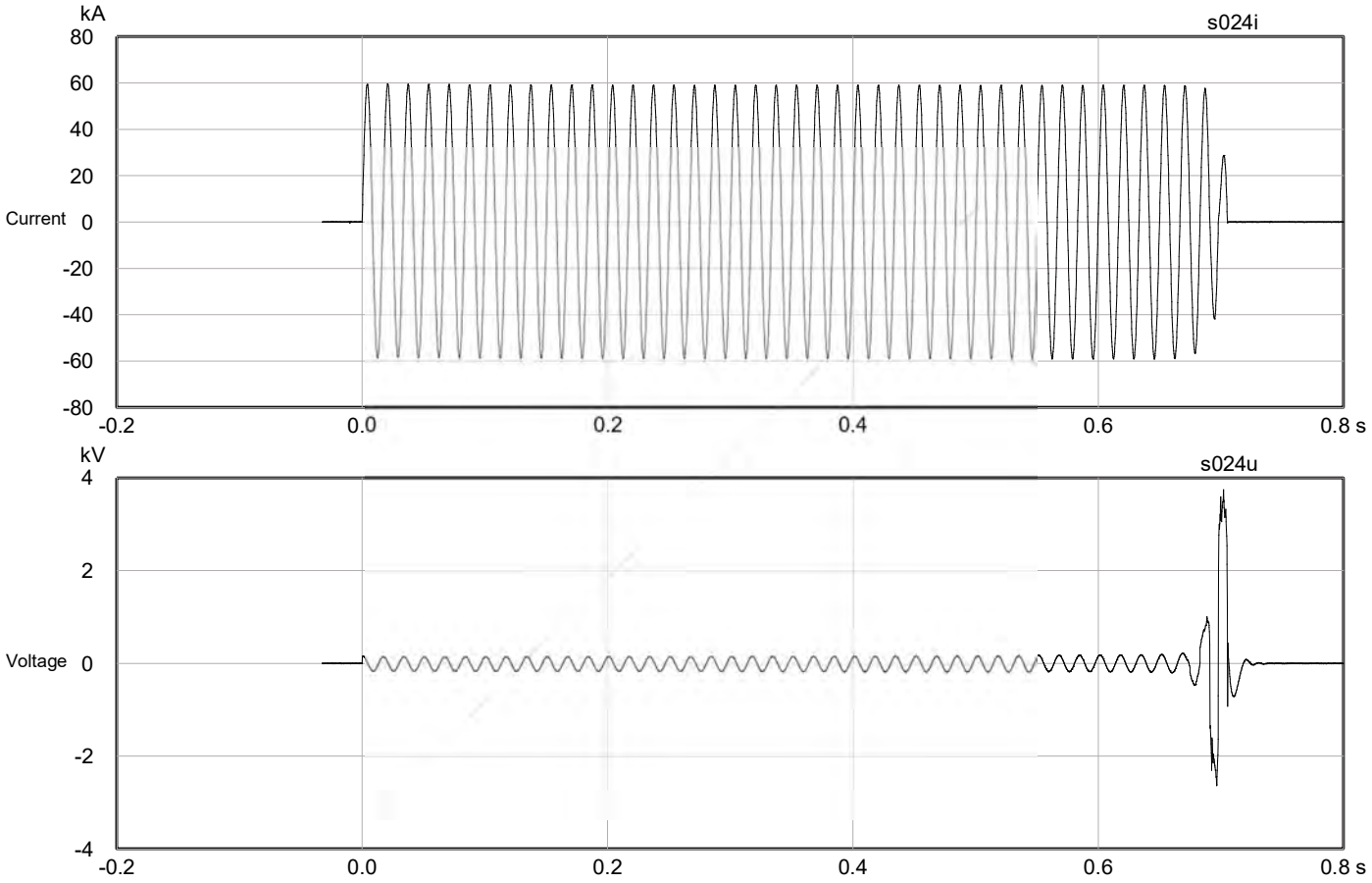


Figure 11: Waveforms for Test #7, Copperweld Scorpius 61 x 072 Sample 11.

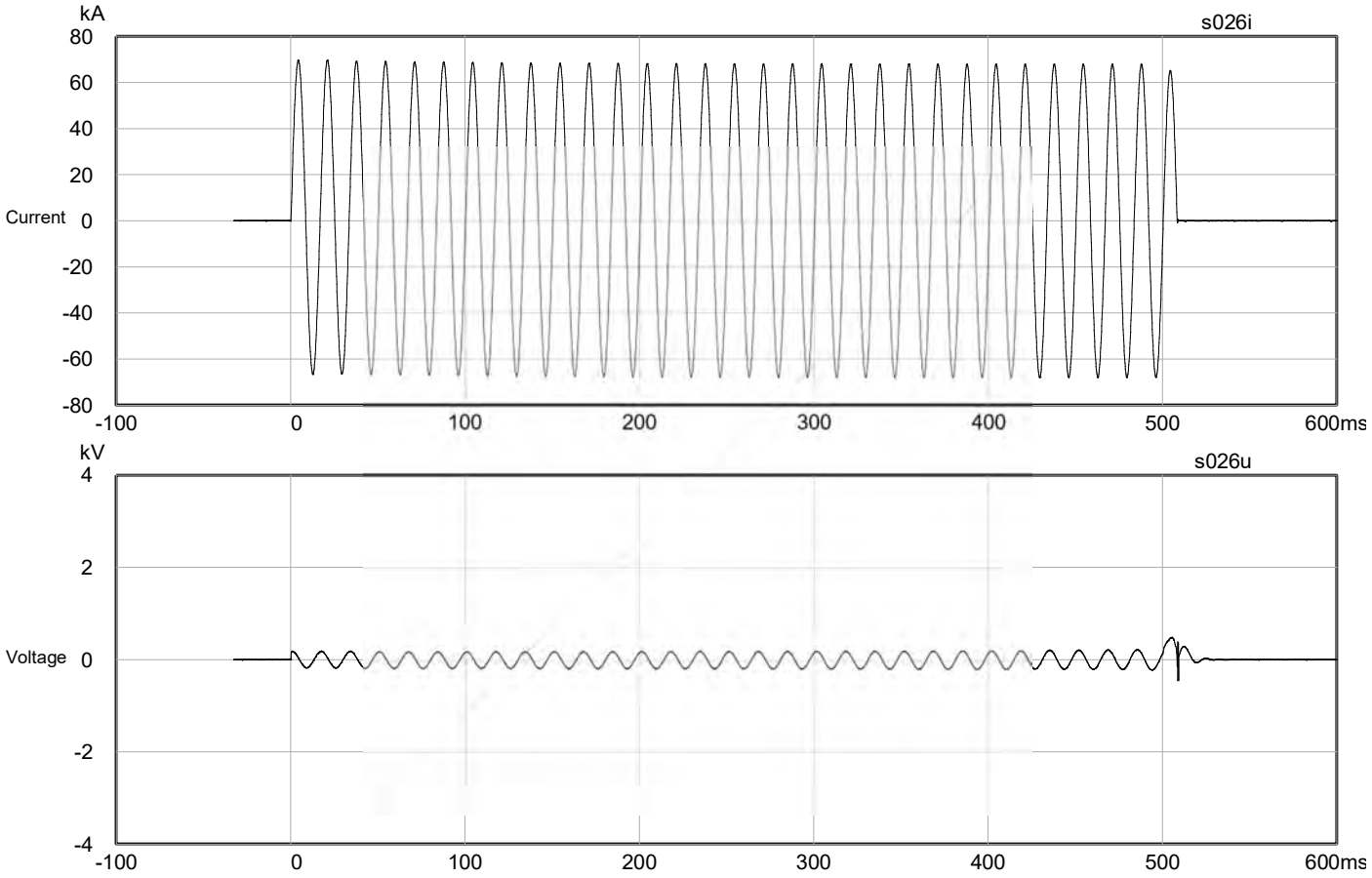


Figure 12: Waveforms for Test #6, Copperweld Scorpius 61 x 072 Sample 12.

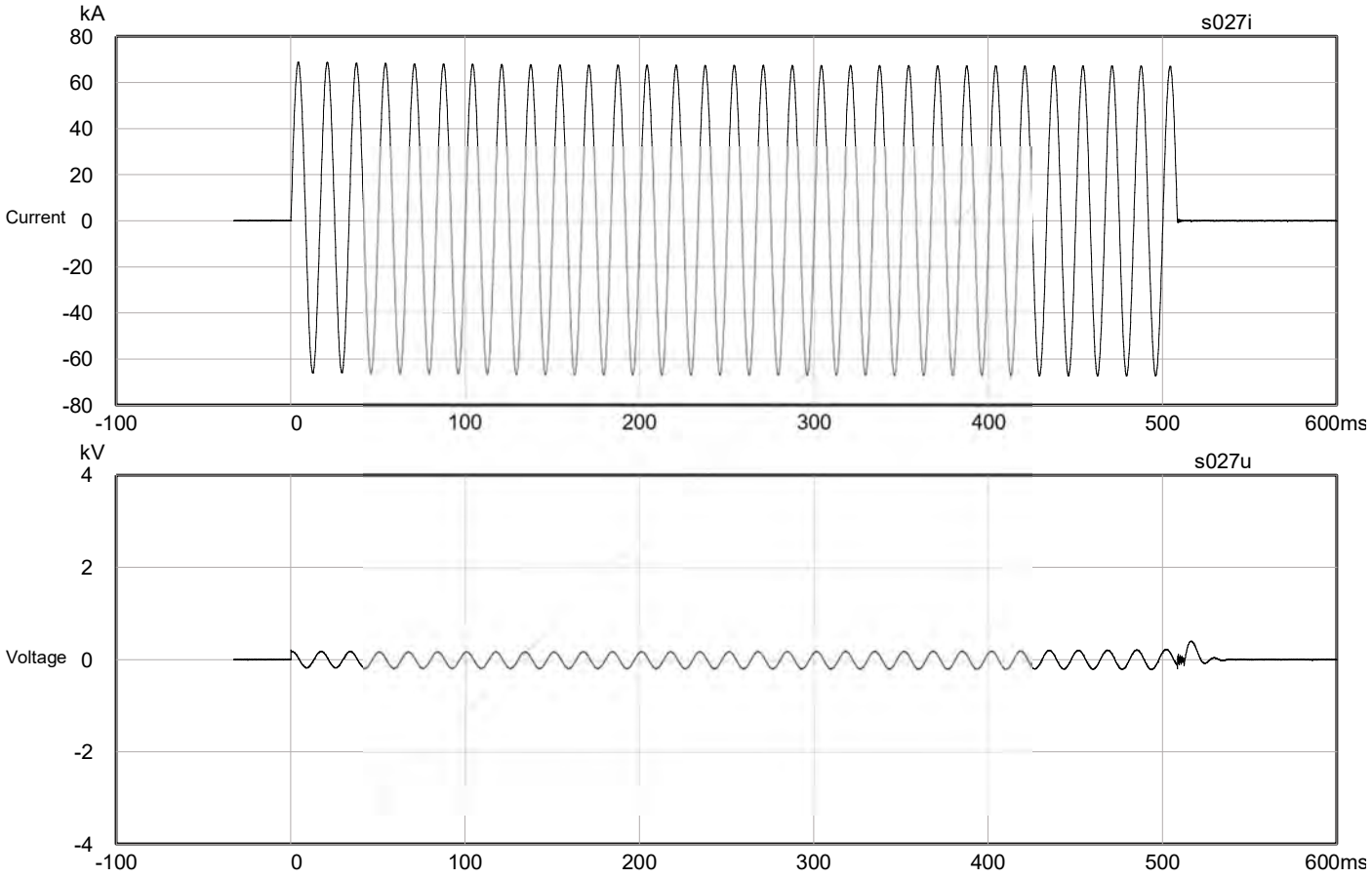


Figure 13: Waveforms for Test #9, Copperweld Scorpius 61 x 072 Sample 13.

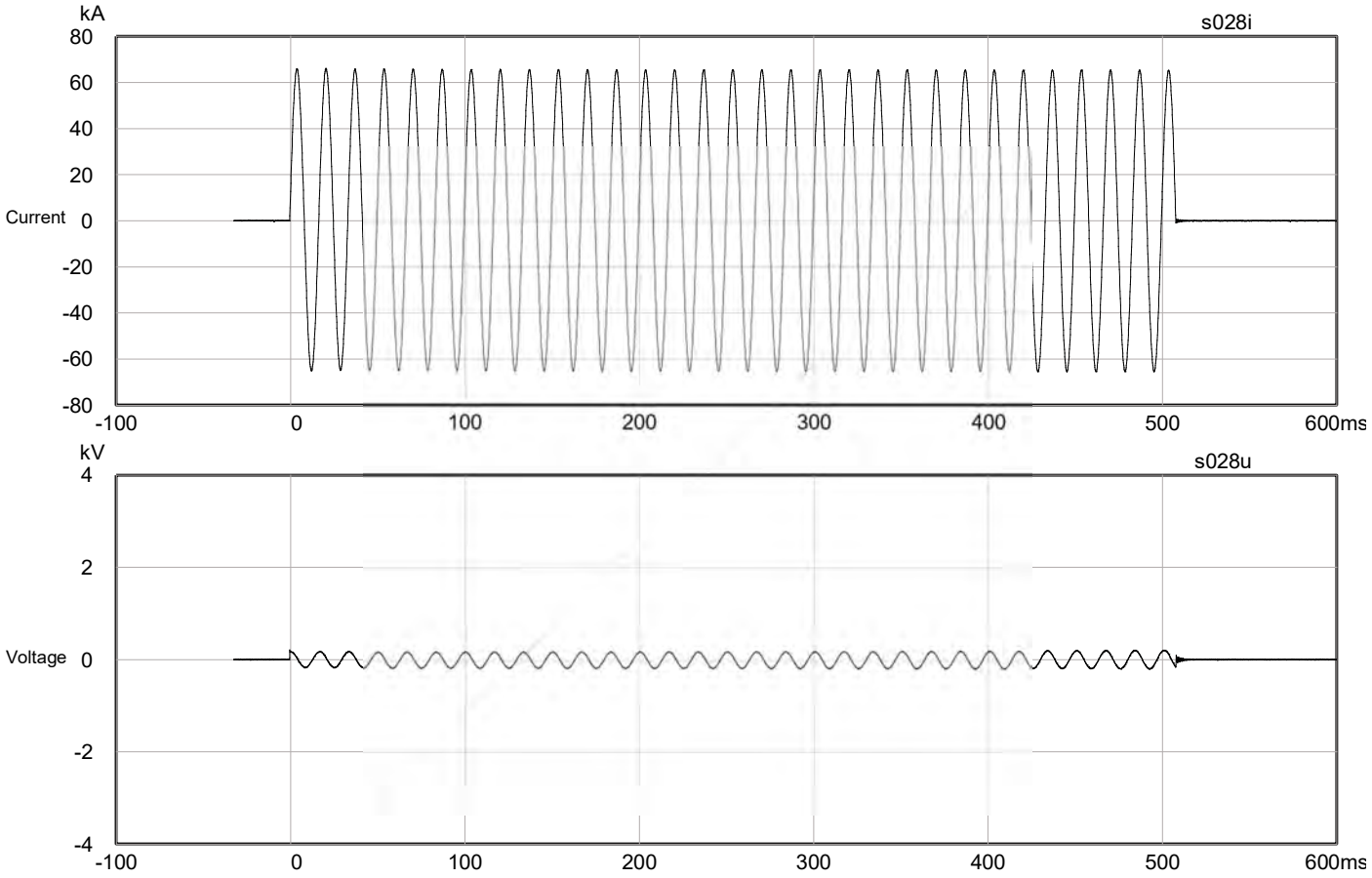


Figure 14: Waveforms for Test #10, Copperweld Scorpius 61 x 072 Sample 14.

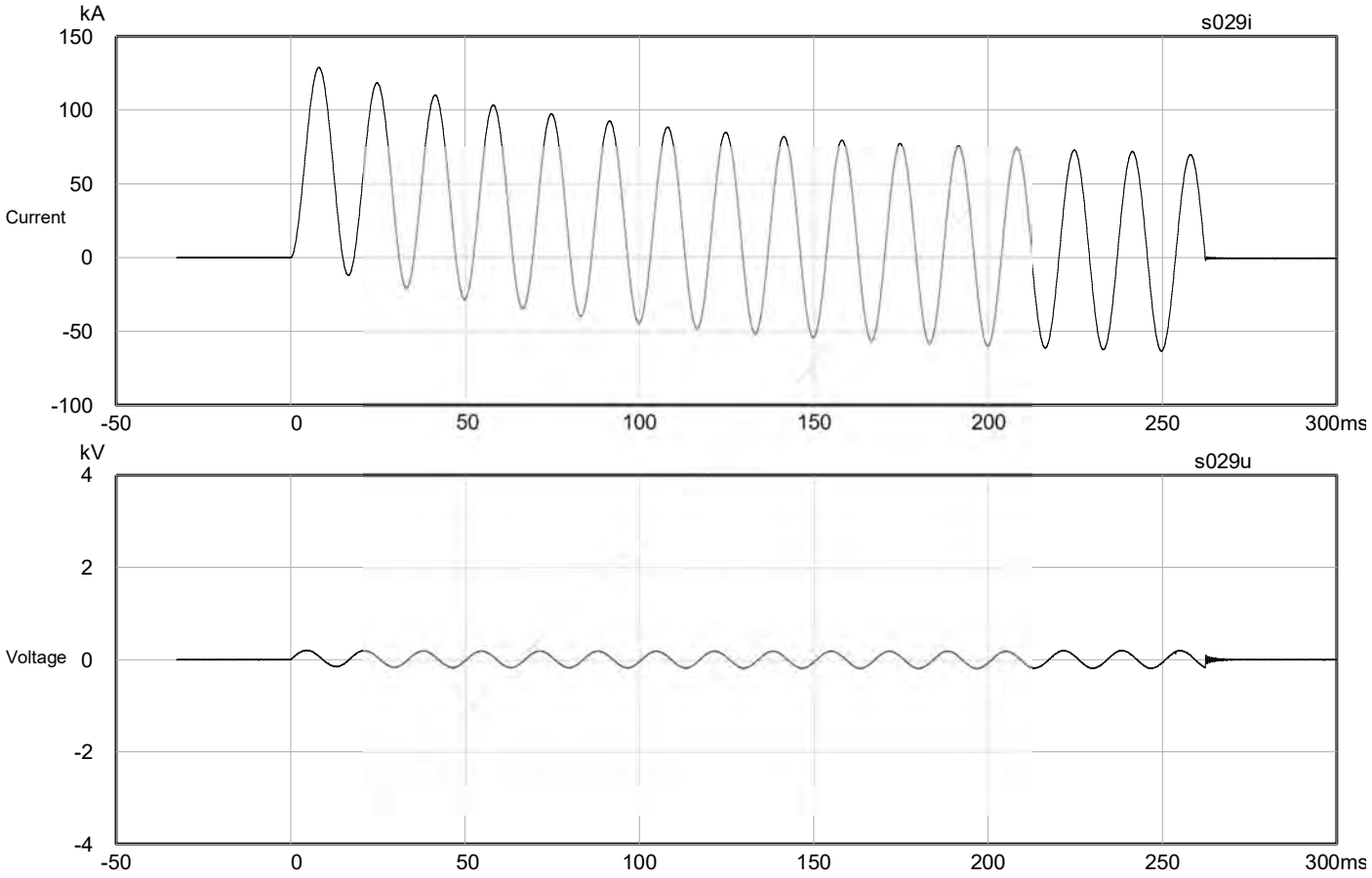


Figure 15: Waveforms for Test #11-1, Copperweld Scorpius 61 x 072 Sample 15.

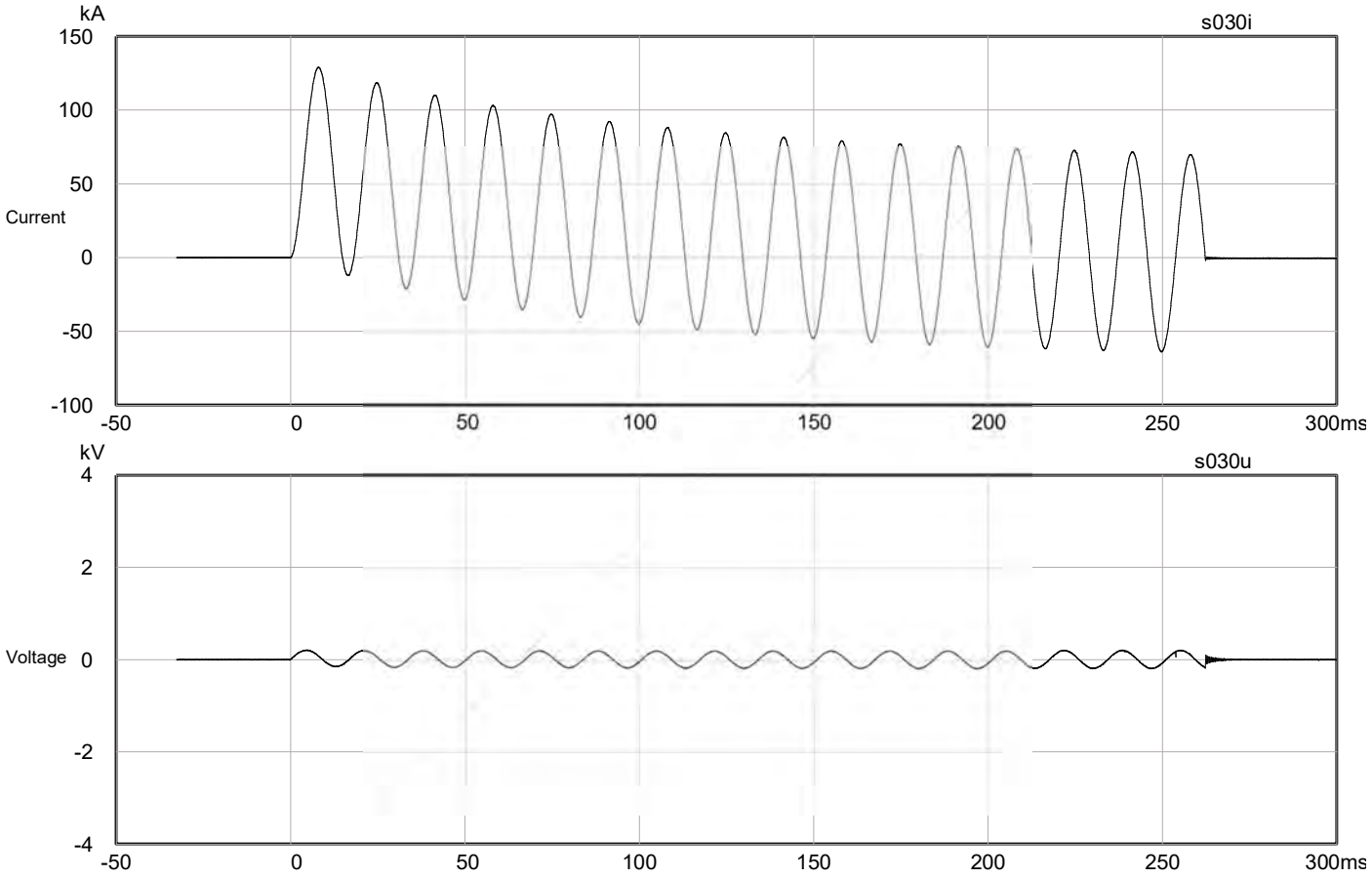


Figure 16: Waveforms for Test #11-2, Copperweld Scorpius 61 x 072 Sample 15.

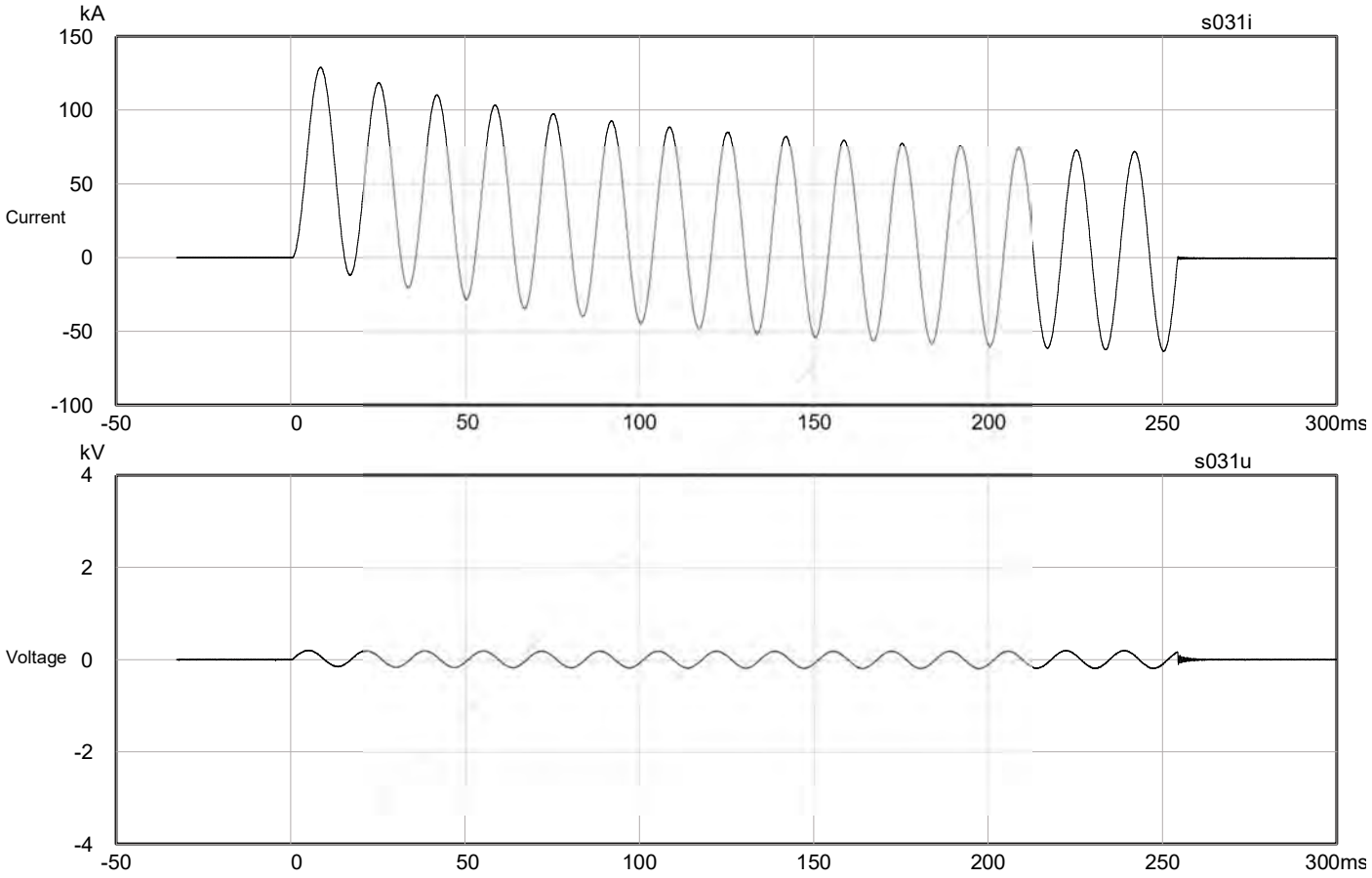


Figure 17: Waveforms for Test #12-1, Copperweld Scorpius 61 x 072 Sample 16.

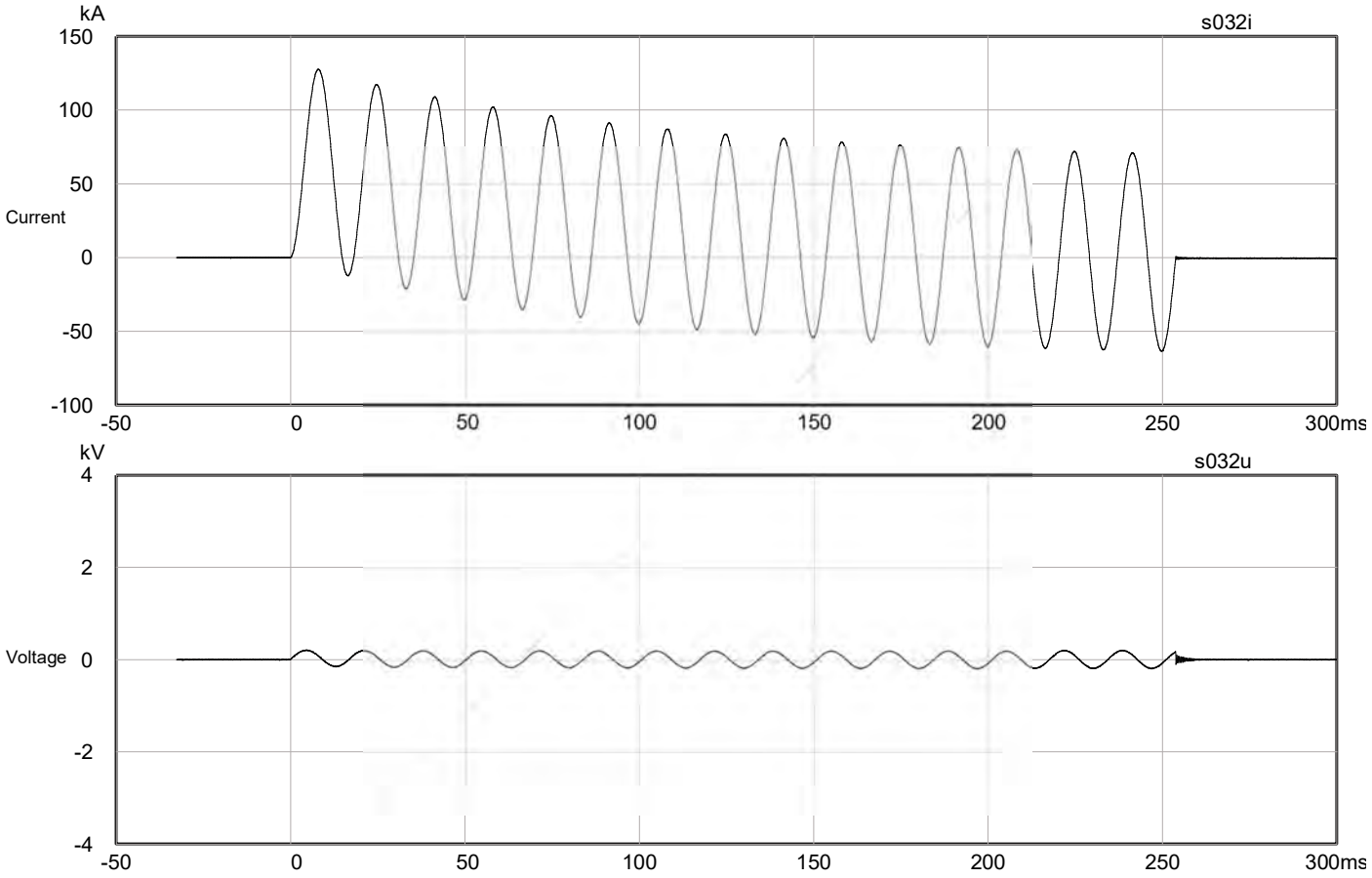


Figure 18: Waveforms for Test #12-2, Copperweld Scorpius 61 x 072 Sample 16.

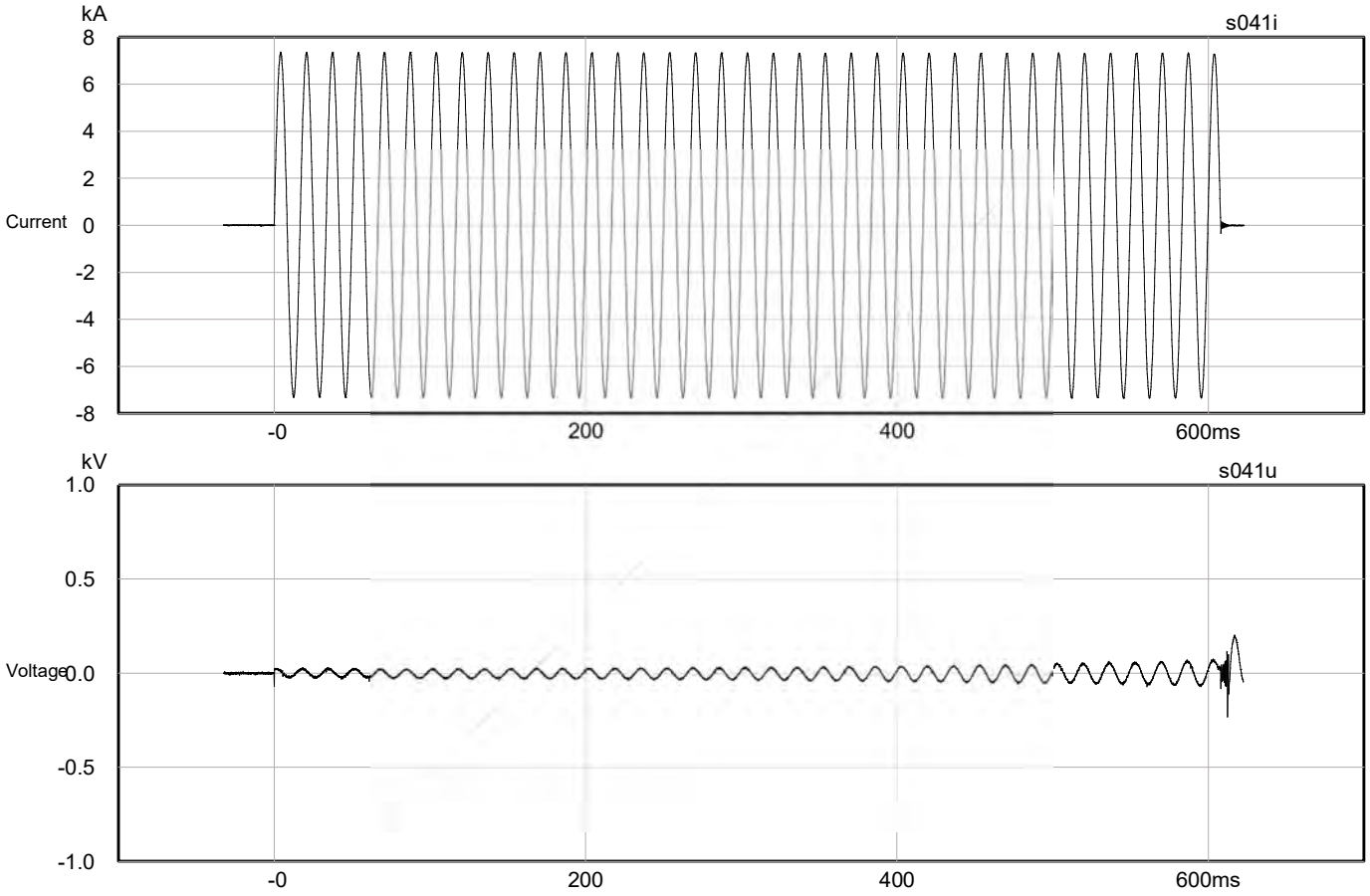


Figure 19: Waveforms for Test #13, Encore #6 AWG Sample 21.

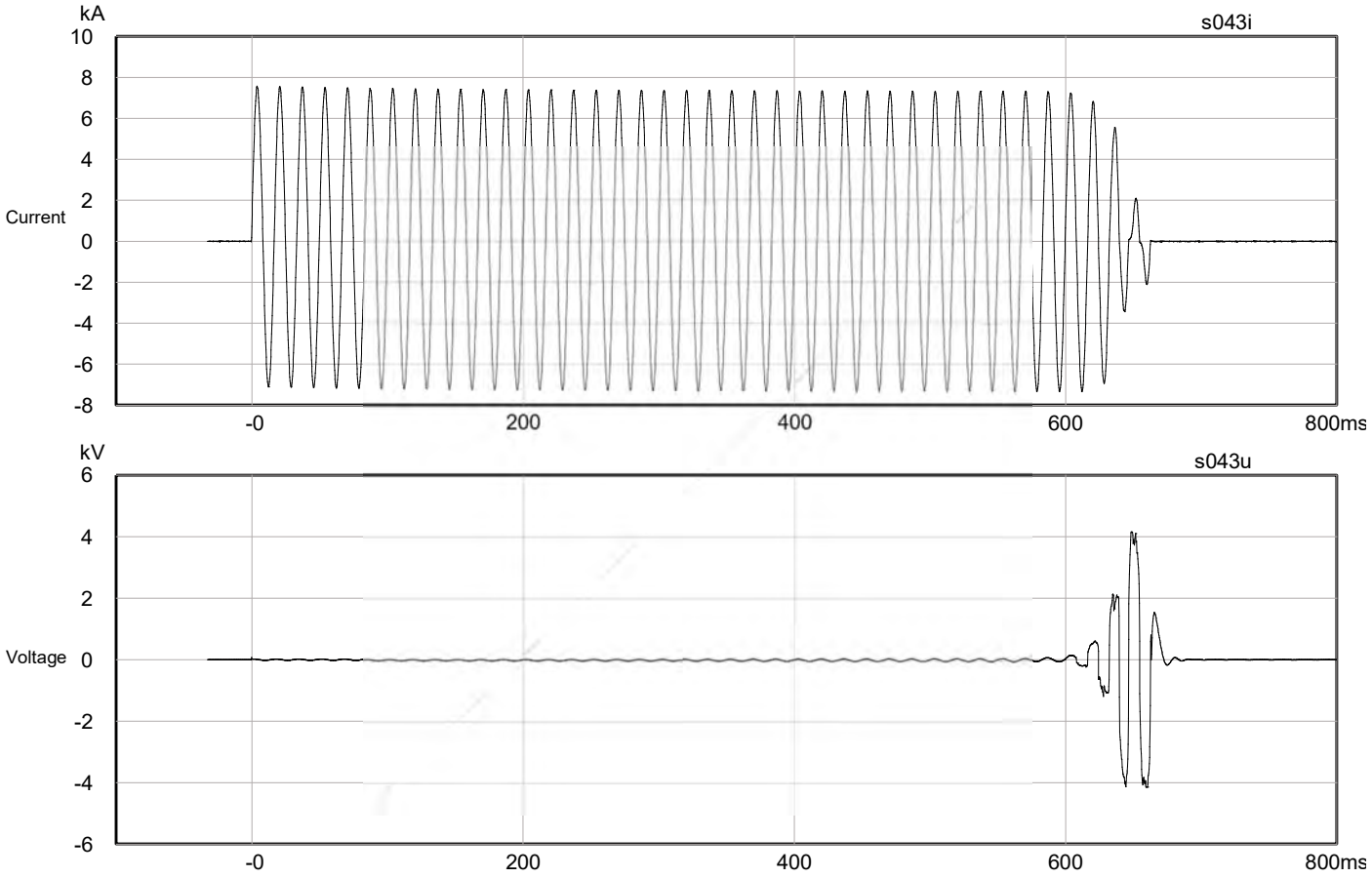


Figure 20: Waveforms for Test #14, Encore #6 AWG Sample 23.

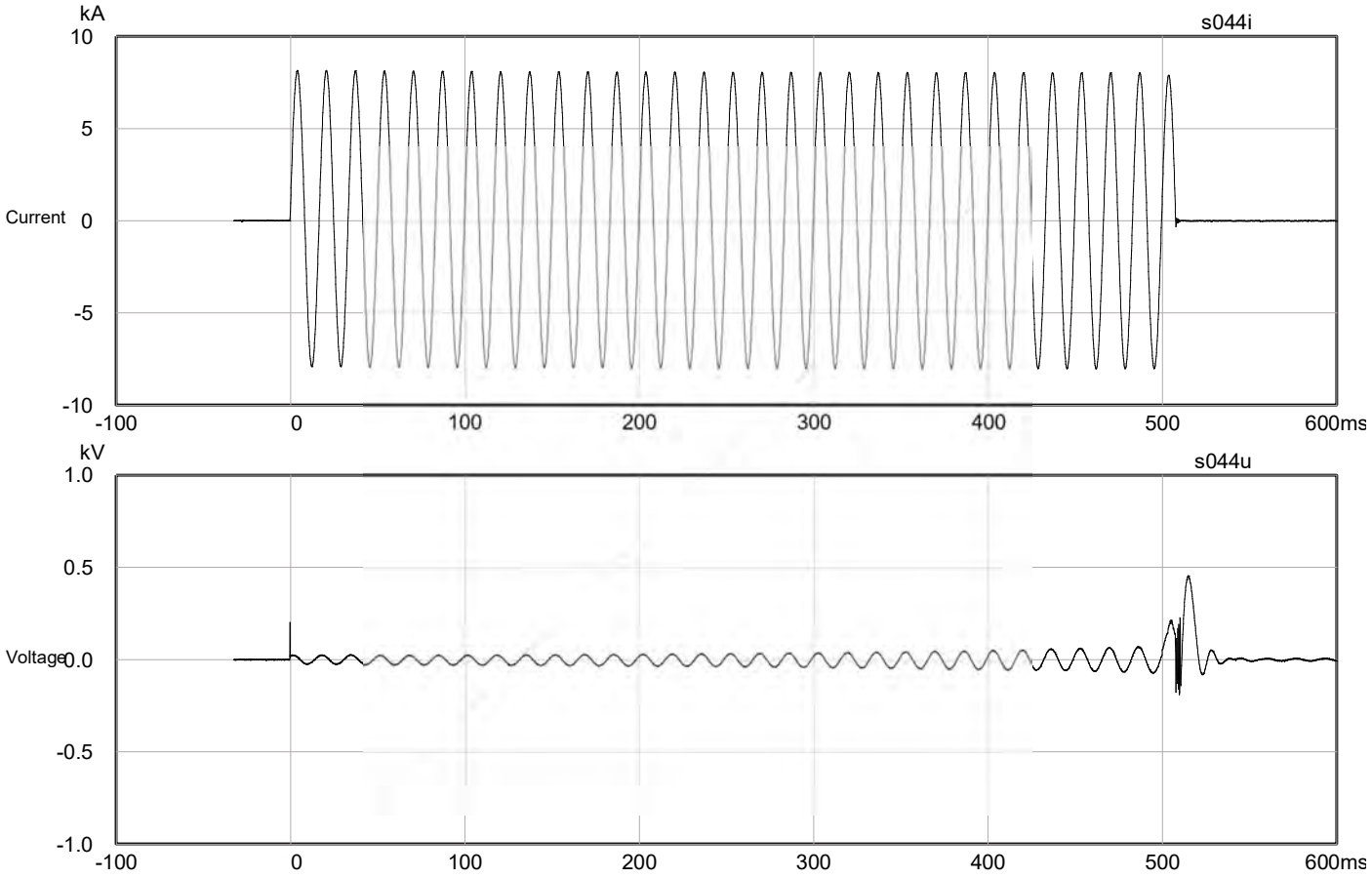


Figure 21: Waveforms for Test #15, Encore #6 AWG Sample 24.

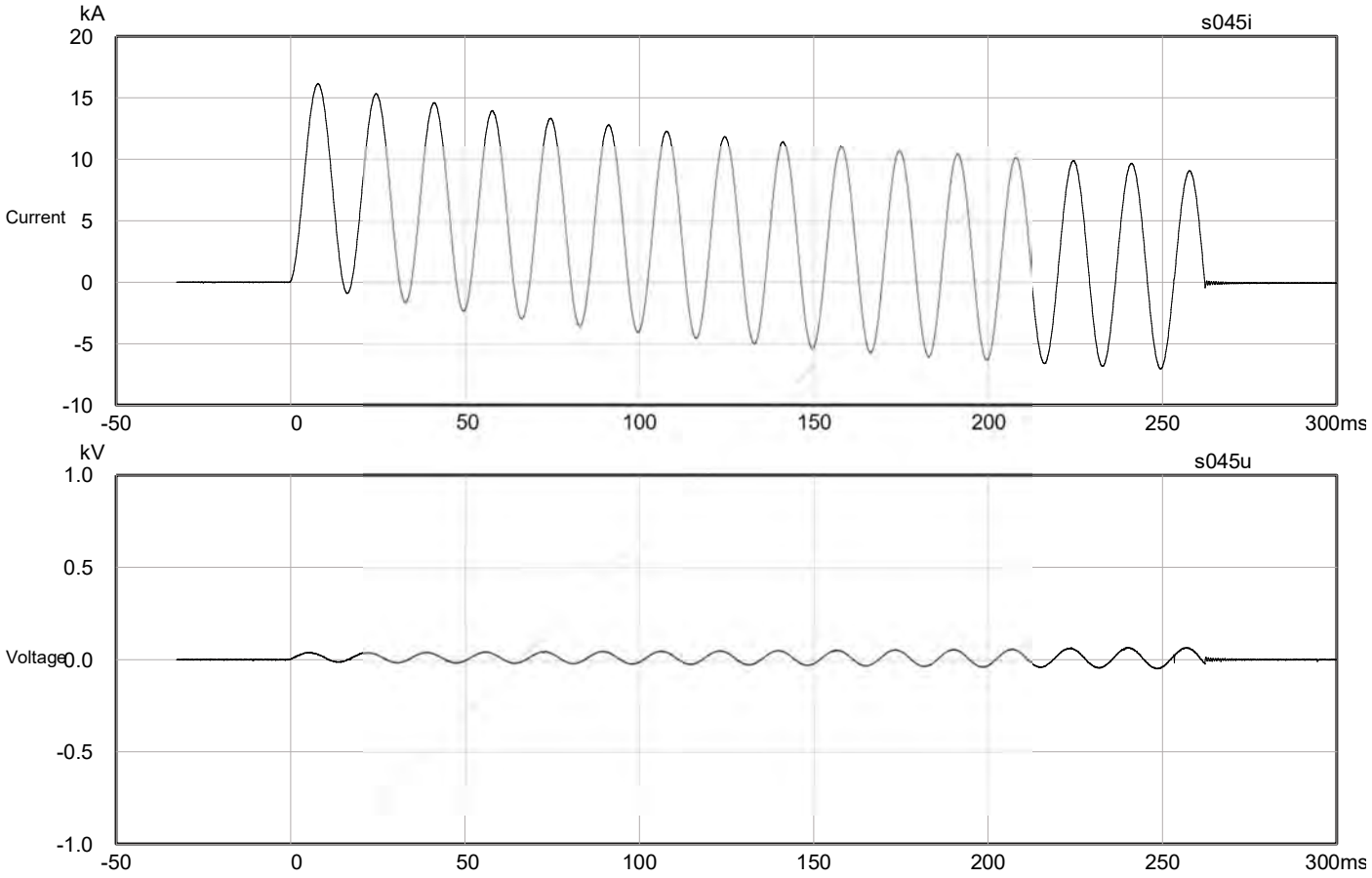


Figure 22: Waveforms for Test #16-1, Encore #6 AWG Sample 25.

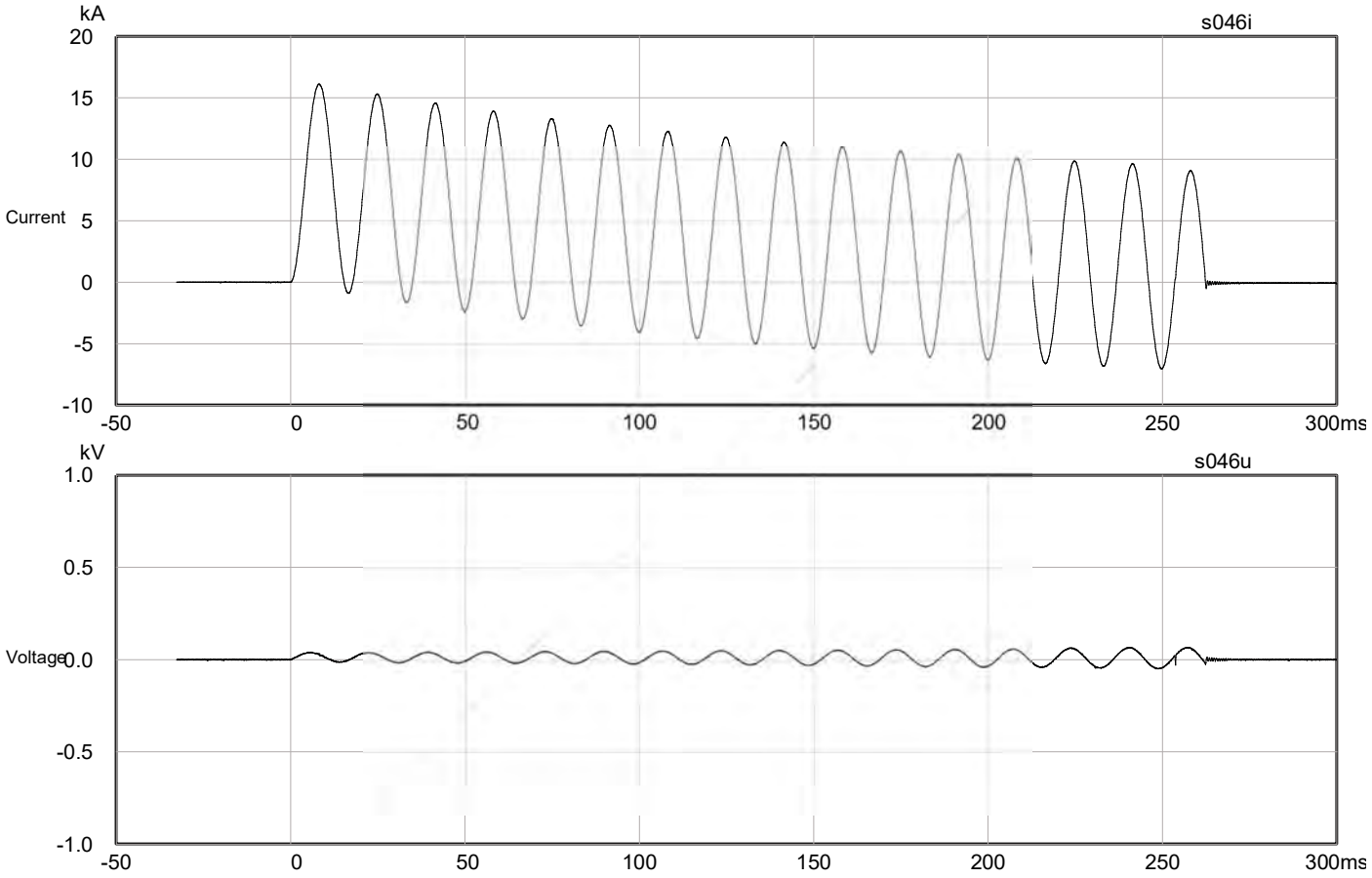


Figure 23: Waveforms for Test #16-2, Encore #6 AWG Sample 25.

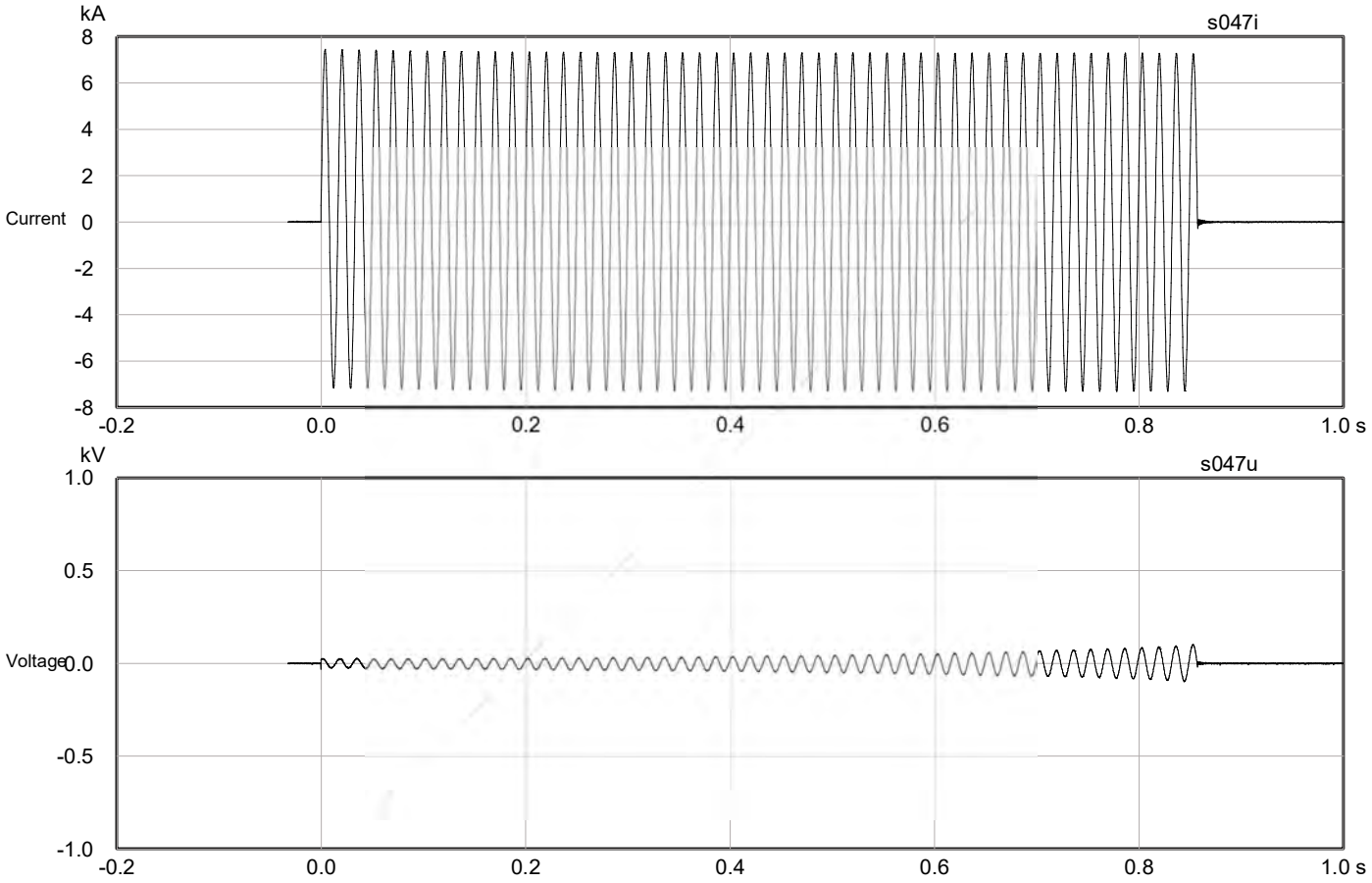


Figure 24: Waveforms for Test #17, Encore #6 AWG Sample 31.

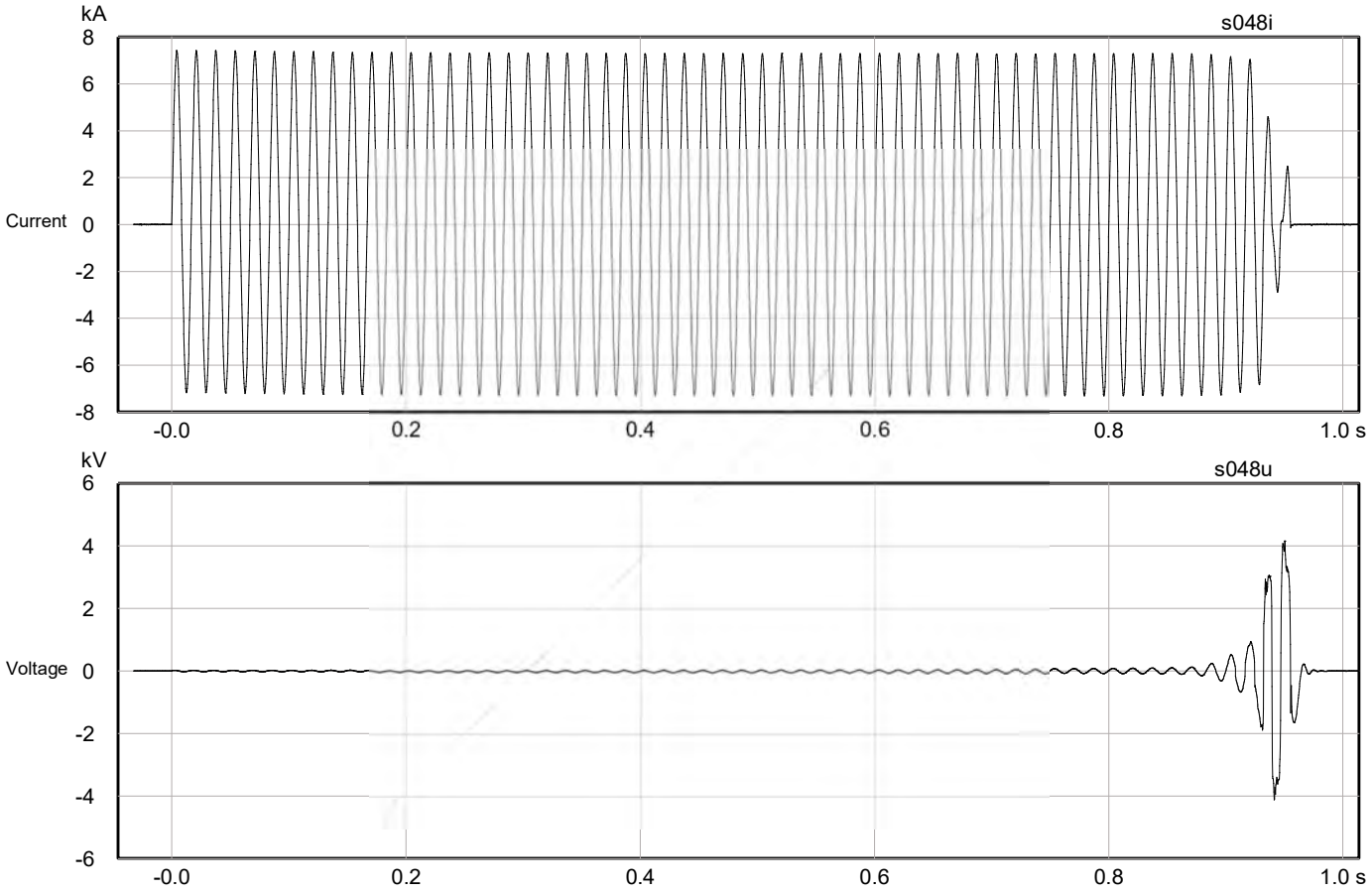


Figure 25: Waveforms for Test #18, Copperweld Scorpius 7 x 080 Sample 32.

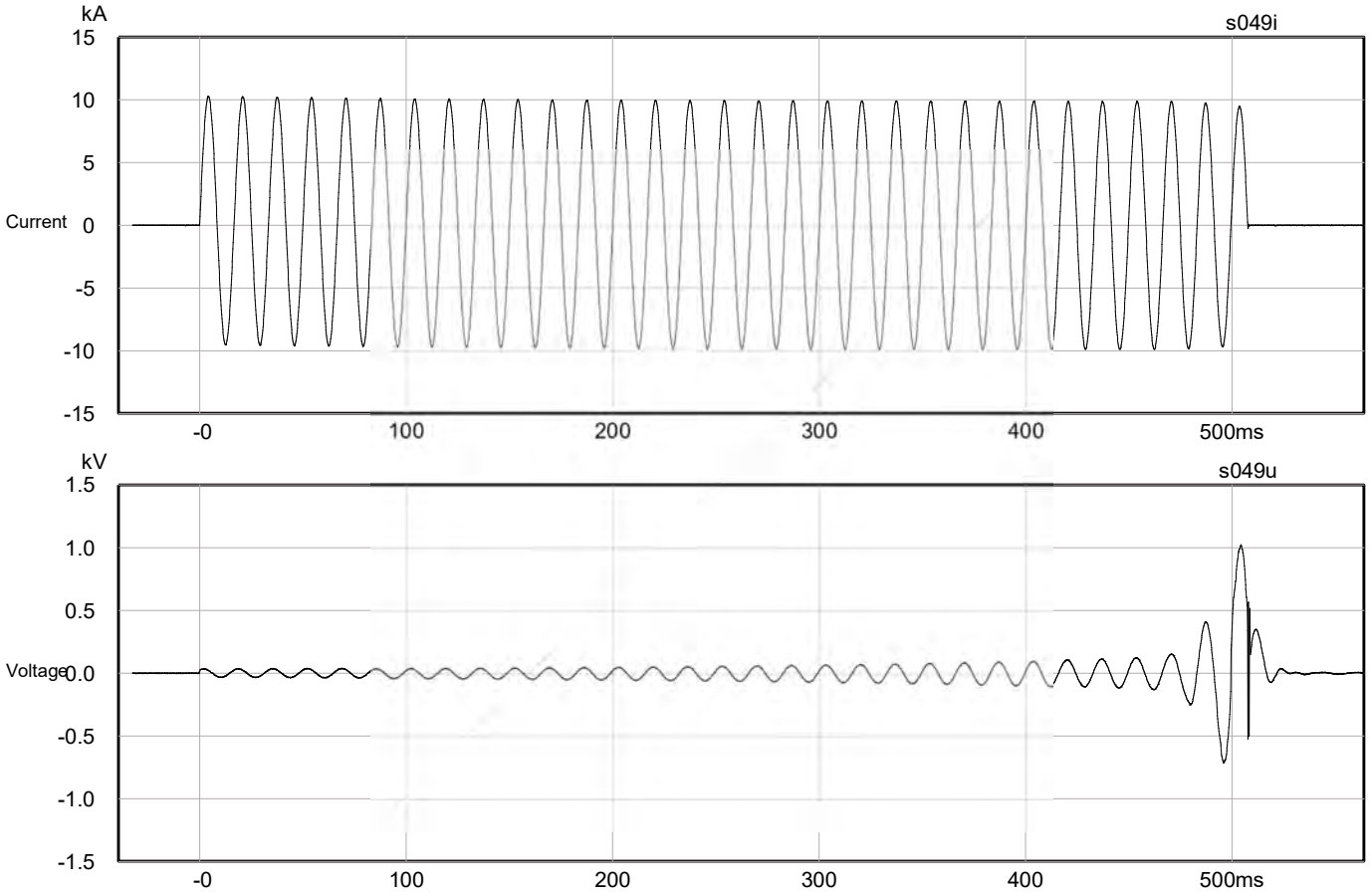


Figure 26: Waveforms for Test #19, Copperweld Scorpius 7 x 080 Sample 33.

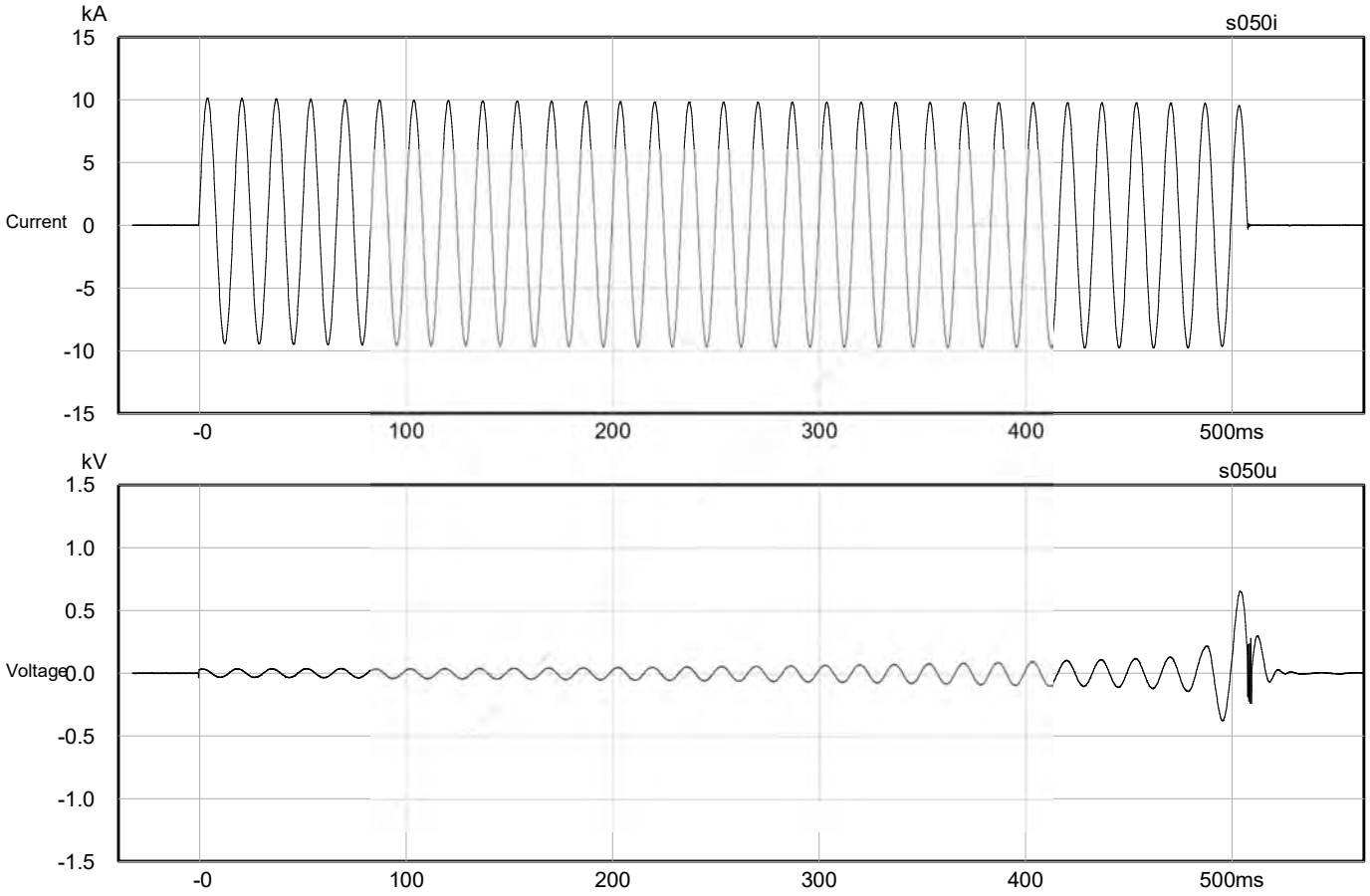


Figure 27: Waveforms for Test #20, Copperweld Scorpius 7 x 080 Sample 34.

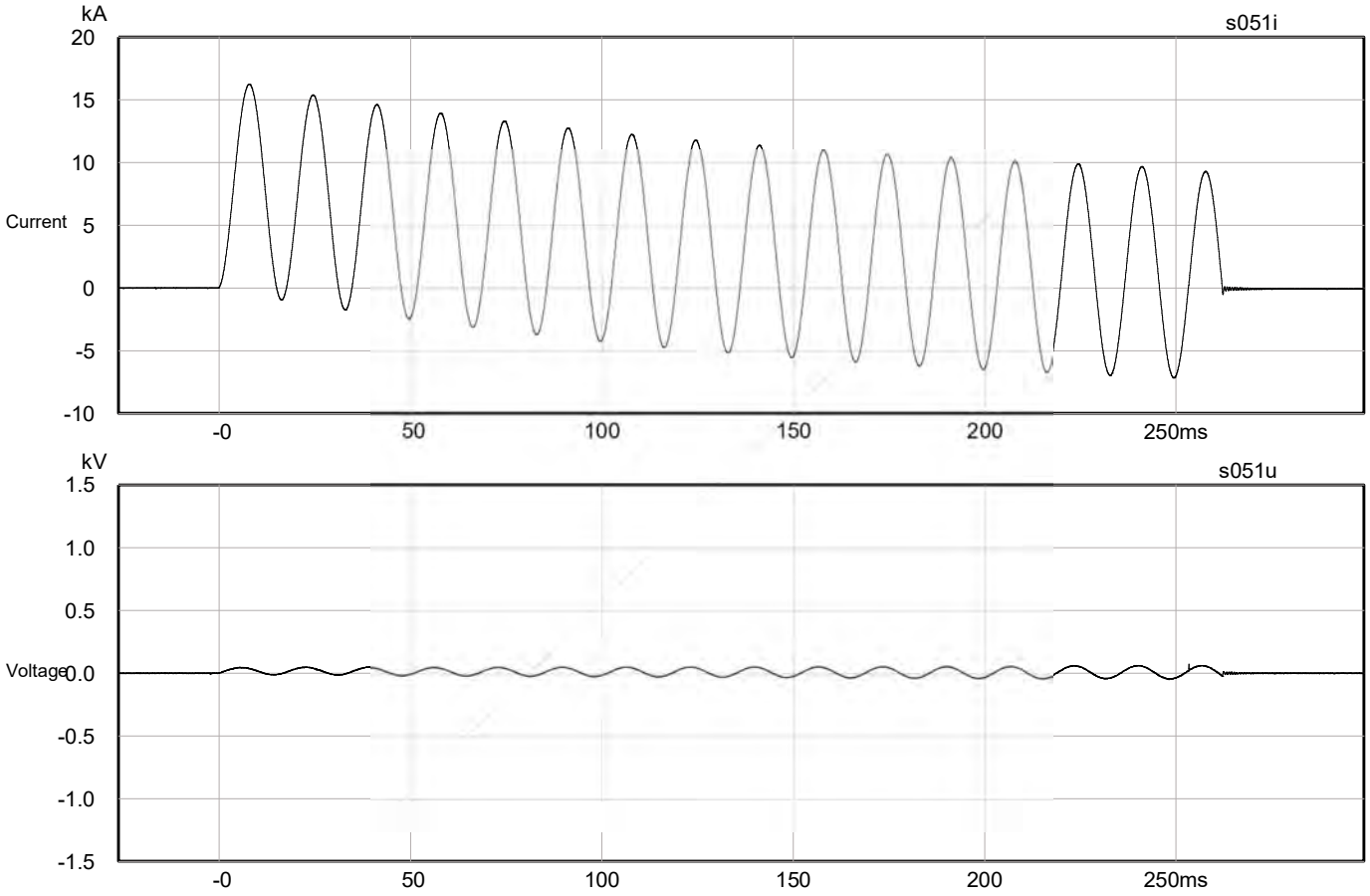


Figure 28: Waveforms for Test #21-1, Copperweld Scorpius 7 x 080 Sample 35.

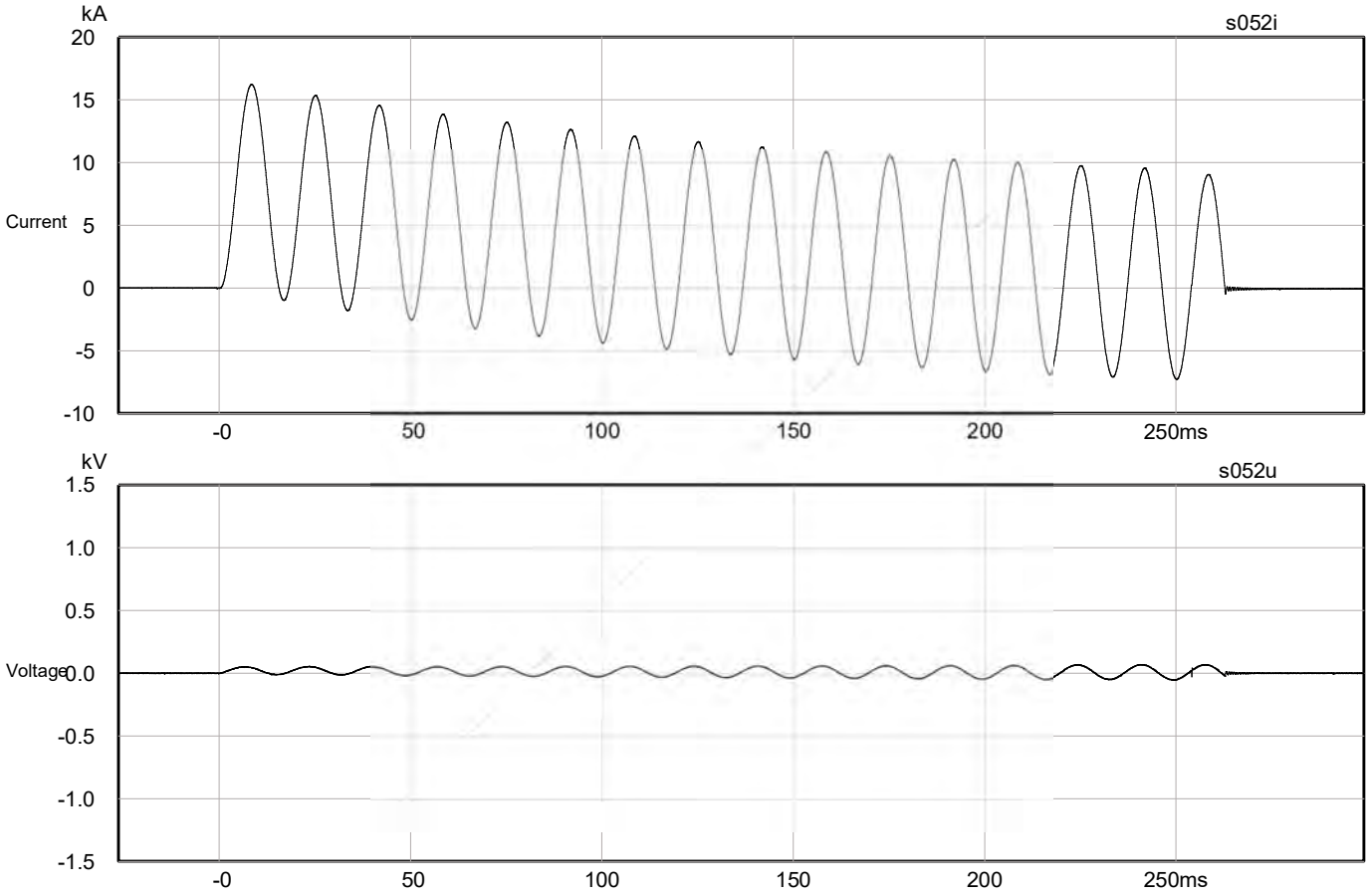


Figure 29: Waveforms for Test #21-2, Copperweld Scorpius 7 x 080 Sample 35.

APPENDIX C – PHOTOGRAPHS OF THE TEST OBJECTS



Figure 30: Test set up for the Encore 4/0 AWG Cu conductor. The power source bus is on the left and the ground bus is on the right.



Figure 31: Test set up for the Copperweld Scorpius 61 x 072 CCS conductor.



Figure 32: Test set up for the Encore #6 AWG Cu conductor.



Figure 33: Test set up for the Copperweld Scorpius 7 x 080 CCS conductor.

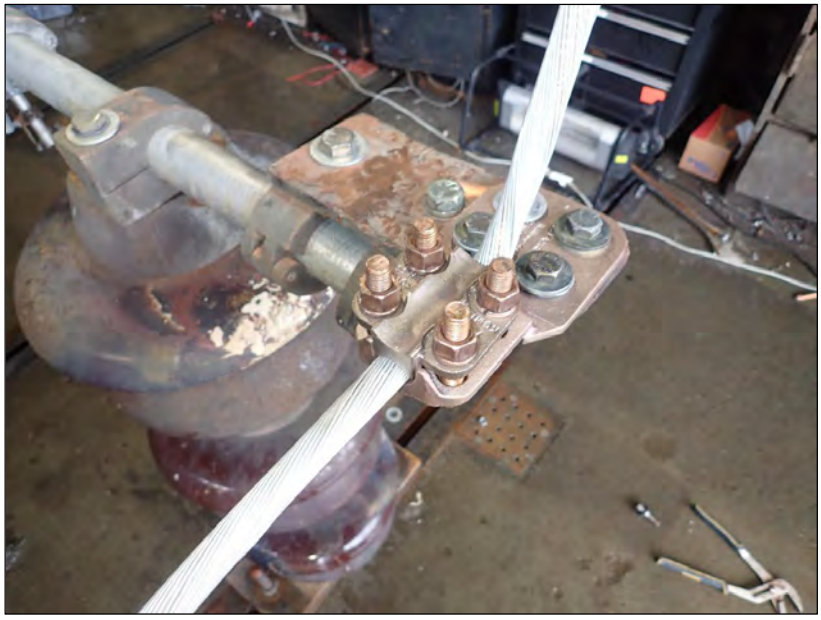


Figure 34: Typical Burndy terminal connector used to connect the Encore 4/0 AWG or Copperweld Scorpius 61 x 072 CCS conductors to the laboratory buses.



Figure 35: Typical Burndy terminal connector used to connect the Encore #6 AWG or Copperweld Scorpius 7 x 080 CCS conductors to the laboratory buses.

APPENDIX D – CALCUATIONS OF TEST CURRENT LEVELS FOR #6 AWG CU CONDUCTOR

Equation (45) in IEEE 80 and Equation (C.1) in IEEE 837 are the same, as follows:

$$I = A\sqrt{\left(\frac{TCAP\times10^{-4}}{t_c\times\alpha_r\times\rho_r}\right)\ln\left(\frac{K_0+T_m}{K_0+T_a}\right)}$$

where

I is root mean square (rms) current in kA
A is conductor cross section in mm^2
T_m is maximum allowable temperature in °C
T_a is initial conductor temperature in °C
T_r is reference temperature for material constants in °C
α_0 is thermal coefficient of resistivity at 0 °C
α_r is thermal coefficient of resistivity at reference temperature T_r
ρ_r is resistivity of the ground conductor at reference temperature T_r in μΩ-cm
K_0 is $1/\alpha_0$, or $(1/\alpha_r)-T_r$ in °C
t_c is time of current flow in seconds (s)
TCAP is thermal capacity factor in joules/cm^3°C

This equation is used to calculate the short-circuit ampacity of a conductor based on it's material constants.

For IEEE 80, Table 6, the symmetrical rms fusing current for #6 AWG soft-drawn Cu conductor at 500 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.5)(0.00393)(1.72)}\cdot\ln\left(\frac{(234+1083)}{(234+40)}\right)} = \boxed{5.29\ kA_{rms}}$$

For IEEE 837, Table 3, the symmetrical rms fusing current for #6 AWG hard-drawn Cu conductor at 250 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.25)(0.00381)(1.78)}\cdot\ln\left(\frac{(242+1084)}{(242+40)}\right)} = 7.41\ kA_{rms}$$

From IEEE 837 Equation (C.4), the asymmetrical rms fusing current is:

$$I_{asym} = \frac{(7.41\ kA)}{(1.148)} = 6.45\ kA_{rms}$$

For the EMF described in IEEE 837, Clause 7.2, a value of 90% of the fusing current is used for conductors up to 4/0 AWG:

$$I_{EMF} = (6.45)(0.9) = \boxed{5.81\ kA_{rms}}$$

Copperweld Bimetallics Data Sheet Packet
Electrical Test Laboratory

Customer:	Copperweld Building Wire	Engineer:	Bill Lewey	Date:	8/25/2020
Sample ID:	EL-13	Tested By:	Bill Lewey, Mike Rozar	Date:	8/25/2020
Product:	Grade 40 Copper Clad Steel Wire Solid Bare #4 and #6 vs Equivalent Solid Copper: Grounding Electrode Conductor Equivalency Test	Sample Condition:	New		
Standard:	ASTM B910/910M Annealed Copper Clad Steel Wire				
Insulation: N/A - Bare		Jacket: N/A - Bare			

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Test Report Summary

Page	Test Performed	Date Completed	Pass/Fail
1	Grounding Electrode Conductor Test for Copper Clad Steel Grade 40	8/25/2020	**Pass**

Requirement:
#4 AWG Grade 40 Copper Clad Steel and #6 AWG Copper Clad Steel when compared to #4 solid copper and #6 solid copper for use as a grounding electrode conductor shall have equal ability to carry amperage during a ground fault condition.

Conclusion:
The ability of bare #4 AWG Copper Clad Steel Grade 40 and bare #6 AWG Copper Clad Steel Grade 40 performed equally to #4 AWG bare solid copper and #6 AWG bare solid copper when used as a grounding electrode conductor under a ground fault condition. The current measured proved equivalency.

Test Equipment Used

Item	Equipment Type	Equipment #	Cal. Due Date
1	Fluke 374FC Clamp Meter	AM-1	Nov 2020
2	Acme Electric 15KVA Transformer	T2535173S	N/A
3	Square D 60A / 600V Safety Interrupter	N/A	N/A
4	Eaton Service Panel	N/A	N/A
5	Eaton Type CH 20 Amp Breaker	N/A	N/A
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

VBU – Verify Before Use

N/A – Not Applicable

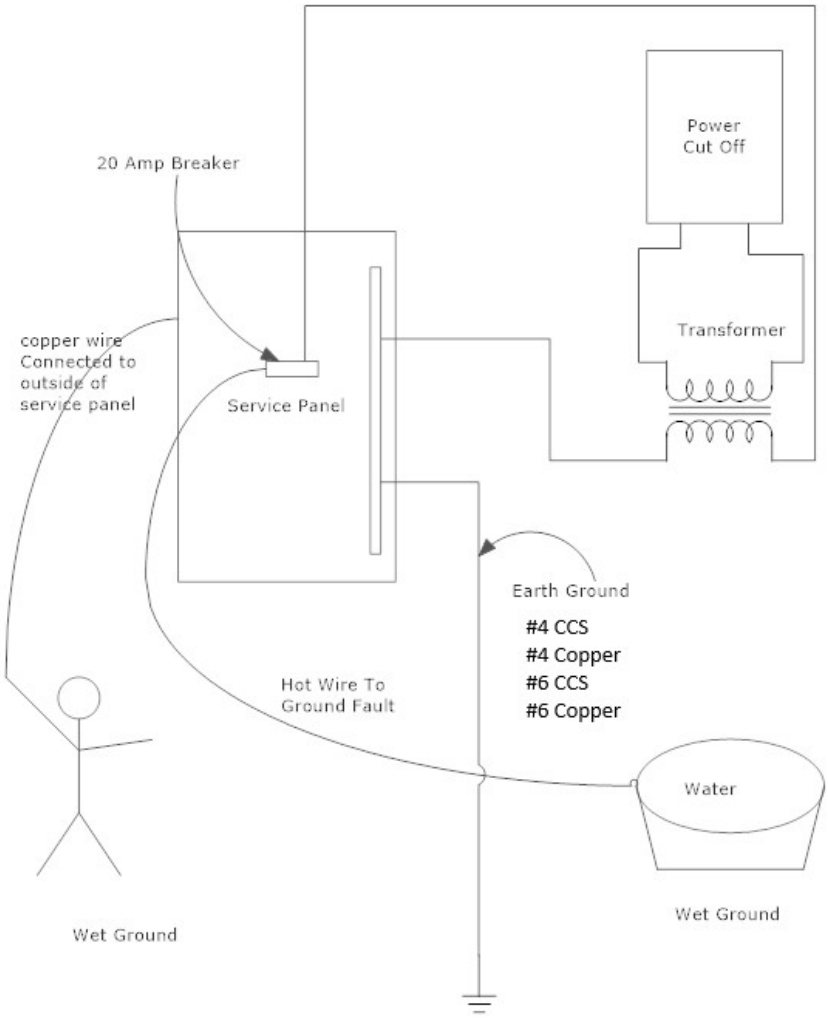
Sample Identification

Item	Description	Length/No. Rec'd
A	#4 AWG 40% Copper Clad Steel Bare	35 Ft
B	#4 AWG Solid Copper Bare	35 Ft
C	#6 AWG 40% Copper Clad Steel Bare	35 Ft
D	#6 AWG Solid Copper Bare	35 Ft
E		
F		

Grounding Electrode Conductor Test

Test Parameters:	
Conditioning:	No preconditioning.
Test Conductors:	1 each of #4 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #6 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #4 AWG Solid Bare copper grounding electrode conductor 1 each of #6 AWG Solid Bare copper grounding electrode conductor
Test Conductor Length:	Each conductor shall be 35 ft.
Test Circuit Configuration:	See schematic shown in Figure 1
Test Current:	Test current from 120 V / 20 A Residential Circuit
Method:	Testing was completed by creating a standard residential test circuit at 120V with 20A breaker wired to an intentional ground fault as shown in figure 1. The ground fault was created by connecting a hot wire from the breaker to a galvanized steel pan full of water and placing the pan on the wet ground. A conductor was also connected to the outside of the electrical panel and a Copper Plated Grounding Electrode (Copperweld Ground Rod) driven 6 inches into the wet ground to determine amount of current going through a grounded person touching the electrical panel during the ground fault condition. The ground fault and the grounded "man" were positioned 20 feet either side of the ground rod. The entire test area was soaked with water overnight using a sprinkler system When the ground fault was electrified, current measurements were taken from the ground fault conductor, the grounding electrode conductor and the grounded "man" conductor. For the four grounding electrode conductors tested, there was one test sequence for each. The current was measured for each. The objective: Compare the amperage measurements of the copper clad steel grounding electrode conductors to those of copper.

Figure 1



Results:			
Ground Conductor	**Fault Conductor Current**	**Current of the Grounding Electrode Conductor**	**Grounded Man Conductor Current**
#4 Copper	2.1 A	1.8 A	0.3 A
#4 40% CCS	2.1 A	1.8A	0.3 A
#6 Copper	1.7 A	1.6 A	0.1 A
#6 40% CCS	1.5 A	1.4 A	0.1 A

Requirement:
For equivalent sizes of Grade 40 Copper Clad steel vs. solid copper grounding conductors, the ability to carry amperage to ground during a ground fault condition is equal.

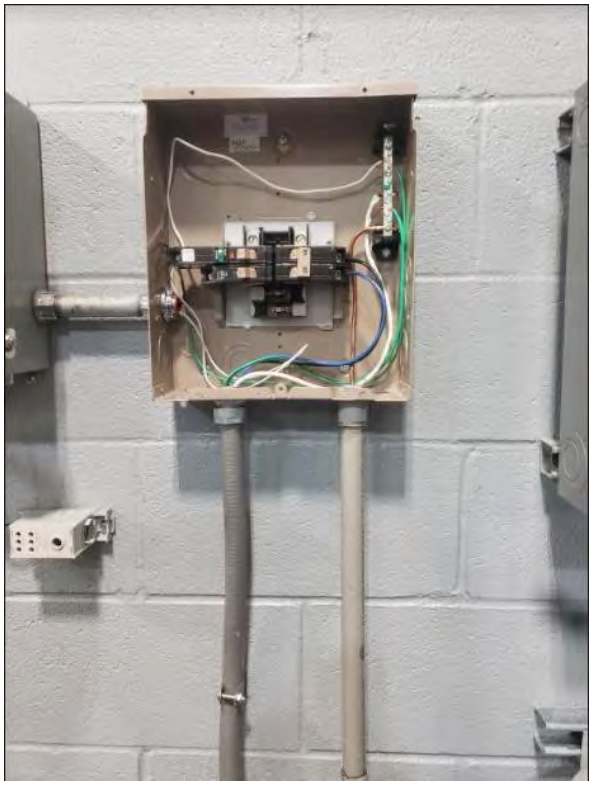
Comments:
____X__ (Pass) The product complies with all applicable requirements of this test. _____ (Fail) The product does not comply with the requirements of this test. **Test Date: 8/25/2020** **Tested By: Bill Lewey**

Environmental Conditions during Testing:

Humidity: % rh __74%_____ Ambient: °C___28_____

Test setup for the electrical service panel







Ground Rod with Grounding Conductor Attached



Ground Fault



Grounded “man”

Public Input No. 2668-NFPA 70-2020 [Section No. 250.52(A)(5)]

(5) Rod and Pipe Electrodes.

Rod and pipe

~~electrodes shall not be~~
electrodes shall be

(a) free from nonconductive coatings such as paint or enamel

(b) not less than 2.44 m (8 ft) in length

~~and shall consist of the following materials. Grounding electrodes of pipe or conduit shall not be smaller~~

(c) not smaller than metric designator 21 (trade size **3**/**4**)

~~and, where of steel, shall have the outer surface~~
if iron or steel pipe or conduit. The outer surface shall be galvanized or otherwise metal-coated for corrosion protection.

~~Rod-type grounding electrodes of stainless steel and copper or zinc coated steel shall be at least~~

(d) not smaller than 15.87 mm (**5**/**8** in.) in diameter

~~, unless listed.~~
if of stainless steel or copper or zinc coated steel. If listed, a rod-type grounding electrode shall be not smaller in diameter than permitted in the applicable product safety standard .

Statement of Problem and Substantiation for Public Input

This Public Input is intended to be editorial in nature rather than substantive. It is intended to improve the requirements and incorporate the requirement in 250.53(A)(1) regarding corrosion protection. That requirement is proposed for deletion in another PI because it is not properly located.

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 27 17:21:22 EDT 2020
Committee: NEC-P05

Public Input No. 2669-NFPA 70-2020 [Section No. 250.52(A)(7)]

(7) Plate Electrodes.

Each plate electrode shall be free from nonconductive coatings such as paint or enamel and:

(a) expose not less than 0.186 m^2 (2 ft^2) of surface to exterior soil. ~~Electrodes of bare or electrically conductive coated iron or steel plates shall~~

(b) be at least 6.4 mm (1/4 in.) in thickness ~~. Solid, uncoated electrodes of nonferrous metal shall~~ if of bare or electrically conductive coated iron or steel.

(c) be at least 1.5 mm (0.06 in.) in thickness if of solid, uncoated nonferrous metal .

Statement of Problem and Substantiation for Public Input

This PI is intended to be editorial in nature rather than substantive. In addition to organizing the requirements in list form, the applicable requirement from 250.53(A)(1) is being included here.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2667-NFPA 70-2020 [Section No. 250.53(A)(1)]	

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 27 18:01:10 EDT 2020
Committee: NEC-P05

Public Input No. 290-NFPA 70-2020 [Section No. 250.52(A)(8)]

(8) Other Local Metal Underground Systems or Structures.

Other local metal underground systems or structures such as piping systems, underground tanks, and underground metal well casings that are not bonded to a metal water pipe and no Cathodic Protective system is installed unless an isolation system is provided in accordance with 250 .6(E).

Statement of Problem and Substantiation for Public Input

Cathode protection is usually provided for these types of equipment or structures. If used as the system grounding it would introduce additional current countering the cathodic protection

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 292-NFPA 70-2020 [Section No. 250.52(B)]	

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: Master electrician
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Zip:
Submittal Date: Wed Jan 15 10:37:45 EST 2020
Committee: NEC-P05

Public Input No. 291-NFPA 70-2020 [Section No. 250.52(A)(8)]

~~**(8)** Other Local Metal Underground Systems or Structures.~~

~~Other local metal underground systems or structures such as piping systems, underground tanks, and underground metal well casings that are not bonded to a metal water pipe.~~

delete this section

Statement of Problem and Substantiation for Public Input

This section gives no guidance to qualify the electrodes permitted in the section. it does not mention direct contact with the soil or square foot/inches exposure for any type of system listed. Example: a water pipe requires 10 feet in direct contact however the Pipe system in this section is silent. Plus introducing a current from the system grounding could have a corrosive affect on an tank or worse the tank could contain volatile liquid or gas.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 292-NFPA 70-2020 [Section No. 250.52(B)]	

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
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Submittal Date: Wed Jan 15 10:47:21 EST 2020
Committee: NEC-P05

Public Input No. 1256-NFPA 70-2020 [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 in 680.26(B)(1) and (B)(2)

(4) Metal underground piping for automatic fire sprinkler systems

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

Statement of Problem and Substantiation for Public Input

This revision is needed to correlate the NEC requirements with requirements in NFPA 13 - Standard for Installation of Sprinkler Systems, and NFPA 24- Standard for the Installation of Private Fire Service Mains and their Appurtenances. Section 6.5.1 of NFPA 13-2019 Edition prohibits underground piping being used as a grounding electrode for electrical systems. Likewise, Section 10.5.1 of NFPA24-2019 Edition prohibits underground piping being used as a grounding electrode for electrical systems.

Submitter Information Verification

Submitter Full Name: Russ Leblanc
Organization: Leblanc Consulting Services
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Zip:
Submittal Date: Tue May 26 13:27:23 EDT 2020
Committee: NEC-P05

Public Input No. 292-NFPA 70-2020 [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) Tanks or Piping systems containg the following:

(a) Volatile liquids or gases

(b) Corrosive liquids or gases

(c) Utilizing a Cathodic Protection System

(2) Aluminum

(3) The structures and structural reinforcing steel 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 Input

Terra mixed the numbers up. The metal gas piping does not explain what type of gas. the assumption is natural gas. however many gases and liquids are volatile and should also be excluded because of the same hazard as natural gas. Tanks are currently allowed unless PI 290 & 91 prevails and should be included for the same reasons a piping system is excluded. A cathodic protection system relies on a anode to cathode protection by way of a chemical transference of ions/electrons the system grounding would introduce an external current flow defeating the cathodic protection

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 290-NFPA 70-2020 [Section No. 250.52(A)(8)]	grounding electrode
Public Input No. 291-NFPA 70-2020 [Section No. 250.52(A)(8)]	grounding electrode

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
Organization: Master electrician
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jan 15 11:05:29 EST 2020
Committee: NEC-P05

Public Input No. 4678-NFPA 70-2020 [Section No. 250.53]

250.53 Grounding Electrode System Installation.

(A) Rod, Pipe, and Plate Electrodes.

Rod, pipe, and plate electrodes shall meet the requirements of 250.53(A)(1) through (A)(3).

(1) Below Permanent Moisture Level.

If practicable, rod, pipe, and plate electrodes shall be embedded below permanent moisture level. Rod, pipe, and plate electrodes shall be free from nonconductive coatings such as paint or enamel.

(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.

(B) Electrode Spacing.

Where more than one of the electrodes of the type specified in 250.52(A)(5) or (A)(7) are used, each electrode of one grounding system (including that used for strike termination devices) shall not be less than 1.83 m (6 ft) from any other electrode of another grounding system. Two or more grounding electrodes that are bonded together shall be considered a single grounding electrode system.

(C) Bonding Jumper.

The bonding jumper(s) used to connect the grounding electrodes together to form the grounding electrode system shall be installed in accordance with 250.64(A) , (B), and (E), shall be sized in accordance with 250.66 , and shall be connected in the manner specified in 250.70 . Rebar shall not be used as a conductor to interconnect the electrodes of grounding electrode systems.

(D) Metal Underground Water Pipe.

If used as a grounding electrode, metal underground water pipe shall meet the requirements of 250.53(D)(1) and (D)(2).

(1) Continuity.

Continuity of the grounding path or the bonding connection to interior piping shall not rely on water meters or filtering devices and similar equipment.

(2) Supplemental Electrode Required.

A metal underground water pipe shall be supplemented by an additional electrode of a type specified in 250.52(A)(2) through (A)(8). If the supplemental electrode is of the rod, pipe, or plate type, it shall comply with 250.53(A) . The supplemental electrode shall be bonded to one of the following:

(1) Grounding electrode conductor

(2) Grounded service-entrance conductor

(3) Nonflexible grounded service raceway

(4) Any grounded service enclosure

(5) As provided by 250.32(B)

Exception: The supplemental electrode shall be permitted to be bonded to the interior metal water piping as specified in 250.68(C) (1).

(E) Supplemental Electrode Bonding Connection Size.

Where 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 wire or 4 AWG aluminum wire.

(F) Ground Ring.

The ground ring shall be installed not less than 750 mm (30 in.) below the surface of the earth.

(G) Concrete Encased Electrode

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:

a. 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.

b. The rebar extension shall not be exposed to contact with the earth without corrosion protection.

Statement of Problem and Substantiation for Public Input

The only change intended in this PI is adding a new (G) for the relocation of the present text in 250.68(C)(3) with subsections a. and b. No other changes are intended but Terra caused the whole section to be underlined.

The text in 250.68(C) has been problematic since it was entered several cycles ago. The parent text of 250.68(C) is for connection to electrodes and the ability to use the metal water pipe and the structural metal as conductors to interconnect other electrodes. The rebar requirements presently there really belong in the grounding electrode installation section of 250.53. The last element in 250.68C()(3)(c) was not carried forward since that is already a requirement in 250.53(C) having been added in the 2020 NEC cycle.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4669-NFPA 70-2020 [Section No. 250.68(C)]	Rebar requirements removed
Public Input No. 4669-NFPA 70-2020 [Section No. 250.68(C)]	

Submitter Information Verification

Submitter Full Name: Charles Mello
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Submittal Date: Thu Sep 10 16:41:40 EDT 2020
Committee: NEC-P05

Public Input No. 2667-NFPA 70-2020 [Section No. 250.53(A)(1)]

(1) Below Permanent Moisture Level.

If practicable, rod, pipe, and plate electrodes shall be embedded below permanent moisture level. ~~Rod, pipe, and plate electrodes shall be free from nonconductive coatings such as paint or enamel.~~

Statement of Problem and Substantiation for Public Input

The sentence "Rod, pipe, and plate electrodes shall be free from nonconductive coatings such as paint or enamel" is not related to the stem. See the proposed addition of this requirement to 250.52(A)(5) and (A)(7).

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2669-NFPA 70-2020 [Section No. 250.52(A)(7)]	

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 27 17:18:42 EDT 2020
Committee: NEC-P05

Public Input No. 519-NFPA 70-2020 [Section No. 250.53(A)(3)]

(3) Supplemental ~~Electrode~~ Electrodes .

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~~ 8 m (~~6 ft~~ 6 ft) apart. If multiple rod or pipe electrodes are installed to meet the requirements of this section, they shall not be less than 2.4 m (8 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 Input

As stated in the informational note and is a well established fact that the spacing of rods or pipes further will increase the efficiency by moving the electrodes further away from the spheres of influence of the other electrode. Since the shortest rod or pipe electrode is 2.4 m (8 ft), it stands to reason that the minimum separation should be 2.4 m (8 ft).

Submitter Information Verification

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Zip:
Submittal Date: Sat Feb 22 16:14:23 EST 2020
Committee: NEC-P05

Public Input No. 965-NFPA 70-2020 [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 1.8 m (6 ft) apart.~~

~~Informational Note: The paralleling efficiency of rods is increased by spacing them~~

than twice the length of the longest ground rod or pipe electrode . Where plate electrodes are installed as supplemental electrodes, they shall be not less than 1.8 m (6 ft) from any rod or pipe electrode.

Statement of Problem and Substantiation for Public Input

This proposed revision incorporates the text of the informational note as a requirement. It is clear in the informational note that parallel efficiency is increased by applying this specified spacing between electrodes. This has been proven by testing. If the code is going to require a second ground rod, where the 25 ohm or less rule cannot be satisfied, the distance between should facilitate parallel efficiency of multiple rods.

Submitter Information Verification

Submitter Full Name: Agnieszka Golriz
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City:
State:
Zip:
Submittal Date: Wed May 06 09:40:32 EDT 2020
Committee: NEC-P05

Public Input No. 2672-NFPA 70-2020 [Section No. 250.53(B)]

(B) Electrode Spacing.

Where more than one of the electrodes of the type specified in 250.52(A)(5) or (A)(7) are used, each electrode of one grounding system (including that used for strike termination devices) shall not be less than 1.83 m (6 ft) from any other electrode of another grounding system. ~~Two or more grounding electrodes that are bonded together shall be considered a single grounding electrode system.~~

Statement of Problem and Substantiation for Public Input

This sentence is proposed to be moved to 250.50 where the rule should be located.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2671-NFPA 70-2020 [Section No. 250.50]	

Submitter Information Verification

Submitter Full Name: Phil Simmons
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City:
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Submittal Date: Thu Aug 27 18:20:56 EDT 2020
Committee: NEC-P05

Public Input No. 125-NFPA 70-2019 [Section No. 250.53(C)]

(C) Bonding Jumper.

The bonding jumper(s) used to connect the grounding electrodes together to form the grounding electrode system shall be installed in accordance with 250.64(A), (B), and (E), shall be sized in accordance with 250.66, and shall be connected in the manner specified in 250.70. ~~Rebar~~ Reinforcing steel bars or rods shall not be used as a conductor to interconnect the electrodes of a grounding electrode ~~systems~~ system .

Statement of Problem and Substantiation for Public Input

The term "rebar" is not a correct term for the reinforcing steel bars that are used in concrete. 250.52(A)(3)(1) uses the term " steel reinforcing bars or rods".

Submitter Information Verification

Submitter Full Name: Phil Simmons
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State:
Zip:
Submittal Date: Wed Nov 20 17:37:31 EST 2019
Committee: NEC-P05

Public Input No. 2679-NFPA 70-2020 [Section No. 250.53(C)]

(C) Bonding Jumper.

The bonding jumper(s) used to connect the grounding electrodes together to form the grounding electrode system shall be installed in accordance with 250.64(A), (B), and (E), shall be sized in accordance with 250.66, and shall be connected in the manner specified in 250.70. ~~Rebar~~ A concrete-encased grounding electrode shall not be used as a conductor to interconnect the electrodes of grounding electrode systems.

Statement of Problem and Substantiation for Public Input

The term "rebar" is trade jargon and should not be used. It is proposed to be replaced with the correct term, "concrete-encased electrode".

Submitter Information Verification

Submitter Full Name: Phil Simmons
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City:
State:
Zip:
Submittal Date: Thu Aug 27 19:34:55 EDT 2020
Committee: NEC-P05

Public Input No. 135-NFPA 70-2019 [Section No. 250.53(E)]

(E) Supplemental Grounding Electrode Bonding ~~Connection Size~~ Conductor Size .

~~Where~~ 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:

(1) 6 AWG copper wire for connections made within the earth or within 450 mm (18 in.) of the earth

(2) 4 AWG aluminum or copper-clad aluminum wire for connections made higher than 450 mm (18 in .) above the earth.

Statement of Problem and Substantiation for Public Input

For adding "Electrode" and the change of "Connection" to "Conductor" in the title, "Electrode" clarifies the application of the section, for changing "Connection" to "Conductor", the section is about the maximum size of the grounding electrode conductor that is required for this function.
For adding information on connection by means of a copper and aluminum conductor, this language incorporates the restriction on the use of an aluminum grounding electrode conductor from 250.64(A) and adds the copper-clad aluminum conductor.

Submitter Information Verification

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Submittal Date: Thu Nov 21 12:47:37 EST 2019
Committee: NEC-P05

Public Input No. 2460-NFPA 70-2020 [Section No. 250.53(E)]

(E) Supplemental Electrode Bonding Connection Size.

Where 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 wire or ~~4 AWG~~ 4 AWG copper-clad aluminum or aluminum wire.

Additional Proposed Changes

File Name	Description	Approved
CCS_Corrosion_paper_Rev2.pdf	50Year CCS Grade 40 Corrosion Study Louisville	
TD002391.doc	Grade 40 CCS UL467 Short Circuit and UL 486A-B Mechanical Sequence	
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

COPPER-CLAD ALUMINUM CONDUCTORS:

Please Consult Section 110.5 Conductor Materials. Copper-Clad Aluminum as a conductor material should not be excluded for this application. With aluminum and copper, Copper-Clad Aluminum is only one of three conductor materials for general wiring permitted by the NEC®. This PI aims to correct an inconsistency in correlation between Articles. It aims to bring safe alternatives to users of this Code. The NFPA Standards Council created in August 2019 a special Bimetals Task Group to in part bring attention to correlation issues effecting Copper-Clad Aluminum, as well as to study expanding its range of applications in 2023. In a coordinated effort, the Bimetals Task Group will submit 19 Public Inputs in this cycle addressing these matters.

COPPER-CLAD STEEL CONDUCTORS:

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 applicate 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 Inputs for This Document

Related Input	Relationship
Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]	Copper-Clad Steel Grounding Conductors
Public Input No. 2472-NFPA 70-2020 [Section No. 250.102(C)(2)]	Copper-Clad Steel Bonding Conductors
Public Input No. 2462-NFPA 70-2020 [Section No. 250.62]	Copper-Clad Steel and Copper-Clad Aluminum Material for Bonding
Public Input No. 2472-NFPA 70-2020 [Section No. 250.102(C)(2)]	

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
Affiliation: American Bimetallic Association
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 23 09:21:45 EDT 2020
Committee: NEC-P05

Testing done for the safety of our valued customer.

Global Circulation Laboratory Test Report

For Global Distribution

UL467 SHORT CIRCUIT & UL 486A-486B MECHANICAL SEQUENCE TESTS

YGHP29C2, YGHC2C2, YGHC26C26, YGHP34C29, YGHC29C29, YGHP34C34, YGHC34C34 HYTAP™ Connectors
YGL2C2, YGL29C29, YGL34C34 HYGRID™ Connectors
YGA4C2N, YGHA272N, YGA282N, YGHA302N HYLUG™ Connectors

5/8" and 3/4"Copper Clad Steel Ground Rod, #4AWG Solid, 4/0AWG Stranded, 7#7, and 19#8 COPPERWELD® 40% IACS Copper Clad Steel Conductors

PAT750XT-18V PATRIOT® Tool
with
UC, UO, U28RT, U29RT, U32RT, U997, PU998, and U1011 Die Sets

TD002391 REV B

Requested by / Date:	***Authorized by / Date:***	***Completed by / Date:***
C. Gandhi 12-Dec-2014	R Robicheau 12-Dec-2014	R Charpentier 06-Apr-2015
Engineering Approval / Date:	***Marketing Approval / Date:***	***Laboratory Approval / Date:***
R.Roman 20-Aug-2020	J Hogan 20-Aug-2020	R Charpentier 20-Aug-2020

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

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TEST COMBINATIONS: 3
CONCLUSIONS: 4
ENGINEERING COMMENTS: 4
TEST PROCEDURES: 4
TEST EQUIPMENT : 5

Burndy LLC 47 East Industrial Park Dr.
Manchester / New Hampshire / 03109
Tel: 603 647 5000 Fax: 603 647 5205

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

PURPOSE OF TEST:

To determine if the Burndy HYTAP™, HYGRID™, and HYLUG™ Connectors can meet the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST REQUESTED:

UL486A-486B Mechanical Sequence
UL467 Short Time Current

TEST RESULTS:

Connector	Cable 1	Cable 2	Die	# of crimps	Securness	Pull	Short Time Current		
					Pass / Fail	Average Pull (lb)	Pass / Fail	Current (Amps)	Time (s)
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	U997	1	Pass	1021.3	Pass	1600	6
YGL2C2	#4 Solid CCS	#4 Solid CCS	U-O	1	Pass	1451.8	Pass	1600	6
YGHC2C2	#4 Solid CCS	#4 Solid CCS	U-C	1	Pass	1544.0	Pass	1600	6
YGA4C2N	#4 Solid CCS	n/a	U4CRT	1	Pass	814.0	Pass	1600	6
YGL29C29	7#7 STR CCS	7#7 STR CCS	U997	1	Pass	1643.2	Pass	4600	9
YGHC26C26	7#7 STRCCS	7#7 STR CCS	U-O	1	Pass	1239.4	Pass	4600	9
YGHA272N	7#7 STRCCS	n/a	U29RT	2	Pass	1574.0	Pass	4600	9
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PU998	1	Pass	1789.8	Pass	6100	9
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1849.8	Pass	6100	9
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1779.1	Pass	6100	9
YGA282N	4/0 AWG CCS	n/a	U28RT	2	Pass	2489.3	Pass	6100	9
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	U1011	3	Pass	2126.8	Pass	9000	9
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	U1011	3	Pass	2380.0	Pass	9000	9
YGL34C34	19#8 STRCCS	19#8 STR CCS	U1011	3	Pass	3158.3	Pass	9000	9
YGHC34C34	19#8 STR CCS	19#8 STR CCS	U1011	3	Pass	3812.1	Pass	9000	9
YGHA302N	19#8 STR CCS	n/a	U32RT	2	Pass	4792.2	Pass	9000	9

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CONCLUSIONS:

All samples tested met the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST PROCEDURES

The table below shows the connector / conductor combinations tested.

Connector	Cable 1	Cable 2	Tool	Die	# of Crimps
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	PAT750	U997	1
YGL2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-O	1
YGHC2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-C	1
YGA4C2N	#4 Solid CCS	n/a	PAT750	U4CRT	1
YGL29C29	7#7 STR CCS	7#7 STR CCS	PAT750	U997	1
YGHC26C26	7#7 STR CCS	7#7 STR CCS	PAT750	U-O	1
YGHA272N	7#7 STR CCS	n/a	PAT750	U997	2
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PAT750	PU998	1
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGA282N	4/0 AWG CCS	n/a	PAT750	U997	2
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	PAT750	U1011	3
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	PAT750	U1011	3
YGL34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHC34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHA302N	19#8 STR CCS	n/a	PAT750	U32RT	2

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All conductors were cut to twenty four (24) inch lengths.
All ground rod was pre-crimped with the appropriate pre-crimp die
5/8in Rod UPRECRIMP58
3/4in Rod UPRECRIMP34

Mechanical Sequence
Four samples of each set were secured to the Secureness tester, the height; weight and bushing size were as specified in UL486A-486B Table 26. Samples were rotated for thirty minutes at 9rpm. Samples were then subjected to a 1-minute pull to the value specified in UL486A-486B Table 27 and then to failure.

Short Time Current
Test samples were assembled in a series loop configuration then attached to a current controller as shown below. The test current and duration are listed below. After completion of the test, electrical continuity was checked with a digital multi-meter.

Test current values were derived from the equation Annex C of IEEE Std 837-2002. The diameter of the conductor(s) were measured and the cross-sectional area of the conductors was calculated.

Conductor	***Current Value (A)***	***Duration (sec)***
#4AWG Solid COPPERWELD® 40% IACS CCS	1600	6
4/0AWG 19 strand COPPERWELD® 40% IACS CCS,	6100	9
7#7 stranded COPPERWELD® 40% IACS CCS	4600	9
19#8 stranded COPPERWELD® 40% IACS CCS	9000	9

TEST EQUIPMENT LIST:

MANUFACTURER	MODEL	DESCRIPTION	SERIAL #	RANGE
FLUKE	79 III	DMM	70591301 (Rene)	AUTO
OHIO SEMITRONICS		CURRENT TRANSDUCER	NA	15000:5
SATEC	T5000	TABLE TOP	2038	5000 lbs
VIRTECH	NA	HIGH CURRENT	NA	12V / 12000A
MITUTOYO	505-675	DIAL CALIPER	08914565 (Rene)	6"

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CORROSION ON BURIED COPPER CLAD STEEL



Cece Syarif

Global Application Engineer

&

Anthony Hale

Manager, Utility Products, North America

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For more information, contact sales@copperweld.com.
The results and conclusions obtained from studies done by Copperweld are only applicable to Copper Clad Steel manufactured by Copperweld. Due to proprietary process used to produce the wire, the findings cannot be superimposed on any other copper-clad steel conductor.

254 Cotton Mill Rd, Fayetteville, TN 37334. Tel. (931) 433 – 7177

July 26, 2011

This paper compiles several studies and analysis regarding the corrosion performance of buried Copperweld® Copper-Clad-Steel (CCS) conductors. These range from the early 1900's with the invention of Copperweld® through the present day with studies performed by independent parties as well as Copperweld Company in-house testing. The purpose is to present the available information so that prospective users of Copperweld® CCS wire and strand can evaluate the corrosion resistance and expected performance within their specific application and area. Copperweld uses oxygen free copper in the manufacture of Copperweld® wire and strand. The copper surface of CCS is expected to oxidize and turn color ranging from green (patination) to brown and black the same as any solid copper wire or strand when exposed to environmental stimuli. Corrosion on exposed steel at the cut tip or end of the wire is also expected. The question to be answered is if the corrosion on either material or the interface between the copper and steel (galvanic reaction) will result in degradation of the wire as to make it unsuitable for use as a grounding conductor.

The oldest known underground corrosion study of bimetallic material was performed in the early 1900s[1]. This study focused on the corrosion behavior of Copperweld® CCS underground rod as well as other materials such as Copper and galvanized steel ground rod. The National Bureau of Standards (NBS) conducted an extensive underground corrosion study that involves 36,500 specimens which include 333 varieties of ferrous, nonferrous, and protective coating materials buried in 128 test locations throughout U.S in 1910 - 1955.

The study summarizes the service life of a ground rod as following:

10 mils copper coating – acceptable for service life up to 40 years

13 mils copper coating – acceptable for service life up to 50 years

Similarly, the Naval Civil Engineering Laboratory in collaboration with the National Association of Corrosion Engineers conducted a 7-year program of testing metal rods for electrical grounding to determine the galvanic corrosion effect. The three metals tested were stainless clad steel, copper-bonded steel (CCS), and galvanized steel. The result on the ⅝" CCS ground rod was as expected. The copper surface of the CCS was

virtually free of corrosion and the steel core has corroded at the tip approximately 2 inches down the length of the rod.

Copperweld Corporation is the inventor and sole manufacturer of Copperweld® Copper-bonded ground rods and Copperweld® wire and strand since 1915. The corrosion behavior of a Copperweld® ground rod is similar to the corrosion on Copperweld® wire and strand conductor. Both materials consist of copper permanently bonded to a steel core. All Copperweld® 40% CCS has a copper thickness of 10% of the overall diameter. For example, Copperweld® 4THOUGHT™ has a configuration of 19 strands of 0.1055 inch wires. It means that each strand has a copper thickness of 10.55 mils. Based on the NBS study, 4THOUGHT™ will have at least a minimum service life of 40 years.

Copperweld has also conducted a 5-year study of buried bare 21% conductivity (copper thickness is 3% of the diameter) Copperweld® CCS in 10 different soil conditions in association with Southwest Research Institute[2]. The study reported 100% surface oxidation and various degrees of deterioration of the steel core as expected after 5 years. The exposed steel on the tip of the wire rusted and formed "scab", as shown in Figure 1. The rust appeared to "seal-off" the un-oxidized material from the corrosive medium. The maximum depth of corrosion was 70% of the wire diameter.



Figure 1: Example of Underground Corrosion of Copper Clad Steel

Although the copper surface oxidation was heavy, the samples showed no signs of pits or holes in the copper cladding. The copper thickness of a severely oxidized 5-year sample showed no discernable difference when compared to an un-oxidized control sample that was not subjected to the corrosive environment. The mechanical and resistance testing

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resulted in negligible differences between 5-year samples and the control samples. Thus, the oxidation had no discernable impact on the strength or electrical performance of the wire.

An accelerated corrosion study based on ASTM B117 was conducted on bare CCS and solid Copper wires to evaluate copper surface corrosion. The wires were exposed to salt fog spray for 504 hours. As a result, corrosion on the CCS copper surface showed no significant difference as compared to the corrosion of copper wire.



(a) Copper Clad Steel (b) Copper

Figure 2: Patination of Copper Surface after 504 hours exposure to Salt Fog Spray

In February 2011, three separate sample strands of Copper Clad Steel were un-earthed and cut out from a substation built in Louisville, KY. The conductors were 40% conductivity, Low Carbon Steel, Dead Soft Annealed, 7 No. 5 (231,613 circular mil) and were installed in 1962.

Table 1: Physical properties of the three strands of Copperweld® conductor that had been buried underground for 48 years in a Kentucky substation

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			Strand 1	Strand 2	Strand 3
Conductor Type			40% Low Carbon Annealed		
Conductor Size			7 No. 5		
Cross Section Area		in^2	0.1819	0.1819	0.1819
Diameter of Single end		*inch*	0.1819	0.1819	0.1819
Diameter of Conductor		*inch*	0.5457	0.5457	0.5457
Copper Thickness	Min	*inch*	0.0142	0.0114	0.0134
	Max	*inch*	0.0213	0.0209	0.01975
% Concentricity			83.30%	77.30%	83.90%
Depth of corrosion	Min	*inch*	0.004	0.028	0.111
	Max	*inch*	0.781	0.859	0.484

The 1962 conductors were manufactured by Copperweld with a nominal copper thickness of 10% of its diameter. Figure 3 shows the copper thickness ranges from 11.4 – 21.3 mils and the concentricity of the conductor averaged at 81.5%. Current manufacturing improvements yield concentricity of copper thickness above 85%.

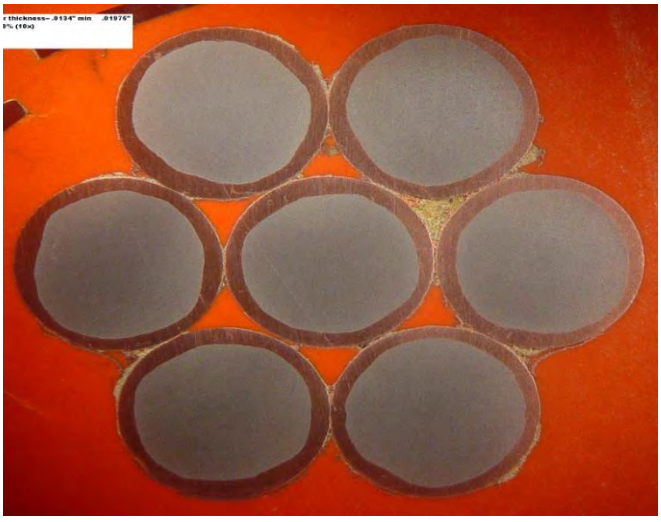


Figure 3: Copperweld® 40% LC DSA 7 No. 5 manufactured in 1962

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Figure 4a shows no visible corrosion observed other than oxidation and patination on the copper surface. At the ends of the wires, the corrosion occurred in the form of steel rust. The maximum depth of the corrosion is 0.859 inch with an average of 0.382 inch, as shown in Figure 4b.



Figure 4a: There is no visible corrosion between the copper and steel on all wires obtained from the substation in Kentucky.



Figure 4b: Corrosion occurred at the ends of the wires. Maximum penetration depth is 0.859 inch.

From all the corrosion studies above, there have not been reported or observed any galvanic corrosion at the interface of copper and steel. The process of cladding for

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Copperweld® ensures a metallurgical bond between the two metals. That metallurgical bond prevents any moisture from penetrating between the two metals precluding the corrosion process. Any propagation of corrosion on an area of exposed steel averages two times the diameter of the wire then stops. The corrosion rate of the copper surface is equivalent to that observed on standard solid copper wire and strand. Based on the results of these studies, it can be summarized that CCS can be expected to have a 50 plus year service life as buried grounding conductors.

REFERENCES:

1. Rempe, Chris. 7 July 2003. "A Technical Report on the Service Life of Ground Rod Electrodes".
2. Fox, Dustin, Belado, Chris, and Brossia, Sean. 23 September 2009. "The Effect of Corrosion on Tracer Wire with a Copper Clad Steel Center Conductor".

Powertech

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Revision: 0 Issued: 2020-04-15

Copper and CCS Wire Withstand Current and Fusing Current Tests

Copperweld Bimetallics, LLC



The Power of Trust. **The Future of Energy.**

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REPORT OF PERFORMANCE

CLIENT	Copperweld Bimetallics,LLC. 5141 Virginia Way, Suite 410 Brentwood, TN, United States 37027
TEST OBJECTS	Copper Clad Steel (CCS) Wires Manufacturer: Copperweld Bimetallics,LLC. Types: Scorpius Prototypes Part Nos.: 61 x 072 7 x 080 Condition: New Copper Conductor Manufacturer: Encore Wire Types: #4/0 AWG (19 strand) CU #6 AWG (single strand) CU Condition: New
TESTED BY	Powertech Labs Inc. 12388 - 88th Ave, Surrey, BC Canada V3W 7R7 www.powertechlabs.com
TEST DATE	2020-01-24 to 2020-01-25
TEST SPECIFICATION	Client Specified, with reference to IEEE Std 80-2013 and IEEE Std 837-2014

Powertech Labs Inc. does not accept any liability for any damages resulting from the use of this report. The results relate only to the item tested, and it is the responsibility of the manufacturer to maintain conformity of any object having the same designations. Information regarding the estimated measurement uncertainty is available upon request. The test report shall not be reproduced except in full, without written approval of Powertech Labs Inc.

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1 INTRODUCTION

At the request of Copperweld Bimetallics,LLC., withstand current and fusing current tests were performed on standard copper and copper clad steel (CCS) wires in accordance with specifications and procedures provided by the client. Reference was made to IEEE Std 80-2013 and IEEE Std 837-2014 as guides for determining current levels and durations for the tests.

The High Power Lab is accredited by the Standards Council of Canada to ISO 17025 for short-circuit testing.

2 TEST OBJECT INFORMATION

The test objects were identified by the client as follows:

Copper Clad Steel Wires (CCS)

Manufacturer:	Copperweld Bimetallics,LLC.
Types:	Scorpius Prototypes
Part Nos.:	61 x 072
	7 x 080
Condition:	New

Copper Conductor

Manufacturer:	Encore Wire
Types:	4/0 AWG (19 strand) CU
	#6 AWG (single strand) CU
Condition:	New

Conductor sample diameters and dc resistance values were measured by the laboratory before testing, as presented in Table 1.

3 GENERAL INFORMATION

3.1 Purpose

The purpose of the tests is to identify the current limits at short durations for standard copper and Copperweld CCS grounding wire products, and to determine if these products meet the applicable requirements of the referenced Standards.

3.2 Witnesses

Name	Company
Jeff Jordan	Copperweld Bimetallics,LLC.
Lora Aboulmouna	Copperweld Bimetallics,LLC.
Jason Smolko	Copperweld Bimetallics,LLC.
Ryan Hale	Copperweld Bimetallics,LLC.

3.3 Tests Performed

Test Standards/Specifications:

Withstand current tests were performed as requested by the client, with reference to the following Standards to determine the test levels:

IEEE Std 80-2013, Table 6 – Specification for the ultimate current carrying capacity of copper grounding cables using symmetrical current.

IEEE Std 837-2014, Clause 7.2 and Table 3 – Electromagnetic force (EMF) test

4 SHORT-CIRCUIT CURRENT TESTS

General Information:

Standard	Client's Specification, with reference to IEEE Std 80-2013 and IEEE Std 837-2014
Test Dates	2020-01-24 to 2020-01-25
Test Leader	Chris Morton

Environmental Conditions:

Ambient temperature	(7 – 9) °C
Relative Humidity	(95 – 99) %

Test Conditions:

Samples were tested in a covered test cell which was open on one side to the outdoor ambient conditions. During each test, one sample was connected horizontally between the laboratory source bus and ground bus, at a bus spacing of 48 inches, as shown in Figures 30 through 33. The samples were terminated using Burndy mechanical connectors, as shown in Figures 34 and 35. The length of each wire sample was the minimum length required to span the distance between the buses, and each sample was at approximately right angles (90°) to both the source and ground bus. Each sample was suspended in free air approximately 46 inches above the floor of the test cell. The temperature of the sample at the start of each test was the natural outdoor ambient temperature of the laboratory, except for tests performed to IEEE 837, where the sample was allowed to cool to less than 100 °C before the second shot.

All tests were performed at a power frequency of 60 Hz using the test circuit shown in Figure 1. Current was initiated by energizing a current limited source that was calibrated to provide the target current through the circuit. The rms current, current symmetry and duration of each test were specified by the client.

The test current was measured using a 300 kA_{peak} rated Rogowski coil (Powertech ID № 39444). The expanded uncertainty of the current measuring system is estimated as 2% (k=2).

Test Results:

The results of the tests are provided in Tables 2 through 5. Current and voltage waveforms for each test are provided in Figures 2 through 29.

The Encore #4/0 AWG Cu wire did not withstand the I^2t calculated from the current and duration specified in IEEE 80, Table 6, for a 500 ms duration (44 kA_{rms}). It was capable of carrying a maximum of 92% of this I^2t value without fusing.

The Encore #4/0 AWG Cu wire did not withstand the EMF current specified in IEEE 837, Table 3 (47 kA_{rms}). It was capable of carrying a maximum of 91% of this current value without failing.

The Copperweld Scorpius CCS 61 x 072 conductor exceeded the 500 ms rms withstand current requirement of IEEE 80, Table 6, and met the EMF current requirements of IEEE 837, Table 3, for a 4/0 conductor.

For the #6 AWG Cu conductor size the Standards did not have current values specified, so these were calculated using Equation (45) from IEEE 80 and Equation (C.1) from IEEE 837. The calculations are presented in Appendix D.

Both the Copperweld Scorpius CCS 7 x 080 conductor and the Encore #6 AWG Cu conductor met the 500 ms rms withstand current requirement of IEEE 80, Table 6 (5.29 kA_{rms}), and the EMF current requirements of IEEE 837, Table 3 (5.81 kA_{rms}), for a #6 AWG Cu conductor.

APPENDIX A – FUSING CURRENT TEST CIRCUIT AND DATA

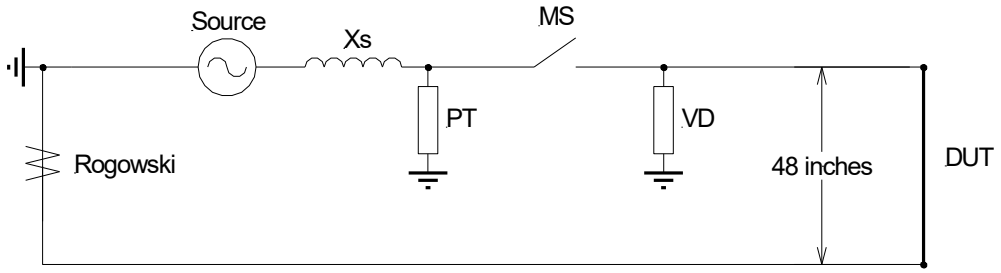


Figure 1: Test circuit schematic for all tests.

Notes:

1. X_S – Source current limiting reactance
2. MS – Making Switch
3. VD – Voltage measurement
4. Rogowski – Current measurement
5. DUT – Device Under Test

Table 1: Strand diameter and dc resistance measurements of sample conductors.

Wire Sample No.	Type	Strand Diameter [1] (in)		Conductor Diameter	Dc Resistance at 20°C
#		1	2	(in)	(μΩ/ft)
1	Encore Wire, 4/0 AWG, 19 strand CU	0.122	0.079	0.492	4.28
2	Encore Wire, 4/0 AWG, 19 strand CU	0.118	0.080	0.501	4.10
3	Encore Wire, 4/0 AWG, 19 strand CU	0.109	0.074	0.495	4.23
4	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.075	0.498	3.98
5	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.079	0.489	4.43
6	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.075	0.490	4.17
7	Encore Wire, 4/0 AWG, 19 strand CU	0.101	0.075	0.489	4.18
8	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.074	0.491	4.15
9	Encore Wire, 4/0 AWG, 19 strand CU	0.106	0.082	0.490	3.97
10	Encore Wire, 4/0 AWG, 19 strand CU	0.105	0.079	0.493	3.73
11	Scorpius 61 x 072 CCS	0.056	---	0.646	6.83
12	Scorpius 61 x 072 CCS	0.058	---	0.649	6.60
13	Scorpius 61 x 072 CCS	0.068	---	0.641	6.60
14	Scorpius 61 x 072 CCS	0.056	---	0.639	6.73
15	Scorpius 61 x 072 CCS	0.067	---	0.646	6.62
16	Scorpius 61 x 072 CCS	0.059	---	0.630	6.53
17	Scorpius 61 x 072 CCS	0.056	---	0.642	6.73
18	Scorpius 61 x 072 CCS	0.067	---	0.637	6.62
19	Scorpius 61 x 072 CCS	0.064	---	0.641	6.85
20	Scorpius 61 x 072 CCS	0.059	---	0.633	6.83
21	Encore Wire, #6 AWG, single strand CU	0.152	---	0.152	33.3
22	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
23	Encore Wire, #6 AWG, single strand CU	0.158	---	0.158	33.2
24	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.4
25	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.3
26	Encore Wire, #6 AWG, single strand CU	0.148	---	0.148	33.6
27	Encore Wire, #6 AWG, single strand CU	0.155	---	0.155	33.3
28	Encore Wire, #6 AWG, single strand CU	0.146	---	0.146	33.1
29	Encore Wire, #6 AWG, single strand CU	0.153	---	0.153	33.2
30	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
31	Scorpius 7 x 080 CCS	0.072	---	0.215	46.3
32	Scorpius 7 x 080 CCS	0.069	---	0.226	45.9
33	Scorpius 7 x 080 CCS	0.065	---	0.220	46.2
34	Scorpius 7 x 080 CCS	0.071	---	0.218	46.4
35	Scorpius 7 x 080 CCS	0.073	---	0.212	46.1
36	Scorpius 7 x 080 CCS	0.065	---	0.216	46.3
37	Scorpius 7 x 080 CCS	0.070	---	0.211	46.1

Note:

[1] Encore 4/0 AWG CU conductor had two sizes of strands, all remaining conductors had one size of strands. Strand and conductor diameters were measured using a digital caliper with a resolution of 0.001 in.

Table 2: Summary of tests on Encore 4/0 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
1	1	Run to fusing	3.85	41.7	60.0	530	923	2	Y
2	2	Withstand	3.85	41.8	62.5	509	889	3	N
3-1	3	EMF (IEEE 837)	4.24	48.0	130	262	826	4	N
3-2	3	EMF (IEEE 837)	4.26	48.0	130	127	503	5	Y
4	4	EMF (IEEE 837)	4.25	48.0	130	260	823	6	Y
5-1	5	EMF (IEEE 837)	4.20	47.4	129	262	808	7	N
5-2	5	EMF (IEEE 837)	4.19	47.4	128	9.9	77	8	Y
6-1	6	EMF (IEEE 837)	3.93	42.6	116	263	662	9	N
6-2	6	EMF (IEEE 837)	3.91	42.6	116	262	654	10	N

Table 3: Summary of tests on Copperweld Scorpius 61 x 072 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
7	11	Run to fusing	3.84	41.7	59.6	673	1173	11	Y
8	12	Run to fusing	4.25	48.1	69.8	500	1157	12	Y
9	13	Run to fusing	4.21	47.5	68.9	508	1150	13	Y
10	14	Withstand	4.09	46.2	66.2	508	1089	14	N
11-1	15	EMF (IEEE 837)	4.21	47.6	129	262	803	15	N
11-2	15	EMF (IEEE 837)	4.20	47.7	129	262	803	16	N
12-1	16	EMF (IEEE 837)	4.21	47.6	129	254	784	17	N
12-2	16	EMF (IEEE 837)	4.19	47.4	128	254	767	18	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

Table 4: Summary of tests on Encore #6 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
13	21	Run to fusing	3.90	5.18	7.36	607	16.3	19	Y
14	23	Run to fusing	3.90	5.18	7.57	600	16.1	20	Y
15	24	Run to fusing	4.27	5.68	8.15	500	16.1	21	Y
16-1	25	EMF (IEEE 837)	3.77	5.86	16.2	262	13.9	22	N
16-2	25	EMF (IEEE 837)	3.77	5.86	16.1	262	13.9	23	N

Table 5: Summary of tests on Copperweld Scorpius 7 x 080 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
17	31	Withstand	3.88	5.16	7.44	858	22.9	24	N
18	32	Run to fusing	3.89	5.16	7.43	908	24.2	25	Y
19	33	Run to fusing	4.48	7.00	10.3	493	24.1	26	Y
20	34	Run to fusing	4.41	6.91	10.2	502	23.9	27	Y
21-1	35	EMF (IEEE 837)	3.81	5.91	16.3	262	14.0	28	N
21-2	35	EMF (IEEE 837)	3.80	5.92	16.2	262	13.8	29	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

APPENDIX B – WAVEFORMS

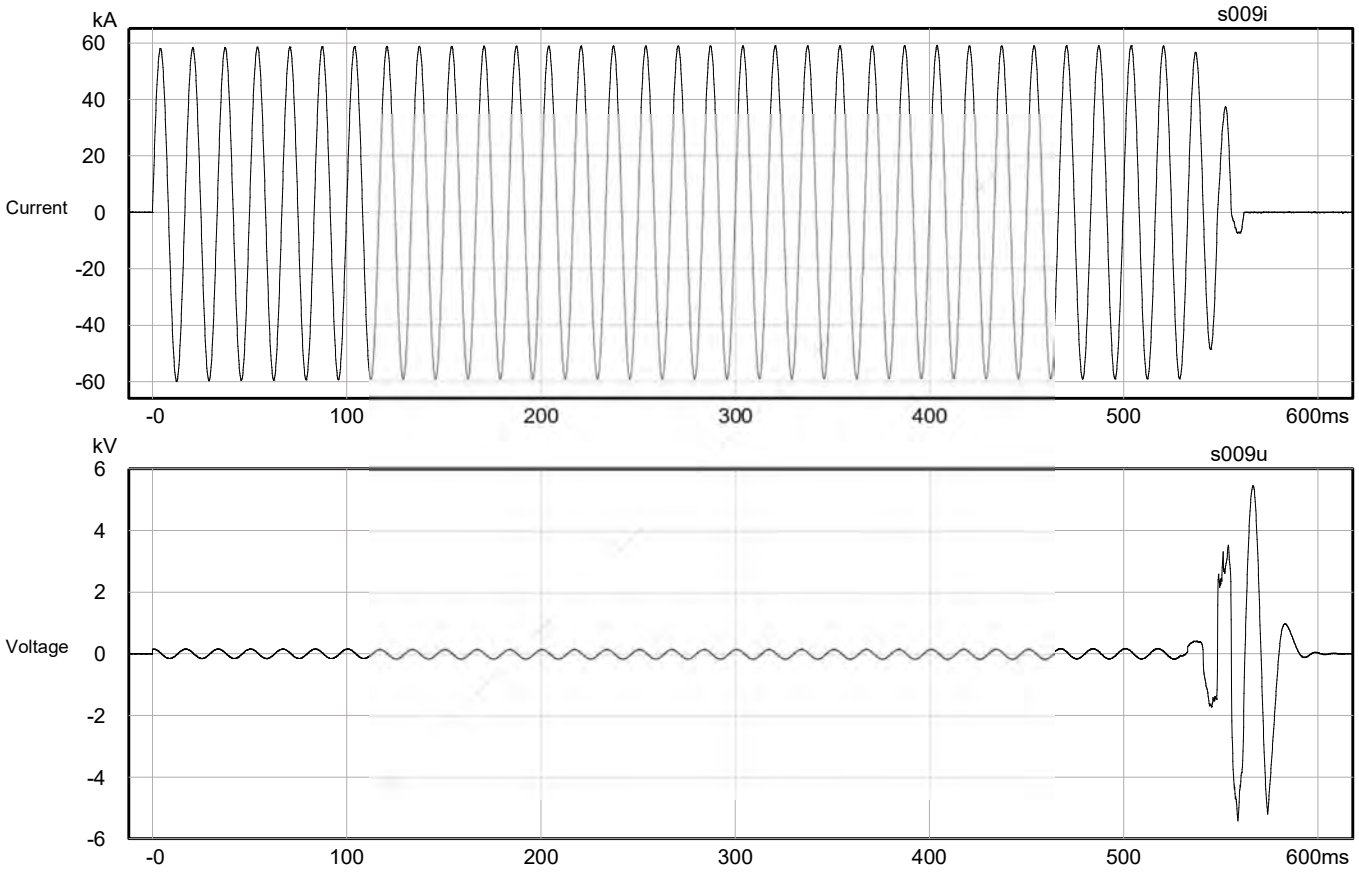


Figure 2: Waveforms for Test #1, Encore 4/0 AWG Sample 1.

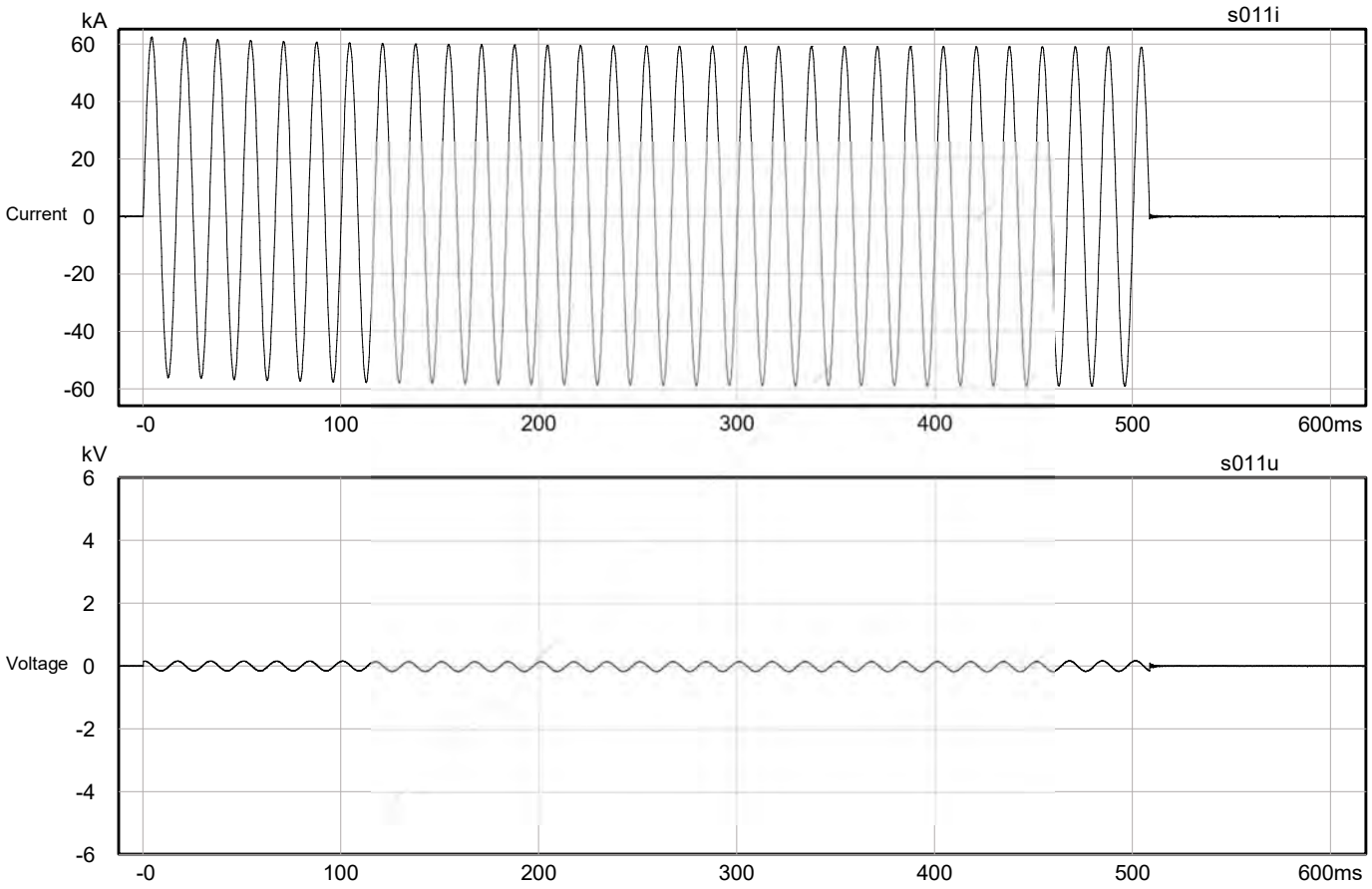


Figure 3: Waveforms for Test #2, Encore 4/0 AWG Sample 2.

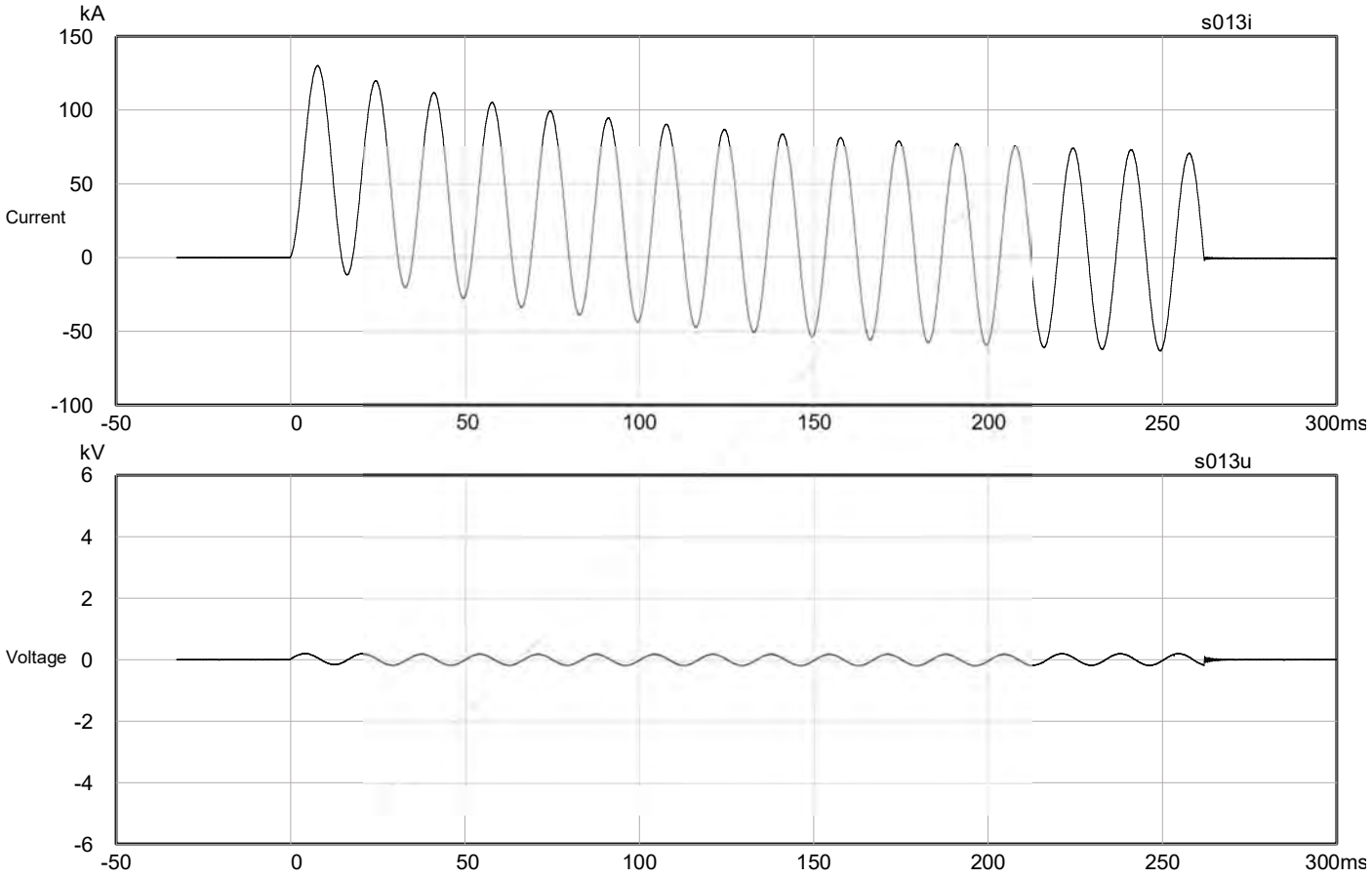


Figure 4: Waveforms for Test #3-1, Encore 4/0 AWG Sample 3.

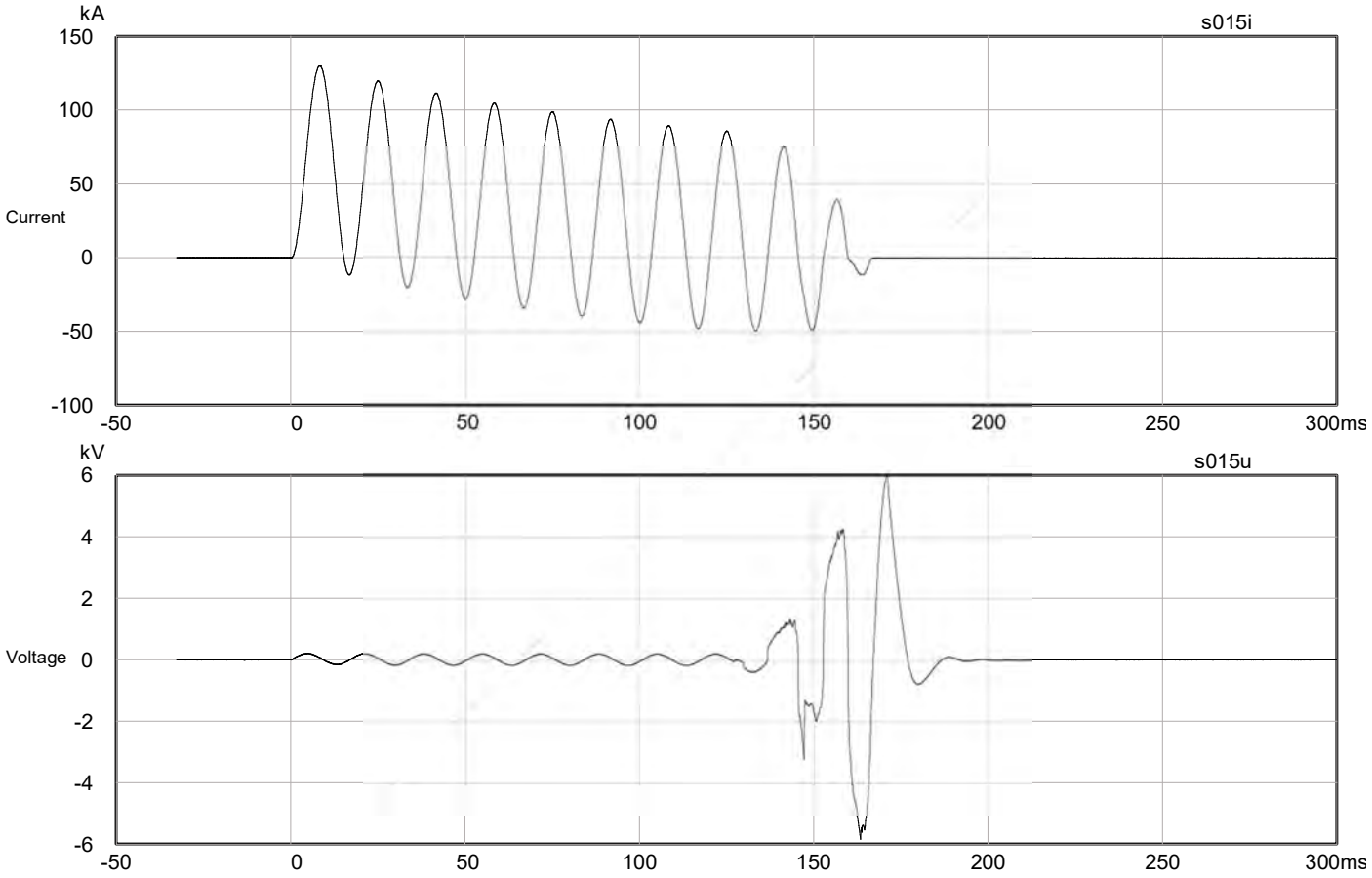


Figure 5: Waveforms for Test #3-2, Encore 4/0 AWG Sample 3.

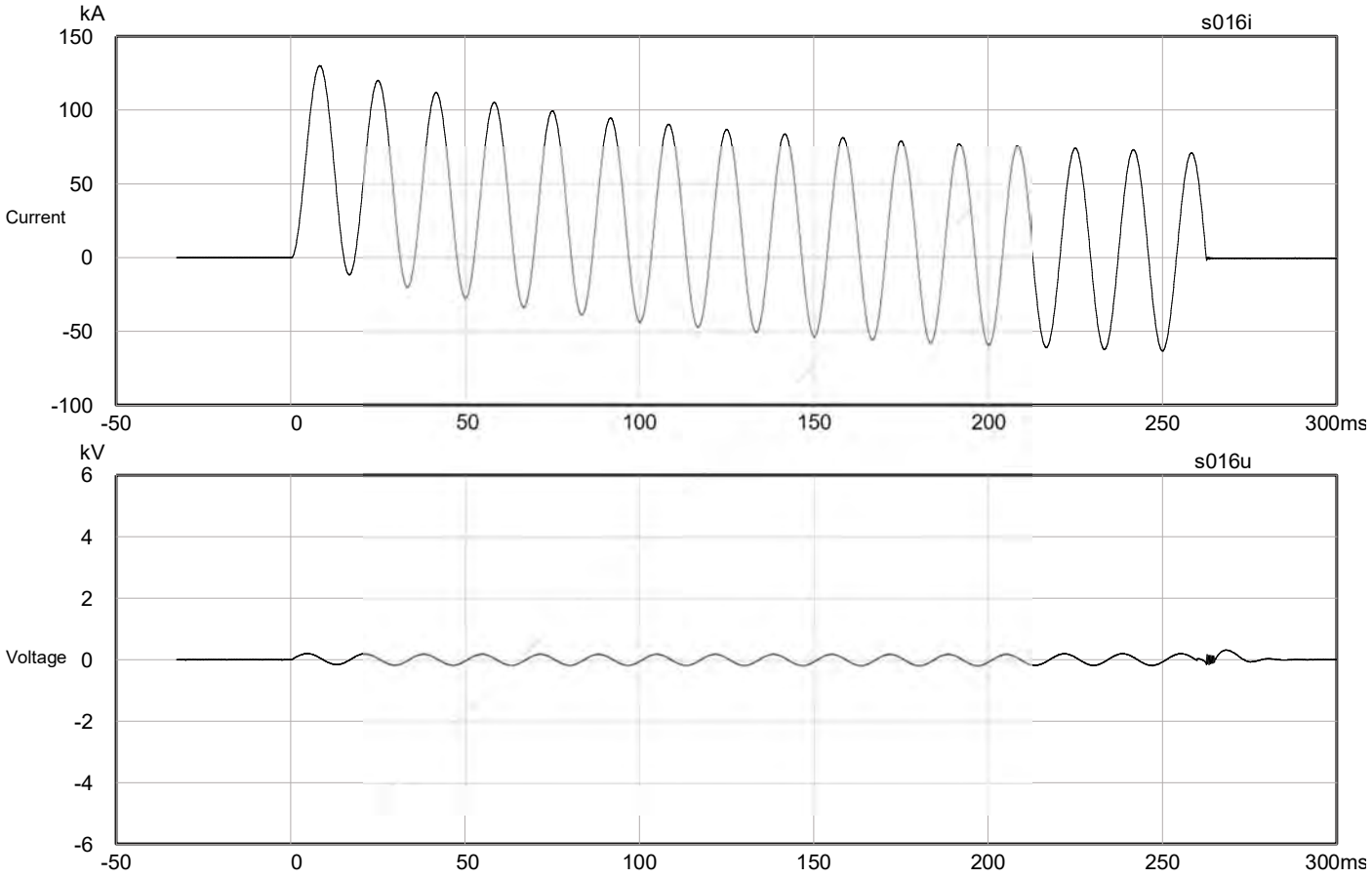


Figure 6: Waveforms for Test #4, Encore 4/0 AWG Sample 4.

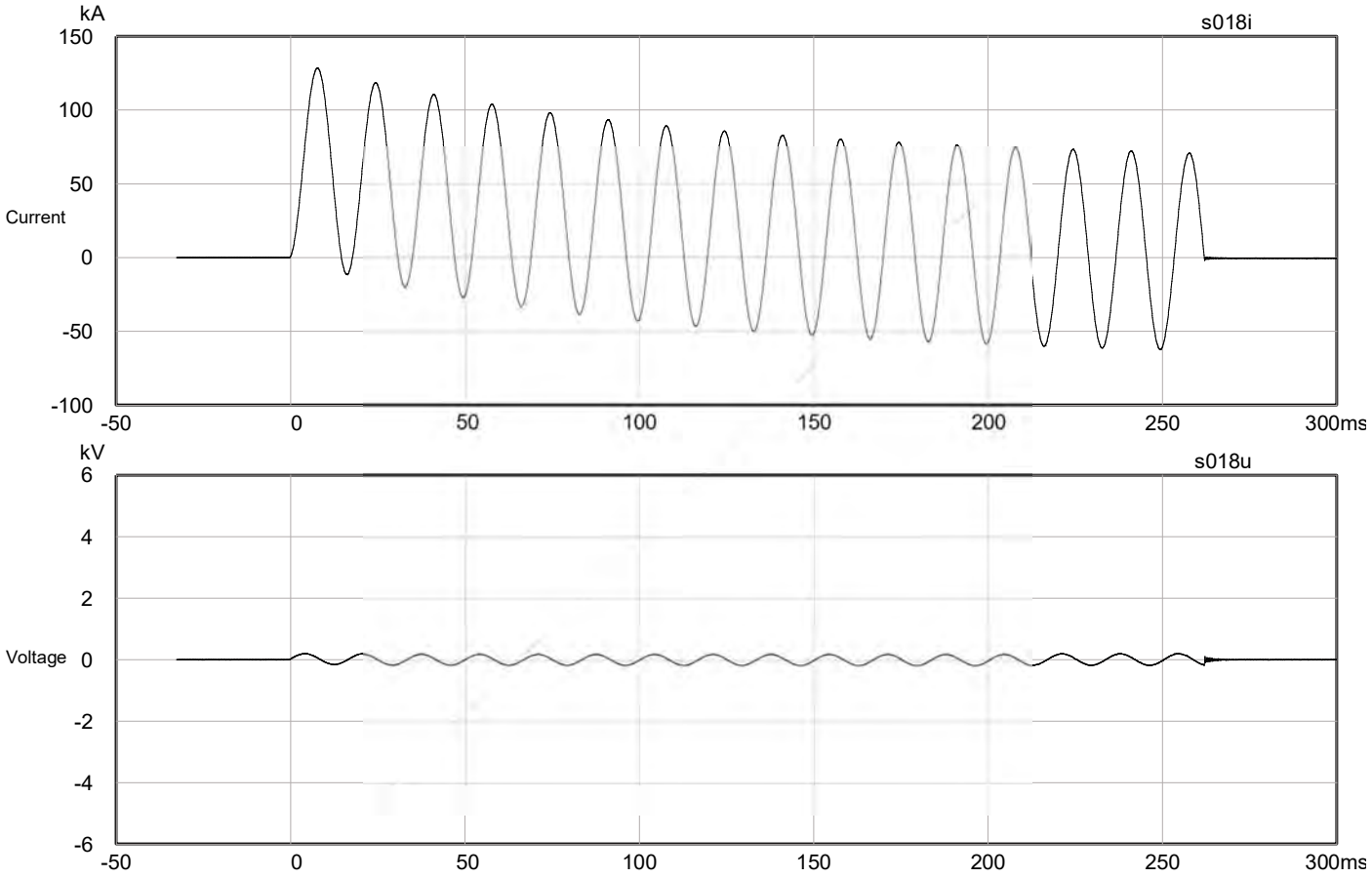


Figure 7: Waveforms for Test #5-1, Encore 4/0 AWG Sample 5.

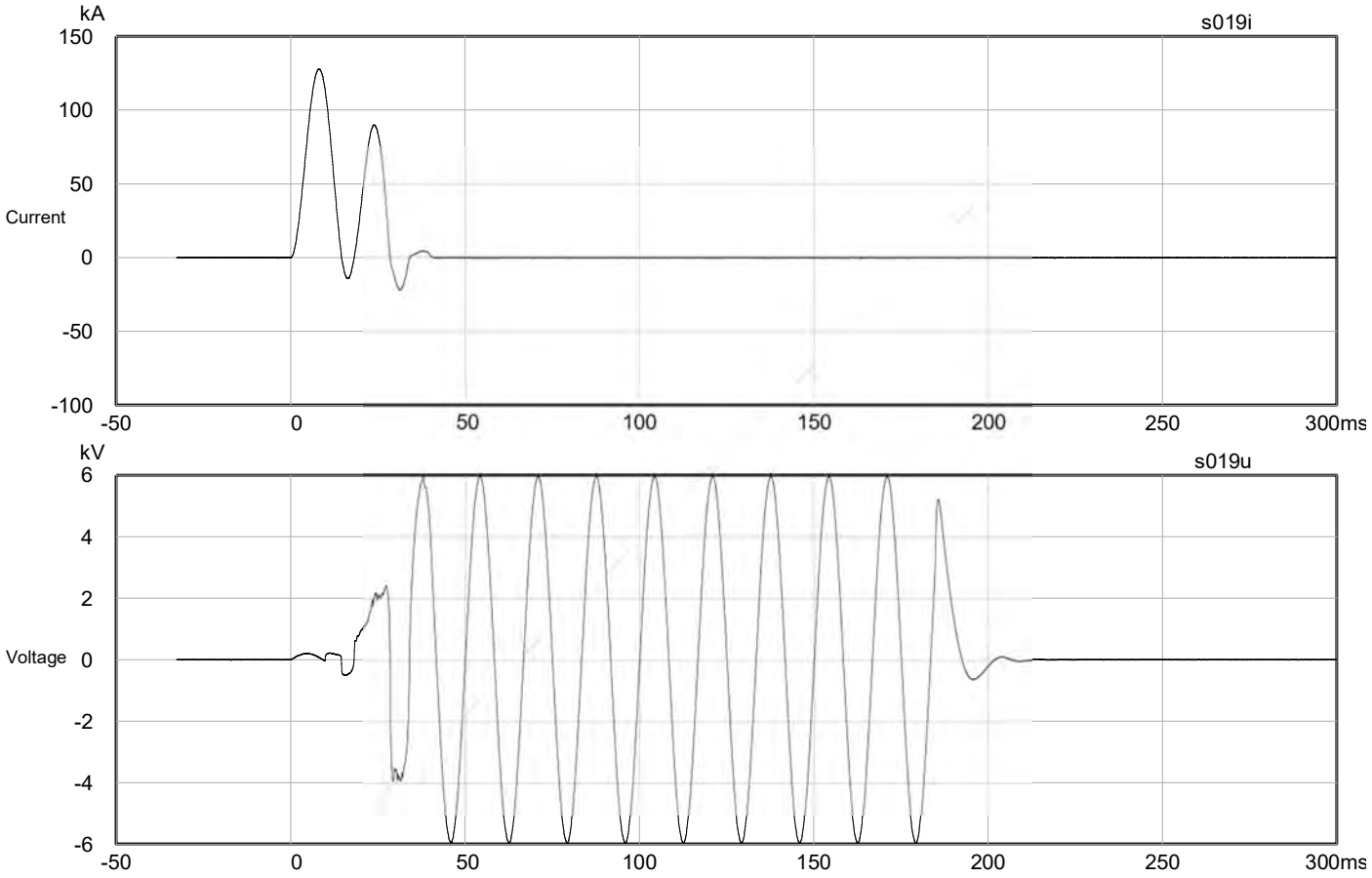


Figure 8: Waveforms for Test #5-2, Encore 4/0 AWG Sample 5.

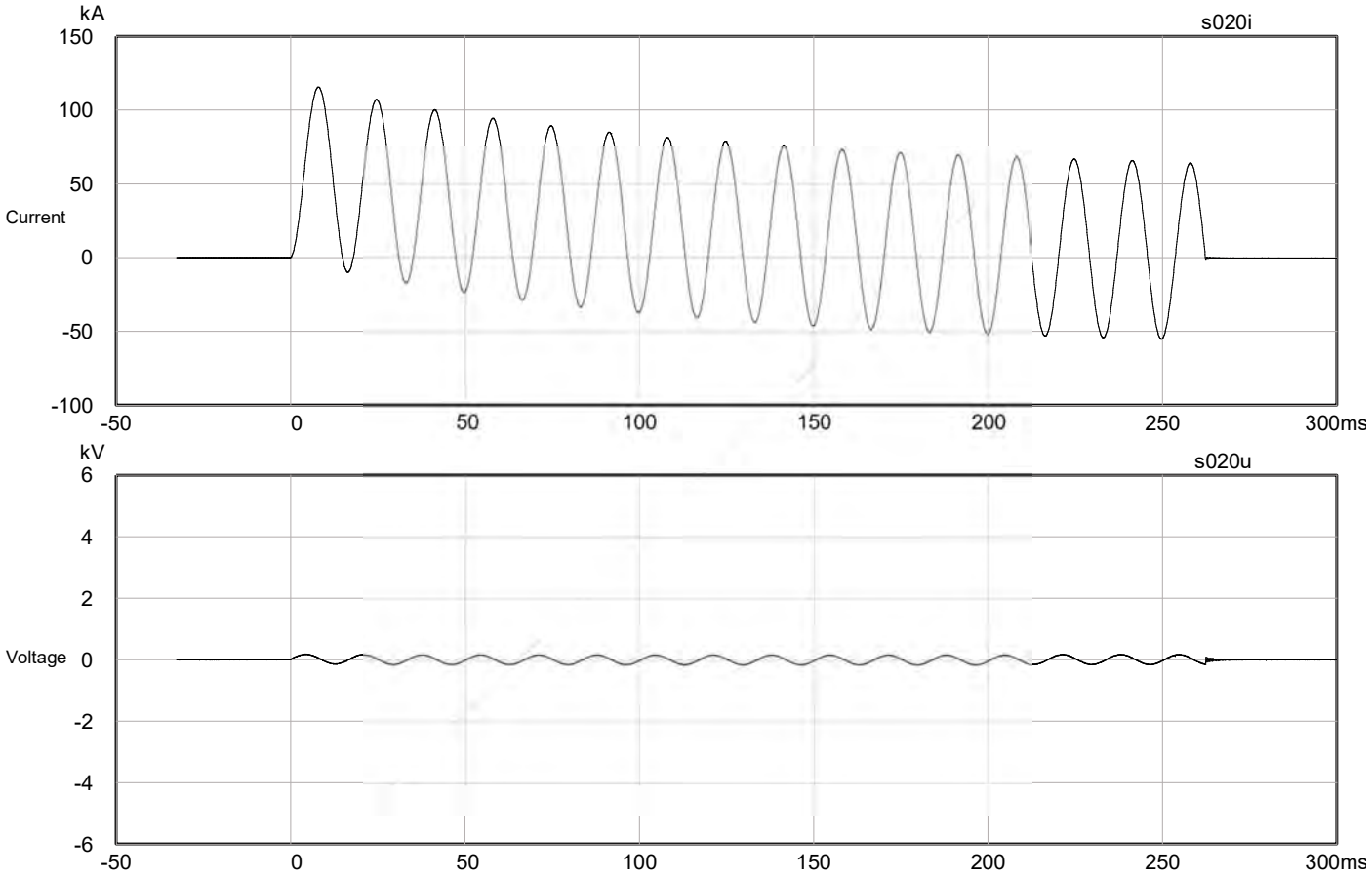


Figure 9: Waveforms for Test #6-1, Encore 4/0 AWG Sample 6.

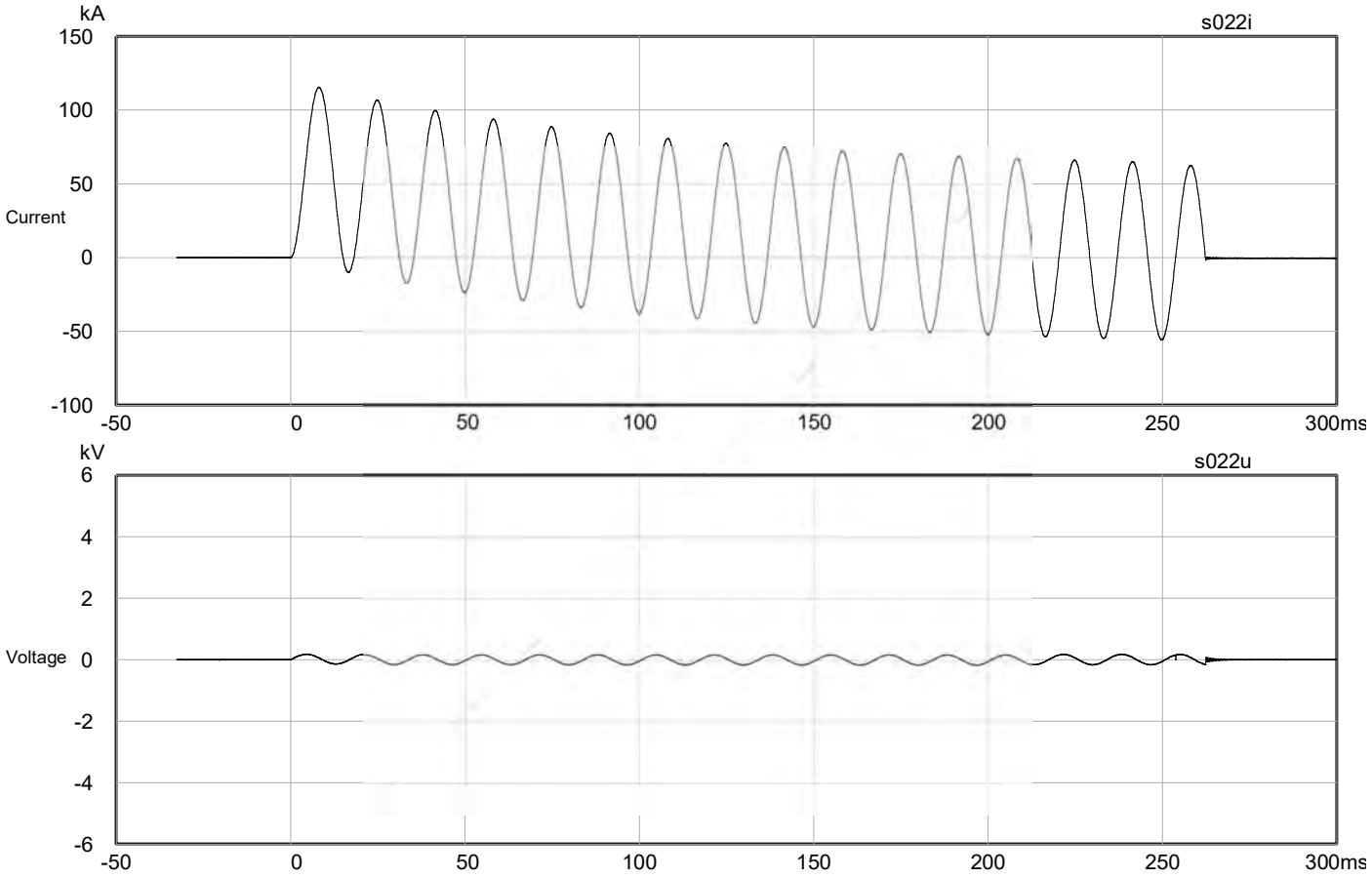


Figure 10: Waveforms for Test #6-2, Encore 4/0 AWG Sample 6.

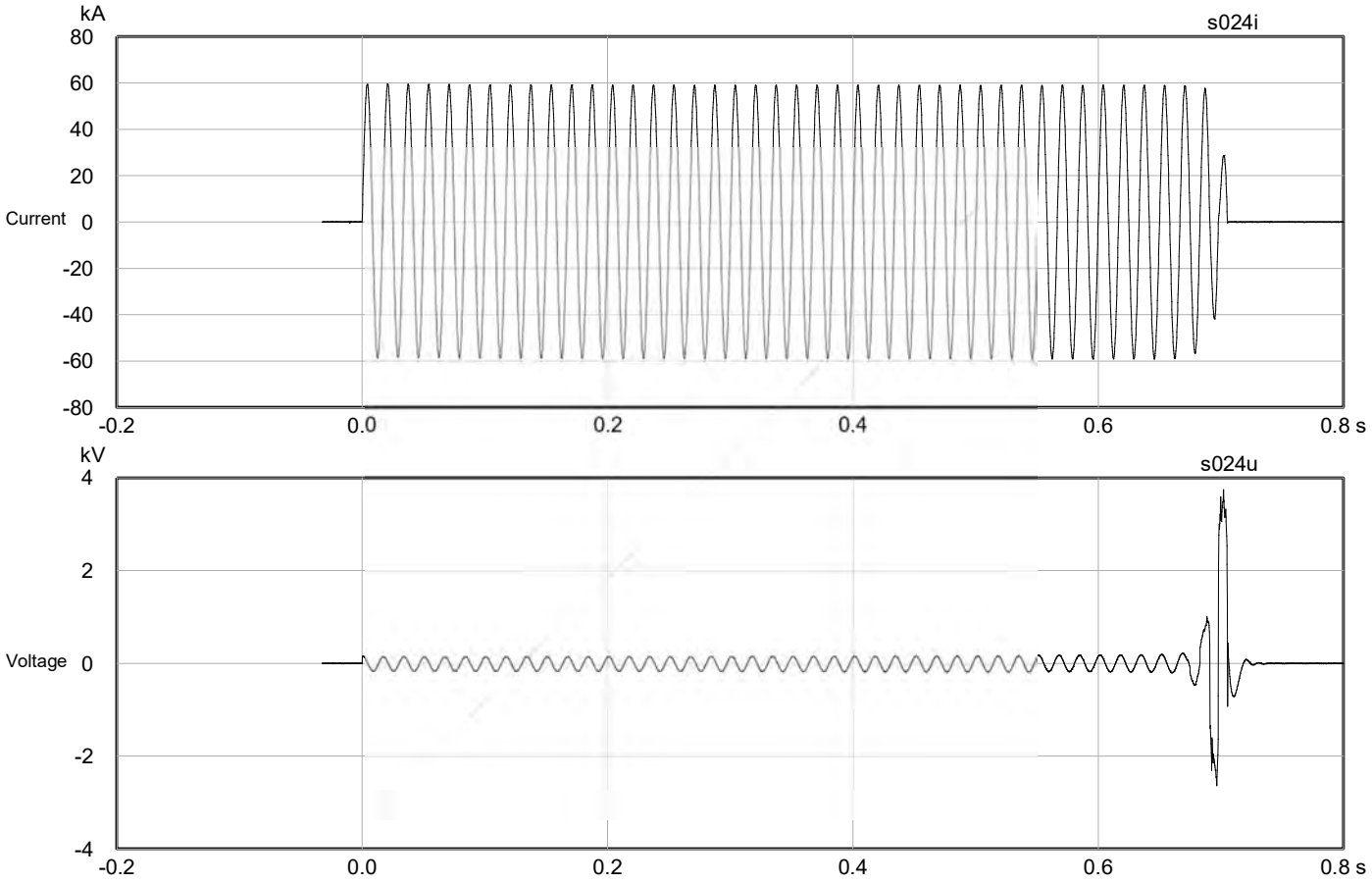


Figure 11: Waveforms for Test #7, Copperweld Scorpius 61 x 072 Sample 11.

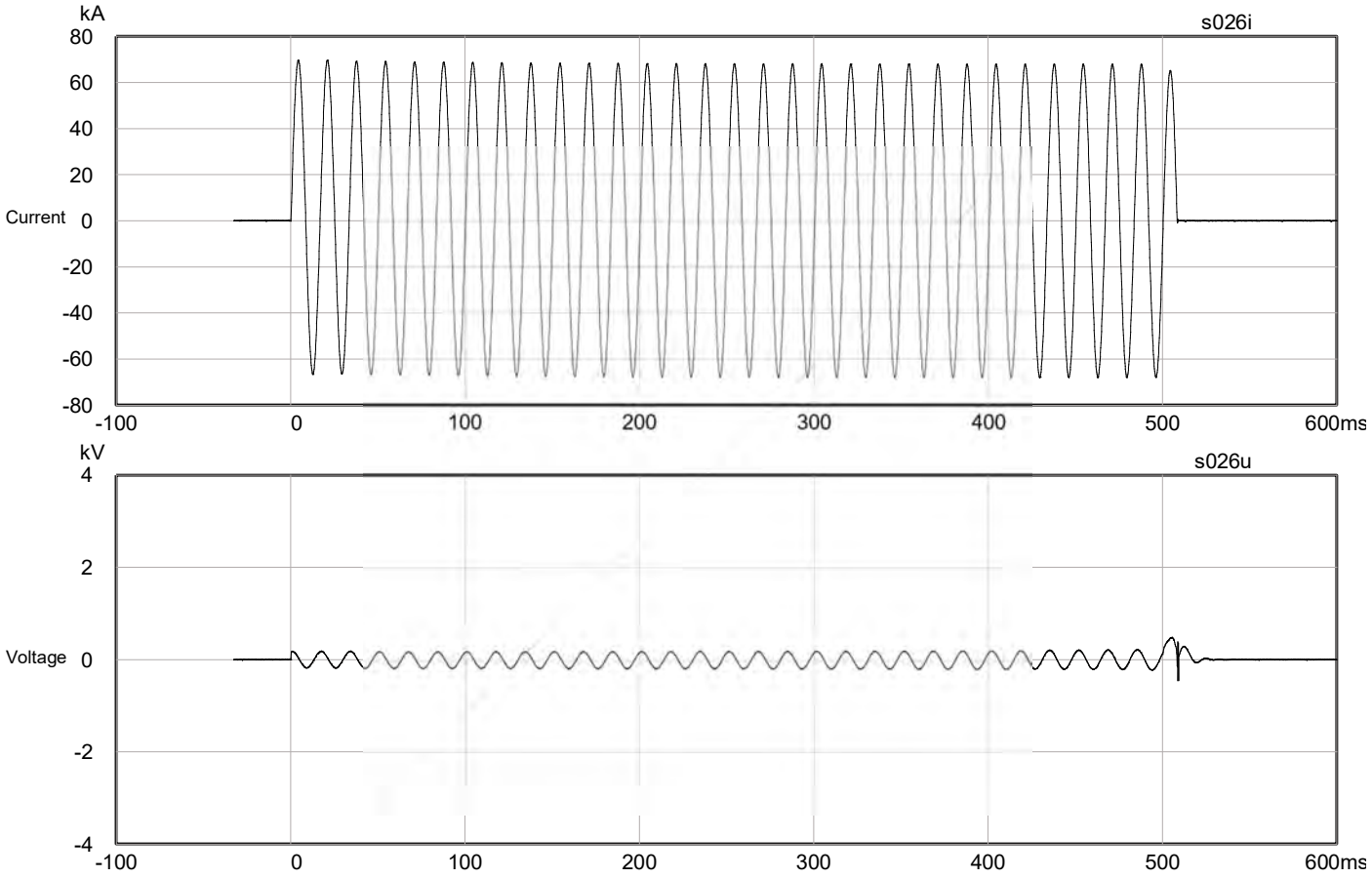


Figure 12: Waveforms for Test #6, Copperweld Scorpius 61 x 072 Sample 12.

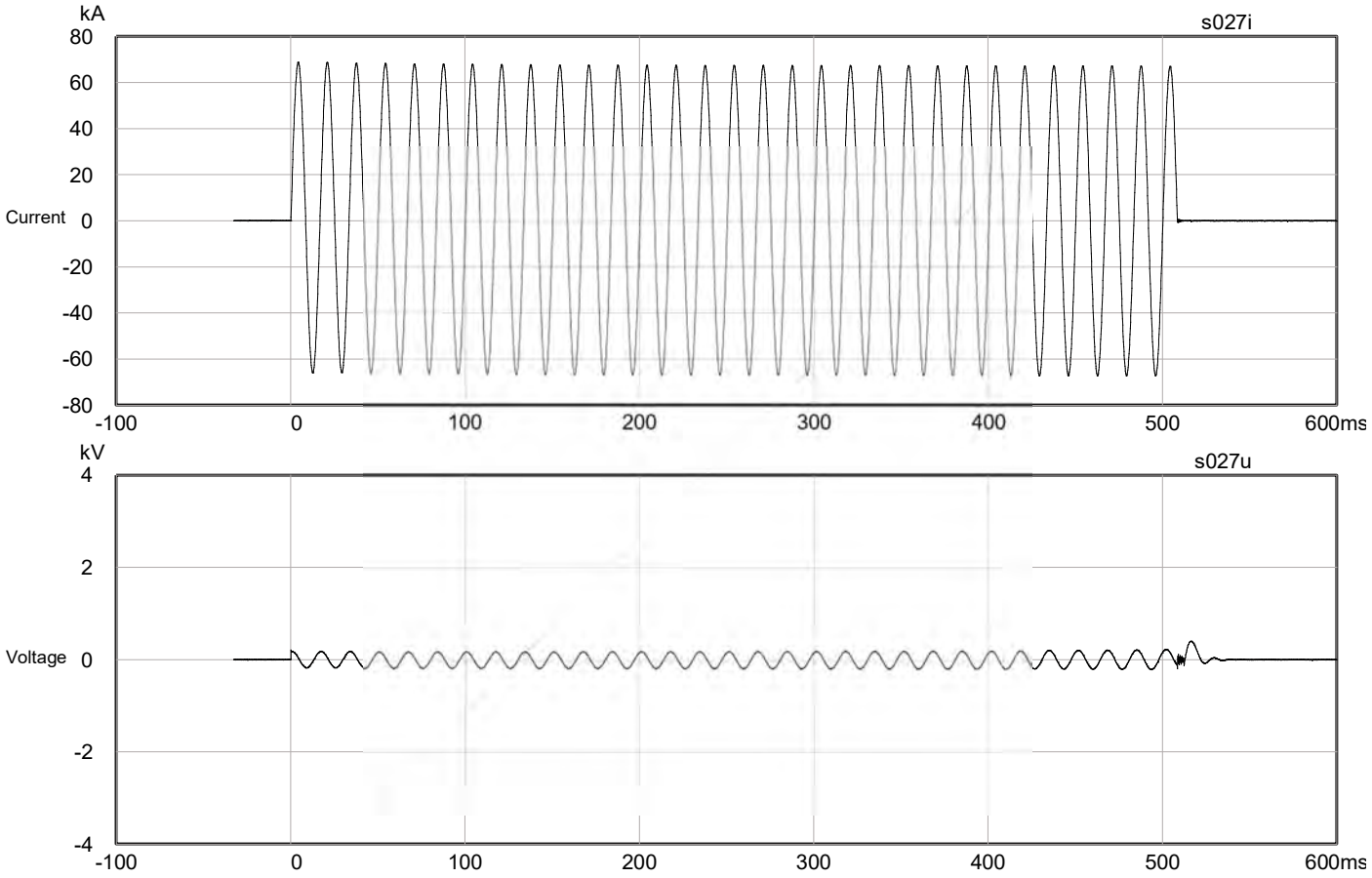


Figure 13: Waveforms for Test #9, Copperweld Scorpius 61 x 072 Sample 13.

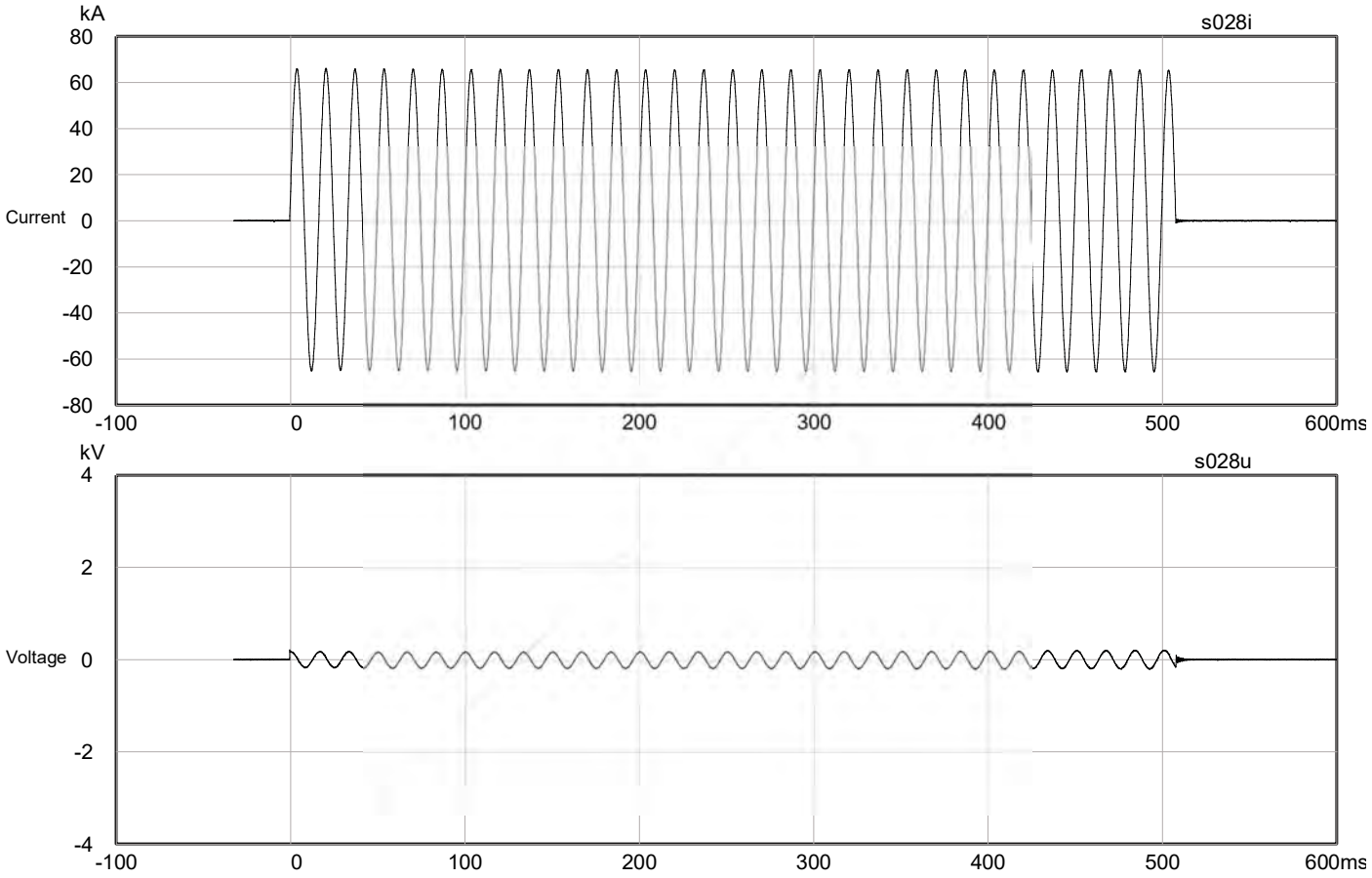


Figure 14: Waveforms for Test #10, Copperweld Scorpius 61 x 072 Sample 14.

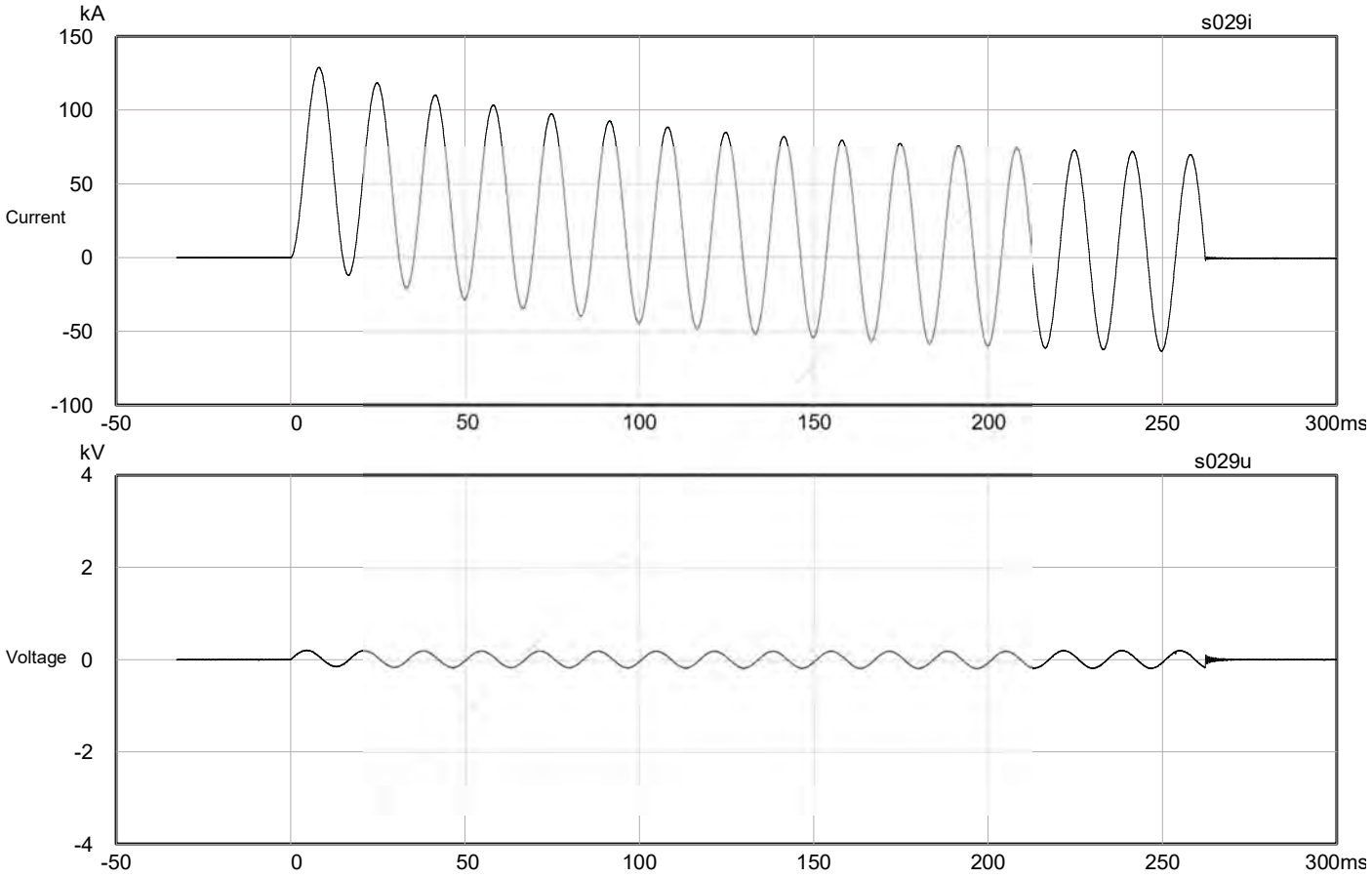


Figure 15: Waveforms for Test #11-1, Copperweld Scorpius 61 x 072 Sample 15.

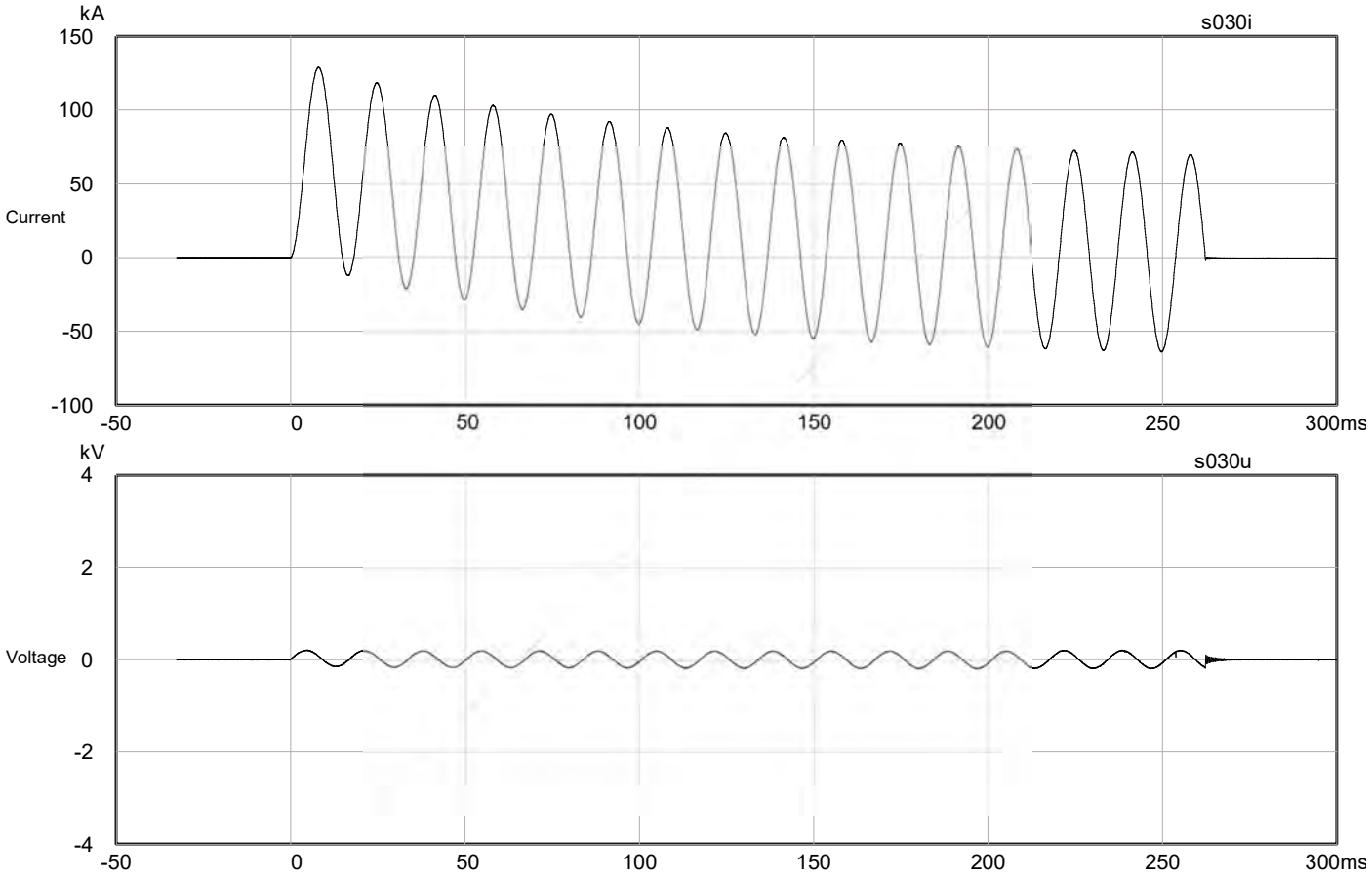


Figure 16: Waveforms for Test #11-2, Copperweld Scorpius 61 x 072 Sample 15.

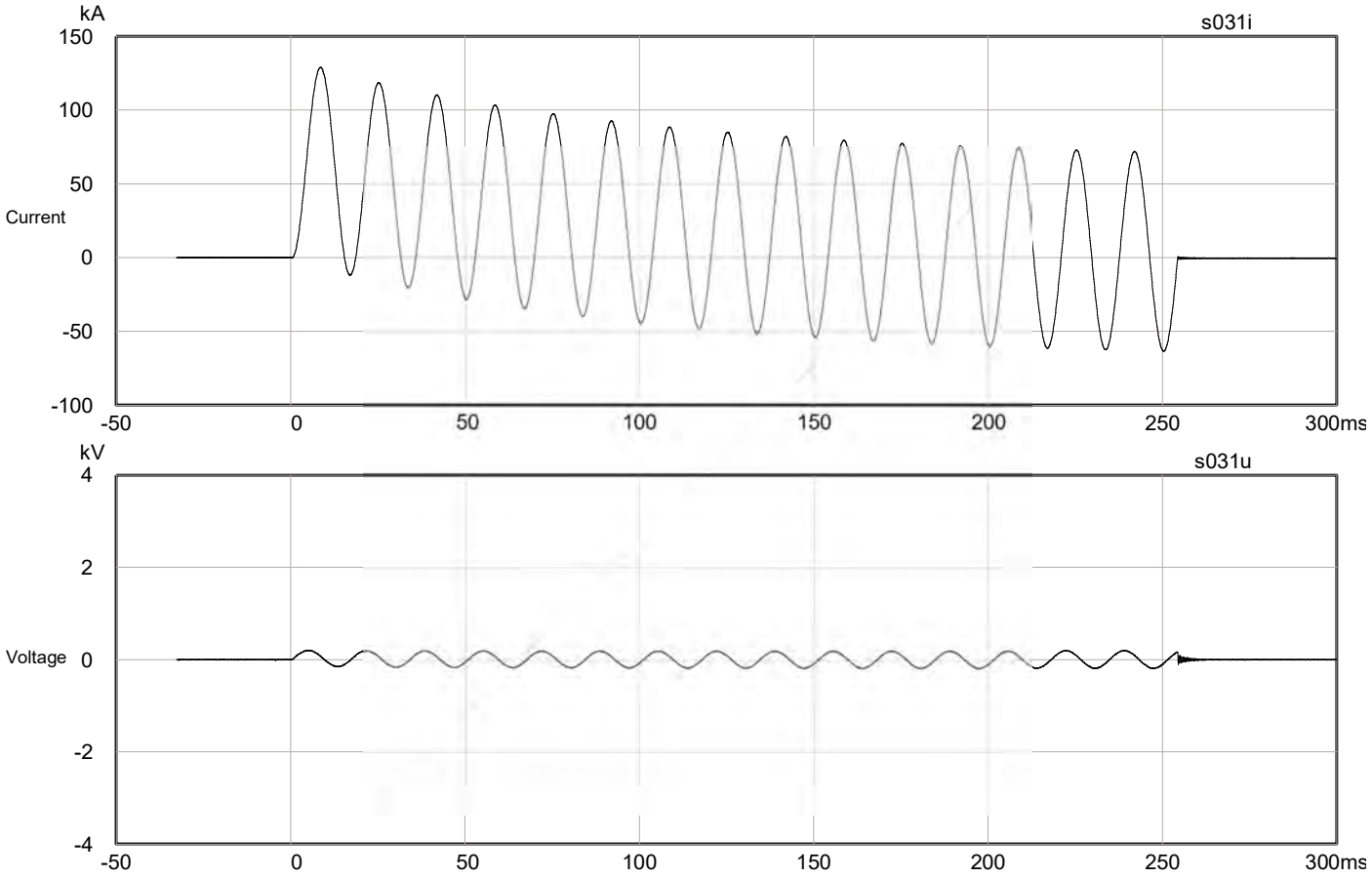


Figure 17: Waveforms for Test #12-1, Copperweld Scorpius 61 x 072 Sample 16.

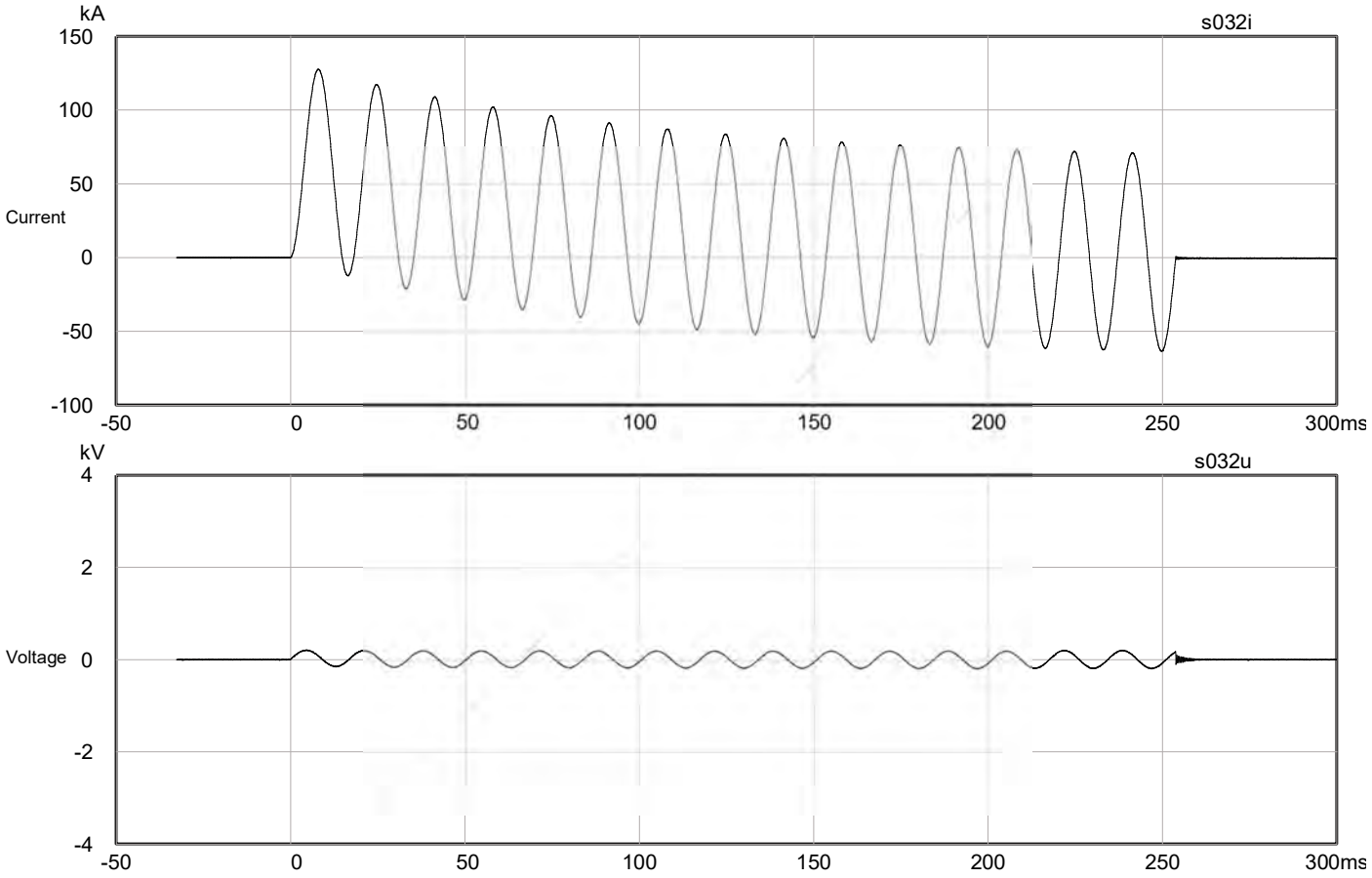


Figure 18: Waveforms for Test #12-2, Copperweld Scorpius 61 x 072 Sample 16.

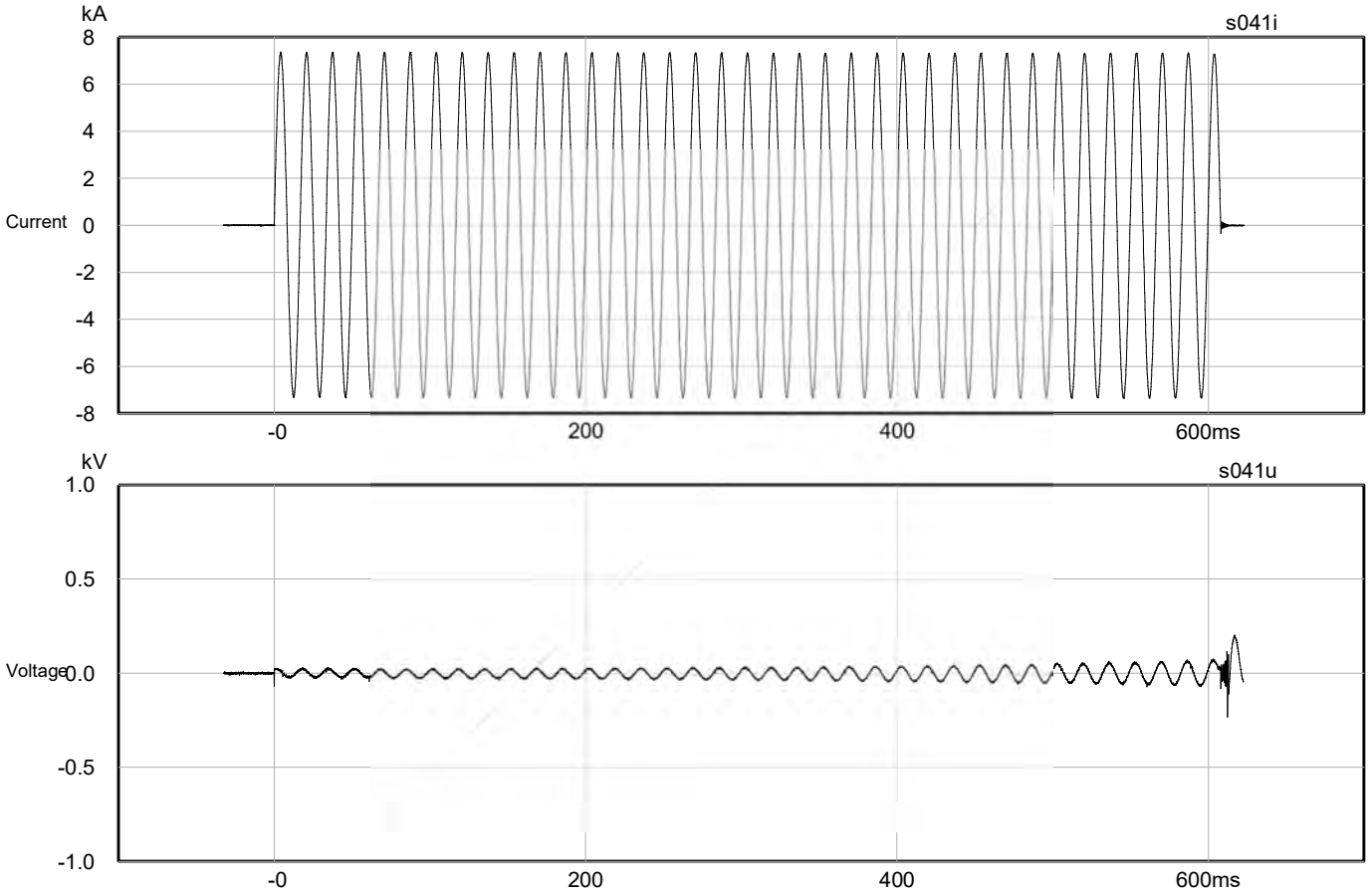


Figure 19: Waveforms for Test #13, Encore #6 AWG Sample 21.

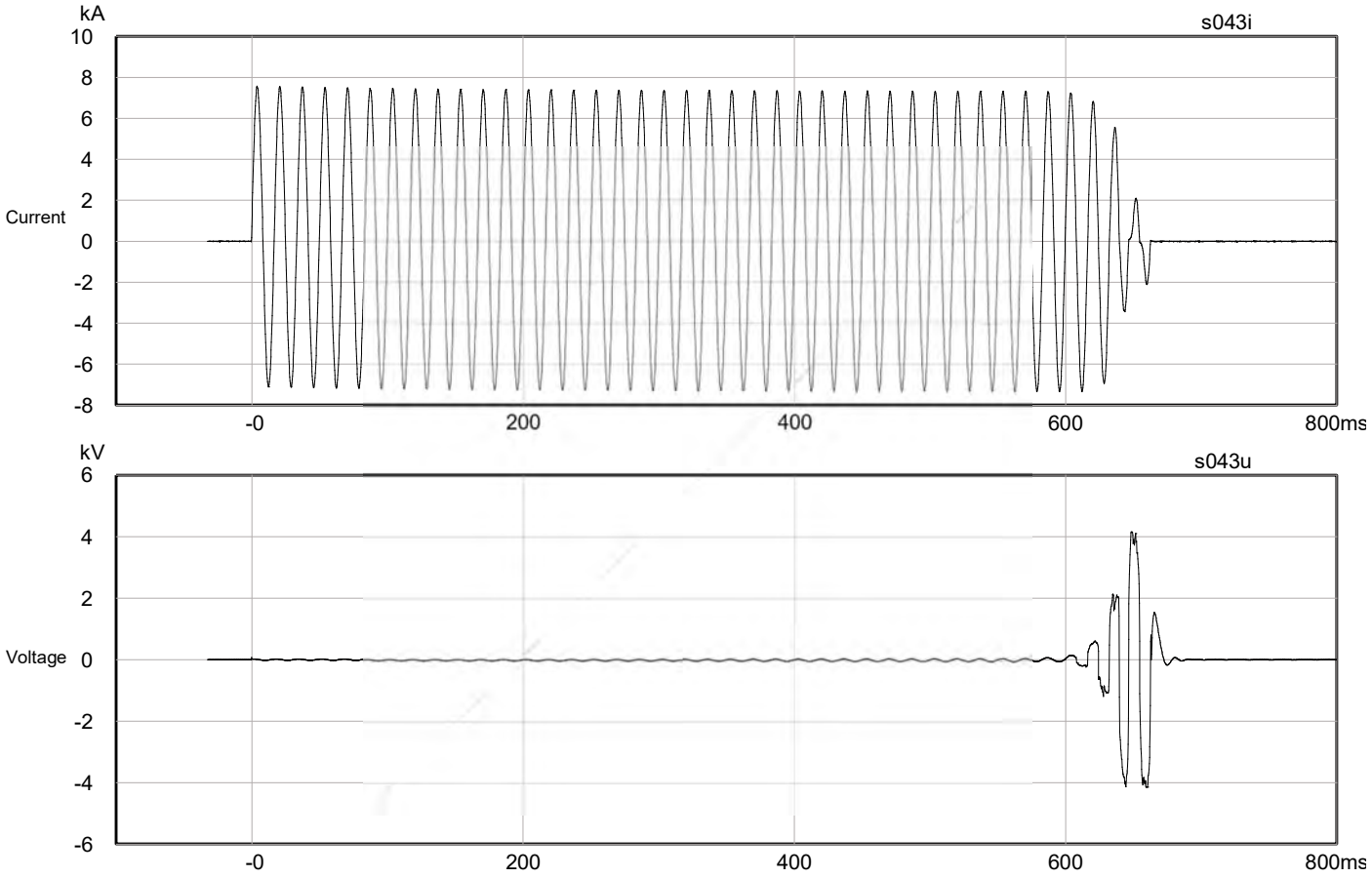


Figure 20: Waveforms for Test #14, Encore #6 AWG Sample 23.

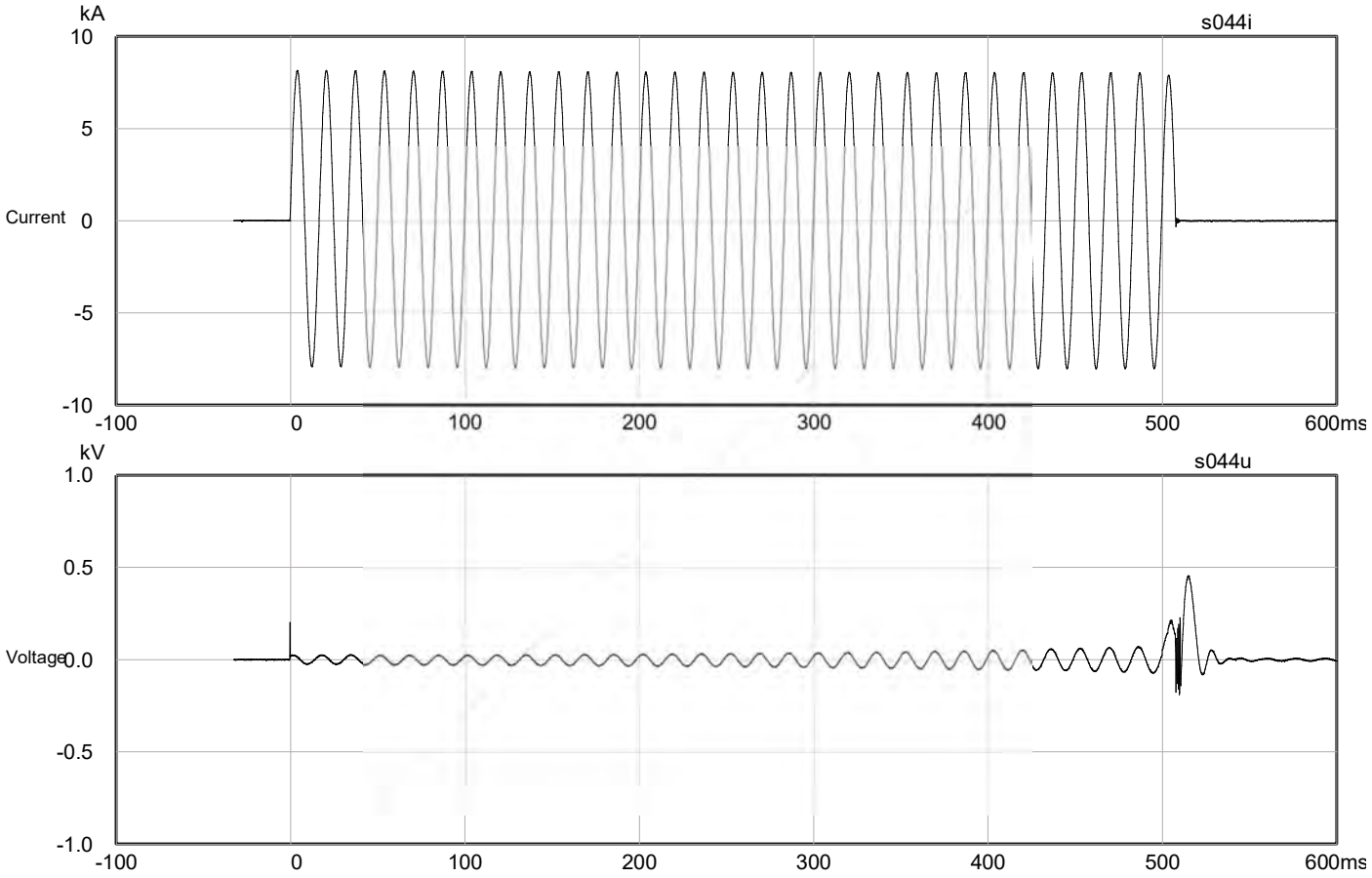


Figure 21: Waveforms for Test #15, Encore #6 AWG Sample 24.

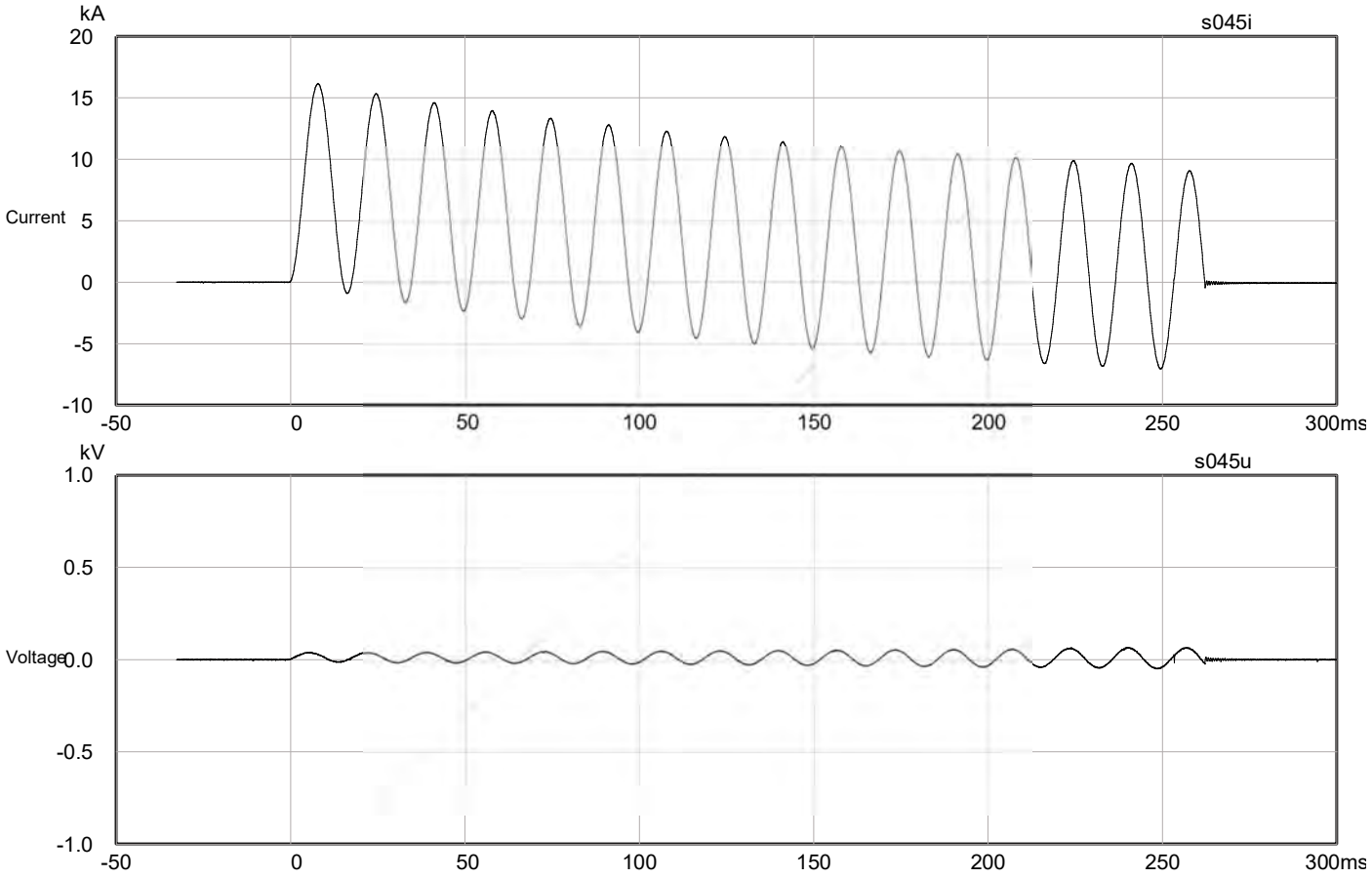


Figure 22: Waveforms for Test #16-1, Encore #6 AWG Sample 25.

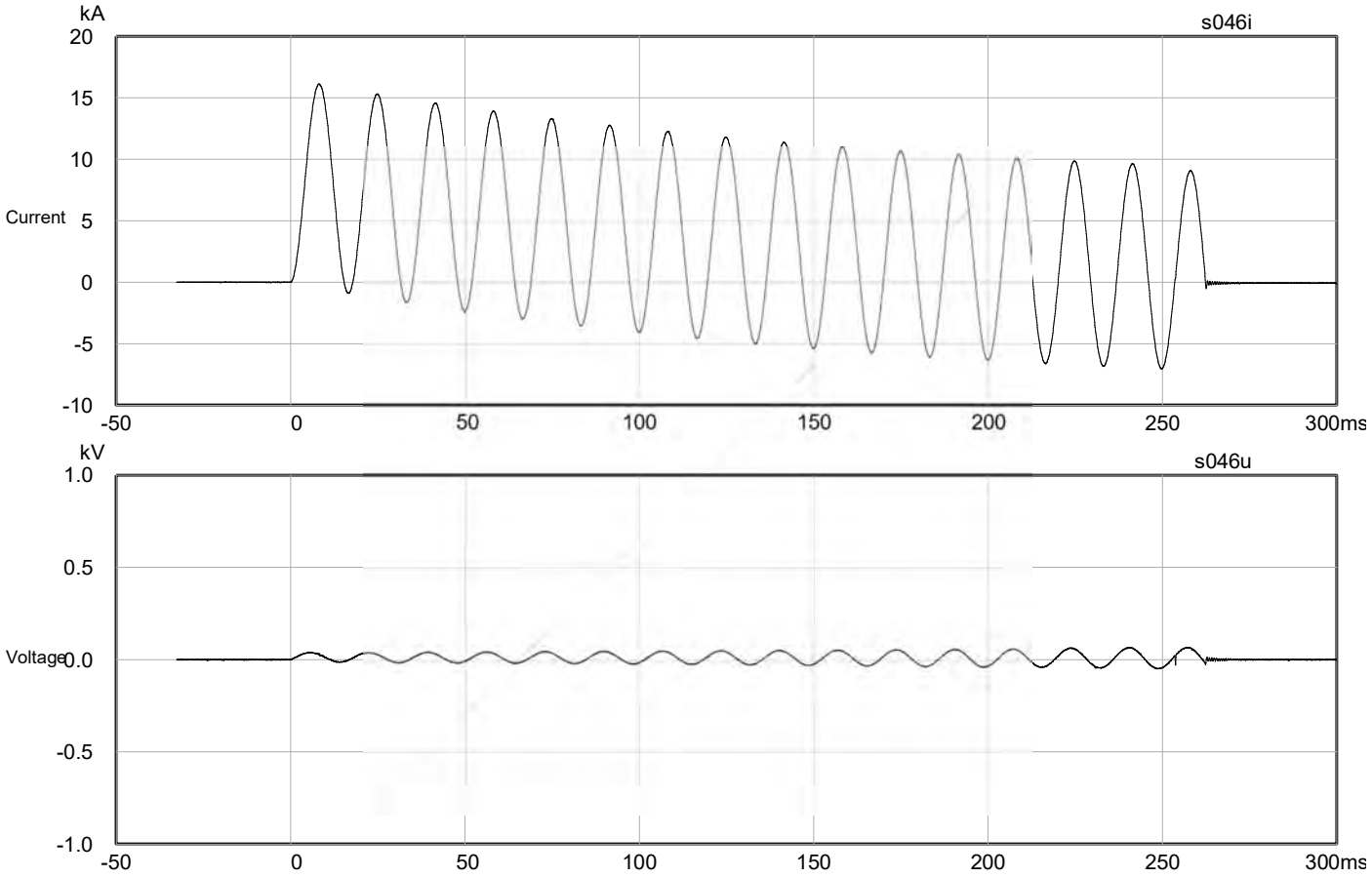


Figure 23: Waveforms for Test #16-2, Encore #6 AWG Sample 25.

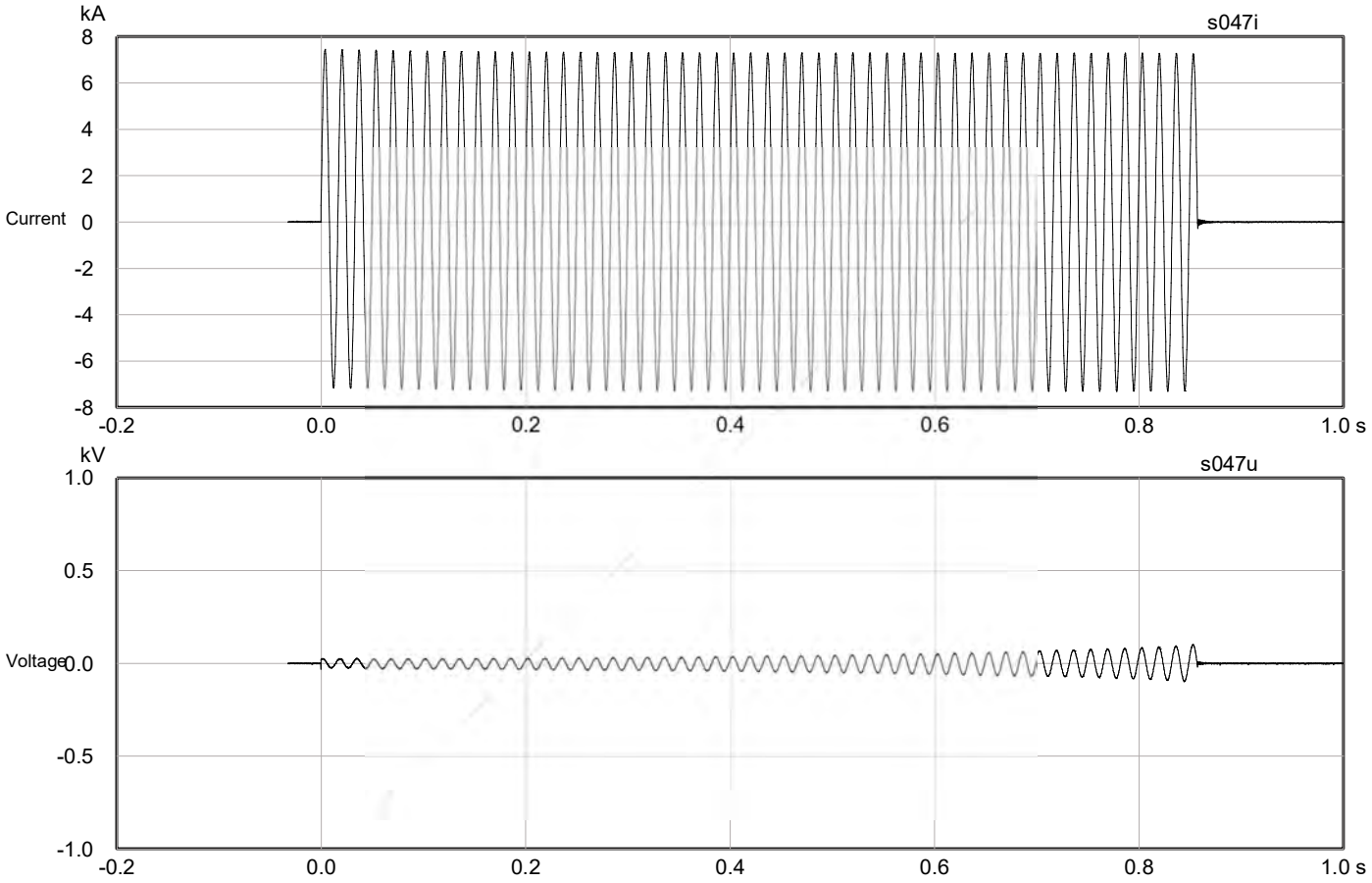


Figure 24: Waveforms for Test #17, Encore #6 AWG Sample 31.

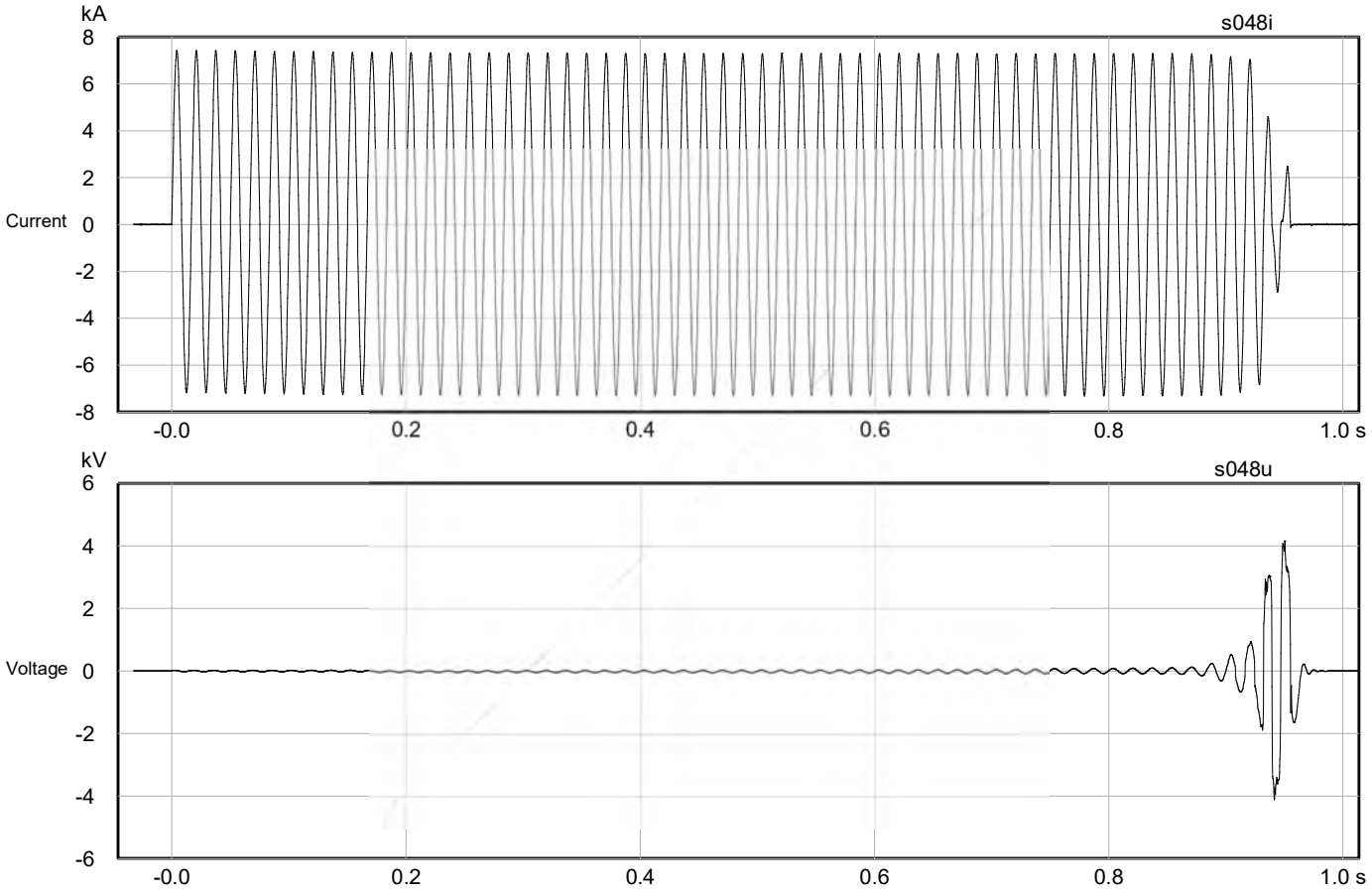


Figure 25: Waveforms for Test #18, Copperweld Scorpius 7 x 080 Sample 32.

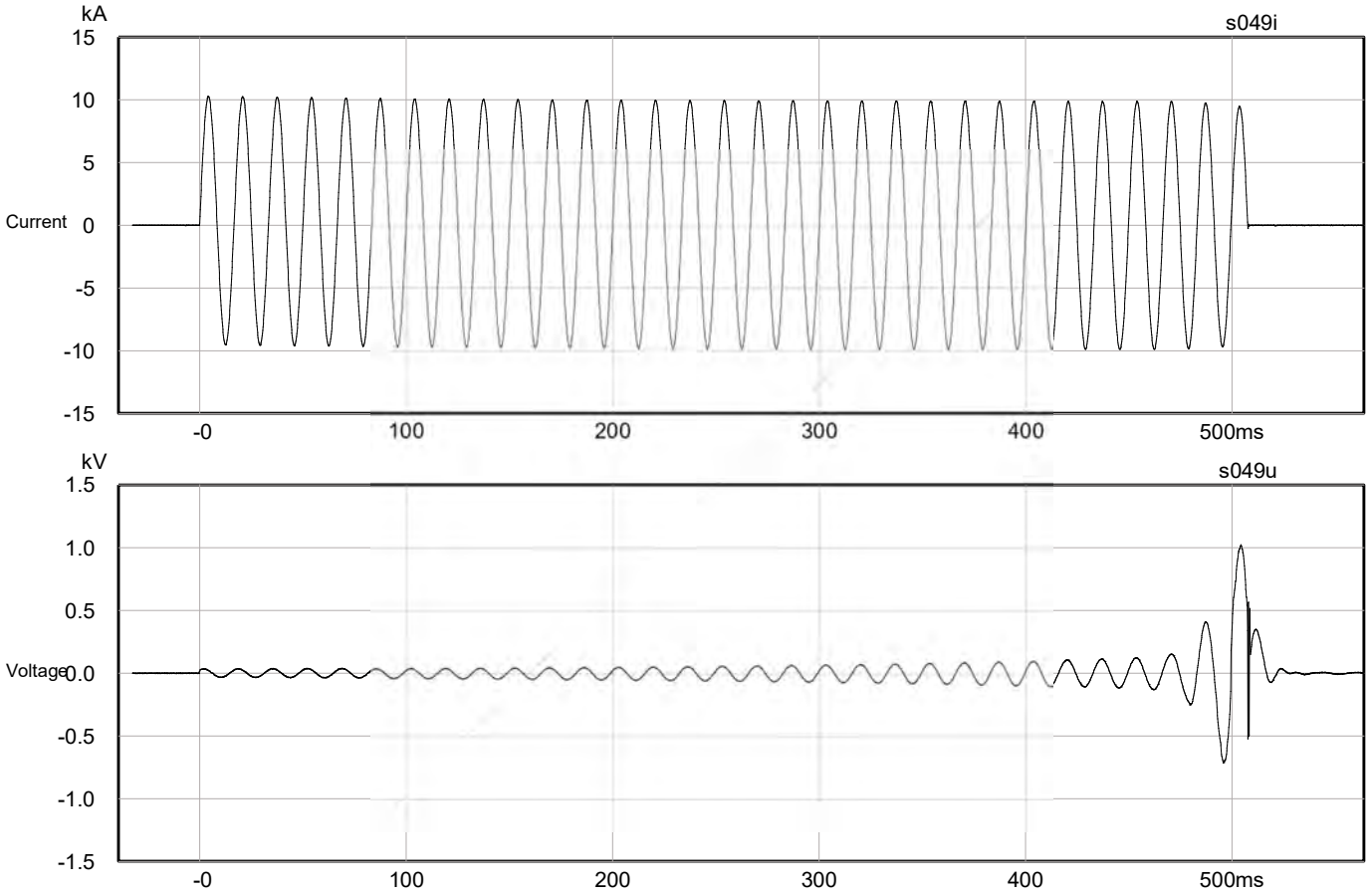


Figure 26: Waveforms for Test #19, Copperweld Scorpius 7 x 080 Sample 33.

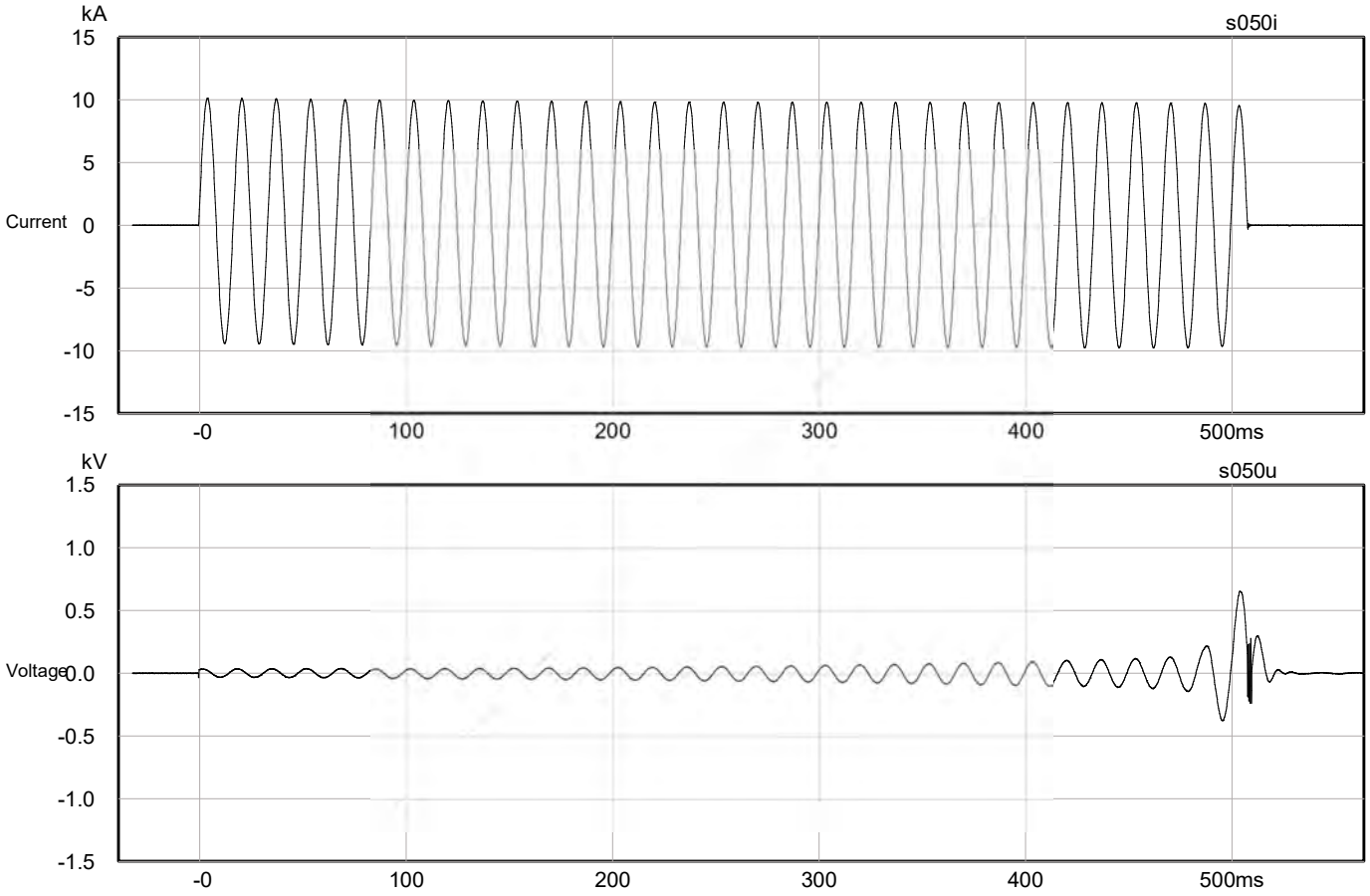


Figure 27: Waveforms for Test #20, Copperweld Scorpius 7 x 080 Sample 34.

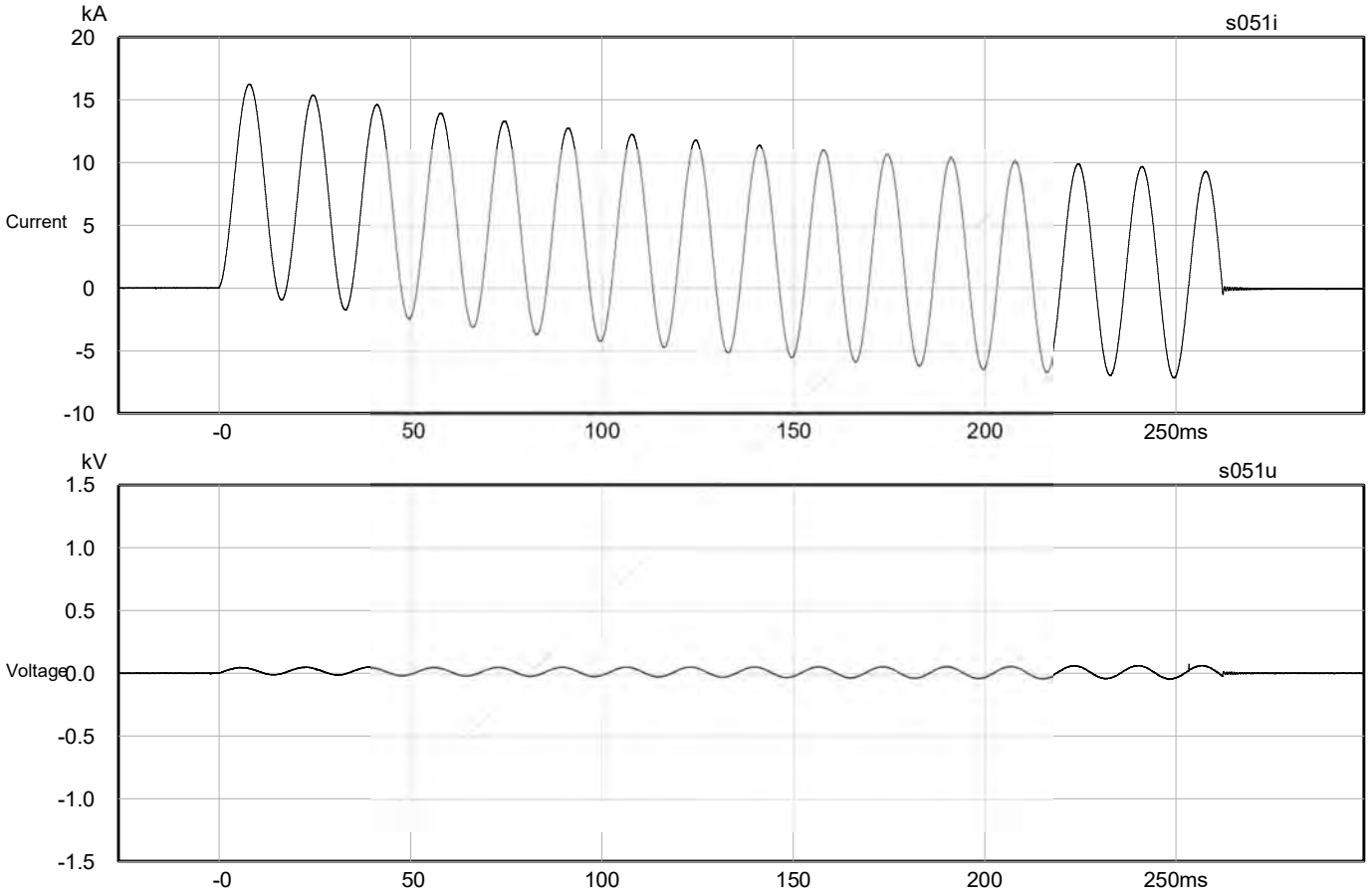


Figure 28: Waveforms for Test #21-1, Copperweld Scorpius 7 x 080 Sample 35.

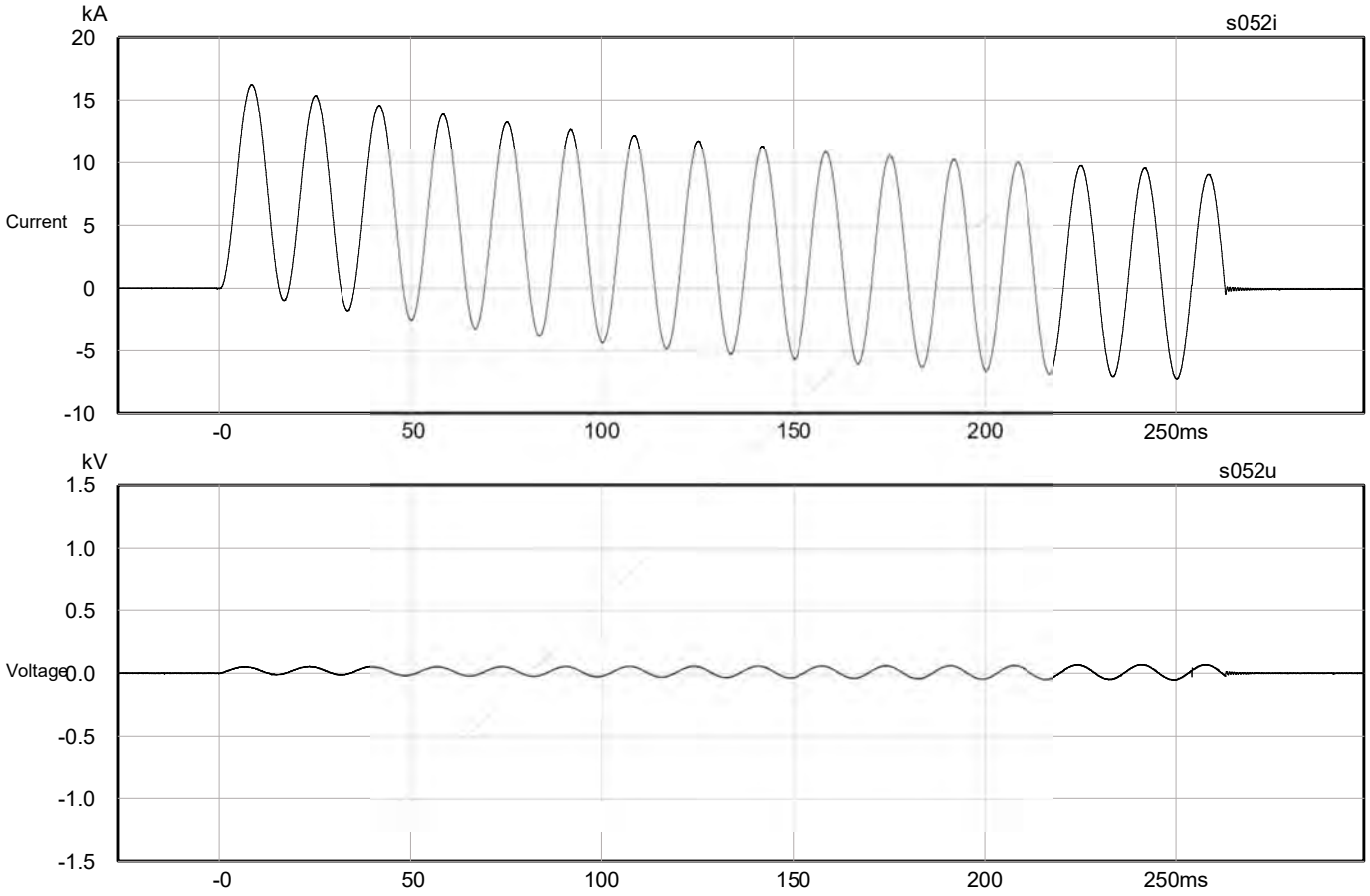


Figure 29: Waveforms for Test #21-2, Copperweld Scorpius 7 x 080 Sample 35.

APPENDIX C – PHOTOGRAPHS OF THE TEST OBJECTS



Figure 30: Test set up for the Encore 4/0 AWG Cu conductor. The power source bus is on the left and the ground bus is on the right.



Figure 31: Test set up for the Copperweld Scorpius 61 x 072 CCS conductor.



Figure 32: Test set up for the Encore #6 AWG Cu conductor.



Figure 33: Test set up for the Copperweld Scorpius 7 x 080 CCS conductor.

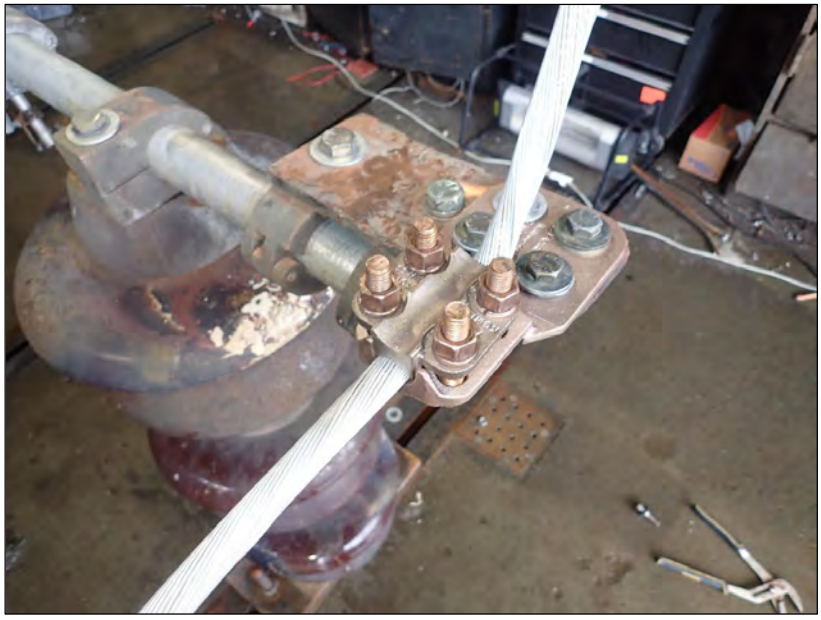


Figure 34: Typical Burndy terminal connector used to connect the Encore 4/0 AWG or Copperweld Scorpius 61 x 072 CCS conductors to the laboratory buses.



Figure 35: Typical Burndy terminal connector used to connect the Encore #6 AWG or Copperweld Scorpius 7 x 080 CCS conductors to the laboratory buses.

APPENDIX D – CALCUATIONS OF TEST CURRENT LEVELS FOR #6 AWG CU CONDUCTOR

Equation (45) in IEEE 80 and Equation (C.1) in IEEE 837 are the same, as follows:

$$I = A\sqrt{\left(\frac{TCAP\times10^{-4}}{t_c\times\alpha_r\times\rho_r}\right)\ln\left(\frac{K_0+T_m}{K_0+T_a}\right)}$$

where

I is root mean square (rms) current in kA
A is conductor cross section in mm^2
T_m is maximum allowable temperature in °C
T_a is initial conductor temperature in °C
T_r is reference temperature for material constants in °C
α_0 is thermal coefficient of resistivity at 0 °C
α_r is thermal coefficient of resistivity at reference temperature T_r
ρ_r is resistivity of the ground conductor at reference temperature T_r in μΩ-cm
K_0 is $1/\alpha_0$, or $(1/\alpha_r)-T_r$ in °C
t_c is time of current flow in seconds (s)
TCAP is thermal capacity factor in joules/cm^3°C

This equation is used to calculate the short-circuit ampacity of a conductor based on it's material constants.

For IEEE 80, Table 6, the symmetrical rms fusing current for #6 AWG soft-drawn Cu conductor at 500 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.5)(0.00393)(1.72)}\cdot\ln\left(\frac{(234+1083)}{(234+40)}\right)} = \boxed{5.29\ kA_{rms}}$$

For IEEE 837, Table 3, the symmetrical rms fusing current for #6 AWG hard-drawn Cu conductor at 250 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.25)(0.00381)(1.78)}\cdot\ln\left(\frac{(242+1084)}{(242+40)}\right)} = 7.41\ kA_{rms}$$

From IEEE 837 Equation (C.4), the asymmetrical rms fusing current is:

$$I_{asym} = \frac{(7.41\ kA)}{(1.148)} = 6.45\ kA_{rms}$$

For the EMF described in IEEE 837, Clause 7.2, a value of 90% of the fusing current is used for conductors up to 4/0 AWG:

$$I_{EMF} = (6.45)(0.9) = \boxed{5.81\ kA_{rms}}$$

Copperweld Bimetallics Data Sheet Packet
Electrical Test Laboratory

Customer:	Copperweld Building Wire	Engineer:	Bill Lewey	Date:	8/25/2020
Sample ID:	EL-13	Tested By:	Bill Lewey, Mike Rozar	Date:	8/25/2020
Product:	Grade 40 Copper Clad Steel Wire Solid Bare #4 and #6 vs Equivalent Solid Copper: Grounding Electrode Conductor Equivalency Test	Sample Condition:	New		
Standard:	ASTM B910/910M Annealed Copper Clad Steel Wire				
Insulation: N/A - Bare		Jacket: N/A - Bare			

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Test Report Summary

Page	Test Performed	Date Completed	Pass/Fail
1	Grounding Electrode Conductor Test for Copper Clad Steel Grade 40	8/25/2020	**Pass**

Requirement:
#4 AWG Grade 40 Copper Clad Steel and #6 AWG Copper Clad Steel when compared to #4 solid copper and #6 solid copper for use as a grounding electrode conductor shall have equal ability to carry amperage during a ground fault condition.

Conclusion:
The ability of bare #4 AWG Copper Clad Steel Grade 40 and bare #6 AWG Copper Clad Steel Grade 40 performed equally to #4 AWG bare solid copper and #6 AWG bare solid copper when used as a grounding electrode conductor under a ground fault condition. The current measured proved equivalency.

Test Equipment Used

Item	Equipment Type	Equipment #	Cal. Due Date
1	Fluke 374FC Clamp Meter	AM-1	Nov 2020
2	Acme Electric 15KVA Transformer	T2535173S	N/A
3	Square D 60A / 600V Safety Interrupter	N/A	N/A
4	Eaton Service Panel	N/A	N/A
5	Eaton Type CH 20 Amp Breaker	N/A	N/A
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

VBU – Verify Before Use

N/A – Not Applicable

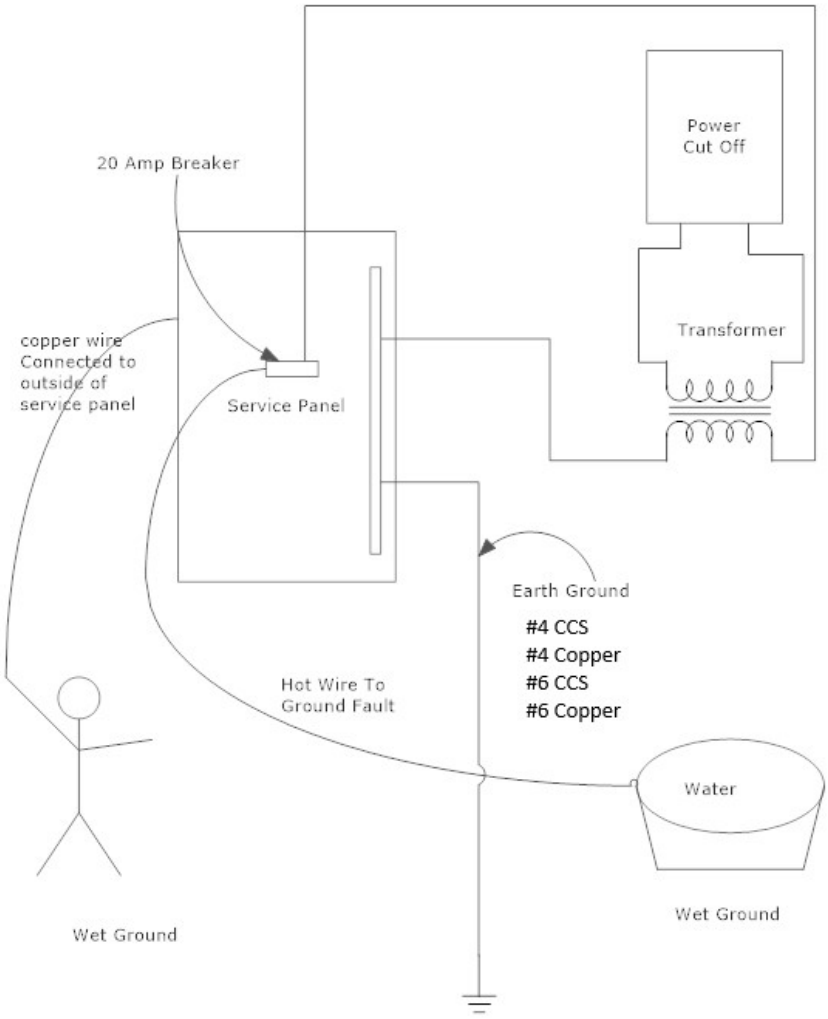
Sample Identification

Item	Description	Length/No. Rec'd
A	#4 AWG 40% Copper Clad Steel Bare	35 Ft
B	#4 AWG Solid Copper Bare	35 Ft
C	#6 AWG 40% Copper Clad Steel Bare	35 Ft
D	#6 AWG Solid Copper Bare	35 Ft
E		
F		

Grounding Electrode Conductor Test

Test Parameters:	
Conditioning:	No preconditioning.
Test Conductors:	1 each of #4 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #6 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #4 AWG Solid Bare copper grounding electrode conductor 1 each of #6 AWG Solid Bare copper grounding electrode conductor
Test Conductor Length:	Each conductor shall be 35 ft.
Test Circuit Configuration:	See schematic shown in Figure 1
Test Current:	Test current from 120 V / 20 A Residential Circuit
Method:	Testing was completed by creating a standard residential test circuit at 120V with 20A breaker wired to an intentional ground fault as shown in figure 1. The ground fault was created by connecting a hot wire from the breaker to a galvanized steel pan full of water and placing the pan on the wet ground. A conductor was also connected to the outside of the electrical panel and a Copper Plated Grounding Electrode (Copperweld Ground Rod) driven 6 inches into the wet ground to determine amount of current going through a grounded person touching the electrical panel during the ground fault condition. The ground fault and the grounded "man" were positioned 20 feet either side of the ground rod. The entire test area was soaked with water overnight using a sprinkler system When the ground fault was electrified, current measurements were taken from the ground fault conductor, the grounding electrode conductor and the grounded "man" conductor. For the four grounding electrode conductors tested, there was one test sequence for each. The current was measured for each. The objective: Compare the amperage measurements of the copper clad steel grounding electrode conductors to those of copper.

Figure 1



Results:			
Ground Conductor	**Fault Conductor Current**	**Current of the Grounding Electrode Conductor**	**Grounded Man Conductor Current**
#4 Copper	2.1 A	1.8 A	0.3 A
#4 40% CCS	2.1 A	1.8A	0.3 A
#6 Copper	1.7 A	1.6 A	0.1 A
#6 40% CCS	1.5 A	1.4 A	0.1 A

Requirement:
For equivalent sizes of Grade 40 Copper Clad steel vs. solid copper grounding conductors, the ability to carry amperage to ground during a ground fault condition is equal.

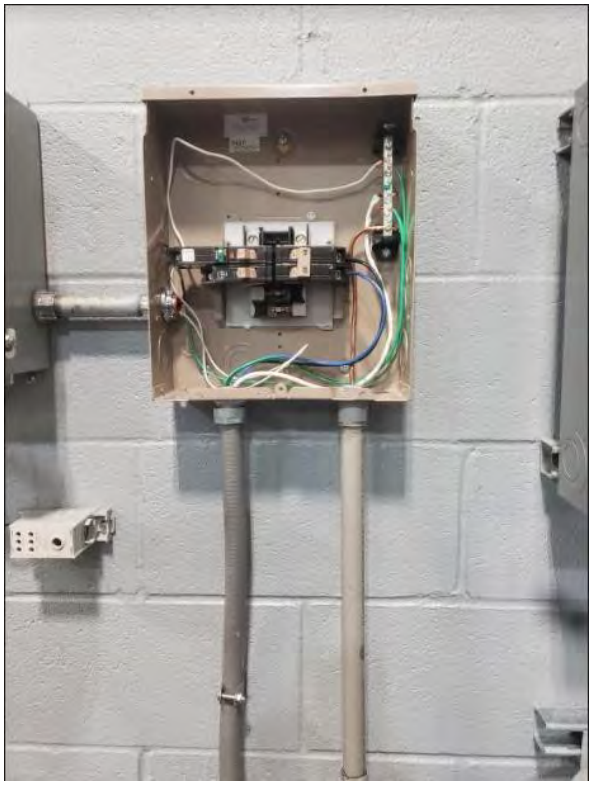
Comments:
____X__ (Pass) The product complies with all applicable requirements of this test. _____ (Fail) The product does not comply with the requirements of this test. **Test Date: 8/25/2020** **Tested By: Bill Lewey**

Environmental Conditions during Testing:

Humidity: % rh __74%_____ Ambient: °C___28_____

Test setup for the electrical service panel







Ground Rod with Grounding Conductor Attached



Ground Fault



Grounded “man”

Public Input No. 1801-NFPA 70-2020 [Section No. 250.54]

250.54 Auxiliary Grounding Electrodes.

One or more auxiliary grounding electrodes shall be permitted to be connected to ~~the~~ equipment to which required circuit equipment grounding conductors are connected. The equipment grounding conductors of any type specified in 250.118 and shall not be required to comply with the ~~electrode~~ required grounding electrode system bonding requirements of 250.50 or 250.53(C) or ~~the resistance~~ maximum resistance requirements of 250.53(A)(2) Exception, but the earth shall not be used as an effective ground-fault current path as specified in 250.4(A)(5) and 250.4(B)(4). The size of the grounding electrode conductor connected to an auxiliary grounding electrode shall be in accordance with Section 250.66.

Statement of Problem and Substantiation for Public Input

The revisions are intended to clarify the requirements and allowances of this section. There are already rules that should be triggered by application of this section, but are or seem to be at this point, just implied. Clarification is necessary to avoid the incorrect applications of this section regarding auxiliary grounding electrode conductors that are connected to equipment that is not connected to a required equipment grounding conductor, thus in violation of 250.4. The new last sentence will provide some direction on sizing the grounding electrode conductors connected to auxiliary grounding electrodes.

Submitter Information Verification

Submitter Full Name: Agnieszka Golriz
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State:
Zip:
Submittal Date: Tue Jul 07 13:14:57 EDT 2020
Committee: NEC-P05

Public Input No. 2931-NFPA 70-2020 [Section No. 250.54]

250.54 Auxiliary Grounding Electrodes.

One or more grounding electrodes shall be permitted to be connected to the equipment grounding conductors specified in 250.118 or other metal parts of the electrical system and shall not be required to comply with the electrode bonding requirements of 250.50 or 250.53(C) or the resistance requirements of 250.53(A)(2) Exception, but the earth shall not be used as an effective ground-fault current path as specified in 250.4(A)(5) and 250.4(B)(4).

Statement of Problem and Substantiation for Public Input

Auxilary grounding electrodes are generally not 'connected' to the circuit equipment grounding conductor. For example, they are connected to the metal parts of a light pole or machine tool, motor, etc. The way the current language is written, a ground rod would not be permitted to be connected to any of these parts.

Submitter Information Verification

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Submittal Date: Thu Sep 03 10:21:21 EDT 2020
Committee: NEC-P05

Public Input No. 2462-NFPA 70-2020 [Section No. 250.62]

250.62 Grounding Electrode Conductor Material.

The grounding electrode conductor shall be of copper-clad steel , 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. Copper-clad steel shall adhere to the following requirements:

1. Shall be a bimetal where the copper cladding and steel core maintain a metallurgical bond

2. Shall be grade 40 Copper-Clad Steel

3. Shall be listed

Informational Note: Copper-clad steel may be specified to ASTM B910/B910M-07, Standard Specification for Annealed Copper-Clad Steel Wire. Listings are based upon meeting a national standard for Copper-Clad Steel wire.

Additional Proposed Changes

File Name	Description	Approved
CCS_Corrosion_paper_Rev2.pdf	50 Year Corrosion Study Grade 40 CCS	
TD002391.doc	Grade 40 CCS UL 467 Short Circuit and UL 486A-B Mechanical Sequence Test	
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 applicate 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 Inputs for This Document

Related Input	Relationship
Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]	Copper-Clad Steel Grounding Conductors
Public Input No. 2459-NFPA 70-2020 [Section No. 250.52(A)(4)]	
Public Input No. 2460-NFPA 70-2020 [Section No. 250.53(E)]	
Public Input No. 2463-NFPA 70-2020 [Section No. 250.64(B)(1)]	
Public Input No. 2465-NFPA 70-2020 [Section No. 250.64(B)(2)]	
Public Input No. 2474-NFPA 70-2020 [Section No. 250.166 [Excluding any Sub-Sections]]	
Public Input No. 2476-NFPA 70-2020 [Section No. 250.166(A)]	
Public Input No. 2481-NFPA 70-2020 [Section No. 250.190(B)]	
Public Input No. 2491-NFPA 70-2020 [Section No. 770.100(A)(2)]	

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Submittal Date: Sun Aug 23 09:36:34 EDT 2020
Committee: NEC-P05

Testing done for the safety of our valued customer.

Global Circulation Laboratory Test Report

For Global Distribution

UL467 SHORT CIRCUIT & UL 486A-486B MECHANICAL SEQUENCE TESTS

YGHP29C2, YGHC2C2, YGHC26C26, YGHP34C29, YGHC29C29, YGHP34C34, YGHC34C34 HYTAP™ Connectors
YGL2C2, YGL29C29, YGL34C34 HYGRID™ Connectors
YGA4C2N, YGHA272N, YGA282N, YGHA302N HYLUG™ Connectors

5/8" and 3/4"Copper Clad Steel Ground Rod, #4AWG Solid, 4/0AWG Stranded, 7#7, and 19#8 COPPERWELD® 40% IACS Copper Clad Steel Conductors

PAT750XT-18V PATRIOT® Tool
with
UC, UO, U28RT, U29RT, U32RT, U997, PU998, and U1011 Die Sets

TD002391 REV B

Requested by / Date:	***Authorized by / Date:***	***Completed by / Date:***
C. Gandhi 12-Dec-2014	R Robicheau 12-Dec-2014	R Charpentier 06-Apr-2015
Engineering Approval / Date:	***Marketing Approval / Date:***	***Laboratory Approval / Date:***
R.Roman 20-Aug-2020	J Hogan 20-Aug-2020	R Charpentier 20-Aug-2020

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

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Burndy LLC 47 East Industrial Park Dr.
Manchester / New Hampshire / 03109
Tel: 603 647 5000 Fax: 603 647 5205

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

PURPOSE OF TEST:

To determine if the Burndy HYTAP™, HYGRID™, and HYLUG™ Connectors can meet the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST REQUESTED:

UL486A-486B Mechanical Sequence
UL467 Short Time Current

TEST RESULTS:

Connector	Cable 1	Cable 2	Die	# of crimps	Securness	Pull	Short Time Current		
					Pass / Fail	Average Pull (lb)	Pass / Fail	Current (Amps)	Time (s)
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	U997	1	Pass	1021.3	Pass	1600	6
YGL2C2	#4 Solid CCS	#4 Solid CCS	U-O	1	Pass	1451.8	Pass	1600	6
YGHC2C2	#4 Solid CCS	#4 Solid CCS	U-C	1	Pass	1544.0	Pass	1600	6
YGA4C2N	#4 Solid CCS	n/a	U4CRT	1	Pass	814.0	Pass	1600	6
YGL29C29	7#7 STR CCS	7#7 STR CCS	U997	1	Pass	1643.2	Pass	4600	9
YGHC26C26	7#7 STRCCS	7#7 STR CCS	U-O	1	Pass	1239.4	Pass	4600	9
YGHA272N	7#7 STRCCS	n/a	U29RT	2	Pass	1574.0	Pass	4600	9
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PU998	1	Pass	1789.8	Pass	6100	9
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1849.8	Pass	6100	9
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1779.1	Pass	6100	9
YGA282N	4/0 AWG CCS	n/a	U28RT	2	Pass	2489.3	Pass	6100	9
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	U1011	3	Pass	2126.8	Pass	9000	9
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	U1011	3	Pass	2380.0	Pass	9000	9
YGL34C34	19#8 STRCCS	19#8 STR CCS	U1011	3	Pass	3158.3	Pass	9000	9
YGHC34C34	19#8 STR CCS	19#8 STR CCS	U1011	3	Pass	3812.1	Pass	9000	9
YGHA302N	19#8 STR CCS	n/a	U32RT	2	Pass	4792.2	Pass	9000	9

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CONCLUSIONS:

All samples tested met the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST PROCEDURES

The table below shows the connector / conductor combinations tested.

Connector	Cable 1	Cable 2	Tool	Die	# of Crimps
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	PAT750	U997	1
YGL2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-O	1
YGHC2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-C	1
YGA4C2N	#4 Solid CCS	n/a	PAT750	U4CRT	1
YGL29C29	7#7 STR CCS	7#7 STR CCS	PAT750	U997	1
YGHC26C26	7#7 STR CCS	7#7 STR CCS	PAT750	U-O	1
YGHA272N	7#7 STR CCS	n/a	PAT750	U997	2
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PAT750	PU998	1
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGA282N	4/0 AWG CCS	n/a	PAT750	U997	2
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	PAT750	U1011	3
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	PAT750	U1011	3
YGL34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHC34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHA302N	19#8 STR CCS	n/a	PAT750	U32RT	2

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All conductors were cut to twenty four (24) inch lengths.
All ground rod was pre-crimped with the appropriate pre-crimp die
5/8in Rod UPRECRIMP58
3/4in Rod UPRECRIMP34

Mechanical Sequence
Four samples of each set were secured to the Secureness tester, the height; weight and bushing size were as specified in UL486A-486B Table 26. Samples were rotated for thirty minutes at 9rpm. Samples were then subjected to a 1-minute pull to the value specified in UL486A-486B Table 27 and then to failure.

Short Time Current
Test samples were assembled in a series loop configuration then attached to a current controller as shown below. The test current and duration are listed below. After completion of the test, electrical continuity was checked with a digital multi-meter.

Test current values were derived from the equation Annex C of IEEE Std 837-2002. The diameter of the conductor(s) were measured and the cross-sectional area of the conductors was calculated.

Conductor	***Current Value (A)***	***Duration (sec)***
#4AWG Solid COPPERWELD® 40% IACS CCS	1600	6
4/0AWG 19 strand COPPERWELD® 40% IACS CCS,	6100	9
7#7 stranded COPPERWELD® 40% IACS CCS	4600	9
19#8 stranded COPPERWELD® 40% IACS CCS	9000	9

TEST EQUIPMENT LIST:

MANUFACTURER	MODEL	DESCRIPTION	SERIAL #	RANGE
FLUKE	79 III	DMM	70591301 (Rene)	AUTO
OHIO SEMITRONICS		CURRENT TRANSDUCER	NA	15000:5
SATEC	T5000	TABLE TOP	2038	5000 lbs
VIRTECH	NA	HIGH CURRENT	NA	12V / 12000A
MITUTOYO	505-675	DIAL CALIPER	08914565 (Rene)	6"

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CORROSION ON BURIED COPPER CLAD STEEL



Cece Syarif

Global Application Engineer

&

Anthony Hale

Manager, Utility Products, North America

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For more information, contact sales@copperweld.com.
The results and conclusions obtained from studies done by Copperweld are only applicable to Copper Clad Steel manufactured by Copperweld. Due to proprietary process used to produce the wire, the findings cannot be superimposed on any other copper-clad steel conductor.

254 Cotton Mill Rd, Fayetteville, TN 37334. Tel. (931) 433 – 7177

July 26, 2011

This paper compiles several studies and analysis regarding the corrosion performance of buried Copperweld® Copper-Clad-Steel (CCS) conductors. These range from the early 1900's with the invention of Copperweld® through the present day with studies performed by independent parties as well as Copperweld Company in-house testing. The purpose is to present the available information so that prospective users of Copperweld® CCS wire and strand can evaluate the corrosion resistance and expected performance within their specific application and area. Copperweld uses oxygen free copper in the manufacture of Copperweld® wire and strand. The copper surface of CCS is expected to oxidize and turn color ranging from green (patination) to brown and black the same as any solid copper wire or strand when exposed to environmental stimuli. Corrosion on exposed steel at the cut tip or end of the wire is also expected. The question to be answered is if the corrosion on either material or the interface between the copper and steel (galvanic reaction) will result in degradation of the wire as to make it unsuitable for use as a grounding conductor.

The oldest known underground corrosion study of bimetallic material was performed in the early 1900s[1]. This study focused on the corrosion behavior of Copperweld® CCS underground rod as well as other materials such as Copper and galvanized steel ground rod. The National Bureau of Standards (NBS) conducted an extensive underground corrosion study that involves 36,500 specimens which include 333 varieties of ferrous, nonferrous, and protective coating materials buried in 128 test locations throughout U.S in 1910 - 1955.

The study summarizes the service life of a ground rod as following:

10 mils copper coating – acceptable for service life up to 40 years

13 mils copper coating – acceptable for service life up to 50 years

Similarly, the Naval Civil Engineering Laboratory in collaboration with the National Association of Corrosion Engineers conducted a 7-year program of testing metal rods for electrical grounding to determine the galvanic corrosion effect. The three metals tested were stainless clad steel, copper-bonded steel (CCS), and galvanized steel. The result on the ⅝" CCS ground rod was as expected. The copper surface of the CCS was

virtually free of corrosion and the steel core has corroded at the tip approximately 2 inches down the length of the rod.

Copperweld Corporation is the inventor and sole manufacturer of Copperweld® Copper-bonded ground rods and Copperweld® wire and strand since 1915. The corrosion behavior of a Copperweld® ground rod is similar to the corrosion on Copperweld® wire and strand conductor. Both materials consist of copper permanently bonded to a steel core. All Copperweld® 40% CCS has a copper thickness of 10% of the overall diameter. For example, Copperweld® 4THOUGHT™ has a configuration of 19 strands of 0.1055 inch wires. It means that each strand has a copper thickness of 10.55 mils. Based on the NBS study, 4THOUGHT™ will have at least a minimum service life of 40 years.

Copperweld has also conducted a 5-year study of buried bare 21% conductivity (copper thickness is 3% of the diameter) Copperweld® CCS in 10 different soil conditions in association with Southwest Research Institute[2]. The study reported 100% surface oxidation and various degrees of deterioration of the steel core as expected after 5 years. The exposed steel on the tip of the wire rusted and formed "scab", as shown in Figure 1. The rust appeared to "seal-off" the un-oxidized material from the corrosive medium. The maximum depth of corrosion was 70% of the wire diameter.



Figure 1: Example of Underground Corrosion of Copper Clad Steel

Although the copper surface oxidation was heavy, the samples showed no signs of pits or holes in the copper cladding. The copper thickness of a severely oxidized 5-year sample showed no discernable difference when compared to an un-oxidized control sample that was not subjected to the corrosive environment. The mechanical and resistance testing

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resulted in negligible differences between 5-year samples and the control samples. Thus, the oxidation had no discernable impact on the strength or electrical performance of the wire.

An accelerated corrosion study based on ASTM B117 was conducted on bare CCS and solid Copper wires to evaluate copper surface corrosion. The wires were exposed to salt fog spray for 504 hours. As a result, corrosion on the CCS copper surface showed no significant difference as compared to the corrosion of copper wire.



(a) Copper Clad Steel (b) Copper

Figure 2: Patination of Copper Surface after 504 hours exposure to Salt Fog Spray

In February 2011, three separate sample strands of Copper Clad Steel were un-earthed and cut out from a substation built in Louisville, KY. The conductors were 40% conductivity, Low Carbon Steel, Dead Soft Annealed, 7 No. 5 (231,613 circular mil) and were installed in 1962.

Table 1: Physical properties of the three strands of Copperweld® conductor that had been buried underground for 48 years in a Kentucky substation

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			Strand 1	Strand 2	Strand 3
Conductor Type			40% Low Carbon Annealed		
Conductor Size			7 No. 5		
Cross Section Area		in^2	0.1819	0.1819	0.1819
Diameter of Single end		*inch*	0.1819	0.1819	0.1819
Diameter of Conductor		*inch*	0.5457	0.5457	0.5457
Copper Thickness	Min	*inch*	0.0142	0.0114	0.0134
	Max	*inch*	0.0213	0.0209	0.01975
% Concentricity			83.30%	77.30%	83.90%
Depth of corrosion	Min	*inch*	0.004	0.028	0.111
	Max	*inch*	0.781	0.859	0.484

The 1962 conductors were manufactured by Copperweld with a nominal copper thickness of 10% of its diameter. Figure 3 shows the copper thickness ranges from 11.4 – 21.3 mils and the concentricity of the conductor averaged at 81.5%. Current manufacturing improvements yield concentricity of copper thickness above 85%.

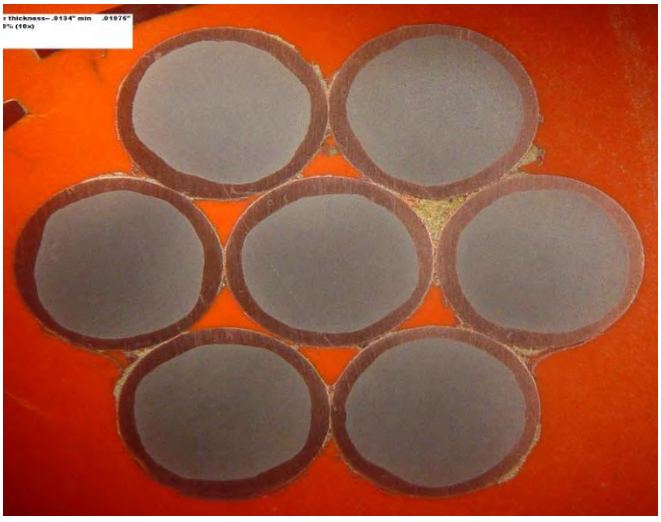


Figure 3: Copperweld® 40% LC DSA 7 No. 5 manufactured in 1962

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Figure 4a shows no visible corrosion observed other than oxidation and patination on the copper surface. At the ends of the wires, the corrosion occurred in the form of steel rust. The maximum depth of the corrosion is 0.859 inch with an average of 0.382 inch, as shown in Figure 4b.



Figure 4a: There is no visible corrosion between the copper and steel on all wires obtained from the substation in Kentucky.



Figure 4b: Corrosion occurred at the ends of the wires. Maximum penetration depth is 0.859 inch.

From all the corrosion studies above, there have not been reported or observed any galvanic corrosion at the interface of copper and steel. The process of cladding for

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Copperweld® ensures a metallurgical bond between the two metals. That metallurgical bond prevents any moisture from penetrating between the two metals precluding the corrosion process. Any propagation of corrosion on an area of exposed steel averages two times the diameter of the wire then stops. The corrosion rate of the copper surface is equivalent to that observed on standard solid copper wire and strand. Based on the results of these studies, it can be summarized that CCS can be expected to have a 50 plus year service life as buried grounding conductors.

REFERENCES:

1. Rempe, Chris. 7 July 2003. "A Technical Report on the Service Life of Ground Rod Electrodes".
2. Fox, Dustin, Belado, Chris, and Brossia, Sean. 23 September 2009. "The Effect of Corrosion on Tracer Wire with a Copper Clad Steel Center Conductor".

Powertech

Report ID: PL-03027 REP1
Revision: 0 Issued: 2020-04-15

Copper and CCS Wire Withstand Current and Fusing Current Tests

Copperweld Bimetallics, LLC



The Power of Trust. **The Future of Energy.**

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REPORT OF PERFORMANCE

CLIENT	Copperweld Bimetallics,LLC. 5141 Virginia Way, Suite 410 Brentwood, TN, United States 37027
TEST OBJECTS	Copper Clad Steel (CCS) Wires Manufacturer: Copperweld Bimetallics,LLC. Types: Scorpius Prototypes Part Nos.: 61 x 072 7 x 080 Condition: New Copper Conductor Manufacturer: Encore Wire Types: #4/0 AWG (19 strand) CU #6 AWG (single strand) CU Condition: New
TESTED BY	Powertech Labs Inc. 12388 - 88th Ave, Surrey, BC Canada V3W 7R7 www.powertechlabs.com
TEST DATE	2020-01-24 to 2020-01-25
TEST SPECIFICATION	Client Specified, with reference to IEEE Std 80-2013 and IEEE Std 837-2014

Powertech Labs Inc. does not accept any liability for any damages resulting from the use of this report. The results relate only to the item tested, and it is the responsibility of the manufacturer to maintain conformity of any object having the same designations. Information regarding the estimated measurement uncertainty is available upon request. The test report shall not be reproduced except in full, without written approval of Powertech Labs Inc.

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1 INTRODUCTION

At the request of Copperweld Bimetallics,LLC., withstand current and fusing current tests were performed on standard copper and copper clad steel (CCS) wires in accordance with specifications and procedures provided by the client. Reference was made to IEEE Std 80-2013 and IEEE Std 837-2014 as guides for determining current levels and durations for the tests.

The High Power Lab is accredited by the Standards Council of Canada to ISO 17025 for short-circuit testing.

2 TEST OBJECT INFORMATION

The test objects were identified by the client as follows:

Copper Clad Steel Wires (CCS)

Manufacturer:	Copperweld Bimetallics,LLC.
Types:	Scorpius Prototypes
Part Nos.:	61 x 072
	7 x 080
Condition:	New

Copper Conductor

Manufacturer:	Encore Wire
Types:	4/0 AWG (19 strand) CU
	#6 AWG (single strand) CU
Condition:	New

Conductor sample diameters and dc resistance values were measured by the laboratory before testing, as presented in Table 1.

3 GENERAL INFORMATION

3.1 Purpose

The purpose of the tests is to identify the current limits at short durations for standard copper and Copperweld CCS grounding wire products, and to determine if these products meet the applicable requirements of the referenced Standards.

3.2 Witnesses

Name	Company
Jeff Jordan	Copperweld Bimetallics,LLC.
Lora Aboulmouna	Copperweld Bimetallics,LLC.
Jason Smolko	Copperweld Bimetallics,LLC.
Ryan Hale	Copperweld Bimetallics,LLC.

3.3 Tests Performed

Test Standards/Specifications:

Withstand current tests were performed as requested by the client, with reference to the following Standards to determine the test levels:

IEEE Std 80-2013, Table 6 – Specification for the ultimate current carrying capacity of copper grounding cables using symmetrical current.

IEEE Std 837-2014, Clause 7.2 and Table 3 – Electromagnetic force (EMF) test

4 SHORT-CIRCUIT CURRENT TESTS

General Information:

Standard	Client's Specification, with reference to IEEE Std 80-2013 and IEEE Std 837-2014
Test Dates	2020-01-24 to 2020-01-25
Test Leader	Chris Morton

Environmental Conditions:

Ambient temperature	(7 – 9) °C
Relative Humidity	(95 – 99) %

Test Conditions:

Samples were tested in a covered test cell which was open on one side to the outdoor ambient conditions. During each test, one sample was connected horizontally between the laboratory source bus and ground bus, at a bus spacing of 48 inches, as shown in Figures 30 through 33. The samples were terminated using Burndy mechanical connectors, as shown in Figures 34 and 35. The length of each wire sample was the minimum length required to span the distance between the buses, and each sample was at approximately right angles (90°) to both the source and ground bus. Each sample was suspended in free air approximately 46 inches above the floor of the test cell. The temperature of the sample at the start of each test was the natural outdoor ambient temperature of the laboratory, except for tests performed to IEEE 837, where the sample was allowed to cool to less than 100 °C before the second shot.

All tests were performed at a power frequency of 60 Hz using the test circuit shown in Figure 1. Current was initiated by energizing a current limited source that was calibrated to provide the target current through the circuit. The rms current, current symmetry and duration of each test were specified by the client.

The test current was measured using a 300 kA_{peak} rated Rogowski coil (Powertech ID № 39444). The expanded uncertainty of the current measuring system is estimated as 2% (k=2).

Test Results:

The results of the tests are provided in Tables 2 through 5. Current and voltage waveforms for each test are provided in Figures 2 through 29.

The Encore #4/0 AWG Cu wire did not withstand the I^2t calculated from the current and duration specified in IEEE 80, Table 6, for a 500 ms duration (44 kA_{rms}). It was capable of carrying a maximum of 92% of this I^2t value without fusing.

The Encore #4/0 AWG Cu wire did not withstand the EMF current specified in IEEE 837, Table 3 (47 kA_{rms}). It was capable of carrying a maximum of 91% of this current value without failing.

The Copperweld Scorpius CCS 61 x 072 conductor exceeded the 500 ms rms withstand current requirement of IEEE 80, Table 6, and met the EMF current requirements of IEEE 837, Table 3, for a 4/0 conductor.

For the #6 AWG Cu conductor size the Standards did not have current values specified, so these were calculated using Equation (45) from IEEE 80 and Equation (C.1) from IEEE 837. The calculations are presented in Appendix D.

Both the Copperweld Scorpius CCS 7 x 080 conductor and the Encore #6 AWG Cu conductor met the 500 ms rms withstand current requirement of IEEE 80, Table 6 (5.29 kA_{rms}), and the EMF current requirements of IEEE 837, Table 3 (5.81 kA_{rms}), for a #6 AWG Cu conductor.

APPENDIX A – FUSING CURRENT TEST CIRCUIT AND DATA

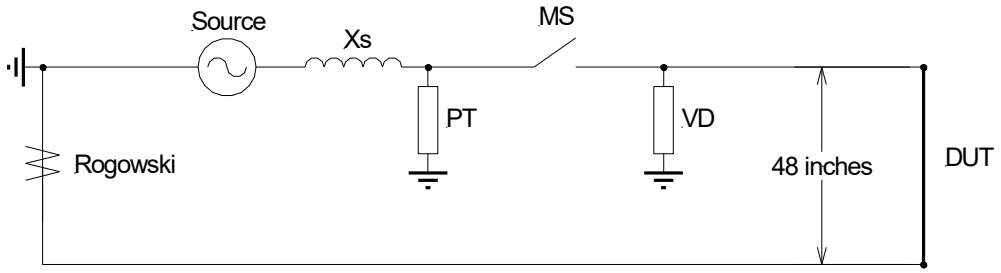


Figure 1: Test circuit schematic for all tests.

Notes:

1. X_S – Source current limiting reactance
2. MS – Making Switch
3. VD – Voltage measurement
4. Rogowski – Current measurement
5. DUT – Device Under Test

Table 1: Strand diameter and dc resistance measurements of sample conductors.

Wire Sample No.	Type	Strand Diameter [1] (in)		Conductor Diameter	Dc Resistance at 20°C
#		1	2	(in)	(μΩ/ft)
1	Encore Wire, 4/0 AWG, 19 strand CU	0.122	0.079	0.492	4.28
2	Encore Wire, 4/0 AWG, 19 strand CU	0.118	0.080	0.501	4.10
3	Encore Wire, 4/0 AWG, 19 strand CU	0.109	0.074	0.495	4.23
4	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.075	0.498	3.98
5	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.079	0.489	4.43
6	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.075	0.490	4.17
7	Encore Wire, 4/0 AWG, 19 strand CU	0.101	0.075	0.489	4.18
8	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.074	0.491	4.15
9	Encore Wire, 4/0 AWG, 19 strand CU	0.106	0.082	0.490	3.97
10	Encore Wire, 4/0 AWG, 19 strand CU	0.105	0.079	0.493	3.73
11	Scorpius 61 x 072 CCS	0.056	---	0.646	6.83
12	Scorpius 61 x 072 CCS	0.058	---	0.649	6.60
13	Scorpius 61 x 072 CCS	0.068	---	0.641	6.60
14	Scorpius 61 x 072 CCS	0.056	---	0.639	6.73
15	Scorpius 61 x 072 CCS	0.067	---	0.646	6.62
16	Scorpius 61 x 072 CCS	0.059	---	0.630	6.53
17	Scorpius 61 x 072 CCS	0.056	---	0.642	6.73
18	Scorpius 61 x 072 CCS	0.067	---	0.637	6.62
19	Scorpius 61 x 072 CCS	0.064	---	0.641	6.85
20	Scorpius 61 x 072 CCS	0.059	---	0.633	6.83
21	Encore Wire, #6 AWG, single strand CU	0.152	---	0.152	33.3
22	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
23	Encore Wire, #6 AWG, single strand CU	0.158	---	0.158	33.2
24	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.4
25	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.3
26	Encore Wire, #6 AWG, single strand CU	0.148	---	0.148	33.6
27	Encore Wire, #6 AWG, single strand CU	0.155	---	0.155	33.3
28	Encore Wire, #6 AWG, single strand CU	0.146	---	0.146	33.1
29	Encore Wire, #6 AWG, single strand CU	0.153	---	0.153	33.2
30	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
31	Scorpius 7 x 080 CCS	0.072	---	0.215	46.3
32	Scorpius 7 x 080 CCS	0.069	---	0.226	45.9
33	Scorpius 7 x 080 CCS	0.065	---	0.220	46.2
34	Scorpius 7 x 080 CCS	0.071	---	0.218	46.4
35	Scorpius 7 x 080 CCS	0.073	---	0.212	46.1
36	Scorpius 7 x 080 CCS	0.065	---	0.216	46.3
37	Scorpius 7 x 080 CCS	0.070	---	0.211	46.1

Note:

[1] Encore 4/0 AWG CU conductor had two sizes of strands, all remaining conductors had one size of strands. Strand and conductor diameters were measured using a digital caliper with a resolution of 0.001 in.

Table 2: Summary of tests on Encore 4/0 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
1	1	Run to fusing	3.85	41.7	60.0	530	923	2	Y
2	2	Withstand	3.85	41.8	62.5	509	889	3	N
3-1	3	EMF (IEEE 837)	4.24	48.0	130	262	826	4	N
3-2	3	EMF (IEEE 837)	4.26	48.0	130	127	503	5	Y
4	4	EMF (IEEE 837)	4.25	48.0	130	260	823	6	Y
5-1	5	EMF (IEEE 837)	4.20	47.4	129	262	808	7	N
5-2	5	EMF (IEEE 837)	4.19	47.4	128	9.9	77	8	Y
6-1	6	EMF (IEEE 837)	3.93	42.6	116	263	662	9	N
6-2	6	EMF (IEEE 837)	3.91	42.6	116	262	654	10	N

Table 3: Summary of tests on Copperweld Scorpius 61 x 072 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
7	11	Run to fusing	3.84	41.7	59.6	673	1173	11	Y
8	12	Run to fusing	4.25	48.1	69.8	500	1157	12	Y
9	13	Run to fusing	4.21	47.5	68.9	508	1150	13	Y
10	14	Withstand	4.09	46.2	66.2	508	1089	14	N
11-1	15	EMF (IEEE 837)	4.21	47.6	129	262	803	15	N
11-2	15	EMF (IEEE 837)	4.20	47.7	129	262	803	16	N
12-1	16	EMF (IEEE 837)	4.21	47.6	129	254	784	17	N
12-2	16	EMF (IEEE 837)	4.19	47.4	128	254	767	18	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

Table 4: Summary of tests on Encore #6 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
13	21	Run to fusing	3.90	5.18	7.36	607	16.3	19	Y
14	23	Run to fusing	3.90	5.18	7.57	600	16.1	20	Y
15	24	Run to fusing	4.27	5.68	8.15	500	16.1	21	Y
16-1	25	EMF (IEEE 837)	3.77	5.86	16.2	262	13.9	22	N
16-2	25	EMF (IEEE 837)	3.77	5.86	16.1	262	13.9	23	N

Table 5: Summary of tests on Copperweld Scorpius 7 x 080 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
17	31	Withstand	3.88	5.16	7.44	858	22.9	24	N
18	32	Run to fusing	3.89	5.16	7.43	908	24.2	25	Y
19	33	Run to fusing	4.48	7.00	10.3	493	24.1	26	Y
20	34	Run to fusing	4.41	6.91	10.2	502	23.9	27	Y
21-1	35	EMF (IEEE 837)	3.81	5.91	16.3	262	14.0	28	N
21-2	35	EMF (IEEE 837)	3.80	5.92	16.2	262	13.8	29	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

APPENDIX B – WAVEFORMS

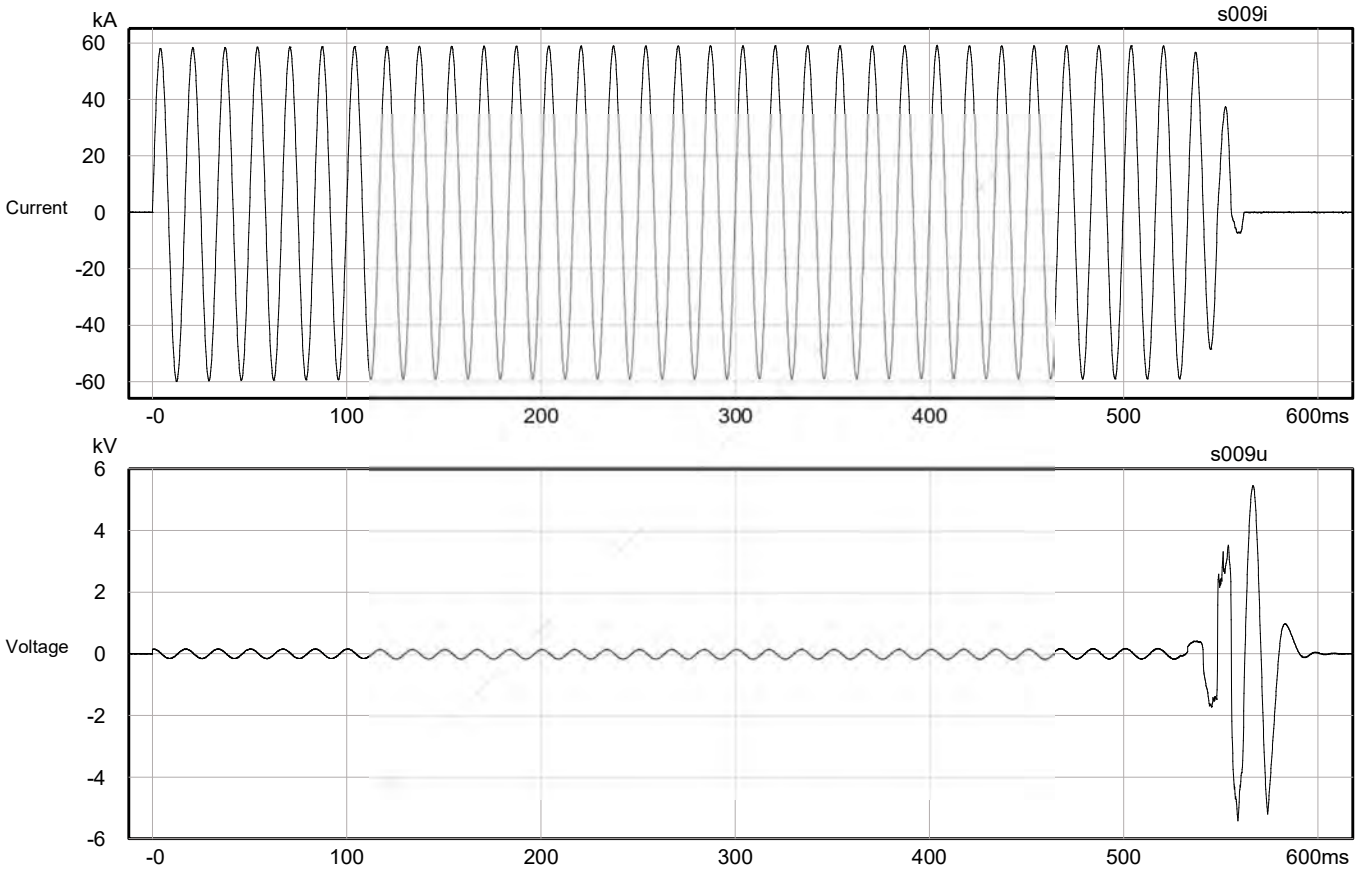


Figure 2: Waveforms for Test #1, Encore 4/0 AWG Sample 1.

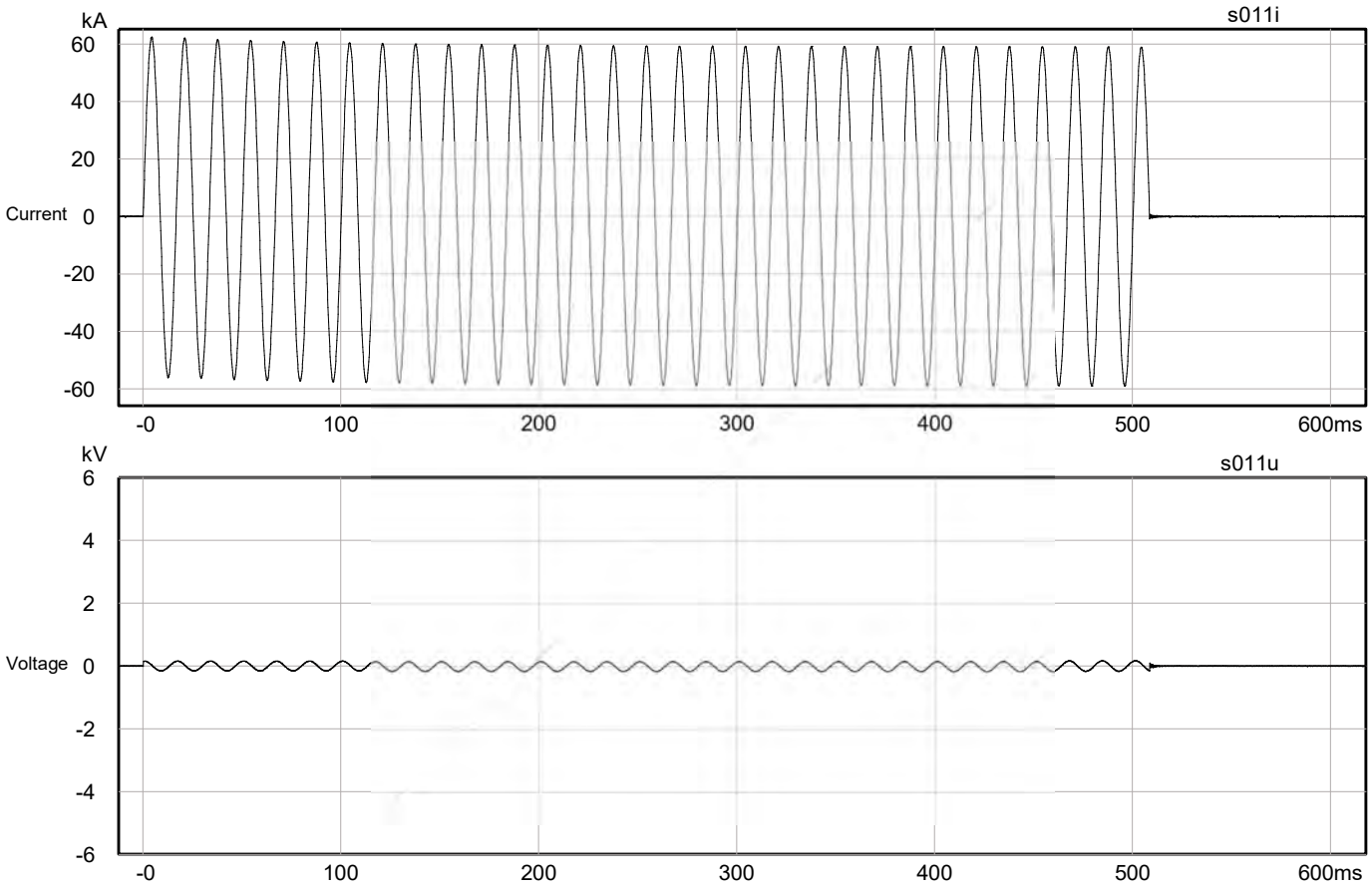


Figure 3: Waveforms for Test #2, Encore 4/0 AWG Sample 2.

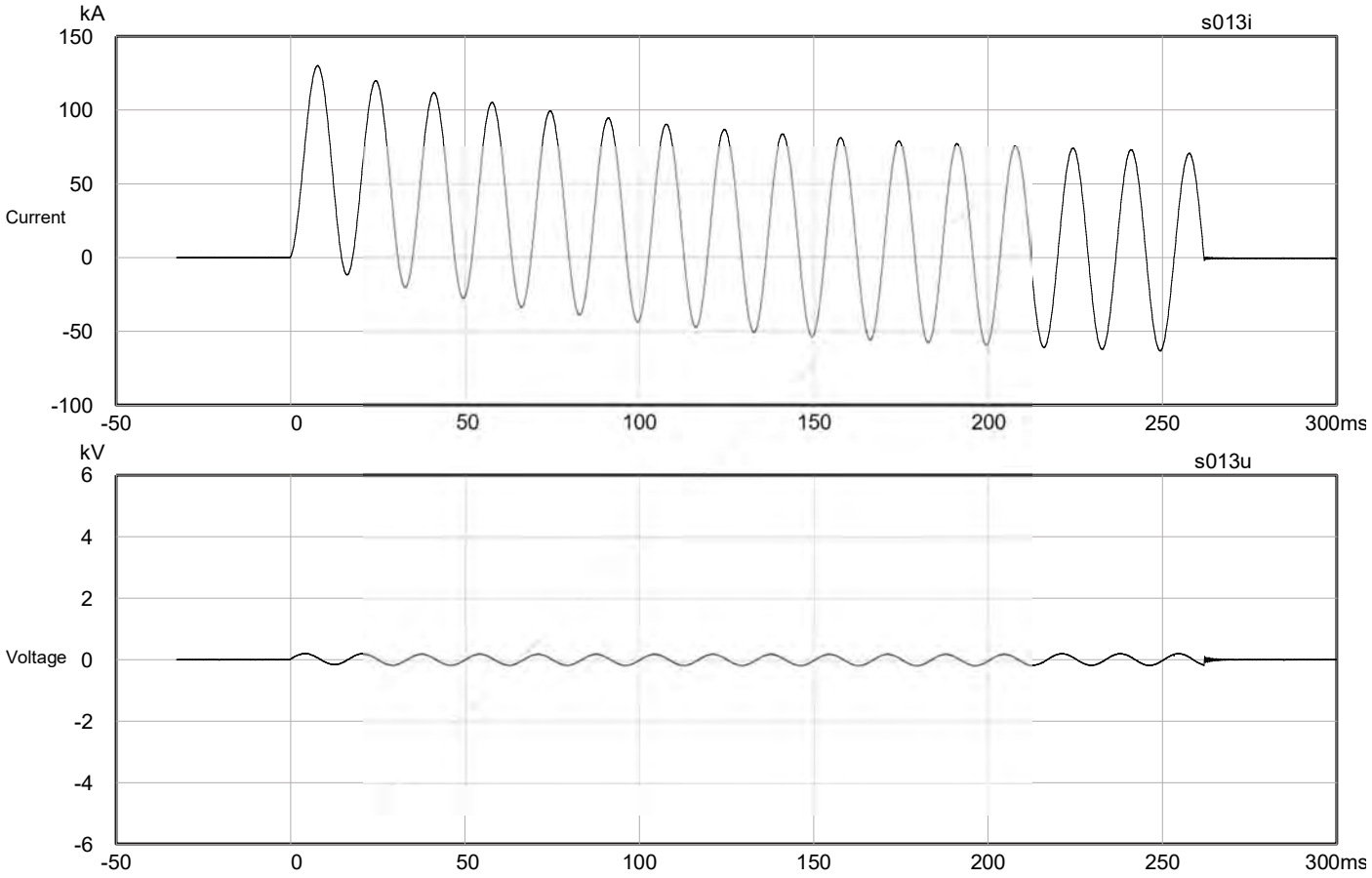


Figure 4: Waveforms for Test #3-1, Encore 4/0 AWG Sample 3.

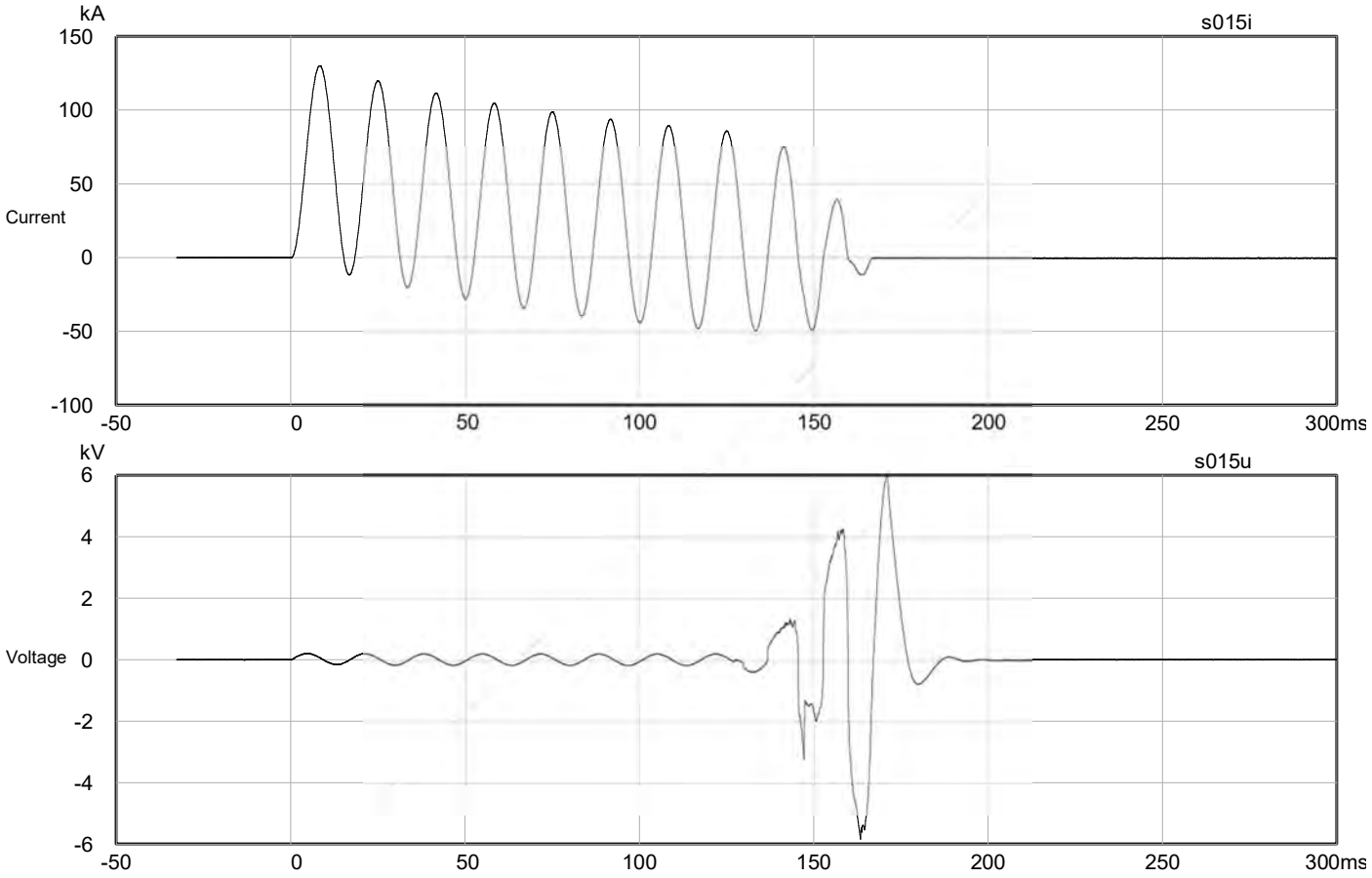


Figure 5: Waveforms for Test #3-2, Encore 4/0 AWG Sample 3.

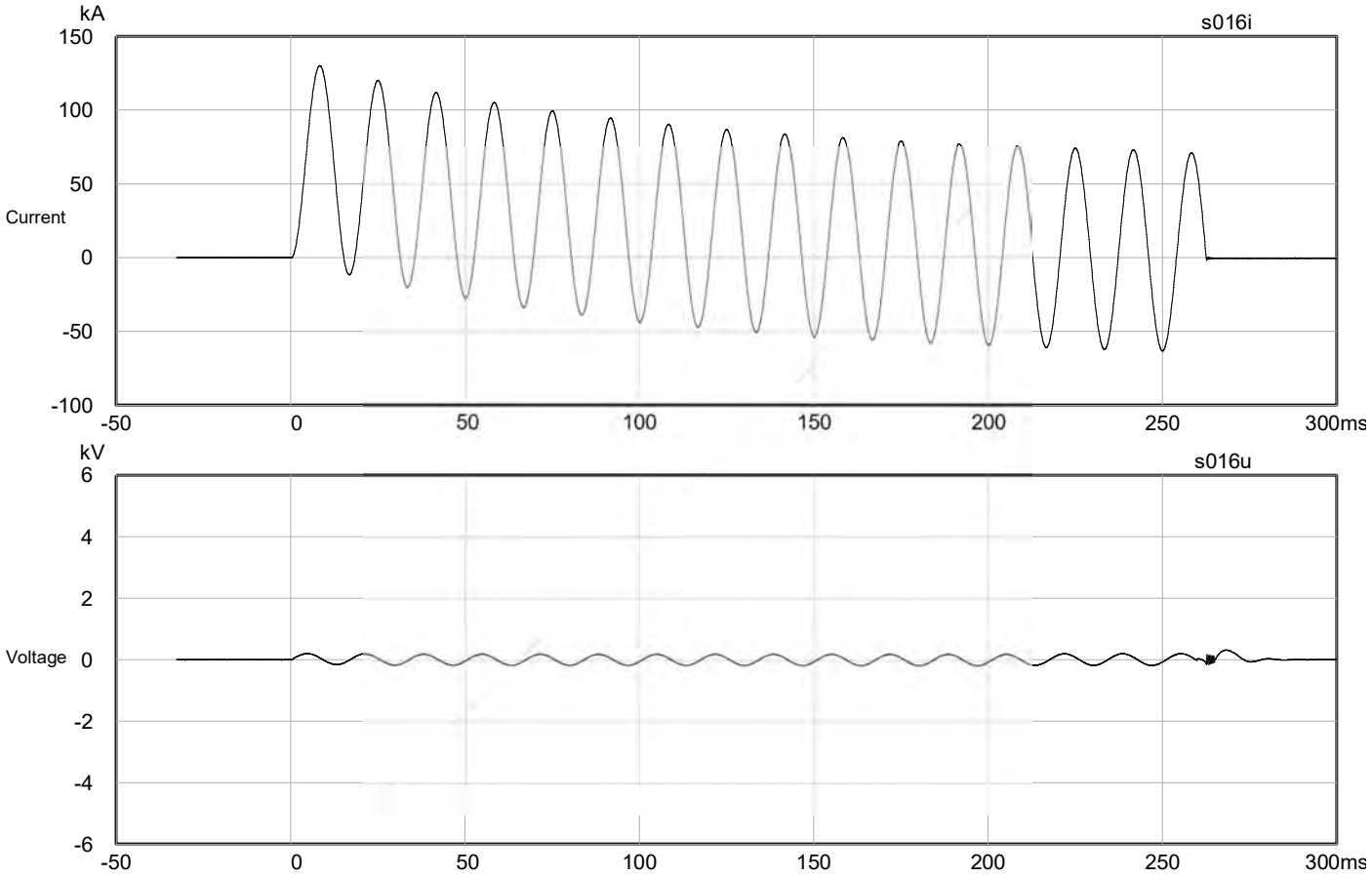


Figure 6: Waveforms for Test #4, Encore 4/0 AWG Sample 4.

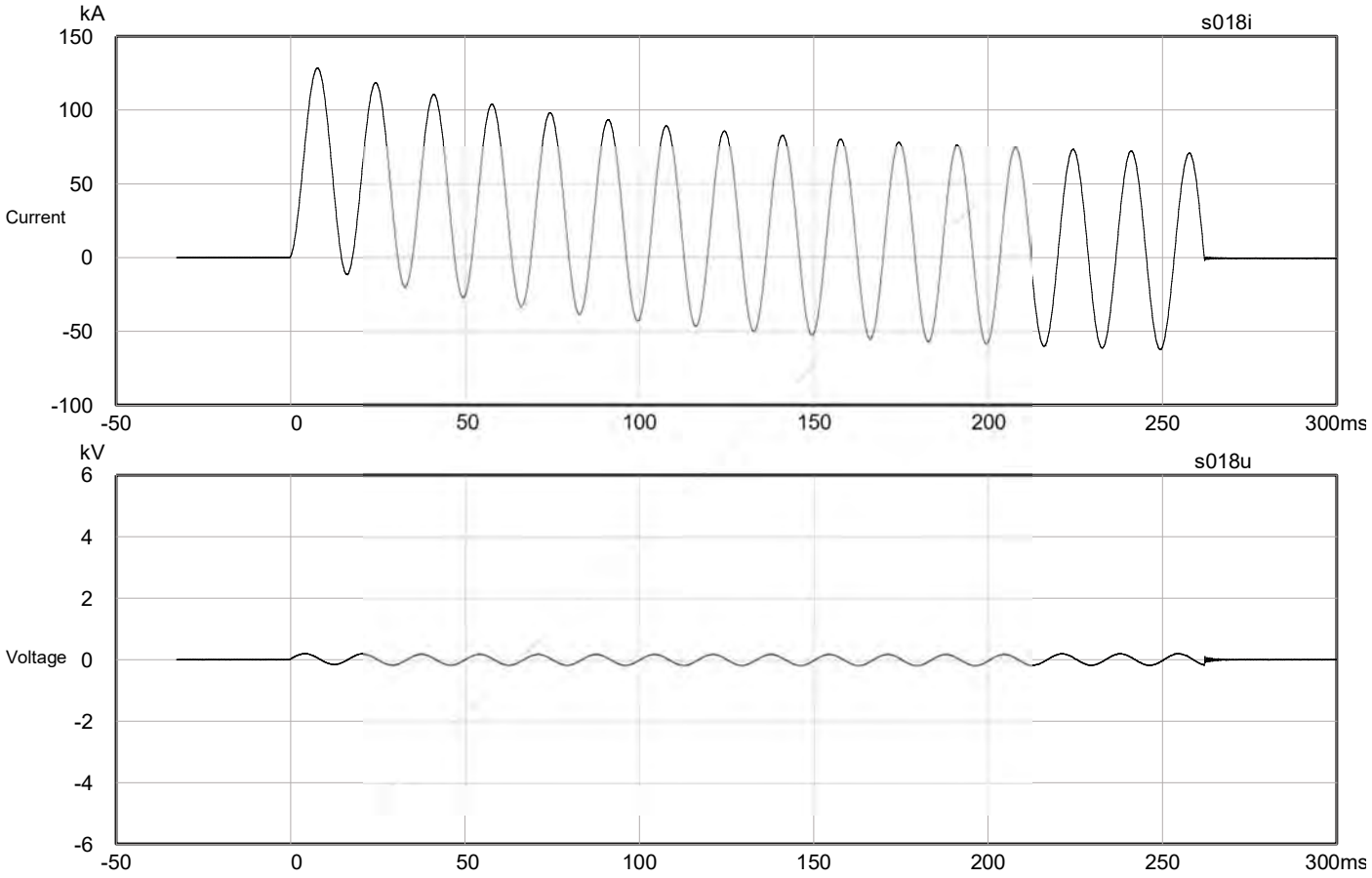


Figure 7: Waveforms for Test #5-1, Encore 4/0 AWG Sample 5.

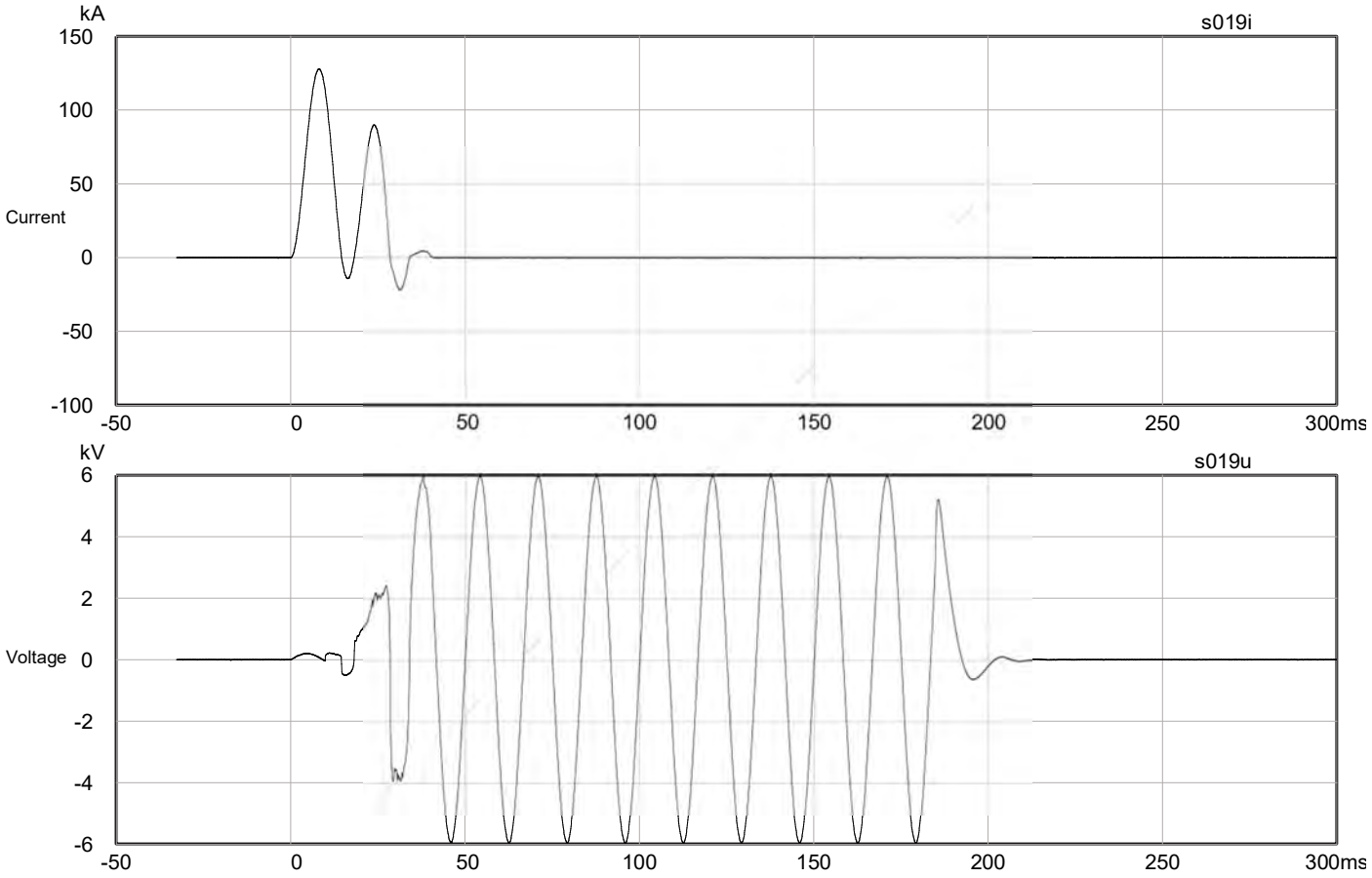


Figure 8: Waveforms for Test #5-2, Encore 4/0 AWG Sample 5.

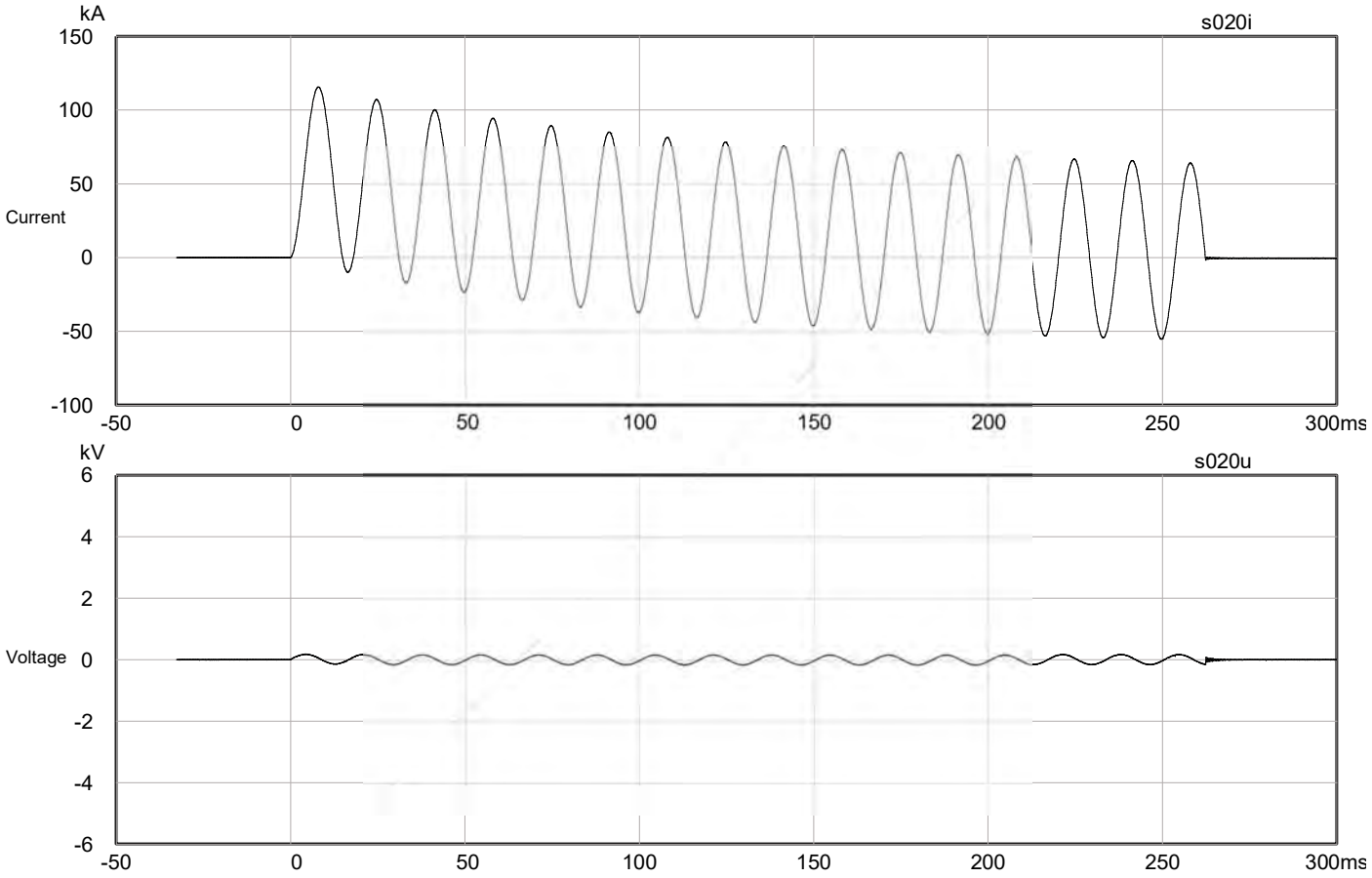


Figure 9: Waveforms for Test #6-1, Encore 4/0 AWG Sample 6.

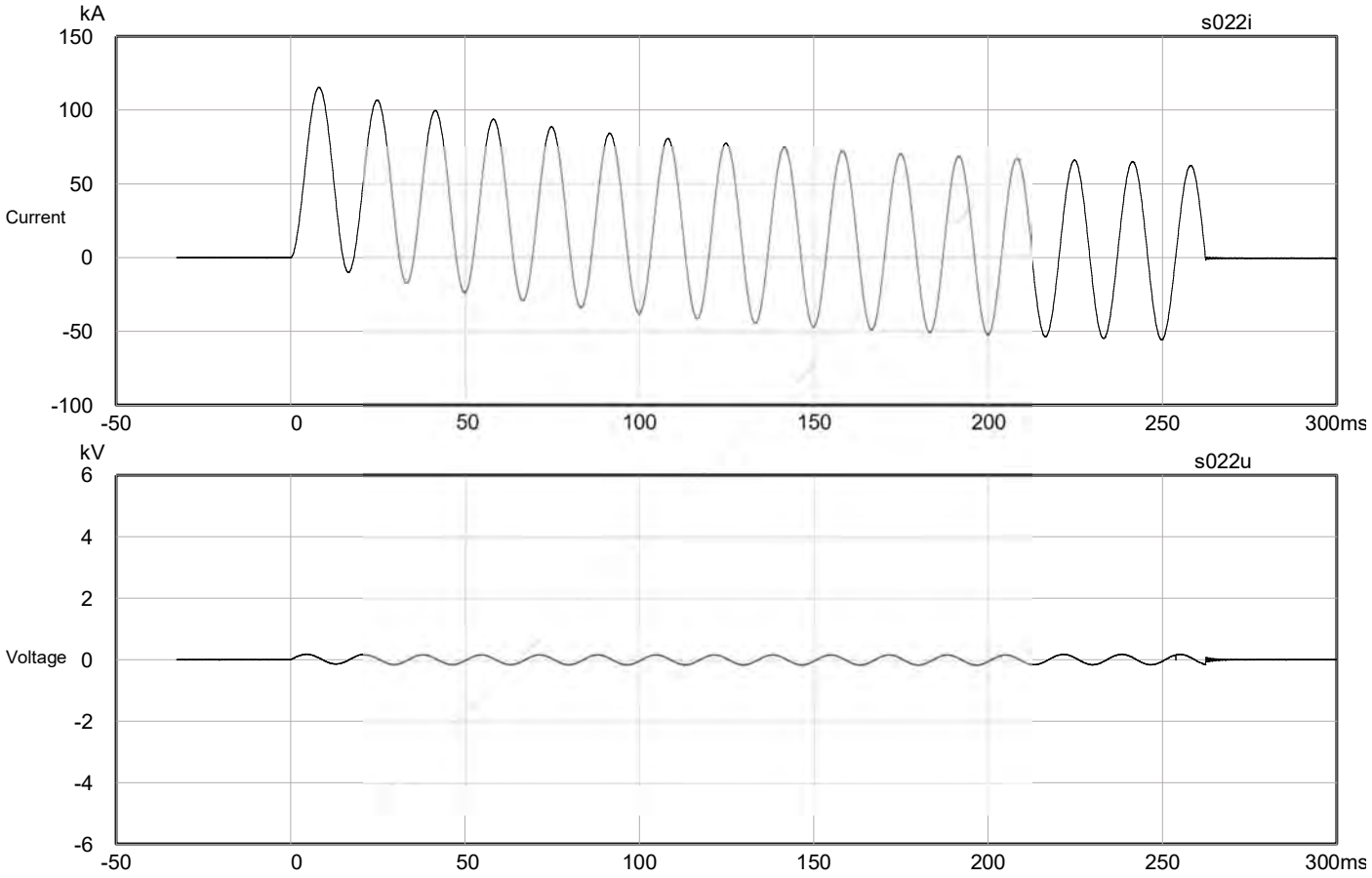


Figure 10: Waveforms for Test #6-2, Encore 4/0 AWG Sample 6.

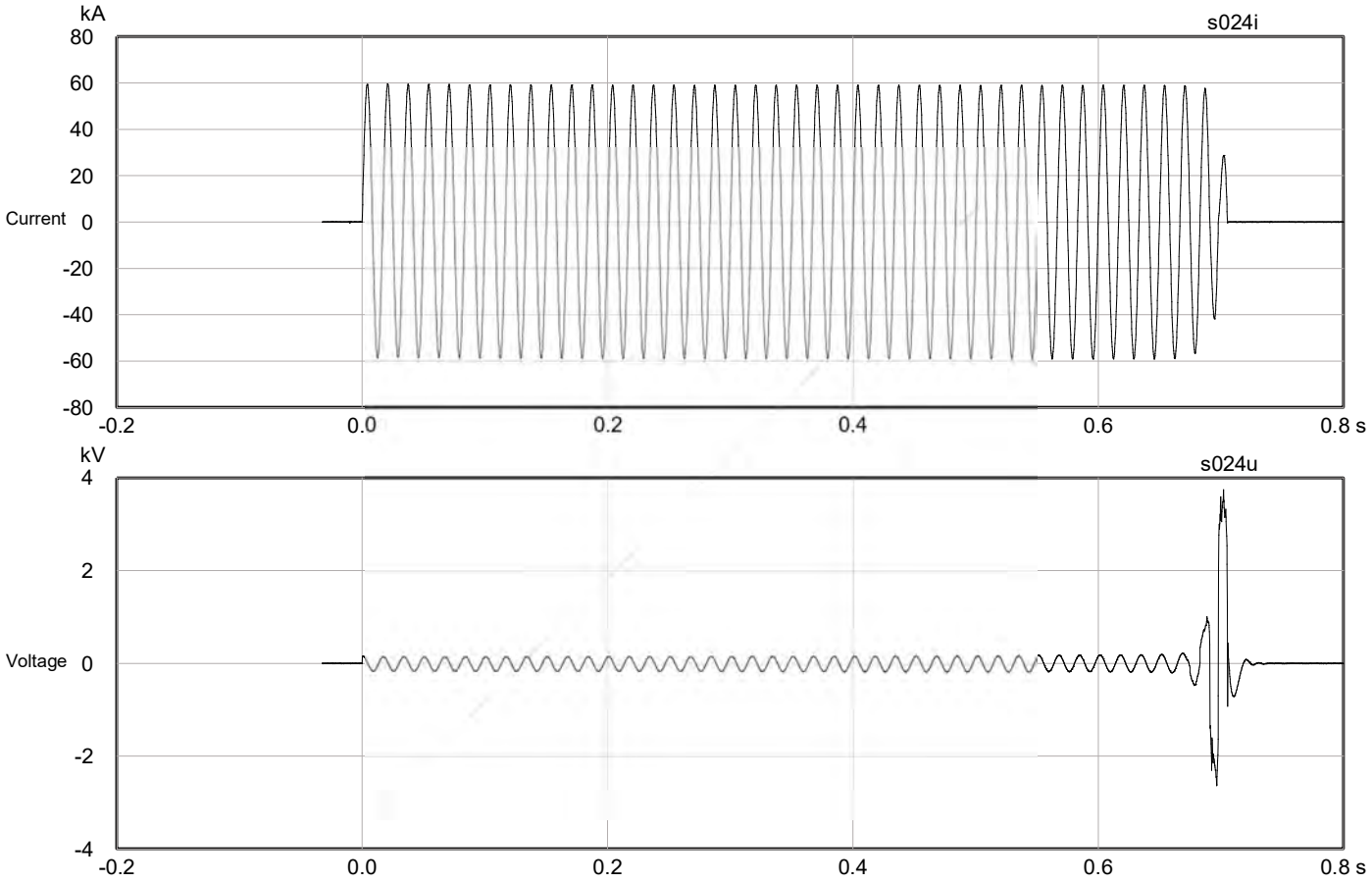


Figure 11: Waveforms for Test #7, Copperweld Scorpius 61 x 072 Sample 11.

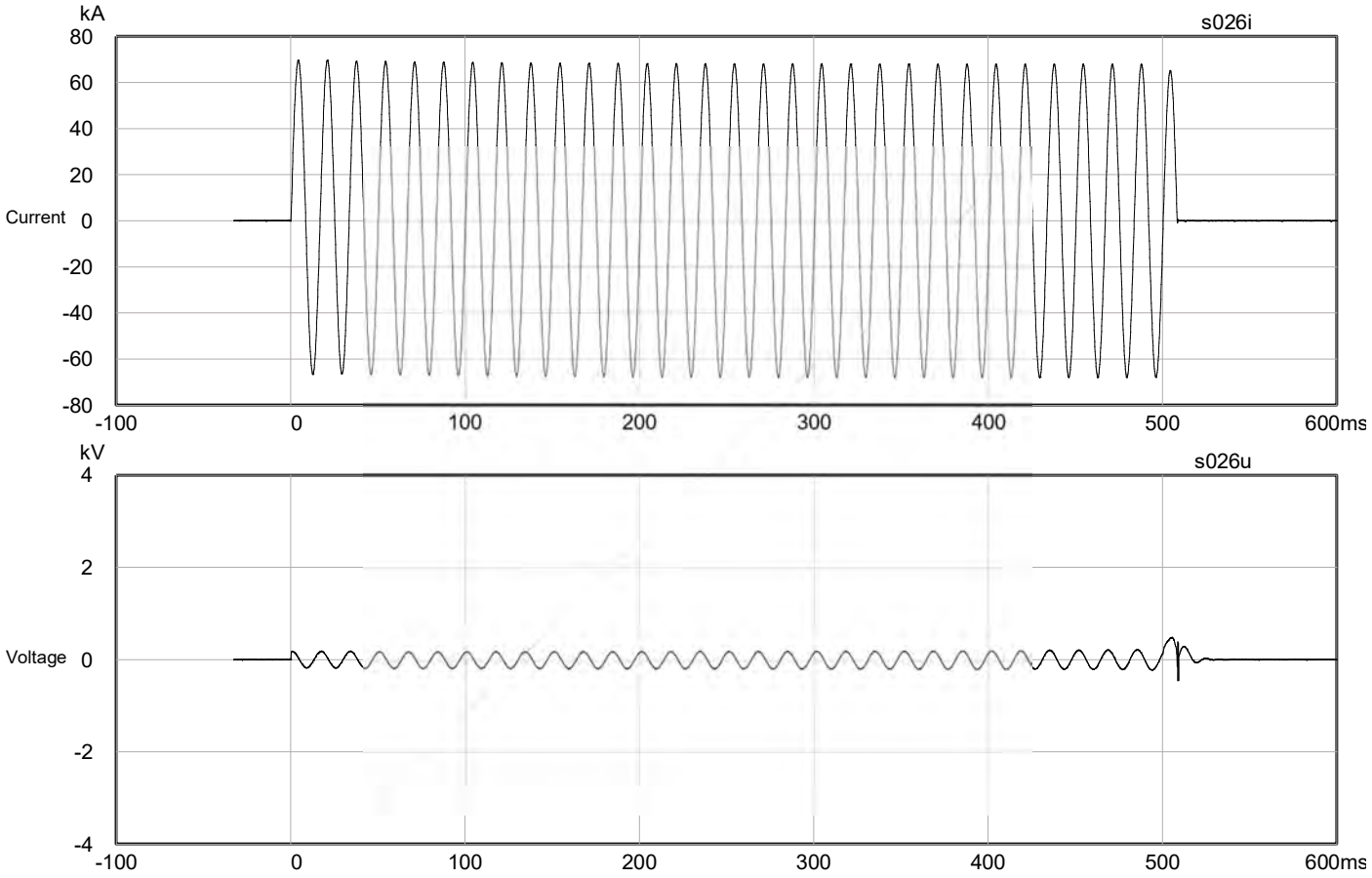


Figure 12: Waveforms for Test #6, Copperweld Scorpius 61 x 072 Sample 12.

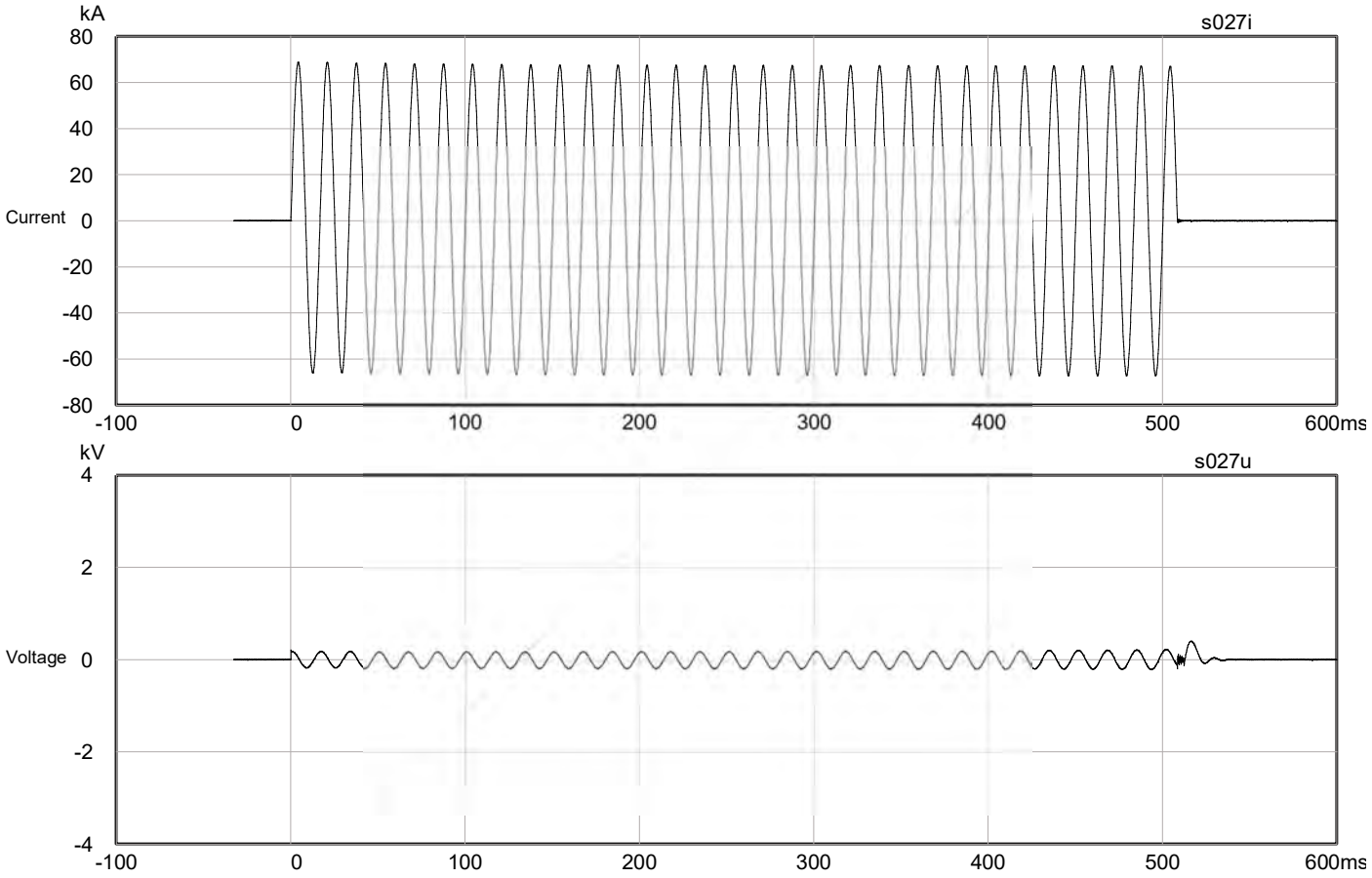


Figure 13: Waveforms for Test #9, Copperweld Scorpius 61 x 072 Sample 13.

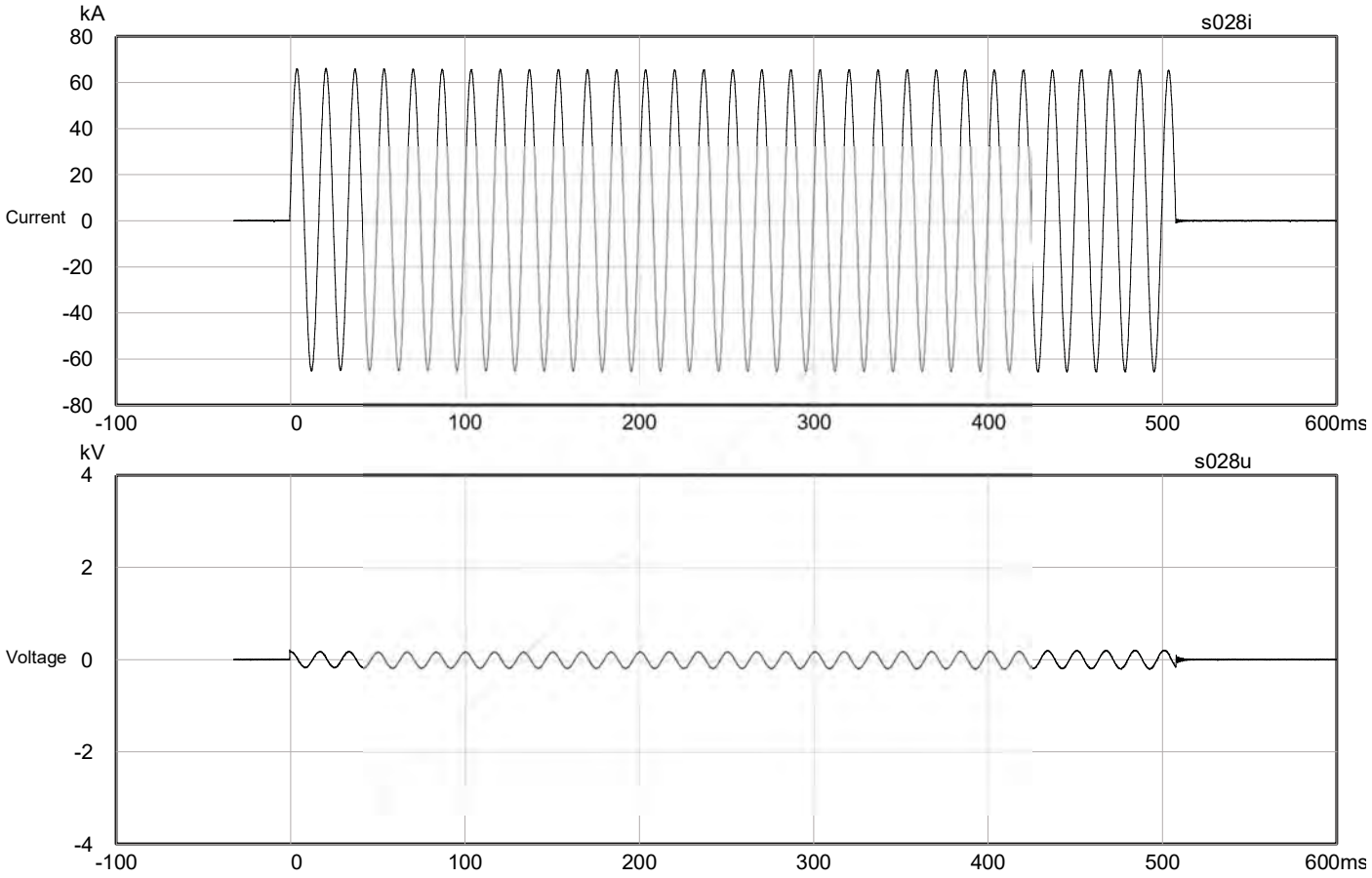


Figure 14: Waveforms for Test #10, Copperweld Scorpius 61 x 072 Sample 14.

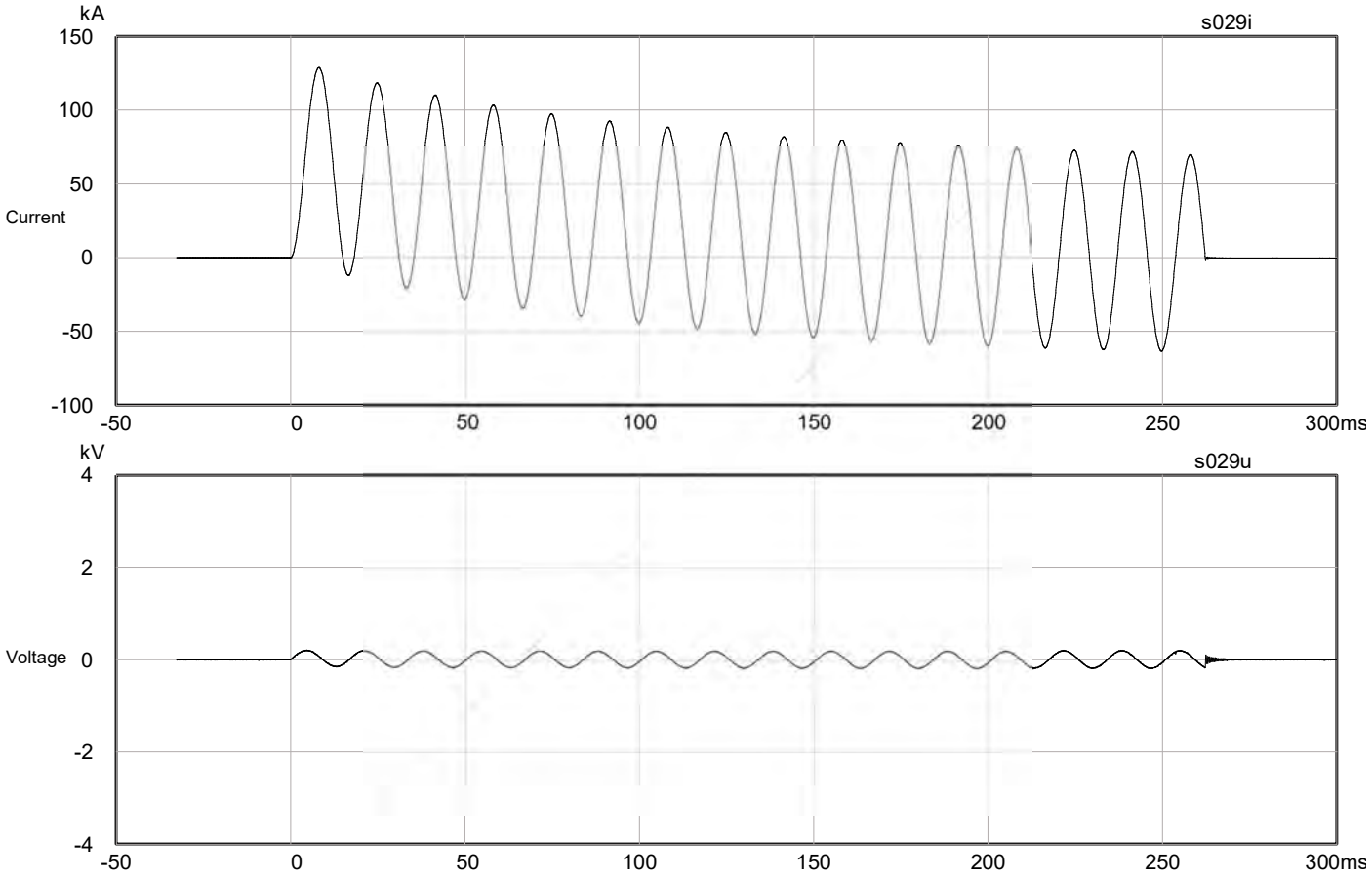


Figure 15: Waveforms for Test #11-1, Copperweld Scorpius 61 x 072 Sample 15.

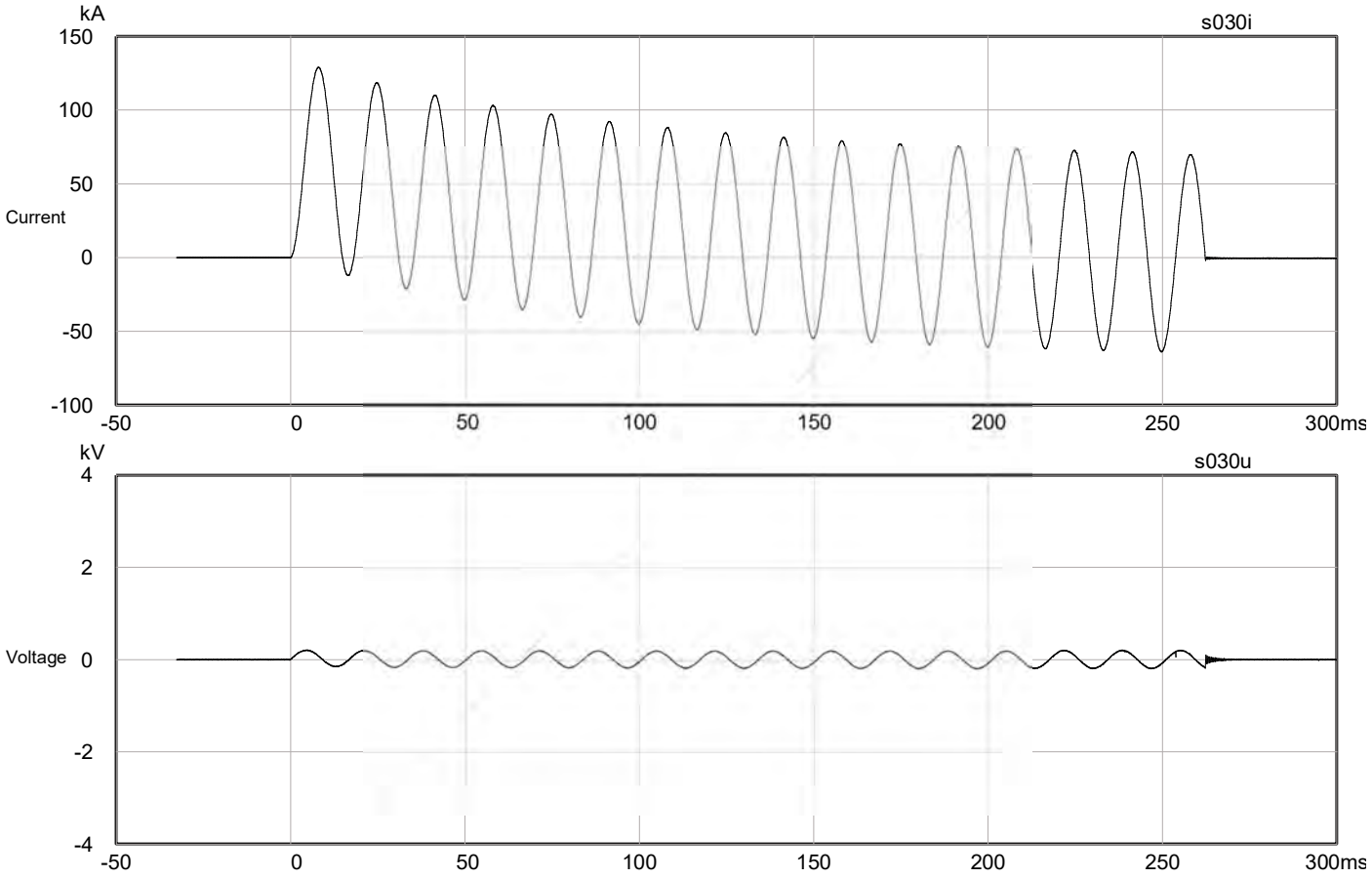


Figure 16: Waveforms for Test #11-2, Copperweld Scorpius 61 x 072 Sample 15.

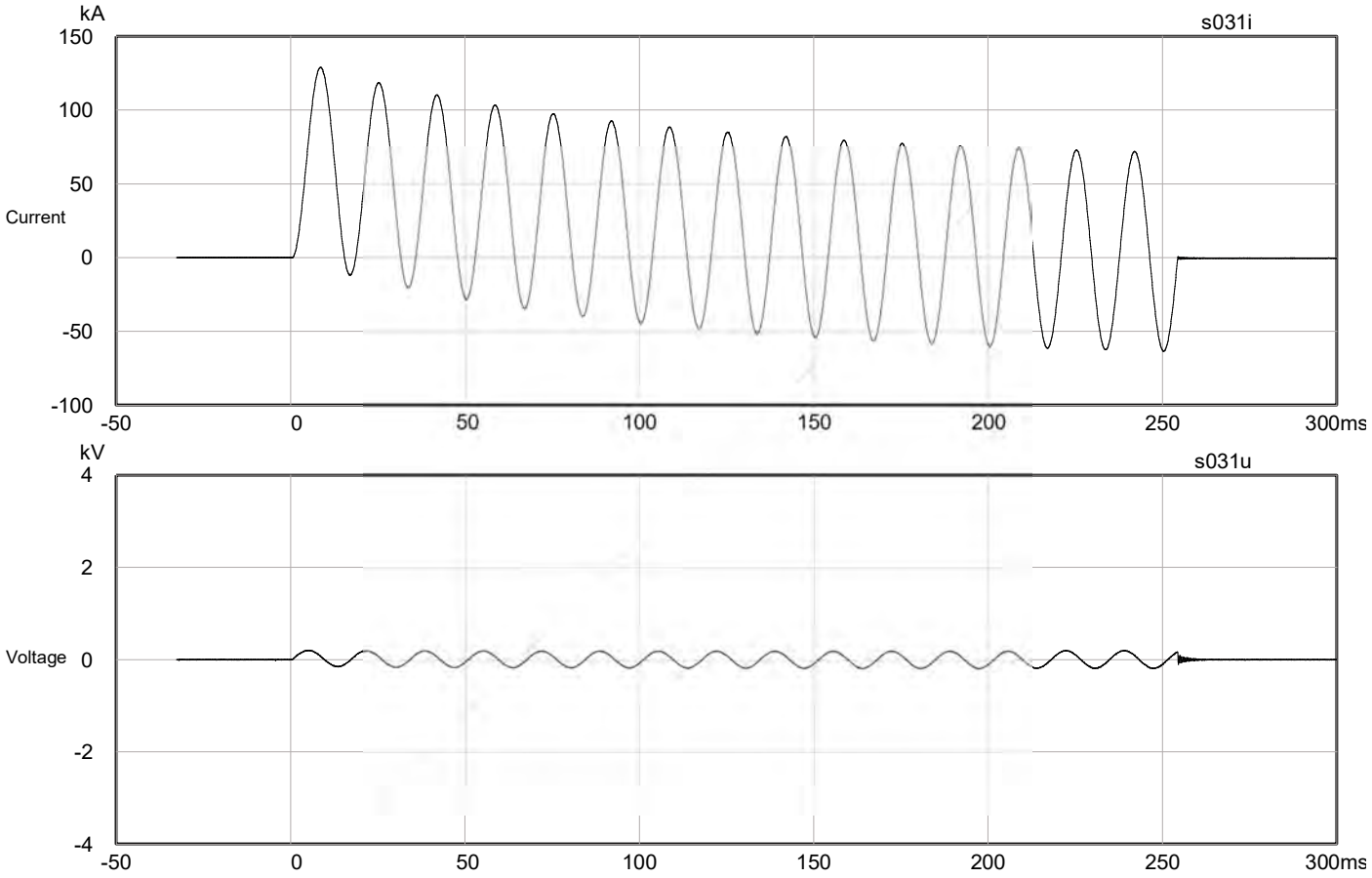


Figure 17: Waveforms for Test #12-1, Copperweld Scorpius 61 x 072 Sample 16.

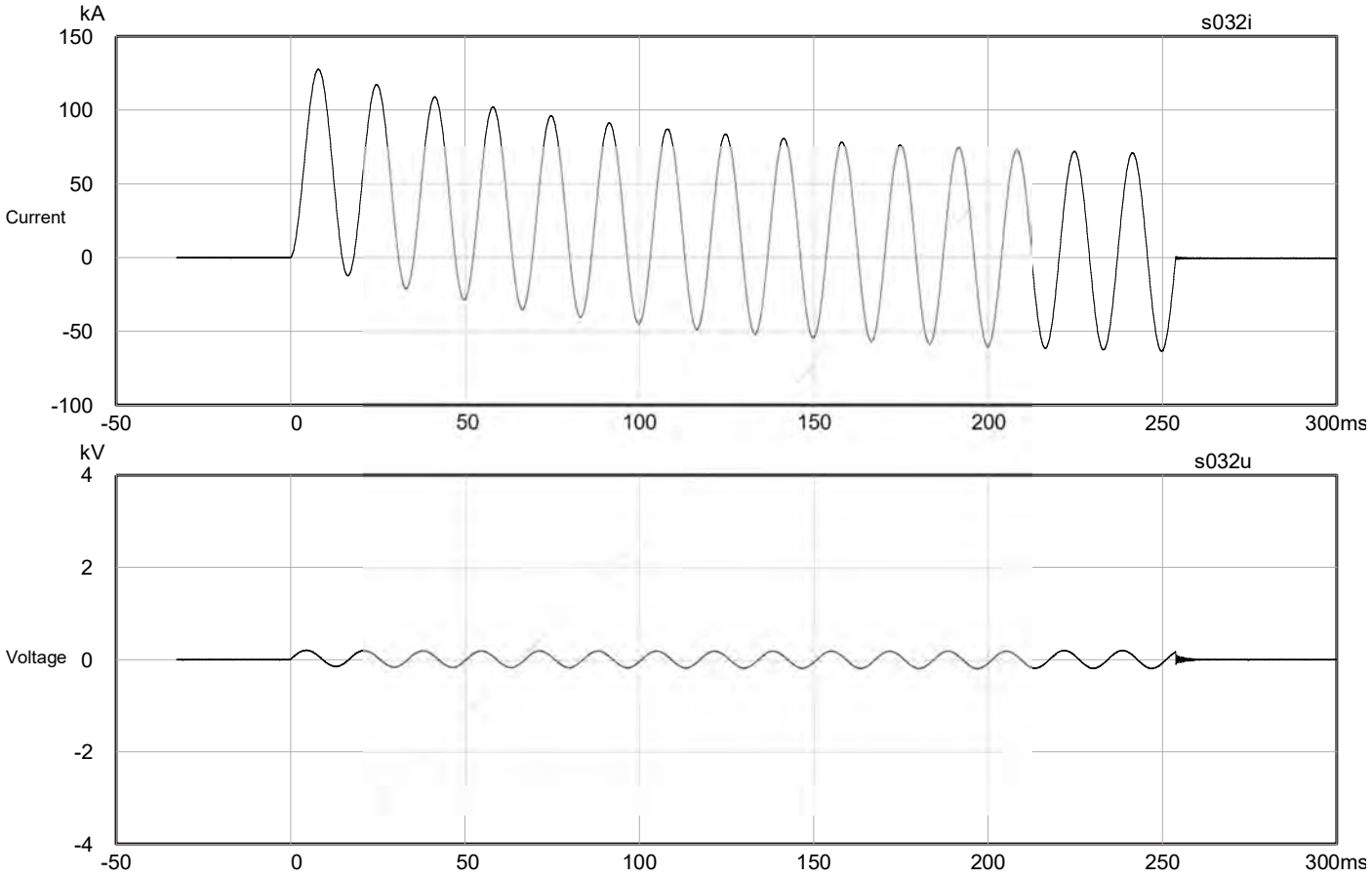


Figure 18: Waveforms for Test #12-2, Copperweld Scorpius 61 x 072 Sample 16.

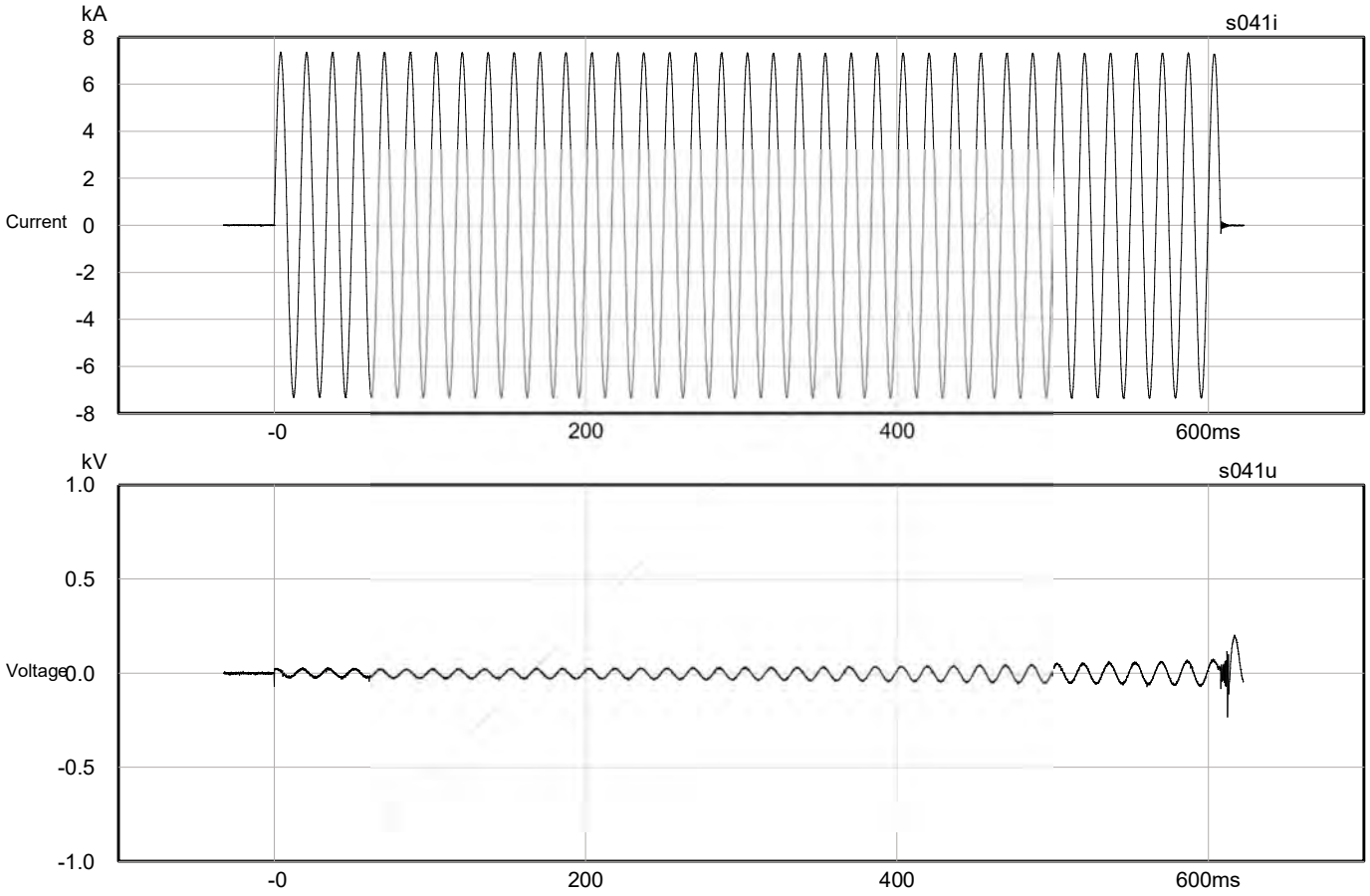


Figure 19: Waveforms for Test #13, Encore #6 AWG Sample 21.

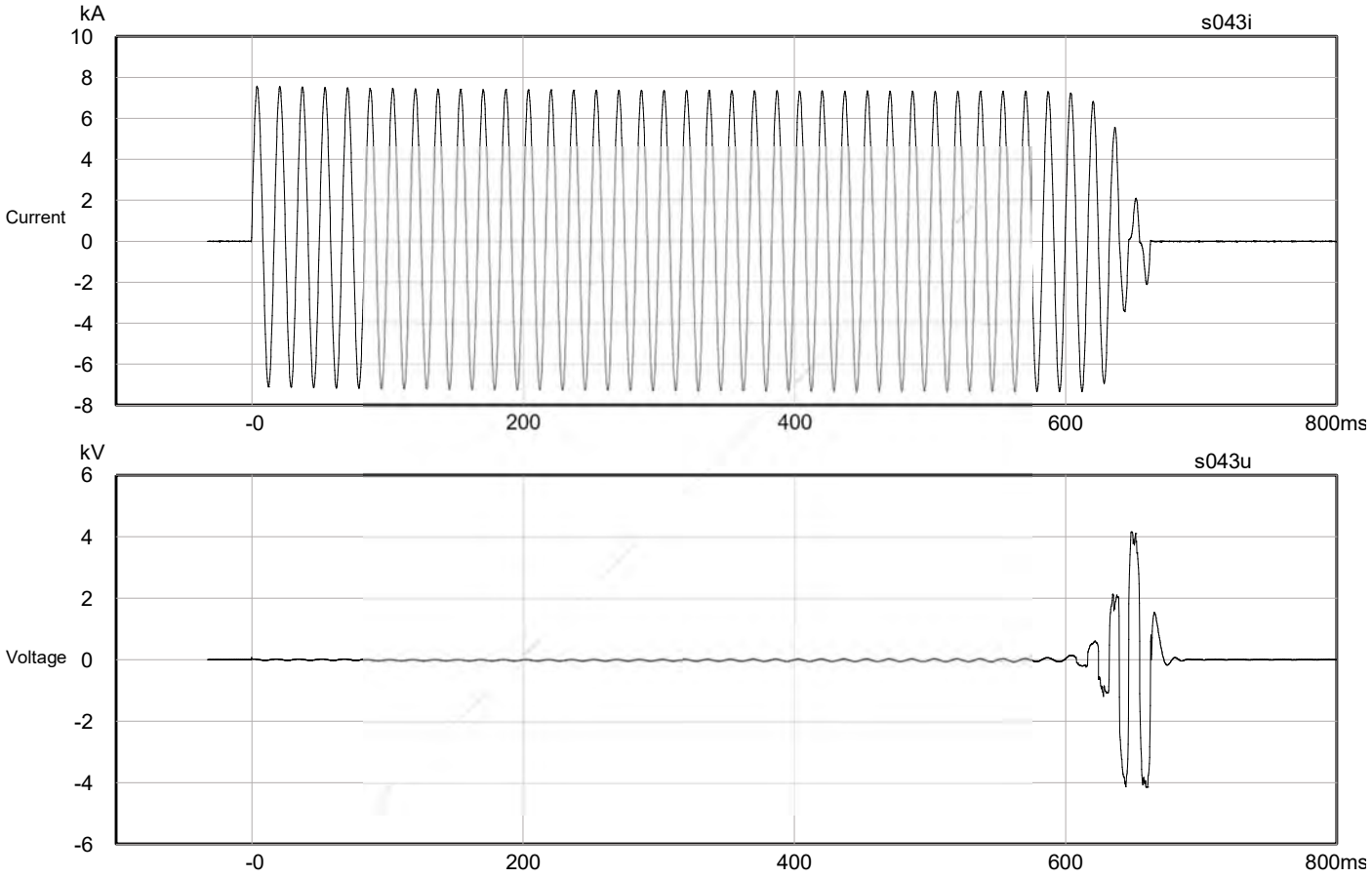


Figure 20: Waveforms for Test #14, Encore #6 AWG Sample 23.

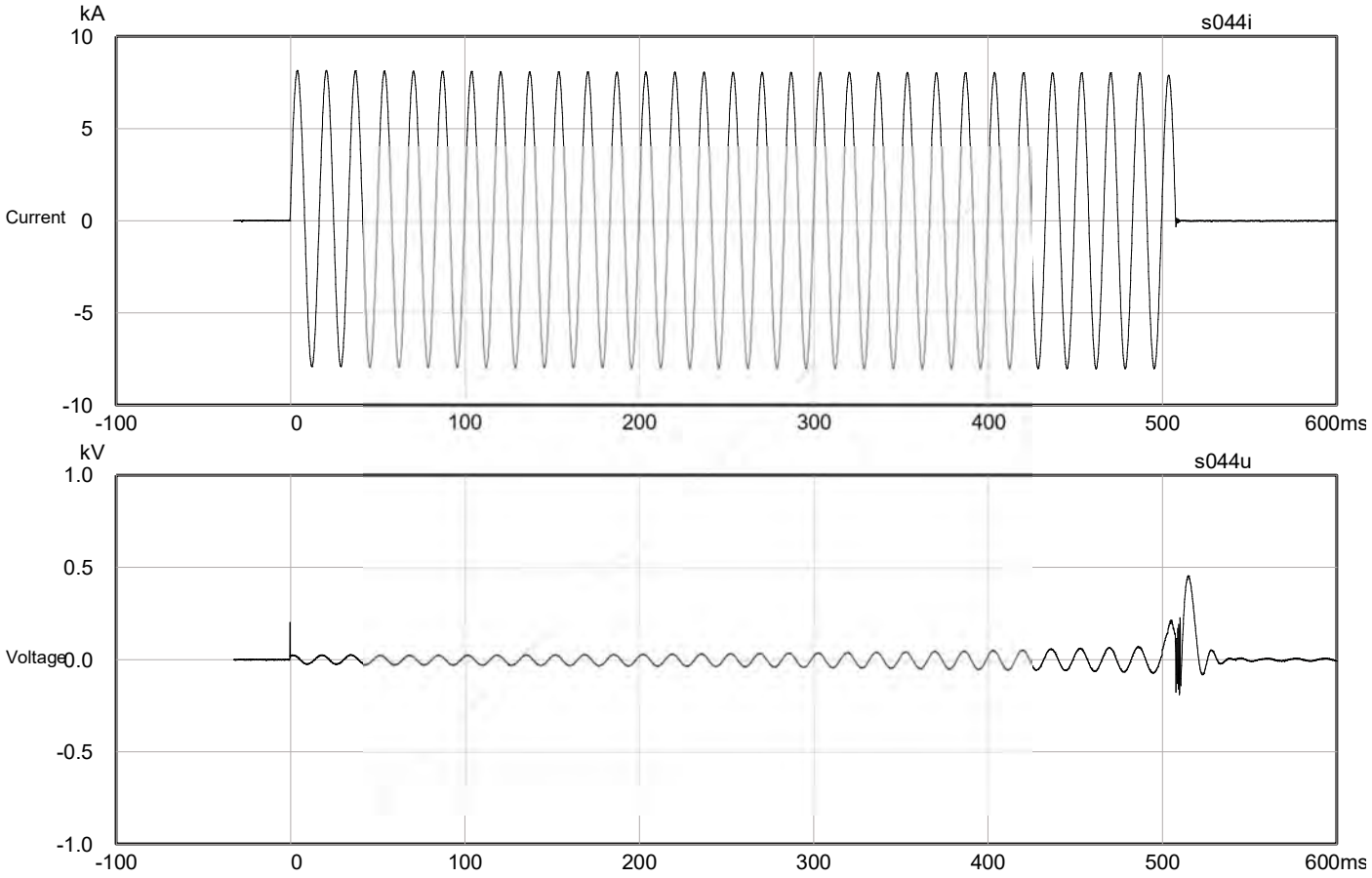


Figure 21: Waveforms for Test #15, Encore #6 AWG Sample 24.

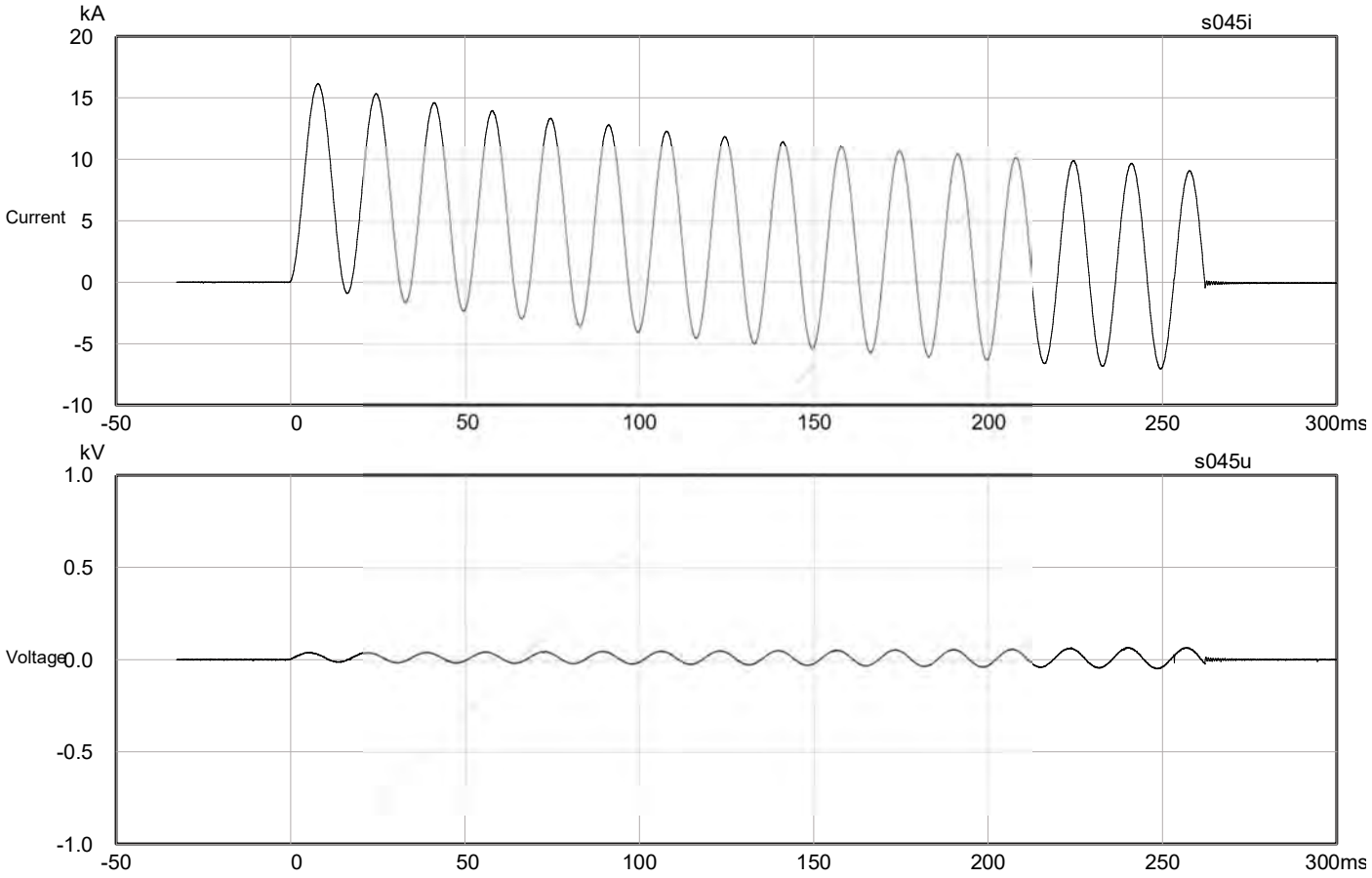


Figure 22: Waveforms for Test #16-1, Encore #6 AWG Sample 25.

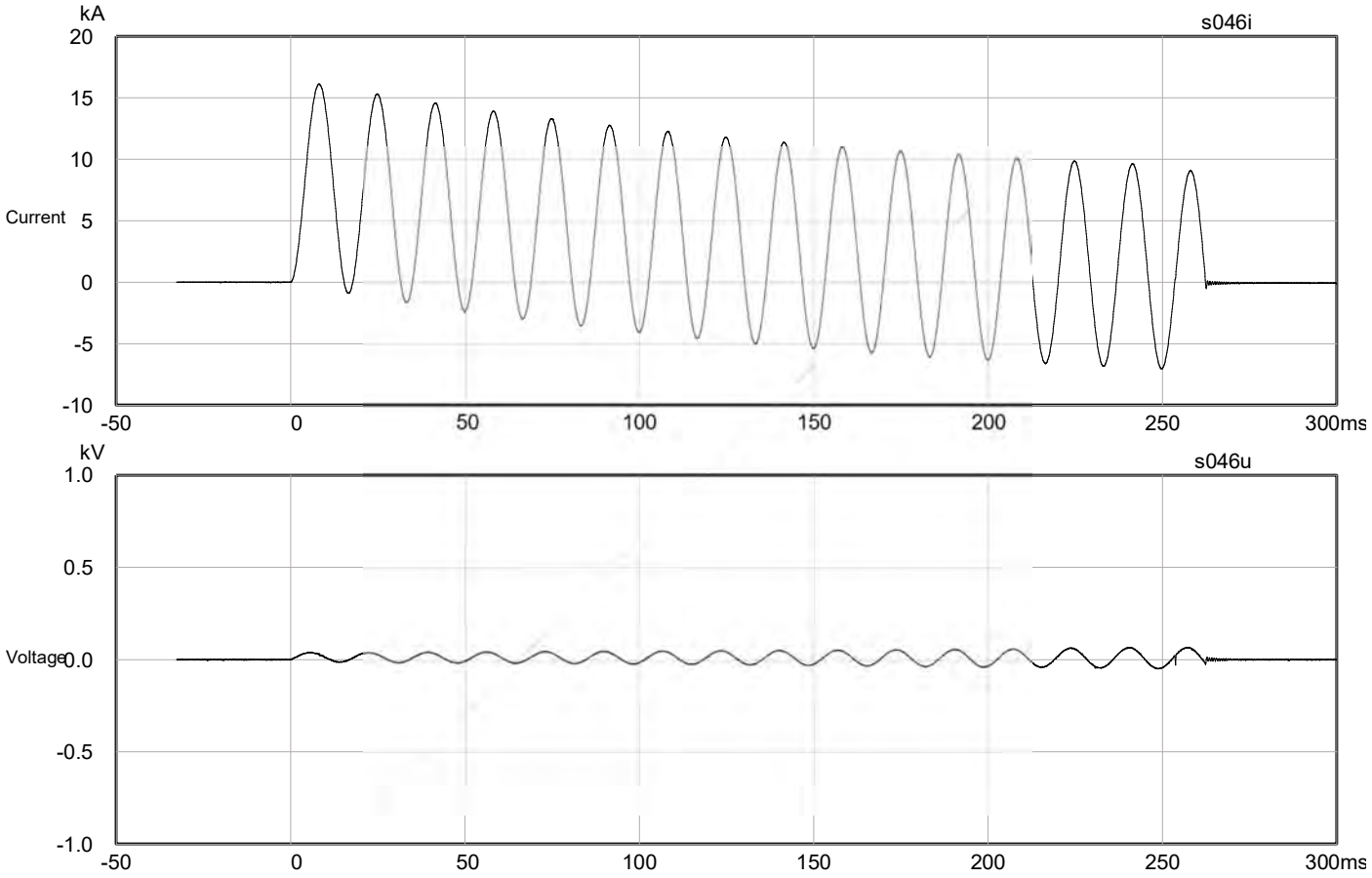


Figure 23: Waveforms for Test #16-2, Encore #6 AWG Sample 25.

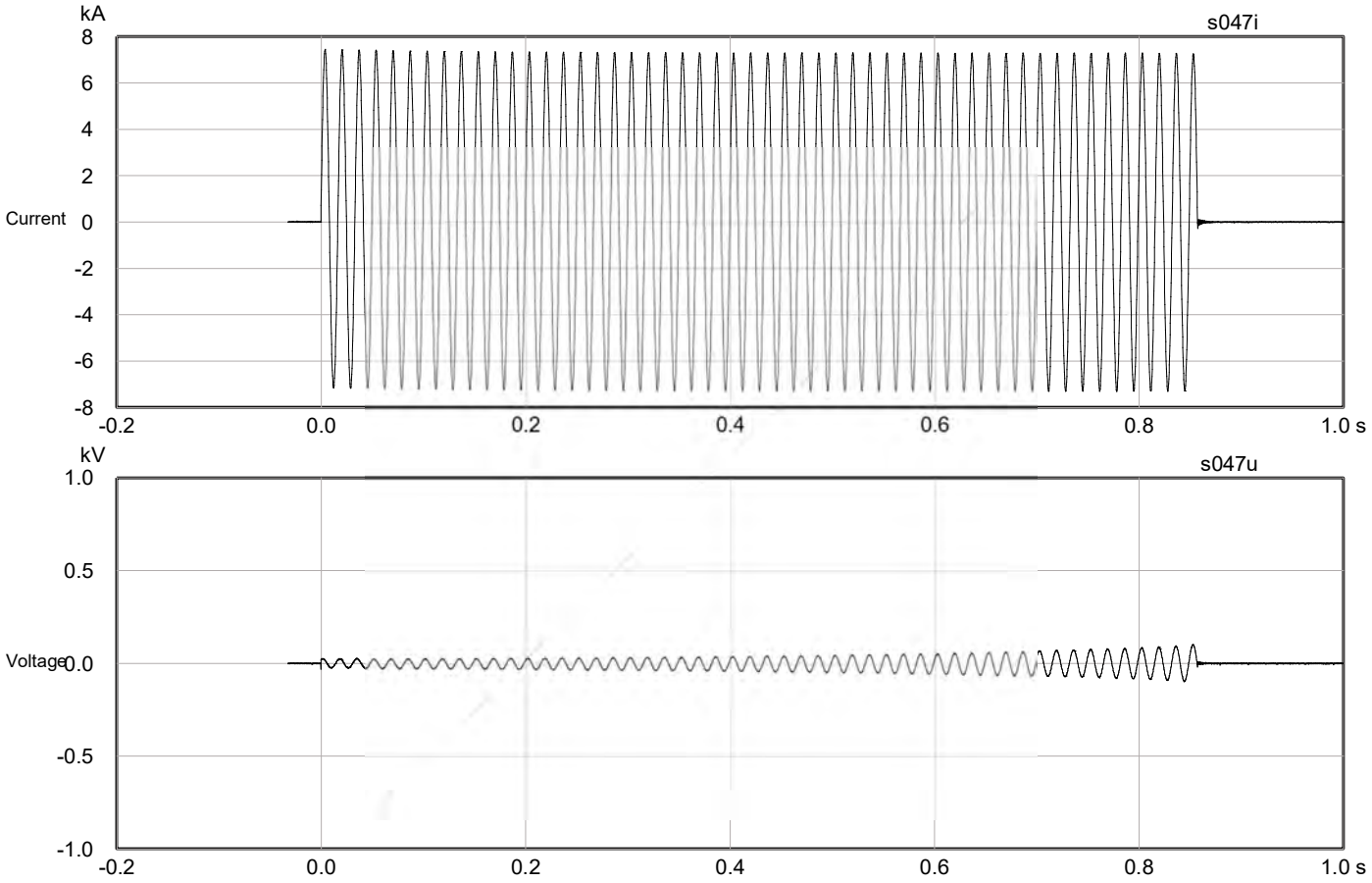


Figure 24: Waveforms for Test #17, Encore #6 AWG Sample 31.

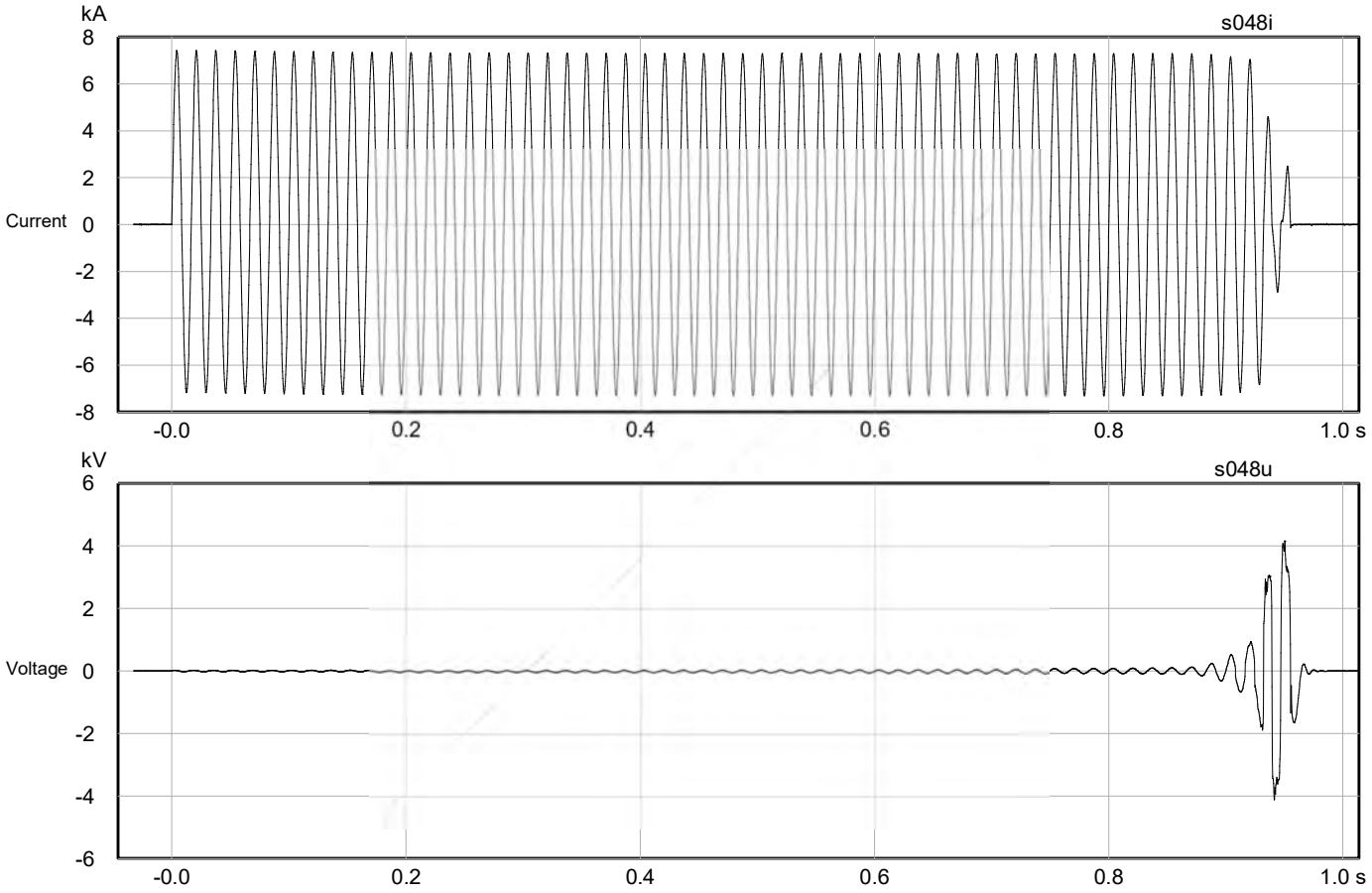


Figure 25: Waveforms for Test #18, Copperweld Scorpius 7 x 080 Sample 32.

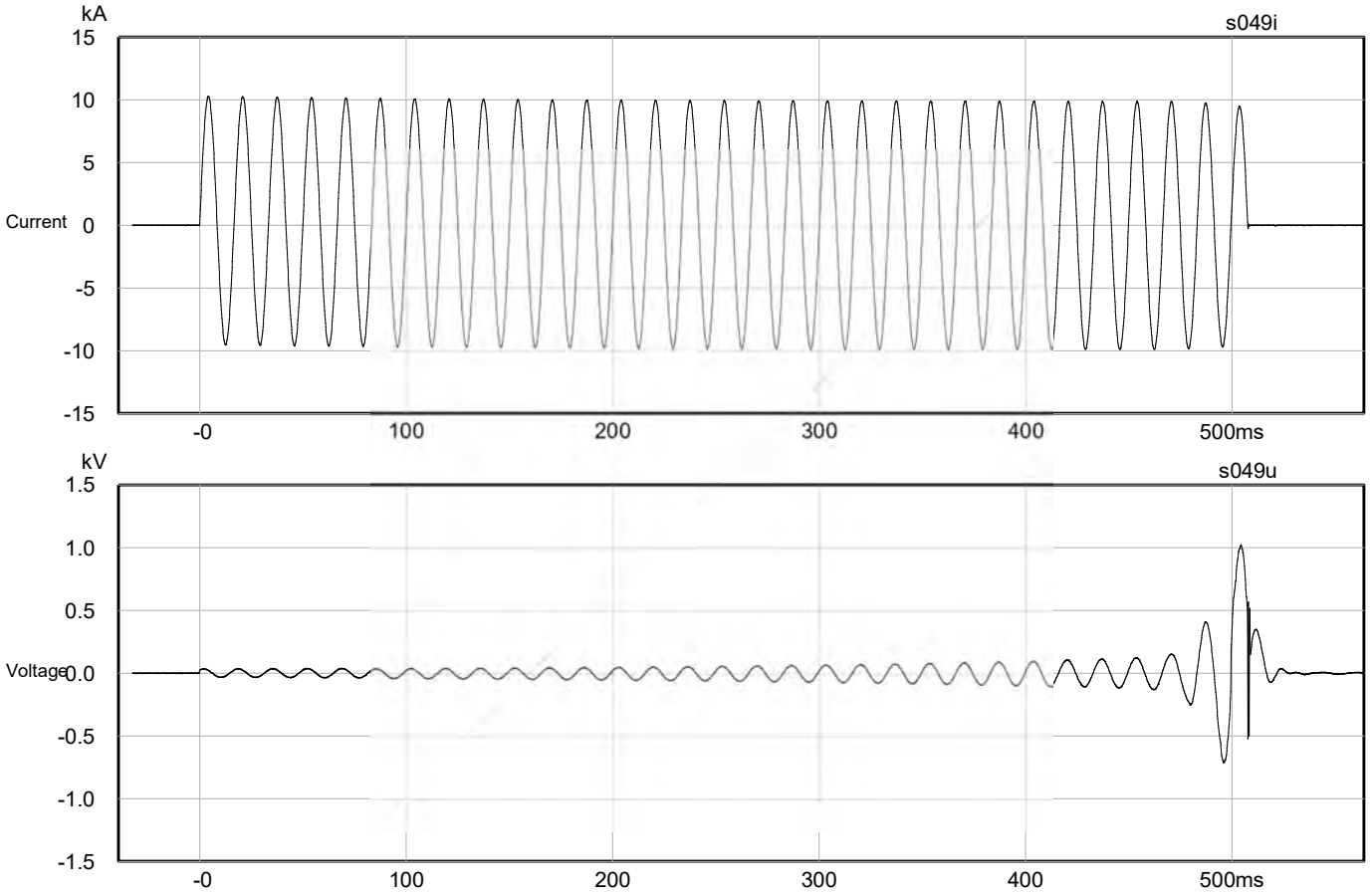


Figure 26: Waveforms for Test #19, Copperweld Scorpius 7 x 080 Sample 33.

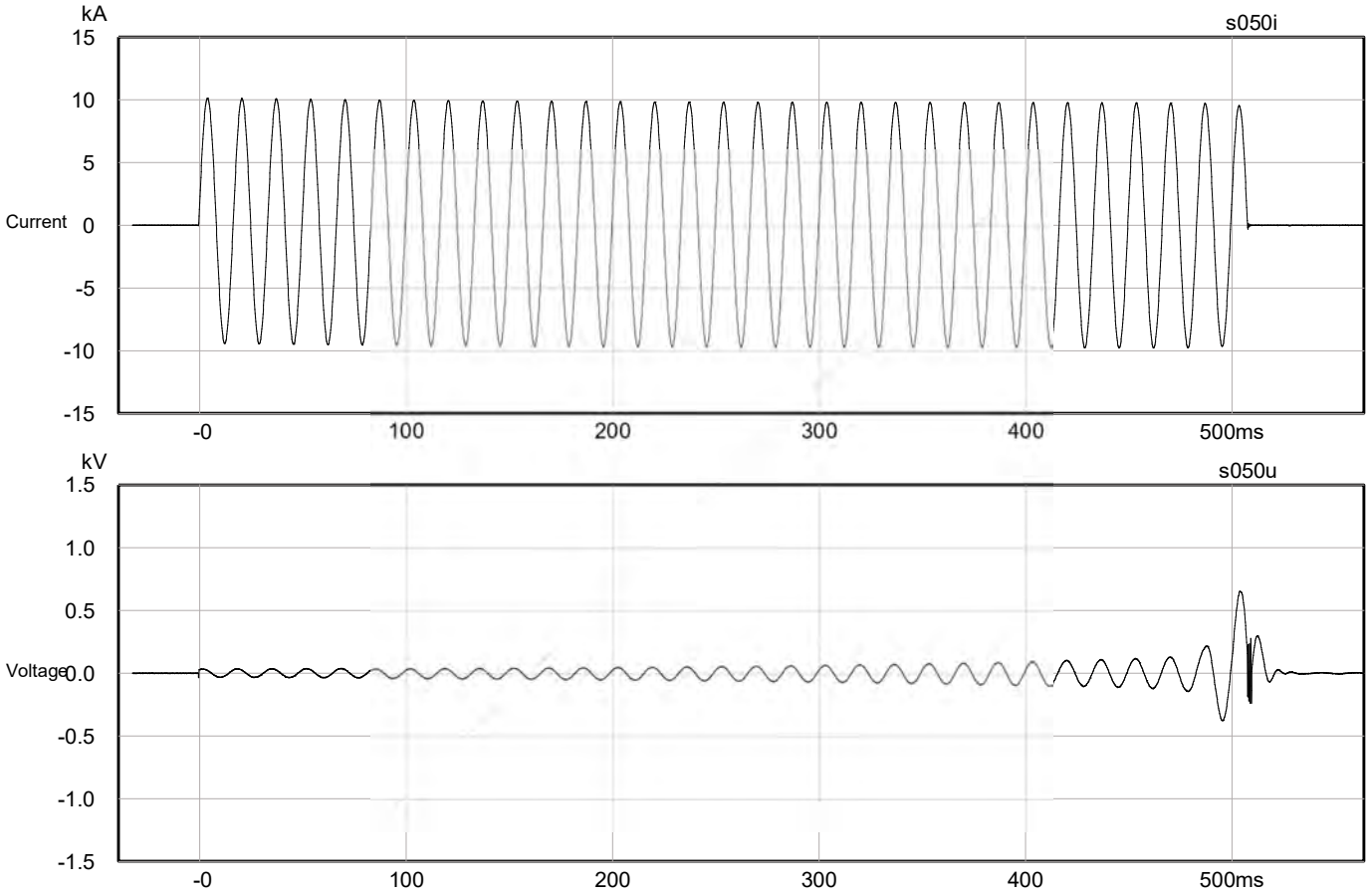


Figure 27: Waveforms for Test #20, Copperweld Scorpius 7 x 080 Sample 34.

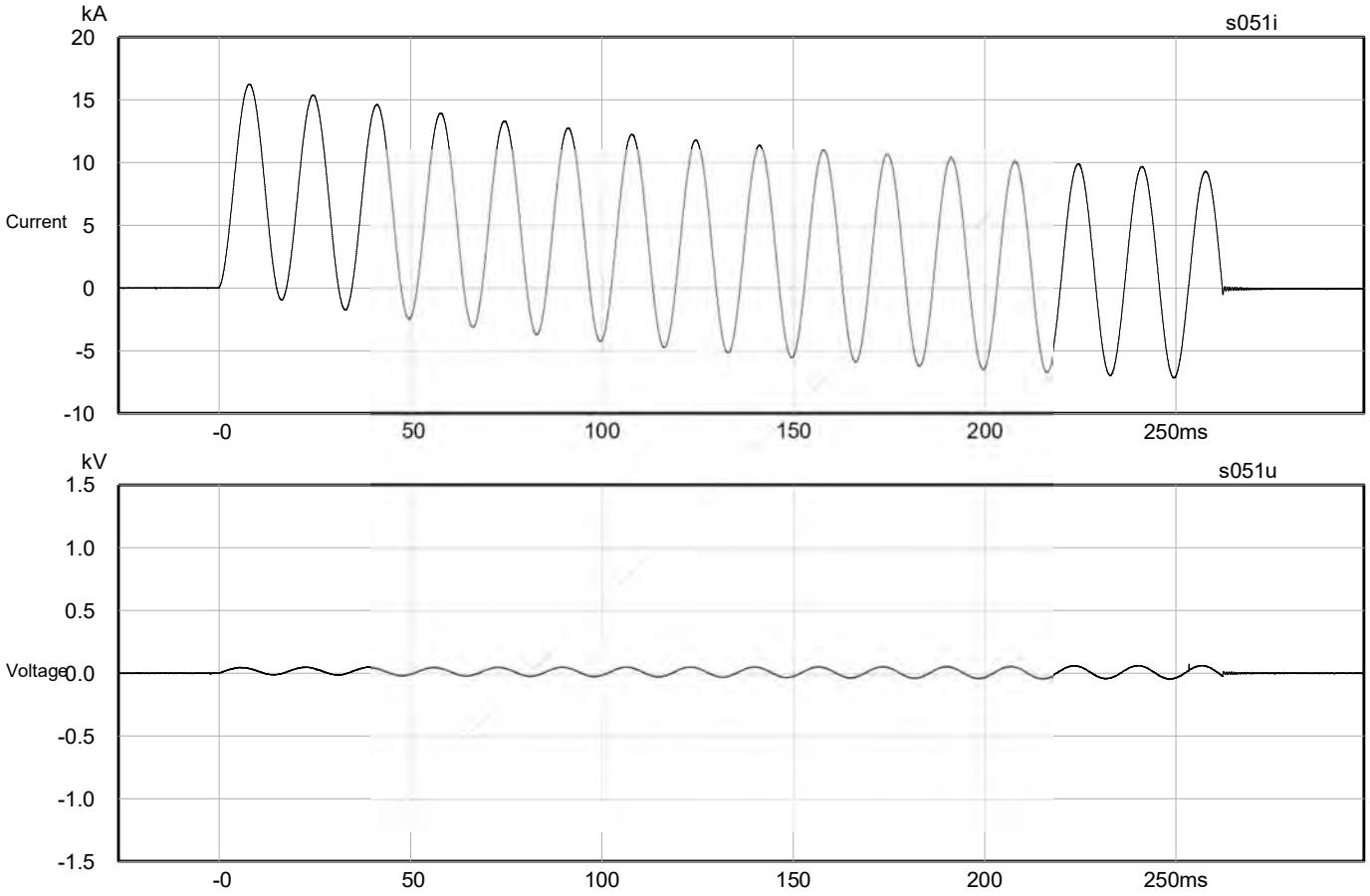


Figure 28: Waveforms for Test #21-1, Copperweld Scorpius 7 x 080 Sample 35.

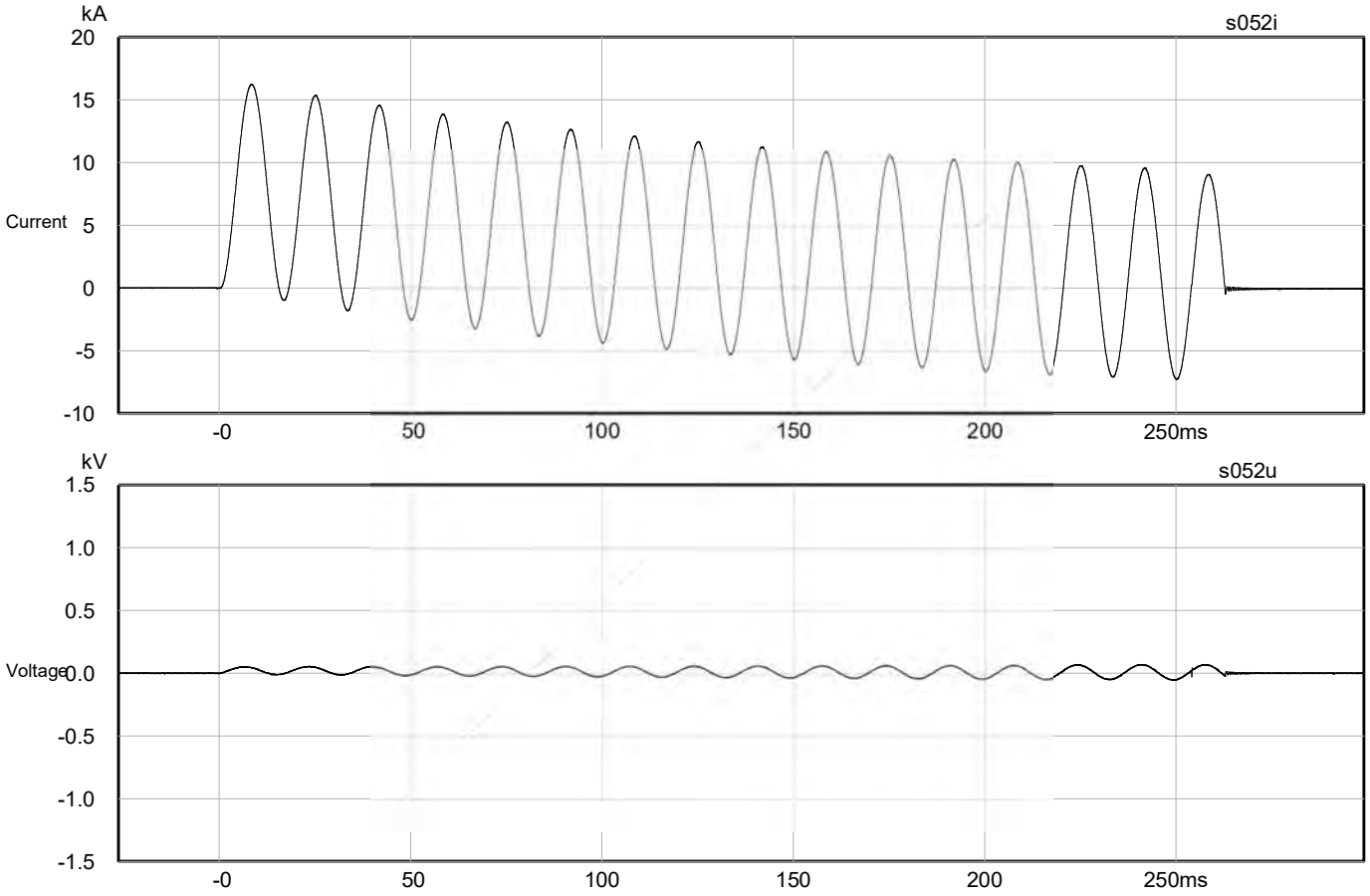


Figure 29: Waveforms for Test #21-2, Copperweld Scorpius 7 x 080 Sample 35.

APPENDIX C – PHOTOGRAPHS OF THE TEST OBJECTS



Figure 30: Test set up for the Encore 4/0 AWG Cu conductor. The power source bus is on the left and the ground bus is on the right.



Figure 31: Test set up for the Copperweld Scorpius 61 x 072 CCS conductor.



Figure 32: Test set up for the Encore #6 AWG Cu conductor.



Figure 33: Test set up for the Copperweld Scorpius 7 x 080 CCS conductor.

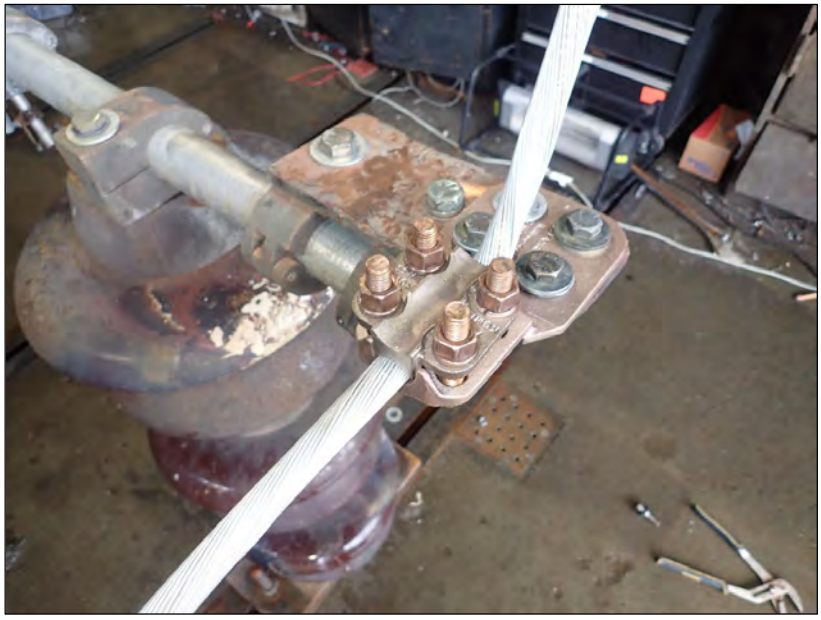


Figure 34: Typical Burndy terminal connector used to connect the Encore 4/0 AWG or Copperweld Scorpius 61 x 072 CCS conductors to the laboratory buses.



Figure 35: Typical Burndy terminal connector used to connect the Encore #6 AWG or Copperweld Scorpius 7 x 080 CCS conductors to the laboratory buses.

APPENDIX D – CALCUATIONS OF TEST CURRENT LEVELS FOR #6 AWG CU CONDUCTOR

Equation (45) in IEEE 80 and Equation (C.1) in IEEE 837 are the same, as follows:

$$I = A\sqrt{\left(\frac{TCAP\times10^{-4}}{t_c\times\alpha_r\times\rho_r}\right)\ln\left(\frac{K_0+T_m}{K_0+T_a}\right)}$$

where

I is root mean square (rms) current in kA
A is conductor cross section in mm^2
T_m is maximum allowable temperature in °C
T_a is initial conductor temperature in °C
T_r is reference temperature for material constants in °C
α_0 is thermal coefficient of resistivity at 0 °C
α_r is thermal coefficient of resistivity at reference temperature T_r
ρ_r is resistivity of the ground conductor at reference temperature T_r in μΩ-cm
K_0 is $1/\alpha_0$, or $(1/\alpha_r)-T_r$ in °C
t_c is time of current flow in seconds (s)
TCAP is thermal capacity factor in joules/cm^3°C

This equation is used to calculate the short-circuit ampacity of a conductor based on it's material constants.

For IEEE 80, Table 6, the symmetrical rms fusing current for #6 AWG soft-drawn Cu conductor at 500 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.5)(0.00393)(1.72)}\cdot\ln\left(\frac{(234+1083)}{(234+40)}\right)} = \boxed{5.29\ kA_{rms}}$$

For IEEE 837, Table 3, the symmetrical rms fusing current for #6 AWG hard-drawn Cu conductor at 250 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.25)(0.00381)(1.78)}\cdot\ln\left(\frac{(242+1084)}{(242+40)}\right)} = 7.41\ kA_{rms}$$

From IEEE 837 Equation (C.4), the asymmetrical rms fusing current is:

$$I_{asym} = \frac{(7.41\ kA)}{(1.148)} = 6.45\ kA_{rms}$$

For the EMF described in IEEE 837, Clause 7.2, a value of 90% of the fusing current is used for conductors up to 4/0 AWG:

$$I_{EMF} = (6.45)(0.9) = \boxed{5.81\ kA_{rms}}$$

Copperweld Bimetallics Data Sheet Packet
Electrical Test Laboratory

Customer:	Copperweld Building Wire	Engineer:	Bill Lewey	Date:	8/25/2020
Sample ID:	EL-13	Tested By:	Bill Lewey, Mike Rozar	Date:	8/25/2020
Product:	Grade 40 Copper Clad Steel Wire Solid Bare #4 and #6 vs Equivalent Solid Copper: Grounding Electrode Conductor Equivalency Test	Sample Condition:	New		
Standard:	ASTM B910/910M Annealed Copper Clad Steel Wire				
Insulation: N/A - Bare		Jacket: N/A - Bare			

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Test Report Summary

Page	Test Performed	Date Completed	Pass/Fail
1	Grounding Electrode Conductor Test for Copper Clad Steel Grade 40	8/25/2020	**Pass**

Requirement:
#4 AWG Grade 40 Copper Clad Steel and #6 AWG Copper Clad Steel when compared to #4 solid copper and #6 solid copper for use as a grounding electrode conductor shall have equal ability to carry amperage during a ground fault condition.

Conclusion:
The ability of bare #4 AWG Copper Clad Steel Grade 40 and bare #6 AWG Copper Clad Steel Grade 40 performed equally to #4 AWG bare solid copper and #6 AWG bare solid copper when used as a grounding electrode conductor under a ground fault condition. The current measured proved equivalency.

Test Equipment Used

Item	Equipment Type	Equipment #	Cal. Due Date
1	Fluke 374FC Clamp Meter	AM-1	Nov 2020
2	Acme Electric 15KVA Transformer	T2535173S	N/A
3	Square D 60A / 600V Safety Interrupter	N/A	N/A
4	Eaton Service Panel	N/A	N/A
5	Eaton Type CH 20 Amp Breaker	N/A	N/A
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

VBU – Verify Before Use

N/A – Not Applicable

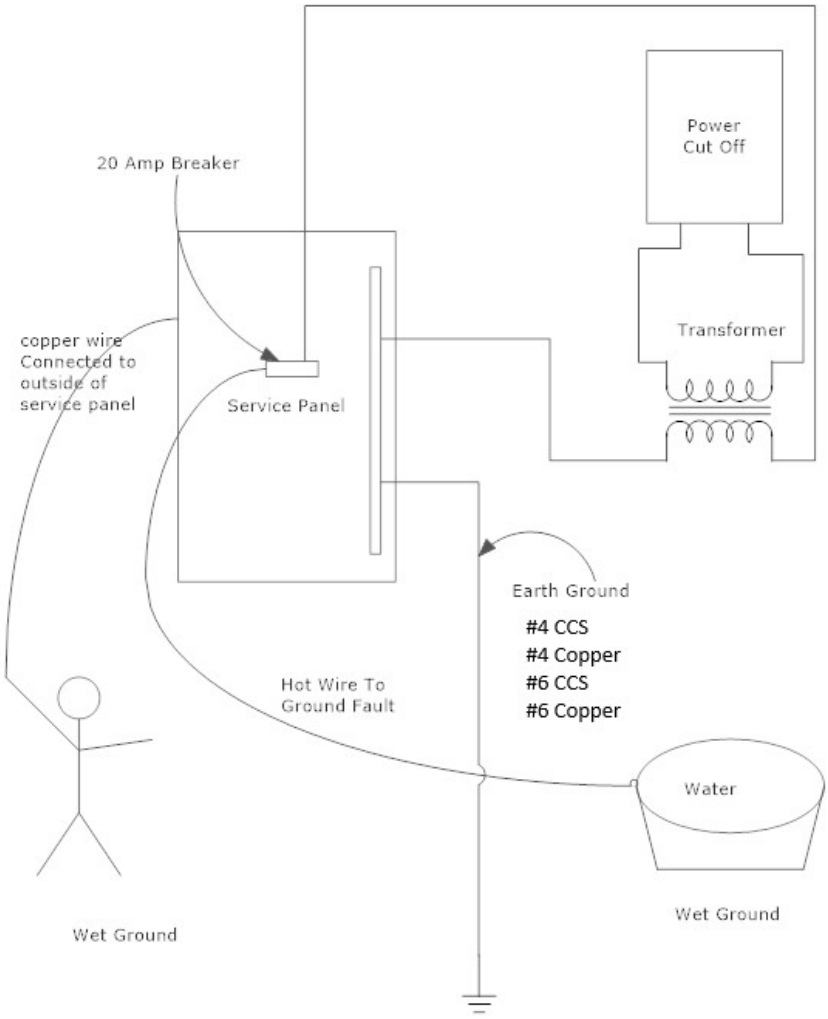
Sample Identification

Item	Description	Length/No. Rec'd
A	#4 AWG 40% Copper Clad Steel Bare	35 Ft
B	#4 AWG Solid Copper Bare	35 Ft
C	#6 AWG 40% Copper Clad Steel Bare	35 Ft
D	#6 AWG Solid Copper Bare	35 Ft
E		
F		

Grounding Electrode Conductor Test

Test Parameters:	
Conditioning:	No preconditioning.
Test Conductors:	1 each of #4 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #6 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #4 AWG Solid Bare copper grounding electrode conductor 1 each of #6 AWG Solid Bare copper grounding electrode conductor
Test Conductor Length:	Each conductor shall be 35 ft.
Test Circuit Configuration:	See schematic shown in Figure 1
Test Current:	Test current from 120 V / 20 A Residential Circuit
Method:	Testing was completed by creating a standard residential test circuit at 120V with 20A breaker wired to an intentional ground fault as shown in figure 1. The ground fault was created by connecting a hot wire from the breaker to a galvanized steel pan full of water and placing the pan on the wet ground. A conductor was also connected to the outside of the electrical panel and a Copper Plated Grounding Electrode (Copperweld Ground Rod) driven 6 inches into the wet ground to determine amount of current going through a grounded person touching the electrical panel during the ground fault condition. The ground fault and the grounded "man" were positioned 20 feet either side of the ground rod. The entire test area was soaked with water overnight using a sprinkler system When the ground fault was electrified, current measurements were taken from the ground fault conductor, the grounding electrode conductor and the grounded "man" conductor. For the four grounding electrode conductors tested, there was one test sequence for each. The current was measured for each. The objective: Compare the amperage measurements of the copper clad steel grounding electrode conductors to those of copper.

Figure 1



Results:			
Ground Conductor	**Fault Conductor Current**	**Current of the Grounding Electrode Conductor**	**Grounded Man Conductor Current**
#4 Copper	2.1 A	1.8 A	0.3 A
#4 40% CCS	2.1 A	1.8A	0.3 A
#6 Copper	1.7 A	1.6 A	0.1 A
#6 40% CCS	1.5 A	1.4 A	0.1 A

Requirement:
For equivalent sizes of Grade 40 Copper Clad steel vs. solid copper grounding conductors, the ability to carry amperage to ground during a ground fault condition is equal.

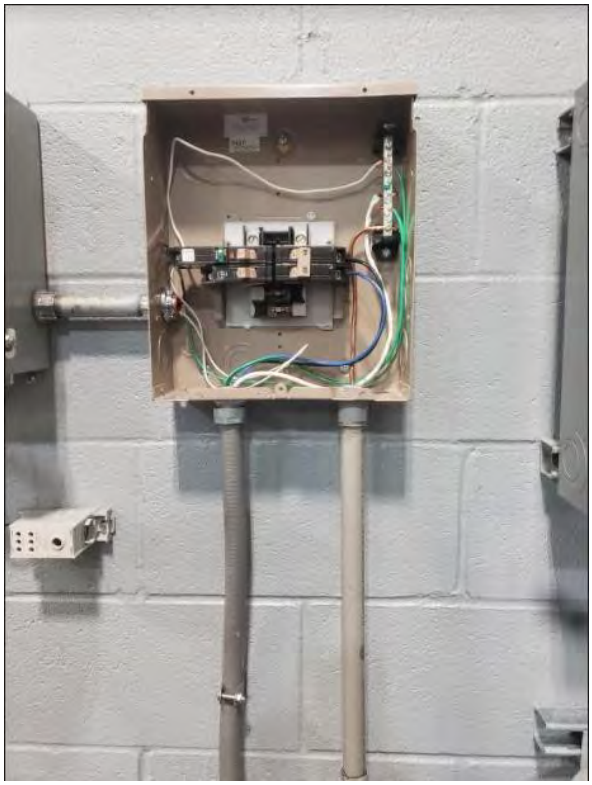
Comments:
____X__ (Pass) The product complies with all applicable requirements of this test. _____ (Fail) The product does not comply with the requirements of this test. **Test Date: 8/25/2020** **Tested By: Bill Lewey**

Environmental Conditions during Testing:

Humidity: % rh __74%_____ Ambient: °C___28_____

Test setup for the electrical service panel







Ground Rod with Grounding Conductor Attached



Ground Fault



Grounded “man”

Public Input No. 3063-NFPA 70-2020 [New Section after 250.64]

TITLE OF NEW CONTENT

Type your content here ...Identification of Grounding Electrode Conductors. Shall be bare, covered, or insulated, having a continuous green outer finish or identified green at the termination.

Statement of Problem and Substantiation for Public Input

The grounding electrode conductors are not always identifeied usually a black conductor and unable to site.

Submitter Information Verification

Submitter Full Name: Mark Rochon
Organization: [Not Specified]
Street Address:
City:
State:
Zip:
Submittal Date: Fri Sep 04 13:22:27 EDT 2020
Committee: NEC-P05

Public Input No. 2001-NFPA 70-2020 [Section No. 250.64]

250.64 Grounding Electrode Conductor Installation.

Grounding electrode conductors at the service, at each building or structure where supplied by a feeder(s) or branch circuit(s), or at a separately derived system shall be installed as specified in 250.64(A) through (F).

(A) Aluminum or Copper-Clad Aluminum Conductors.

Grounding electrode conductors of bare, covered, or insulated aluminum or copper-clad aluminum shall comply with the following:

(1) Bare or covered conductors without an extruded polymeric covering shall not be installed where subject to corrosive conditions or be installed in direct contact with concrete.

(2) Terminations made within outdoor enclosures that are listed and identified for the environment shall be permitted within 450 mm (18 in.) of the bottom of the enclosure.

(3) Aluminum or copper-clad aluminum conductors external to buildings or equipment enclosures shall not be terminated within 450 mm (18 in.) of the earth.

(B) Securing and Protection Against Physical Damage.

Where 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 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 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, but shall be buried or otherwise protected if subject to physical damage.

(C) Continuous.

Except as provided in 250.30(A)(5) and (A)(6), 250.30(B)(1), and 250.68(C), grounding electrode conductor(s) shall be installed in one continuous length without a splice or joint. If necessary, splices or connections shall be made as permitted in (1) through (4):

(1) Splicing of the wire-type grounding electrode conductor shall be permitted only by irreversible compression-type connectors listed as grounding and bonding equipment or by the exothermic welding process.

(2) Sections of busbars shall be permitted to be connected together to form a grounding electrode conductor.

(3) Bolted, riveted, or welded connections of structural metal frames of buildings or structures.

(4) Threaded, welded, brazed, soldered or bolted-flange connections of metal water piping.

(D) Building or Structure with Multiple Disconnecting Means in Separate Enclosures.

If a building or structure is supplied by a service or feeder with two or more disconnecting means in separate enclosures, the grounding electrode connections shall be made in accordance with 250.64(D)(1), 250.64(D)(2), or 250.64(D)(3).

(1) Common Grounding Electrode Conductor and Taps.

A common grounding electrode conductor and grounding electrode conductor taps shall be installed. The common grounding electrode conductor shall be sized in accordance with 250.66, based on the sum of the circular mil area of the largest ungrounded conductor(s) of each set of conductors that supplies the disconnecting means. If the service-entrance conductors connect directly to the overhead service conductors, service drop, underground service conductors, or service lateral, the common grounding electrode conductor shall be sized in accordance with Table 250.66, note 1.

A grounding electrode conductor tap shall extend to the inside of each disconnecting means enclosure. The grounding electrode conductor taps shall be sized in accordance with 250.66 for the largest service-entrance or feeder conductor serving the individual enclosure. The tap conductors shall be connected to the common grounding electrode conductor by one of the following methods in such a manner that the common grounding electrode conductor remains without a splice or joint:

(1) Exothermic welding.

(2) Connectors listed as grounding and bonding equipment.

(3) Connections to an aluminum or copper busbar not less than 6 mm thick × 50 mm wide (¼ in. thick × 2 in. wide) and of sufficient length to accommodate the number of terminations necessary for the installation. The busbar shall be securely fastened and shall be installed in an accessible location. Connections shall be made by a listed connector or by the exothermic welding process. If aluminum busbars are used, the installation shall comply with 250.64(A).

(2) Individual Grounding Electrode Conductors.

A grounding electrode conductor shall be connected between the grounding electrode system and one or more of the following, as applicable:

(1) Grounded conductor in each service equipment disconnecting means enclosure

(2) Equipment grounding conductor installed with the feeder

(3) Supply-side bonding jumper

Each grounding electrode conductor shall be sized in accordance with 250.66 based on the service-entrance or feeder conductor(s) supplying the individual disconnecting means.

(3) Common Location.

A grounding electrode conductor shall be connected in a wireway or other accessible enclosure on the supply side of the disconnecting means to one or more of the following, as applicable:

(1) Grounded service conductor(s)

(2) Equipment grounding conductor installed with the feeder

(3) Supply-side bonding jumper

The connection shall be made with exothermic welding or a connector listed as grounding and bonding equipment. The grounding electrode conductor shall be sized in accordance with 250.66 based on the service-entrance or feeder conductor(s) at the common location where the connection is made.

(E) Raceways and Enclosures for Grounding Electrode Conductors.

(1)_ General.

Ferrous metal raceways, enclosures, and cable armor for grounding electrode conductors shall be electrically continuous from the point of attachment to cabinets or equipment to the grounding electrode and shall be securely fastened to the ground clamp or fitting. Ferrous metal raceways, enclosures, and cable armor shall be bonded at each end of the raceway or enclosure to the grounding electrode or grounding electrode conductor to create an electrically parallel path. Nonferrous metal raceways, enclosures, and cable armor shall not be required to be electrically continuous.

(2)_ Methods.

Bonding shall be in compliance with 250.92(B) and ensured by one of the methods in 250.92(B) (2) through (B)(4).

(3)_ Size.

The bonding jumper for a grounding electrode conductor(s), raceway(s), enclosure(s), or cable armor shall be the same size as, or larger than, the largest enclosed grounding electrode conductor.

(4)_ Wiring Methods.

If a raceway is used as protection for a grounding electrode conductor, the installation shall comply with the requirements of the appropriate raceway article.

(F)_ Installation to Electrode(s).

Grounding electrode conductor(s) and bonding jumpers interconnecting grounding electrodes shall be installed in accordance with (1), (2), or (3). The grounding electrode conductor shall be sized for the largest grounding electrode conductor required among all the electrodes connected to it.

(1) The grounding electrode conductor shall be permitted to be run to any convenient grounding electrode available in the grounding electrode system where the other electrode(s), if any, is connected by bonding jumpers that are installed in accordance with 250.53(C) .

(2) Grounding electrode conductor(s) shall be permitted to be run to one or more grounding electrode(s) individually.

(3) Bonding jumper(s) from grounding electrode(s) shall be permitted to be connected to an aluminum or copper busbar not less than 6 mm thick × 50 mm wide (1/4 in. thick × 2 in wide.) and of sufficient length to accommodate the number of terminations necessary for the installation. The busbar shall be securely fastened and shall be installed in an accessible location. Connections shall be made by a listed connector or by the exothermic welding process. The grounding electrode conductor shall be permitted to be run to the busbar. Where aluminum busbars are used, the installation shall comply with 250.64(A) .

(4) (G) Mechanical Continuity.

(5) When the grounding electrode conductor passes through an enclosure, panelboard switchboard, or other equipment, not in a raceway, the grounding electrode conductor shall be mechanically secured to the equipment by a fitting that is identified or approved for the purpose.

Additional Proposed Changes

File Name	Description	Approved
WP_xfmr_with_GEC_thru_vent_hole.jpg	GEC through enclosure	

Statement of Problem and Substantiation for Public Input

There needs to be a rule that requires the GEC to be 'mechanicall' secured to the enclosure wall that it passes through. Currently people make a KO and pass the GEC through the opening, or punch out a 1/2 KO and pass the GEC through the KO, or they use a Romex connector, or many other methods. There are actually listed fitting designed for the mechanical GEC, but they are not used, since there is no rule to require mechanical connection.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Fri Jul 24 16:42:36 EDT 2020
Committee: NEC-P05


X1
H3
X2
X0
H1
X3
H2

Public Input No. 124-NFPA 70-2019 [Section No. 250.64(A)]

(A) Aluminum or Copper-Clad Aluminum Conductors.

Grounding electrode conductors of bare, covered, or insulated aluminum or copper-clad aluminum shall comply with the following:

(1) Bare or covered conductors without an approved and identified extruded polymeric covering shall not be installed where subject to corrosive conditions or be installed in direct contact with concrete.

(2) Terminations made within outdoor enclosures that are listed and identified for the environment shall be permitted within 450 mm (18 in.) of the bottom of the enclosure.

(3) Aluminum or copper-clad aluminum conductors external to buildings or equipment enclosures shall not be terminated within 450 mm (18 in.) of the earth.

Statement of Problem and Substantiation for Public Input

The present text is not acceptable because it will allow any polymeric material that is extruded to be used on aluminum or copper-clad aluminum conductors.
The terms "Approved" and "Identified" are defined in Article 100 and will add safeguards to the level of quality of the polymeric material. The term "Identified" will require that the material be "suitable for the purpose" but does not required it to be Listed.

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Wed Nov 20 17:29:56 EST 2019
Committee: NEC-P05

Public Input No. 1619-NFPA 70-2020 [Section No. 250.64(B)]

(B) Securing and Protection Against Physical Damage.

Where exposed, a grounding electrode conductor ~~or its enclosure~~ shall be securely fastened to the surface on which it is carried and shall be mechanically secured to any enclosure through which it passes . Grounding electrode conductors shall be permitted to be installed on or through framing members.

Exception: A bare grounding electrode conductor is not required to be secured to an enclosure that provides the 1/4 inch entry for the are conductor.

(1) Not Exposed to Physical Damage.

~~A~~ Exposed 6 AWG or larger copper or aluminum grounding electrode conductor not ~~exposed~~ subject 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~~ Exposed 6 AWG or larger copper or aluminum grounding electrode ~~conductor exposed~~ conductors subject to physical damage shall be protected ~~in rigid metal conduit (~~ by RMC~~)~~ , ~~intermediate metal conduit (~~ IMC~~), Schedule 80 rigid polyvinyl chloride conduit (PVC), reinforced thermosetting resin conduit Type XW (~~ , Schedule 80 PVC, 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~~ by 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~~, but~~ but shall be buried or otherwise protected if subject to physical damage.

Additional Proposed Changes

File Name	Description	Approved
WP_xfmr_with_GEC_thru_vent_hole.jpg	GEC not mechanically secured to an enclosure.	

Statement of Problem and Substantiation for Public Input

My text is intended to require the GEC to be mechanically secured to any enclosure through which it passes, and other changes are just editing. I revised the text in (2) to match the text in (3). See attached photo.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:

Zip:	
Submittal Date:	Wed Jun 24 13:32:26 EDT 2020
Committee:	NEC-P05


X1
H3
X2
X0
H1
X3
H2

Public Input No. 2463-NFPA 70-2020 [Section No. 250.64(B)(1)]

(1) Not Exposed to Physical Damage.

A 6 AWG or larger copper-clad steel or copper or 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.

Additional Proposed Changes

File Name	Description	Approved
CCS_Corrosion_paper_Rev2.pdf	50 Year Corrosion Study 40% CCS	
TD002391.doc	UL 467 Short Circuit and UL 486A-B Mechanical Sequence Tests	
Withstand.FusingTest.PowerTech.pdf	IEEE 80 and 837 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

COPPER-CLAD ALUMINUM CONDUCTORS:

Please Consult Section 110.5 Conductor Materials. Copper-Clad Aluminum as a conductor material should not be excluded from this application. Along with aluminum and copper, Copper-Clad Aluminum is only one of three conductor materials for general wiring permitted by the NEC. This Public Input aims to correct an inconsistency in correlation between articles. It aims to bring safe alternatives to users of this Code. The NFPA Standards Council created in August 2019 a special Bimetals Task Group to in part bring attention to correlation issues effecting Copper-Clad Aluminum, as well as to study expanding its range of applications in 2023. In a coordinated effort, the Bimetals Task Group will submit 19 Public Inputs in this cycle addressing these matters.

COPPER-CLAD STEEL CONDUCTORS:

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 applicate 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 Inputs for This Document

Related Input	Relationship
Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]	Copper-Clad Steel Grounding Conductors
Public Input No. 2462-NFPA 70-2020 [Section No. 250.62]	Copper-Clad Steel 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 09:53:18 EDT 2020
Committee: NEC-P05

CORROSION ON BURIED COPPER CLAD STEEL



Cece Syarif

Global Application Engineer

&

Anthony Hale

Manager, Utility Products, North America

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For more information, contact sales@copperweld.com.
The results and conclusions obtained from studies done by Copperweld are only applicable to Copper Clad Steel manufactured by Copperweld. Due to proprietary process used to produce the wire, the findings cannot be superimposed on any other copper-clad steel conductor.

254 Cotton Mill Rd, Fayetteville, TN 37334. Tel. (931) 433 – 7177

July 26, 2011

This paper compiles several studies and analysis regarding the corrosion performance of buried Copperweld® Copper-Clad-Steel (CCS) conductors. These range from the early 1900's with the invention of Copperweld® through the present day with studies performed by independent parties as well as Copperweld Company in-house testing. The purpose is to present the available information so that prospective users of Copperweld® CCS wire and strand can evaluate the corrosion resistance and expected performance within their specific application and area. Copperweld uses oxygen free copper in the manufacture of Copperweld® wire and strand. The copper surface of CCS is expected to oxidize and turn color ranging from green (patination) to brown and black the same as any solid copper wire or strand when exposed to environmental stimuli. Corrosion on exposed steel at the cut tip or end of the wire is also expected. The question to be answered is if the corrosion on either material or the interface between the copper and steel (galvanic reaction) will result in degradation of the wire as to make it unsuitable for use as a grounding conductor.

The oldest known underground corrosion study of bimetallic material was performed in the early 1900s[1]. This study focused on the corrosion behavior of Copperweld® CCS underground rod as well as other materials such as Copper and galvanized steel ground rod. The National Bureau of Standards (NBS) conducted an extensive underground corrosion study that involves 36,500 specimens which include 333 varieties of ferrous, nonferrous, and protective coating materials buried in 128 test locations throughout U.S in 1910 - 1955.

The study summarizes the service life of a ground rod as following:

10 mils copper coating – acceptable for service life up to 40 years

13 mils copper coating – acceptable for service life up to 50 years

Similarly, the Naval Civil Engineering Laboratory in collaboration with the National Association of Corrosion Engineers conducted a 7-year program of testing metal rods for electrical grounding to determine the galvanic corrosion effect. The three metals tested were stainless clad steel, copper-bonded steel (CCS), and galvanized steel. The result on the ⅝" CCS ground rod was as expected. The copper surface of the CCS was

virtually free of corrosion and the steel core has corroded at the tip approximately 2 inches down the length of the rod.

Copperweld Corporation is the inventor and sole manufacturer of Copperweld® Copper-bonded ground rods and Copperweld® wire and strand since 1915. The corrosion behavior of a Copperweld® ground rod is similar to the corrosion on Copperweld® wire and strand conductor. Both materials consist of copper permanently bonded to a steel core. All Copperweld® 40% CCS has a copper thickness of 10% of the overall diameter. For example, Copperweld® 4THOUGHT™ has a configuration of 19 strands of 0.1055 inch wires. It means that each strand has a copper thickness of 10.55 mils. Based on the NBS study, 4THOUGHT™ will have at least a minimum service life of 40 years.

Copperweld has also conducted a 5-year study of buried bare 21% conductivity (copper thickness is 3% of the diameter) Copperweld® CCS in 10 different soil conditions in association with Southwest Research Institute[2]. The study reported 100% surface oxidation and various degrees of deterioration of the steel core as expected after 5 years. The exposed steel on the tip of the wire rusted and formed "scab", as shown in Figure 1. The rust appeared to "seal-off" the un-oxidized material from the corrosive medium. The maximum depth of corrosion was 70% of the wire diameter.



Figure 1: Example of Underground Corrosion of Copper Clad Steel

Although the copper surface oxidation was heavy, the samples showed no signs of pits or holes in the copper cladding. The copper thickness of a severely oxidized 5-year sample showed no discernable difference when compared to an un-oxidized control sample that was not subjected to the corrosive environment. The mechanical and resistance testing

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resulted in negligible differences between 5-year samples and the control samples. Thus, the oxidation had no discernable impact on the strength or electrical performance of the wire.

An accelerated corrosion study based on ASTM B117 was conducted on bare CCS and solid Copper wires to evaluate copper surface corrosion. The wires were exposed to salt fog spray for 504 hours. As a result, corrosion on the CCS copper surface showed no significant difference as compared to the corrosion of copper wire.



(a) Copper Clad Steel (b) Copper

Figure 2: Patination of Copper Surface after 504 hours exposure to Salt Fog Spray

In February 2011, three separate sample strands of Copper Clad Steel were un-earthed and cut out from a substation built in Louisville, KY. The conductors were 40% conductivity, Low Carbon Steel, Dead Soft Annealed, 7 No. 5 (231,613 circular mil) and were installed in 1962.

Table 1: Physical properties of the three strands of Copperweld® conductor that had been buried underground for 48 years in a Kentucky substation

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			Strand 1	Strand 2	Strand 3
Conductor Type			40% Low Carbon Annealed		
Conductor Size			7 No. 5		
Cross Section Area		in^2	0.1819	0.1819	0.1819
Diameter of Single end		*inch*	0.1819	0.1819	0.1819
Diameter of Conductor		*inch*	0.5457	0.5457	0.5457
Copper Thickness	Min	*inch*	0.0142	0.0114	0.0134
	Max	*inch*	0.0213	0.0209	0.01975
% Concentricity			83.30%	77.30%	83.90%
Depth of corrosion	Min	*inch*	0.004	0.028	0.111
	Max	*inch*	0.781	0.859	0.484

The 1962 conductors were manufactured by Copperweld with a nominal copper thickness of 10% of its diameter. Figure 3 shows the copper thickness ranges from 11.4 – 21.3 mils and the concentricity of the conductor averaged at 81.5%. Current manufacturing improvements yield concentricity of copper thickness above 85%.

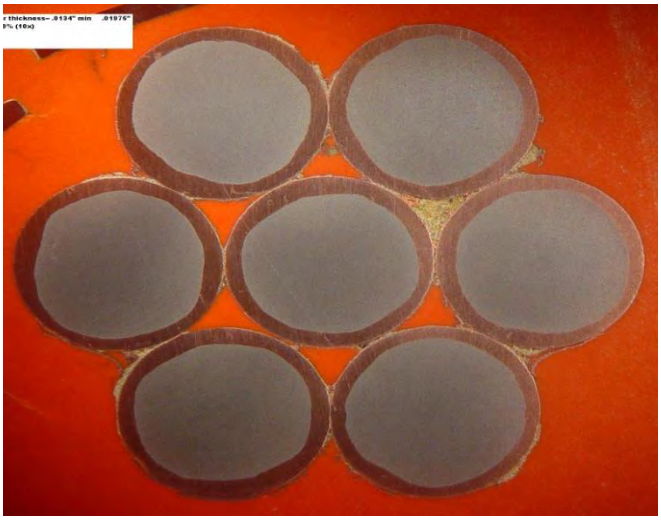


Figure 3: Copperweld® 40% LC DSA 7 No. 5 manufactured in 1962

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Figure 4a shows no visible corrosion observed other than oxidation and patination on the copper surface. At the ends of the wires, the corrosion occurred in the form of steel rust. The maximum depth of the corrosion is 0.859 inch with an average of 0.382 inch, as shown in Figure 4b.



Figure 4a: There is no visible corrosion between the copper and steel on all wires obtained from the substation in Kentucky.



Figure 4b: Corrosion occurred at the ends of the wires. Maximum penetration depth is 0.859 inch.

From all the corrosion studies above, there have not been reported or observed any galvanic corrosion at the interface of copper and steel. The process of cladding for

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Copperweld® ensures a metallurgical bond between the two metals. That metallurgical bond prevents any moisture from penetrating between the two metals precluding the corrosion process. Any propagation of corrosion on an area of exposed steel averages two times the diameter of the wire then stops. The corrosion rate of the copper surface is equivalent to that observed on standard solid copper wire and strand. Based on the results of these studies, it can be summarized that CCS can be expected to have a 50 plus year service life as buried grounding conductors.

REFERENCES:

1. Rempe, Chris. 7 July 2003. "A Technical Report on the Service Life of Ground Rod Electrodes".
2. Fox, Dustin, Belado, Chris, and Brossia, Sean. 23 September 2009. "The Effect of Corrosion on Tracer Wire with a Copper Clad Steel Center Conductor".

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Global Circulation Laboratory Test Report

For Global Distribution

UL467 SHORT CIRCUIT & UL 486A-486B MECHANICAL SEQUENCE TESTS

YGHP29C2, YGHC2C2, YGHC26C26, YGHP34C29, YGHC29C29, YGHP34C34, YGHC34C34 HYTAP™ Connectors
YGL2C2, YGL29C29, YGL34C34 HYGRID™ Connectors
YGA4C2N, YGHA272N, YGA282N, YGHA302N HYLUG™ Connectors

5/8" and 3/4"Copper Clad Steel Ground Rod, #4AWG Solid, 4/0AWG Stranded, 7#7, and 19#8 COPPERWELD® 40% IACS Copper Clad Steel Conductors

PAT750XT-18V PATRIOT® Tool
with
UC, UO, U28RT, U29RT, U32RT, U997, PU998, and U1011 Die Sets

TD002391 REV B

Requested by / Date:	***Authorized by / Date:***	***Completed by / Date:***
C. Gandhi 12-Dec-2014	R Robicheau 12-Dec-2014	R Charpentier 06-Apr-2015
Engineering Approval / Date:	***Marketing Approval / Date:***	***Laboratory Approval / Date:***
R.Roman 20-Aug-2020	J Hogan 20-Aug-2020	R Charpentier 20-Aug-2020

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

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Burndy LLC 47 East Industrial Park Dr.
Manchester / New Hampshire / 03109
Tel: 603 647 5000 Fax: 603 647 5205

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

PURPOSE OF TEST:

To determine if the Burndy HYTAP™, HYGRID™, and HYLUG™ Connectors can meet the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST REQUESTED:

UL486A-486B Mechanical Sequence
UL467 Short Time Current

TEST RESULTS:

Connector	Cable 1	Cable 2	Die	# of crimps	Securness	Pull	Short Time Current		
					Pass / Fail	Average Pull (lb)	Pass / Fail	Current (Amps)	Time (s)
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	U997	1	Pass	1021.3	Pass	1600	6
YGL2C2	#4 Solid CCS	#4 Solid CCS	U-O	1	Pass	1451.8	Pass	1600	6
YGHC2C2	#4 Solid CCS	#4 Solid CCS	U-C	1	Pass	1544.0	Pass	1600	6
YGA4C2N	#4 Solid CCS	n/a	U4CRT	1	Pass	814.0	Pass	1600	6
YGL29C29	7#7 STR CCS	7#7 STR CCS	U997	1	Pass	1643.2	Pass	4600	9
YGHC26C26	7#7 STRCCS	7#7 STR CCS	U-O	1	Pass	1239.4	Pass	4600	9
YGHA272N	7#7 STRCCS	n/a	U29RT	2	Pass	1574.0	Pass	4600	9
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PU998	1	Pass	1789.8	Pass	6100	9
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1849.8	Pass	6100	9
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1779.1	Pass	6100	9
YGA282N	4/0 AWG CCS	n/a	U28RT	2	Pass	2489.3	Pass	6100	9
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	U1011	3	Pass	2126.8	Pass	9000	9
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	U1011	3	Pass	2380.0	Pass	9000	9
YGL34C34	19#8 STRCCS	19#8 STR CCS	U1011	3	Pass	3158.3	Pass	9000	9
YGHC34C34	19#8 STR CCS	19#8 STR CCS	U1011	3	Pass	3812.1	Pass	9000	9
YGHA302N	19#8 STR CCS	n/a	U32RT	2	Pass	4792.2	Pass	9000	9

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Global Circulation Laboratory Test Report

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CONCLUSIONS:

All samples tested met the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST PROCEDURES

The table below shows the connector / conductor combinations tested.

Connector	Cable 1	Cable 2	Tool	Die	# of Crimps
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	PAT750	U997	1
YGL2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-O	1
YGHC2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-C	1
YGA4C2N	#4 Solid CCS	n/a	PAT750	U4CRT	1
YGL29C29	7#7 STR CCS	7#7 STR CCS	PAT750	U997	1
YGHC26C26	7#7 STR CCS	7#7 STR CCS	PAT750	U-O	1
YGHA272N	7#7 STR CCS	n/a	PAT750	U997	2
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PAT750	PU998	1
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGA282N	4/0 AWG CCS	n/a	PAT750	U997	2
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	PAT750	U1011	3
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	PAT750	U1011	3
YGL34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHC34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHA302N	19#8 STR CCS	n/a	PAT750	U32RT	2

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All conductors were cut to twenty four (24) inch lengths.
All ground rod was pre-crimped with the appropriate pre-crimp die
5/8in Rod UPRECRIMP58
3/4in Rod UPRECRIMP34

Mechanical Sequence
Four samples of each set were secured to the Secureness tester, the height; weight and bushing size were as specified in UL486A-486B Table 26. Samples were rotated for thirty minutes at 9rpm. Samples were then subjected to a 1-minute pull to the value specified in UL486A-486B Table 27 and then to failure.

Short Time Current
Test samples were assembled in a series loop configuration then attached to a current controller as shown below. The test current and duration are listed below. After completion of the test, electrical continuity was checked with a digital multi-meter.

Test current values were derived from the equation Annex C of IEEE Std 837-2002. The diameter of the conductor(s) were measured and the cross-sectional area of the conductors was calculated.

Conductor	***Current Value (A)***	***Duration (sec)***
#4AWG Solid COPPERWELD® 40% IACS CCS	1600	6
4/0AWG 19 strand COPPERWELD® 40% IACS CCS,	6100	9
7#7 stranded COPPERWELD® 40% IACS CCS	4600	9
19#8 stranded COPPERWELD® 40% IACS CCS	9000	9

TEST EQUIPMENT LIST:

MANUFACTURER	MODEL	DESCRIPTION	SERIAL #	RANGE
FLUKE	79 III	DMM	70591301 (Rene)	AUTO
OHIO SEMITRONICS		CURRENT TRANSDUCER	NA	15000:5
SATEC	T5000	TABLE TOP	2038	5000 lbs
VIRTECH	NA	HIGH CURRENT	NA	12V / 12000A
MITUTOYO	505-675	DIAL CALIPER	08914565 (Rene)	6"

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Powertech

Report ID: PL-03027 REP1
Revision: 0 Issued: 2020-04-15

Copper and CCS Wire Withstand Current and Fusing Current Tests

Copperweld Bimetallics, LLC



Powertech

REPORT OF PERFORMANCE

CLIENT	Copperweld Bimetallics,LLC. 5141 Virginia Way, Suite 410 Brentwood, TN, United States 37027
TEST OBJECTS	Copper Clad Steel (CCS) Wires Manufacturer: Copperweld Bimetallics,LLC. Types: Scorpius Prototypes Part Nos.: 61 x 072 7 x 080 Condition: New Copper Conductor Manufacturer: Encore Wire Types: #4/0 AWG (19 strand) CU #6 AWG (single strand) CU Condition: New
TESTED BY	Powertech Labs Inc. 12388 - 88th Ave, Surrey, BC Canada V3W 7R7 www.powertechlabs.com
TEST DATE	2020-01-24 to 2020-01-25
TEST SPECIFICATION	Client Specified, with reference to IEEE Std 80-2013 and IEEE Std 837-2014

Powertech Labs Inc. does not accept any liability for any damages resulting from the use of this report. The results relate only to the item tested, and it is the responsibility of the manufacturer to maintain conformity of any object having the same designations. Information regarding the estimated measurement uncertainty is available upon request. The test report shall not be reproduced except in full, without written approval of Powertech Labs Inc.

Prepared by:



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Powertech Labs Inc.

Reviewed by:



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Specialist Engineer, High Power Lab
Powertech Labs Inc.

Powertech

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1 INTRODUCTION

At the request of Copperweld Bimetallics,LLC., withstand current and fusing current tests were performed on standard copper and copper clad steel (CCS) wires in accordance with specifications and procedures provided by the client. Reference was made to IEEE Std 80-2013 and IEEE Std 837-2014 as guides for determining current levels and durations for the tests.

The High Power Lab is accredited by the Standards Council of Canada to ISO 17025 for short-circuit testing.

2 TEST OBJECT INFORMATION

The test objects were identified by the client as follows:

Copper Clad Steel Wires (CCS)

Manufacturer:	Copperweld Bimetallics,LLC.
Types:	Scorpius Prototypes
Part Nos.:	61 x 072
	7 x 080
Condition:	New

Copper Conductor

Manufacturer:	Encore Wire
Types:	4/0 AWG (19 strand) CU
	#6 AWG (single strand) CU
Condition:	New

Conductor sample diameters and dc resistance values were measured by the laboratory before testing, as presented in Table 1.

3 GENERAL INFORMATION

3.1 Purpose

The purpose of the tests is to identify the current limits at short durations for standard copper and Copperweld CCS grounding wire products, and to determine if these products meet the applicable requirements of the referenced Standards.

3.2 Witnesses

Name	Company
Jeff Jordan	Copperweld Bimetallics,LLC.
Lora Aboulmouna	Copperweld Bimetallics,LLC.
Jason Smolko	Copperweld Bimetallics,LLC.
Ryan Hale	Copperweld Bimetallics,LLC.

3.3 Tests Performed

Test Standards/Specifications:

Withstand current tests were performed as requested by the client, with reference to the following Standards to determine the test levels:

IEEE Std 80-2013, Table 6 – Specification for the ultimate current carrying capacity of copper grounding cables using symmetrical current.

IEEE Std 837-2014, Clause 7.2 and Table 3 – Electromagnetic force (EMF) test

4 SHORT-CIRCUIT CURRENT TESTS

General Information:

Standard	Client's Specification, with reference to IEEE Std 80-2013 and IEEE Std 837-2014
Test Dates	2020-01-24 to 2020-01-25
Test Leader	Chris Morton

Environmental Conditions:

Ambient temperature	(7 – 9) °C
Relative Humidity	(95 – 99) %

Test Conditions:

Samples were tested in a covered test cell which was open on one side to the outdoor ambient conditions. During each test, one sample was connected horizontally between the laboratory source bus and ground bus, at a bus spacing of 48 inches, as shown in Figures 30 through 33. The samples were terminated using Burndy mechanical connectors, as shown in Figures 34 and 35. The length of each wire sample was the minimum length required to span the distance between the buses, and each sample was at approximately right angles (90°) to both the source and ground bus. Each sample was suspended in free air approximately 46 inches above the floor of the test cell. The temperature of the sample at the start of each test was the natural outdoor ambient temperature of the laboratory, except for tests performed to IEEE 837, where the sample was allowed to cool to less than 100 °C before the second shot.

All tests were performed at a power frequency of 60 Hz using the test circuit shown in Figure 1. Current was initiated by energizing a current limited source that was calibrated to provide the target current through the circuit. The rms current, current symmetry and duration of each test were specified by the client.

The test current was measured using a 300 kA_{peak} rated Rogowski coil (Powertech ID № 39444). The expanded uncertainty of the current measuring system is estimated as 2% (k=2).

Test Results:

The results of the tests are provided in Tables 2 through 5. Current and voltage waveforms for each test are provided in Figures 2 through 29.

The Encore #4/0 AWG Cu wire did not withstand the I^2t calculated from the current and duration specified in IEEE 80, Table 6, for a 500 ms duration (44 kA_{rms}). It was capable of carrying a maximum of 92% of this I^2t value without fusing.

The Encore #4/0 AWG Cu wire did not withstand the EMF current specified in IEEE 837, Table 3 (47 kA_{rms}). It was capable of carrying a maximum of 91% of this current value without failing.

The Copperweld Scorpius CCS 61 x 072 conductor exceeded the 500 ms rms withstand current requirement of IEEE 80, Table 6, and met the EMF current requirements of IEEE 837, Table 3, for a 4/0 conductor.

For the #6 AWG Cu conductor size the Standards did not have current values specified, so these were calculated using Equation (45) from IEEE 80 and Equation (C.1) from IEEE 837. The calculations are presented in Appendix D.

Both the Copperweld Scorpius CCS 7 x 080 conductor and the Encore #6 AWG Cu conductor met the 500 ms rms withstand current requirement of IEEE 80, Table 6 (5.29 kA_{rms}), and the EMF current requirements of IEEE 837, Table 3 (5.81 kA_{rms}), for a #6 AWG Cu conductor.

APPENDIX A – FUSING CURRENT TEST CIRCUIT AND DATA

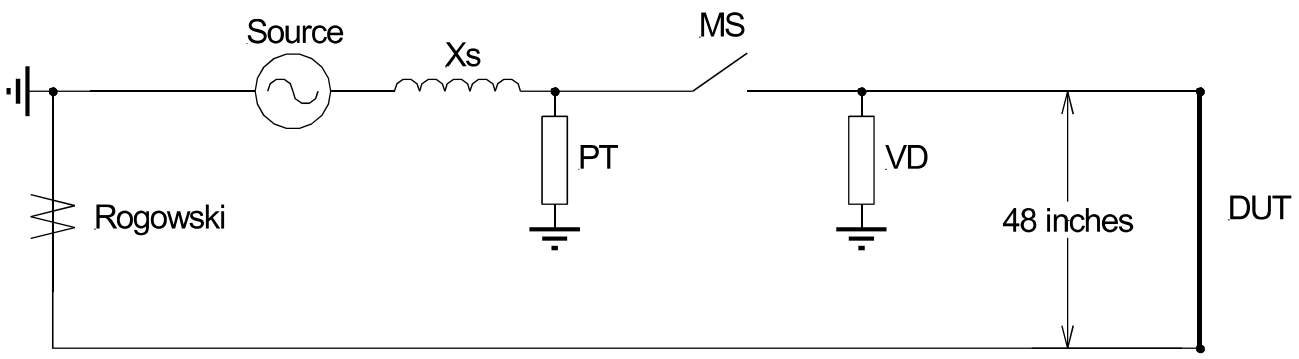


Figure 1: Test circuit schematic for all tests.

Notes:

1. *X_S – Source current limiting reactance*
2. *MS – Making Switch*
3. *VD – Voltage measurement*
4. *Rogowski – Current measurement*
5. *DUT – Device Under Test*

Copperweld Bimetallics Data Sheet Packet
Electrical Test Laboratory

Customer:	Copperweld Building Wire	Engineer:	Bill Lewey	Date:	8/25/2020
Sample ID:	EL-13	Tested By:	Bill Lewey, Mike Rozar	Date:	8/25/2020
Product:	Grade 40 Copper Clad Steel Wire Solid Bare #4 and #6 vs Equivalent Solid Copper: Grounding Electrode Conductor Equivalency Test	Sample Condition:	New		
Standard:	ASTM B910/910M Annealed Copper Clad Steel Wire				
Insulation: N/A - Bare		Jacket: N/A - Bare			

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Test Report Summary

Page	Test Performed	Date Completed	Pass/Fail
1	Grounding Electrode Conductor Test for Copper Clad Steel Grade 40	8/25/2020	**Pass**

Requirement:
#4 AWG Grade 40 Copper Clad Steel and #6 AWG Copper Clad Steel when compared to #4 solid copper and #6 solid copper for use as a grounding electrode conductor shall have equal ability to carry amperage during a ground fault condition.

Conclusion:
The ability of bare #4 AWG Copper Clad Steel Grade 40 and bare #6 AWG Copper Clad Steel Grade 40 performed equally to #4 AWG bare solid copper and #6 AWG bare solid copper when used as a grounding electrode conductor under a ground fault condition. The current measured proved equivalency.

Test Equipment Used

Item	Equipment Type	Equipment #	Cal. Due Date
1	Fluke 374FC Clamp Meter	AM-1	Nov 2020
2	Acme Electric 15KVA Transformer	T2535173S	N/A
3	Square D 60A / 600V Safety Interrupter	N/A	N/A
4	Eaton Service Panel	N/A	N/A
5	Eaton Type CH 20 Amp Breaker	N/A	N/A
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

VBU – Verify Before Use

N/A – Not Applicable

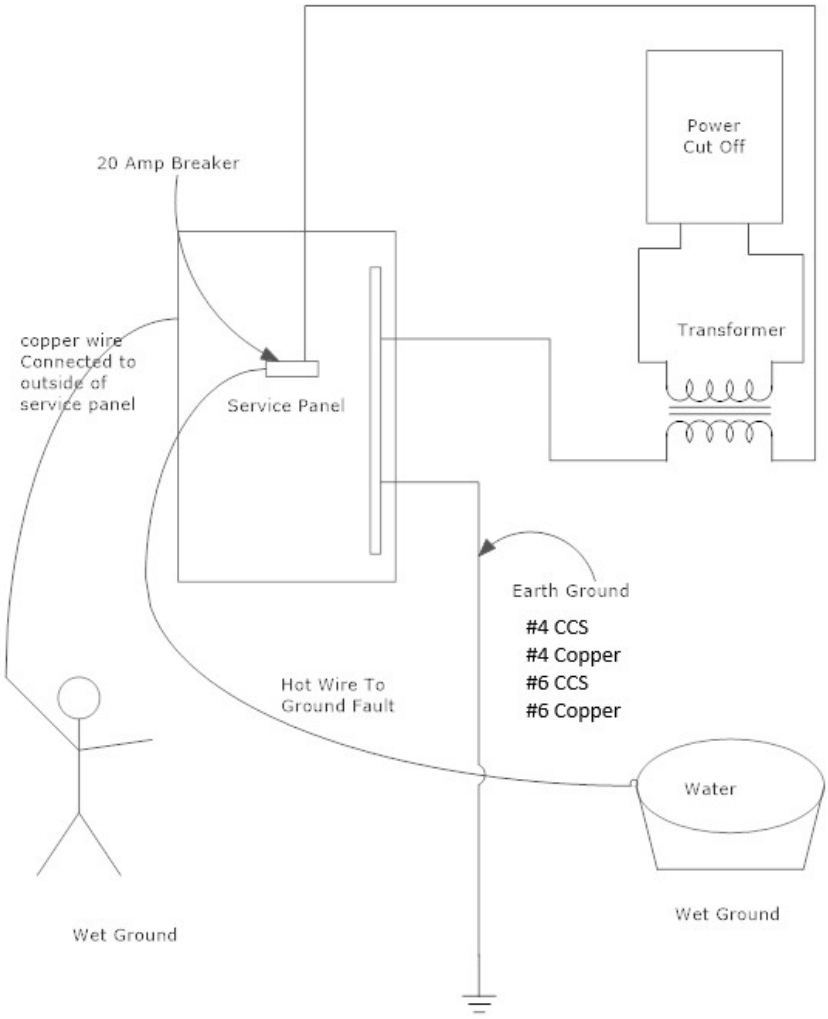
Sample Identification

Item	Description	Length/No. Rec'd
A	#4 AWG 40% Copper Clad Steel Bare	35 Ft
B	#4 AWG Solid Copper Bare	35 Ft
C	#6 AWG 40% Copper Clad Steel Bare	35 Ft
D	#6 AWG Solid Copper Bare	35 Ft
E		
F		

Grounding Electrode Conductor Test

Test Parameters:	
Conditioning:	No preconditioning.
Test Conductors:	1 each of #4 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #6 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #4 AWG Solid Bare copper grounding electrode conductor 1 each of #6 AWG Solid Bare copper grounding electrode conductor
Test Conductor Length:	Each conductor shall be 35 ft.
Test Circuit Configuration:	See schematic shown in Figure 1
Test Current:	Test current from 120 V / 20 A Residential Circuit
Method:	Testing was completed by creating a standard residential test circuit at 120V with 20A breaker wired to an intentional ground fault as shown in figure 1. The ground fault was created by connecting a hot wire from the breaker to a galvanized steel pan full of water and placing the pan on the wet ground. A conductor was also connected to the outside of the electrical panel and a Copper Plated Grounding Electrode (Copperweld Ground Rod) driven 6 inches into the wet ground to determine amount of current going through a grounded person touching the electrical panel during the ground fault condition. The ground fault and the grounded "man" were positioned 20 feet either side of the ground rod. The entire test area was soaked with water overnight using a sprinkler system When the ground fault was electrified, current measurements were taken from the ground fault conductor, the grounding electrode conductor and the grounded "man" conductor. For the four grounding electrode conductors tested, there was one test sequence for each. The current was measured for each. The objective: Compare the amperage measurements of the copper clad steel grounding electrode conductors to those of copper.

Figure 1



Results:			
Ground Conductor	**Fault Conductor Current**	**Current of the Grounding Electrode Conductor**	**Grounded Man Conductor Current**
#4 Copper	2.1 A	1.8 A	0.3 A
#4 40% CCS	2.1 A	1.8A	0.3 A
#6 Copper	1.7 A	1.6 A	0.1 A
#6 40% CCS	1.5 A	1.4 A	0.1 A

Requirement:
For equivalent sizes of Grade 40 Copper Clad steel vs. solid copper grounding conductors, the ability to carry amperage to ground during a ground fault condition is equal.

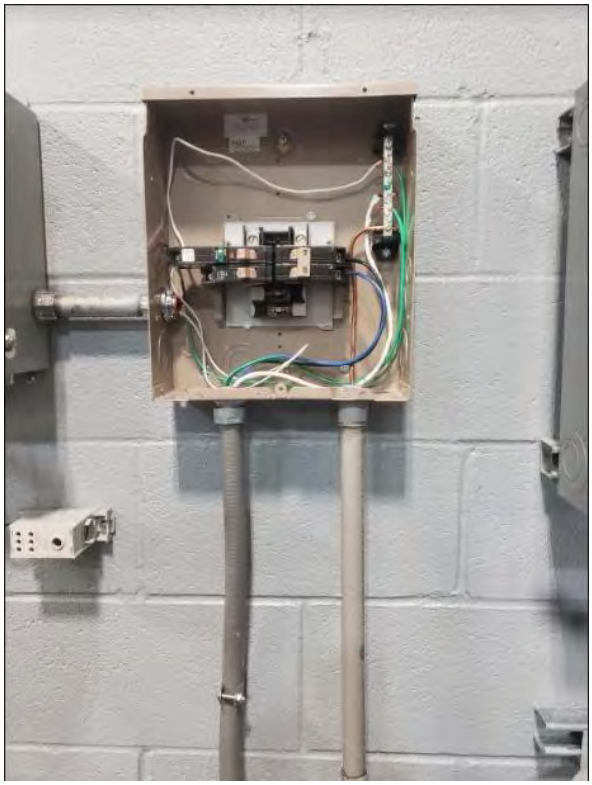
Comments:
____X__ (Pass) The product complies with all applicable requirements of this test. _____ (Fail) The product does not comply with the requirements of this test. **Test Date: 8/25/2020** **Tested By: Bill Lewey**

Environmental Conditions during Testing:

Humidity: % rh __74%_____ Ambient: °C___28_____

Test setup for the electrical service panel







Ground Rod with Grounding Conductor Attached



Ground Fault



Grounded “man”

Public Input No. 1079-NFPA 70-2020 [Sections 250.64(B)(1), 250.64(B)(2)]

Sections 250.64(B)(1), 250.64(B)(2)

(1) Not Exposed to Physical Damage.

A 6 AWG or ~~larger copper or aluminum~~ larger 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 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.

Statement of Problem and Substantiation for Public Input

The present wording completely ignores copper-clad conductors. By removing references to copper, and aluminum conductors all types of grounding electrode conductors will be covered by this rule. Copper, aluminum and copper-clad aluminum grounding electrode conductors should have these particular rules applied equally to each conductor material type. There is no solid reason why these rules should not apply to copper-clad aluminum grounding electrode conductors.

Submitter Information Verification

Submitter Full Name: Russ Leblanc
Organization: Leblanc Consulting Services
Street Address:
City:
State:
Zip:
Submittal Date: Fri May 15 17:22:49 EDT 2020
Committee: NEC-P05

Public Input No. 2465-NFPA 70-2020 [Section No. 250.64(B)(2)]

(2) Exposed to Physical Damage.

A 6 AWG or larger copper-clad steel or copper or 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.

Additional Proposed Changes

File Name	Description	Approved
CCS_Corrosion_paper_Rev2.pdf	50 Year Corrosion Study Grade 40 CCS	
TD002391.doc	UL 467 Short Circuit and UL 486A-B Mechanical Sequence Testing Grade 40 CCS	
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

COPPER-CLAD ALUMINUM CONDUCTORS:

Please Consult Section 110.5 Conductor Materials. Copper-Clad Aluminum as a conductor material should not be excluded for this application. Along with aluminum and copper, Copper-Clad Aluminum is only one of three conductor materials for general wiring permitted by the NEC® . This Public Input aims to correct an inconsistency in correlation between Articles. It aims to bring safe alternatives to users of this Code. The NFPA Standards Council created in August 2019 a special Bimetals Task Group to in part bring attention to correlation issues effecting Copper-Clad Aluminum, as well as to study expanding its range of applications in 2023. In a coordinated effort, the Bimetals Task Group will submit 19 Public Inputs in this cycle addressing these matters.

COPPER-CLAD STEEL CONDUCTORS:

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 applicate 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 Inputs for This Document

Related Input	Relationship
Public Input No. 2462-NFPA 70-2020 [Section No. 250.62]	
Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]	

Submitter Information Verification

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State:
Zip:
Submittal Date: Sun Aug 23 10:04:16 EDT 2020
Committee: NEC-P05

Testing done for the safety of our valued customer.

Global Circulation Laboratory Test Report

For Global Distribution

UL467 SHORT CIRCUIT & UL 486A-486B MECHANICAL SEQUENCE TESTS

YGHP29C2, YGHC2C2, YGHC26C26, YGHP34C29, YGHC29C29, YGHP34C34, YGHC34C34 HYTAP™ Connectors
YGL2C2, YGL29C29, YGL34C34 HYGRID™ Connectors
YGA4C2N, YGHA272N, YGA282N, YGHA302N HYLUG™ Connectors

5/8" and 3/4"Copper Clad Steel Ground Rod, #4AWG Solid, 4/0AWG Stranded, 7#7, and 19#8 COPPERWELD® 40% IACS Copper Clad Steel Conductors

PAT750XT-18V PATRIOT® Tool
with
UC, UO, U28RT, U29RT, U32RT, U997, PU998, and U1011 Die Sets

TD002391 REV B

Requested by / Date:	***Authorized by / Date:***	***Completed by / Date:***
C. Gandhi 12-Dec-2014	R Robicheau 12-Dec-2014	R Charpentier 06-Apr-2015
Engineering Approval / Date:	***Marketing Approval / Date:***	***Laboratory Approval / Date:***
R.Roman 20-Aug-2020	J Hogan 20-Aug-2020	R Charpentier 20-Aug-2020

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

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TEST EQUIPMENT : 5

Burndy LLC 47 East Industrial Park Dr.
Manchester / New Hampshire / 03109
Tel: 603 647 5000 Fax: 603 647 5205

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

PURPOSE OF TEST:

To determine if the Burndy HYTAP™, HYGRID™, and HYLUG™ Connectors can meet the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST REQUESTED:

UL486A-486B Mechanical Sequence
UL467 Short Time Current

TEST RESULTS:

Connector	Cable 1	Cable 2	Die	# of crimps	Securness	Pull	Short Time Current		
					Pass / Fail	Average Pull (lb)	Pass / Fail	Current (Amps)	Time (s)
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	U997	1	Pass	1021.3	Pass	1600	6
YGL2C2	#4 Solid CCS	#4 Solid CCS	U-O	1	Pass	1451.8	Pass	1600	6
YGHC2C2	#4 Solid CCS	#4 Solid CCS	U-C	1	Pass	1544.0	Pass	1600	6
YGA4C2N	#4 Solid CCS	n/a	U4CRT	1	Pass	814.0	Pass	1600	6
YGL29C29	7#7 STR CCS	7#7 STR CCS	U997	1	Pass	1643.2	Pass	4600	9
YGHC26C26	7#7 STRCCS	7#7 STR CCS	U-O	1	Pass	1239.4	Pass	4600	9
YGHA272N	7#7 STRCCS	n/a	U29RT	2	Pass	1574.0	Pass	4600	9
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PU998	1	Pass	1789.8	Pass	6100	9
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1849.8	Pass	6100	9
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1779.1	Pass	6100	9
YGA282N	4/0 AWG CCS	n/a	U28RT	2	Pass	2489.3	Pass	6100	9
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	U1011	3	Pass	2126.8	Pass	9000	9
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	U1011	3	Pass	2380.0	Pass	9000	9
YGL34C34	19#8 STRCCS	19#8 STR CCS	U1011	3	Pass	3158.3	Pass	9000	9
YGHC34C34	19#8 STR CCS	19#8 STR CCS	U1011	3	Pass	3812.1	Pass	9000	9
YGHA302N	19#8 STR CCS	n/a	U32RT	2	Pass	4792.2	Pass	9000	9

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Global Circulation Laboratory Test Report

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CONCLUSIONS:

All samples tested met the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST PROCEDURES

The table below shows the connector / conductor combinations tested.

Connector	Cable 1	Cable 2	Tool	Die	# of Crimps
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	PAT750	U997	1
YGL2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-O	1
YGHC2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-C	1
YGA4C2N	#4 Solid CCS	n/a	PAT750	U4CRT	1
YGL29C29	7#7 STR CCS	7#7 STR CCS	PAT750	U997	1
YGHC26C26	7#7 STR CCS	7#7 STR CCS	PAT750	U-O	1
YGHA272N	7#7 STR CCS	n/a	PAT750	U997	2
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PAT750	PU998	1
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGA282N	4/0 AWG CCS	n/a	PAT750	U997	2
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	PAT750	U1011	3
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	PAT750	U1011	3
YGL34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHC34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHA302N	19#8 STR CCS	n/a	PAT750	U32RT	2

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Global Circulation Laboratory Test Report

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All conductors were cut to twenty four (24) inch lengths.
All ground rod was pre-crimped with the appropriate pre-crimp die
5/8in Rod UPRECRIMP58
3/4in Rod UPRECRIMP34

Mechanical Sequence
Four samples of each set were secured to the Secureness tester, the height; weight and bushing size were as specified in UL486A-486B Table 26. Samples were rotated for thirty minutes at 9rpm. Samples were then subjected to a 1-minute pull to the value specified in UL486A-486B Table 27 and then to failure.

Short Time Current
Test samples were assembled in a series loop configuration then attached to a current controller as shown below. The test current and duration are listed below. After completion of the test, electrical continuity was checked with a digital multi-meter.

Test current values were derived from the equation Annex C of IEEE Std 837-2002. The diameter of the conductor(s) were measured and the cross-sectional area of the conductors was calculated.

Conductor	***Current Value (A)***	***Duration (sec)***
#4AWG Solid COPPERWELD® 40% IACS CCS	1600	6
4/0AWG 19 strand COPPERWELD® 40% IACS CCS,	6100	9
7#7 stranded COPPERWELD® 40% IACS CCS	4600	9
19#8 stranded COPPERWELD® 40% IACS CCS	9000	9

TEST EQUIPMENT LIST:

MANUFACTURER	MODEL	DESCRIPTION	SERIAL #	RANGE
FLUKE	79 III	DMM	70591301 (Rene)	AUTO
OHIO SEMITRONICS		CURRENT TRANSDUCER	NA	15000:5
SATEC	T5000	TABLE TOP	2038	5000 lbs
VIRTECH	NA	HIGH CURRENT	NA	12V / 12000A
MITUTOYO	505-675	DIAL CALIPER	08914565 (Rene)	6"

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CORROSION ON BURIED COPPER CLAD STEEL



Cece Syarif

Global Application Engineer

&

Anthony Hale

Manager, Utility Products, North America

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For more information, contact sales@copperweld.com.
The results and conclusions obtained from studies done by Copperweld are only applicable to Copper Clad Steel manufactured by Copperweld. Due to proprietary process used to produce the wire, the findings cannot be superimposed on any other copper-clad steel conductor.

254 Cotton Mill Rd, Fayetteville, TN 37334. Tel. (931) 433 – 7177

July 26, 2011

This paper compiles several studies and analysis regarding the corrosion performance of buried Copperweld® Copper-Clad-Steel (CCS) conductors. These range from the early 1900's with the invention of Copperweld® through the present day with studies performed by independent parties as well as Copperweld Company in-house testing. The purpose is to present the available information so that prospective users of Copperweld® CCS wire and strand can evaluate the corrosion resistance and expected performance within their specific application and area. Copperweld uses oxygen free copper in the manufacture of Copperweld® wire and strand. The copper surface of CCS is expected to oxidize and turn color ranging from green (patination) to brown and black the same as any solid copper wire or strand when exposed to environmental stimuli. Corrosion on exposed steel at the cut tip or end of the wire is also expected. The question to be answered is if the corrosion on either material or the interface between the copper and steel (galvanic reaction) will result in degradation of the wire as to make it unsuitable for use as a grounding conductor.

The oldest known underground corrosion study of bimetallic material was performed in the early 1900s[1]. This study focused on the corrosion behavior of Copperweld® CCS underground rod as well as other materials such as Copper and galvanized steel ground rod. The National Bureau of Standards (NBS) conducted an extensive underground corrosion study that involves 36,500 specimens which include 333 varieties of ferrous, nonferrous, and protective coating materials buried in 128 test locations throughout U.S in 1910 - 1955.

The study summarizes the service life of a ground rod as following:

10 mils copper coating – acceptable for service life up to 40 years

13 mils copper coating – acceptable for service life up to 50 years

Similarly, the Naval Civil Engineering Laboratory in collaboration with the National Association of Corrosion Engineers conducted a 7-year program of testing metal rods for electrical grounding to determine the galvanic corrosion effect. The three metals tested were stainless clad steel, copper-bonded steel (CCS), and galvanized steel. The result on the ⅝" CCS ground rod was as expected. The copper surface of the CCS was

virtually free of corrosion and the steel core has corroded at the tip approximately 2 inches down the length of the rod.

Copperweld Corporation is the inventor and sole manufacturer of Copperweld® Copper-bonded ground rods and Copperweld® wire and strand since 1915. The corrosion behavior of a Copperweld® ground rod is similar to the corrosion on Copperweld® wire and strand conductor. Both materials consist of copper permanently bonded to a steel core. All Copperweld® 40% CCS has a copper thickness of 10% of the overall diameter. For example, Copperweld® 4THOUGHT™ has a configuration of 19 strands of 0.1055 inch wires. It means that each strand has a copper thickness of 10.55 mils. Based on the NBS study, 4THOUGHT™ will have at least a minimum service life of 40 years.

Copperweld has also conducted a 5-year study of buried bare 21% conductivity (copper thickness is 3% of the diameter) Copperweld® CCS in 10 different soil conditions in association with Southwest Research Institute[2]. The study reported 100% surface oxidation and various degrees of deterioration of the steel core as expected after 5 years. The exposed steel on the tip of the wire rusted and formed "scab", as shown in Figure 1. The rust appeared to "seal-off" the un-oxidized material from the corrosive medium. The maximum depth of corrosion was 70% of the wire diameter.



Figure 1: Example of Underground Corrosion of Copper Clad Steel

Although the copper surface oxidation was heavy, the samples showed no signs of pits or holes in the copper cladding. The copper thickness of a severely oxidized 5-year sample showed no discernable difference when compared to an un-oxidized control sample that was not subjected to the corrosive environment. The mechanical and resistance testing

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resulted in negligible differences between 5-year samples and the control samples. Thus, the oxidation had no discernable impact on the strength or electrical performance of the wire.

An accelerated corrosion study based on ASTM B117 was conducted on bare CCS and solid Copper wires to evaluate copper surface corrosion. The wires were exposed to salt fog spray for 504 hours. As a result, corrosion on the CCS copper surface showed no significant difference as compared to the corrosion of copper wire.



(a) Copper Clad Steel (b) Copper

Figure 2: Patination of Copper Surface after 504 hours exposure to Salt Fog Spray

In February 2011, three separate sample strands of Copper Clad Steel were un-earthed and cut out from a substation built in Louisville, KY. The conductors were 40% conductivity, Low Carbon Steel, Dead Soft Annealed, 7 No. 5 (231,613 circular mil) and were installed in 1962.

Table 1: Physical properties of the three strands of Copperweld® conductor that had been buried underground for 48 years in a Kentucky substation

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			Strand 1	Strand 2	Strand 3
Conductor Type			40% Low Carbon Annealed		
Conductor Size			7 No. 5		
Cross Section Area		in^2	0.1819	0.1819	0.1819
Diameter of Single end		*inch*	0.1819	0.1819	0.1819
Diameter of Conductor		*inch*	0.5457	0.5457	0.5457
Copper Thickness	Min	*inch*	0.0142	0.0114	0.0134
	Max	*inch*	0.0213	0.0209	0.01975
% Concentricity			83.30%	77.30%	83.90%
Depth of corrosion	Min	*inch*	0.004	0.028	0.111
	Max	*inch*	0.781	0.859	0.484

The 1962 conductors were manufactured by Copperweld with a nominal copper thickness of 10% of its diameter. Figure 3 shows the copper thickness ranges from 11.4 – 21.3 mils and the concentricity of the conductor averaged at 81.5%. Current manufacturing improvements yield concentricity of copper thickness above 85%.

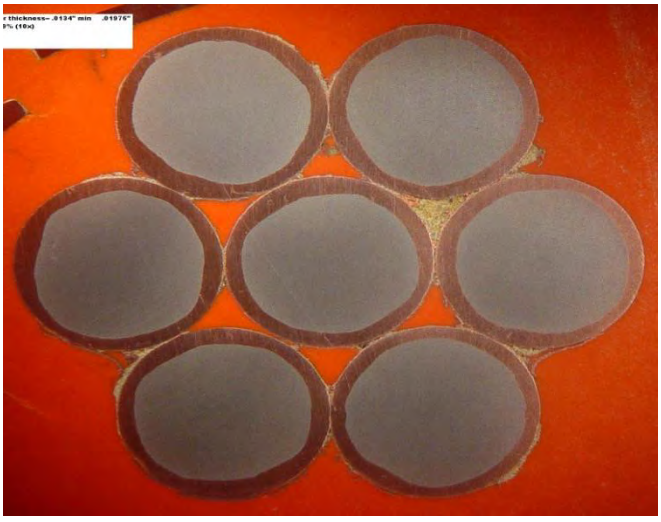


Figure 3: Copperweld® 40% LC DSA 7 No. 5 manufactured in 1962

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Figure 4a shows no visible corrosion observed other than oxidation and patination on the copper surface. At the ends of the wires, the corrosion occurred in the form of steel rust. The maximum depth of the corrosion is 0.859 inch with an average of 0.382 inch, as shown in Figure 4b.



Figure 4a: There is no visible corrosion between the copper and steel on all wires obtained from the substation in Kentucky.



Figure 4b: Corrosion occurred at the ends of the wires. Maximum penetration depth is 0.859 inch.

From all the corrosion studies above, there have not been reported or observed any galvanic corrosion at the interface of copper and steel. The process of cladding for

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Copperweld® ensures a metallurgical bond between the two metals. That metallurgical bond prevents any moisture from penetrating between the two metals precluding the corrosion process. Any propagation of corrosion on an area of exposed steel averages two times the diameter of the wire then stops. The corrosion rate of the copper surface is equivalent to that observed on standard solid copper wire and strand. Based on the results of these studies, it can be summarized that CCS can be expected to have a 50 plus year service life as buried grounding conductors.

REFERENCES:

1. Rempe, Chris. 7 July 2003. "A Technical Report on the Service Life of Ground Rod Electrodes".
2. Fox, Dustin, Belado, Chris, and Brossia, Sean. 23 September 2009. "The Effect of Corrosion on Tracer Wire with a Copper Clad Steel Center Conductor".

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Revision: 0 Issued: 2020-04-15

Copper and CCS Wire Withstand Current and Fusing Current Tests

Copperweld Bimetallics, LLC



The Power of Trust. **The Future of Energy.**

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REPORT OF PERFORMANCE

CLIENT	Copperweld Bimetallics,LLC. 5141 Virginia Way, Suite 410 Brentwood, TN, United States 37027
TEST OBJECTS	Copper Clad Steel (CCS) Wires Manufacturer: Copperweld Bimetallics,LLC. Types: Scorpius Prototypes Part Nos.: 61 x 072 7 x 080 Condition: New Copper Conductor Manufacturer: Encore Wire Types: #4/0 AWG (19 strand) CU #6 AWG (single strand) CU Condition: New
TESTED BY	Powertech Labs Inc. 12388 - 88th Ave, Surrey, BC Canada V3W 7R7 www.powertechlabs.com
TEST DATE	2020-01-24 to 2020-01-25
TEST SPECIFICATION	Client Specified, with reference to IEEE Std 80-2013 and IEEE Std 837-2014

Powertech Labs Inc. does not accept any liability for any damages resulting from the use of this report. The results relate only to the item tested, and it is the responsibility of the manufacturer to maintain conformity of any object having the same designations. Information regarding the estimated measurement uncertainty is available upon request. The test report shall not be reproduced except in full, without written approval of Powertech Labs Inc.

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1 INTRODUCTION

At the request of Copperweld Bimetallics,LLC., withstand current and fusing current tests were performed on standard copper and copper clad steel (CCS) wires in accordance with specifications and procedures provided by the client. Reference was made to IEEE Std 80-2013 and IEEE Std 837-2014 as guides for determining current levels and durations for the tests.

The High Power Lab is accredited by the Standards Council of Canada to ISO 17025 for short-circuit testing.

2 TEST OBJECT INFORMATION

The test objects were identified by the client as follows:

Copper Clad Steel Wires (CCS)

Manufacturer:	Copperweld Bimetallics,LLC.
Types:	Scorpius Prototypes
Part Nos.:	61 x 072
	7 x 080
Condition:	New

Copper Conductor

Manufacturer:	Encore Wire
Types:	4/0 AWG (19 strand) CU
	#6 AWG (single strand) CU
Condition:	New

Conductor sample diameters and dc resistance values were measured by the laboratory before testing, as presented in Table 1.

3 GENERAL INFORMATION

3.1 Purpose

The purpose of the tests is to identify the current limits at short durations for standard copper and Copperweld CCS grounding wire products, and to determine if these products meet the applicable requirements of the referenced Standards.

3.2 Witnesses

Name	Company
Jeff Jordan	Copperweld Bimetallics,LLC.
Lora Aboulmouna	Copperweld Bimetallics,LLC.
Jason Smolko	Copperweld Bimetallics,LLC.
Ryan Hale	Copperweld Bimetallics,LLC.

3.3 Tests Performed

Test Standards/Specifications:

Withstand current tests were performed as requested by the client, with reference to the following Standards to determine the test levels:

IEEE Std 80-2013, Table 6 – Specification for the ultimate current carrying capacity of copper grounding cables using symmetrical current.

IEEE Std 837-2014, Clause 7.2 and Table 3 – Electromagnetic force (EMF) test

4 SHORT-CIRCUIT CURRENT TESTS

General Information:

Standard	Client's Specification, with reference to IEEE Std 80-2013 and IEEE Std 837-2014
Test Dates	2020-01-24 to 2020-01-25
Test Leader	Chris Morton

Environmental Conditions:

Ambient temperature	(7 – 9) °C
Relative Humidity	(95 – 99) %

Test Conditions:

Samples were tested in a covered test cell which was open on one side to the outdoor ambient conditions. During each test, one sample was connected horizontally between the laboratory source bus and ground bus, at a bus spacing of 48 inches, as shown in Figures 30 through 33. The samples were terminated using Burndy mechanical connectors, as shown in Figures 34 and 35. The length of each wire sample was the minimum length required to span the distance between the buses, and each sample was at approximately right angles (90°) to both the source and ground bus. Each sample was suspended in free air approximately 46 inches above the floor of the test cell. The temperature of the sample at the start of each test was the natural outdoor ambient temperature of the laboratory, except for tests performed to IEEE 837, where the sample was allowed to cool to less than 100 °C before the second shot.

All tests were performed at a power frequency of 60 Hz using the test circuit shown in Figure 1. Current was initiated by energizing a current limited source that was calibrated to provide the target current through the circuit. The rms current, current symmetry and duration of each test were specified by the client.

The test current was measured using a 300 kA_{peak} rated Rogowski coil (Powertech ID № 39444). The expanded uncertainty of the current measuring system is estimated as 2% (k=2).

Test Results:

The results of the tests are provided in Tables 2 through 5. Current and voltage waveforms for each test are provided in Figures 2 through 29.

The Encore #4/0 AWG Cu wire did not withstand the I^2t calculated from the current and duration specified in IEEE 80, Table 6, for a 500 ms duration (44 kA_{rms}). It was capable of carrying a maximum of 92% of this I^2t value without fusing.

The Encore #4/0 AWG Cu wire did not withstand the EMF current specified in IEEE 837, Table 3 (47 kA_{rms}). It was capable of carrying a maximum of 91% of this current value without failing.

The Copperweld Scorpius CCS 61 x 072 conductor exceeded the 500 ms rms withstand current requirement of IEEE 80, Table 6, and met the EMF current requirements of IEEE 837, Table 3, for a 4/0 conductor.

For the #6 AWG Cu conductor size the Standards did not have current values specified, so these were calculated using Equation (45) from IEEE 80 and Equation (C.1) from IEEE 837. The calculations are presented in Appendix D.

Both the Copperweld Scorpius CCS 7 x 080 conductor and the Encore #6 AWG Cu conductor met the 500 ms rms withstand current requirement of IEEE 80, Table 6 (5.29 kA_{rms}), and the EMF current requirements of IEEE 837, Table 3 (5.81 kA_{rms}), for a #6 AWG Cu conductor.

APPENDIX A – FUSING CURRENT TEST CIRCUIT AND DATA

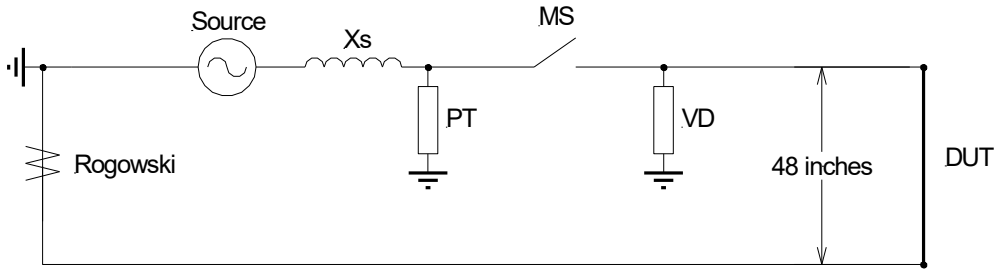


Figure 1: Test circuit schematic for all tests.

Notes:

1. X_S – Source current limiting reactance
2. MS – Making Switch
3. VD – Voltage measurement
4. Rogowski – Current measurement
5. DUT – Device Under Test

Table 1: Strand diameter and dc resistance measurements of sample conductors.

Wire Sample No.	Type	Strand Diameter [1] (in)		Conductor Diameter	Dc Resistance at 20°C
#		1	2	(in)	(μΩ/ft)
1	Encore Wire, 4/0 AWG, 19 strand CU	0.122	0.079	0.492	4.28
2	Encore Wire, 4/0 AWG, 19 strand CU	0.118	0.080	0.501	4.10
3	Encore Wire, 4/0 AWG, 19 strand CU	0.109	0.074	0.495	4.23
4	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.075	0.498	3.98
5	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.079	0.489	4.43
6	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.075	0.490	4.17
7	Encore Wire, 4/0 AWG, 19 strand CU	0.101	0.075	0.489	4.18
8	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.074	0.491	4.15
9	Encore Wire, 4/0 AWG, 19 strand CU	0.106	0.082	0.490	3.97
10	Encore Wire, 4/0 AWG, 19 strand CU	0.105	0.079	0.493	3.73
11	Scorpius 61 x 072 CCS	0.056	---	0.646	6.83
12	Scorpius 61 x 072 CCS	0.058	---	0.649	6.60
13	Scorpius 61 x 072 CCS	0.068	---	0.641	6.60
14	Scorpius 61 x 072 CCS	0.056	---	0.639	6.73
15	Scorpius 61 x 072 CCS	0.067	---	0.646	6.62
16	Scorpius 61 x 072 CCS	0.059	---	0.630	6.53
17	Scorpius 61 x 072 CCS	0.056	---	0.642	6.73
18	Scorpius 61 x 072 CCS	0.067	---	0.637	6.62
19	Scorpius 61 x 072 CCS	0.064	---	0.641	6.85
20	Scorpius 61 x 072 CCS	0.059	---	0.633	6.83
21	Encore Wire, #6 AWG, single strand CU	0.152	---	0.152	33.3
22	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
23	Encore Wire, #6 AWG, single strand CU	0.158	---	0.158	33.2
24	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.4
25	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.3
26	Encore Wire, #6 AWG, single strand CU	0.148	---	0.148	33.6
27	Encore Wire, #6 AWG, single strand CU	0.155	---	0.155	33.3
28	Encore Wire, #6 AWG, single strand CU	0.146	---	0.146	33.1
29	Encore Wire, #6 AWG, single strand CU	0.153	---	0.153	33.2
30	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
31	Scorpius 7 x 080 CCS	0.072	---	0.215	46.3
32	Scorpius 7 x 080 CCS	0.069	---	0.226	45.9
33	Scorpius 7 x 080 CCS	0.065	---	0.220	46.2
34	Scorpius 7 x 080 CCS	0.071	---	0.218	46.4
35	Scorpius 7 x 080 CCS	0.073	---	0.212	46.1
36	Scorpius 7 x 080 CCS	0.065	---	0.216	46.3
37	Scorpius 7 x 080 CCS	0.070	---	0.211	46.1

Note:

[1] Encore 4/0 AWG CU conductor had two sizes of strands, all remaining conductors had one size of strands. Strand and conductor diameters were measured using a digital caliper with a resolution of 0.001 in.

Table 2: Summary of tests on Encore 4/0 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
1	1	Run to fusing	3.85	41.7	60.0	530	923	2	Y
2	2	Withstand	3.85	41.8	62.5	509	889	3	N
3-1	3	EMF (IEEE 837)	4.24	48.0	130	262	826	4	N
3-2	3	EMF (IEEE 837)	4.26	48.0	130	127	503	5	Y
4	4	EMF (IEEE 837)	4.25	48.0	130	260	823	6	Y
5-1	5	EMF (IEEE 837)	4.20	47.4	129	262	808	7	N
5-2	5	EMF (IEEE 837)	4.19	47.4	128	9.9	77	8	Y
6-1	6	EMF (IEEE 837)	3.93	42.6	116	263	662	9	N
6-2	6	EMF (IEEE 837)	3.91	42.6	116	262	654	10	N

Table 3: Summary of tests on Copperweld Scorpius 61 x 072 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
7	11	Run to fusing	3.84	41.7	59.6	673	1173	11	Y
8	12	Run to fusing	4.25	48.1	69.8	500	1157	12	Y
9	13	Run to fusing	4.21	47.5	68.9	508	1150	13	Y
10	14	Withstand	4.09	46.2	66.2	508	1089	14	N
11-1	15	EMF (IEEE 837)	4.21	47.6	129	262	803	15	N
11-2	15	EMF (IEEE 837)	4.20	47.7	129	262	803	16	N
12-1	16	EMF (IEEE 837)	4.21	47.6	129	254	784	17	N
12-2	16	EMF (IEEE 837)	4.19	47.4	128	254	767	18	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

Table 4: Summary of tests on Encore #6 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
13	21	Run to fusing	3.90	5.18	7.36	607	16.3	19	Y
14	23	Run to fusing	3.90	5.18	7.57	600	16.1	20	Y
15	24	Run to fusing	4.27	5.68	8.15	500	16.1	21	Y
16-1	25	EMF (IEEE 837)	3.77	5.86	16.2	262	13.9	22	N
16-2	25	EMF (IEEE 837)	3.77	5.86	16.1	262	13.9	23	N

Table 5: Summary of tests on Copperweld Scorpius 7 x 080 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
17	31	Withstand	3.88	5.16	7.44	858	22.9	24	N
18	32	Run to fusing	3.89	5.16	7.43	908	24.2	25	Y
19	33	Run to fusing	4.48	7.00	10.3	493	24.1	26	Y
20	34	Run to fusing	4.41	6.91	10.2	502	23.9	27	Y
21-1	35	EMF (IEEE 837)	3.81	5.91	16.3	262	14.0	28	N
21-2	35	EMF (IEEE 837)	3.80	5.92	16.2	262	13.8	29	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

APPENDIX B – WAVEFORMS

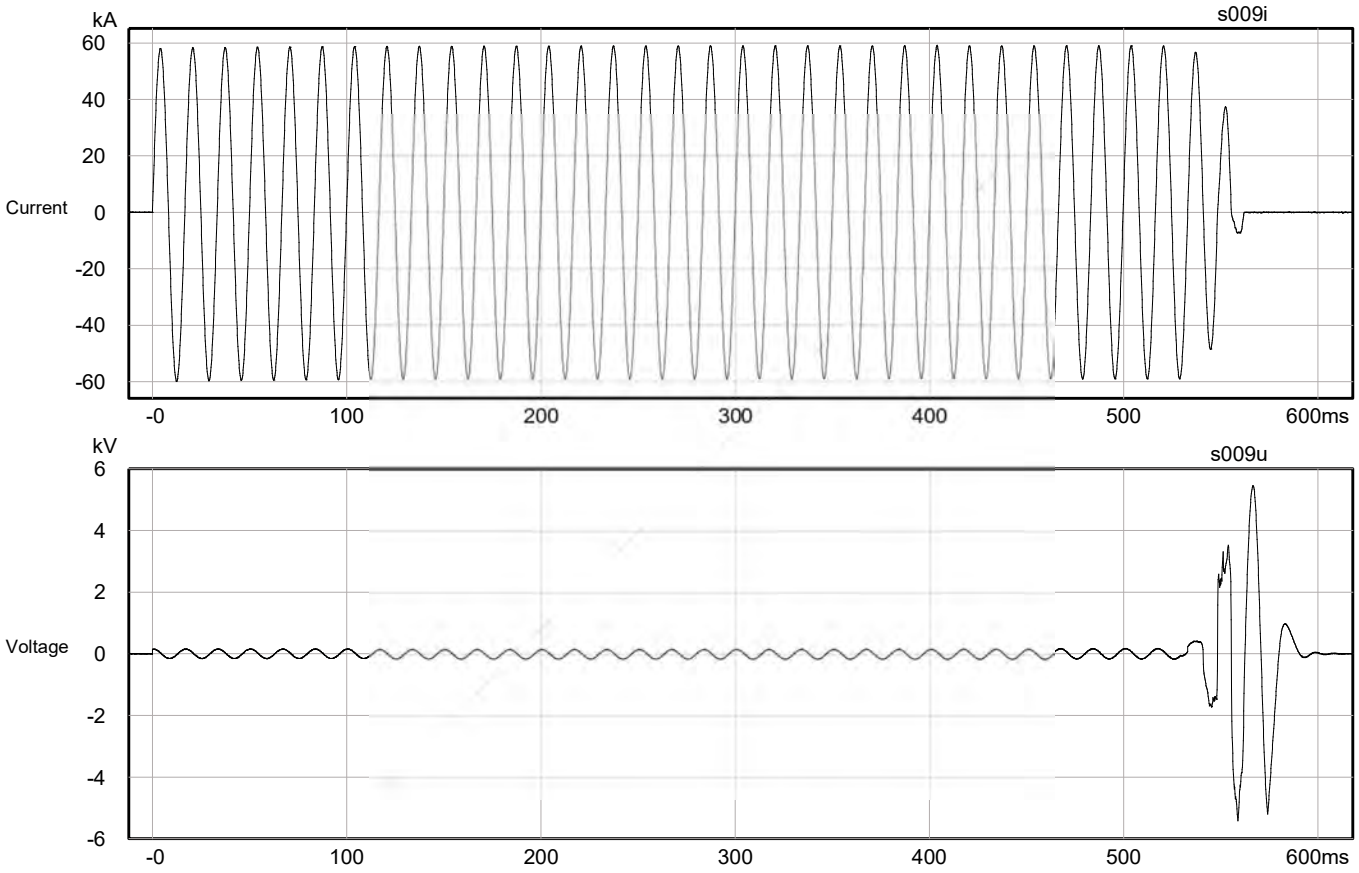


Figure 2: Waveforms for Test #1, Encore 4/0 AWG Sample 1.

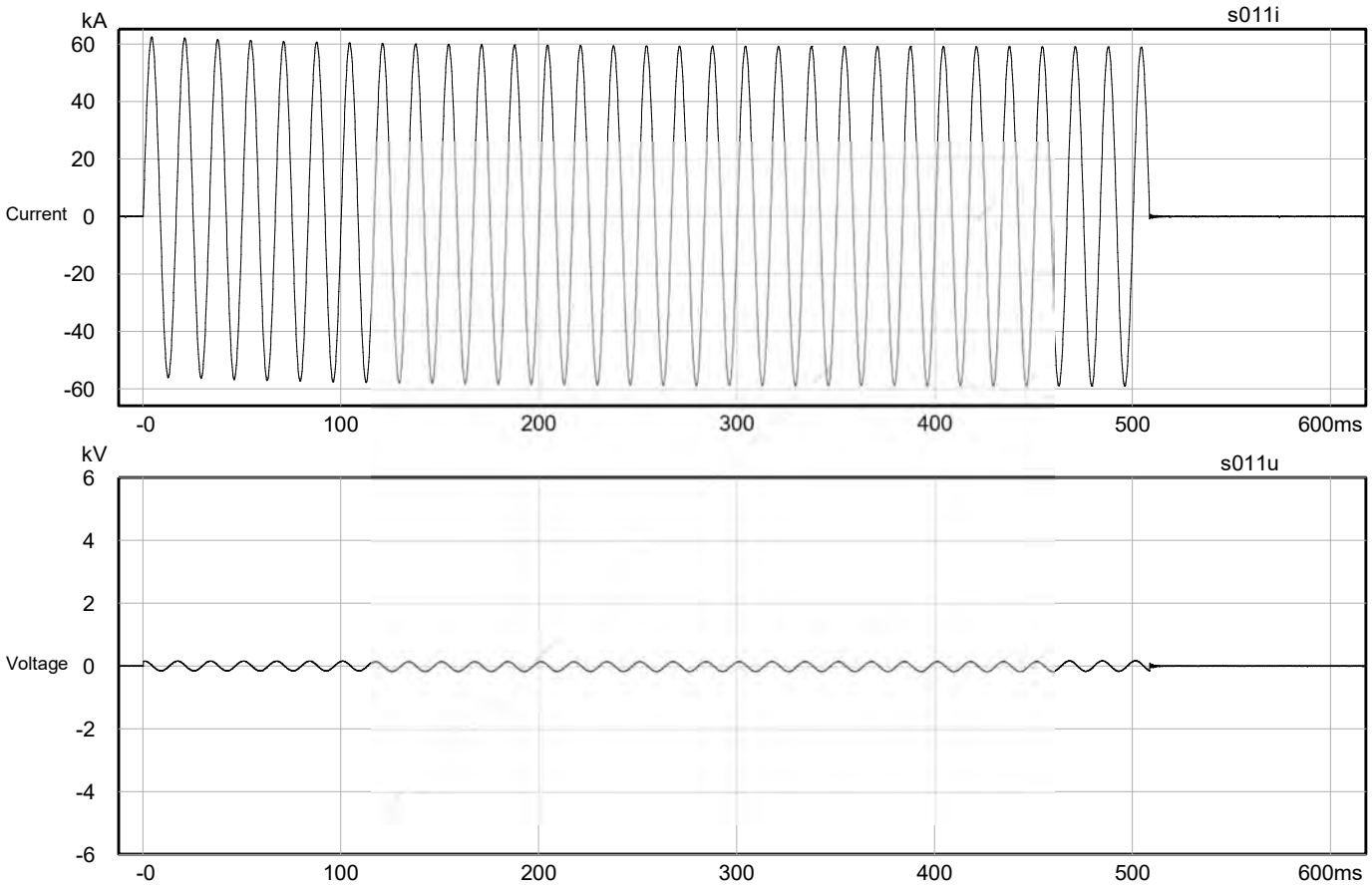


Figure 3: Waveforms for Test #2, Encore 4/0 AWG Sample 2.

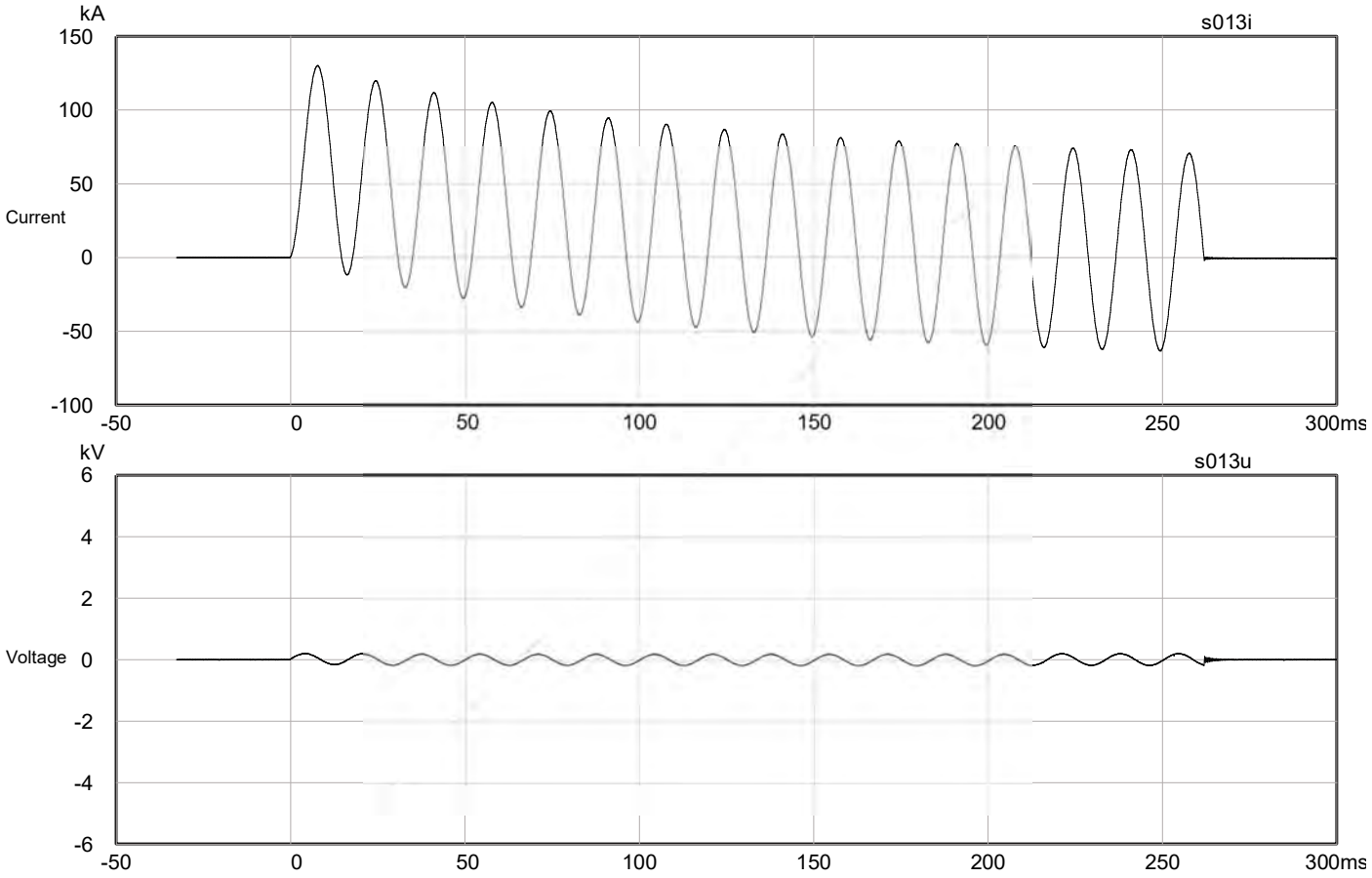


Figure 4: Waveforms for Test #3-1, Encore 4/0 AWG Sample 3.

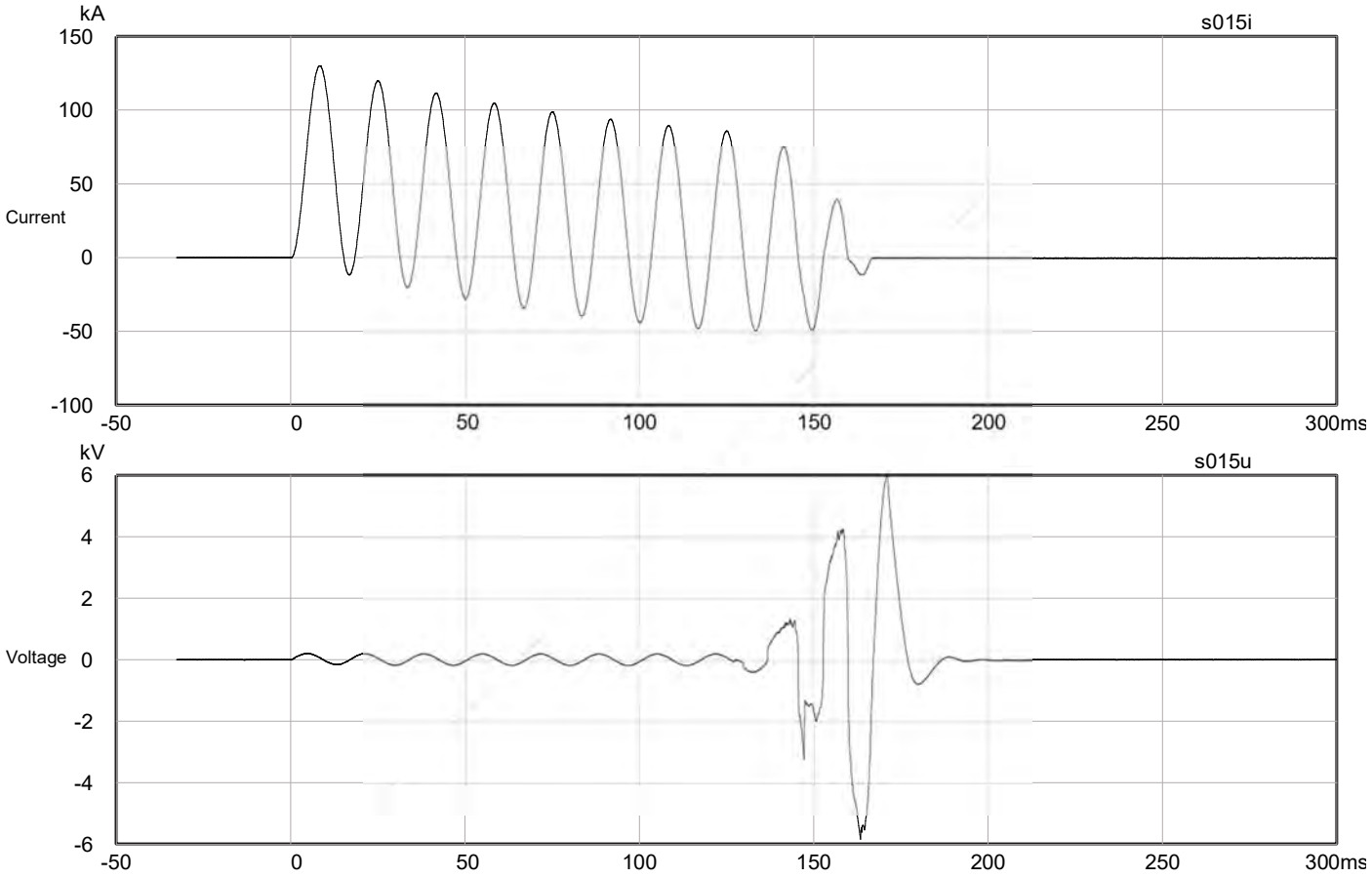


Figure 5: Waveforms for Test #3-2, Encore 4/0 AWG Sample 3.

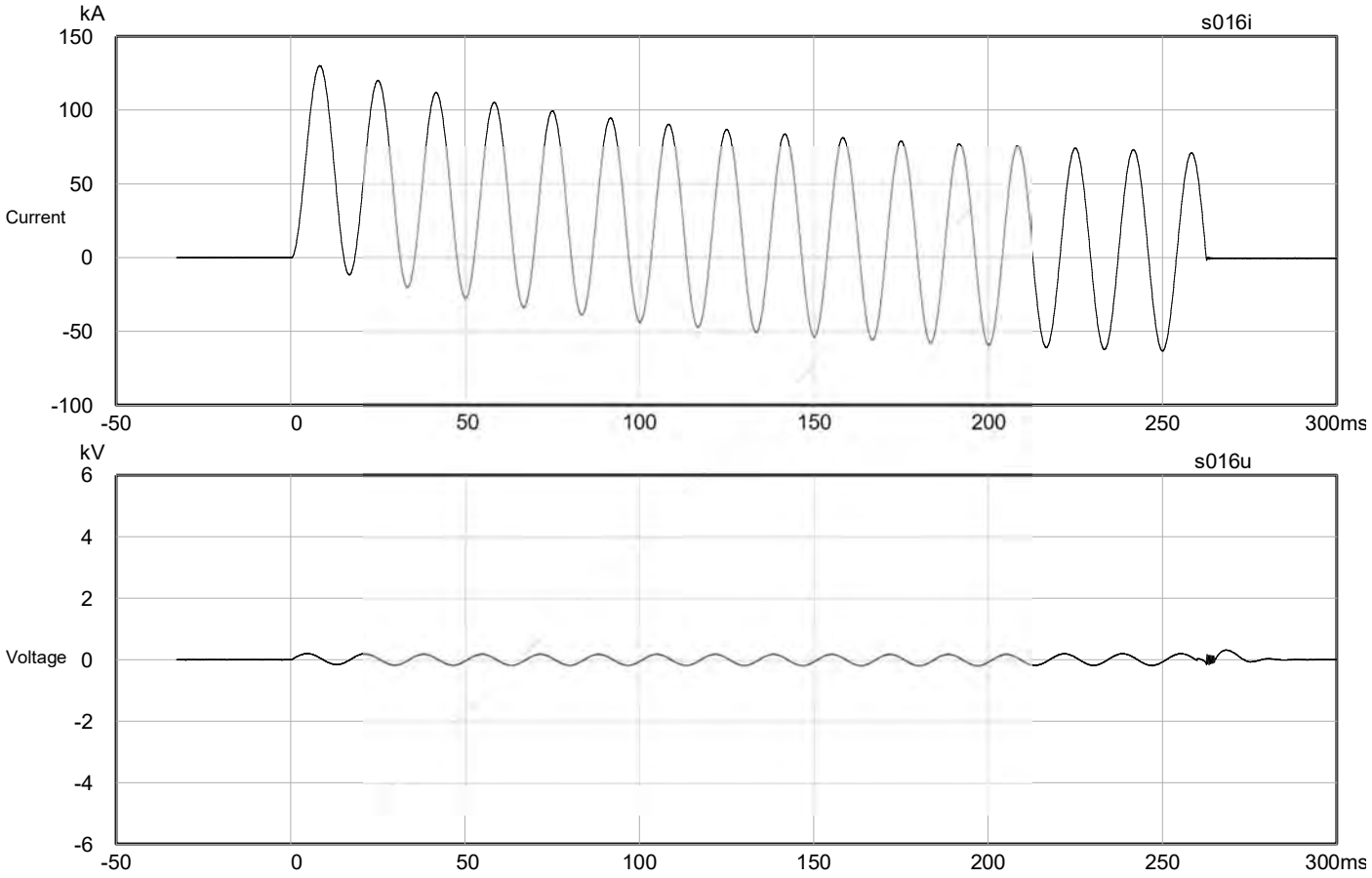


Figure 6: Waveforms for Test #4, Encore 4/0 AWG Sample 4.

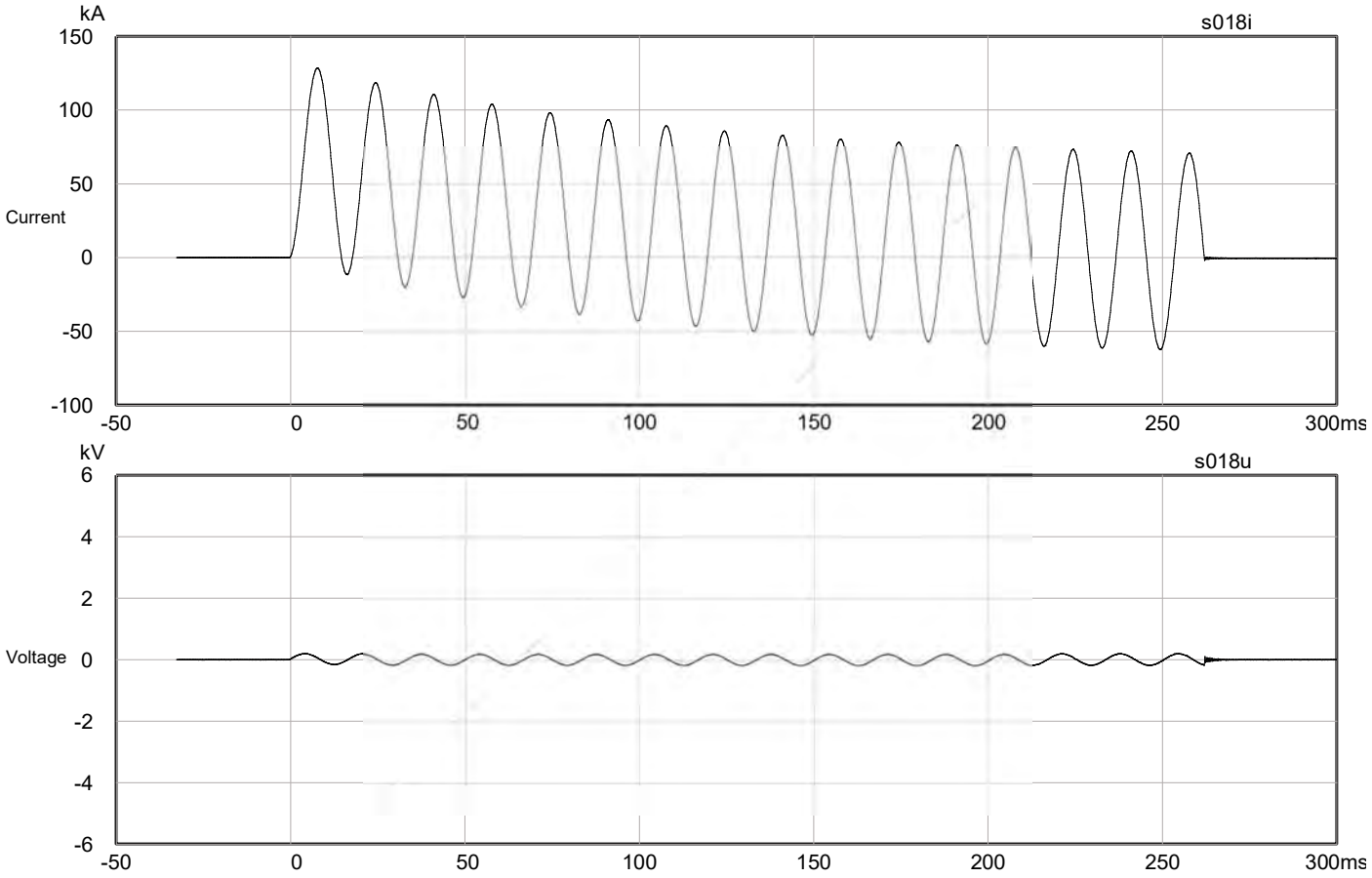


Figure 7: Waveforms for Test #5-1, Encore 4/0 AWG Sample 5.

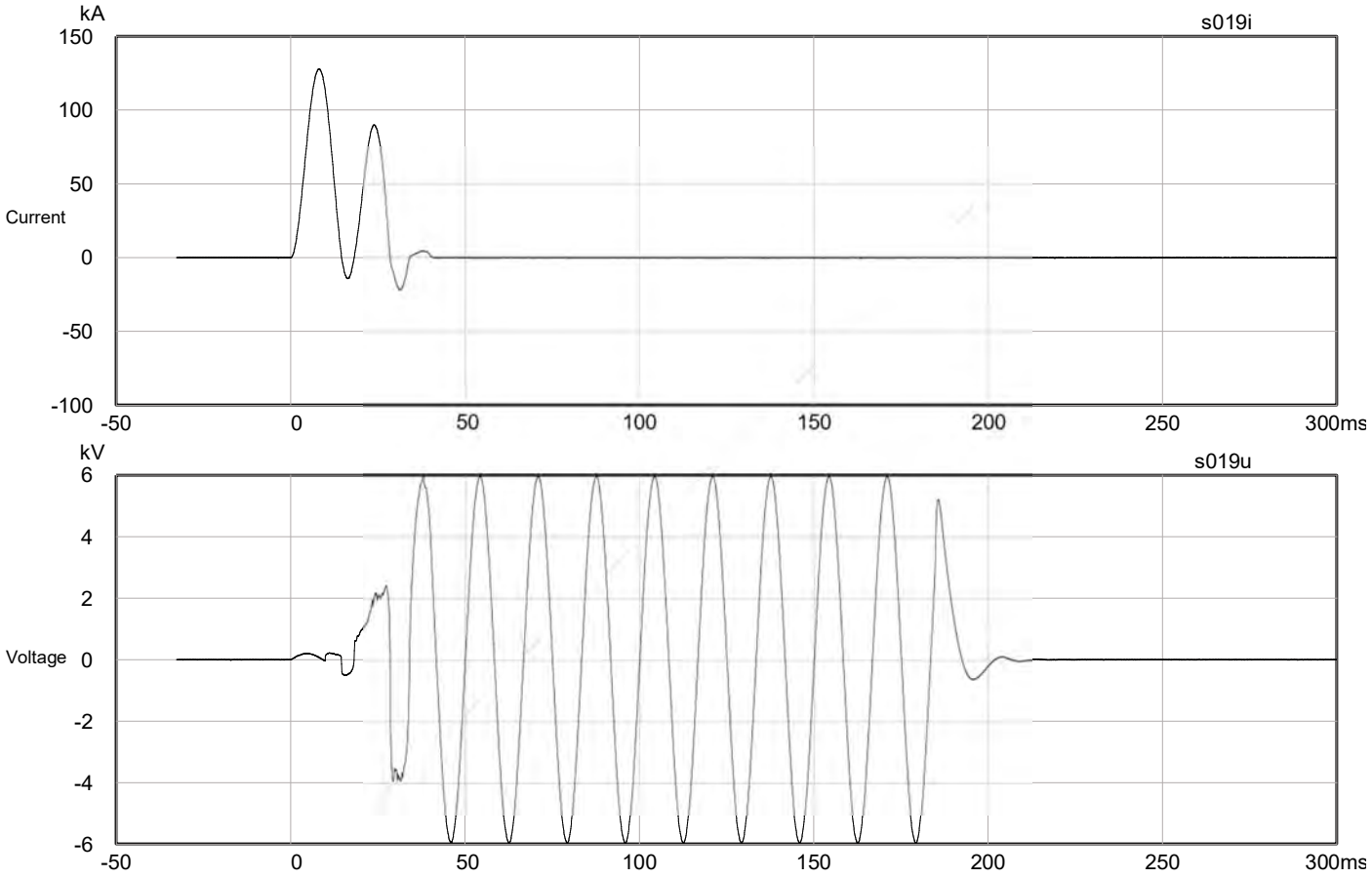


Figure 8: Waveforms for Test #5-2, Encore 4/0 AWG Sample 5.

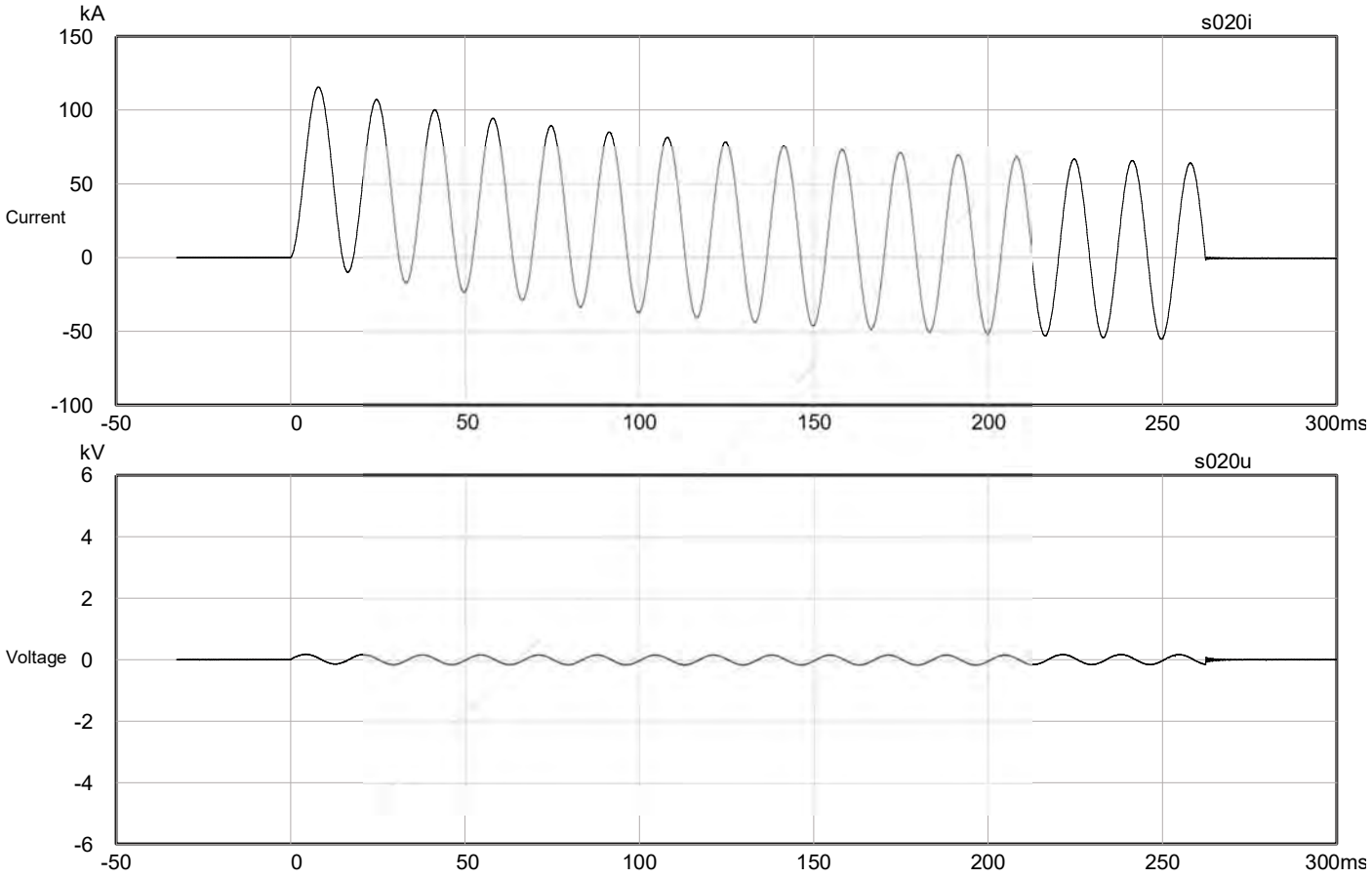


Figure 9: Waveforms for Test #6-1, Encore 4/0 AWG Sample 6.

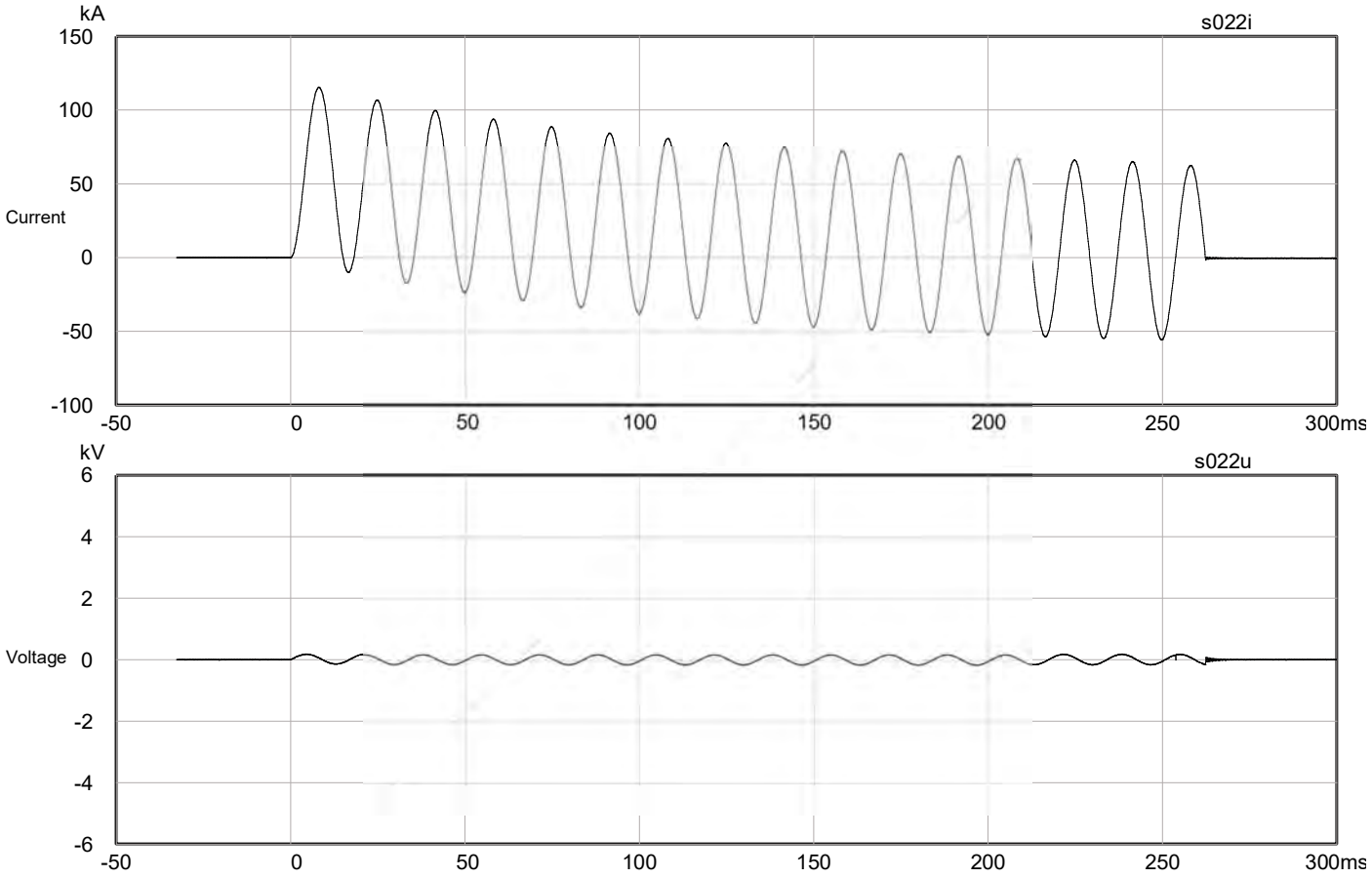


Figure 10: Waveforms for Test #6-2, Encore 4/0 AWG Sample 6.

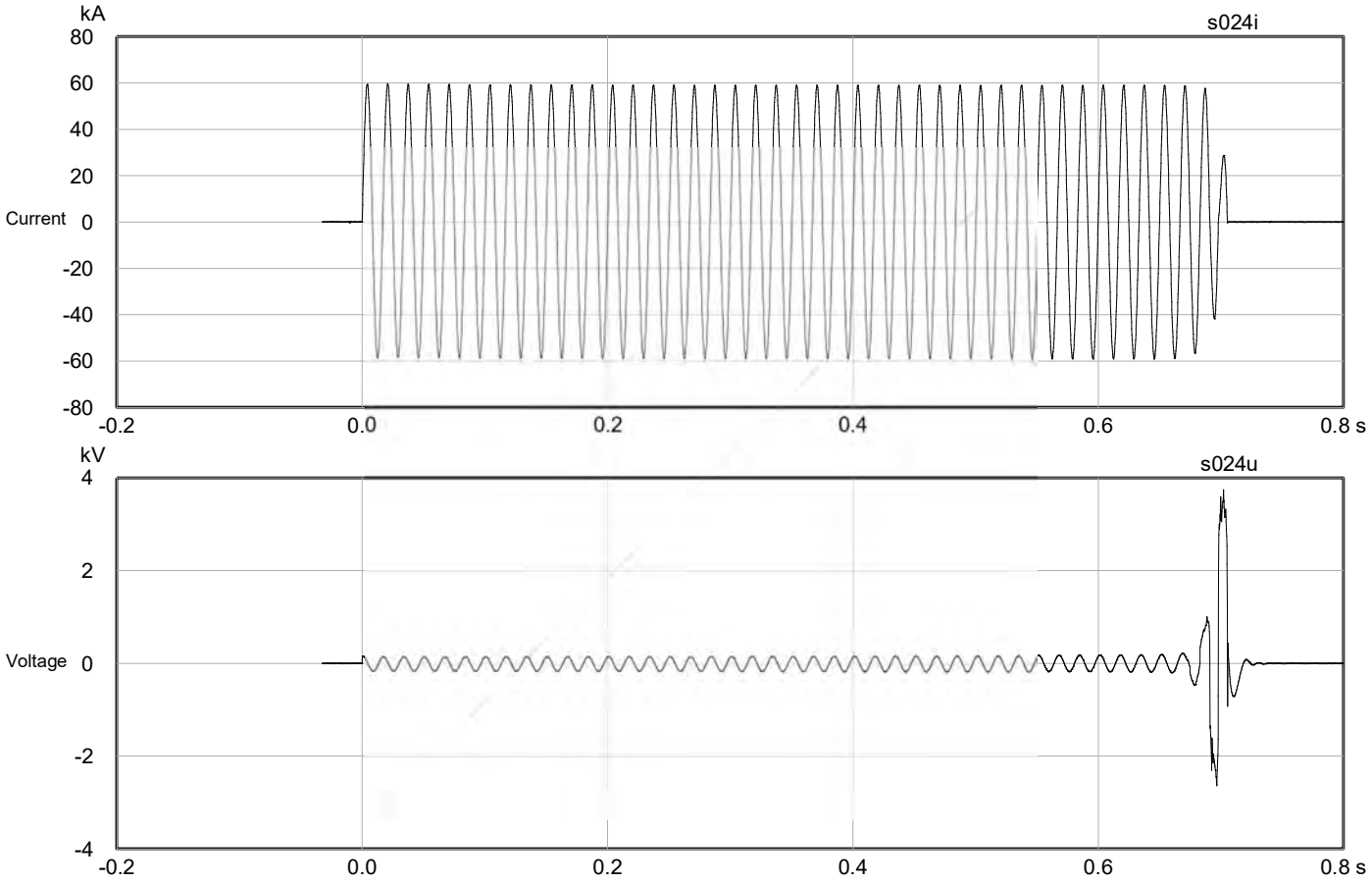


Figure 11: Waveforms for Test #7, Copperweld Scorpius 61 x 072 Sample 11.

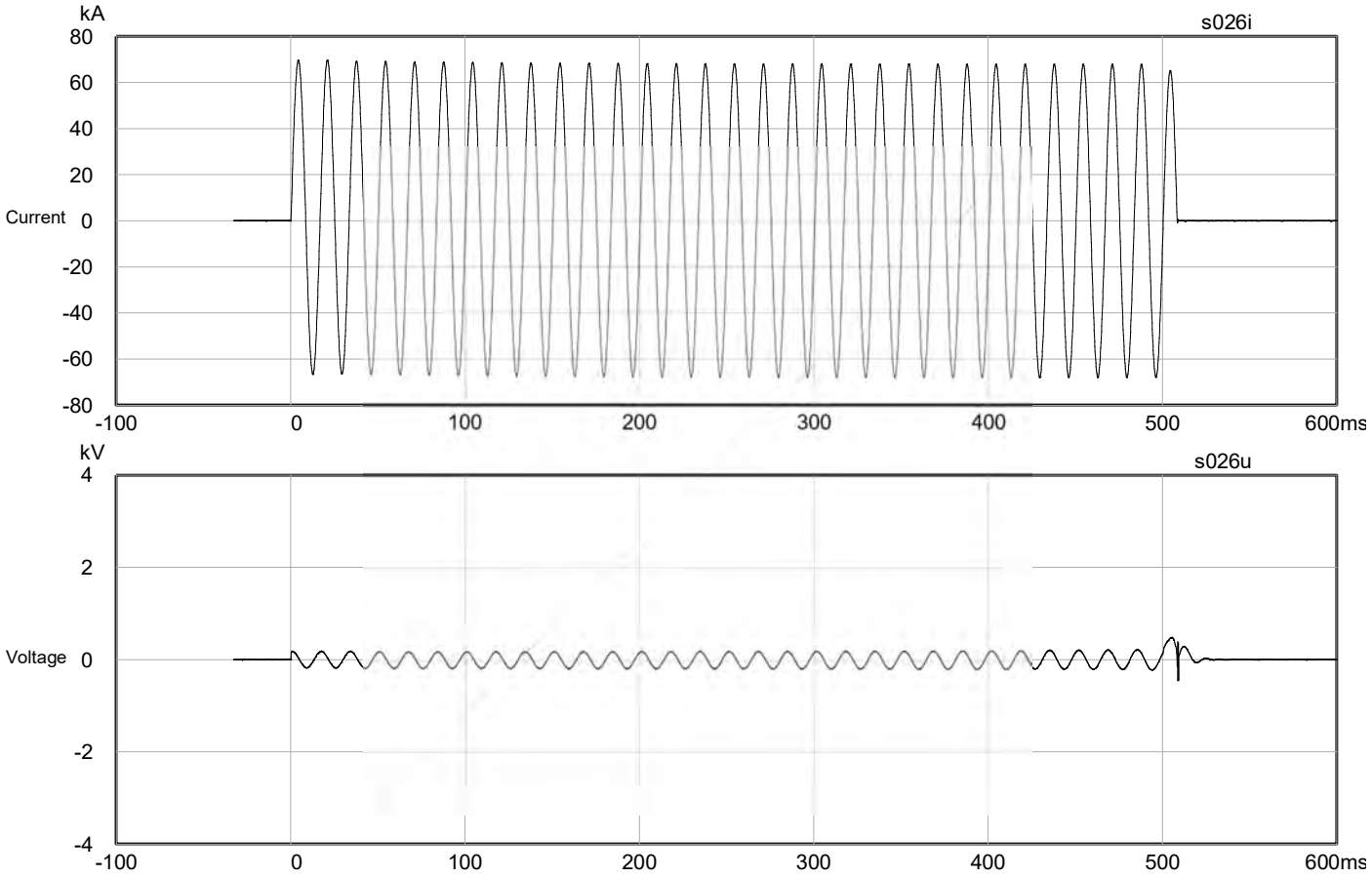


Figure 12: Waveforms for Test #6, Copperweld Scorpius 61 x 072 Sample 12.

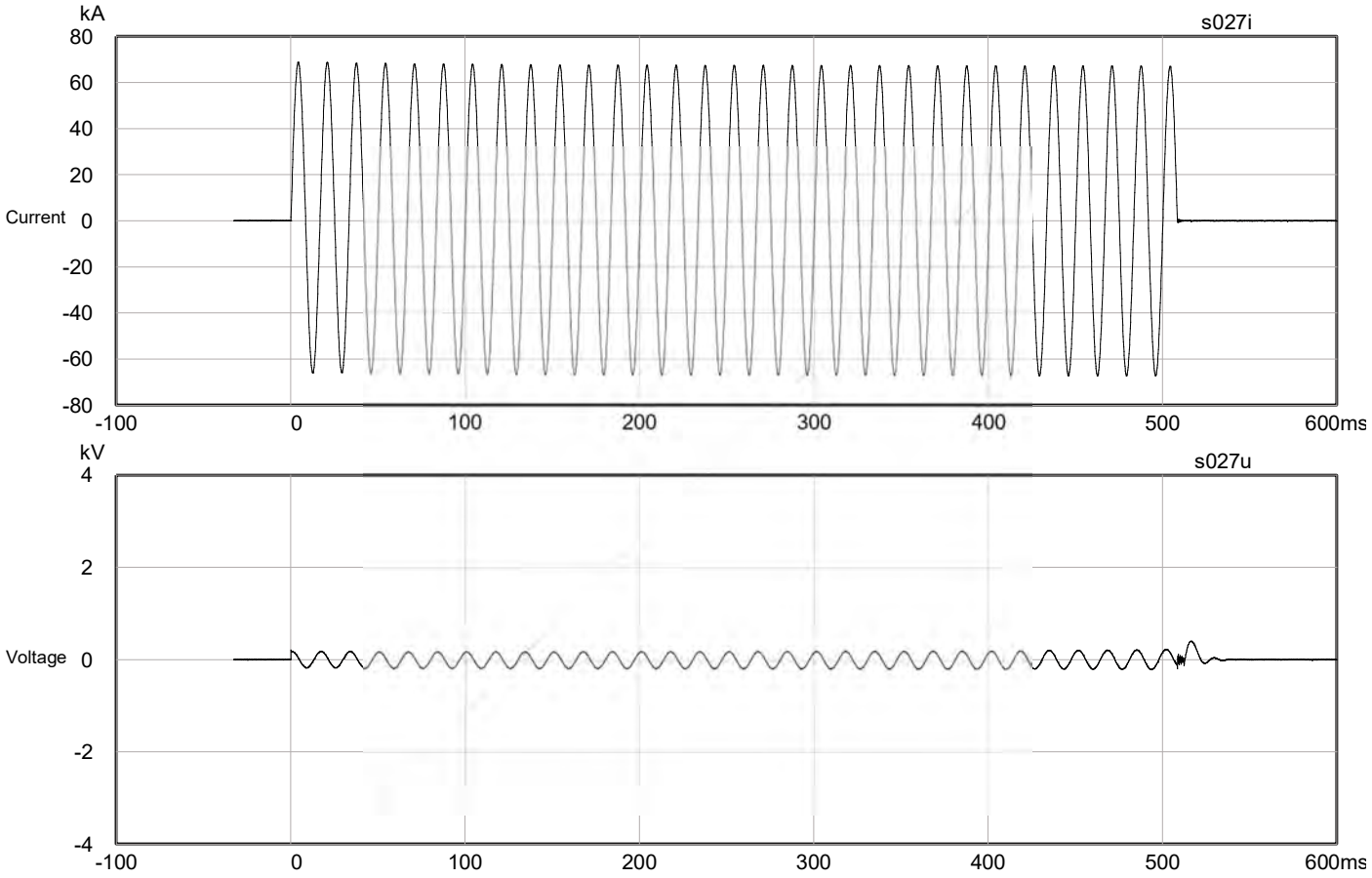


Figure 13: Waveforms for Test #9, Copperweld Scorpius 61 x 072 Sample 13.

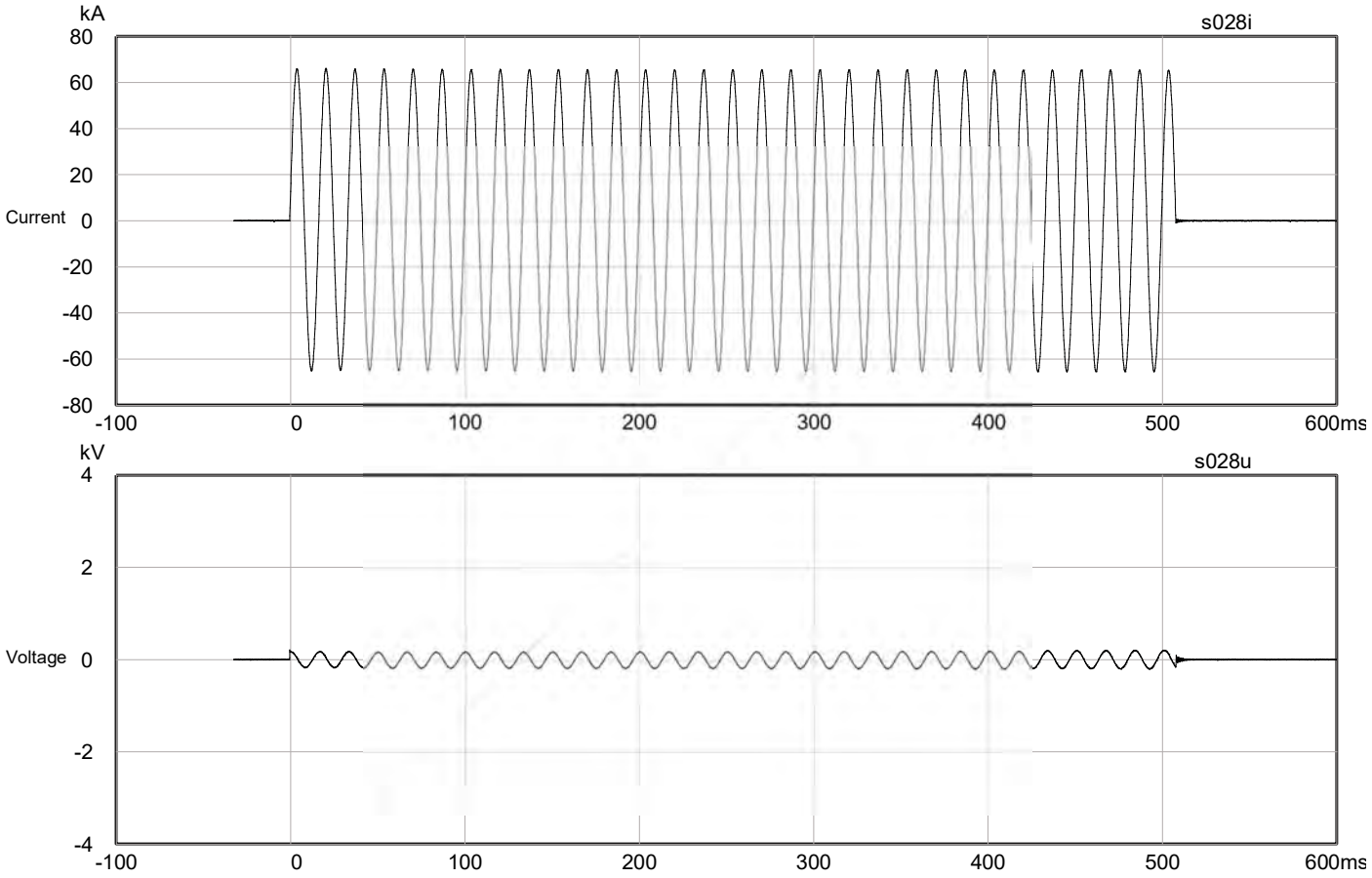


Figure 14: Waveforms for Test #10, Copperweld Scorpius 61 x 072 Sample 14.

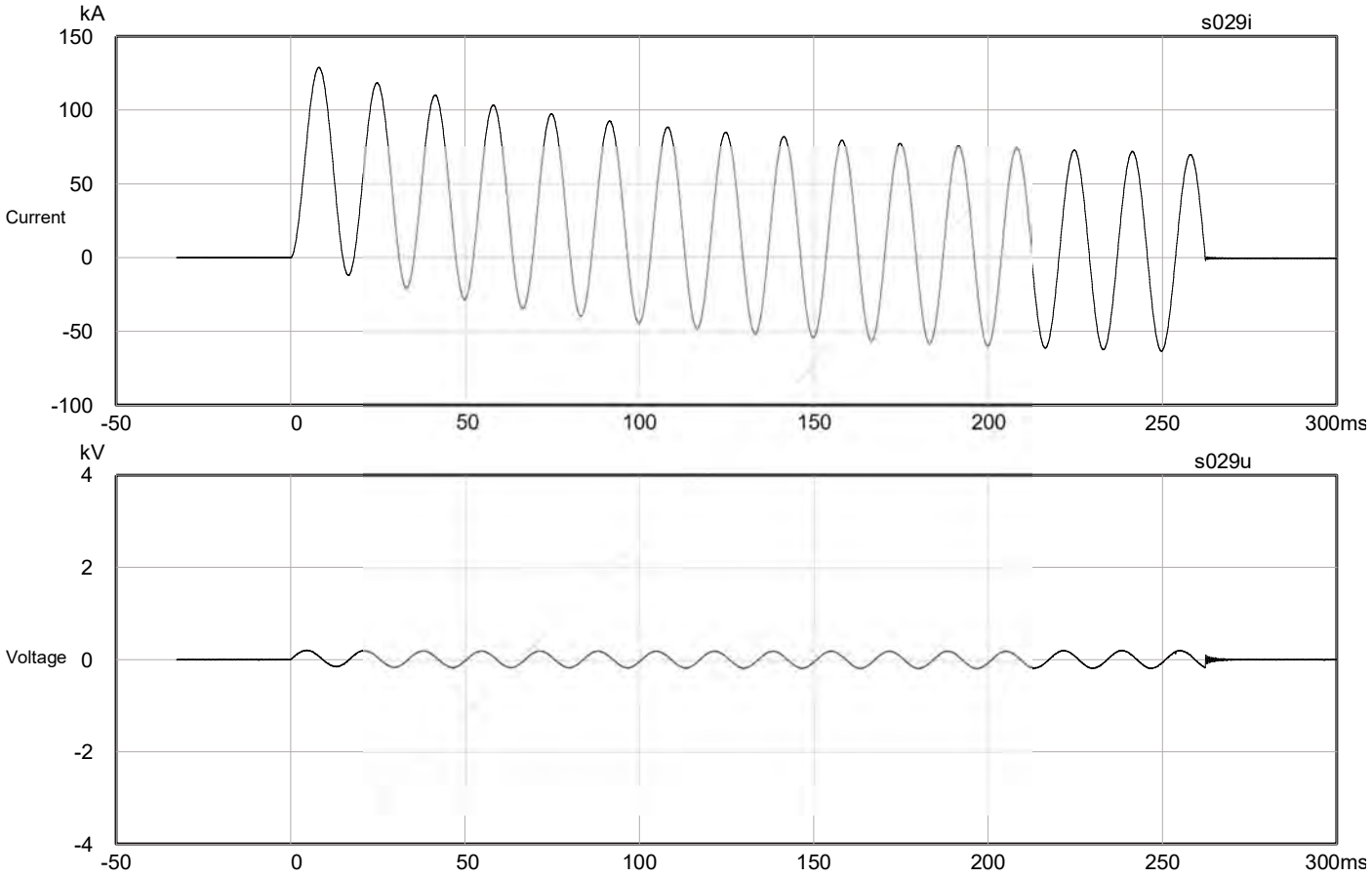


Figure 15: Waveforms for Test #11-1, Copperweld Scorpius 61 x 072 Sample 15.

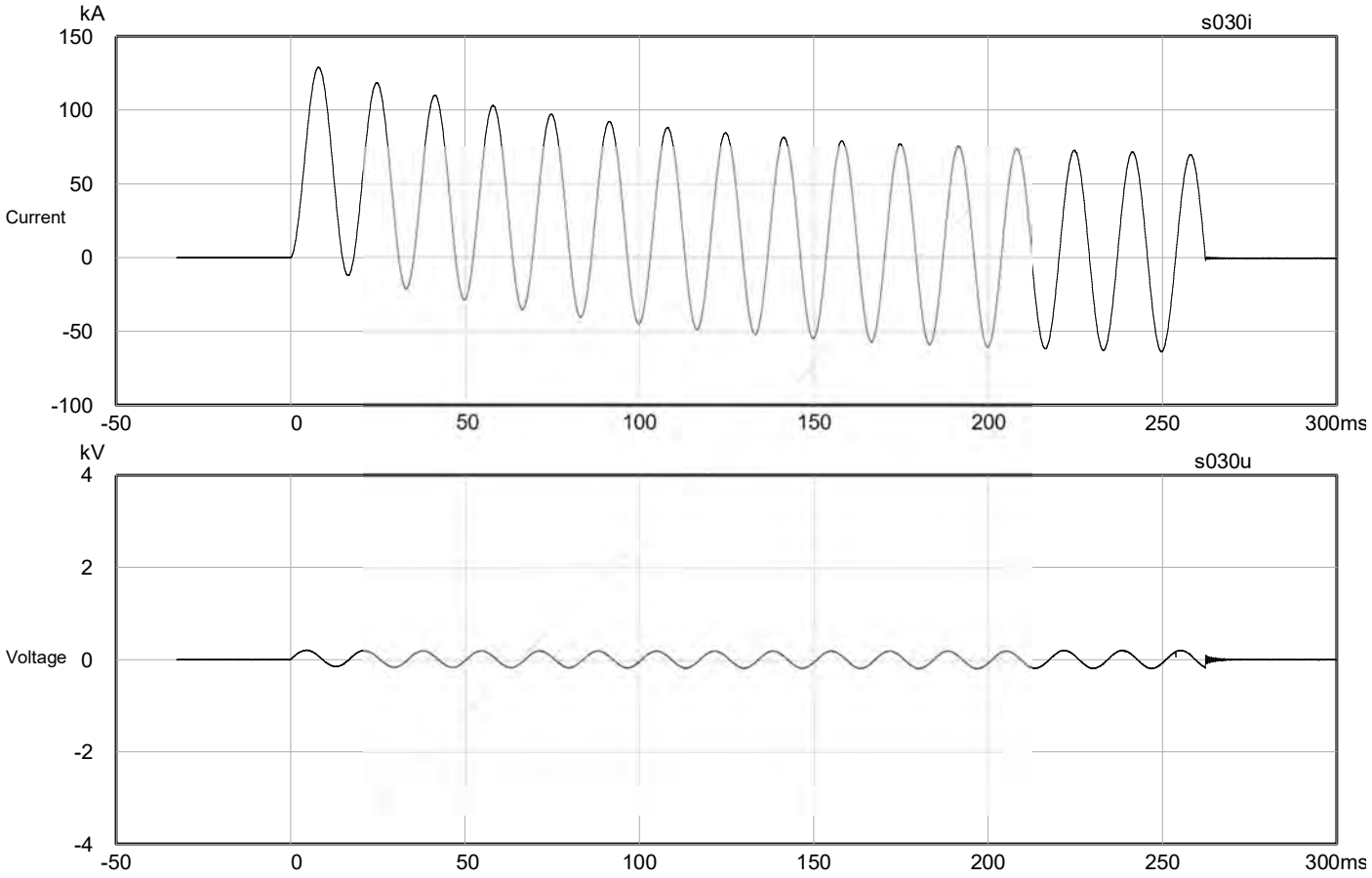


Figure 16: Waveforms for Test #11-2, Copperweld Scorpius 61 x 072 Sample 15.

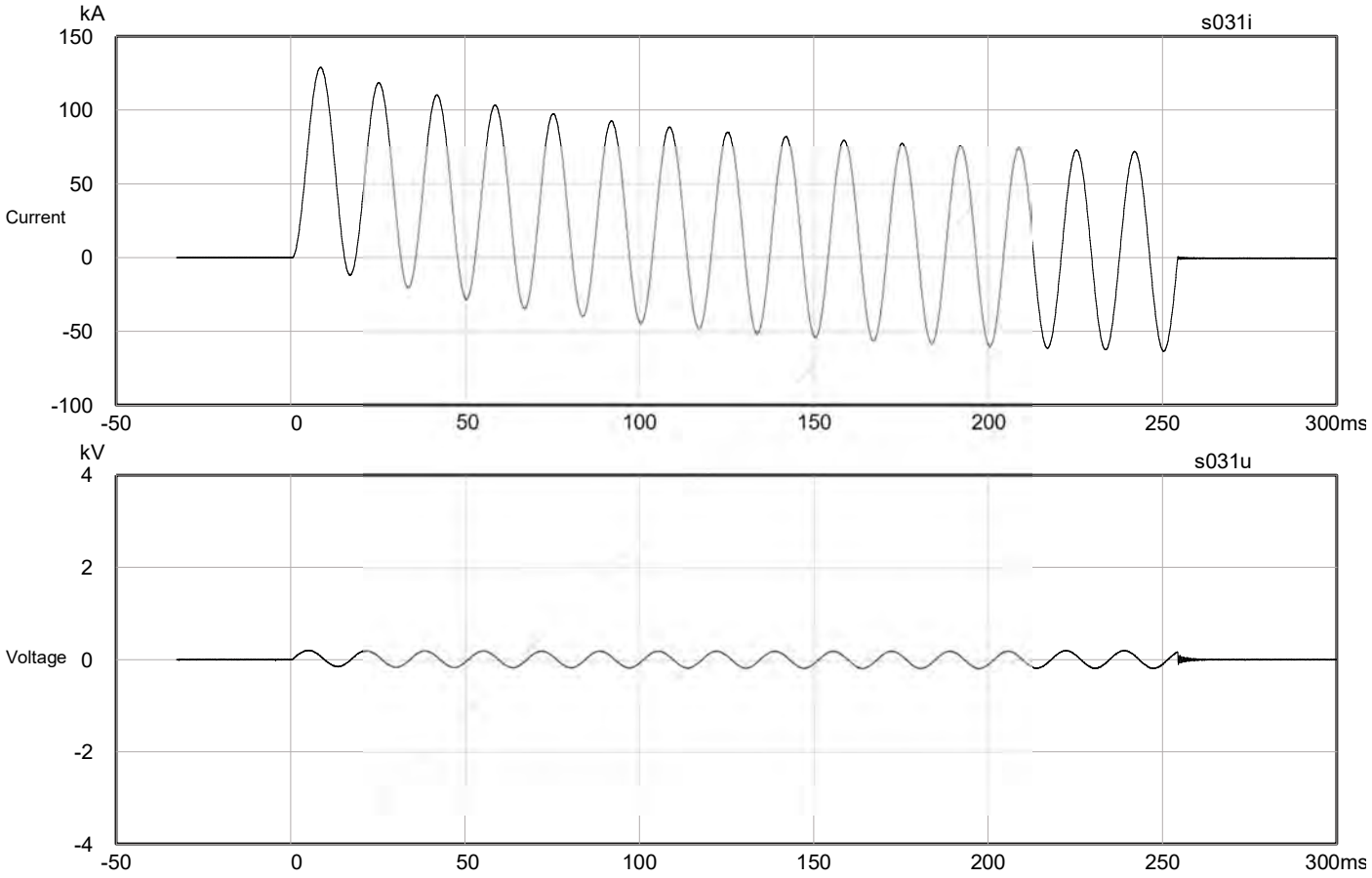


Figure 17: Waveforms for Test #12-1, Copperweld Scorpius 61 x 072 Sample 16.

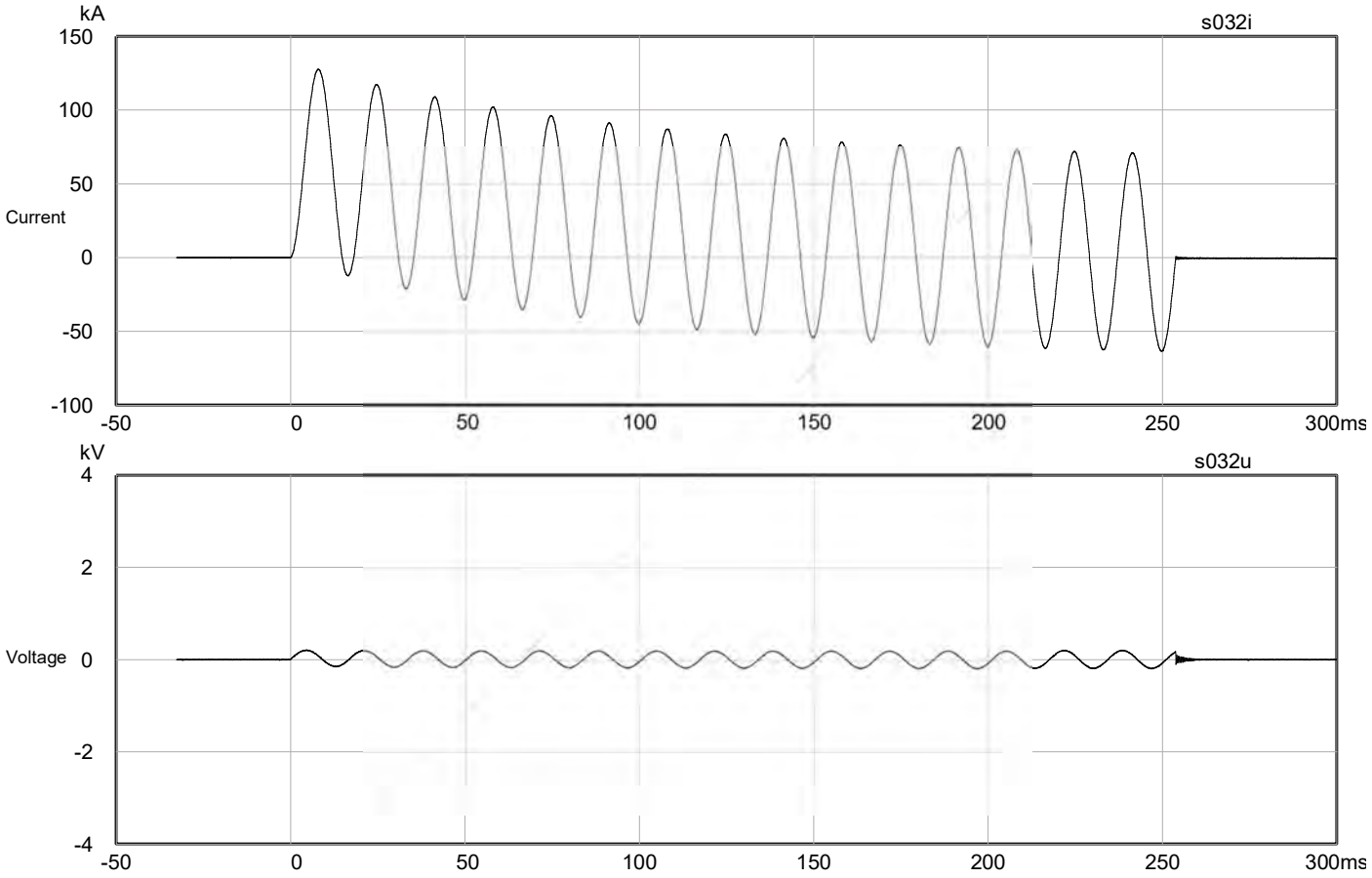


Figure 18: Waveforms for Test #12-2, Copperweld Scorpius 61 x 072 Sample 16.

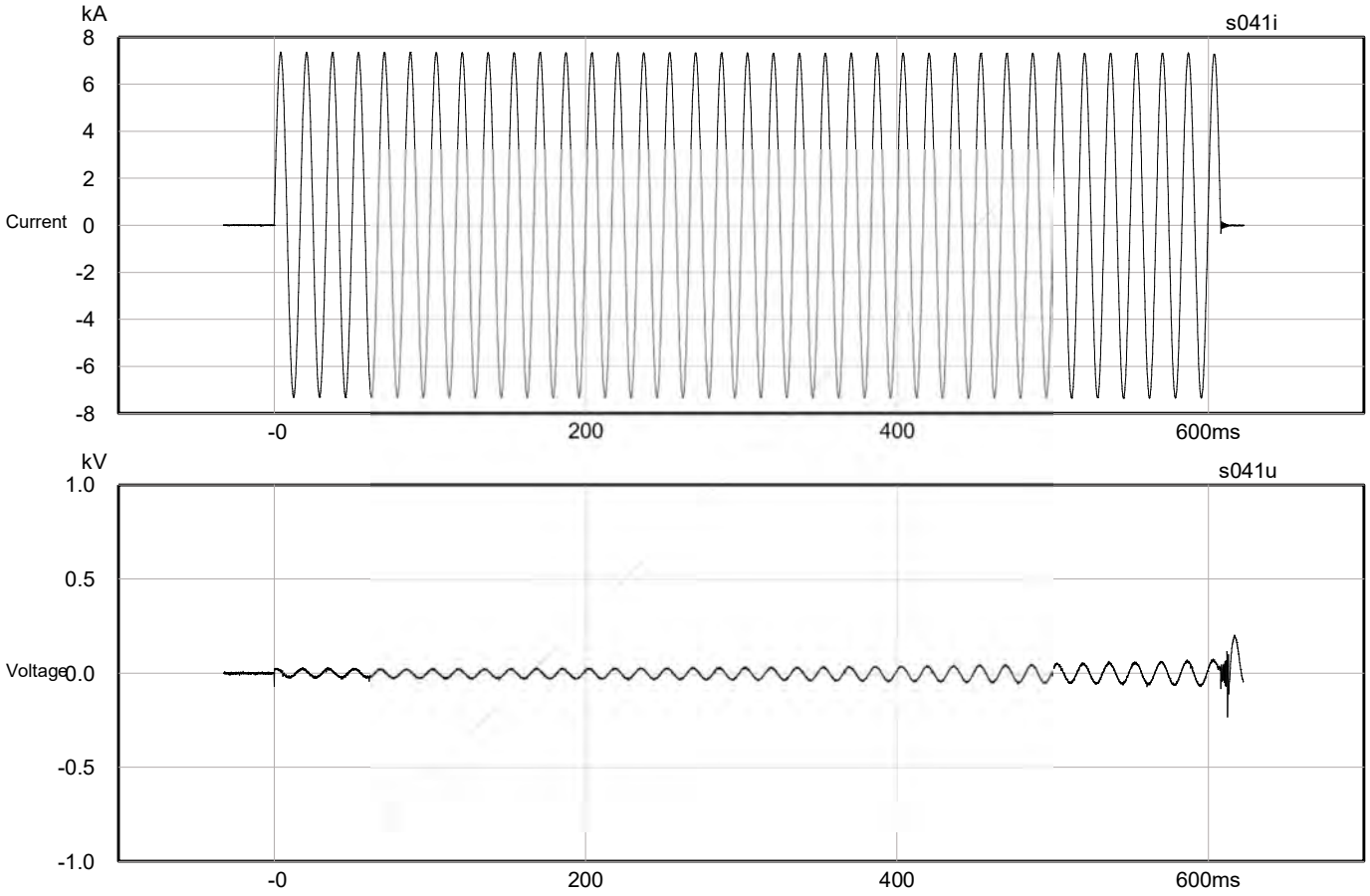


Figure 19: Waveforms for Test #13, Encore #6 AWG Sample 21.

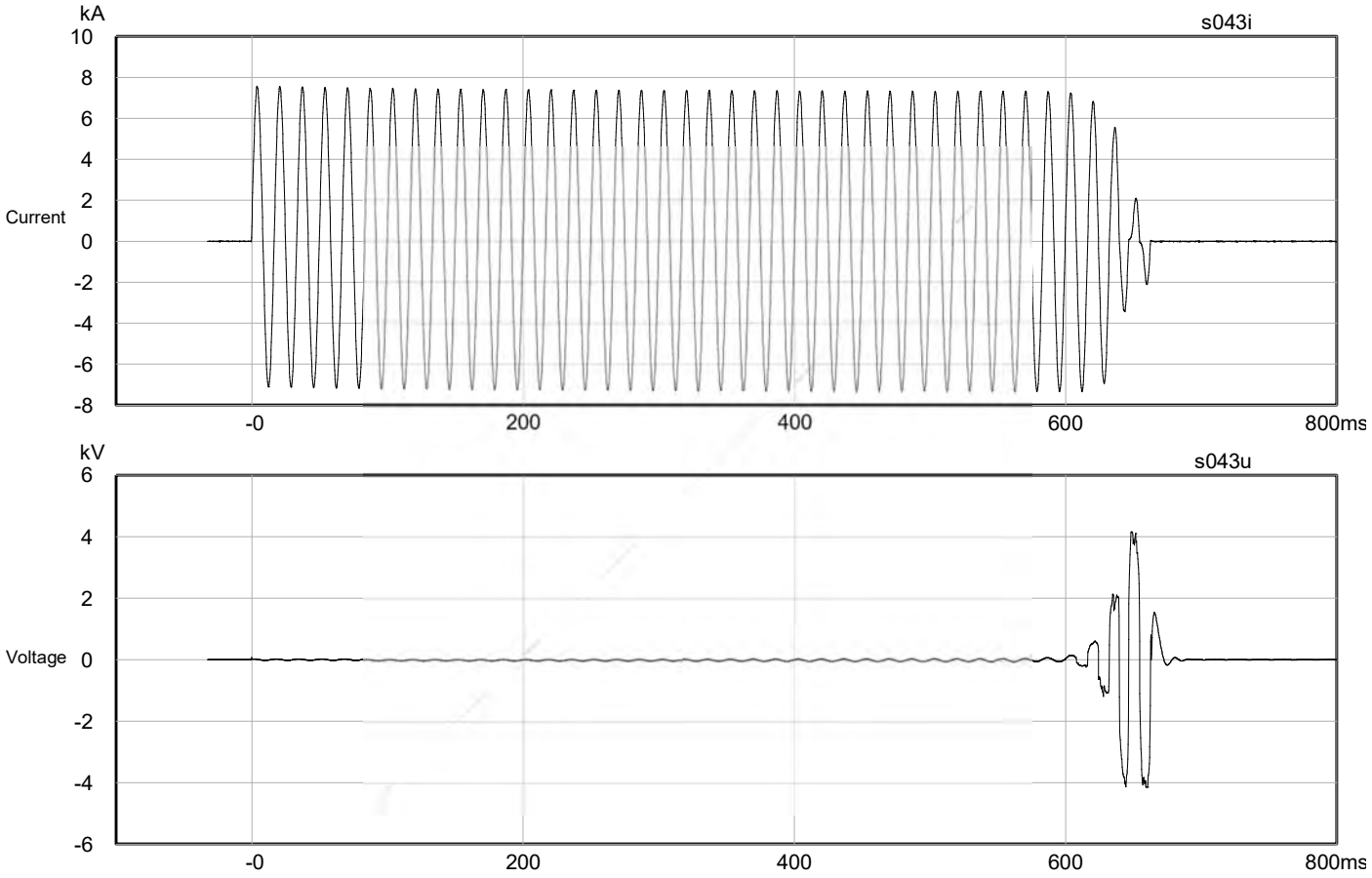


Figure 20: Waveforms for Test #14, Encore #6 AWG Sample 23.

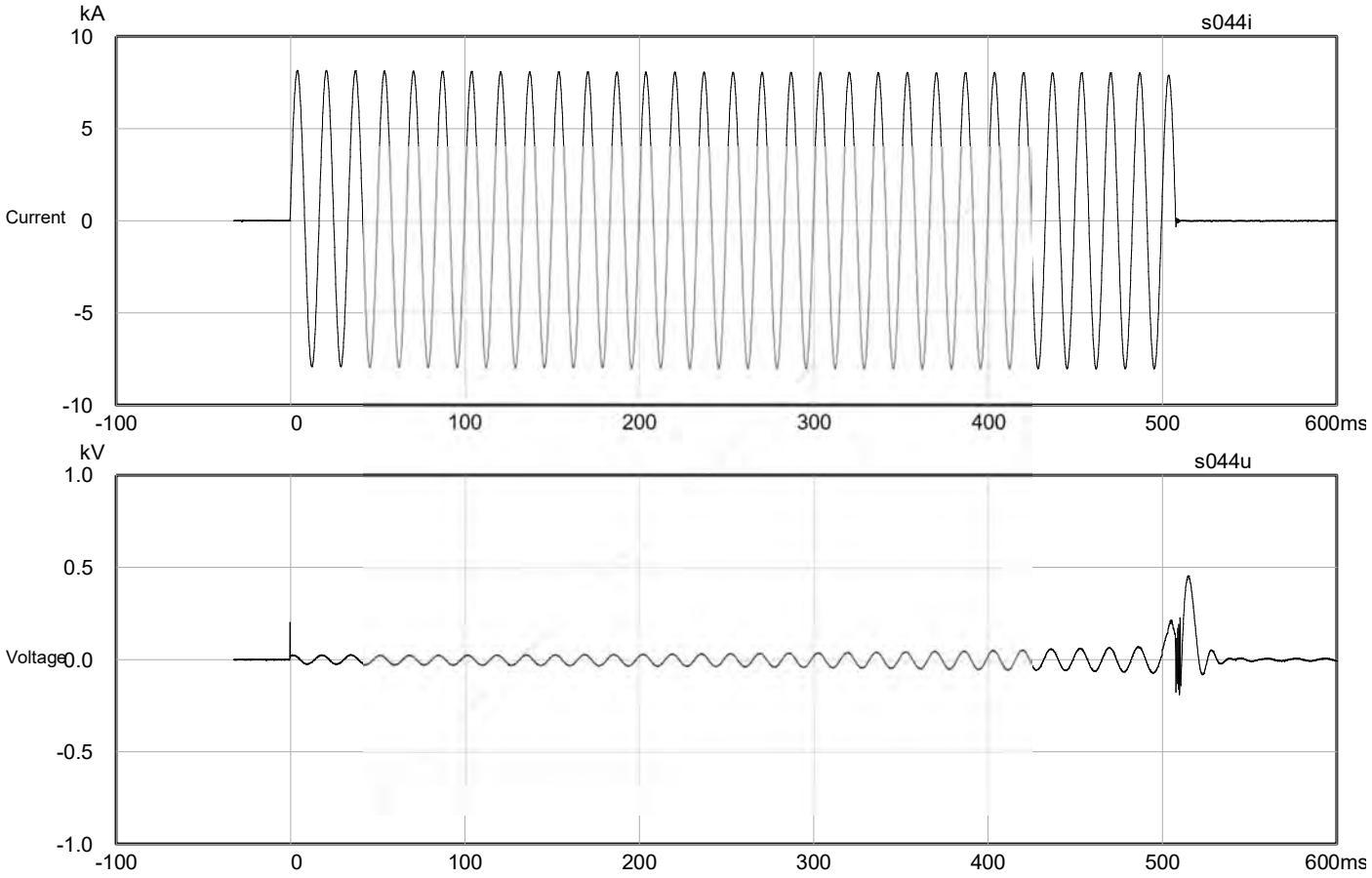


Figure 21: Waveforms for Test #15, Encore #6 AWG Sample 24.

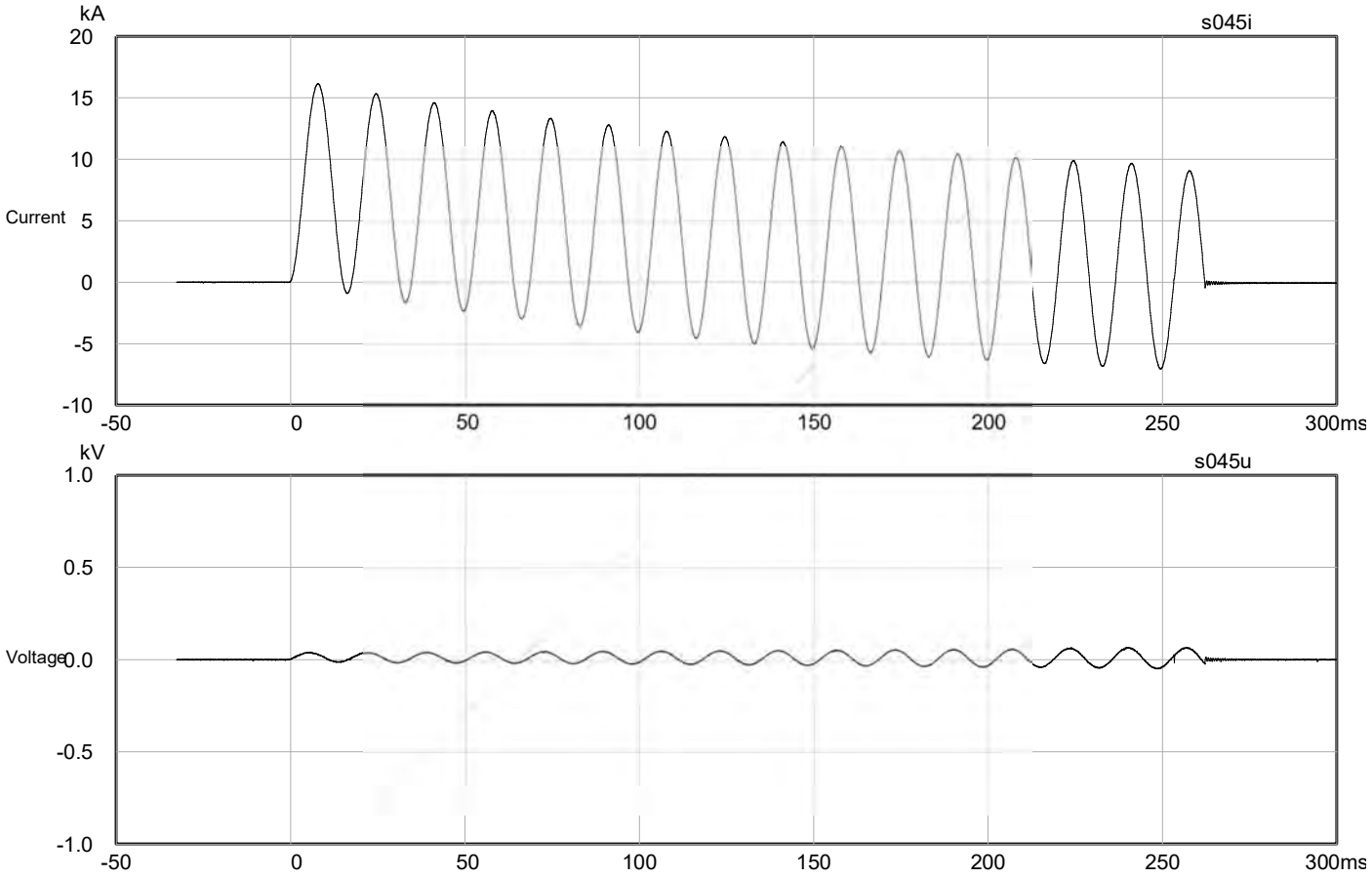


Figure 22: Waveforms for Test #16-1, Encore #6 AWG Sample 25.

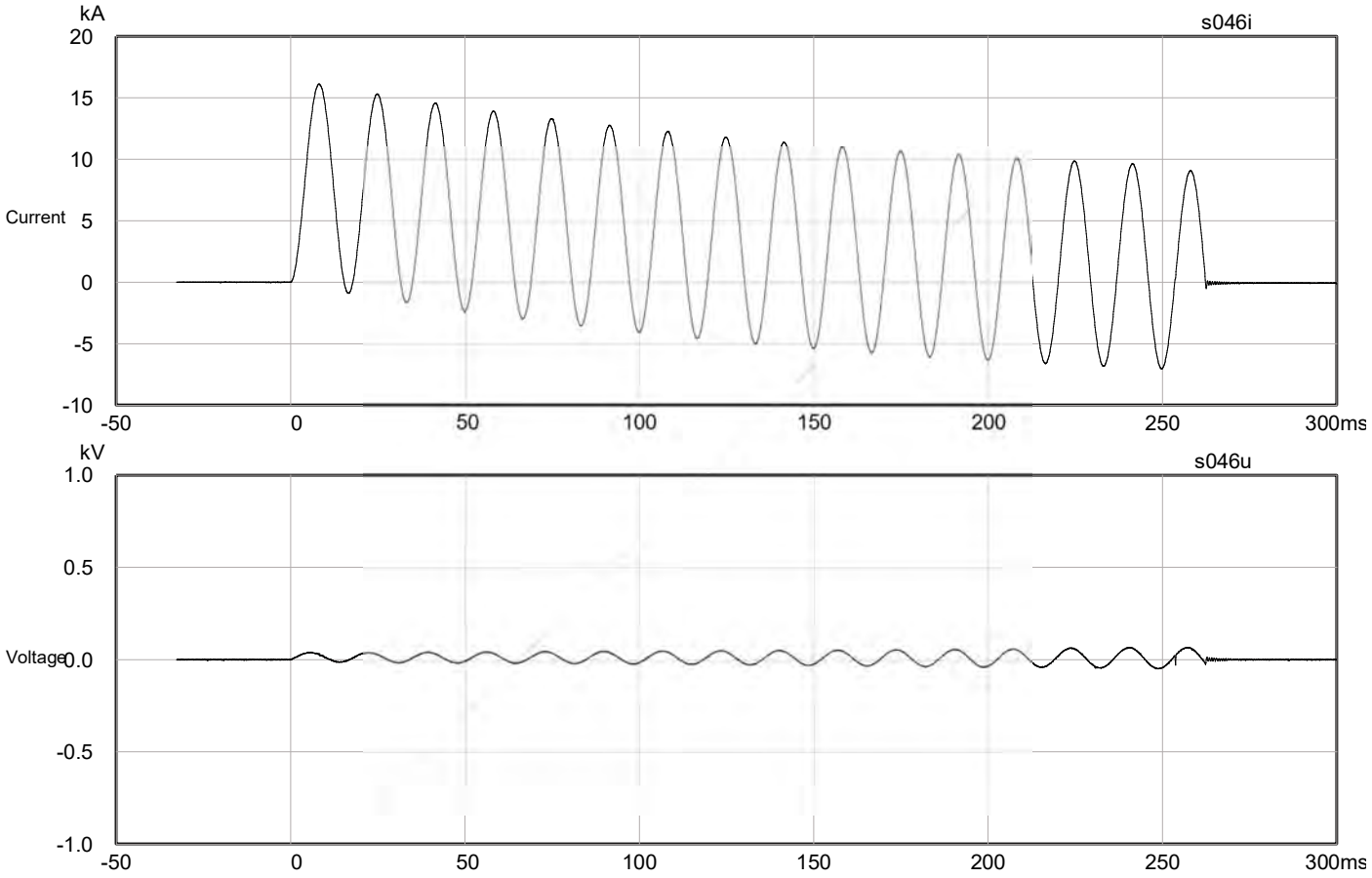


Figure 23: Waveforms for Test #16-2, Encore #6 AWG Sample 25.

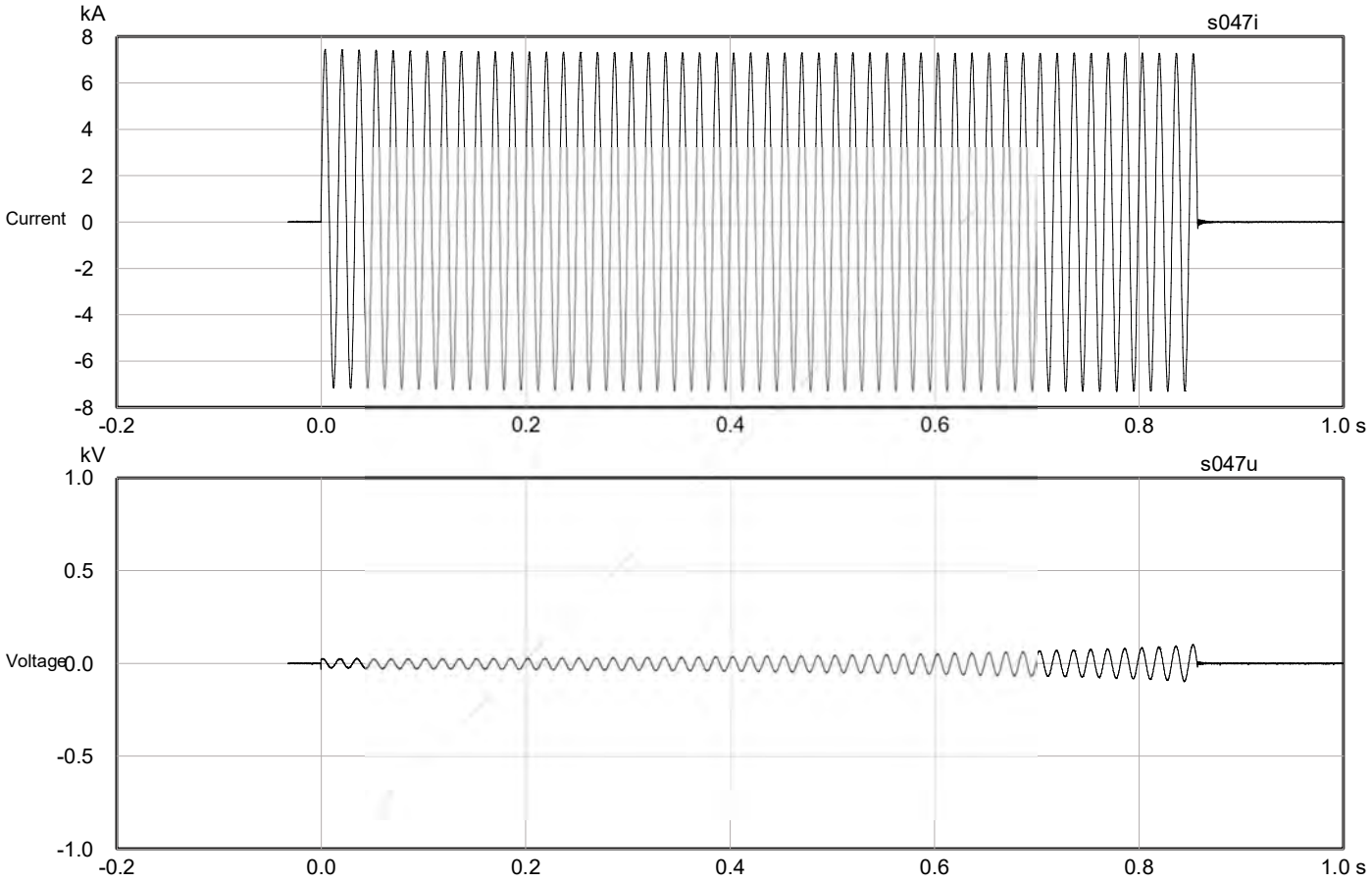


Figure 24: Waveforms for Test #17, Encore #6 AWG Sample 31.

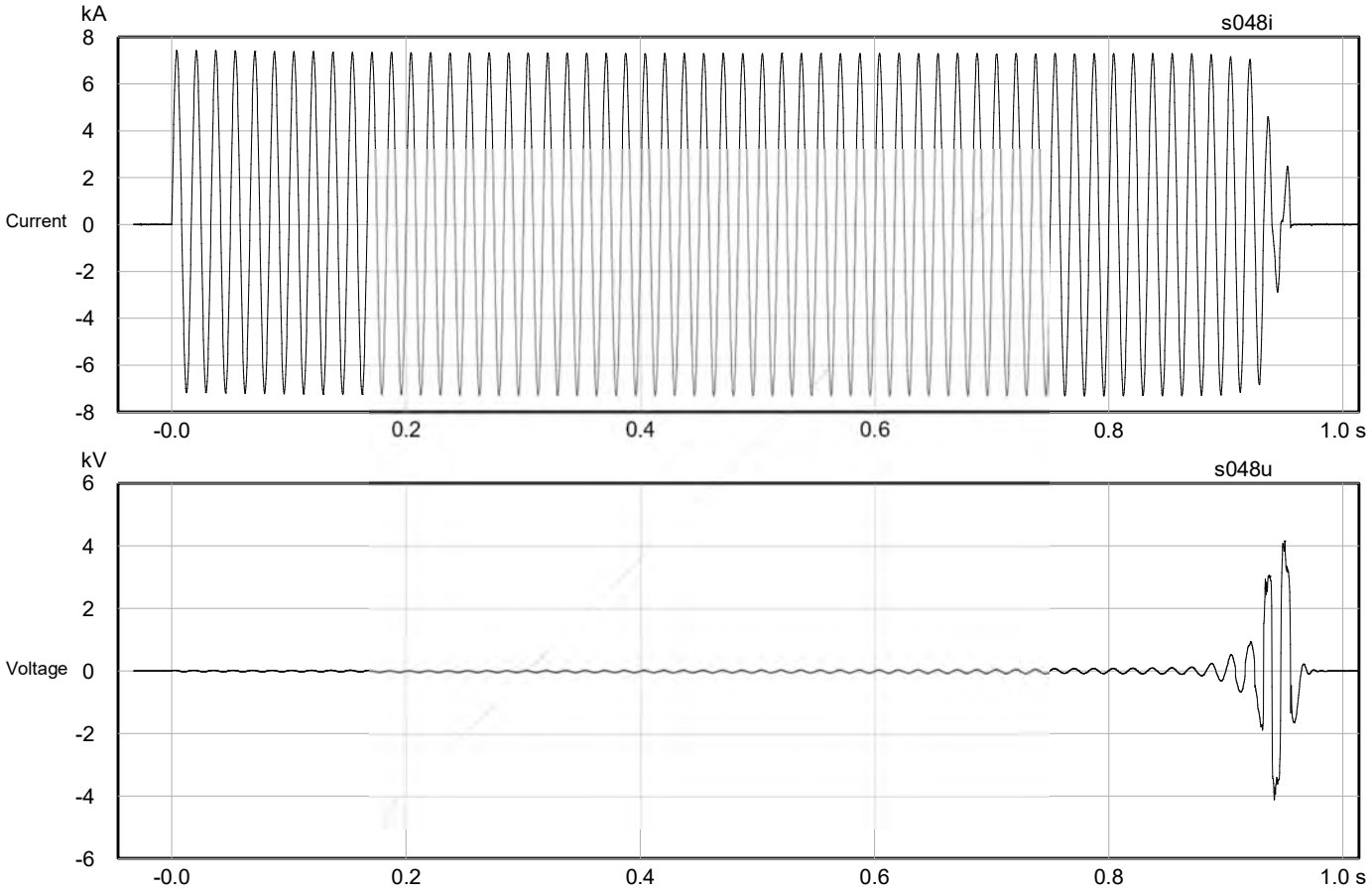


Figure 25: Waveforms for Test #18, Copperweld Scorpius 7 x 080 Sample 32.

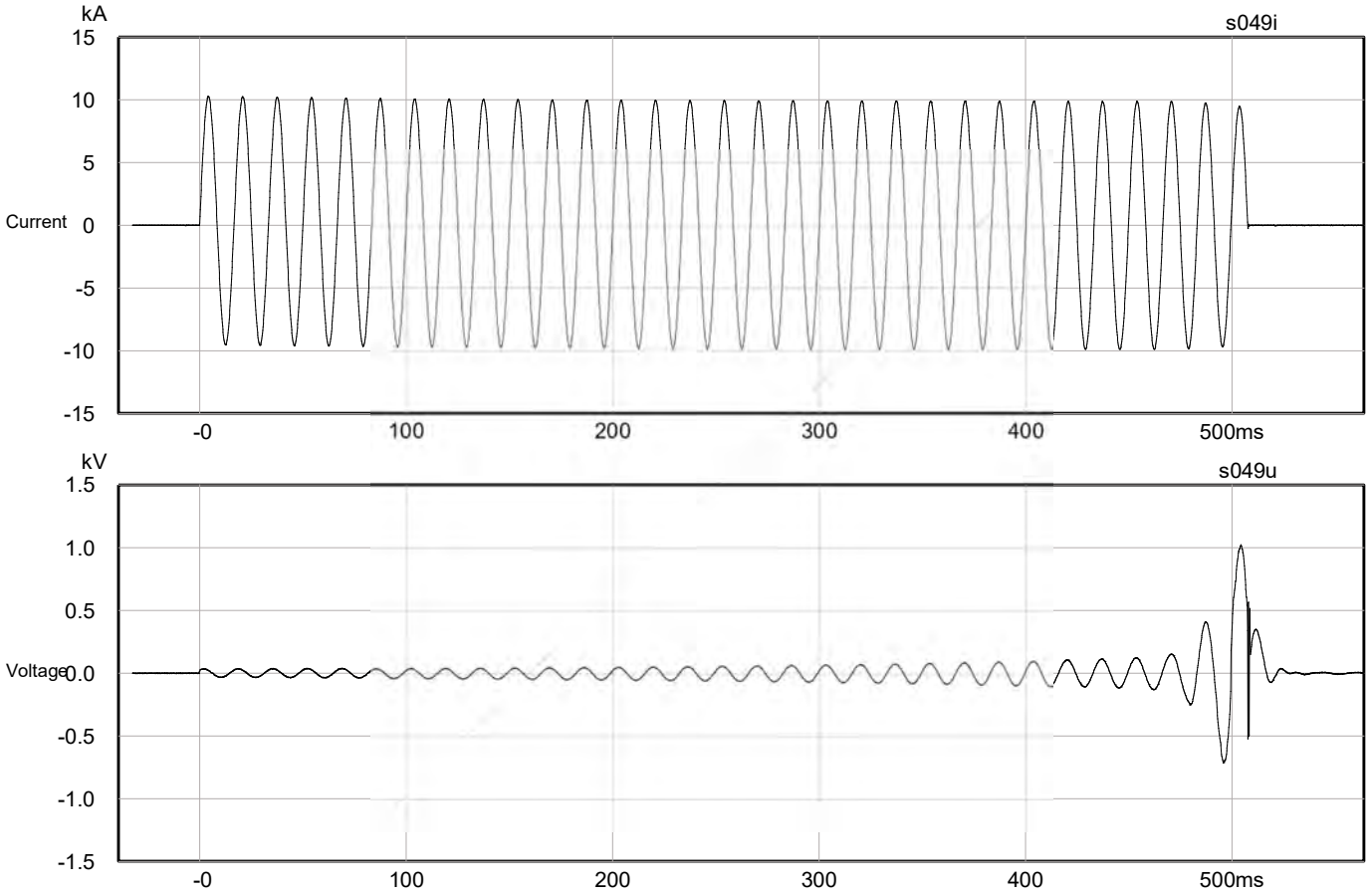


Figure 26: Waveforms for Test #19, Copperweld Scorpius 7 x 080 Sample 33.

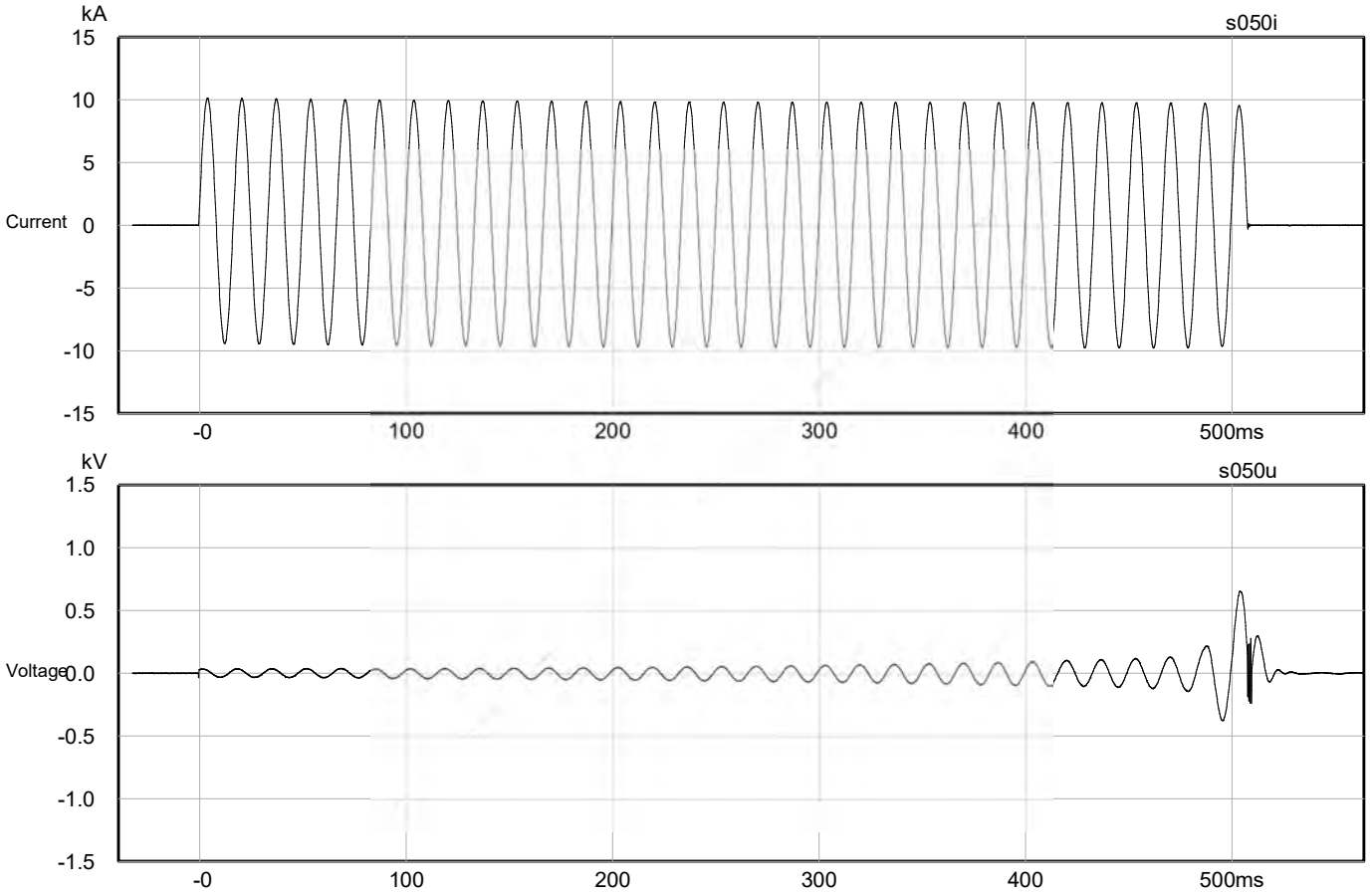


Figure 27: Waveforms for Test #20, Copperweld Scorpius 7 x 080 Sample 34.

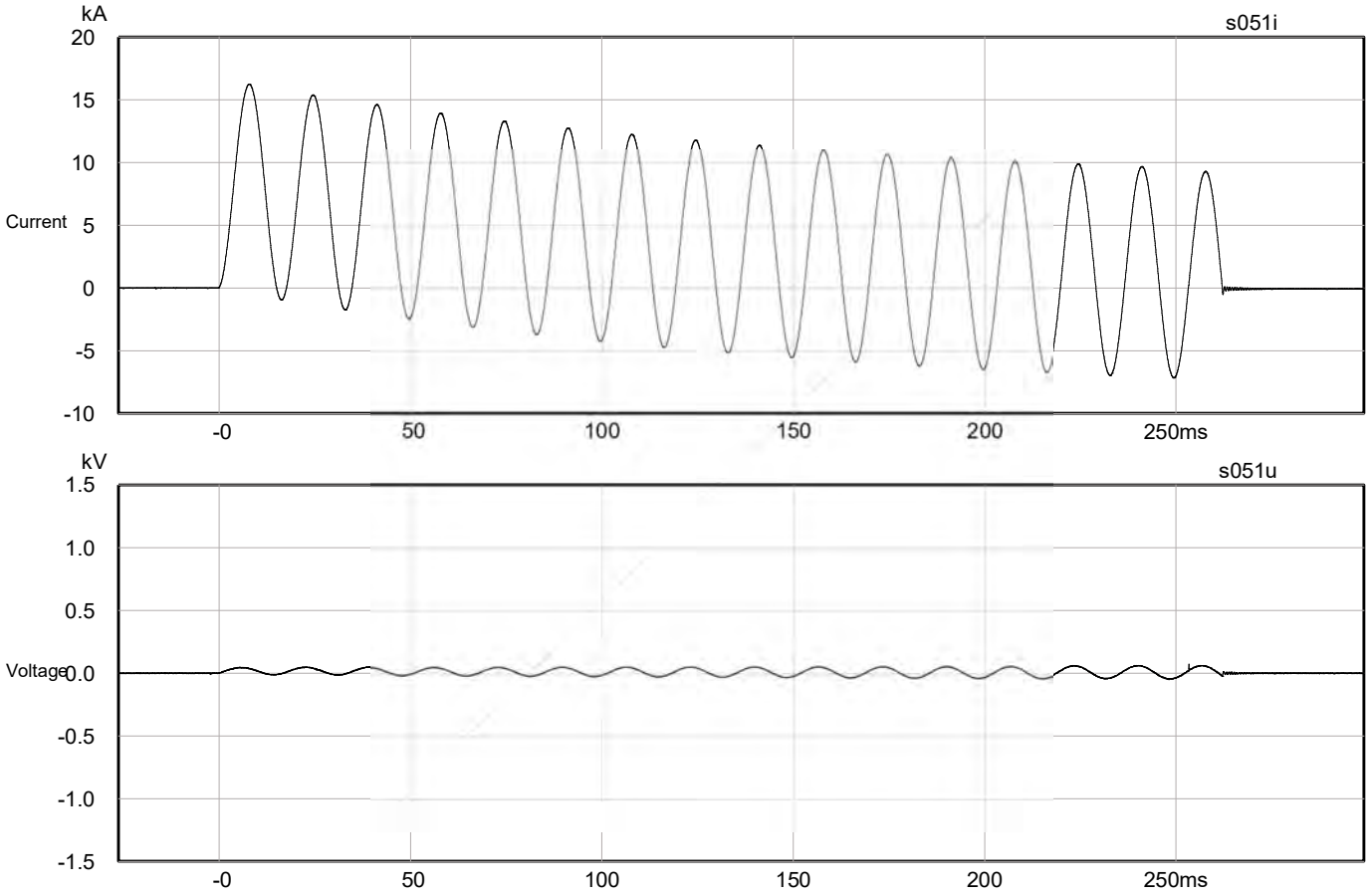


Figure 28: Waveforms for Test #21-1, Copperweld Scorpius 7 x 080 Sample 35.

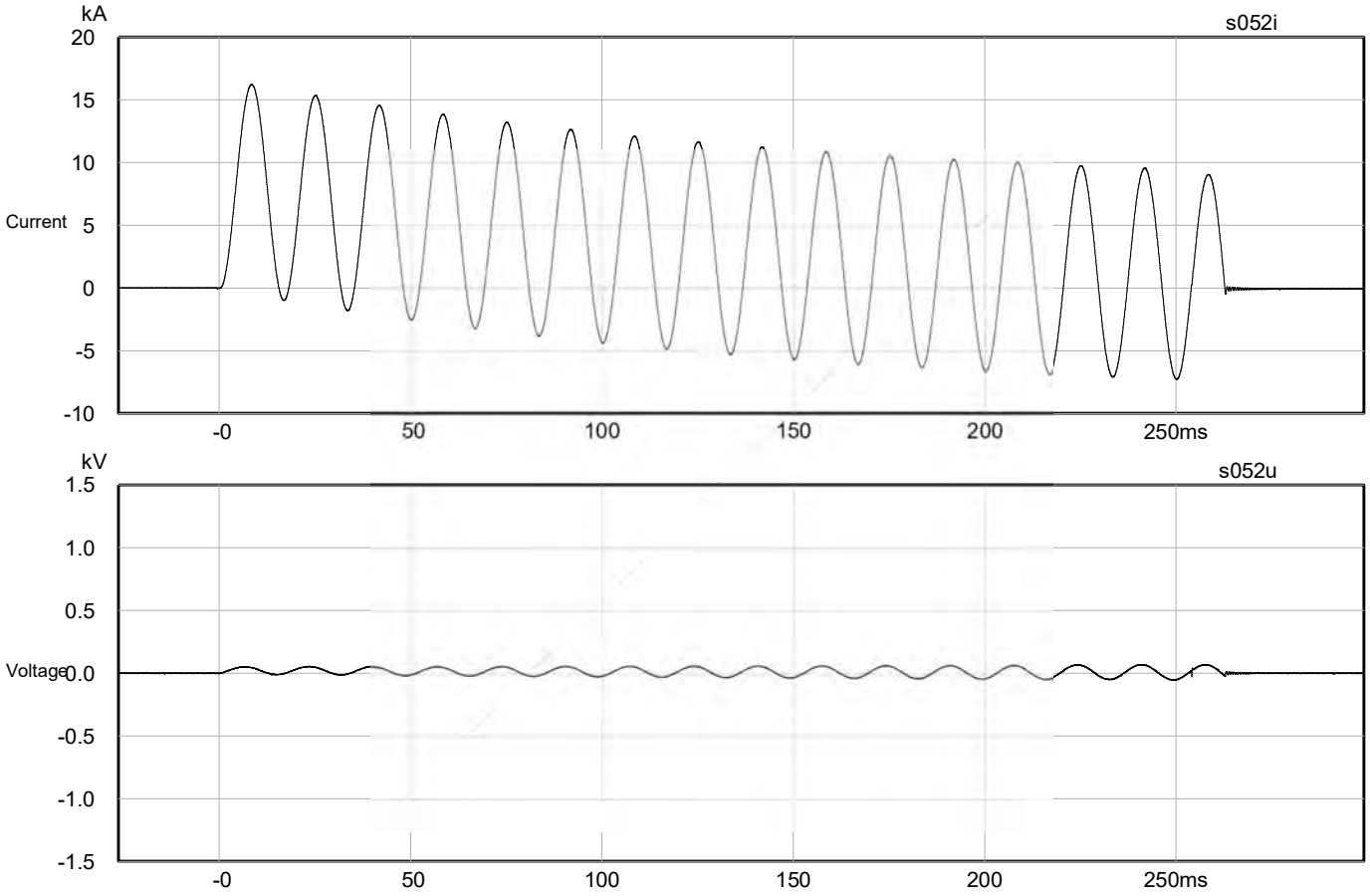


Figure 29: Waveforms for Test #21-2, Copperweld Scorpius 7 x 080 Sample 35.

APPENDIX C – PHOTOGRAPHS OF THE TEST OBJECTS



Figure 30: Test set up for the Encore 4/0 AWG Cu conductor. The power source bus is on the left and the ground bus is on the right.



Figure 31: Test set up for the Copperweld Scorpius 61 x 072 CCS conductor.



Figure 32: Test set up for the Encore #6 AWG Cu conductor.



Figure 33: Test set up for the Copperweld Scorpius 7 x 080 CCS conductor.

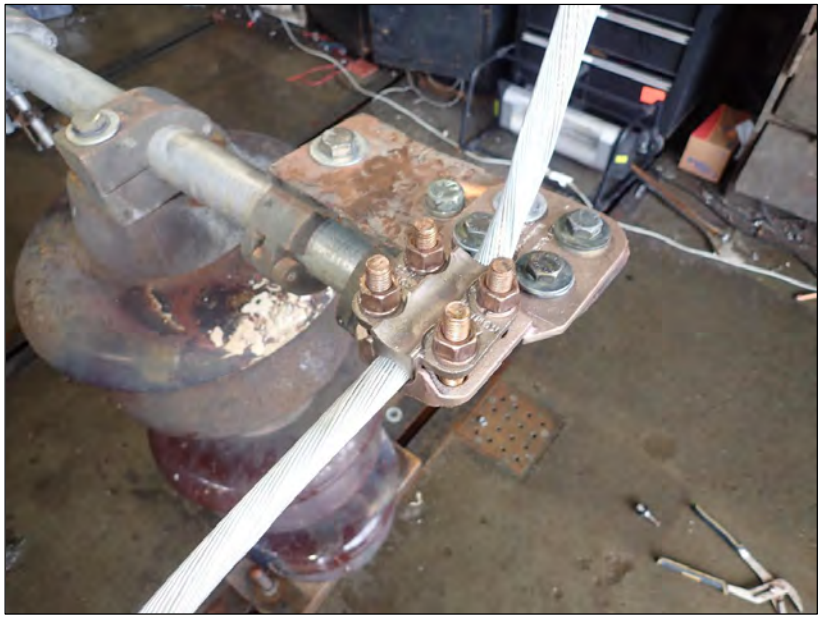


Figure 34: Typical Burndy terminal connector used to connect the Encore 4/0 AWG or Copperweld Scorpius 61 x 072 CCS conductors to the laboratory buses.



Figure 35: Typical Burndy terminal connector used to connect the Encore #6 AWG or Copperweld Scorpius 7 x 080 CCS conductors to the laboratory buses.

APPENDIX D – CALCUATIONS OF TEST CURRENT LEVELS FOR #6 AWG CU CONDUCTOR

Equation (45) in IEEE 80 and Equation (C.1) in IEEE 837 are the same, as follows:

$$I = A\sqrt{\left(\frac{TCAP\times 10^{-4}}{t_c\times\alpha_r\times\rho_r}\right)\ln\left(\frac{K_0+T_m}{K_0+T_a}\right)}$$

where

I is root mean square (rms) current in kA
A is conductor cross section in mm^2
T_m is maximum allowable temperature in °C
T_a is initial conductor temperature in °C
T_r is reference temperature for material constants in °C
α_0 is thermal coefficient of resistivity at 0 °C
α_r is thermal coefficient of resistivity at reference temperature T_r
ρ_r is resistivity of the ground conductor at reference temperature T_r in μΩ-cm
K_0 is $1/\alpha_0$, or $(1/\alpha_r)-T_r$ in °C
t_c is time of current flow in seconds (s)
TCAP is thermal capacity factor in joules/cm^3°C

This equation is used to calculate the short-circuit ampacity of a conductor based on it's material constants.

For IEEE 80, Table 6, the symmetrical rms fusing current for #6 AWG soft-drawn Cu conductor at 500 ms duration is determined to be:

$$\mathrm{I_{sym}} = (13.3)\sqrt{\frac{(3.4\mathrm{x}10^{-4})}{(0.5)(0.00393)(1.72)}\cdot\ln\left(\frac{(234+1083)}{(234+40)}\right)} = \boxed{5.29\ \mathrm{kA_{rms}}}$$

For IEEE 837, Table 3, the symmetrical rms fusing current for #6 AWG hard-drawn Cu conductor at 250 ms duration is determined to be:

$$\mathrm{I_{sym}} = (13.3)\sqrt{\frac{(3.4\mathrm{x}10^{-4})}{(0.25)(0.00381)(1.78)}\cdot\ln\left(\frac{(242+1084)}{(242+40)}\right)} = 7.41\ \mathrm{kA_{rms}}$$

From IEEE 837 Equation (C.4), the asymmetrical rms fusing current is:

$$\mathrm{I_{asym}} = \frac{(7.41\ \mathrm{kA})}{(1.148)} = 6.45\ \mathrm{kA_{rms}}$$

For the EMF described in IEEE 837, Clause 7.2, a value of 90% of the fusing current is used for conductors up to 4/0 AWG:

$$\mathrm{I_{EMF}} = (6.45)(0.9) = \boxed{5.81\ \mathrm{kA_{rms}}}$$

Copperweld Bimetallics Data Sheet Packet
Electrical Test Laboratory

Customer:	Copperweld Building Wire	Engineer:	Bill Lewey	Date:	8/25/2020
Sample ID:	EL-13	Tested By:	Bill Lewey, Mike Rozar	Date:	8/25/2020
Product:	Grade 40 Copper Clad Steel Wire Solid Bare #4 and #6 vs Equivalent Solid Copper: Grounding Electrode Conductor Equivalency Test	Sample Condition:	New		
Standard:	ASTM B910/910M Annealed Copper Clad Steel Wire				
Insulation: N/A - Bare		Jacket: N/A - Bare			

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Test Report Summary

Page	Test Performed	Date Completed	Pass/Fail
1	Grounding Electrode Conductor Test for Copper Clad Steel Grade 40	8/25/2020	**Pass**

Requirement:
#4 AWG Grade 40 Copper Clad Steel and #6 AWG Copper Clad Steel when compared to #4 solid copper and #6 solid copper for use as a grounding electrode conductor shall have equal ability to carry amperage during a ground fault condition.

Conclusion:
The ability of bare #4 AWG Copper Clad Steel Grade 40 and bare #6 AWG Copper Clad Steel Grade 40 performed equally to #4 AWG bare solid copper and #6 AWG bare solid copper when used as a grounding electrode conductor under a ground fault condition. The current measured proved equivalency.

Test Equipment Used

Item	Equipment Type	Equipment #	Cal. Due Date
1	Fluke 374FC Clamp Meter	AM-1	Nov 2020
2	Acme Electric 15KVA Transformer	T2535173S	N/A
3	Square D 60A / 600V Safety Interrupter	N/A	N/A
4	Eaton Service Panel	N/A	N/A
5	Eaton Type CH 20 Amp Breaker	N/A	N/A
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

VBU – Verify Before Use

N/A – Not Applicable

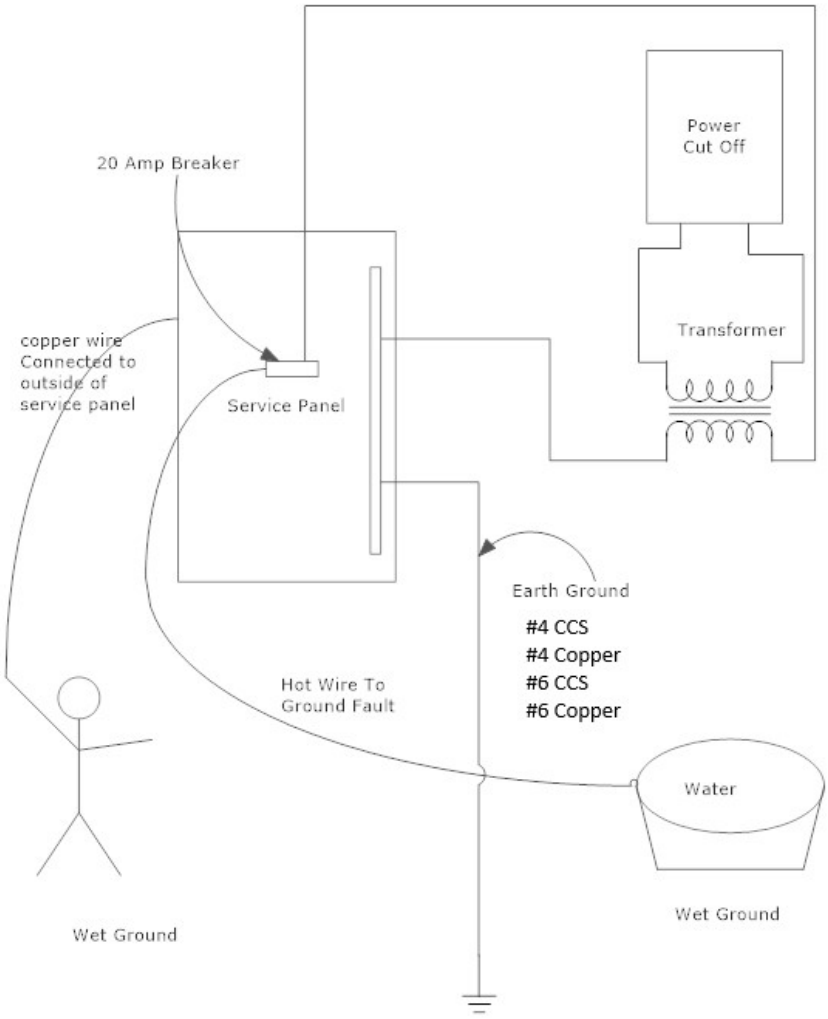
Sample Identification

Item	Description	Length/No. Rec'd
A	#4 AWG 40% Copper Clad Steel Bare	35 Ft
B	#4 AWG Solid Copper Bare	35 Ft
C	#6 AWG 40% Copper Clad Steel Bare	35 Ft
D	#6 AWG Solid Copper Bare	35 Ft
E		
F		

Grounding Electrode Conductor Test

Test Parameters:	
Conditioning:	No preconditioning.
Test Conductors:	1 each of #4 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #6 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #4 AWG Solid Bare copper grounding electrode conductor 1 each of #6 AWG Solid Bare copper grounding electrode conductor
Test Conductor Length:	Each conductor shall be 35 ft.
Test Circuit Configuration:	See schematic shown in Figure 1
Test Current:	Test current from 120 V / 20 A Residential Circuit
Method:	Testing was completed by creating a standard residential test circuit at 120V with 20A breaker wired to an intentional ground fault as shown in figure 1. The ground fault was created by connecting a hot wire from the breaker to a galvanized steel pan full of water and placing the pan on the wet ground. A conductor was also connected to the outside of the electrical panel and a Copper Plated Grounding Electrode (Copperweld Ground Rod) driven 6 inches into the wet ground to determine amount of current going through a grounded person touching the electrical panel during the ground fault condition. The ground fault and the grounded "man" were positioned 20 feet either side of the ground rod. The entire test area was soaked with water overnight using a sprinkler system When the ground fault was electrified, current measurements were taken from the ground fault conductor, the grounding electrode conductor and the grounded "man" conductor. For the four grounding electrode conductors tested, there was one test sequence for each. The current was measured for each. The objective: Compare the amperage measurements of the copper clad steel grounding electrode conductors to those of copper.

Figure 1



Results:			
Ground Conductor	**Fault Conductor Current**	**Current of the Grounding Electrode Conductor**	**Grounded Man Conductor Current**
#4 Copper	2.1 A	1.8 A	0.3 A
#4 40% CCS	2.1 A	1.8A	0.3 A
#6 Copper	1.7 A	1.6 A	0.1 A
#6 40% CCS	1.5 A	1.4 A	0.1 A

Requirement:
For equivalent sizes of Grade 40 Copper Clad steel vs. solid copper grounding conductors, the ability to carry amperage to ground during a ground fault condition is equal.

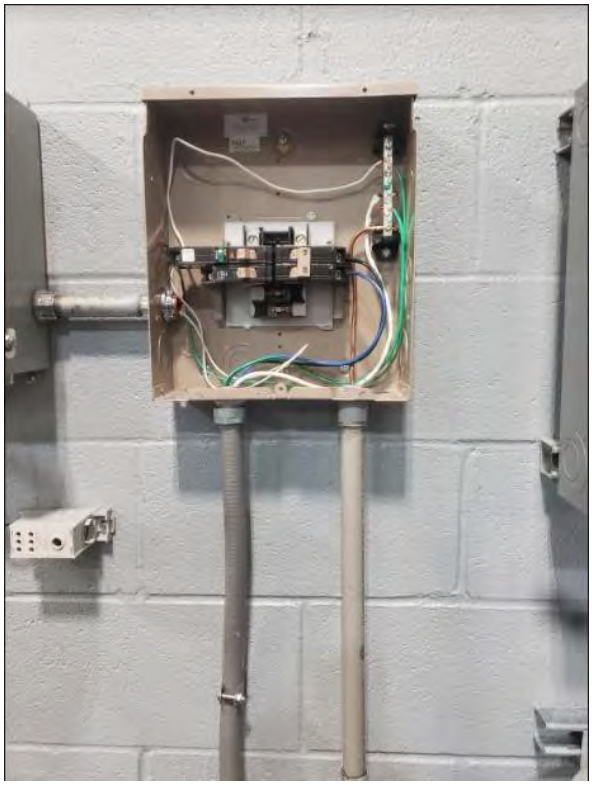
Comments:
____X__ (Pass) The product complies with all applicable requirements of this test. _____ (Fail) The product does not comply with the requirements of this test. **Test Date: 8/25/2020** **Tested By: Bill Lewey**

Environmental Conditions during Testing:

Humidity: % rh __74%_____ Ambient: °C___28_____

Test setup for the electrical service panel







Ground Rod with Grounding Conductor Attached



Ground Fault



Grounded “man”

Public Input No. 1017-NFPA 70-2020 [Section No. 250.64(B)(4)]

(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 300.50 , but shall be buried or otherwise protected if subject to physical damage.

Statement of Problem and Substantiation for Public Input

Does a grounding electrode conductor need to comply with 300.50 cover requirements? Apparently it does for a circuit or system operating above 1000 volts. Section 250.180 states "If systems over 1000 volts are grounded, they shall comply with all applicable requirements of 250.1 through 250.178 and with 250.182 through 250.194, which supplement and modify the preceding sections." There is no wording in Article 250 to suggest that 300.50 would NOT apply to Part X of Article 250. This revision is needed to clarify the cover requirements for grounding electrode conductors of circuits 1000-volts and greater.

Submitter Information Verification

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Submittal Date: Sun May 10 08:17:04 EDT 2020
Committee: NEC-P05

Public Input No. 1310-NFPA 70-2020 [Section No. 250.64(C)]

(C) Continuous.

Except as provided in 250.30(A)(5) and (A)(6), 250.30(B)(1), and 250.68(C), grounding electrode conductor(s) shall be installed in one continuous length without a splice or joint. If necessary, splices or connections shall be made as permitted in (1) through (4):

(1) Splicing of the wire-type grounding electrode conductor shall be permitted only by irreversible compression-type connectors listed as grounding and bonding equipment ~~or~~ , by the exothermic welding process, or c onnectors listed as grounding and bonding equipment .

(2) Sections of busbars shall be permitted to be connected together to form a grounding electrode conductor.

(3) Bolted, riveted, or welded connections of structural metal frames of buildings or structures.

(4) Threaded, welded, brazed, soldered or bolted-flange connections of metal water piping.

Statement of Problem and Substantiation for Public Input

The equipment grounding conductor is part of the effective ground-fault current path, and it is permitted to be spliced with connectors listed as grounding and bonding equipment. Section 250.64(D)(1)(2) permits grounding electrode taps to be spliced with a fitting listed as grounding and bonding equipment. There is not a technical reason to prohibit the grounding electrode conductor to be spliced with a fitting listed as grounding and bonding equipment.

Submitter Information Verification

Submitter Full Name: Mike Holt
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Submittal Date: Sun May 31 19:32:38 EDT 2020
Committee: NEC-P05

Public Input No. 156-NFPA 70-2019 [Section No. 250.64(D)(1)]

(1) Common Grounding Electrode Conductor and Taps.

A common grounding electrode conductor and grounding electrode conductor taps shall be installed. The common grounding electrode conductor shall be sized in accordance with 250.66, based on the sum of the circular mil area of the largest ungrounded conductor(s) of each set of conductors that supplies the disconnecting means except as permitted in 250 .66(A) through (C). If the service-entrance conductors connect directly to the overhead service conductors, service drop, underground service conductors, or service lateral, the common grounding electrode conductor shall be sized in accordance with Table 250.66, note 1.

A grounding electrode conductor tap shall extend to the inside of each disconnecting means enclosure. The grounding electrode conductor taps shall be sized in accordance with 250.66 for the largest service-entrance or feeder conductor serving the individual enclosure. The tap conductors shall be connected to the common grounding electrode conductor by one of the following methods in such a manner that the common grounding electrode conductor remains without a splice or joint:

(1) Exothermic welding.

(2) Connectors listed as grounding and bonding equipment.

(3) Connections to an aluminum or copper busbar not less than 6 mm thick × 50 mm wide (¼ in. thick × 2 in. wide) and of sufficient length to accommodate the number of terminations necessary for the installation. The busbar shall be securely fastened and shall be installed in an accessible location. Connections shall be made by a listed connector or by the exothermic welding process. If aluminum busbars are used, the installation shall comply with 250.64(A).

Statement of Problem and Substantiation for Public Input

Greetings CMP Members,

It is common knowledge that 250.64(D)(1) is referencing Table 250.66 for sizing the common grounding electrode. The sizing information with regards to parallel set applications is simply the method where using Table 250.66. We also know that once you are at 250.66 you are permitted to utilize the permissions of 250.66(A) through (C), where applicable, which would result in no necessary sizing requirements.

For example, 250.66(A) permits a conductor not required to be larger than 6 AWG CU or 4 AWG AL if all the conditions are met. The level of voltage or conductor sizing under this permission is irrelevant due to the nature of the electrode itself. So for years we have seen folks using the rules in 250.64(D)(1) sizing the common grounding electrode conductor at sizes upwards of 500 kcmil CU with grounding electrode conductor taps from multiple disconnects at sizes 6 AWG and smaller, depending on the service sizes. The public input I am proposing is simply to make it clear that you can utilize 250.66(A) through (C) even under 250.64(D)(1) so as to avoid confusion.

If you read the language literally it would come across (and it has been complained about before) that the Common GEC would need to be larger even if only ground rods are utilized and that is simply false. The proposed additional statement helps to clear that up for the end user and adds usability to the NEC.

Submitter Information Verification

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Committee:	NEC-P05

Public Input No. 592-NFPA 70-2020 [Section No. 250.64(E)]

(E) Raceways, Cable Armor, and Enclosures for Grounding Electrode Conductors.

(1) General.

Ferrous metal raceways, enclosures, and cable armor for grounding electrode conductors shall be electrically continuous from the point of attachment to cabinets or equipment to the grounding electrode and shall be securely fastened to the ground clamp or fitting. Ferrous metal raceways, enclosures, and cable armor shall be bonded at each end of the raceway or enclosure to the grounding electrode or grounding electrode conductor to create an electrically parallel path. Nonferrous metal raceways, enclosures, and cable armor shall not be required to be electrically continuous.

(2) Methods.

Bonding shall be in compliance with 250.92(B) and ensured by one of the methods in 250.92(B) (2) through (B)(4).

(3) Size.

The bonding jumper for a grounding electrode conductor(s), raceway(s), enclosure(s), or cable armor shall be the same size as, or larger than, the largest enclosed grounding electrode conductor.

(4) Wiring Methods.

If a raceway is used as protection for a grounding electrode conductor, the installation shall comply with the requirements of the appropriate raceway article.

Statement of Problem and Substantiation for Public Input

Greetings CMP Members - My only change as to the heading of 250.64(E) to add the term "Cable Armor" in order to be consistent with the changes that took place to the body of the code rule in the 2020 NEC revision cycle. I did not make any changes to the portion in Item (1) that Terraview seems to say I changed. I again simply added the term "Cable Armor" to the header to be consistent with the code language already established during the last cycle.

Submitter Information Verification

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Submittal Date:	Tue Mar 03 12:35:14 EST 2020
Committee:	NEC-P05

Public Input No. 1485-NFPA 70-2020 [Section No. 250.64(E)(1)]

(1) General.

Ferrous metal raceways, enclosures, and cable armor for grounding electrode conductors shall be electrically continuous from the point of attachment to cabinets or equipment to the grounding electrode and shall be securely fastened to the ground clamp or fitting. Ferrous metal raceways, ~~enclosures, and~~ and cable armor shall be bonded at each end of the raceway or ~~enclosure to~~ cable armor to the grounding electrode or grounding electrode conductor to create an electrically parallel path. ~~Nonferrous metal~~ Ferrous metal enclosures shall be bonded to the grounding electrode conductor at each point where the grounding electrode conductor enters or exits the enclosure. Nonferrous metal raceways, enclosures, and cable armor shall not be required to be electrically continuous.

Exception: Bonding ferrous metal enclosures at each point where the grounding electrode conductor enters or exits the enclosure shall not be required where the grounding electrode conductor is installed in a ferrous metal raceway connected to the enclosure.

Statement of Problem and Substantiation for Public Input

This revision is needed to make the distinctions between bonding the “ends” of raceways and cable armor as compared to bonding the “end” of an enclosure. Raceways and cable armor typically have clearly defined “ends”. However, the “end” of a meter socket or cabinet is better described and more easily understood as the “entry or exit point” of the GEC. Where would the end of a meter socket, cabinet or 8X8X8” box be? I believe it is much easier to understand and apply these rules with my proposed revisions. These revisions also help clarify the enclosure bonding requirements for a GEC installed in PVC conduit or directly entering a ferrous metal enclosure such as meter socket or panelboard enclosure without being installed in a raceway or cable armor. In these instances these revisions make it clear that the GEC must be bonded to the enclosure where the GEC enters/exits the enclosure. The present wording also literally requires BOTH a ferrous metal raceway AND the ferrous metal enclosure to be bonded to the GEC at the “end” where the metal raceway enclosing the GEC is connected to the metal enclosure such as a cabinet, even though most installers typically only bond the “end” of the raceway, but not the “end” of the enclosure or cabinet.. The present wording literally requires BOTH to be bonded! However, the exception I have proposed will address this concern by relieving this bonding requirement when the GEC is installed in a metal raceway connected to the metal enclosure. In this case, bonding the metal enclosure or cabinet at the point where the GEC enters the enclosure will not be required since the metal raceway is already bonded at both ends and connected to the metal enclosure. This exception is recognizing how most installers and inspectors are probably applying the present rules anyway.

Submitter Information Verification

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Committee: NEC-P05

Public Input No. 935-NFPA 70-2020 [Section No. 250.64 [Excluding any Sub-Sections]]

Grounding electrode conductors at the service, at each building or structure where supplied by a feeder(s) or branch circuit(s), or at a separately derived system shall be installed as specified in 250.64(A) through (F). This conductor shall be identified (building steel, ufer, water pipe ect...) by toe tag or other means to distinguish it from bonding jumpers and other GEC's

Additional Proposed Changes

File Name	Description	Approved
gec.jpg	ground bar	

Statement of Problem and Substantiation for Public Input

We often see a auxiliary ground bar with multiple wires landed on them with no ideal on what wire if for what. Not knowing what wire is a bonding jumper or an actual electrode. I do see certain companies that do identify each wire but believe it should be a code requirement. another example is 1 wire going to multiple electrodes, it would not be known if a replacement service was installed

Submitter Information Verification

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Committee: NEC-P05

Public Input No. 4598-NFPA 70-2020 [Section No. 250.66]

250.66 Size of Alternating-Current Grounding Electrode Conductor, Grounding Electrode Bonding Conductor, Metal Water Pipe Bonding Conductor and Structural Metal Bonding Conductor .

The size of the grounding electrode conductor at the service, at each building or structure where supplied by a feeder(s) or branch circuit(s), or at a separately derived system of a grounded or ungrounded ac system shall not be less than given in Table 250.66, except as permitted in 250.66(A) through (C). The size of the grounding electrode bonding conductor(s), metal water pipe bonding conductor(s), and structural metal bonding conductor(s) shall not be less than given in Table 250.66, except as permitted in 250.66(A) thorugh (C).

Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems

Size of Largest Ungrounded Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil)			Size of Grounding Electrode Conductor (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum		Copper	Aluminum or Copper-Clad Aluminum
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. Where 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 wire or 4 AWG 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 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.

Statement of Problem and Substantiation for Public Input

Starting with the 2008 NEC cycle, CMP-5 has done an excellent job to separate requirements for grounding (connection to earth) and bonding (connection together and capable to carry ground fault current). Part of this was the creation of the new Table 250.120(C)(1) and designating this table for certain bonding conductors and the grounded (neutral) conductor where these will need to carry ground fault current. There is an asterix note that clarifies that Table 250.102(C) bonding conductor are for the main bonding jumper, system bonding jumper, and supply side bonding jumper. This greatly simplified the various sections with the 12 1/2 percent rule and other similar parts into one location.

In the past couple of cycles CMP-5 has also made changes to other "bonding conductors" that are not necessarily intended to primarily carry ground fault current. This is possibly a case of making something fit where it really does not. The change for the metal water pipe bonding from 250.104(A) is an example where what seemed to be a logical change (this is a bonding conductor) to reference Table 250.102(C)(1). But now there is a bonding jumper that is not one of those listed in the table note. The next cycle this change then resulted another change needed to establish a limit of the size to 3/0 copper or 250 kcmil aluminum. Therefore the size is really right back to Table 260.66. There was no good technical reason that the original requirement referencing Table 250.66 was incorrect, just that the table title and text seemed to limit this to just grounding electrode conductors. This change and related PIs are to now expand Table 250.66, similar to what was done for Table 250.102(C)(1) to include the grounding electrode conductor and add the grounding electrode bonding conductors that 250.53(C) reference to Table 250.66, and revert the water pipe and structural metal bonding conductors, that are not there to primarily be part of the effective ground fault current path, back to the original state. If the bonding conductor is part of the effective ground fault current path, then is should be sized to Table 250.102(C)(1) and related requirements. If the bonding conductor is there to connect two or more electrodes together or to bond primarily to maintain equal potential to the electrical system, then it should be sized to Table 250.66.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4631-NFPA 70-2020 [Section No. 250.104(A)]	Water pipe bonding
Public Input No. 4653-NFPA 70-2020 [Section No. 250.104(C)]	Structural metal bonding
Public Input No. 4655-NFPA 70-2020 [Section No. 250.104(D)]	Separately derived system bonding
Public Input No. 4481-NFPA 70-2020 [New Part after II.]	
Public Input No. 4576-NFPA 70-2020 [Section No. 250.68(A)]	
Public Input No. 4653-NFPA 70-2020 [Section No. 250.104(C)]	

Submitter Information Verification

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Submittal Date: Thu Sep 10 15:37:22 EDT 2020
Committee: NEC-P05

Public Input No. 2468-NFPA 70-2020 [Section No. 250.66(A)]

(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~~ 6 AWG copper-clad steel or copper wire or ~~4 AWG~~ 4 AWG copper-clad aluminum or aluminum wire.

Additional Proposed Changes

File Name	Description	Approved
CCS_Corrosion_paper_Rev2.pdf	50 Year Corrosion Study Grade 40 CCS	
TD002391.doc	UL 467 Short Circuit and UL 486A-B Mechanical Sequence Testing Grade 40 CCS	
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

COPPER-CLAD ALUMINUM CONDUCTORS:

Please Consult Sections 110.14 Electrical Connections and 110.5 Conductor Materials. Copper-Clad Aluminum as a conductor material should not be excluded for this application. With aluminum and copper, Copper-Clad Aluminum is only one of three conductor materials for general wiring permitted by the NEC®. Copper-Clad Aluminum is referenced as a GEC in Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems. This PI aims to correct an inconsistency in correlation between sections and articles. It aims to bring safe alternatives to users of this Code. The NFPA Standards Council created in August 2019 a special Bimetals Task Group to in part bring attention to correlation issues effecting Copper-Clad Aluminum, as well as to study expanding its range of applications in 2023. In a coordinated effort, the Bimetals Task Group will submit 19 Public Inputs in this cycle addressing these matters.

COPPER-CLAD STEEL CONDUCTORS:

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 applicate 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 Inputs for This Document

Related Input	Relationship
Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]	Copper-Clad Steel Grounding Conductors

Submitter Information Verification

Submitter Full Name: Peter Graser
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Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 23 10:18:44 EDT 2020
Committee: NEC-P05

Testing done for the safety of our valued customer.

Global Circulation Laboratory Test Report

For Global Distribution

UL467 SHORT CIRCUIT & UL 486A-486B MECHANICAL SEQUENCE TESTS

YGHP29C2, YGHC2C2, YGHC26C26, YGHP34C29, YGHC29C29, YGHP34C34, YGHC34C34 HYTAP™ Connectors
YGL2C2, YGL29C29, YGL34C34 HYGRID™ Connectors
YGA4C2N, YGHA272N, YGA282N, YGHA302N HYLUG™ Connectors

5/8" and 3/4"Copper Clad Steel Ground Rod, #4AWG Solid, 4/0AWG Stranded, 7#7, and 19#8 COPPERWELD® 40% IACS Copper Clad Steel Conductors

PAT750XT-18V PATRIOT® Tool
with
UC, UO, U28RT, U29RT, U32RT, U997, PU998, and U1011 Die Sets

TD002391 REV B

Requested by / Date:	***Authorized by / Date:***	***Completed by / Date:***
C. Gandhi 12-Dec-2014	R Robicheau 12-Dec-2014	R Charpentier 06-Apr-2015
Engineering Approval / Date:	***Marketing Approval / Date:***	***Laboratory Approval / Date:***
R.Roman 20-Aug-2020	J Hogan 20-Aug-2020	R Charpentier 20-Aug-2020

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

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Burndy LLC 47 East Industrial Park Dr.
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TD002391

Global Circulation Laboratory Test Report

For Global Distribution

PURPOSE OF TEST:

To determine if the Burndy HYTAP™, HYGRID™, and HYLUG™ Connectors can meet the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST REQUESTED:

UL486A-486B Mechanical Sequence
UL467 Short Time Current

TEST RESULTS:

Connector	Cable 1	Cable 2	Die	# of crimps	Securness	Pull	Short Time Current		
					Pass / Fail	Average Pull (lb)	Pass / Fail	Current (Amps)	Time (s)
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	U997	1	Pass	1021.3	Pass	1600	6
YGL2C2	#4 Solid CCS	#4 Solid CCS	U-O	1	Pass	1451.8	Pass	1600	6
YGHC2C2	#4 Solid CCS	#4 Solid CCS	U-C	1	Pass	1544.0	Pass	1600	6
YGA4C2N	#4 Solid CCS	n/a	U4CRT	1	Pass	814.0	Pass	1600	6
YGL29C29	7#7 STR CCS	7#7 STR CCS	U997	1	Pass	1643.2	Pass	4600	9
YGHC26C26	7#7 STRCCS	7#7 STR CCS	U-O	1	Pass	1239.4	Pass	4600	9
YGHA272N	7#7 STRCCS	n/a	U29RT	2	Pass	1574.0	Pass	4600	9
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PU998	1	Pass	1789.8	Pass	6100	9
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1849.8	Pass	6100	9
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1779.1	Pass	6100	9
YGA282N	4/0 AWG CCS	n/a	U28RT	2	Pass	2489.3	Pass	6100	9
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	U1011	3	Pass	2126.8	Pass	9000	9
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	U1011	3	Pass	2380.0	Pass	9000	9
YGL34C34	19#8 STRCCS	19#8 STR CCS	U1011	3	Pass	3158.3	Pass	9000	9
YGHC34C34	19#8 STR CCS	19#8 STR CCS	U1011	3	Pass	3812.1	Pass	9000	9
YGHA302N	19#8 STR CCS	n/a	U32RT	2	Pass	4792.2	Pass	9000	9

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Global Circulation Laboratory Test Report

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CONCLUSIONS:

All samples tested met the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST PROCEDURES

The table below shows the connector / conductor combinations tested.

Connector	Cable 1	Cable 2	Tool	Die	# of Crimps
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	PAT750	U997	1
YGL2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-O	1
YGHC2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-C	1
YGA4C2N	#4 Solid CCS	n/a	PAT750	U4CRT	1
YGL29C29	7#7 STR CCS	7#7 STR CCS	PAT750	U997	1
YGHC26C26	7#7 STR CCS	7#7 STR CCS	PAT750	U-O	1
YGHA272N	7#7 STR CCS	n/a	PAT750	U997	2
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PAT750	PU998	1
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGA282N	4/0 AWG CCS	n/a	PAT750	U997	2
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	PAT750	U1011	3
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	PAT750	U1011	3
YGL34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHC34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHA302N	19#8 STR CCS	n/a	PAT750	U32RT	2

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All conductors were cut to twenty four (24) inch lengths.
All ground rod was pre-crimped with the appropriate pre-crimp die
5/8in Rod UPRECRIMP58
3/4in Rod UPRECRIMP34

Mechanical Sequence
Four samples of each set were secured to the Secureness tester, the height; weight and bushing size were as specified in UL486A-486B Table 26. Samples were rotated for thirty minutes at 9rpm. Samples were then subjected to a 1-minute pull to the value specified in UL486A-486B Table 27 and then to failure.

Short Time Current
Test samples were assembled in a series loop configuration then attached to a current controller as shown below. The test current and duration are listed below. After completion of the test, electrical continuity was checked with a digital multi-meter.

Test current values were derived from the equation Annex C of IEEE Std 837-2002. The diameter of the conductor(s) were measured and the cross-sectional area of the conductors was calculated.

Conductor	***Current Value (A)***	***Duration (sec)***
#4AWG Solid COPPERWELD® 40% IACS CCS	1600	6
4/0AWG 19 strand COPPERWELD® 40% IACS CCS,	6100	9
7#7 stranded COPPERWELD® 40% IACS CCS	4600	9
19#8 stranded COPPERWELD® 40% IACS CCS	9000	9

TEST EQUIPMENT LIST:

MANUFACTURER	MODEL	DESCRIPTION	SERIAL #	RANGE
FLUKE	79 III	DMM	70591301 (Rene)	AUTO
OHIO SEMITRONICS		CURRENT TRANSDUCER	NA	15000:5
SATEC	T5000	TABLE TOP	2038	5000 lbs
VIRTECH	NA	HIGH CURRENT	NA	12V / 12000A
MITUTOYO	505-675	DIAL CALIPER	08914565 (Rene)	6"

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CORROSION ON BURIED COPPER CLAD STEEL



Cece Syarif

Global Application Engineer

&

Anthony Hale

Manager, Utility Products, North America

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For more information, contact sales@copperweld.com.
The results and conclusions obtained from studies done by Copperweld are only applicable to Copper Clad Steel manufactured by Copperweld. Due to proprietary process used to produce the wire, the findings cannot be superimposed on any other copper-clad steel conductor.

254 Cotton Mill Rd, Fayetteville, TN 37334. Tel. (931) 433 – 7177

July 26, 2011

This paper compiles several studies and analysis regarding the corrosion performance of buried Copperweld® Copper-Clad-Steel (CCS) conductors. These range from the early 1900's with the invention of Copperweld® through the present day with studies performed by independent parties as well as Copperweld Company in-house testing. The purpose is to present the available information so that prospective users of Copperweld® CCS wire and strand can evaluate the corrosion resistance and expected performance within their specific application and area. Copperweld uses oxygen free copper in the manufacture of Copperweld® wire and strand. The copper surface of CCS is expected to oxidize and turn color ranging from green (patination) to brown and black the same as any solid copper wire or strand when exposed to environmental stimuli. Corrosion on exposed steel at the cut tip or end of the wire is also expected. The question to be answered is if the corrosion on either material or the interface between the copper and steel (galvanic reaction) will result in degradation of the wire as to make it unsuitable for use as a grounding conductor.

The oldest known underground corrosion study of bimetallic material was performed in the early 1900s[1]. This study focused on the corrosion behavior of Copperweld® CCS underground rod as well as other materials such as Copper and galvanized steel ground rod. The National Bureau of Standards (NBS) conducted an extensive underground corrosion study that involves 36,500 specimens which include 333 varieties of ferrous, nonferrous, and protective coating materials buried in 128 test locations throughout U.S in 1910 - 1955.

The study summarizes the service life of a ground rod as following:

10 mils copper coating – acceptable for service life up to 40 years

13 mils copper coating – acceptable for service life up to 50 years

Similarly, the Naval Civil Engineering Laboratory in collaboration with the National Association of Corrosion Engineers conducted a 7-year program of testing metal rods for electrical grounding to determine the galvanic corrosion effect. The three metals tested were stainless clad steel, copper-bonded steel (CCS), and galvanized steel. The result on the ⅝" CCS ground rod was as expected. The copper surface of the CCS was

virtually free of corrosion and the steel core has corroded at the tip approximately 2 inches down the length of the rod.

Copperweld Corporation is the inventor and sole manufacturer of Copperweld® Copper-bonded ground rods and Copperweld® wire and strand since 1915. The corrosion behavior of a Copperweld® ground rod is similar to the corrosion on Copperweld® wire and strand conductor. Both materials consist of copper permanently bonded to a steel core. All Copperweld® 40% CCS has a copper thickness of 10% of the overall diameter. For example, Copperweld® 4THOUGHT™ has a configuration of 19 strands of 0.1055 inch wires. It means that each strand has a copper thickness of 10.55 mils. Based on the NBS study, 4THOUGHT™ will have at least a minimum service life of 40 years.

Copperweld has also conducted a 5-year study of buried bare 21% conductivity (copper thickness is 3% of the diameter) Copperweld® CCS in 10 different soil conditions in association with Southwest Research Institute[2]. The study reported 100% surface oxidation and various degrees of deterioration of the steel core as expected after 5 years. The exposed steel on the tip of the wire rusted and formed "scab", as shown in Figure 1. The rust appeared to "seal-off" the un-oxidized material from the corrosive medium. The maximum depth of corrosion was 70% of the wire diameter.



Figure 1: Example of Underground Corrosion of Copper Clad Steel

Although the copper surface oxidation was heavy, the samples showed no signs of pits or holes in the copper cladding. The copper thickness of a severely oxidized 5-year sample showed no discernable difference when compared to an un-oxidized control sample that was not subjected to the corrosive environment. The mechanical and resistance testing

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resulted in negligible differences between 5-year samples and the control samples. Thus, the oxidation had no discernable impact on the strength or electrical performance of the wire.

An accelerated corrosion study based on ASTM B117 was conducted on bare CCS and solid Copper wires to evaluate copper surface corrosion. The wires were exposed to salt fog spray for 504 hours. As a result, corrosion on the CCS copper surface showed no significant difference as compared to the corrosion of copper wire.



(a) Copper Clad Steel (b) Copper

Figure 2: Patination of Copper Surface after 504 hours exposure to Salt Fog Spray

In February 2011, three separate sample strands of Copper Clad Steel were un-earthed and cut out from a substation built in Louisville, KY. The conductors were 40% conductivity, Low Carbon Steel, Dead Soft Annealed, 7 No. 5 (231,613 circular mil) and were installed in 1962.

Table 1: Physical properties of the three strands of Copperweld® conductor that had been buried underground for 48 years in a Kentucky substation

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			Strand 1	Strand 2	Strand 3
Conductor Type			40% Low Carbon Annealed		
Conductor Size			7 No. 5		
Cross Section Area		in^2	0.1819	0.1819	0.1819
Diameter of Single end		*inch*	0.1819	0.1819	0.1819
Diameter of Conductor		*inch*	0.5457	0.5457	0.5457
Copper Thickness	Min	*inch*	0.0142	0.0114	0.0134
	Max	*inch*	0.0213	0.0209	0.01975
% Concentricity			83.30%	77.30%	83.90%
Depth of corrosion	Min	*inch*	0.004	0.028	0.111
	Max	*inch*	0.781	0.859	0.484

The 1962 conductors were manufactured by Copperweld with a nominal copper thickness of 10% of its diameter. Figure 3 shows the copper thickness ranges from 11.4 – 21.3 mils and the concentricity of the conductor averaged at 81.5%. Current manufacturing improvements yield concentricity of copper thickness above 85%.

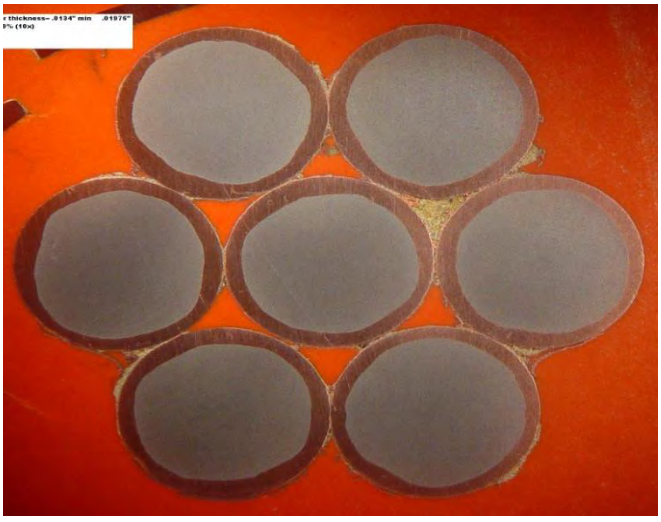


Figure 3: Copperweld® 40% LC DSA 7 No. 5 manufactured in 1962

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Figure 4a shows no visible corrosion observed other than oxidation and patination on the copper surface. At the ends of the wires, the corrosion occurred in the form of steel rust. The maximum depth of the corrosion is 0.859 inch with an average of 0.382 inch, as shown in Figure 4b.



Figure 4a: There is no visible corrosion between the copper and steel on all wires obtained from the substation in Kentucky.



Figure 4b: Corrosion occurred at the ends of the wires. Maximum penetration depth is 0.859 inch.

From all the corrosion studies above, there have not been reported or observed any galvanic corrosion at the interface of copper and steel. The process of cladding for

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Copperweld® ensures a metallurgical bond between the two metals. That metallurgical bond prevents any moisture from penetrating between the two metals precluding the corrosion process. Any propagation of corrosion on an area of exposed steel averages two times the diameter of the wire then stops. The corrosion rate of the copper surface is equivalent to that observed on standard solid copper wire and strand. Based on the results of these studies, it can be summarized that CCS can be expected to have a 50 plus year service life as buried grounding conductors.

REFERENCES:

1. Rempe, Chris. 7 July 2003. "A Technical Report on the Service Life of Ground Rod Electrodes".
2. Fox, Dustin, Belado, Chris, and Brossia, Sean. 23 September 2009. "The Effect of Corrosion on Tracer Wire with a Copper Clad Steel Center Conductor".

Powertech

Report ID: PL-03027 REP1
Revision: 0 Issued: 2020-04-15

Copper and CCS Wire Withstand Current and Fusing Current Tests

Copperweld Bimetallics, LLC



The Power of Trust. **The Future of Energy.**

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REPORT OF PERFORMANCE

CLIENT	Copperweld Bimetallics,LLC. 5141 Virginia Way, Suite 410 Brentwood, TN, United States 37027
TEST OBJECTS	Copper Clad Steel (CCS) Wires Manufacturer: Copperweld Bimetallics,LLC. Types: Scorpius Prototypes Part Nos.: 61 x 072 7 x 080 Condition: New Copper Conductor Manufacturer: Encore Wire Types: #4/0 AWG (19 strand) CU #6 AWG (single strand) CU Condition: New
TESTED BY	Powertech Labs Inc. 12388 - 88th Ave, Surrey, BC Canada V3W 7R7 www.powertechlabs.com
TEST DATE	2020-01-24 to 2020-01-25
TEST SPECIFICATION	Client Specified, with reference to IEEE Std 80-2013 and IEEE Std 837-2014

Powertech Labs Inc. does not accept any liability for any damages resulting from the use of this report. The results relate only to the item tested, and it is the responsibility of the manufacturer to maintain conformity of any object having the same designations. Information regarding the estimated measurement uncertainty is available upon request. The test report shall not be reproduced except in full, without written approval of Powertech Labs Inc.

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Powertech

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1 INTRODUCTION

At the request of Copperweld Bimetallics,LLC., withstand current and fusing current tests were performed on standard copper and copper clad steel (CCS) wires in accordance with specifications and procedures provided by the client. Reference was made to IEEE Std 80-2013 and IEEE Std 837-2014 as guides for determining current levels and durations for the tests.

The High Power Lab is accredited by the Standards Council of Canada to ISO 17025 for short-circuit testing.

2 TEST OBJECT INFORMATION

The test objects were identified by the client as follows:

Copper Clad Steel Wires (CCS)

Manufacturer:	Copperweld Bimetallics,LLC.
Types:	Scorpius Prototypes
Part Nos.:	61 x 072
	7 x 080
Condition:	New

Copper Conductor

Manufacturer:	Encore Wire
Types:	4/0 AWG (19 strand) CU
	#6 AWG (single strand) CU
Condition:	New

Conductor sample diameters and dc resistance values were measured by the laboratory before testing, as presented in Table 1.

3 GENERAL INFORMATION

3.1 Purpose

The purpose of the tests is to identify the current limits at short durations for standard copper and Copperweld CCS grounding wire products, and to determine if these products meet the applicable requirements of the referenced Standards.

3.2 Witnesses

Name	Company
Jeff Jordan	Copperweld Bimetallics,LLC.
Lora Aboulmouna	Copperweld Bimetallics,LLC.
Jason Smolko	Copperweld Bimetallics,LLC.
Ryan Hale	Copperweld Bimetallics,LLC.

3.3 Tests Performed

Test Standards/Specifications:

Withstand current tests were performed as requested by the client, with reference to the following Standards to determine the test levels:

IEEE Std 80-2013, Table 6 – Specification for the ultimate current carrying capacity of copper grounding cables using symmetrical current.

IEEE Std 837-2014, Clause 7.2 and Table 3 – Electromagnetic force (EMF) test

4 SHORT-CIRCUIT CURRENT TESTS

General Information:

Standard	Client's Specification, with reference to IEEE Std 80-2013 and IEEE Std 837-2014
Test Dates	2020-01-24 to 2020-01-25
Test Leader	Chris Morton

Environmental Conditions:

Ambient temperature	(7 – 9) °C
Relative Humidity	(95 – 99) %

Test Conditions:

Samples were tested in a covered test cell which was open on one side to the outdoor ambient conditions. During each test, one sample was connected horizontally between the laboratory source bus and ground bus, at a bus spacing of 48 inches, as shown in Figures 30 through 33. The samples were terminated using Burndy mechanical connectors, as shown in Figures 34 and 35. The length of each wire sample was the minimum length required to span the distance between the buses, and each sample was at approximately right angles (90°) to both the source and ground bus. Each sample was suspended in free air approximately 46 inches above the floor of the test cell. The temperature of the sample at the start of each test was the natural outdoor ambient temperature of the laboratory, except for tests performed to IEEE 837, where the sample was allowed to cool to less than 100 °C before the second shot.

All tests were performed at a power frequency of 60 Hz using the test circuit shown in Figure 1. Current was initiated by energizing a current limited source that was calibrated to provide the target current through the circuit. The rms current, current symmetry and duration of each test were specified by the client.

The test current was measured using a 300 kA_{peak} rated Rogowski coil (Powertech ID № 39444). The expanded uncertainty of the current measuring system is estimated as 2% (k=2).

Test Results:

The results of the tests are provided in Tables 2 through 5. Current and voltage waveforms for each test are provided in Figures 2 through 29.

The Encore #4/0 AWG Cu wire did not withstand the I^2t calculated from the current and duration specified in IEEE 80, Table 6, for a 500 ms duration (44 kA_{rms}). It was capable of carrying a maximum of 92% of this I^2t value without fusing.

The Encore #4/0 AWG Cu wire did not withstand the EMF current specified in IEEE 837, Table 3 (47 kA_{rms}). It was capable of carrying a maximum of 91% of this current value without failing.

The Copperweld Scorpius CCS 61 x 072 conductor exceeded the 500 ms rms withstand current requirement of IEEE 80, Table 6, and met the EMF current requirements of IEEE 837, Table 3, for a 4/0 conductor.

For the #6 AWG Cu conductor size the Standards did not have current values specified, so these were calculated using Equation (45) from IEEE 80 and Equation (C.1) from IEEE 837. The calculations are presented in Appendix D.

Both the Copperweld Scorpius CCS 7 x 080 conductor and the Encore #6 AWG Cu conductor met the 500 ms rms withstand current requirement of IEEE 80, Table 6 (5.29 kA_{rms}), and the EMF current requirements of IEEE 837, Table 3 (5.81 kA_{rms}), for a #6 AWG Cu conductor.

APPENDIX A – FUSING CURRENT TEST CIRCUIT AND DATA

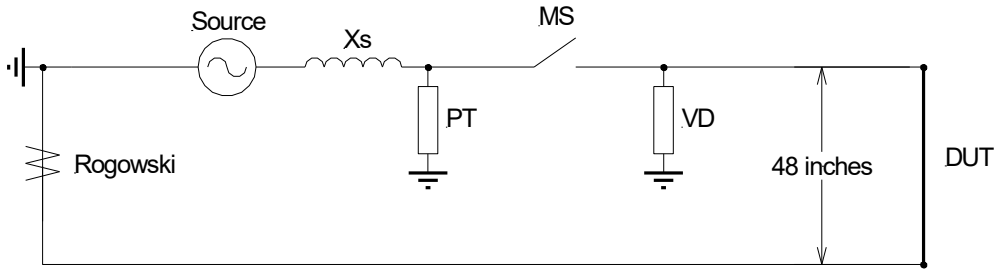


Figure 1: Test circuit schematic for all tests.

Notes:

1. X_S – Source current limiting reactance
2. MS – Making Switch
3. VD – Voltage measurement
4. Rogowski – Current measurement
5. DUT – Device Under Test

Table 1: Strand diameter and dc resistance measurements of sample conductors.

Wire Sample No.	Type	Strand Diameter [1] (in)		Conductor Diameter	Dc Resistance at 20°C
#		1	2	(in)	(μΩ/ft)
1	Encore Wire, 4/0 AWG, 19 strand CU	0.122	0.079	0.492	4.28
2	Encore Wire, 4/0 AWG, 19 strand CU	0.118	0.080	0.501	4.10
3	Encore Wire, 4/0 AWG, 19 strand CU	0.109	0.074	0.495	4.23
4	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.075	0.498	3.98
5	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.079	0.489	4.43
6	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.075	0.490	4.17
7	Encore Wire, 4/0 AWG, 19 strand CU	0.101	0.075	0.489	4.18
8	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.074	0.491	4.15
9	Encore Wire, 4/0 AWG, 19 strand CU	0.106	0.082	0.490	3.97
10	Encore Wire, 4/0 AWG, 19 strand CU	0.105	0.079	0.493	3.73
11	Scorpius 61 x 072 CCS	0.056	---	0.646	6.83
12	Scorpius 61 x 072 CCS	0.058	---	0.649	6.60
13	Scorpius 61 x 072 CCS	0.068	---	0.641	6.60
14	Scorpius 61 x 072 CCS	0.056	---	0.639	6.73
15	Scorpius 61 x 072 CCS	0.067	---	0.646	6.62
16	Scorpius 61 x 072 CCS	0.059	---	0.630	6.53
17	Scorpius 61 x 072 CCS	0.056	---	0.642	6.73
18	Scorpius 61 x 072 CCS	0.067	---	0.637	6.62
19	Scorpius 61 x 072 CCS	0.064	---	0.641	6.85
20	Scorpius 61 x 072 CCS	0.059	---	0.633	6.83
21	Encore Wire, #6 AWG, single strand CU	0.152	---	0.152	33.3
22	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
23	Encore Wire, #6 AWG, single strand CU	0.158	---	0.158	33.2
24	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.4
25	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.3
26	Encore Wire, #6 AWG, single strand CU	0.148	---	0.148	33.6
27	Encore Wire, #6 AWG, single strand CU	0.155	---	0.155	33.3
28	Encore Wire, #6 AWG, single strand CU	0.146	---	0.146	33.1
29	Encore Wire, #6 AWG, single strand CU	0.153	---	0.153	33.2
30	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
31	Scorpius 7 x 080 CCS	0.072	---	0.215	46.3
32	Scorpius 7 x 080 CCS	0.069	---	0.226	45.9
33	Scorpius 7 x 080 CCS	0.065	---	0.220	46.2
34	Scorpius 7 x 080 CCS	0.071	---	0.218	46.4
35	Scorpius 7 x 080 CCS	0.073	---	0.212	46.1
36	Scorpius 7 x 080 CCS	0.065	---	0.216	46.3
37	Scorpius 7 x 080 CCS	0.070	---	0.211	46.1

Note:

[1] Encore 4/0 AWG CU conductor had two sizes of strands, all remaining conductors had one size of strands. Strand and conductor diameters were measured using a digital caliper with a resolution of 0.001 in.

Table 2: Summary of tests on Encore 4/0 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
1	1	Run to fusing	3.85	41.7	60.0	530	923	2	Y
2	2	Withstand	3.85	41.8	62.5	509	889	3	N
3-1	3	EMF (IEEE 837)	4.24	48.0	130	262	826	4	N
3-2	3	EMF (IEEE 837)	4.26	48.0	130	127	503	5	Y
4	4	EMF (IEEE 837)	4.25	48.0	130	260	823	6	Y
5-1	5	EMF (IEEE 837)	4.20	47.4	129	262	808	7	N
5-2	5	EMF (IEEE 837)	4.19	47.4	128	9.9	77	8	Y
6-1	6	EMF (IEEE 837)	3.93	42.6	116	263	662	9	N
6-2	6	EMF (IEEE 837)	3.91	42.6	116	262	654	10	N

Table 3: Summary of tests on Copperweld Scorpius 61 x 072 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
7	11	Run to fusing	3.84	41.7	59.6	673	1173	11	Y
8	12	Run to fusing	4.25	48.1	69.8	500	1157	12	Y
9	13	Run to fusing	4.21	47.5	68.9	508	1150	13	Y
10	14	Withstand	4.09	46.2	66.2	508	1089	14	N
11-1	15	EMF (IEEE 837)	4.21	47.6	129	262	803	15	N
11-2	15	EMF (IEEE 837)	4.20	47.7	129	262	803	16	N
12-1	16	EMF (IEEE 837)	4.21	47.6	129	254	784	17	N
12-2	16	EMF (IEEE 837)	4.19	47.4	128	254	767	18	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

Table 4: Summary of tests on Encore #6 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
13	21	Run to fusing	3.90	5.18	7.36	607	16.3	19	Y
14	23	Run to fusing	3.90	5.18	7.57	600	16.1	20	Y
15	24	Run to fusing	4.27	5.68	8.15	500	16.1	21	Y
16-1	25	EMF (IEEE 837)	3.77	5.86	16.2	262	13.9	22	N
16-2	25	EMF (IEEE 837)	3.77	5.86	16.1	262	13.9	23	N

Table 5: Summary of tests on Copperweld Scorpius 7 x 080 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
17	31	Withstand	3.88	5.16	7.44	858	22.9	24	N
18	32	Run to fusing	3.89	5.16	7.43	908	24.2	25	Y
19	33	Run to fusing	4.48	7.00	10.3	493	24.1	26	Y
20	34	Run to fusing	4.41	6.91	10.2	502	23.9	27	Y
21-1	35	EMF (IEEE 837)	3.81	5.91	16.3	262	14.0	28	N
21-2	35	EMF (IEEE 837)	3.80	5.92	16.2	262	13.8	29	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

APPENDIX B – WAVEFORMS

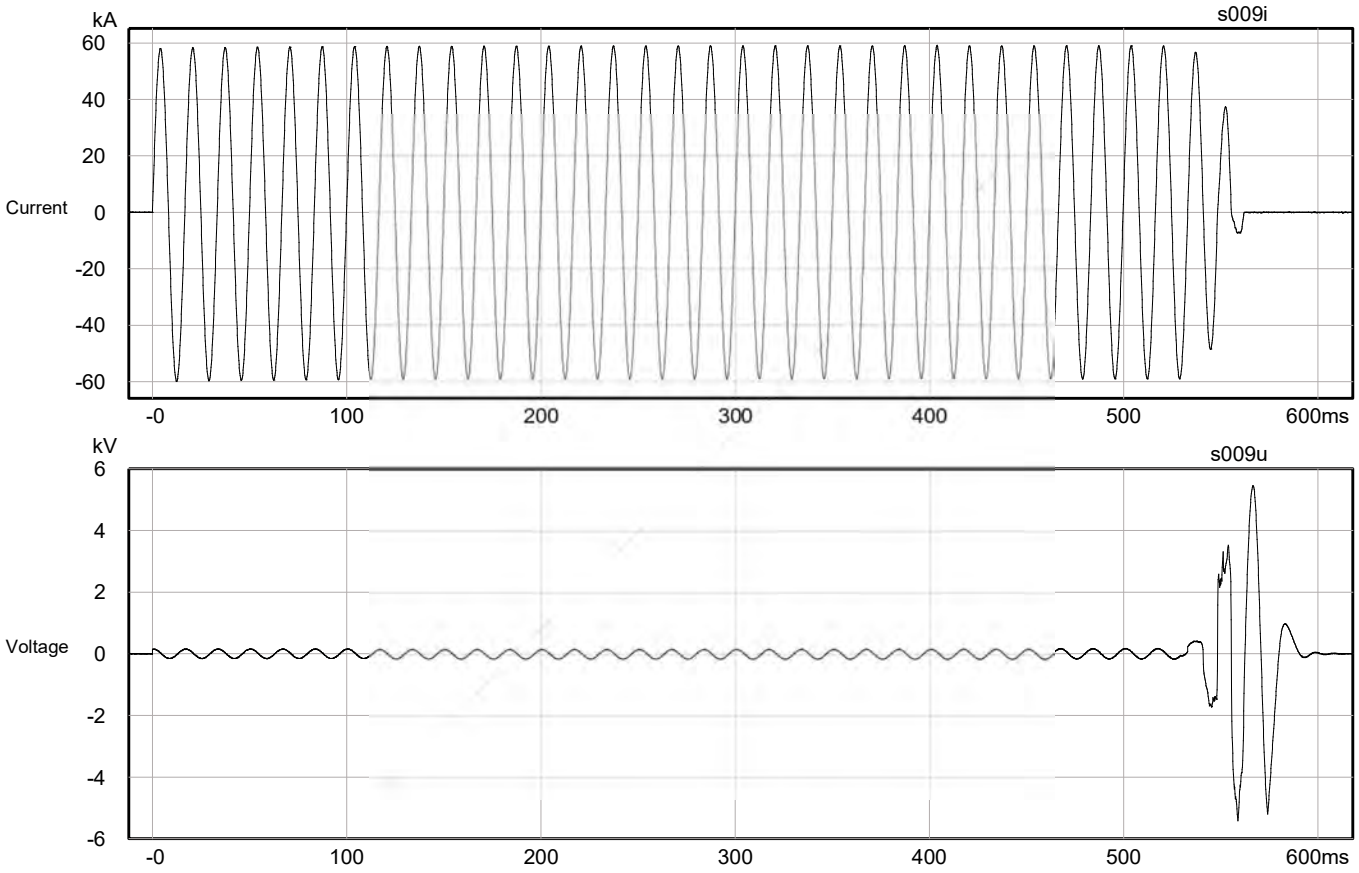


Figure 2: Waveforms for Test #1, Encore 4/0 AWG Sample 1.

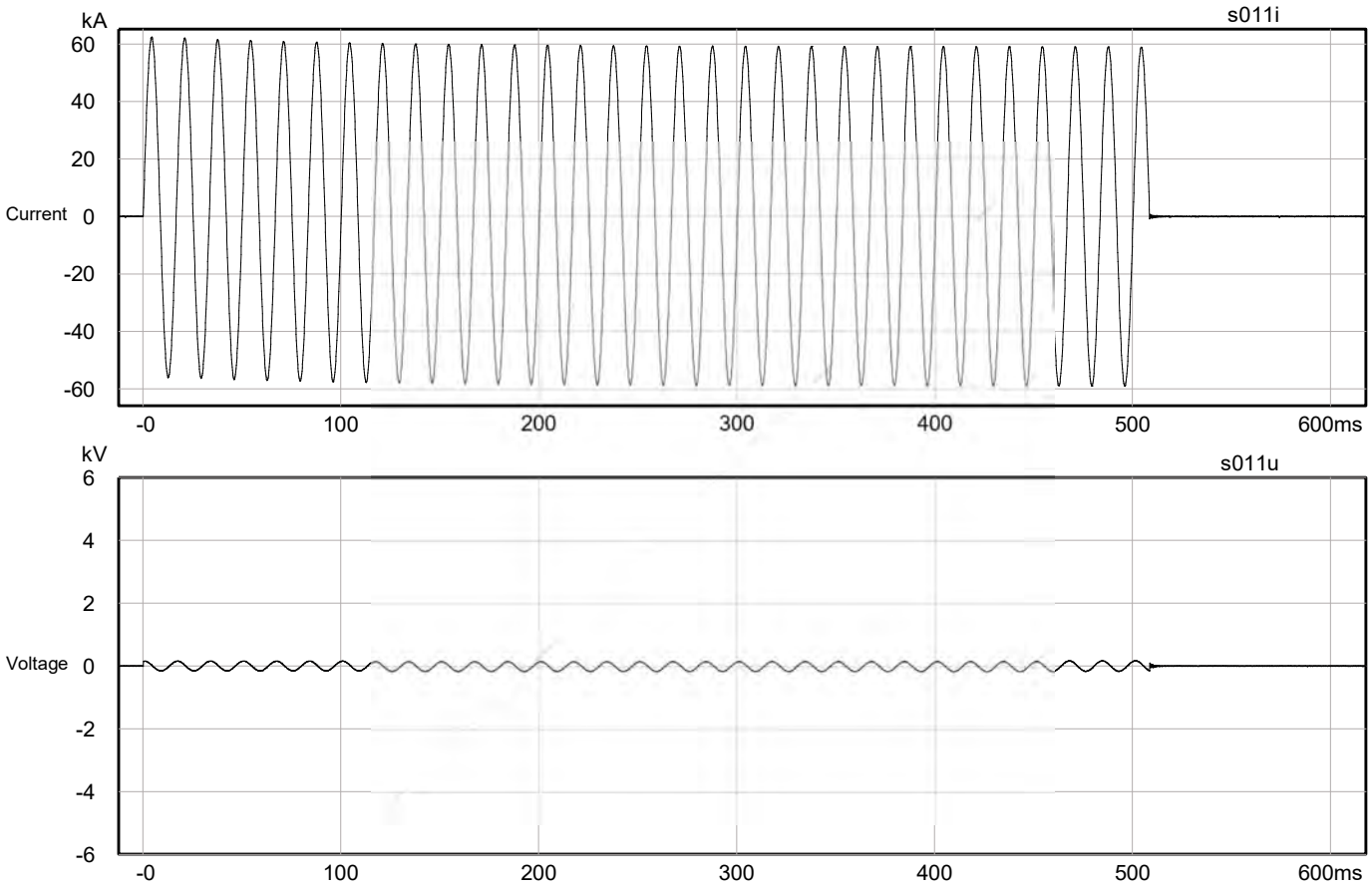


Figure 3: Waveforms for Test #2, Encore 4/0 AWG Sample 2.

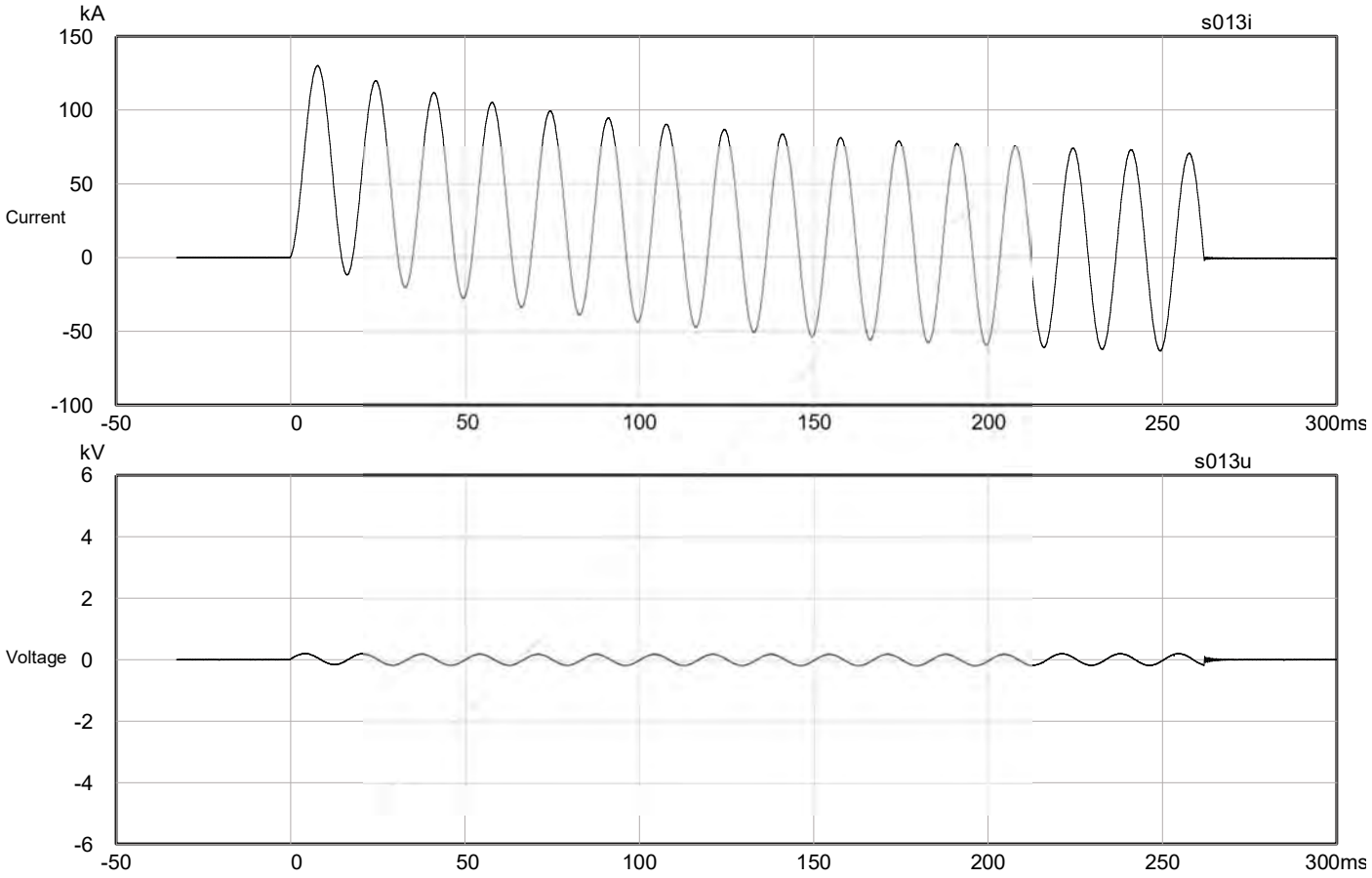


Figure 4: Waveforms for Test #3-1, Encore 4/0 AWG Sample 3.

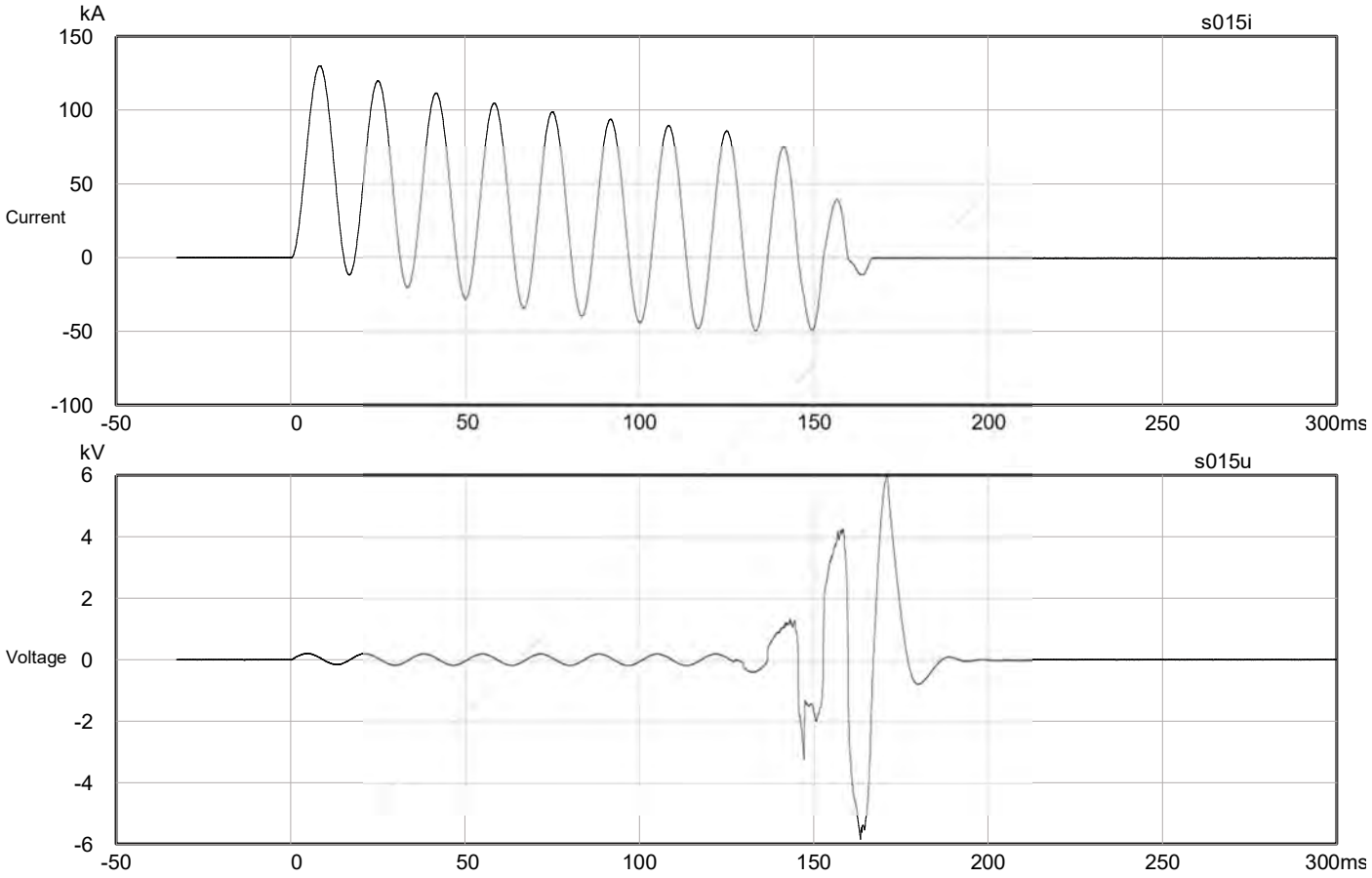


Figure 5: Waveforms for Test #3-2, Encore 4/0 AWG Sample 3.

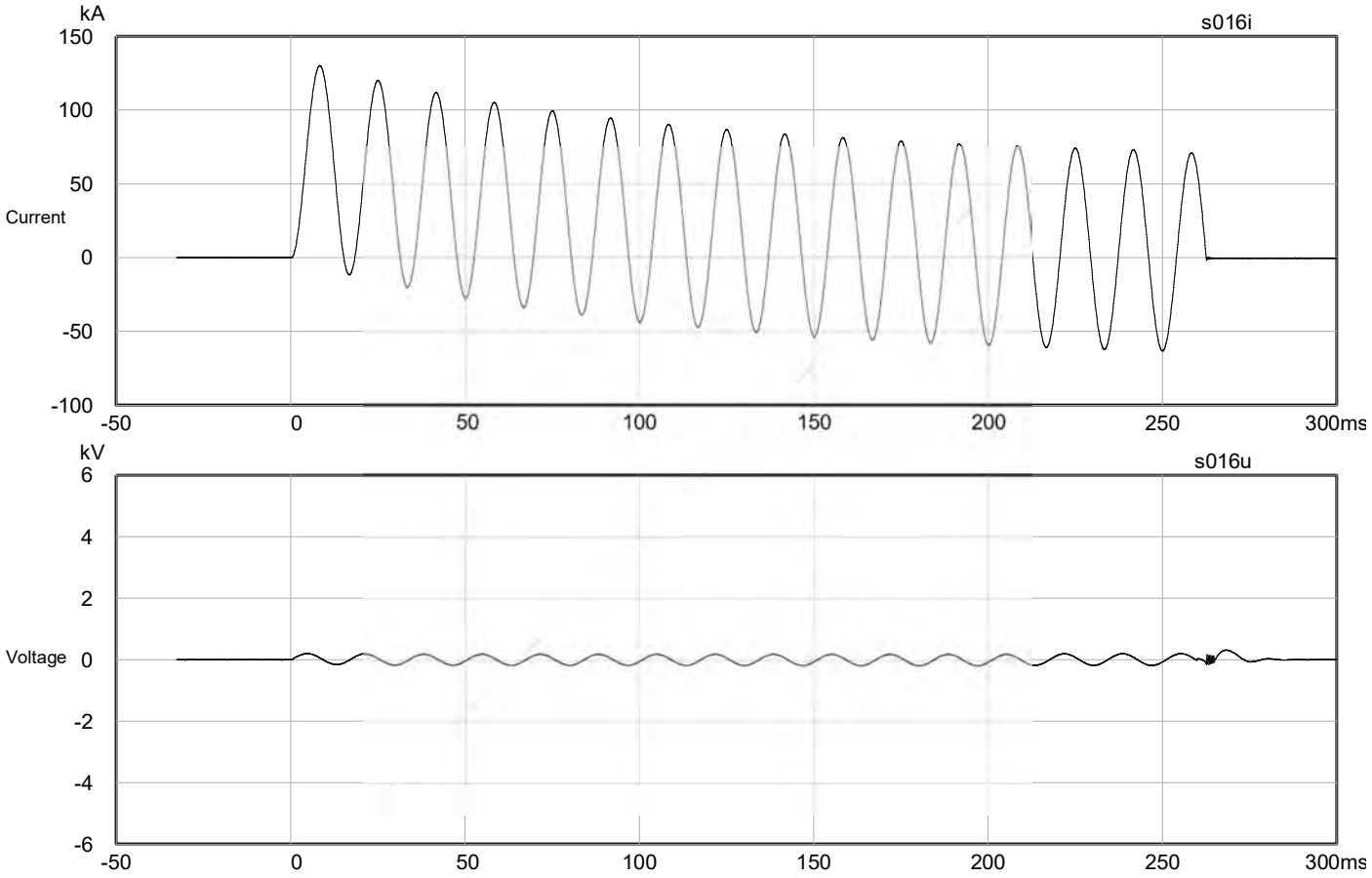


Figure 6: Waveforms for Test #4, Encore 4/0 AWG Sample 4.

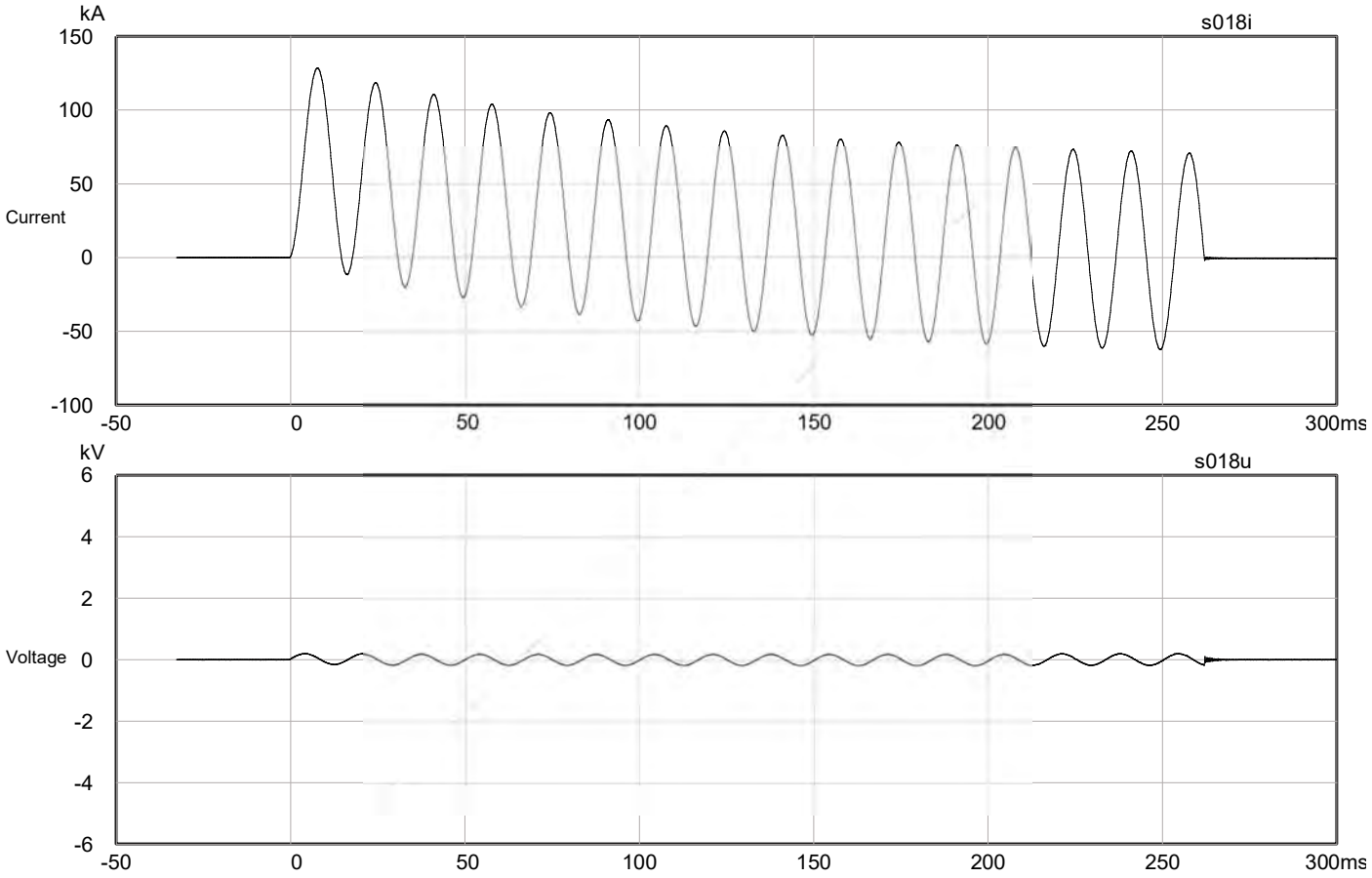


Figure 7: Waveforms for Test #5-1, Encore 4/0 AWG Sample 5.

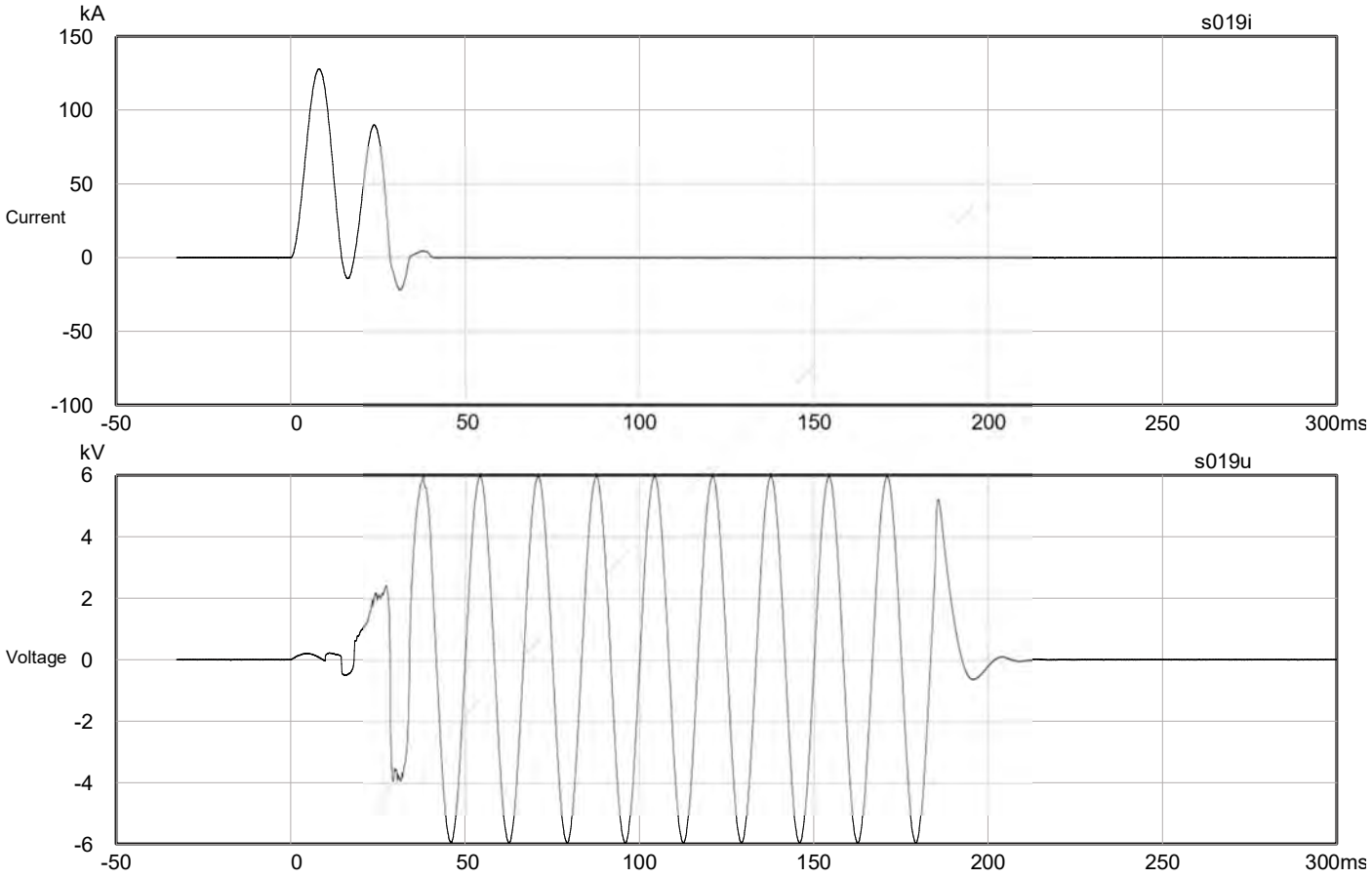


Figure 8: Waveforms for Test #5-2, Encore 4/0 AWG Sample 5.

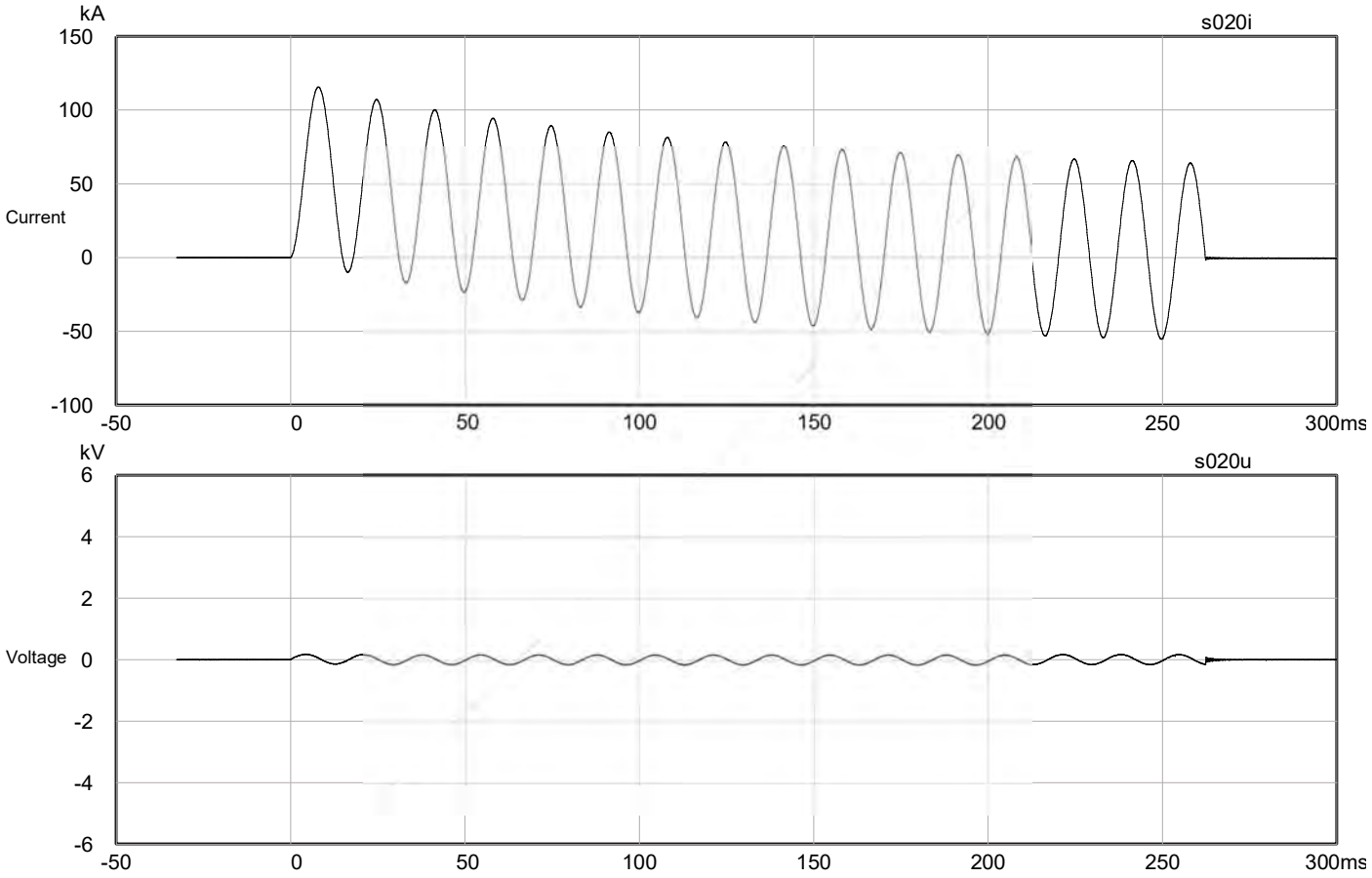


Figure 9: Waveforms for Test #6-1, Encore 4/0 AWG Sample 6.

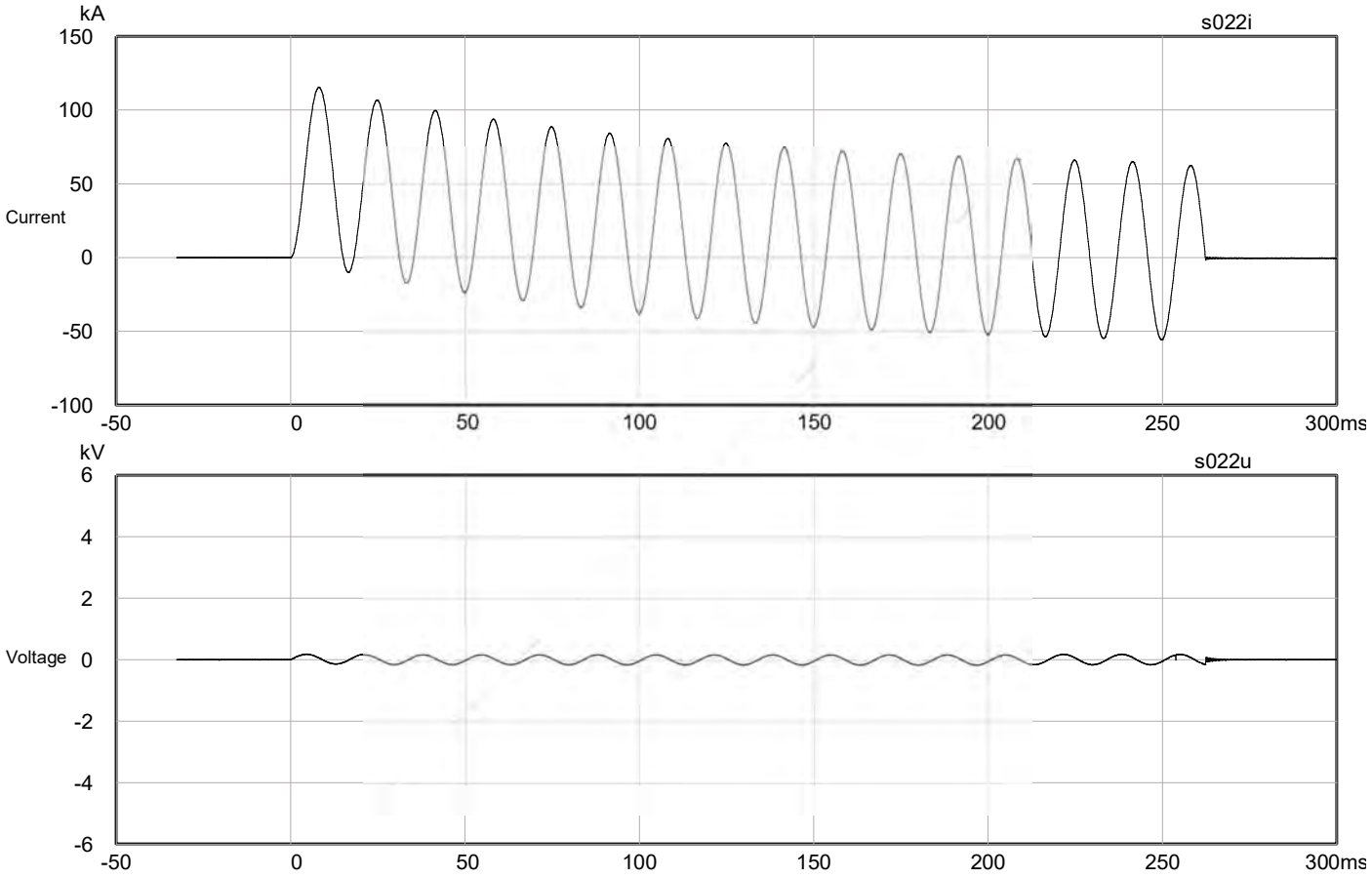


Figure 10: Waveforms for Test #6-2, Encore 4/0 AWG Sample 6.

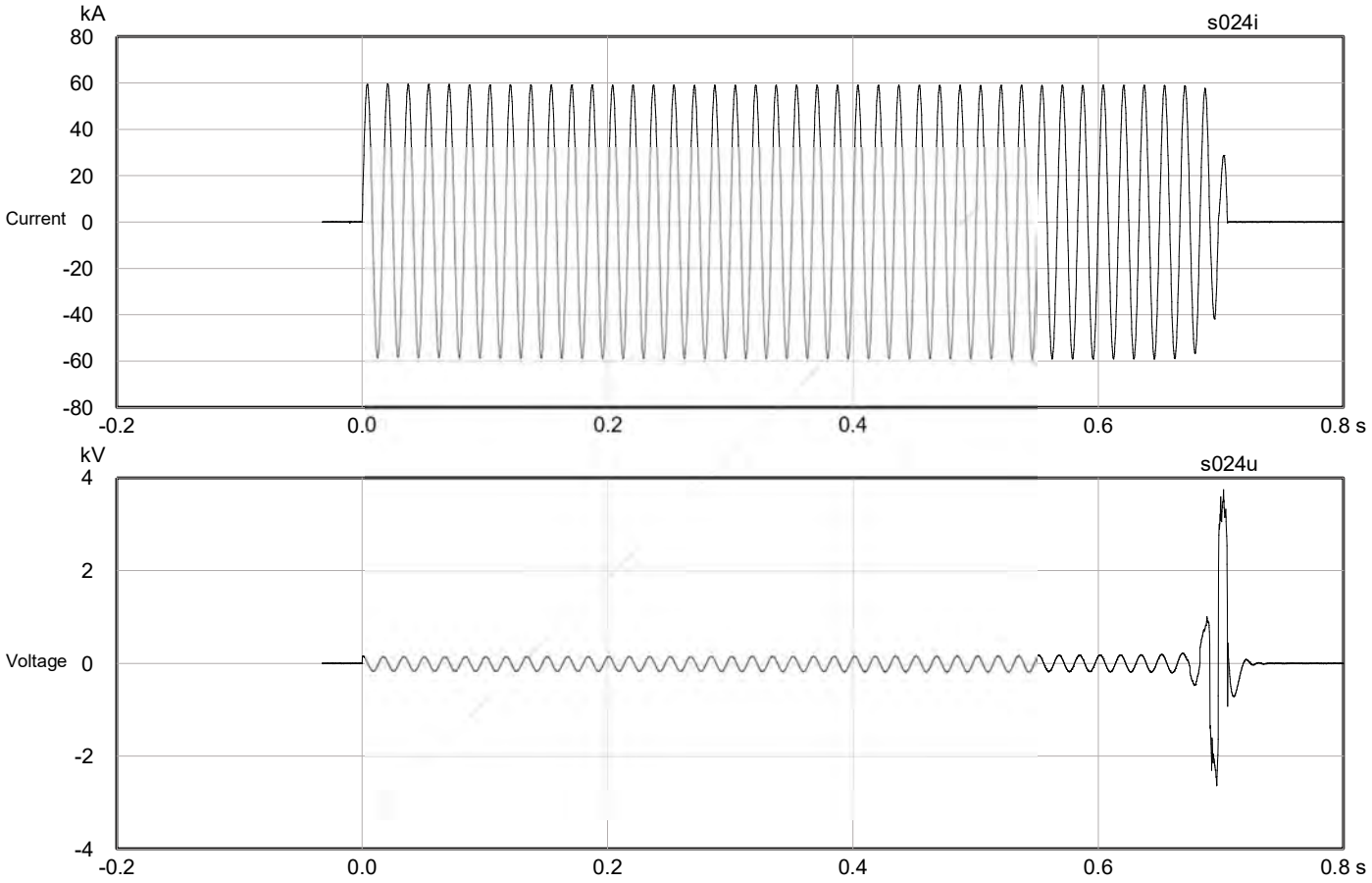


Figure 11: Waveforms for Test #7, Copperweld Scorpius 61 x 072 Sample 11.

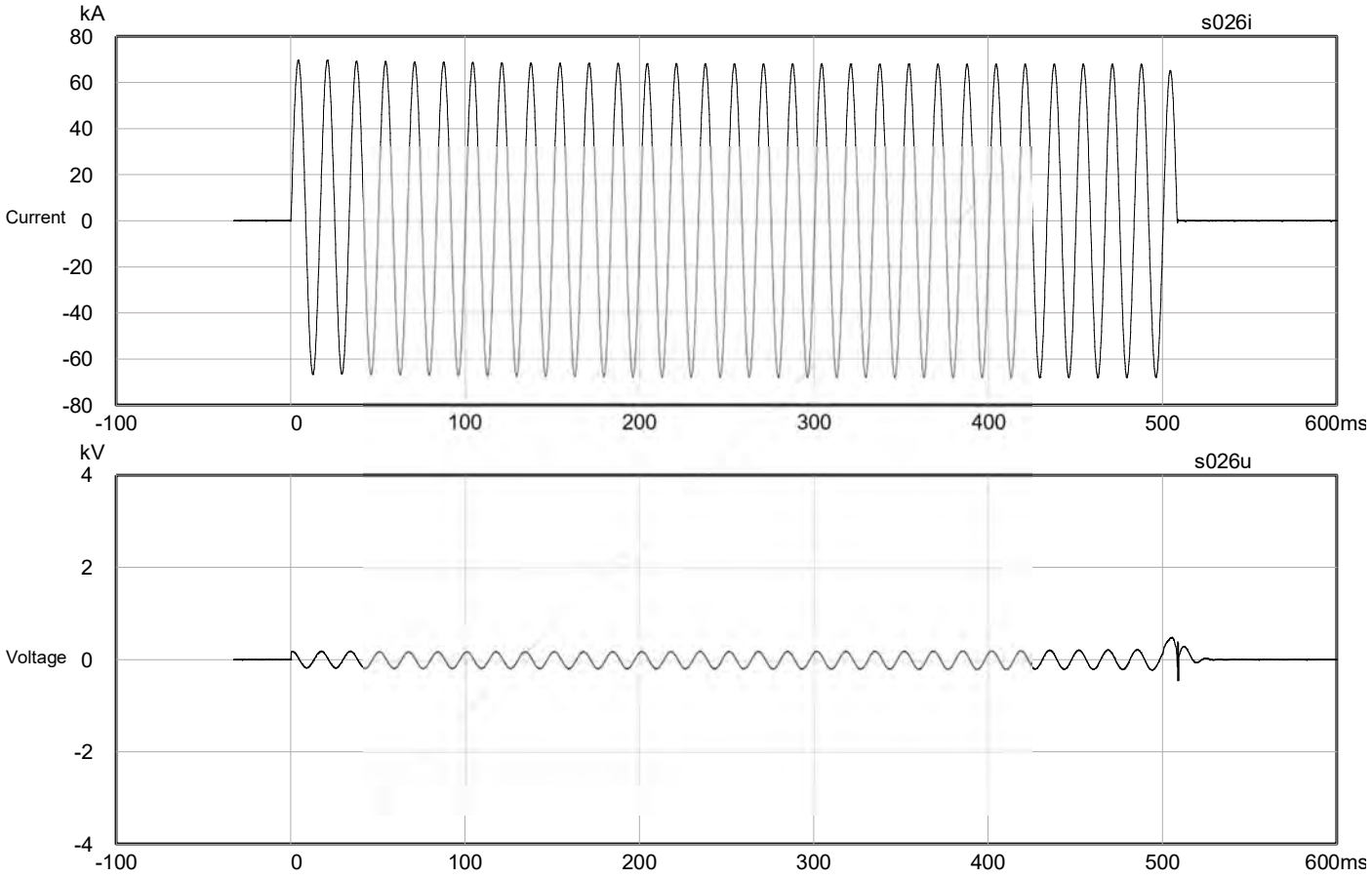


Figure 12: Waveforms for Test #6, Copperweld Scorpius 61 x 072 Sample 12.

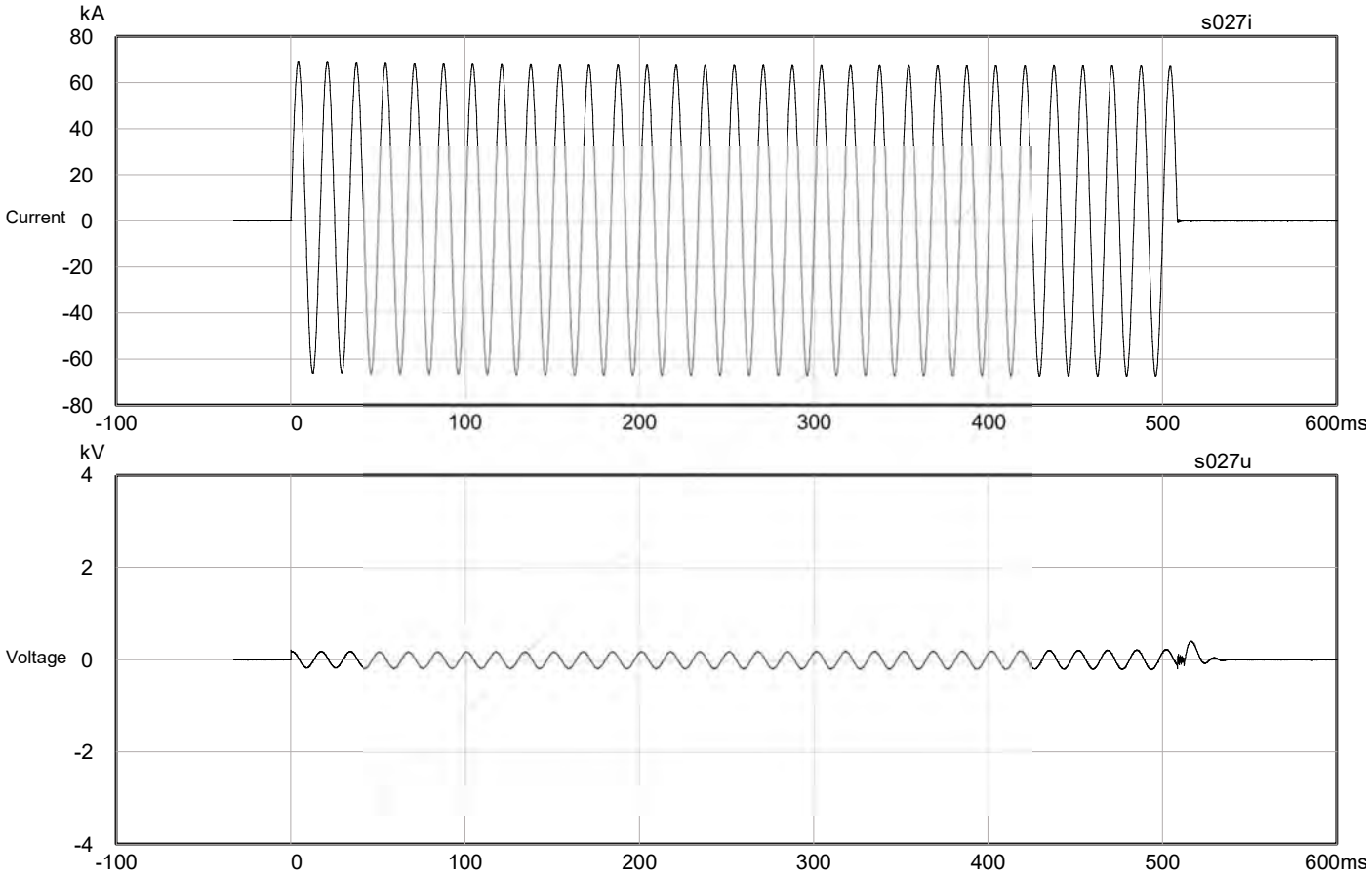


Figure 13: Waveforms for Test #9, Copperweld Scorpius 61 x 072 Sample 13.

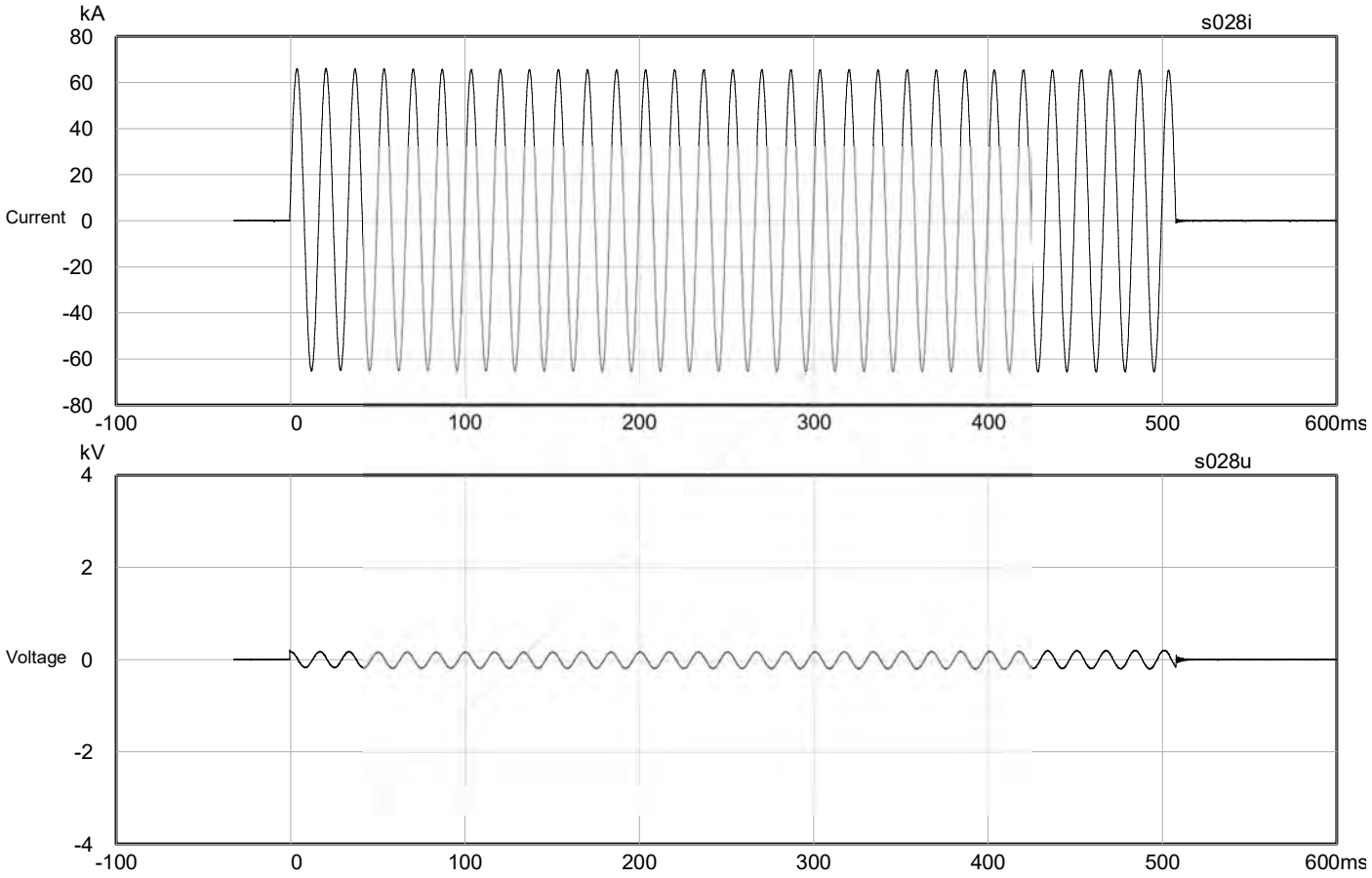


Figure 14: Waveforms for Test #10, Copperweld Scorpius 61 x 072 Sample 14.

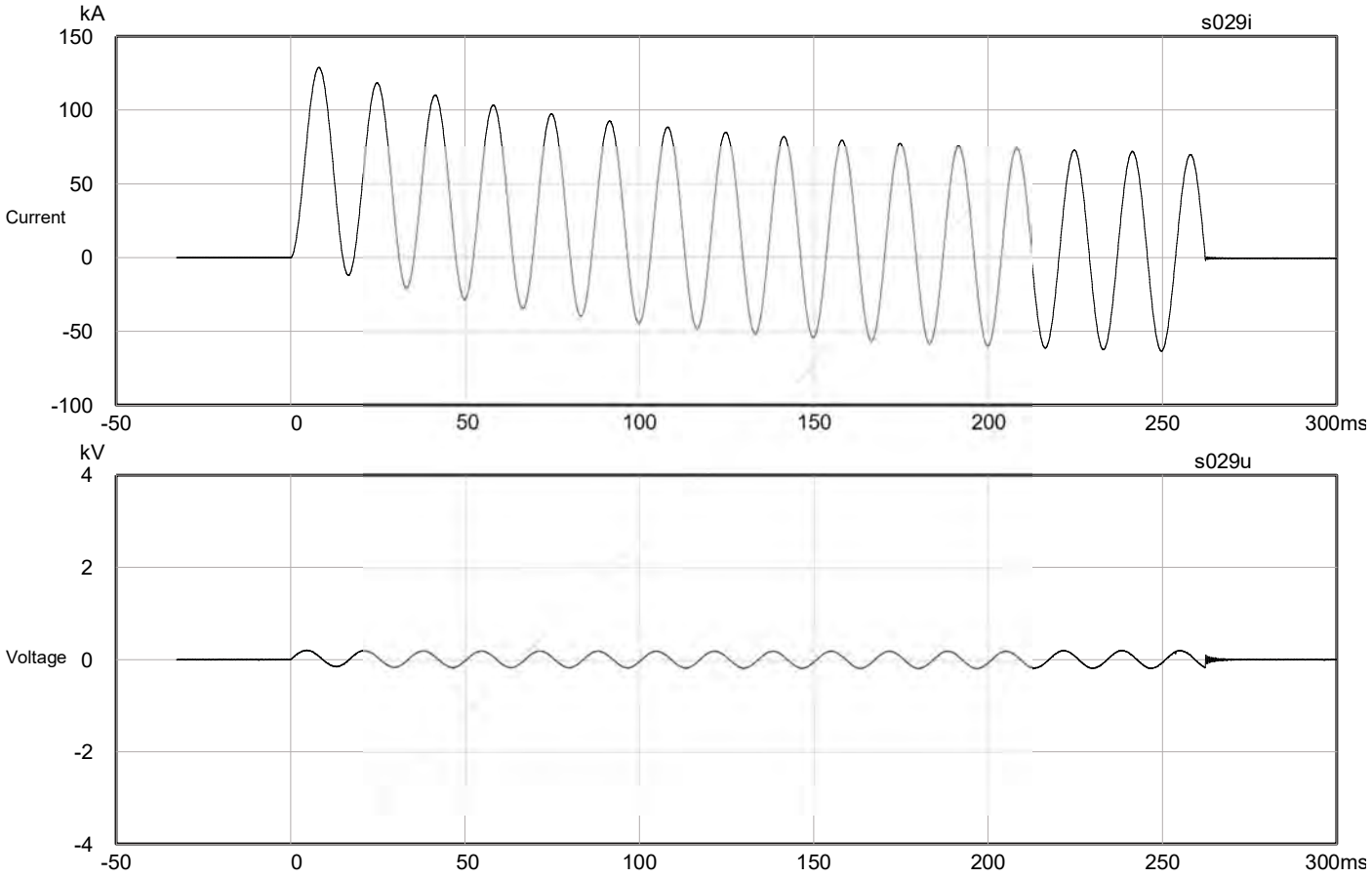


Figure 15: Waveforms for Test #11-1, Copperweld Scorpius 61 x 072 Sample 15.

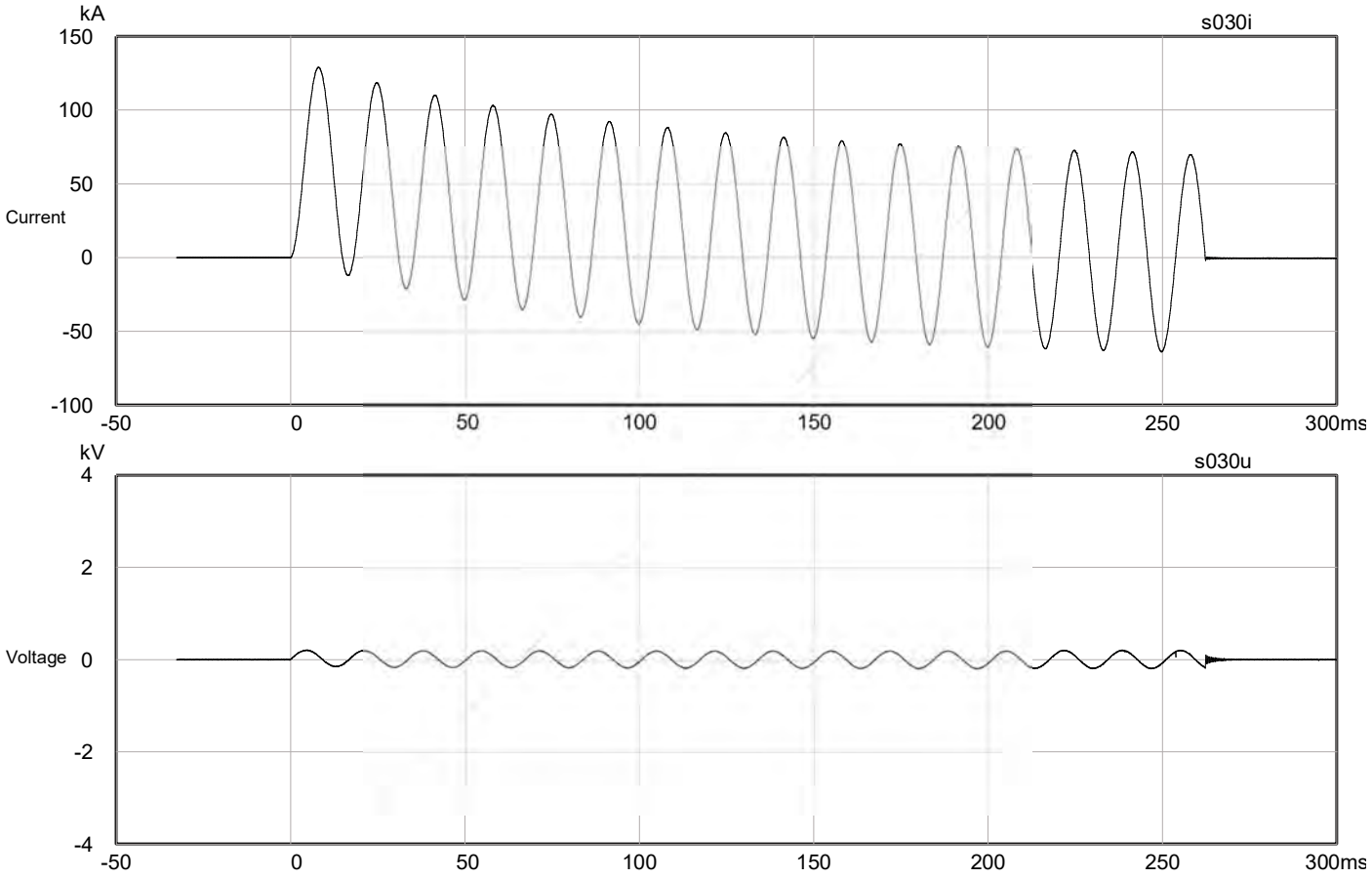


Figure 16: Waveforms for Test #11-2, Copperweld Scorpius 61 x 072 Sample 15.

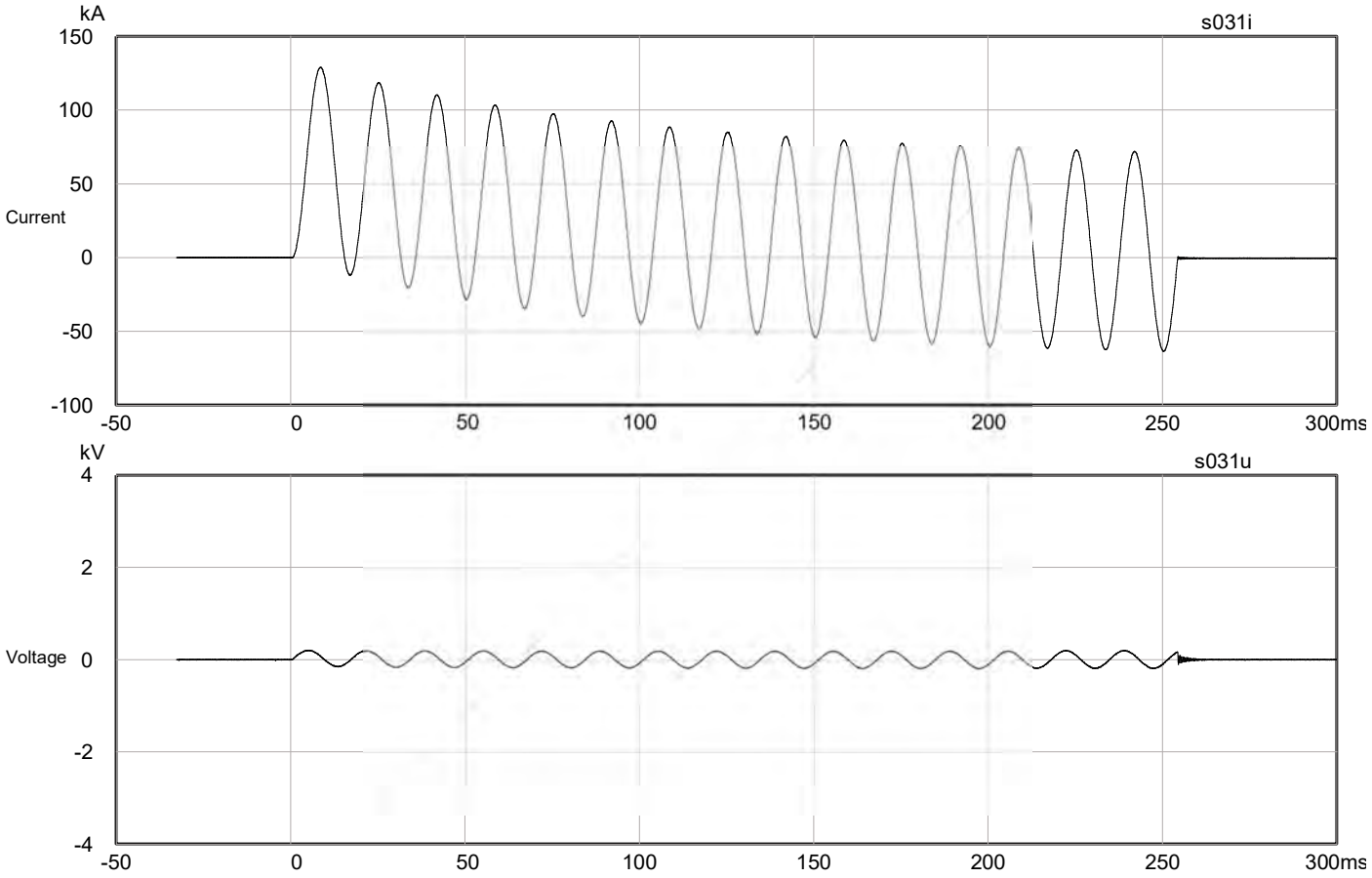


Figure 17: Waveforms for Test #12-1, Copperweld Scorpius 61 x 072 Sample 16.

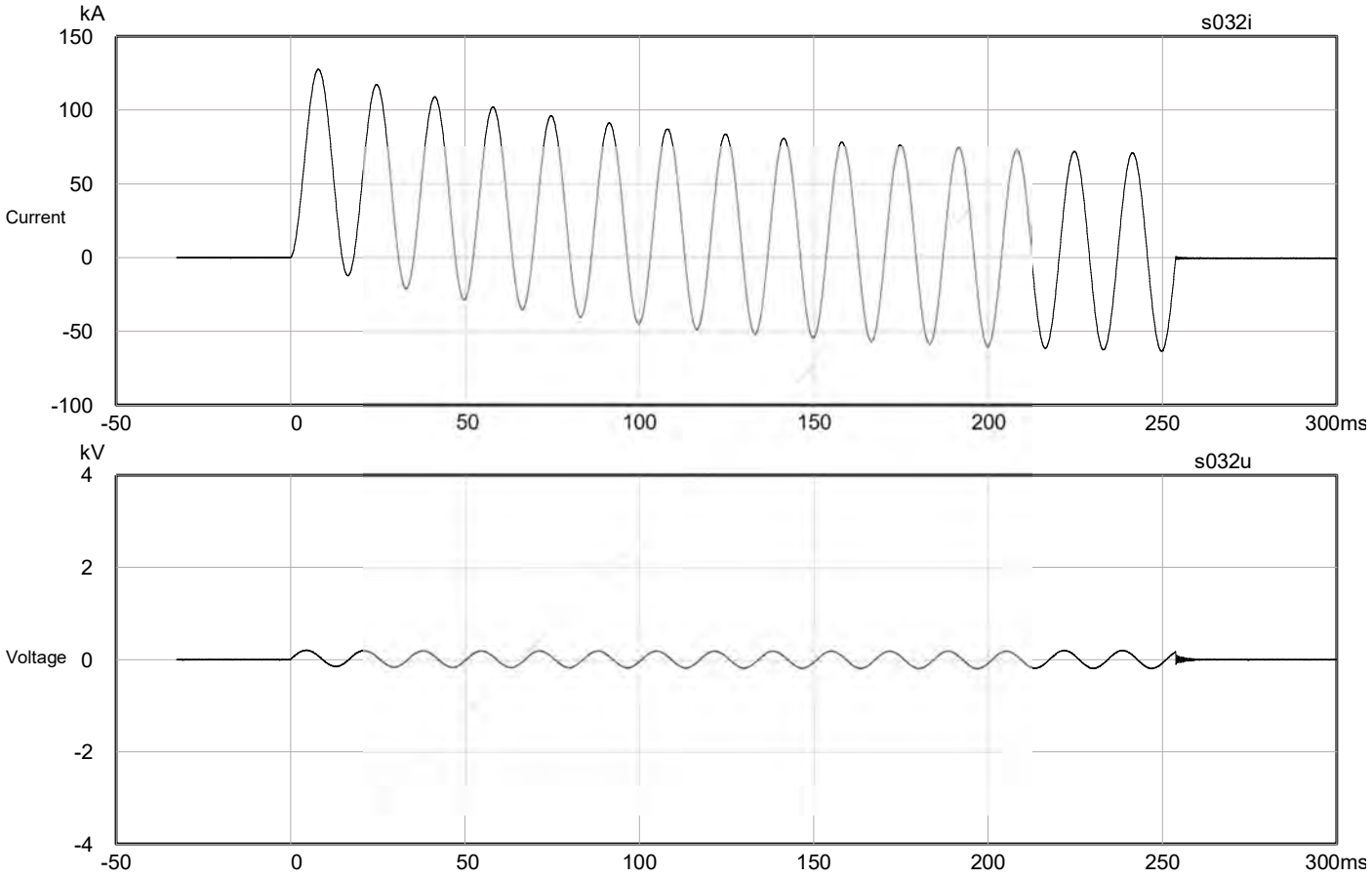


Figure 18: Waveforms for Test #12-2, Copperweld Scorpius 61 x 072 Sample 16.

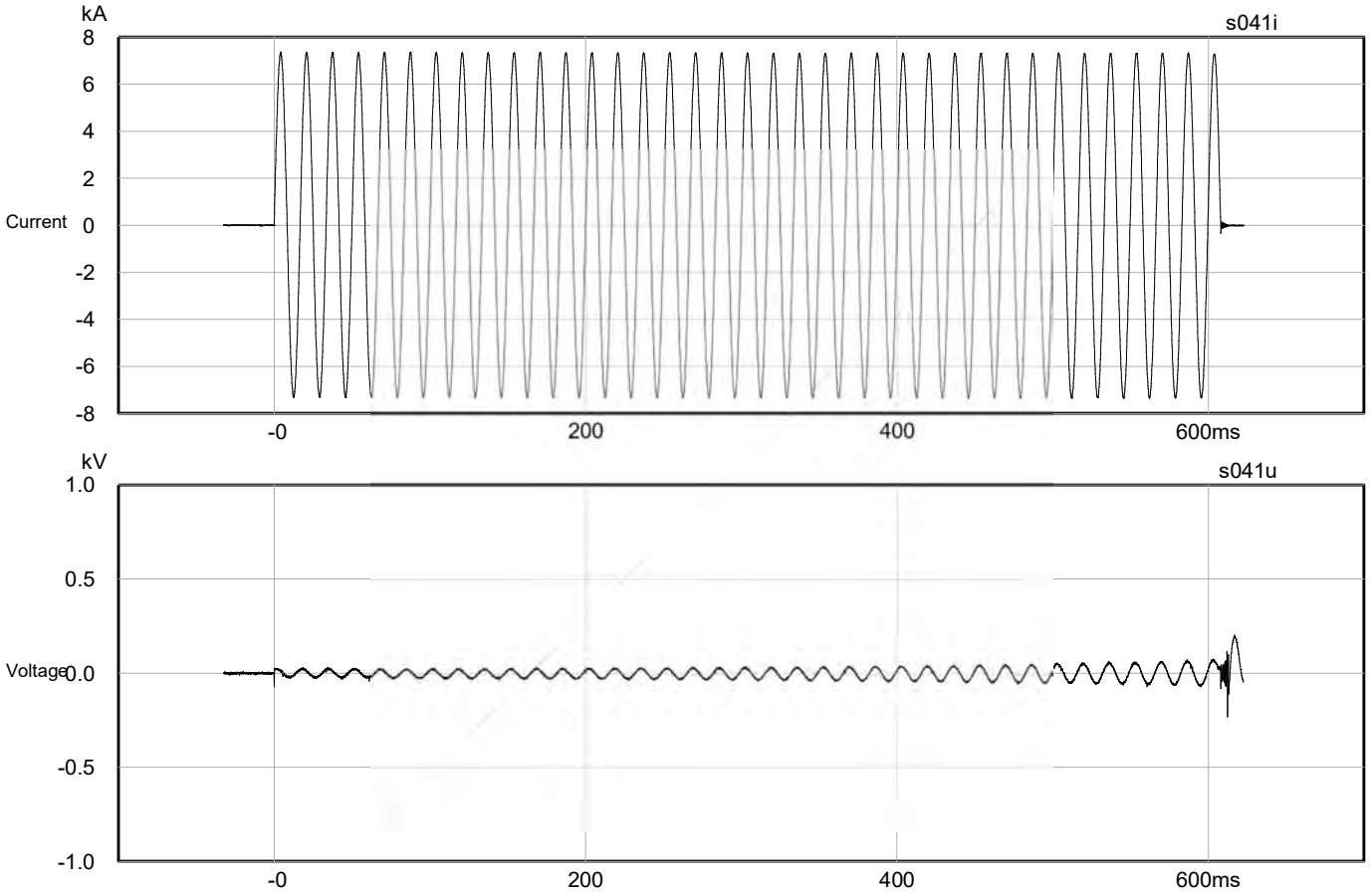


Figure 19: Waveforms for Test #13, Encore #6 AWG Sample 21.

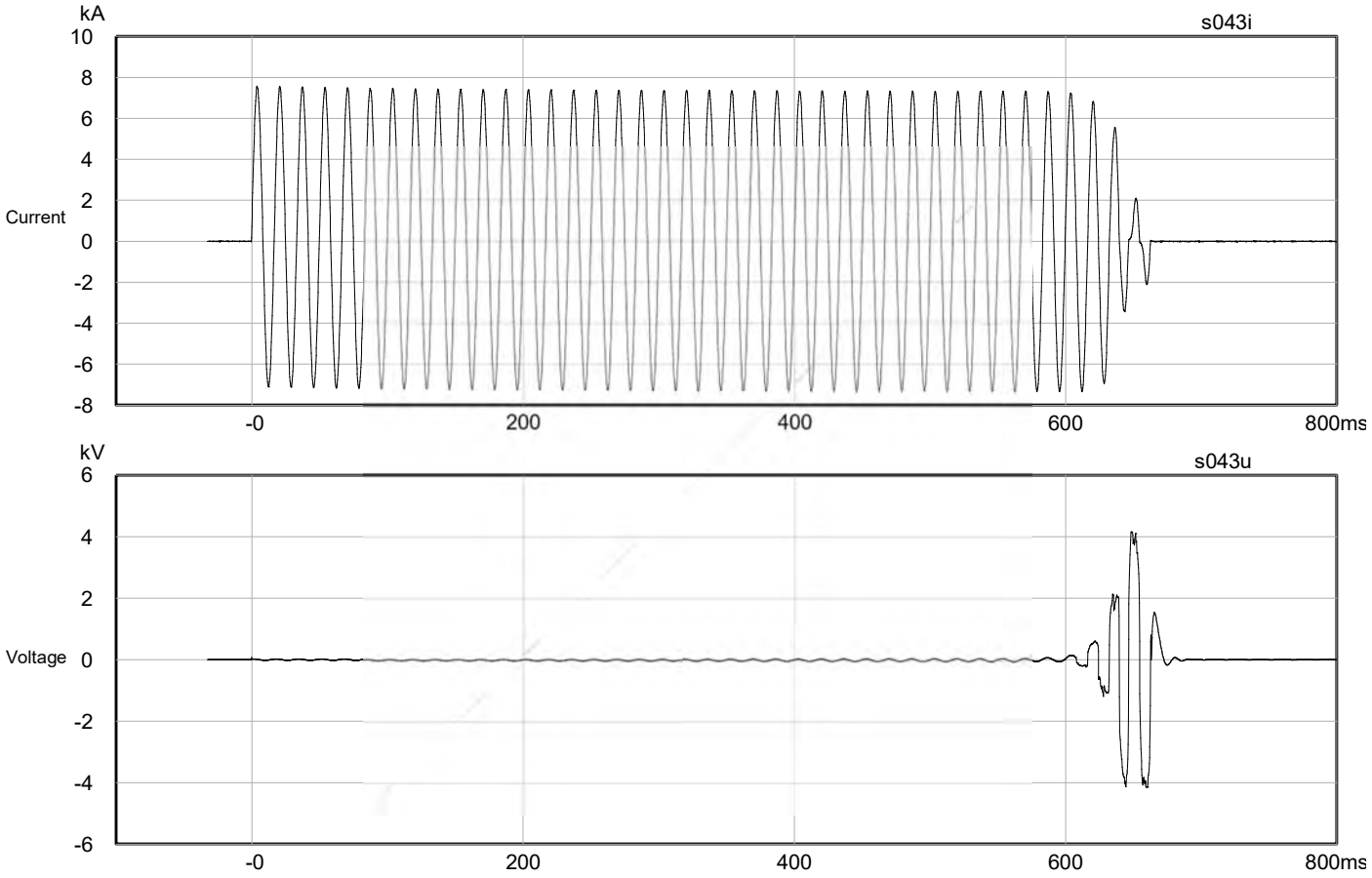


Figure 20: Waveforms for Test #14, Encore #6 AWG Sample 23.

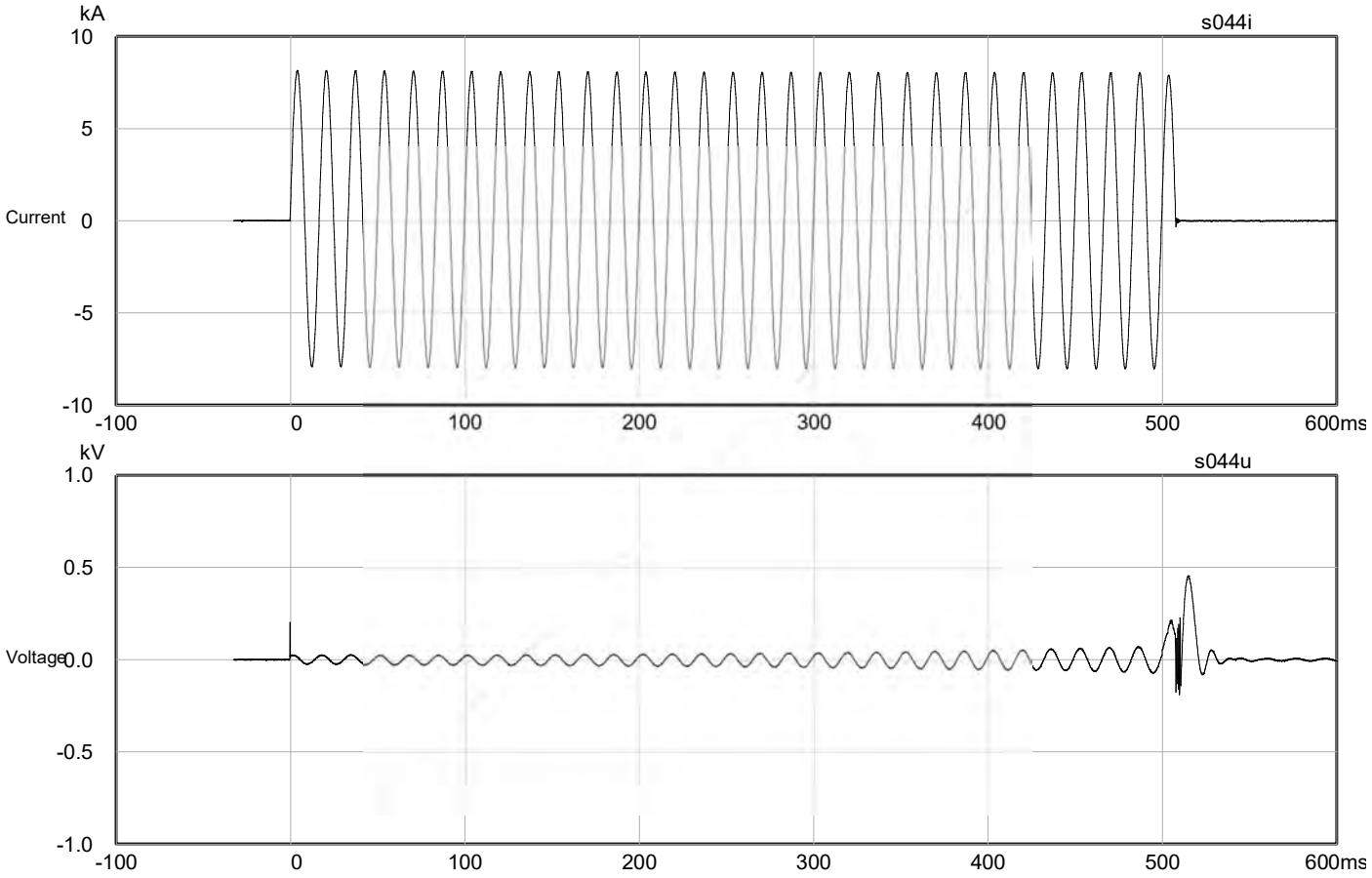


Figure 21: Waveforms for Test #15, Encore #6 AWG Sample 24.

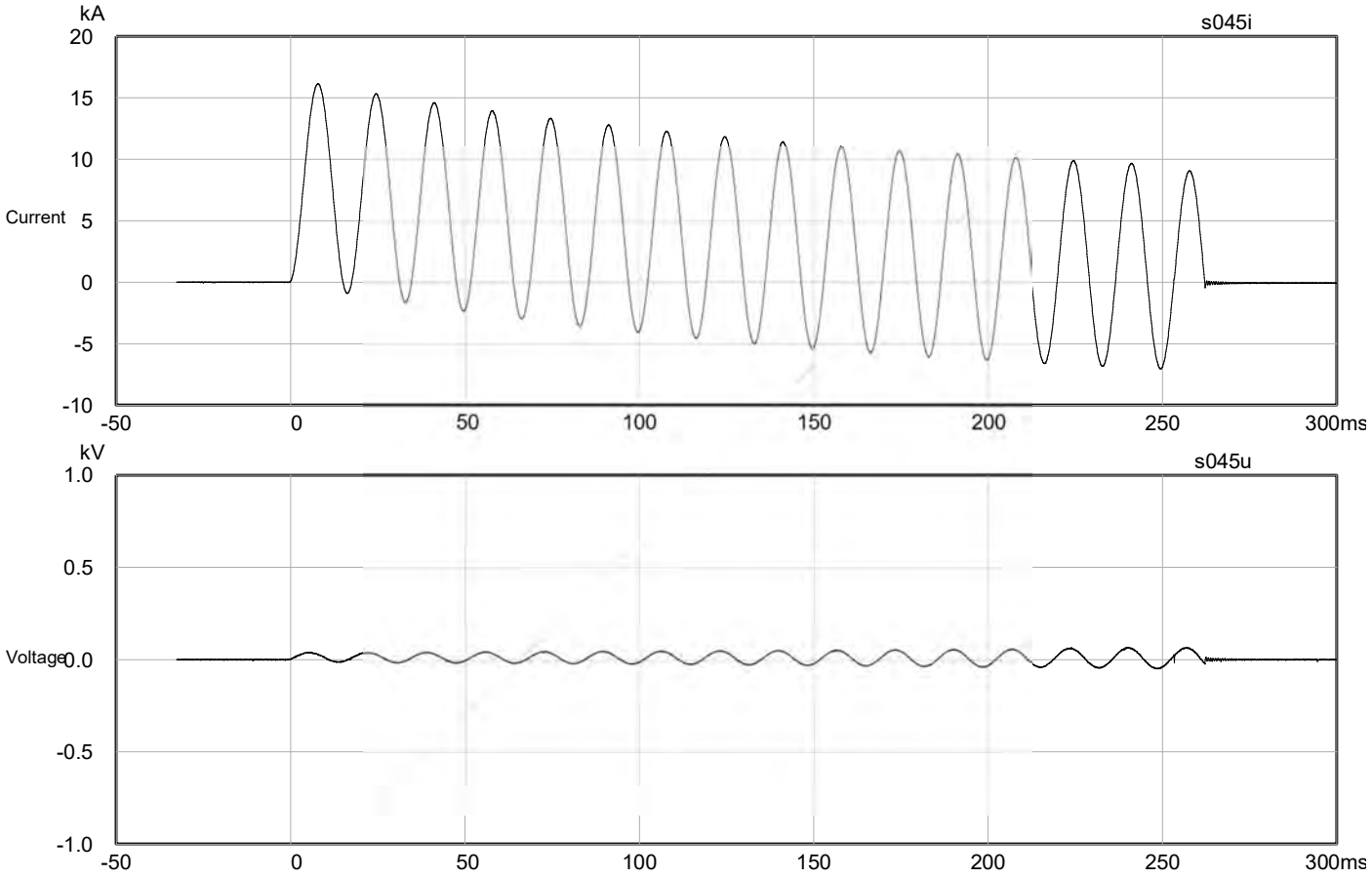


Figure 22: Waveforms for Test #16-1, Encore #6 AWG Sample 25.

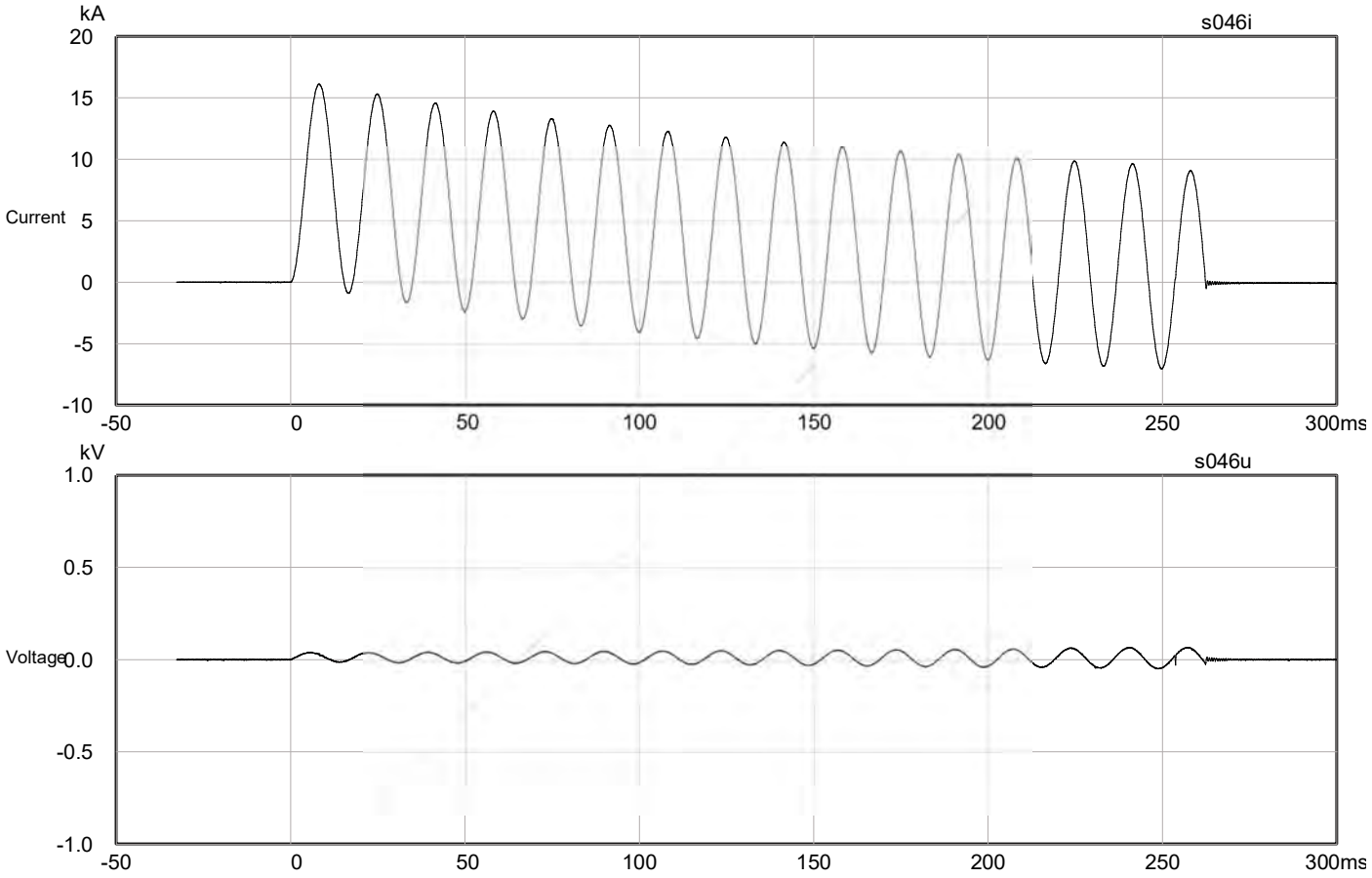


Figure 23: Waveforms for Test #16-2, Encore #6 AWG Sample 25.

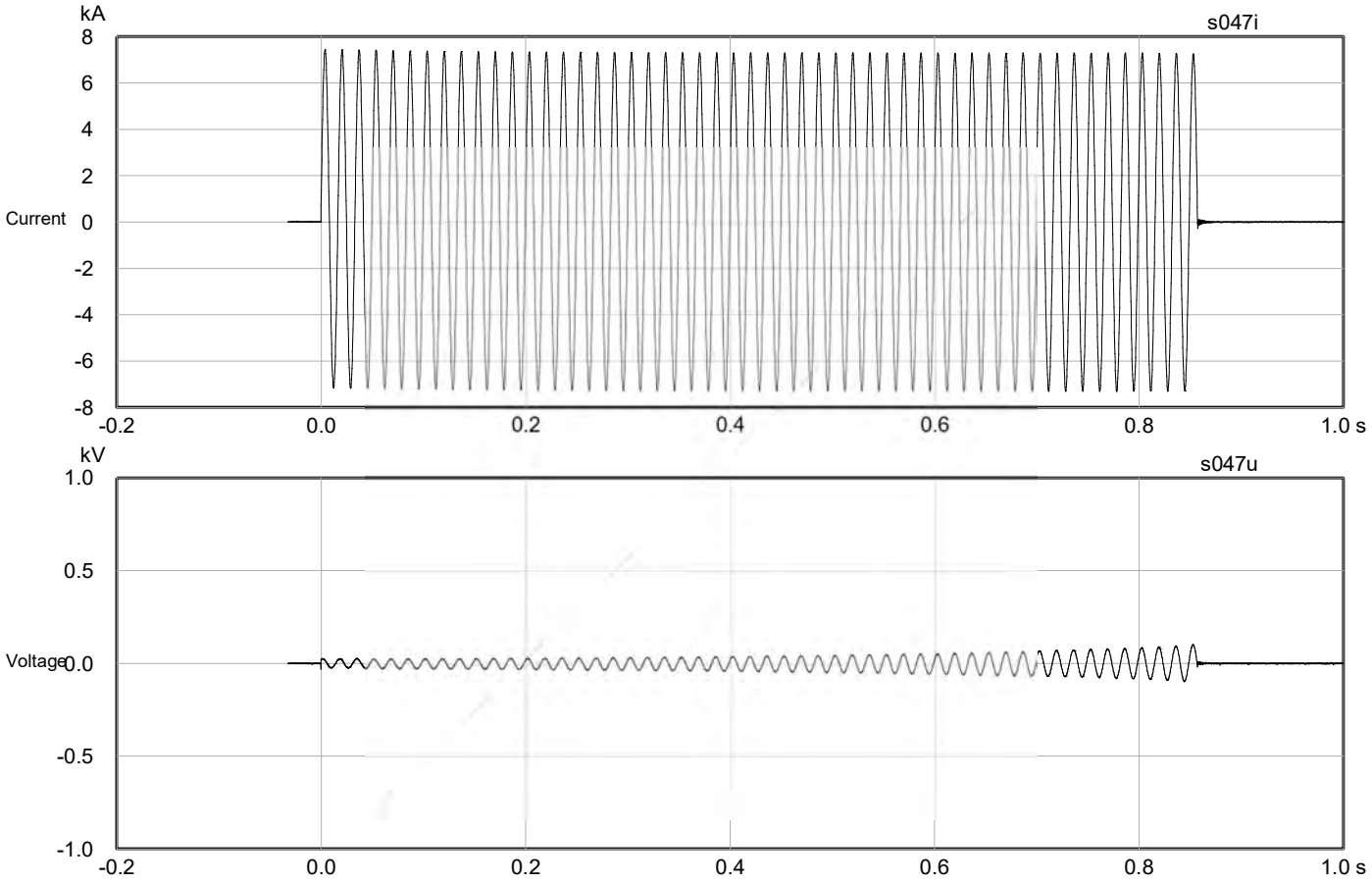


Figure 24: Waveforms for Test #17, Encore #6 AWG Sample 31.

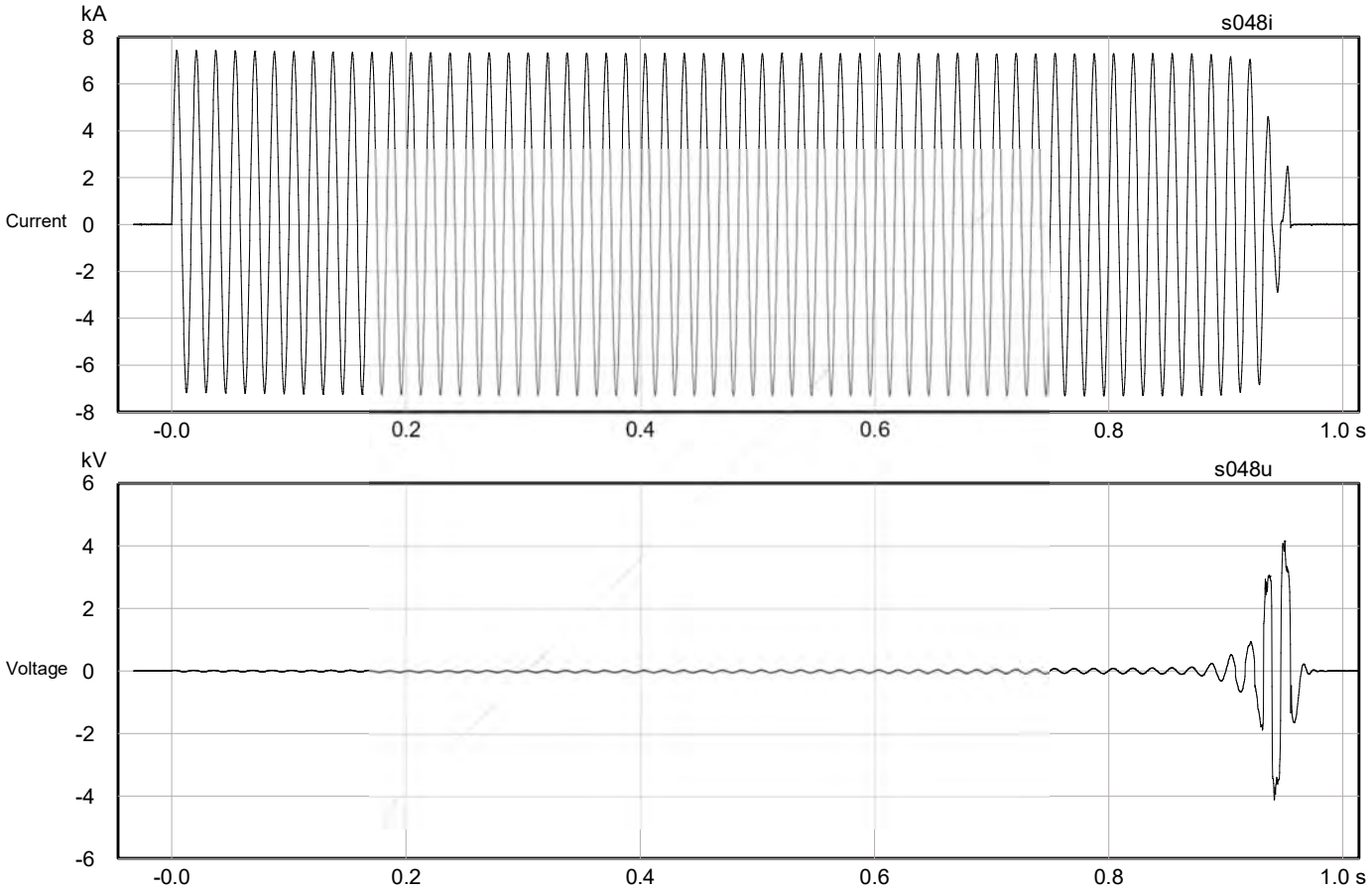


Figure 25: Waveforms for Test #18, Copperweld Scorpius 7 x 080 Sample 32.

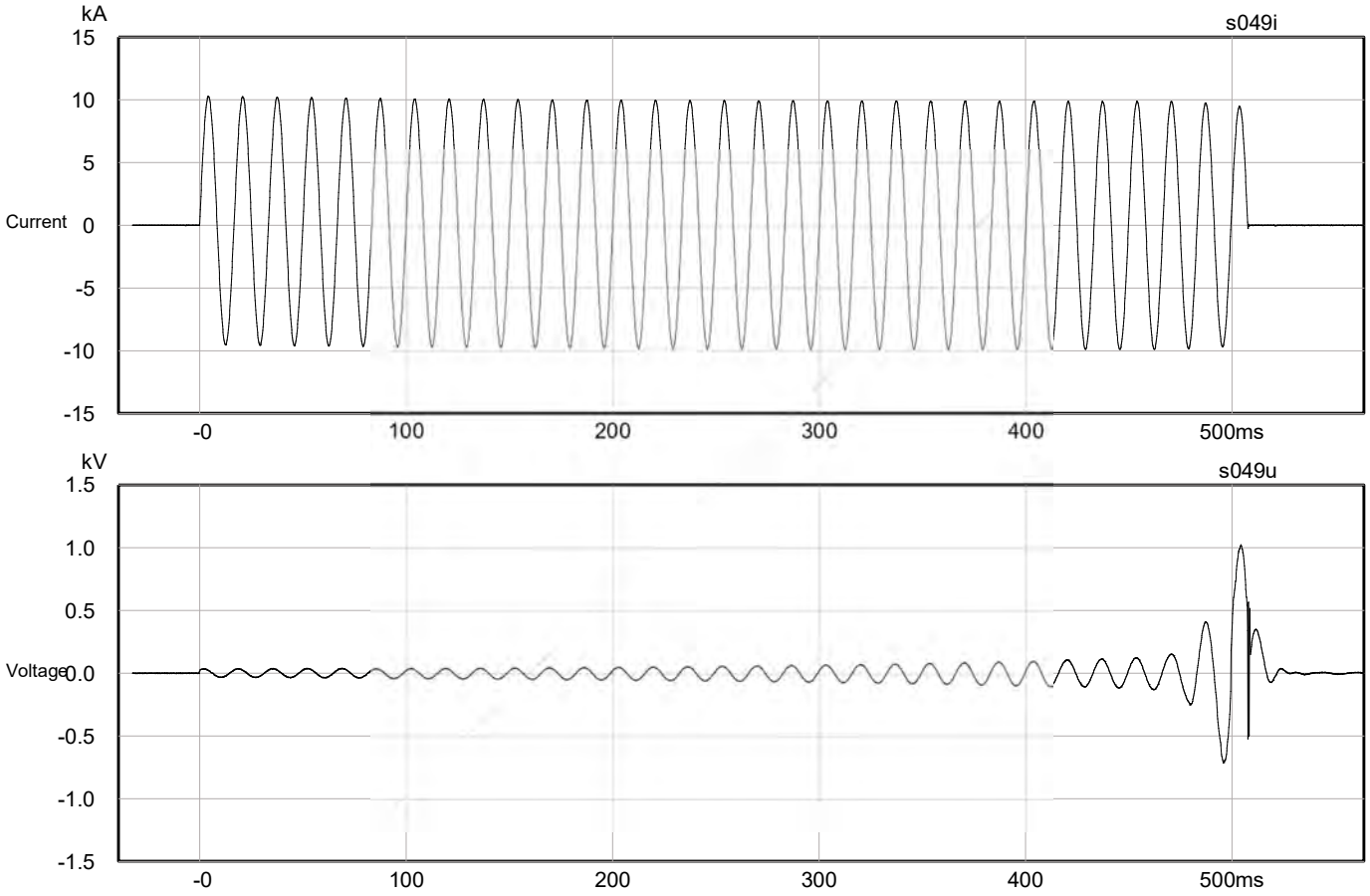


Figure 26: Waveforms for Test #19, Copperweld Scorpius 7 x 080 Sample 33.

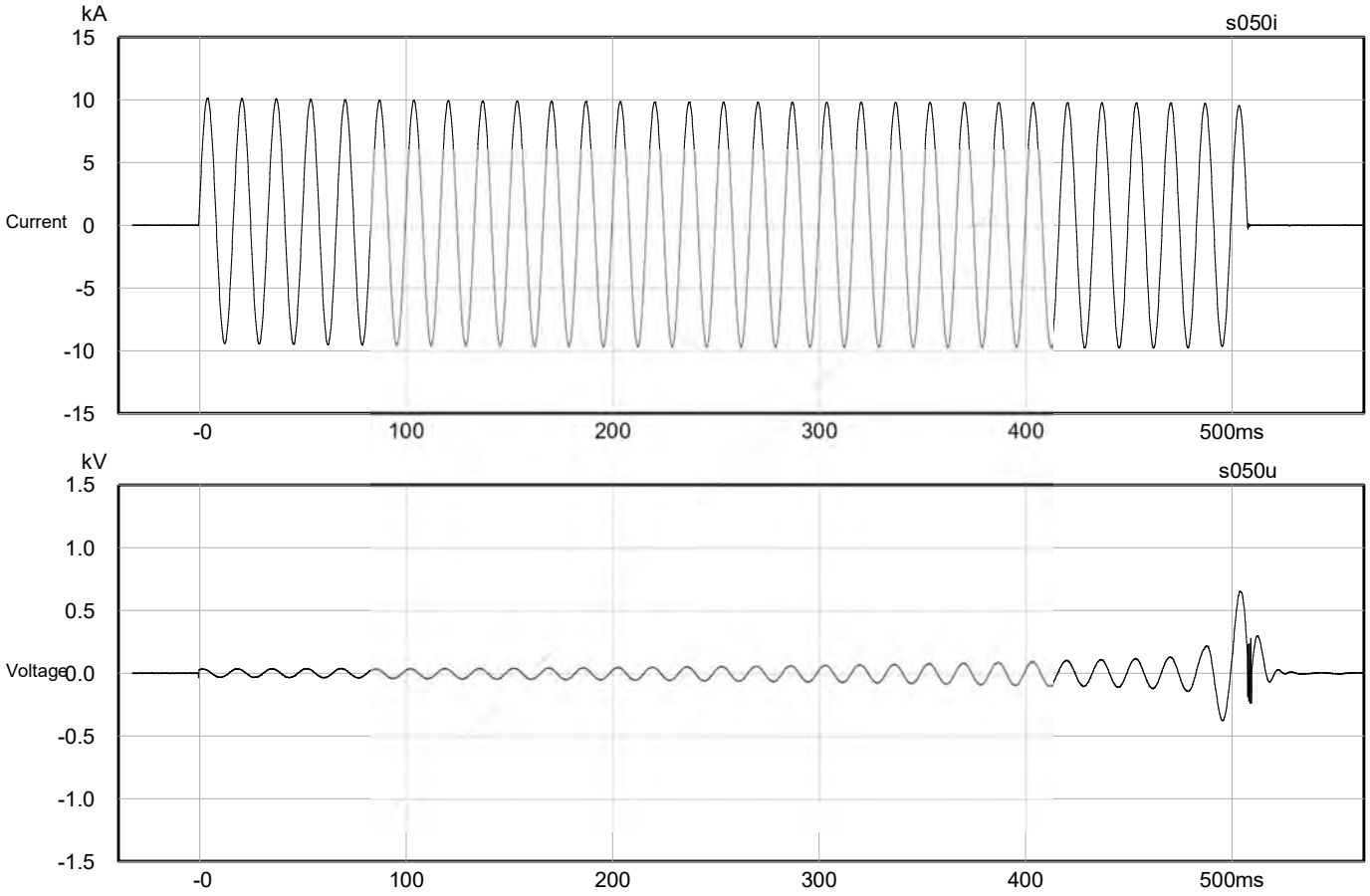


Figure 27: Waveforms for Test #20, Copperweld Scorpius 7 x 080 Sample 34.

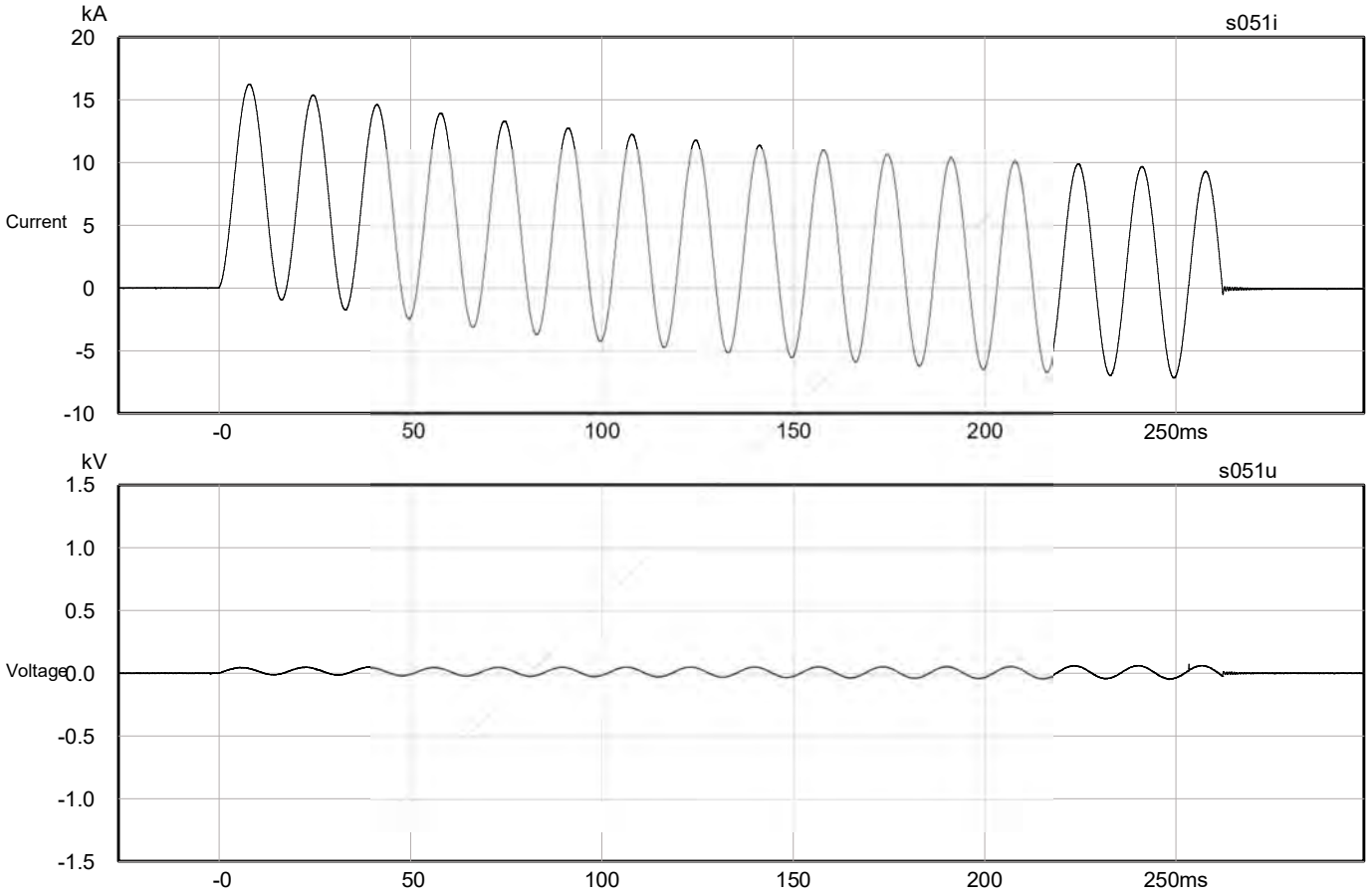


Figure 28: Waveforms for Test #21-1, Copperweld Scorpius 7 x 080 Sample 35.

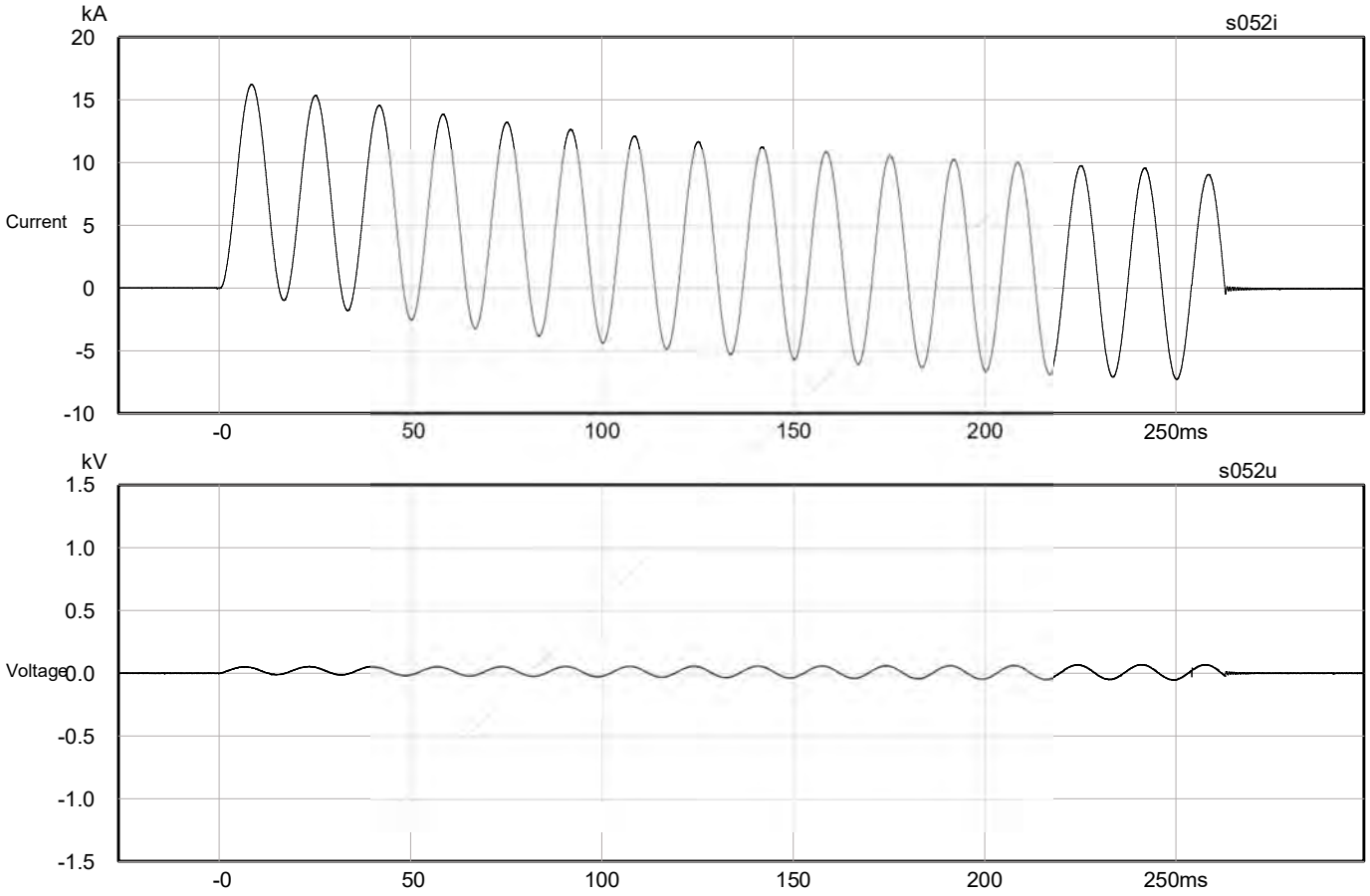


Figure 29: Waveforms for Test #21-2, Copperweld Scorpius 7 x 080 Sample 35.

APPENDIX C – PHOTOGRAPHS OF THE TEST OBJECTS



Figure 30: Test set up for the Encore 4/0 AWG Cu conductor. The power source bus is on the left and the ground bus is on the right.



Figure 31: Test set up for the Copperweld Scorpius 61 x 072 CCS conductor.



Figure 32: Test set up for the Encore #6 AWG Cu conductor.



Figure 33: Test set up for the Copperweld Scorpius 7 x 080 CCS conductor.

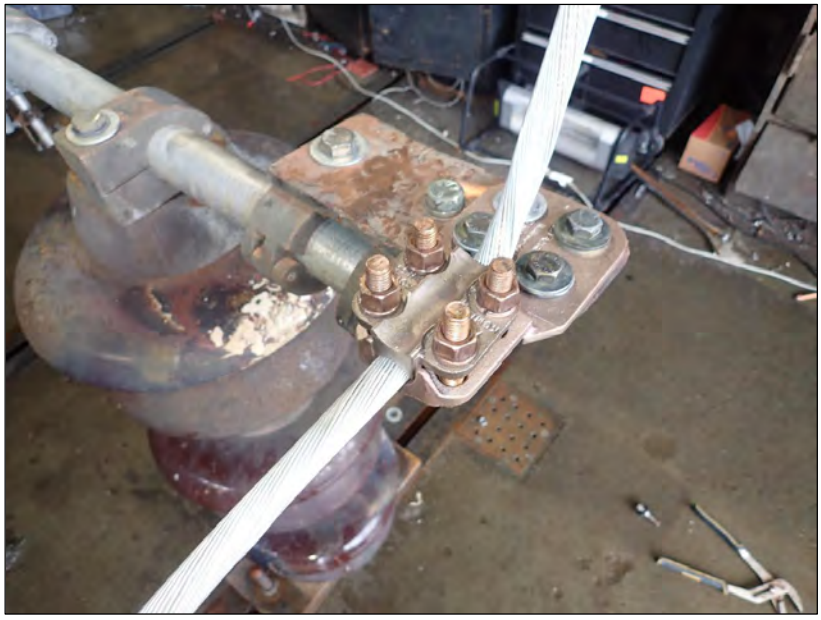


Figure 34: Typical Burndy terminal connector used to connect the Encore 4/0 AWG or Copperweld Scorpius 61 x 072 CCS conductors to the laboratory buses.



Figure 35: Typical Burndy terminal connector used to connect the Encore #6 AWG or Copperweld Scorpius 7 x 080 CCS conductors to the laboratory buses.

APPENDIX D – CALCUATIONS OF TEST CURRENT LEVELS FOR #6 AWG CU CONDUCTOR

Equation (45) in IEEE 80 and Equation (C.1) in IEEE 837 are the same, as follows:

$$I = A\sqrt{\left(\frac{TCAP\times10^{-4}}{t_c\times\alpha_r\times\rho_r}\right)\ln\left(\frac{K_0+T_m}{K_0+T_a}\right)}$$

where

I is root mean square (rms) current in kA
A is conductor cross section in mm^2
T_m is maximum allowable temperature in °C
T_a is initial conductor temperature in °C
T_r is reference temperature for material constants in °C
α_0 is thermal coefficient of resistivity at 0 °C
α_r is thermal coefficient of resistivity at reference temperature T_r
ρ_r is resistivity of the ground conductor at reference temperature T_r in μΩ-cm
K_0 is $1/\alpha_0$, or $(1/\alpha_r)-T_r$ in °C
t_c is time of current flow in seconds (s)
TCAP is thermal capacity factor in joules/cm^3°C

This equation is used to calculate the short-circuit ampacity of a conductor based on it's material constants.

For IEEE 80, Table 6, the symmetrical rms fusing current for #6 AWG soft-drawn Cu conductor at 500 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.5)(0.00393)(1.72)}\cdot\ln\left(\frac{(234+1083)}{(234+40)}\right)} = \boxed{5.29\ kA_{rms}}$$

For IEEE 837, Table 3, the symmetrical rms fusing current for #6 AWG hard-drawn Cu conductor at 250 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.25)(0.00381)(1.78)}\cdot\ln\left(\frac{(242+1084)}{(242+40)}\right)} = 7.41\ kA_{rms}$$

From IEEE 837 Equation (C.4), the asymmetrical rms fusing current is:

$$I_{asym} = \frac{(7.41\ kA)}{(1.148)} = 6.45\ kA_{rms}$$

For the EMF described in IEEE 837, Clause 7.2, a value of 90% of the fusing current is used for conductors up to 4/0 AWG:

$$I_{EMF} = (6.45)(0.9) = \boxed{5.81\ kA_{rms}}$$

Copperweld Bimetallics Data Sheet Packet
Electrical Test Laboratory

Customer:	Copperweld Building Wire	Engineer:	Bill Lewey	Date:	8/25/2020
Sample ID:	EL-13	Tested By:	Bill Lewey, Mike Rozar	Date:	8/25/2020
Product:	Grade 40 Copper Clad Steel Wire Solid Bare #4 and #6 vs Equivalent Solid Copper: Grounding Electrode Conductor Equivalency Test	Sample Condition:	New		
Standard:	ASTM B910/910M Annealed Copper Clad Steel Wire				
Insulation: N/A - Bare		Jacket: N/A - Bare			

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Test Report Summary

Page	Test Performed	Date Completed	Pass/Fail
1	Grounding Electrode Conductor Test for Copper Clad Steel Grade 40	8/25/2020	**Pass**

Requirement:
#4 AWG Grade 40 Copper Clad Steel and #6 AWG Copper Clad Steel when compared to #4 solid copper and #6 solid copper for use as a grounding electrode conductor shall have equal ability to carry amperage during a ground fault condition.

Conclusion:
The ability of bare #4 AWG Copper Clad Steel Grade 40 and bare #6 AWG Copper Clad Steel Grade 40 performed equally to #4 AWG bare solid copper and #6 AWG bare solid copper when used as a grounding electrode conductor under a ground fault condition. The current measured proved equivalency.

Test Equipment Used

Item	Equipment Type	Equipment #	Cal. Due Date
1	Fluke 374FC Clamp Meter	AM-1	Nov 2020
2	Acme Electric 15KVA Transformer	T2535173S	N/A
3	Square D 60A / 600V Safety Interrupter	N/A	N/A
4	Eaton Service Panel	N/A	N/A
5	Eaton Type CH 20 Amp Breaker	N/A	N/A
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

VBU – Verify Before Use

N/A – Not Applicable

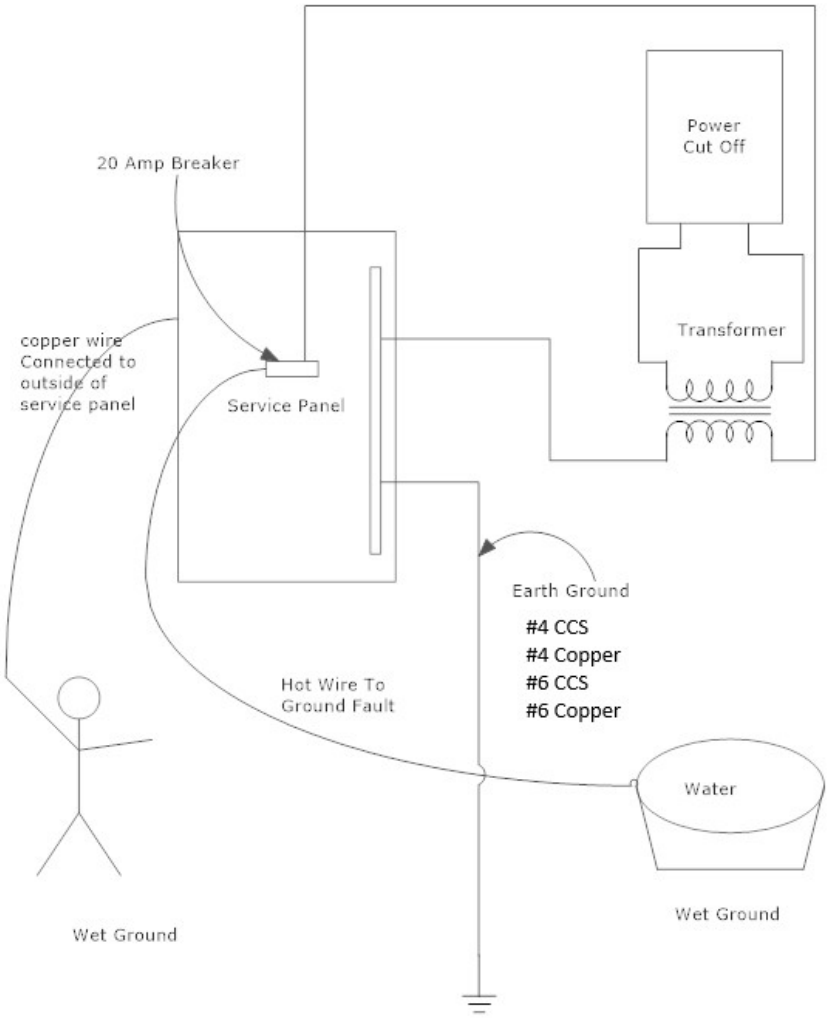
Sample Identification

Item	Description	Length/No. Rec'd
A	#4 AWG 40% Copper Clad Steel Bare	35 Ft
B	#4 AWG Solid Copper Bare	35 Ft
C	#6 AWG 40% Copper Clad Steel Bare	35 Ft
D	#6 AWG Solid Copper Bare	35 Ft
E		
F		

Grounding Electrode Conductor Test

Test Parameters:	
Conditioning:	No preconditioning.
Test Conductors:	1 each of #4 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #6 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #4 AWG Solid Bare copper grounding electrode conductor 1 each of #6 AWG Solid Bare copper grounding electrode conductor
Test Conductor Length:	Each conductor shall be 35 ft.
Test Circuit Configuration:	See schematic shown in Figure 1
Test Current:	Test current from 120 V / 20 A Residential Circuit
Method:	Testing was completed by creating a standard residential test circuit at 120V with 20A breaker wired to an intentional ground fault as shown in figure 1. The ground fault was created by connecting a hot wire from the breaker to a galvanized steel pan full of water and placing the pan on the wet ground. A conductor was also connected to the outside of the electrical panel and a Copper Plated Grounding Electrode (Copperweld Ground Rod) driven 6 inches into the wet ground to determine amount of current going through a grounded person touching the electrical panel during the ground fault condition. The ground fault and the grounded "man" were positioned 20 feet either side of the ground rod. The entire test area was soaked with water overnight using a sprinkler system When the ground fault was electrified, current measurements were taken from the ground fault conductor, the grounding electrode conductor and the grounded "man" conductor. For the four grounding electrode conductors tested, there was one test sequence for each. The current was measured for each. The objective: Compare the amperage measurements of the copper clad steel grounding electrode conductors to those of copper.

Figure 1



Results:			
Ground Conductor	**Fault Conductor Current**	**Current of the Grounding Electrode Conductor**	**Grounded Man Conductor Current**
#4 Copper	2.1 A	1.8 A	0.3 A
#4 40% CCS	2.1 A	1.8A	0.3 A
#6 Copper	1.7 A	1.6 A	0.1 A
#6 40% CCS	1.5 A	1.4 A	0.1 A

Requirement:
For equivalent sizes of Grade 40 Copper Clad steel vs. solid copper grounding conductors, the ability to carry amperage to ground during a ground fault condition is equal.

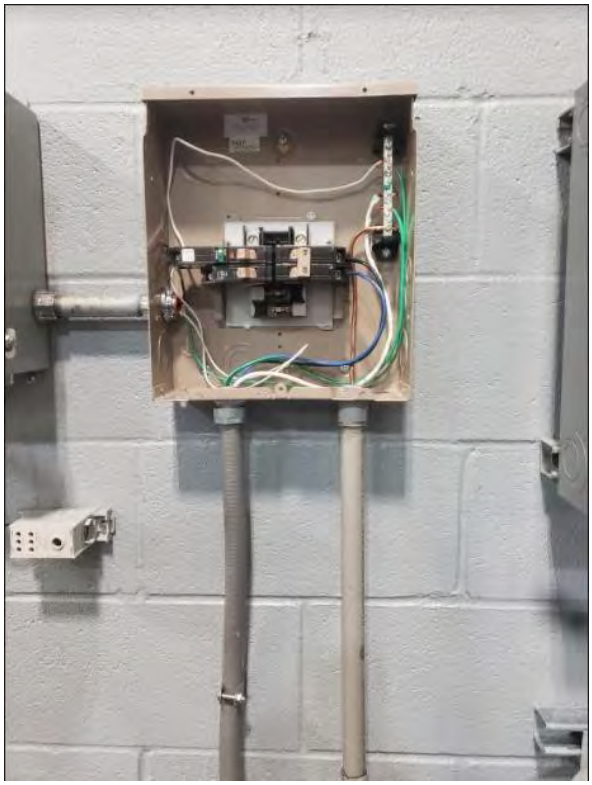
Comments:
____X__ (Pass) The product complies with all applicable requirements of this test. _____ (Fail) The product does not comply with the requirements of this test. **Test Date: 8/25/2020** **Tested By: Bill Lewey**

Environmental Conditions during Testing:

Humidity: % rh __74%_____ Ambient: °C___28_____

Test setup for the electrical service panel







Ground Rod with Grounding Conductor Attached



Ground Fault



Grounded “man”

Public Input No. 2470-NFPA 70-2020 [Section No. 250.66(B)]

(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~~ 4 AWG copper-clad steel or copper wire.

Additional Proposed Changes

File Name	Description	Approved
CCS_Corrosion_paper_Rev2.pdf	50 Year Corrosion Study Grade 40 CCS	
TD002391.doc	UL 467 Short Circuit and UL 486A-B Mechanical Sequence Grade 40 CCS	
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

COPPER-CLAD STEEL CONDUCTORS:

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 applicate 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 Inputs for This Document

Related Input	Relationship
Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]	Copper-Clad Aluminum Conductors
Public Input No. 2474-NFPA 70-2020 [Section No. 250.166 [Excluding any Sub-Sections]]	

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
Affiliation: American Bimetallic Association
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 23 10:36:55 EDT 2020
Committee: NEC-P05

Testing done for the safety of our valued customer.

Global Circulation Laboratory Test Report

For Global Distribution

UL467 SHORT CIRCUIT & UL 486A-486B MECHANICAL SEQUENCE TESTS

YGHP29C2, YGHC2C2, YGHC26C26, YGHP34C29, YGHC29C29, YGHP34C34, YGHC34C34 HYTAP™ Connectors
YGL2C2, YGL29C29, YGL34C34 HYGRID™ Connectors
YGA4C2N, YGHA272N, YGA282N, YGHA302N HYLUG™ Connectors

5/8" and 3/4"Copper Clad Steel Ground Rod, #4AWG Solid, 4/0AWG Stranded, 7#7, and 19#8 COPPERWELD® 40% IACS Copper Clad Steel Conductors

PAT750XT-18V PATRIOT® Tool
with
UC, UO, U28RT, U29RT, U32RT, U997, PU998, and U1011 Die Sets

TD002391 REV B

Requested by / Date:	***Authorized by / Date:***	***Completed by / Date:***
C. Gandhi 12-Dec-2014	R Robicheau 12-Dec-2014	R Charpentier 06-Apr-2015
Engineering Approval / Date:	***Marketing Approval / Date:***	***Laboratory Approval / Date:***
R.Roman 20-Aug-2020	J Hogan 20-Aug-2020	R Charpentier 20-Aug-2020

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

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TEST EQUIPMENT : 5

Burndy LLC 47 East Industrial Park Dr.
Manchester / New Hampshire / 03109
Tel: 603 647 5000 Fax: 603 647 5205

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

PURPOSE OF TEST:

To determine if the Burndy HYTAP™, HYGRID™, and HYLUG™ Connectors can meet the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST REQUESTED:

UL486A-486B Mechanical Sequence
UL467 Short Time Current

TEST RESULTS:

Connector	Cable 1	Cable 2	Die	# of crimps	Securness	Pull	Short Time Current		
					Pass / Fail	Average Pull (lb)	Pass / Fail	Current (Amps)	Time (s)
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	U997	1	Pass	1021.3	Pass	1600	6
YGL2C2	#4 Solid CCS	#4 Solid CCS	U-O	1	Pass	1451.8	Pass	1600	6
YGHC2C2	#4 Solid CCS	#4 Solid CCS	U-C	1	Pass	1544.0	Pass	1600	6
YGA4C2N	#4 Solid CCS	n/a	U4CRT	1	Pass	814.0	Pass	1600	6
YGL29C29	7#7 STR CCS	7#7 STR CCS	U997	1	Pass	1643.2	Pass	4600	9
YGHC26C26	7#7 STRCCS	7#7 STR CCS	U-O	1	Pass	1239.4	Pass	4600	9
YGHA272N	7#7 STRCCS	n/a	U29RT	2	Pass	1574.0	Pass	4600	9
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PU998	1	Pass	1789.8	Pass	6100	9
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1849.8	Pass	6100	9
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1779.1	Pass	6100	9
YGA282N	4/0 AWG CCS	n/a	U28RT	2	Pass	2489.3	Pass	6100	9
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	U1011	3	Pass	2126.8	Pass	9000	9
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	U1011	3	Pass	2380.0	Pass	9000	9
YGL34C34	19#8 STRCCS	19#8 STR CCS	U1011	3	Pass	3158.3	Pass	9000	9
YGHC34C34	19#8 STR CCS	19#8 STR CCS	U1011	3	Pass	3812.1	Pass	9000	9
YGHA302N	19#8 STR CCS	n/a	U32RT	2	Pass	4792.2	Pass	9000	9

Burndy LLC 47 East Industrial Park Dr.
Manchester / New Hampshire / 03109
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TD002391

Global Circulation Laboratory Test Report

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CONCLUSIONS:

All samples tested met the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST PROCEDURES

The table below shows the connector / conductor combinations tested.

Connector	Cable 1	Cable 2	Tool	Die	# of Crimps
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	PAT750	U997	1
YGL2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-O	1
YGHC2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-C	1
YGA4C2N	#4 Solid CCS	n/a	PAT750	U4CRT	1
YGL29C29	7#7 STR CCS	7#7 STR CCS	PAT750	U997	1
YGHC26C26	7#7 STR CCS	7#7 STR CCS	PAT750	U-O	1
YGHA272N	7#7 STR CCS	n/a	PAT750	U997	2
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PAT750	PU998	1
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGA282N	4/0 AWG CCS	n/a	PAT750	U997	2
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	PAT750	U1011	3
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	PAT750	U1011	3
YGL34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHC34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHA302N	19#8 STR CCS	n/a	PAT750	U32RT	2

Burndy LLC 47 East Industrial Park Dr.
Manchester / New Hampshire / 03109
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Global Circulation Laboratory Test Report

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All conductors were cut to twenty four (24) inch lengths.
All ground rod was pre-crimped with the appropriate pre-crimp die
5/8in Rod UPRECRIMP58
3/4in Rod UPRECRIMP34

Mechanical Sequence
Four samples of each set were secured to the Secureness tester, the height; weight and bushing size were as specified in UL486A-486B Table 26. Samples were rotated for thirty minutes at 9rpm. Samples were then subjected to a 1-minute pull to the value specified in UL486A-486B Table 27 and then to failure.

Short Time Current
Test samples were assembled in a series loop configuration then attached to a current controller as shown below. The test current and duration are listed below. After completion of the test, electrical continuity was checked with a digital multi-meter.

Test current values were derived from the equation Annex C of IEEE Std 837-2002. The diameter of the conductor(s) were measured and the cross-sectional area of the conductors was calculated.

Conductor	***Current Value (A)***	***Duration (sec)***
#4AWG Solid COPPERWELD® 40% IACS CCS	1600	6
4/0AWG 19 strand COPPERWELD® 40% IACS CCS,	6100	9
7#7 stranded COPPERWELD® 40% IACS CCS	4600	9
19#8 stranded COPPERWELD® 40% IACS CCS	9000	9

TEST EQUIPMENT LIST:

MANUFACTURER	MODEL	DESCRIPTION	SERIAL #	RANGE
FLUKE	79 III	DMM	70591301 (Rene)	AUTO
OHIO SEMITRONICS		CURRENT TRANSDUCER	NA	15000:5
SATEC	T5000	TABLE TOP	2038	5000 lbs
VIRTECH	NA	HIGH CURRENT	NA	12V / 12000A
MITUTOYO	505-675	DIAL CALIPER	08914565 (Rene)	6"

Burndy LLC 47 East Industrial Park Dr.
Manchester / New Hampshire / 03109
Tel: 603 647 5000 Fax: 603 647 5205

CORROSION ON BURIED COPPER CLAD STEEL



Cece Syarif

Global Application Engineer

&

Anthony Hale

Manager, Utility Products, North America

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For more information, contact sales@copperweld.com.
The results and conclusions obtained from studies done by Copperweld are only applicable to Copper Clad Steel manufactured by Copperweld. Due to proprietary process used to produce the wire, the findings cannot be superimposed on any other copper-clad steel conductor.

254 Cotton Mill Rd, Fayetteville, TN 37334. Tel. (931) 433 – 7177

July 26, 2011

This paper compiles several studies and analysis regarding the corrosion performance of buried Copperweld® Copper-Clad-Steel (CCS) conductors. These range from the early 1900's with the invention of Copperweld® through the present day with studies performed by independent parties as well as Copperweld Company in-house testing. The purpose is to present the available information so that prospective users of Copperweld® CCS wire and strand can evaluate the corrosion resistance and expected performance within their specific application and area. Copperweld uses oxygen free copper in the manufacture of Copperweld® wire and strand. The copper surface of CCS is expected to oxidize and turn color ranging from green (patination) to brown and black the same as any solid copper wire or strand when exposed to environmental stimuli. Corrosion on exposed steel at the cut tip or end of the wire is also expected. The question to be answered is if the corrosion on either material or the interface between the copper and steel (galvanic reaction) will result in degradation of the wire as to make it unsuitable for use as a grounding conductor.

The oldest known underground corrosion study of bimetallic material was performed in the early 1900s[1]. This study focused on the corrosion behavior of Copperweld® CCS underground rod as well as other materials such as Copper and galvanized steel ground rod. The National Bureau of Standards (NBS) conducted an extensive underground corrosion study that involves 36,500 specimens which include 333 varieties of ferrous, nonferrous, and protective coating materials buried in 128 test locations throughout U.S in 1910 - 1955.

The study summarizes the service life of a ground rod as following:

10 mils copper coating – acceptable for service life up to 40 years

13 mils copper coating – acceptable for service life up to 50 years

Similarly, the Naval Civil Engineering Laboratory in collaboration with the National Association of Corrosion Engineers conducted a 7-year program of testing metal rods for electrical grounding to determine the galvanic corrosion effect. The three metals tested were stainless clad steel, copper-bonded steel (CCS), and galvanized steel. The result on the ⅝" CCS ground rod was as expected. The copper surface of the CCS was

virtually free of corrosion and the steel core has corroded at the tip approximately 2 inches down the length of the rod.

Copperweld Corporation is the inventor and sole manufacturer of Copperweld® Copper-bonded ground rods and Copperweld® wire and strand since 1915. The corrosion behavior of a Copperweld® ground rod is similar to the corrosion on Copperweld® wire and strand conductor. Both materials consist of copper permanently bonded to a steel core. All Copperweld® 40% CCS has a copper thickness of 10% of the overall diameter. For example, Copperweld® 4THOUGHT™ has a configuration of 19 strands of 0.1055 inch wires. It means that each strand has a copper thickness of 10.55 mils. Based on the NBS study, 4THOUGHT™ will have at least a minimum service life of 40 years.

Copperweld has also conducted a 5-year study of buried bare 21% conductivity (copper thickness is 3% of the diameter) Copperweld® CCS in 10 different soil conditions in association with Southwest Research Institute[2]. The study reported 100% surface oxidation and various degrees of deterioration of the steel core as expected after 5 years. The exposed steel on the tip of the wire rusted and formed "scab", as shown in Figure 1. The rust appeared to "seal-off" the un-oxidized material from the corrosive medium. The maximum depth of corrosion was 70% of the wire diameter.



Figure 1: Example of Underground Corrosion of Copper Clad Steel

Although the copper surface oxidation was heavy, the samples showed no signs of pits or holes in the copper cladding. The copper thickness of a severely oxidized 5-year sample showed no discernable difference when compared to an un-oxidized control sample that was not subjected to the corrosive environment. The mechanical and resistance testing

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resulted in negligible differences between 5-year samples and the control samples. Thus, the oxidation had no discernable impact on the strength or electrical performance of the wire.

An accelerated corrosion study based on ASTM B117 was conducted on bare CCS and solid Copper wires to evaluate copper surface corrosion. The wires were exposed to salt fog spray for 504 hours. As a result, corrosion on the CCS copper surface showed no significant difference as compared to the corrosion of copper wire.



(a) Copper Clad Steel (b) Copper

Figure 2: Patination of Copper Surface after 504 hours exposure to Salt Fog Spray

In February 2011, three separate sample strands of Copper Clad Steel were un-earthed and cut out from a substation built in Louisville, KY. The conductors were 40% conductivity, Low Carbon Steel, Dead Soft Annealed, 7 No. 5 (231,613 circular mil) and were installed in 1962.

Table 1: Physical properties of the three strands of Copperweld® conductor that had been buried underground for 48 years in a Kentucky substation

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			Strand 1	Strand 2	Strand 3
Conductor Type			40% Low Carbon Annealed		
Conductor Size			7 No. 5		
Cross Section Area		in^2	0.1819	0.1819	0.1819
Diameter of Single end		*inch*	0.1819	0.1819	0.1819
Diameter of Conductor		*inch*	0.5457	0.5457	0.5457
Copper Thickness	Min	*inch*	0.0142	0.0114	0.0134
	Max	*inch*	0.0213	0.0209	0.01975
% Concentricity			83.30%	77.30%	83.90%
Depth of corrosion	Min	*inch*	0.004	0.028	0.111
	Max	*inch*	0.781	0.859	0.484

The 1962 conductors were manufactured by Copperweld with a nominal copper thickness of 10% of its diameter. Figure 3 shows the copper thickness ranges from 11.4 – 21.3 mils and the concentricity of the conductor averaged at 81.5%. Current manufacturing improvements yield concentricity of copper thickness above 85%.

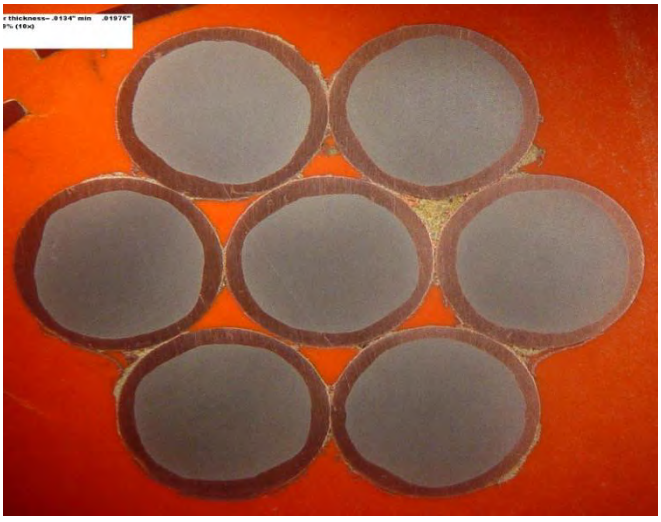


Figure 3: Copperweld® 40% LC DSA 7 No. 5 manufactured in 1962

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Figure 4a shows no visible corrosion observed other than oxidation and patination on the copper surface. At the ends of the wires, the corrosion occurred in the form of steel rust. The maximum depth of the corrosion is 0.859 inch with an average of 0.382 inch, as shown in Figure 4b.



Figure 4a: There is no visible corrosion between the copper and steel on all wires obtained from the substation in Kentucky.



Figure 4b: Corrosion occurred at the ends of the wires. Maximum penetration depth is 0.859 inch.

From all the corrosion studies above, there have not been reported or observed any galvanic corrosion at the interface of copper and steel. The process of cladding for

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Copperweld® ensures a metallurgical bond between the two metals. That metallurgical bond prevents any moisture from penetrating between the two metals precluding the corrosion process. Any propagation of corrosion on an area of exposed steel averages two times the diameter of the wire then stops. The corrosion rate of the copper surface is equivalent to that observed on standard solid copper wire and strand. Based on the results of these studies, it can be summarized that CCS can be expected to have a 50 plus year service life as buried grounding conductors.

REFERENCES:

1. Rempe, Chris. 7 July 2003. "A Technical Report on the Service Life of Ground Rod Electrodes".
2. Fox, Dustin, Belado, Chris, and Brossia, Sean. 23 September 2009. "The Effect of Corrosion on Tracer Wire with a Copper Clad Steel Center Conductor".

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Report ID: PL-03027 REP1
Revision: 0 Issued: 2020-04-15

Copper and CCS Wire Withstand Current and Fusing Current Tests

Copperweld Bimetallics, LLC



The Power of Trust. **The Future of Energy.**

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REPORT OF PERFORMANCE

CLIENT	Copperweld Bimetallics,LLC. 5141 Virginia Way, Suite 410 Brentwood, TN, United States 37027
TEST OBJECTS	Copper Clad Steel (CCS) Wires Manufacturer: Copperweld Bimetallics,LLC. Types: Scorpius Prototypes Part Nos.: 61 x 072 7 x 080 Condition: New Copper Conductor Manufacturer: Encore Wire Types: #4/0 AWG (19 strand) CU #6 AWG (single strand) CU Condition: New
TESTED BY	Powertech Labs Inc. 12388 - 88th Ave, Surrey, BC Canada V3W 7R7 www.powertechlabs.com
TEST DATE	2020-01-24 to 2020-01-25
TEST SPECIFICATION	Client Specified, with reference to IEEE Std 80-2013 and IEEE Std 837-2014

Powertech Labs Inc. does not accept any liability for any damages resulting from the use of this report. The results relate only to the item tested, and it is the responsibility of the manufacturer to maintain conformity of any object having the same designations. Information regarding the estimated measurement uncertainty is available upon request. The test report shall not be reproduced except in full, without written approval of Powertech Labs Inc.

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1 INTRODUCTION

At the request of Copperweld Bimetallics,LLC., withstand current and fusing current tests were performed on standard copper and copper clad steel (CCS) wires in accordance with specifications and procedures provided by the client. Reference was made to IEEE Std 80-2013 and IEEE Std 837-2014 as guides for determining current levels and durations for the tests.

The High Power Lab is accredited by the Standards Council of Canada to ISO 17025 for short-circuit testing.

2 TEST OBJECT INFORMATION

The test objects were identified by the client as follows:

Copper Clad Steel Wires (CCS)

Manufacturer:	Copperweld Bimetallics,LLC.
Types:	Scorpius Prototypes
Part Nos.:	61 x 072
	7 x 080
Condition:	New

Copper Conductor

Manufacturer:	Encore Wire
Types:	4/0 AWG (19 strand) CU
	#6 AWG (single strand) CU
Condition:	New

Conductor sample diameters and dc resistance values were measured by the laboratory before testing, as presented in Table 1.

3 GENERAL INFORMATION

3.1 Purpose

The purpose of the tests is to identify the current limits at short durations for standard copper and Copperweld CCS grounding wire products, and to determine if these products meet the applicable requirements of the referenced Standards.

3.2 Witnesses

Name	Company
Jeff Jordan	Copperweld Bimetallics,LLC.
Lora Aboulmouna	Copperweld Bimetallics,LLC.
Jason Smolko	Copperweld Bimetallics,LLC.
Ryan Hale	Copperweld Bimetallics,LLC.

3.3 Tests Performed

Test Standards/Specifications:

Withstand current tests were performed as requested by the client, with reference to the following Standards to determine the test levels:

IEEE Std 80-2013, Table 6 – Specification for the ultimate current carrying capacity of copper grounding cables using symmetrical current.

IEEE Std 837-2014, Clause 7.2 and Table 3 – Electromagnetic force (EMF) test

4 SHORT-CIRCUIT CURRENT TESTS

General Information:

Standard	Client's Specification, with reference to IEEE Std 80-2013 and IEEE Std 837-2014
Test Dates	2020-01-24 to 2020-01-25
Test Leader	Chris Morton

Environmental Conditions:

Ambient temperature	(7 – 9) °C
Relative Humidity	(95 – 99) %

Test Conditions:

Samples were tested in a covered test cell which was open on one side to the outdoor ambient conditions. During each test, one sample was connected horizontally between the laboratory source bus and ground bus, at a bus spacing of 48 inches, as shown in Figures 30 through 33. The samples were terminated using Burndy mechanical connectors, as shown in Figures 34 and 35. The length of each wire sample was the minimum length required to span the distance between the buses, and each sample was at approximately right angles (90°) to both the source and ground bus. Each sample was suspended in free air approximately 46 inches above the floor of the test cell. The temperature of the sample at the start of each test was the natural outdoor ambient temperature of the laboratory, except for tests performed to IEEE 837, where the sample was allowed to cool to less than 100 °C before the second shot.

All tests were performed at a power frequency of 60 Hz using the test circuit shown in Figure 1. Current was initiated by energizing a current limited source that was calibrated to provide the target current through the circuit. The rms current, current symmetry and duration of each test were specified by the client.

The test current was measured using a 300 kA_{peak} rated Rogowski coil (Powertech ID № 39444). The expanded uncertainty of the current measuring system is estimated as 2% (k=2).

Test Results:

The results of the tests are provided in Tables 2 through 5. Current and voltage waveforms for each test are provided in Figures 2 through 29.

The Encore #4/0 AWG Cu wire did not withstand the I^2t calculated from the current and duration specified in IEEE 80, Table 6, for a 500 ms duration (44 kA_{rms}). It was capable of carrying a maximum of 92% of this I^2t value without fusing.

The Encore #4/0 AWG Cu wire did not withstand the EMF current specified in IEEE 837, Table 3 (47 kA_{rms}). It was capable of carrying a maximum of 91% of this current value without failing.

The Copperweld Scorpius CCS 61 x 072 conductor exceeded the 500 ms rms withstand current requirement of IEEE 80, Table 6, and met the EMF current requirements of IEEE 837, Table 3, for a 4/0 conductor.

For the #6 AWG Cu conductor size the Standards did not have current values specified, so these were calculated using Equation (45) from IEEE 80 and Equation (C.1) from IEEE 837. The calculations are presented in Appendix D.

Both the Copperweld Scorpius CCS 7 x 080 conductor and the Encore #6 AWG Cu conductor met the 500 ms rms withstand current requirement of IEEE 80, Table 6 (5.29 kA_{rms}), and the EMF current requirements of IEEE 837, Table 3 (5.81 kA_{rms}), for a #6 AWG Cu conductor.

APPENDIX A – FUSING CURRENT TEST CIRCUIT AND DATA

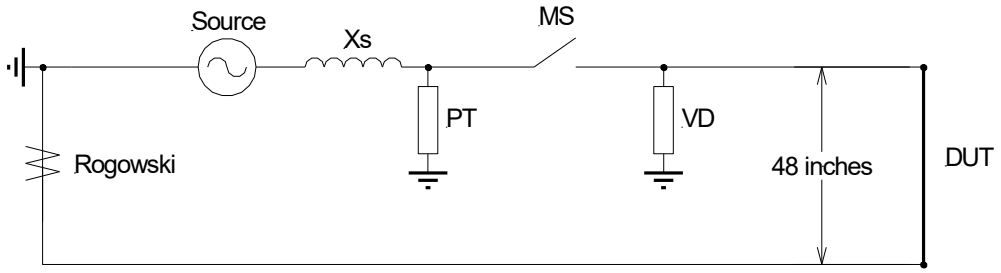


Figure 1: Test circuit schematic for all tests.

Notes:

1. X_S – Source current limiting reactance
2. MS – Making Switch
3. VD – Voltage measurement
4. Rogowski – Current measurement
5. DUT – Device Under Test

Table 1: Strand diameter and dc resistance measurements of sample conductors.

Wire Sample No.	Type	Strand Diameter [1] (in)		Conductor Diameter	Dc Resistance at 20°C
#		1	2	(in)	(μΩ/ft)
1	Encore Wire, 4/0 AWG, 19 strand CU	0.122	0.079	0.492	4.28
2	Encore Wire, 4/0 AWG, 19 strand CU	0.118	0.080	0.501	4.10
3	Encore Wire, 4/0 AWG, 19 strand CU	0.109	0.074	0.495	4.23
4	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.075	0.498	3.98
5	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.079	0.489	4.43
6	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.075	0.490	4.17
7	Encore Wire, 4/0 AWG, 19 strand CU	0.101	0.075	0.489	4.18
8	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.074	0.491	4.15
9	Encore Wire, 4/0 AWG, 19 strand CU	0.106	0.082	0.490	3.97
10	Encore Wire, 4/0 AWG, 19 strand CU	0.105	0.079	0.493	3.73
11	Scorpius 61 x 072 CCS	0.056	---	0.646	6.83
12	Scorpius 61 x 072 CCS	0.058	---	0.649	6.60
13	Scorpius 61 x 072 CCS	0.068	---	0.641	6.60
14	Scorpius 61 x 072 CCS	0.056	---	0.639	6.73
15	Scorpius 61 x 072 CCS	0.067	---	0.646	6.62
16	Scorpius 61 x 072 CCS	0.059	---	0.630	6.53
17	Scorpius 61 x 072 CCS	0.056	---	0.642	6.73
18	Scorpius 61 x 072 CCS	0.067	---	0.637	6.62
19	Scorpius 61 x 072 CCS	0.064	---	0.641	6.85
20	Scorpius 61 x 072 CCS	0.059	---	0.633	6.83
21	Encore Wire, #6 AWG, single strand CU	0.152	---	0.152	33.3
22	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
23	Encore Wire, #6 AWG, single strand CU	0.158	---	0.158	33.2
24	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.4
25	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.3
26	Encore Wire, #6 AWG, single strand CU	0.148	---	0.148	33.6
27	Encore Wire, #6 AWG, single strand CU	0.155	---	0.155	33.3
28	Encore Wire, #6 AWG, single strand CU	0.146	---	0.146	33.1
29	Encore Wire, #6 AWG, single strand CU	0.153	---	0.153	33.2
30	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
31	Scorpius 7 x 080 CCS	0.072	---	0.215	46.3
32	Scorpius 7 x 080 CCS	0.069	---	0.226	45.9
33	Scorpius 7 x 080 CCS	0.065	---	0.220	46.2
34	Scorpius 7 x 080 CCS	0.071	---	0.218	46.4
35	Scorpius 7 x 080 CCS	0.073	---	0.212	46.1
36	Scorpius 7 x 080 CCS	0.065	---	0.216	46.3
37	Scorpius 7 x 080 CCS	0.070	---	0.211	46.1

Note:

[1] Encore 4/0 AWG CU conductor had two sizes of strands, all remaining conductors had one size of strands. Strand and conductor diameters were measured using a digital caliper with a resolution of 0.001 in.

Table 2: Summary of tests on Encore 4/0 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
1	1	Run to fusing	3.85	41.7	60.0	530	923	2	Y
2	2	Withstand	3.85	41.8	62.5	509	889	3	N
3-1	3	EMF (IEEE 837)	4.24	48.0	130	262	826	4	N
3-2	3	EMF (IEEE 837)	4.26	48.0	130	127	503	5	Y
4	4	EMF (IEEE 837)	4.25	48.0	130	260	823	6	Y
5-1	5	EMF (IEEE 837)	4.20	47.4	129	262	808	7	N
5-2	5	EMF (IEEE 837)	4.19	47.4	128	9.9	77	8	Y
6-1	6	EMF (IEEE 837)	3.93	42.6	116	263	662	9	N
6-2	6	EMF (IEEE 837)	3.91	42.6	116	262	654	10	N

Table 3: Summary of tests on Copperweld Scorpius 61 x 072 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
7	11	Run to fusing	3.84	41.7	59.6	673	1173	11	Y
8	12	Run to fusing	4.25	48.1	69.8	500	1157	12	Y
9	13	Run to fusing	4.21	47.5	68.9	508	1150	13	Y
10	14	Withstand	4.09	46.2	66.2	508	1089	14	N
11-1	15	EMF (IEEE 837)	4.21	47.6	129	262	803	15	N
11-2	15	EMF (IEEE 837)	4.20	47.7	129	262	803	16	N
12-1	16	EMF (IEEE 837)	4.21	47.6	129	254	784	17	N
12-2	16	EMF (IEEE 837)	4.19	47.4	128	254	767	18	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

Table 4: Summary of tests on Encore #6 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
13	21	Run to fusing	3.90	5.18	7.36	607	16.3	19	Y
14	23	Run to fusing	3.90	5.18	7.57	600	16.1	20	Y
15	24	Run to fusing	4.27	5.68	8.15	500	16.1	21	Y
16-1	25	EMF (IEEE 837)	3.77	5.86	16.2	262	13.9	22	N
16-2	25	EMF (IEEE 837)	3.77	5.86	16.1	262	13.9	23	N

Table 5: Summary of tests on Copperweld Scorpius 7 x 080 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
17	31	Withstand	3.88	5.16	7.44	858	22.9	24	N
18	32	Run to fusing	3.89	5.16	7.43	908	24.2	25	Y
19	33	Run to fusing	4.48	7.00	10.3	493	24.1	26	Y
20	34	Run to fusing	4.41	6.91	10.2	502	23.9	27	Y
21-1	35	EMF (IEEE 837)	3.81	5.91	16.3	262	14.0	28	N
21-2	35	EMF (IEEE 837)	3.80	5.92	16.2	262	13.8	29	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

APPENDIX B – WAVEFORMS

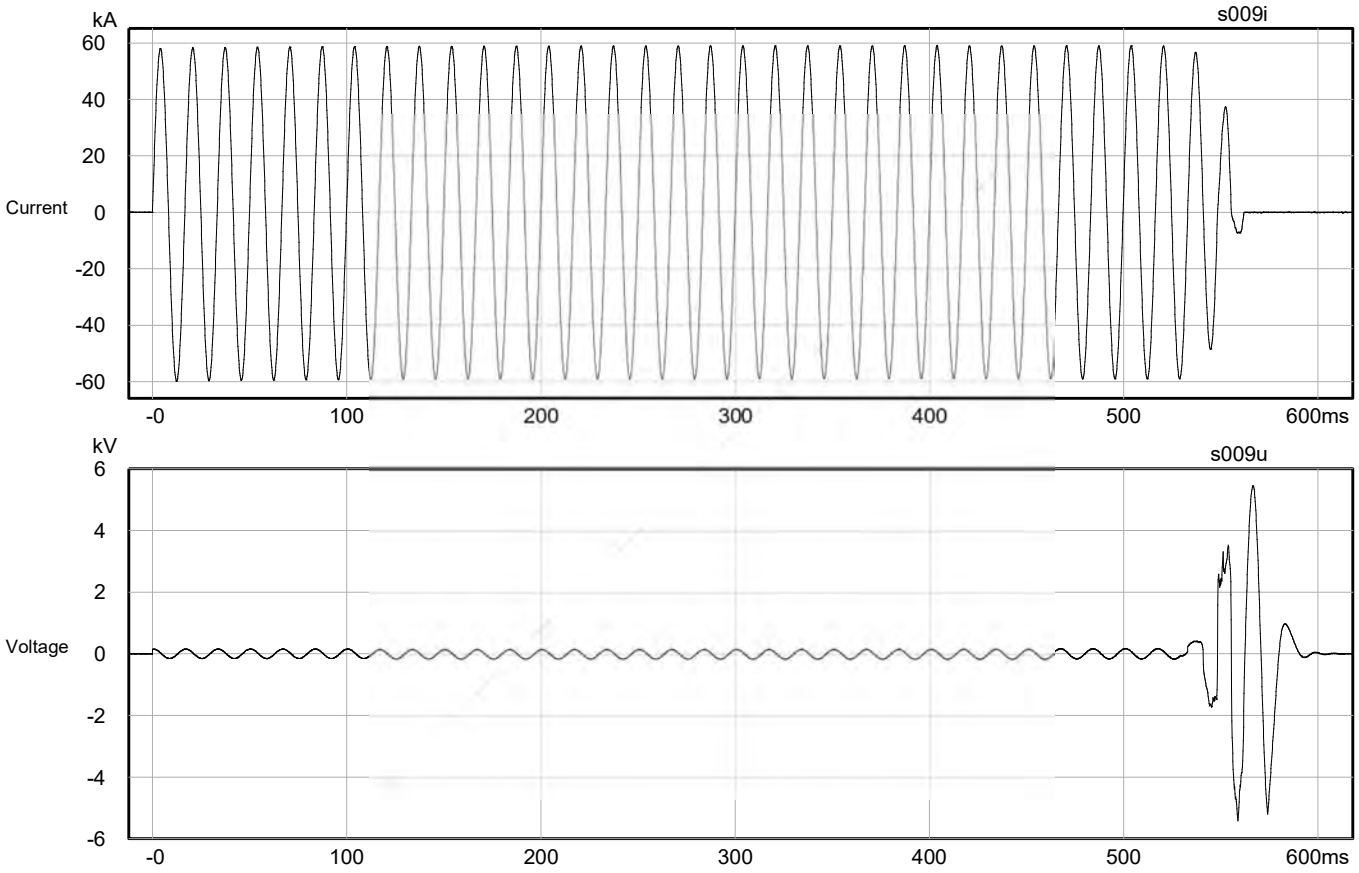


Figure 2: Waveforms for Test #1, Encore 4/0 AWG Sample 1.

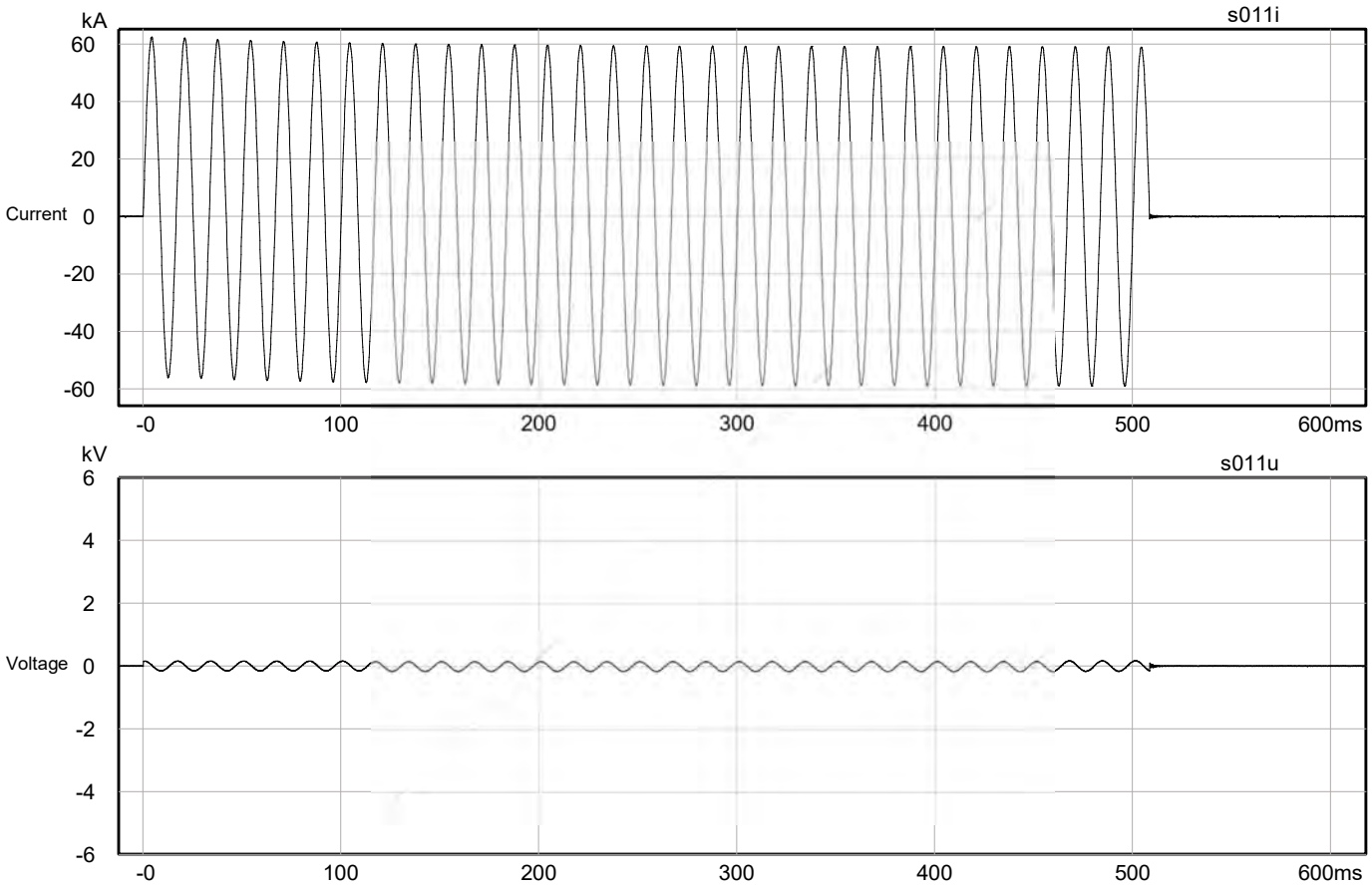


Figure 3: Waveforms for Test #2, Encore 4/0 AWG Sample 2.

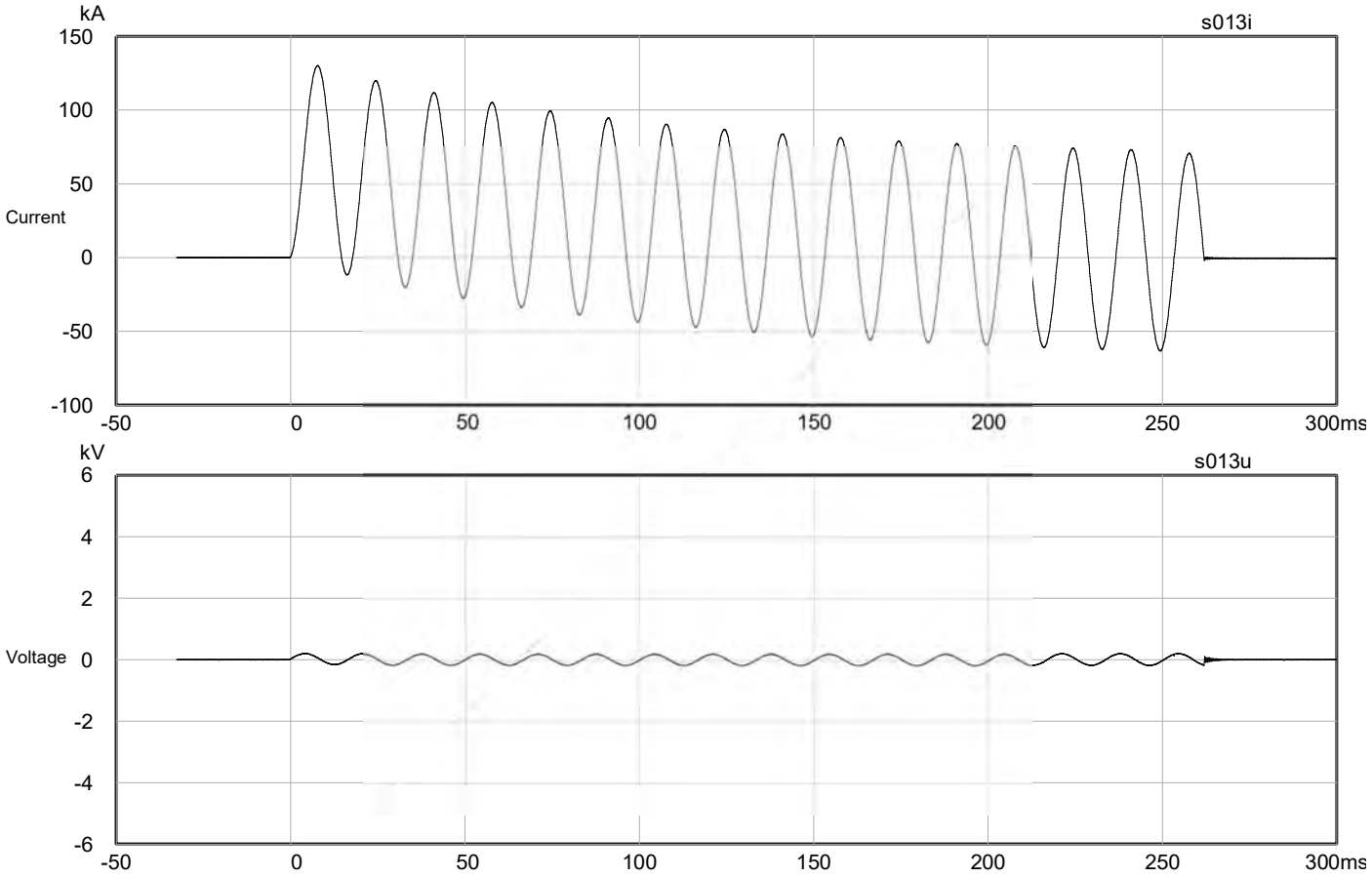


Figure 4: Waveforms for Test #3-1, Encore 4/0 AWG Sample 3.

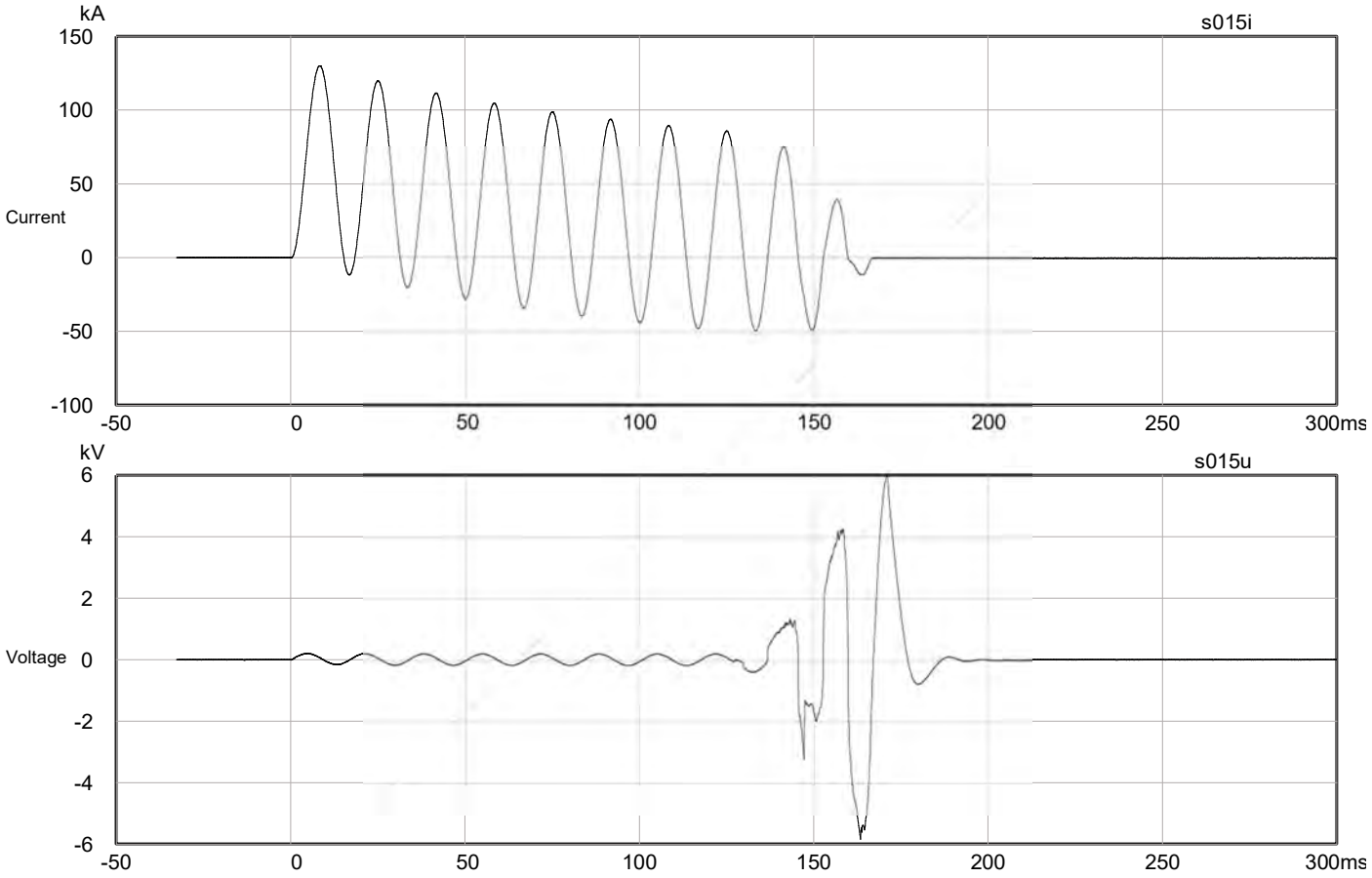


Figure 5: Waveforms for Test #3-2, Encore 4/0 AWG Sample 3.

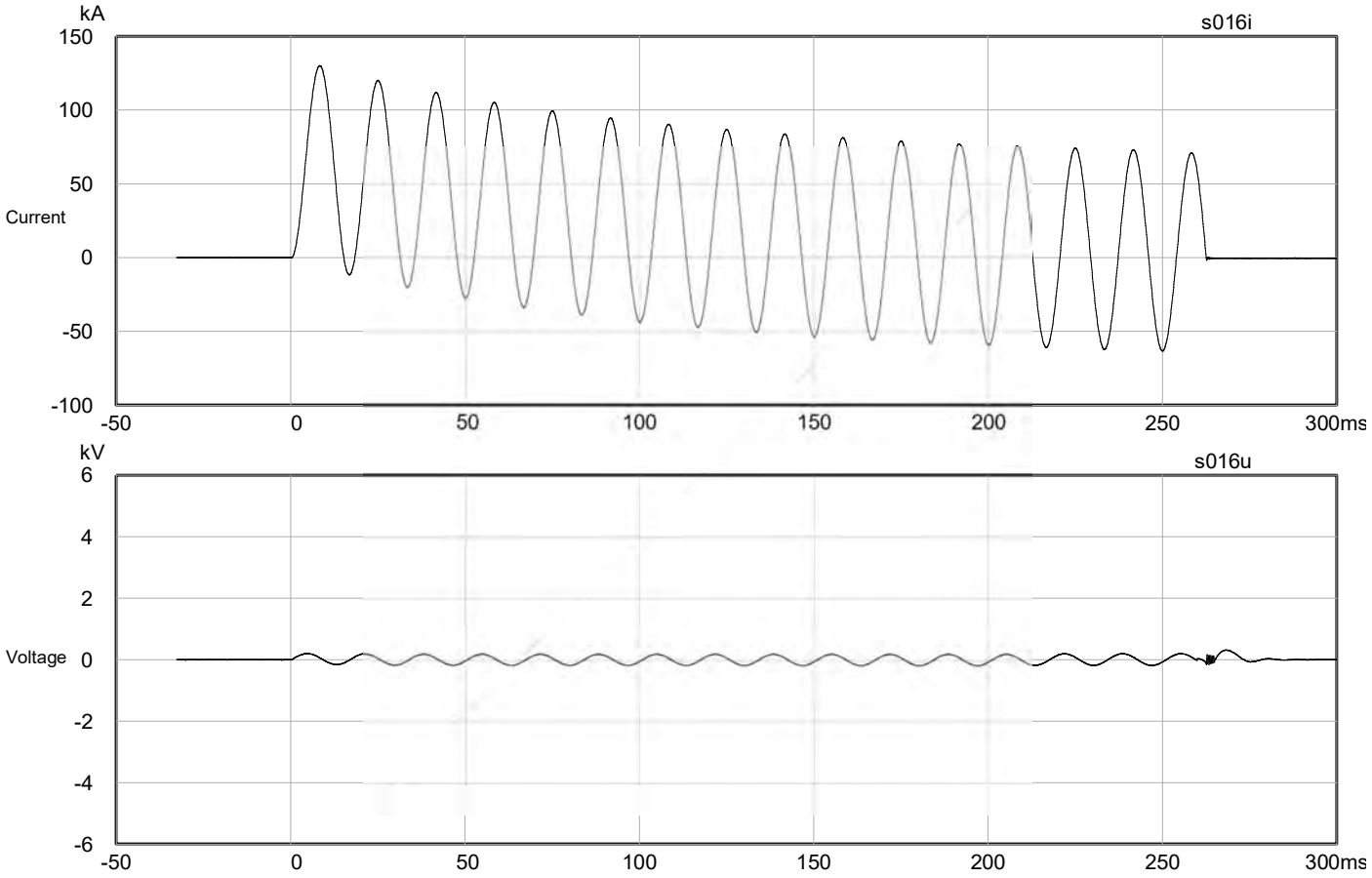


Figure 6: Waveforms for Test #4, Encore 4/0 AWG Sample 4.

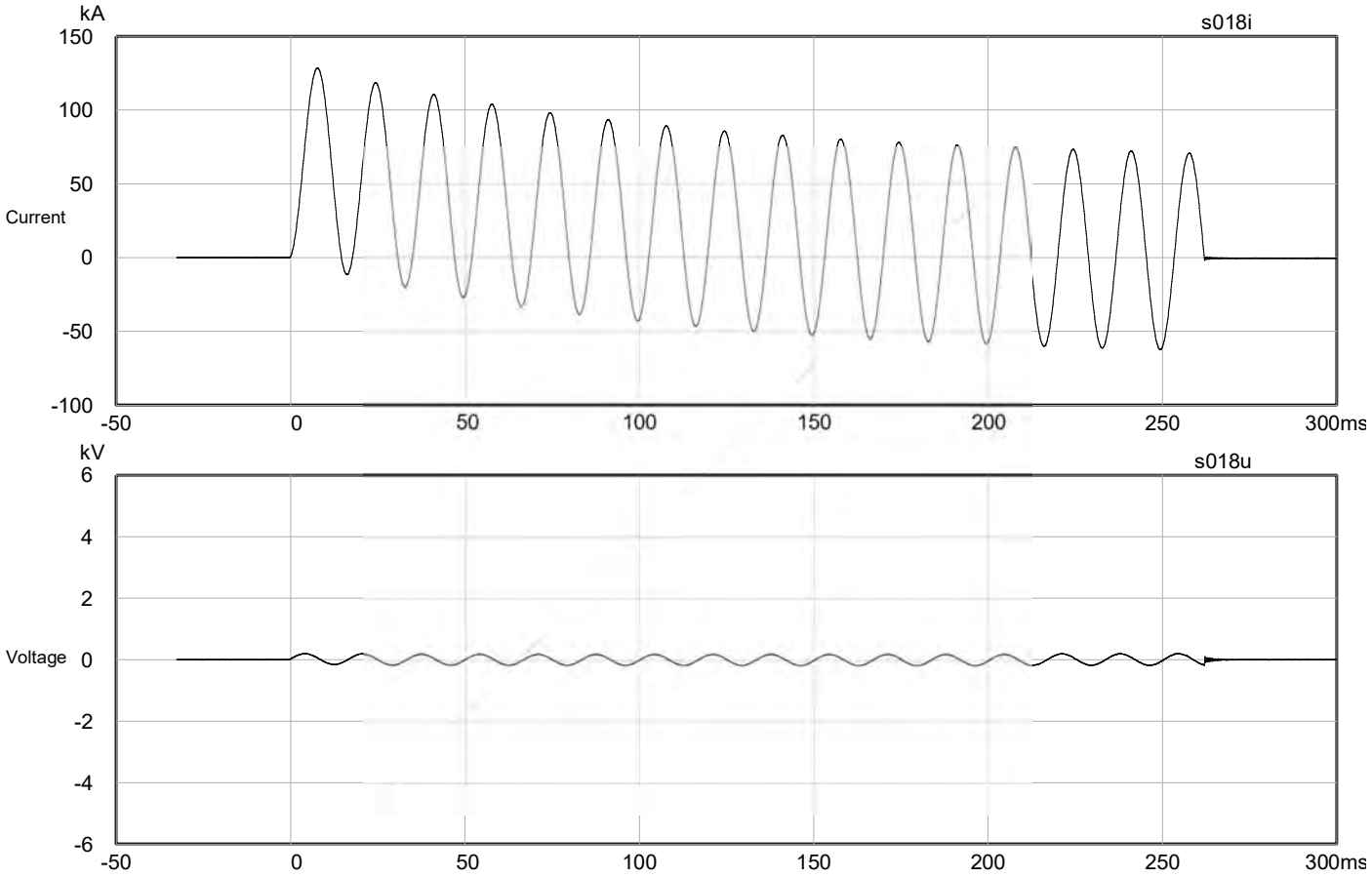


Figure 7: Waveforms for Test #5-1, Encore 4/0 AWG Sample 5.

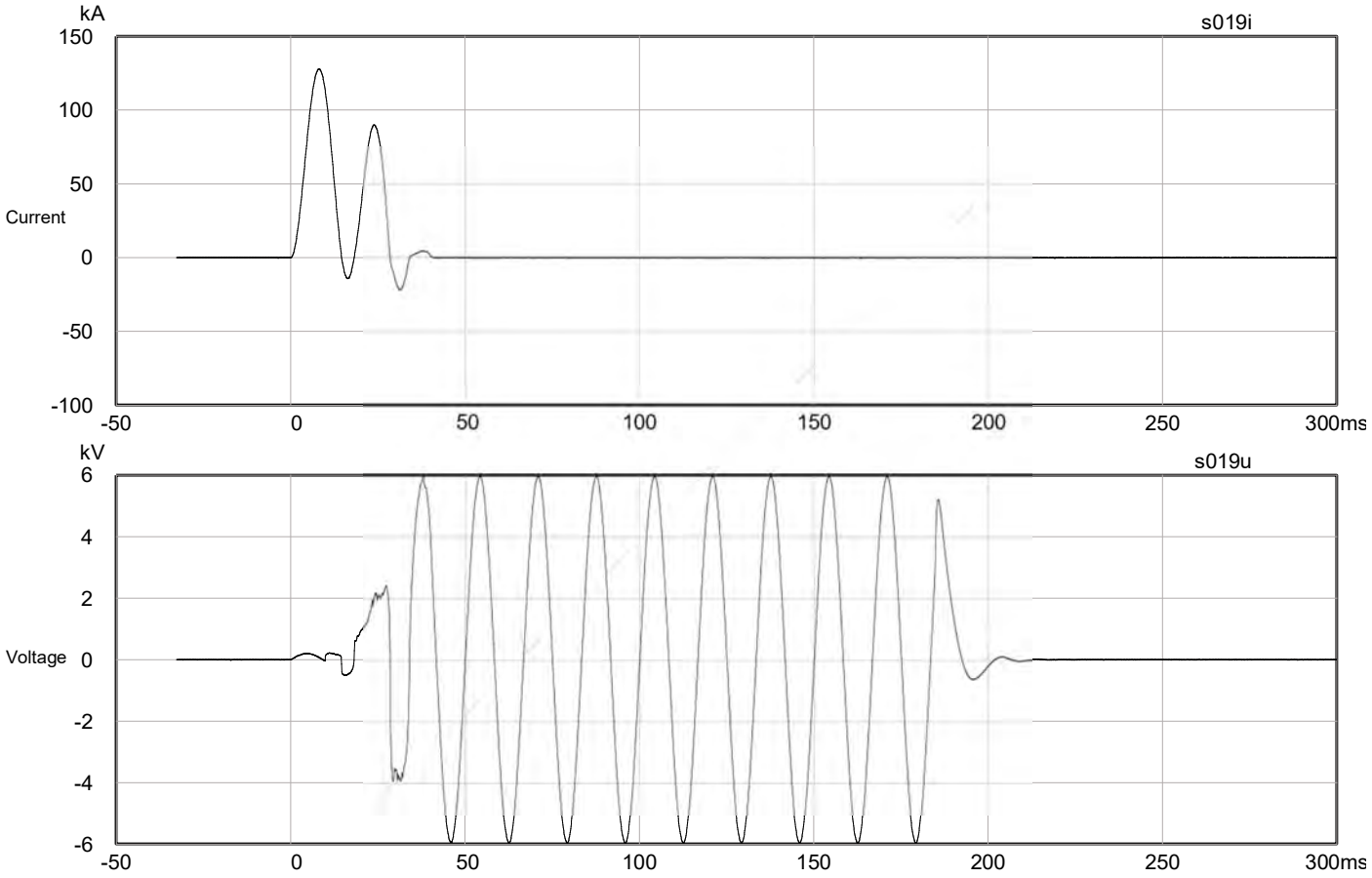


Figure 8: Waveforms for Test #5-2, Encore 4/0 AWG Sample 5.

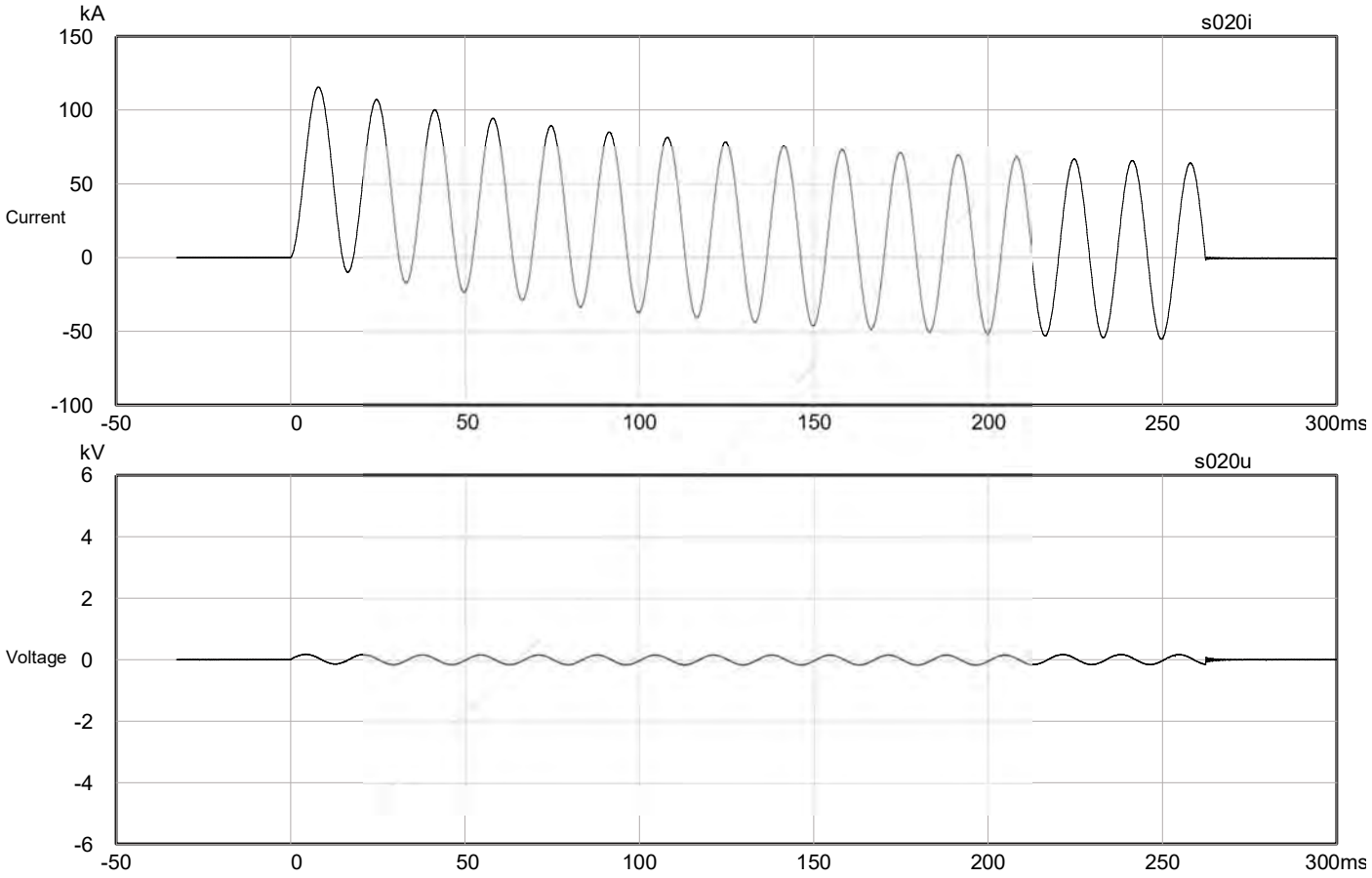


Figure 9: Waveforms for Test #6-1, Encore 4/0 AWG Sample 6.

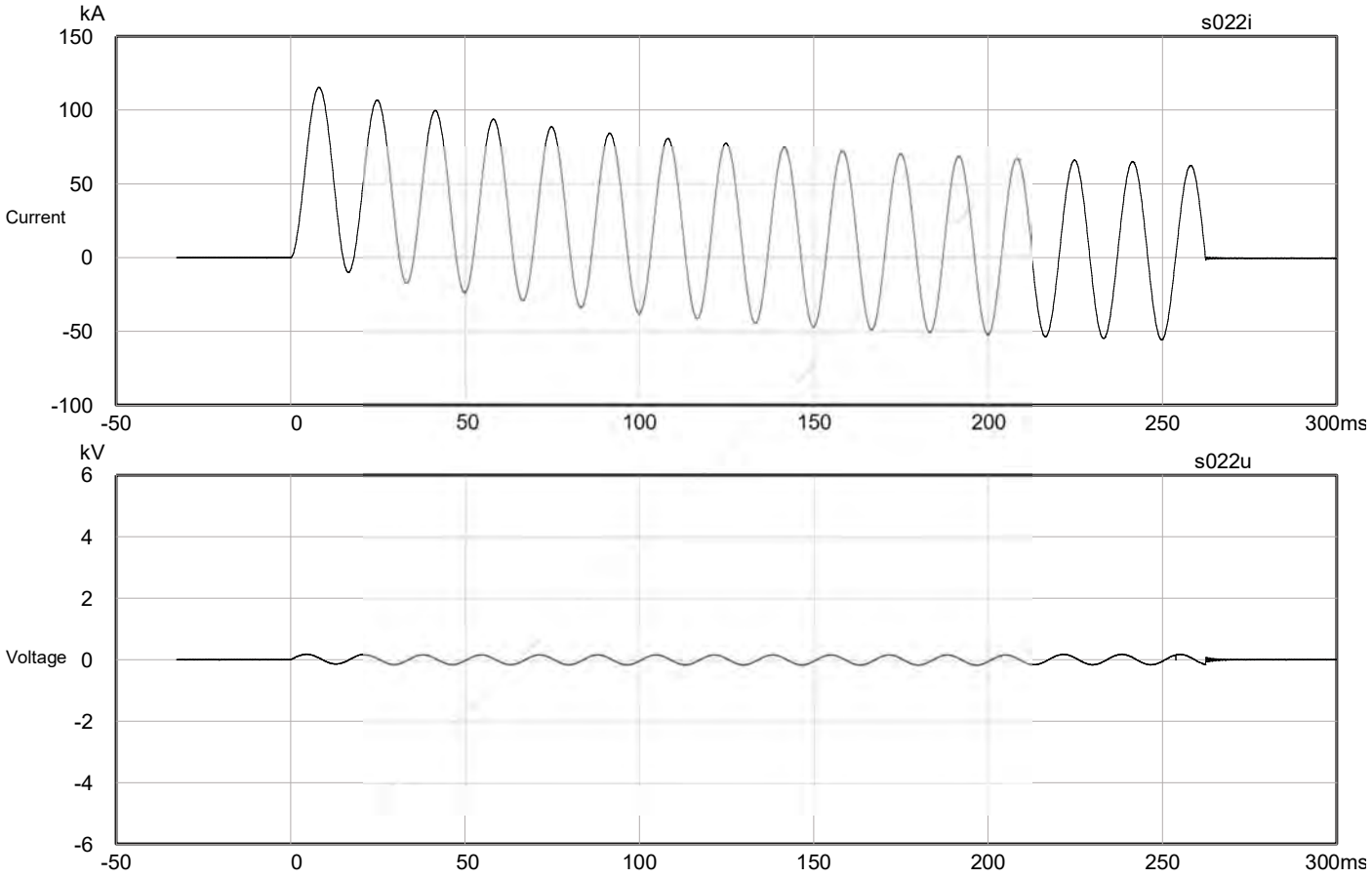


Figure 10: Waveforms for Test #6-2, Encore 4/0 AWG Sample 6.

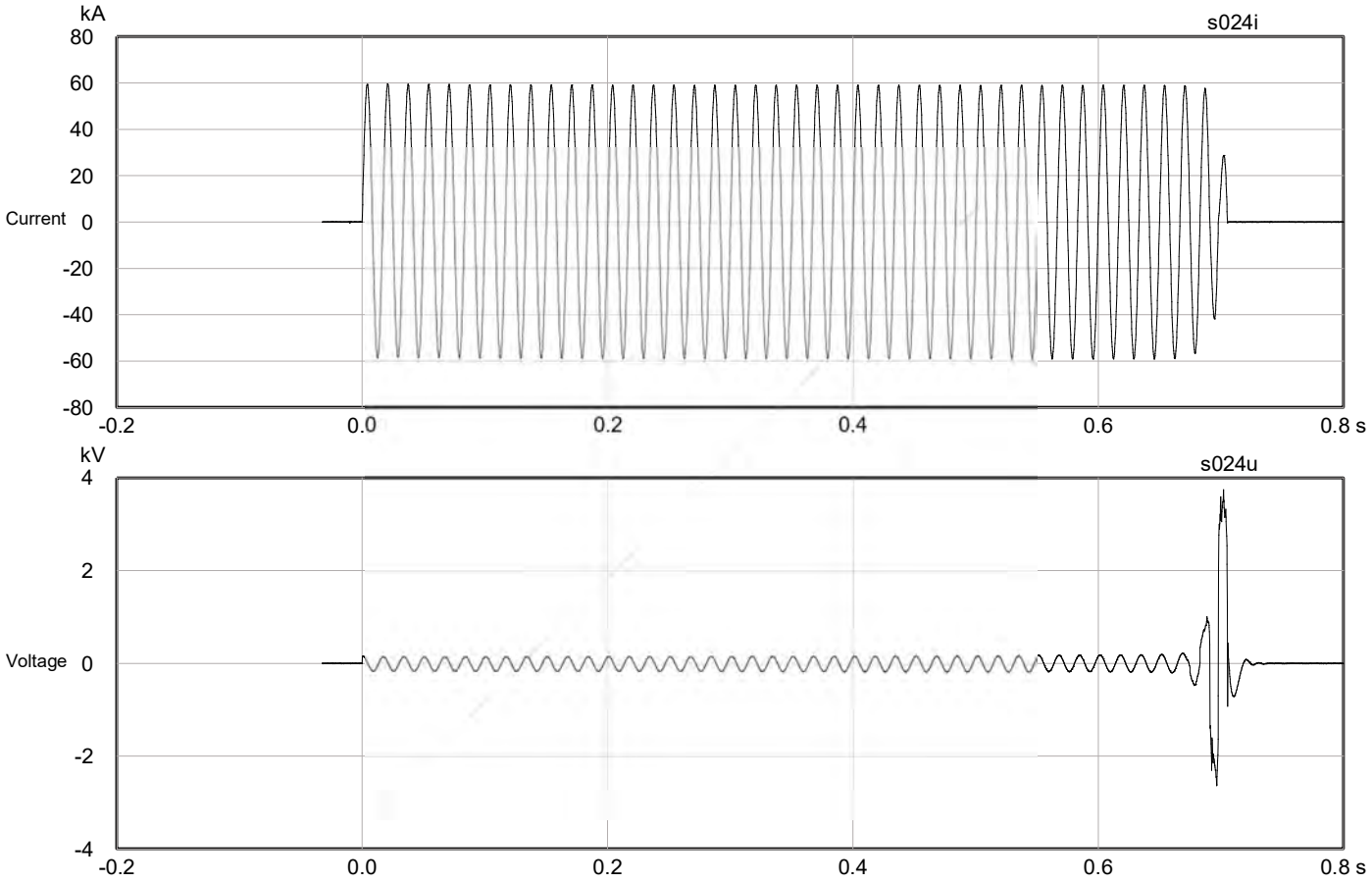


Figure 11: Waveforms for Test #7, Copperweld Scorpius 61 x 072 Sample 11.

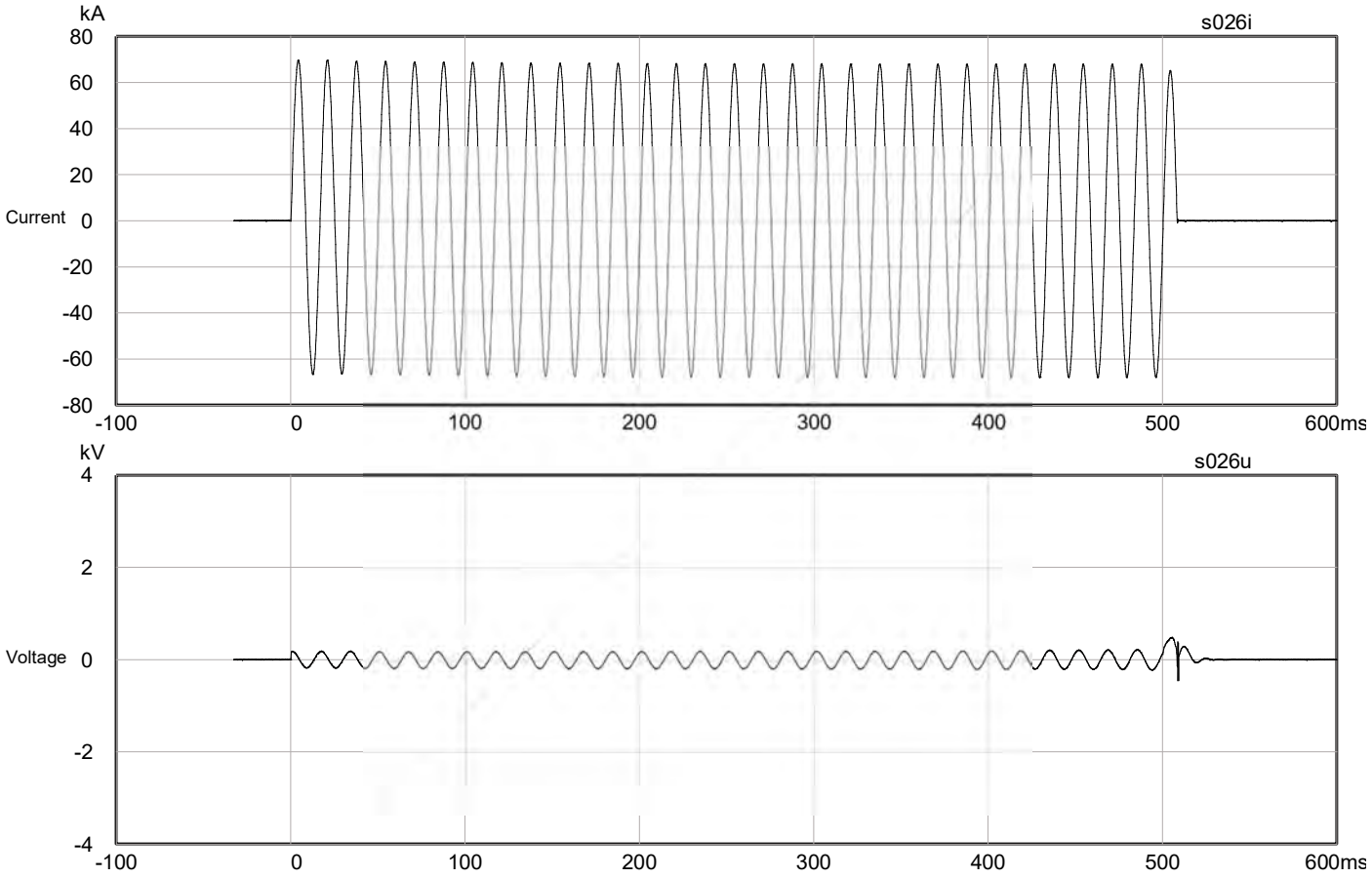


Figure 12: Waveforms for Test #6, Copperweld Scorpius 61 x 072 Sample 12.

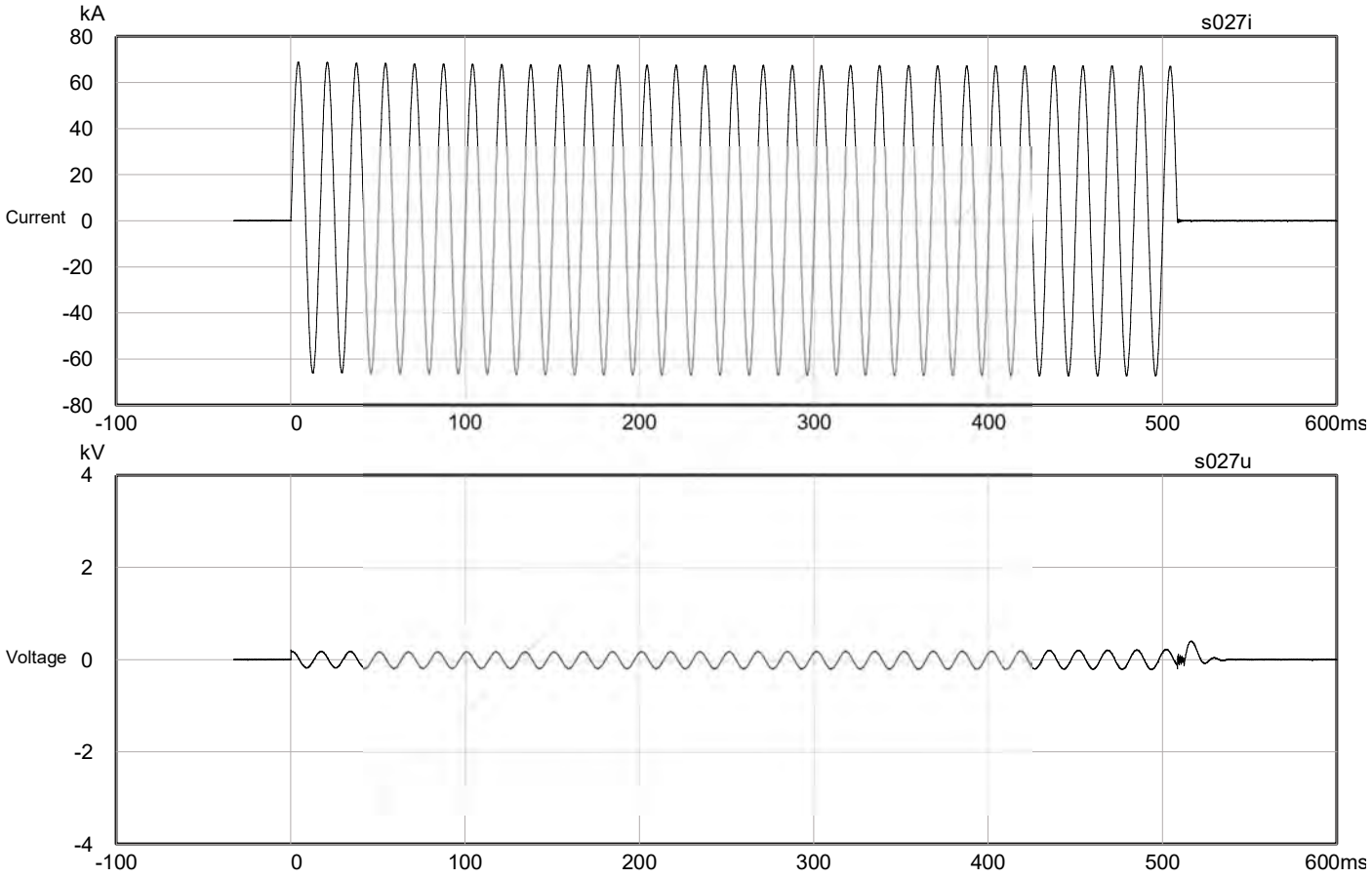


Figure 13: Waveforms for Test #9, Copperweld Scorpius 61 x 072 Sample 13.

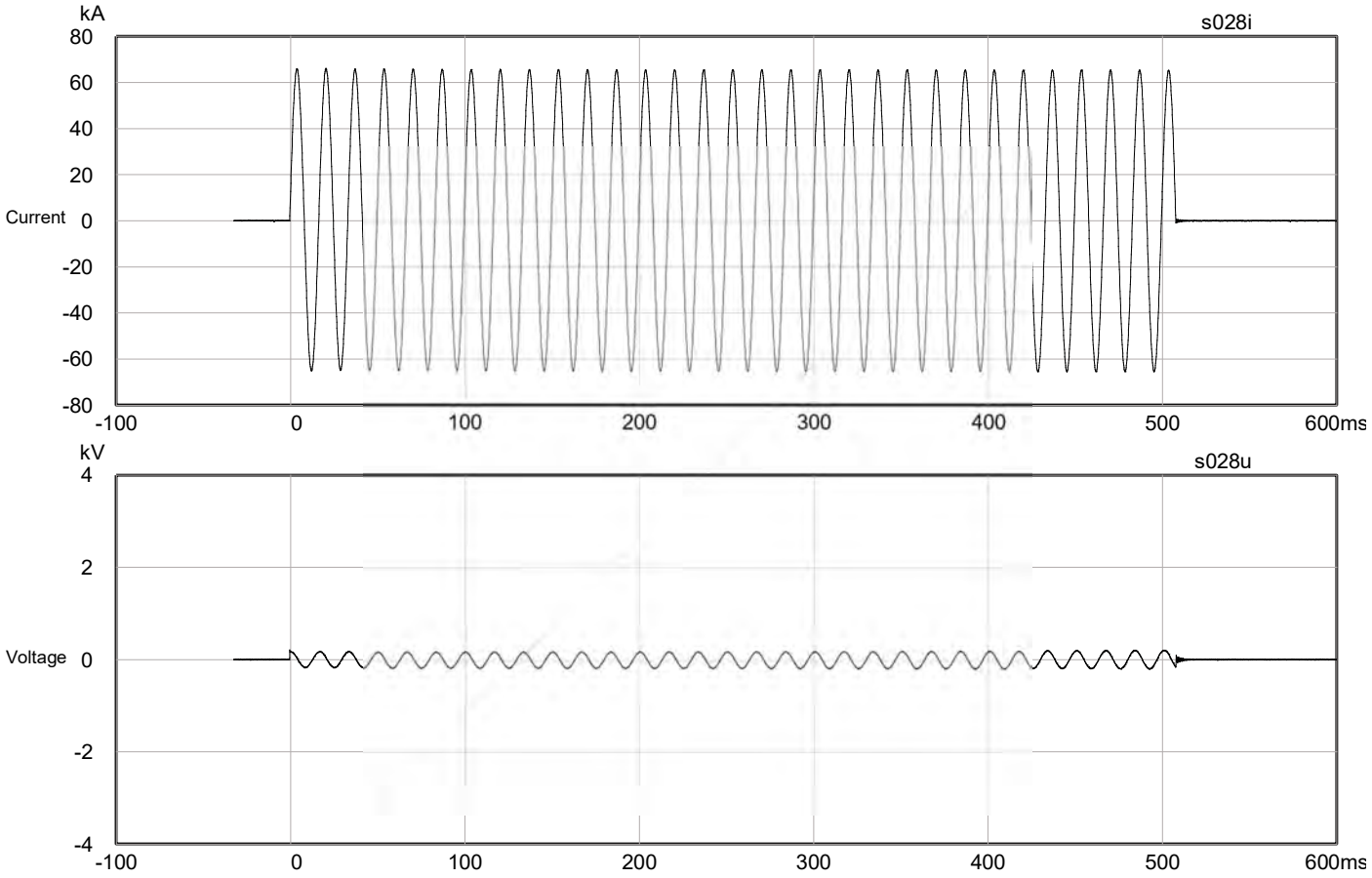


Figure 14: Waveforms for Test #10, Copperweld Scorpius 61 x 072 Sample 14.

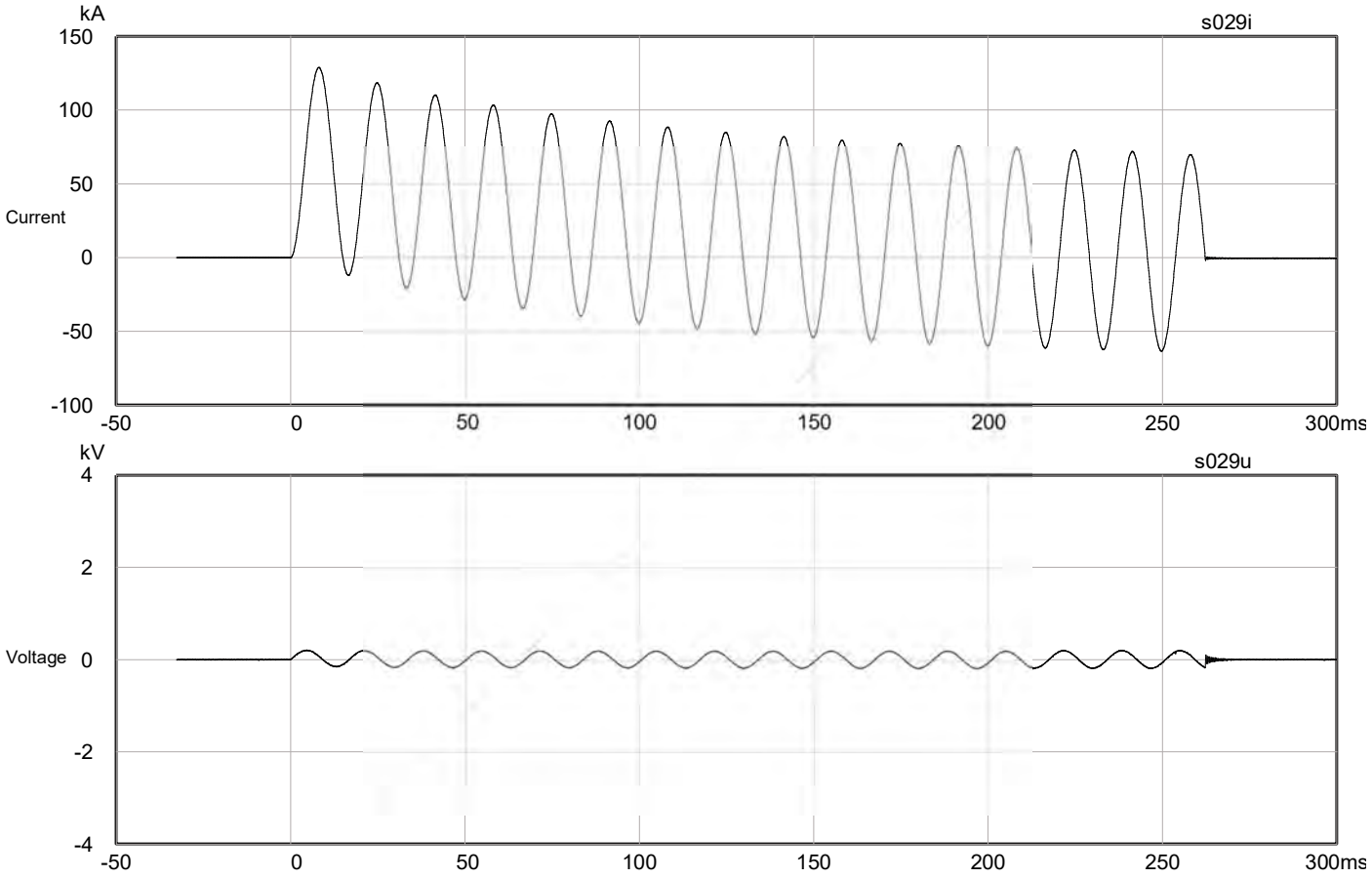


Figure 15: Waveforms for Test #11-1, Copperweld Scorpius 61 x 072 Sample 15.

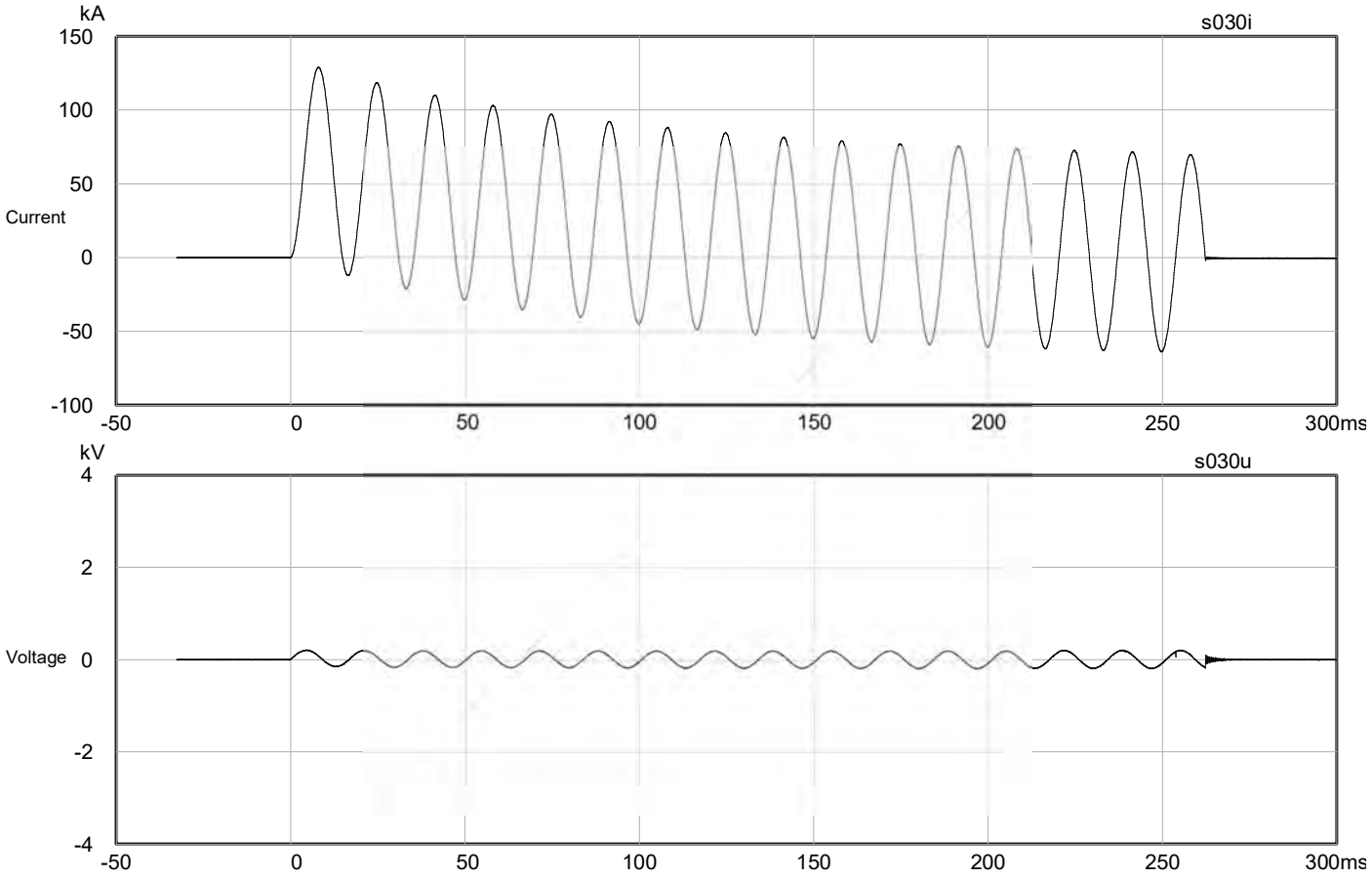


Figure 16: Waveforms for Test #11-2, Copperweld Scorpius 61 x 072 Sample 15.

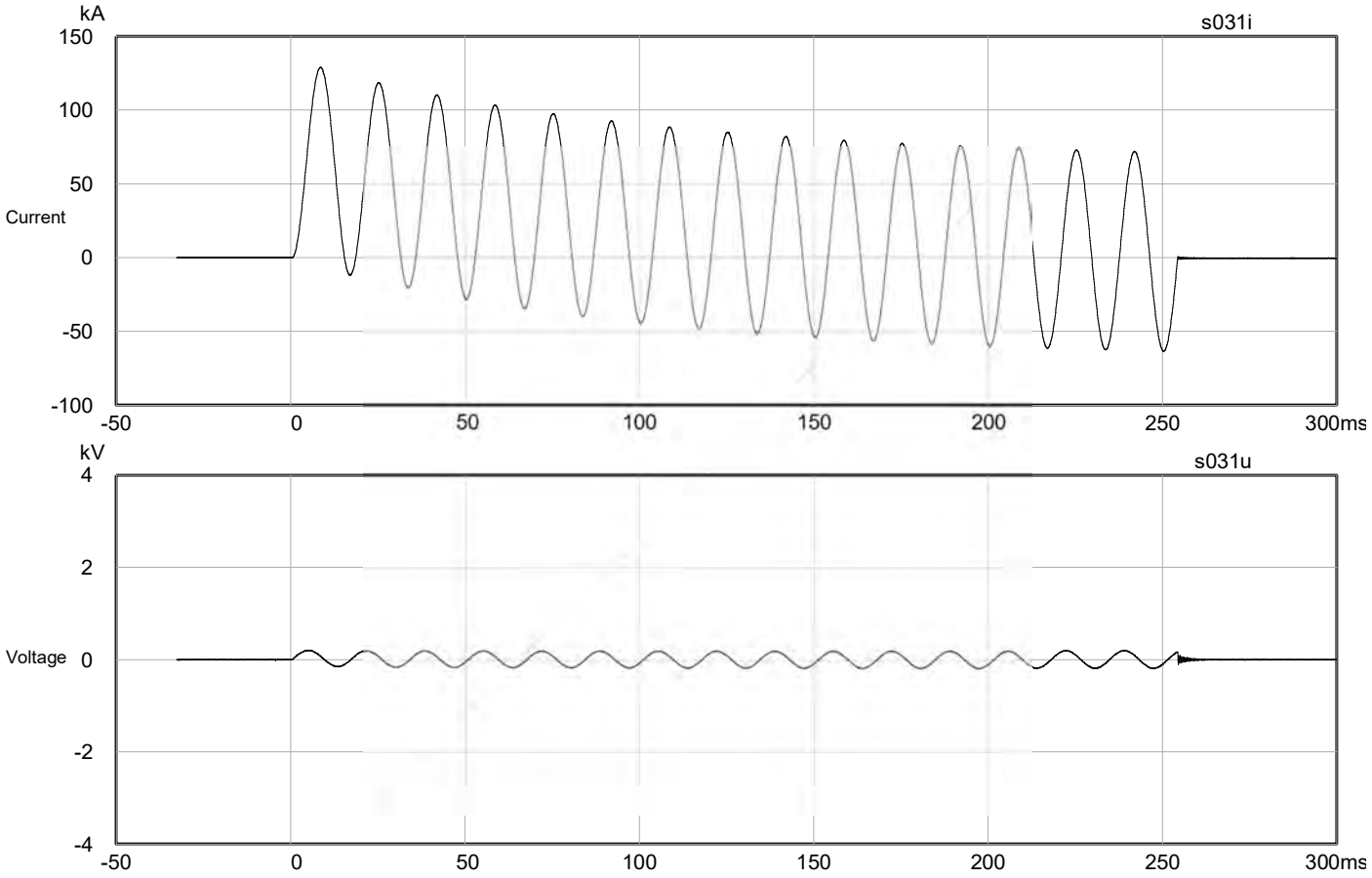


Figure 17: Waveforms for Test #12-1, Copperweld Scorpius 61 x 072 Sample 16.

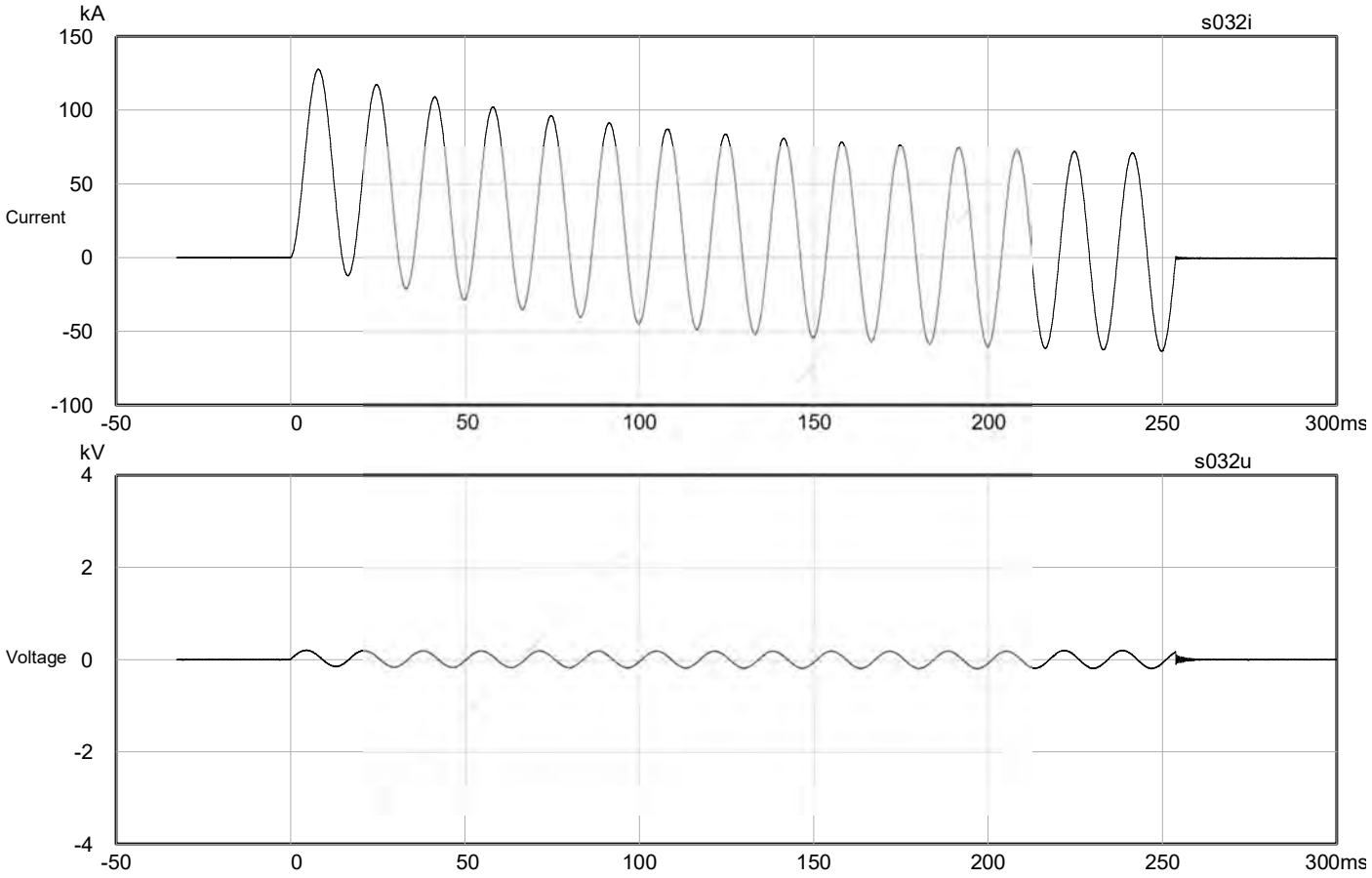


Figure 18: Waveforms for Test #12-2, Copperweld Scorpius 61 x 072 Sample 16.

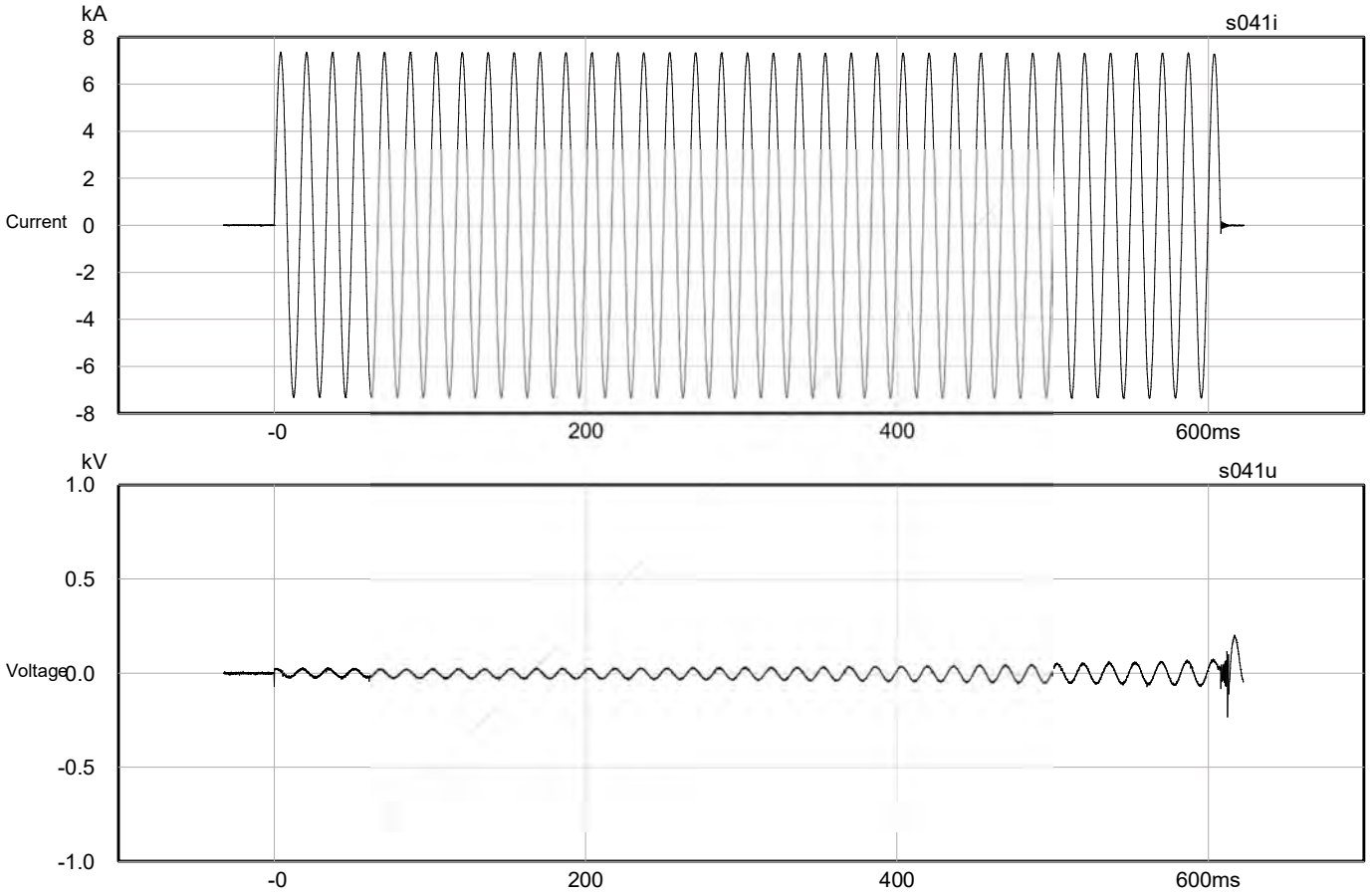


Figure 19: Waveforms for Test #13, Encore #6 AWG Sample 21.

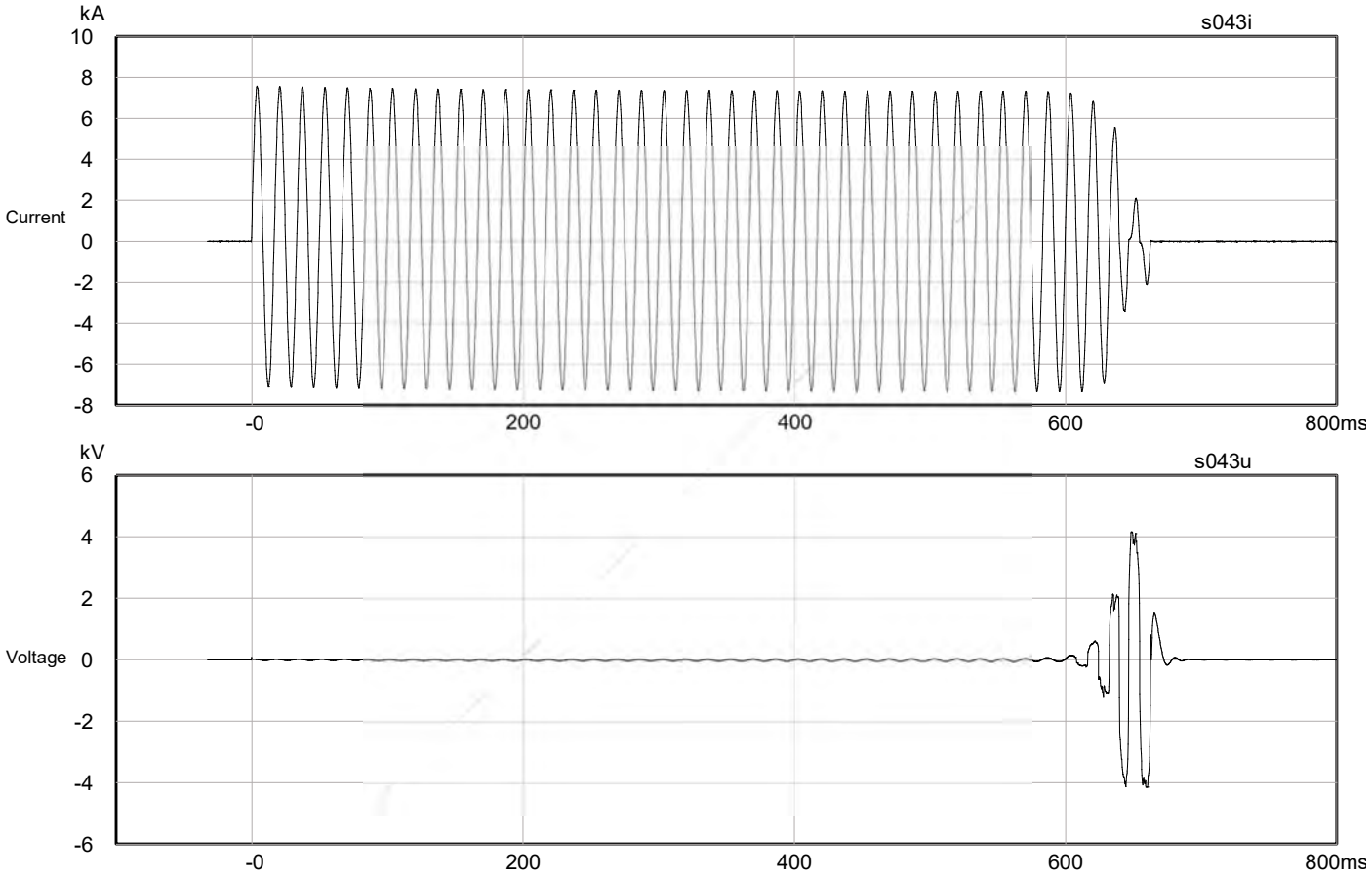


Figure 20: Waveforms for Test #14, Encore #6 AWG Sample 23.

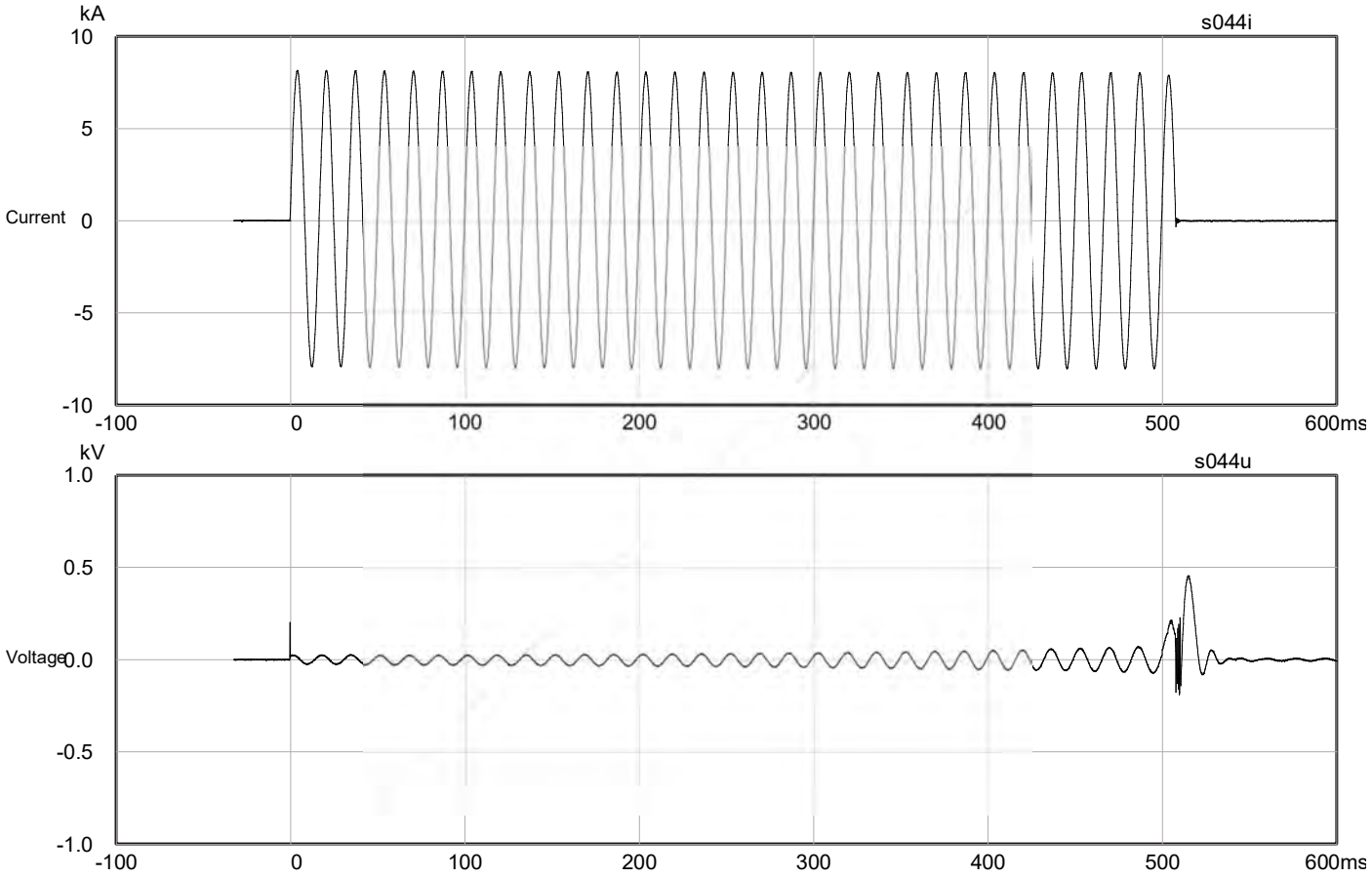


Figure 21: Waveforms for Test #15, Encore #6 AWG Sample 24.

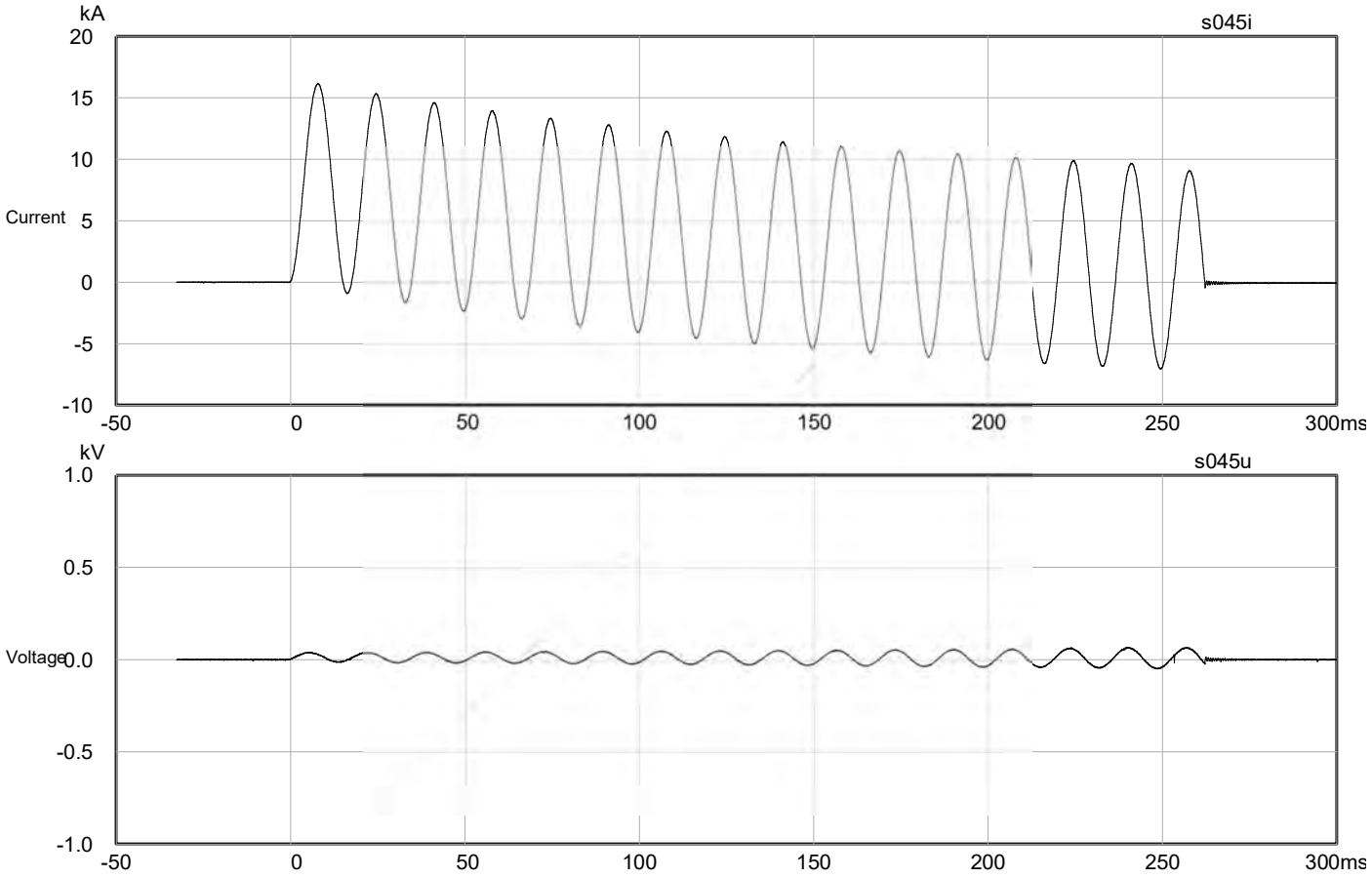


Figure 22: Waveforms for Test #16-1, Encore #6 AWG Sample 25.

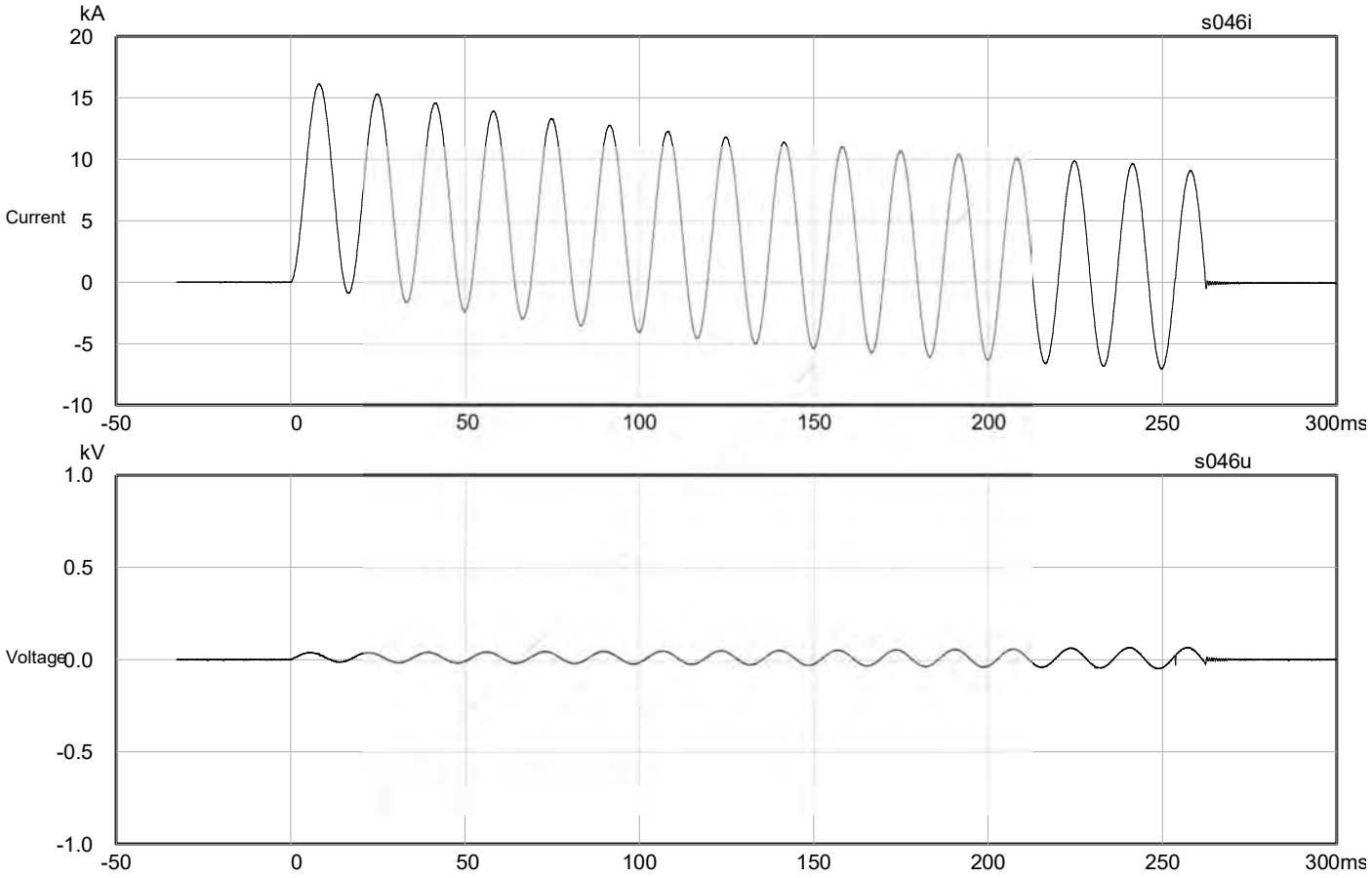


Figure 23: Waveforms for Test #16-2, Encore #6 AWG Sample 25.

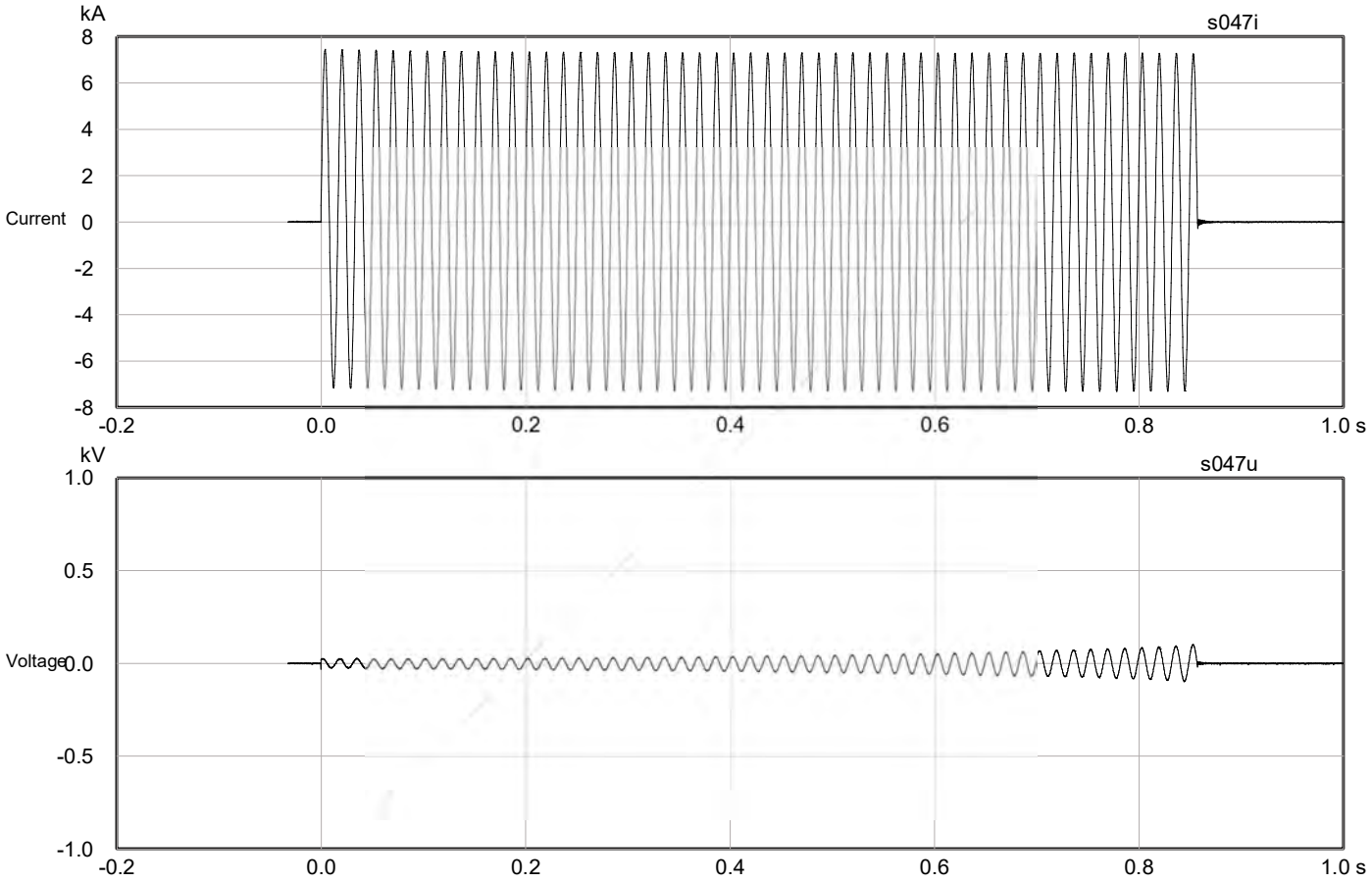


Figure 24: Waveforms for Test #17, Encore #6 AWG Sample 31.

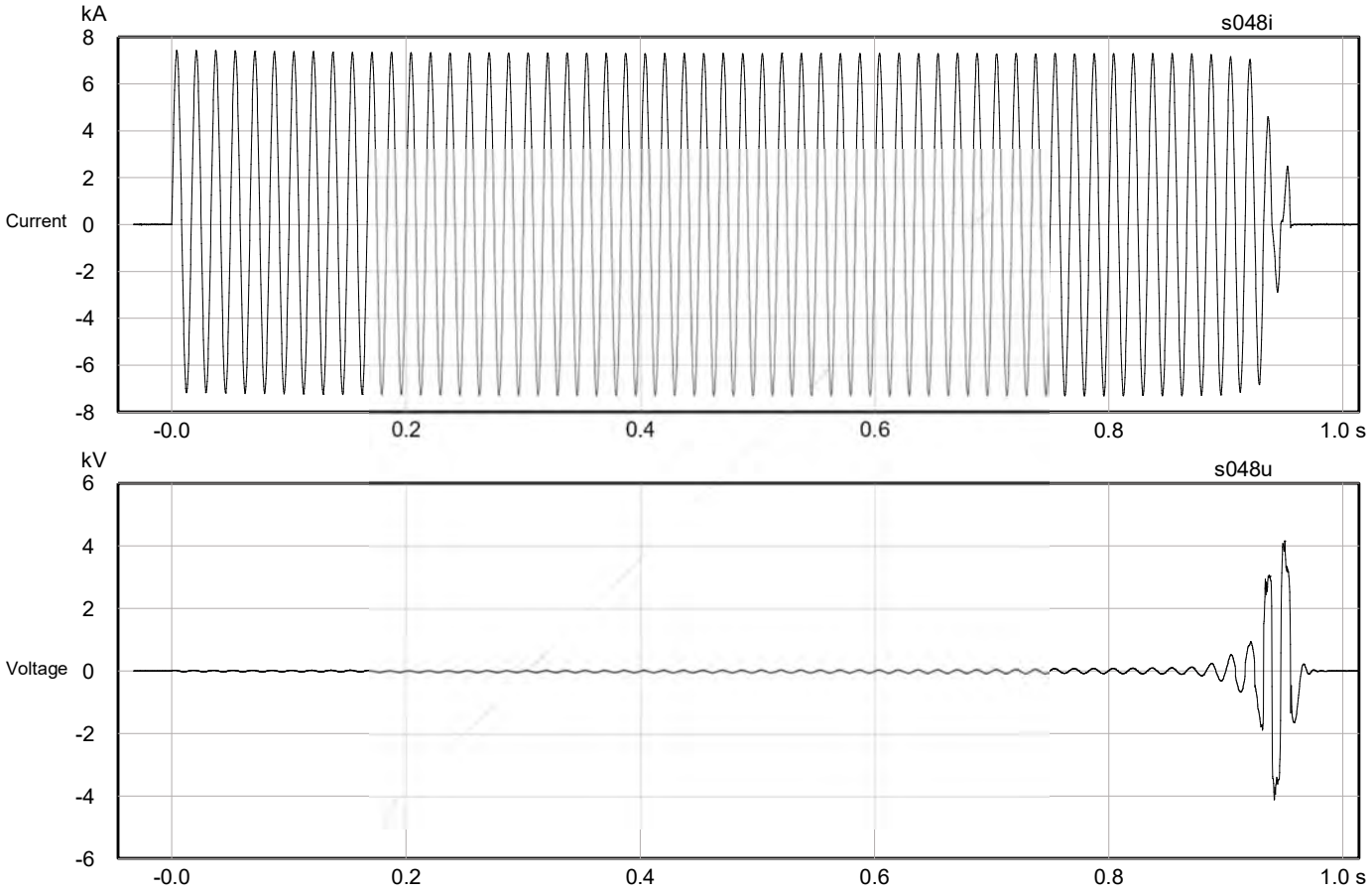


Figure 25: Waveforms for Test #18, Copperweld Scorpius 7 x 080 Sample 32.

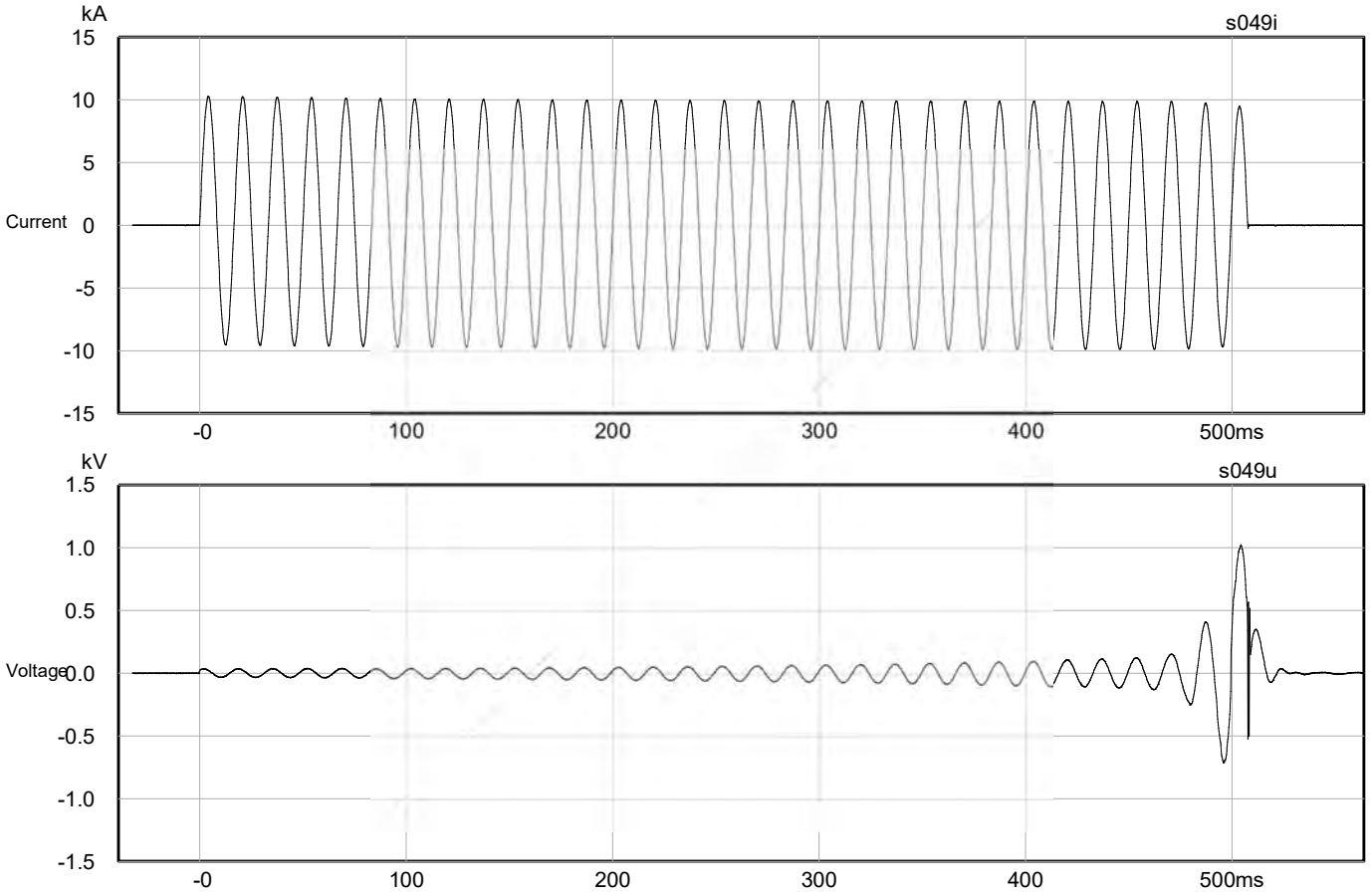


Figure 26: Waveforms for Test #19, Copperweld Scorpius 7 x 080 Sample 33.

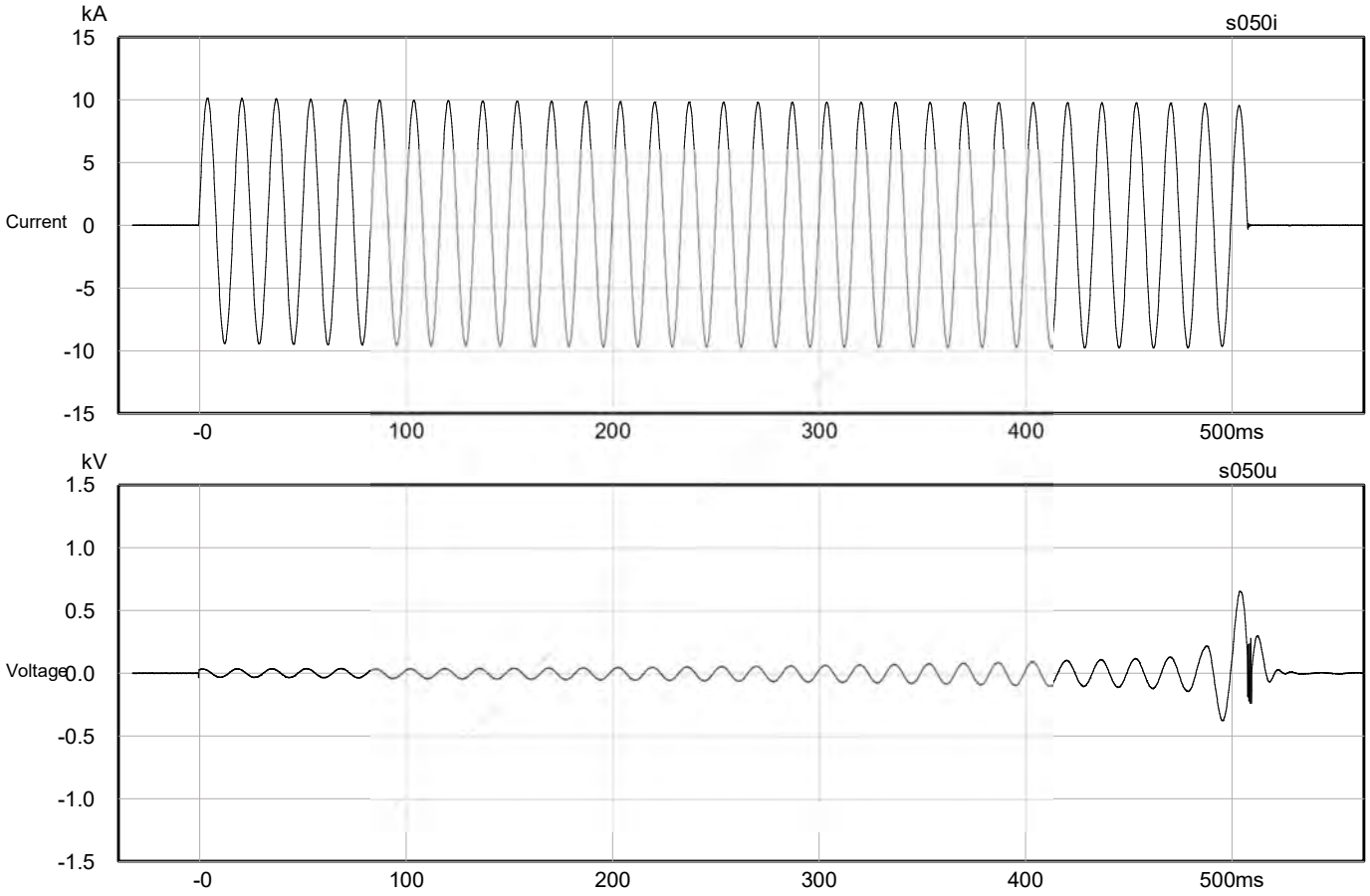


Figure 27: Waveforms for Test #20, Copperweld Scorpius 7 x 080 Sample 34.

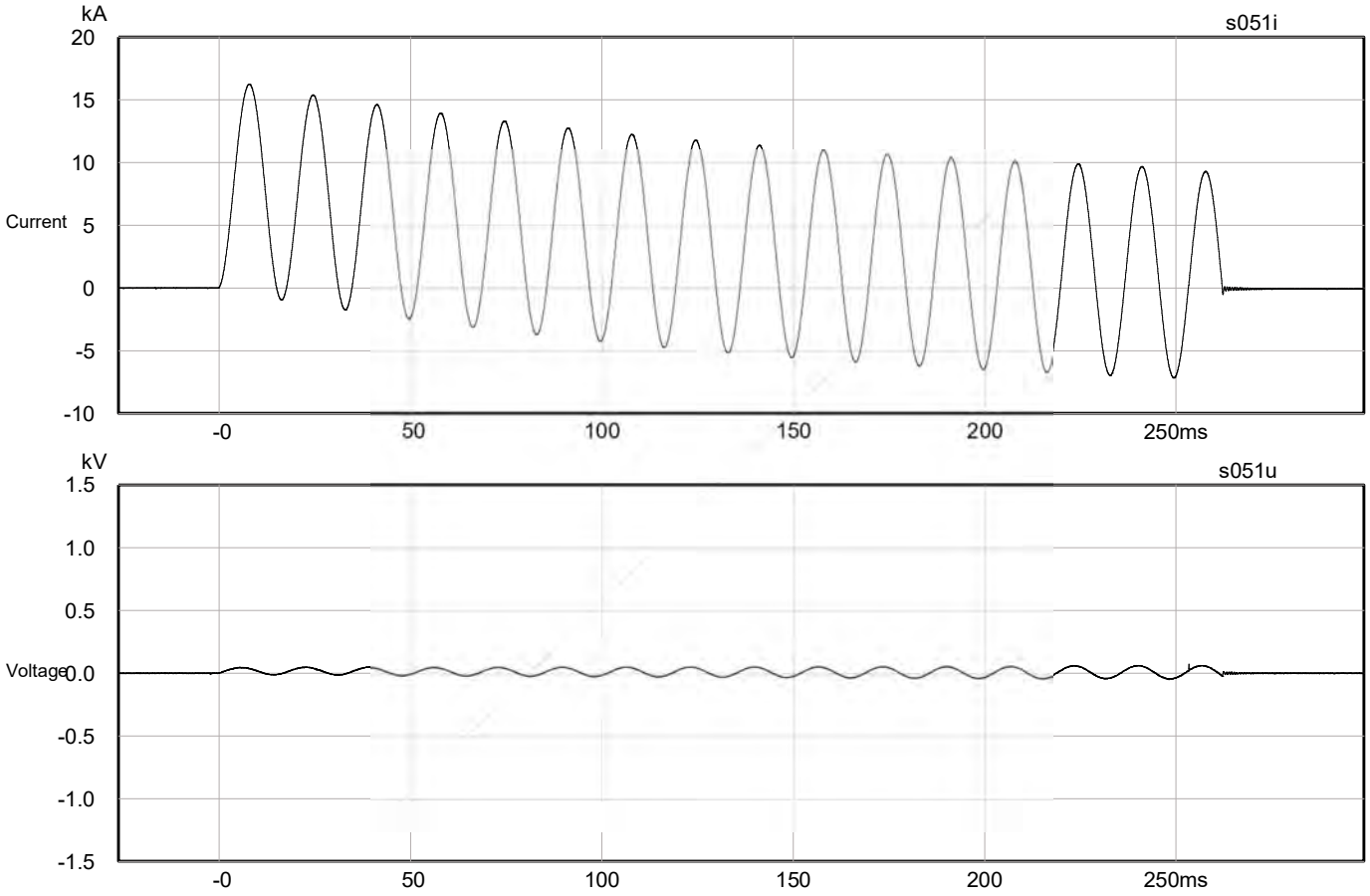


Figure 28: Waveforms for Test #21-1, Copperweld Scorpius 7 x 080 Sample 35.

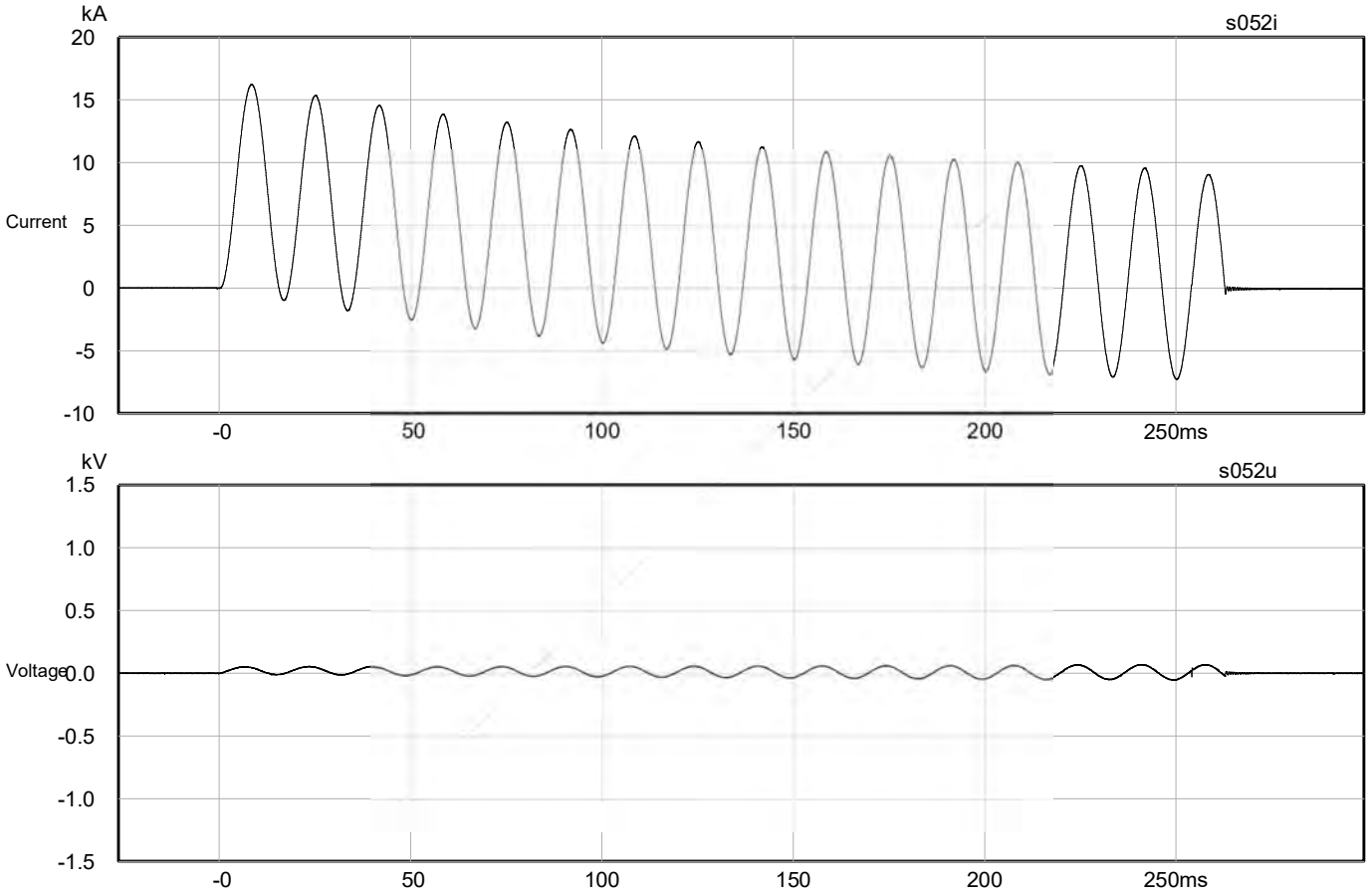


Figure 29: Waveforms for Test #21-2, Copperweld Scorpius 7 x 080 Sample 35.

APPENDIX C – PHOTOGRAPHS OF THE TEST OBJECTS



Figure 30: Test set up for the Encore 4/0 AWG Cu conductor. The power source bus is on the left and the ground bus is on the right.



Figure 31: Test set up for the Copperweld Scorpius 61 x 072 CCS conductor.



Figure 32: Test set up for the Encore #6 AWG Cu conductor.



Figure 33: Test set up for the Copperweld Scorpius 7 x 080 CCS conductor.

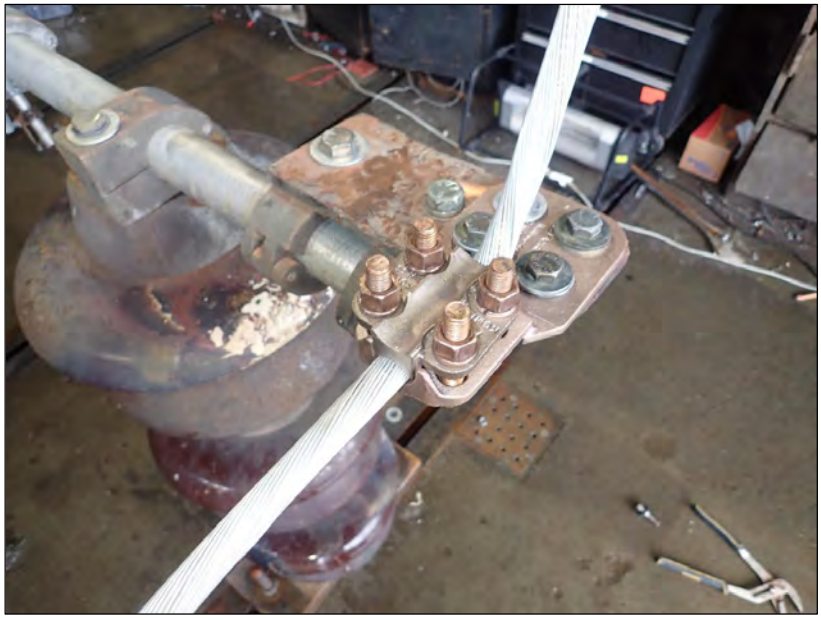


Figure 34: Typical Burndy terminal connector used to connect the Encore 4/0 AWG or Copperweld Scorpius 61 x 072 CCS conductors to the laboratory buses.



Figure 35: Typical Burndy terminal connector used to connect the Encore #6 AWG or Copperweld Scorpius 7 x 080 CCS conductors to the laboratory buses.

APPENDIX D – CALCUATIONS OF TEST CURRENT LEVELS FOR #6 AWG CU CONDUCTOR

Equation (45) in IEEE 80 and Equation (C.1) in IEEE 837 are the same, as follows:

$$I = A\sqrt{\left(\frac{TCAP\times10^{-4}}{t_c\times\alpha_r\times\rho_r}\right)\ln\left(\frac{K_0+T_m}{K_0+T_a}\right)}$$

where

I is root mean square (rms) current in kA
A is conductor cross section in mm^2
T_m is maximum allowable temperature in °C
T_a is initial conductor temperature in °C
T_r is reference temperature for material constants in °C
α_0 is thermal coefficient of resistivity at 0 °C
α_r is thermal coefficient of resistivity at reference temperature T_r
ρ_r is resistivity of the ground conductor at reference temperature T_r in μΩ-cm
K_0 is $1/\alpha_0$, or $(1/\alpha_r)-T_r$ in °C
t_c is time of current flow in seconds (s)
TCAP is thermal capacity factor in joules/cm^3°C

This equation is used to calculate the short-circuit ampacity of a conductor based on it's material constants.

For IEEE 80, Table 6, the symmetrical rms fusing current for #6 AWG soft-drawn Cu conductor at 500 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.5)(0.00393)(1.72)}\cdot\ln\left(\frac{(234+1083)}{(234+40)}\right)} = \boxed{5.29\ kA_{rms}}$$

For IEEE 837, Table 3, the symmetrical rms fusing current for #6 AWG hard-drawn Cu conductor at 250 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.25)(0.00381)(1.78)}\cdot\ln\left(\frac{(242+1084)}{(242+40)}\right)} = 7.41\ kA_{rms}$$

From IEEE 837 Equation (C.4), the asymmetrical rms fusing current is:

$$I_{asym} = \frac{(7.41\ kA)}{(1.148)} = 6.45\ kA_{rms}$$

For the EMF described in IEEE 837, Clause 7.2, a value of 90% of the fusing current is used for conductors up to 4/0 AWG:

$$I_{EMF} = (6.45)(0.9) = \boxed{5.81\ kA_{rms}}$$

Copperweld Bimetallics Data Sheet Packet
Electrical Test Laboratory

Customer:	Copperweld Building Wire	Engineer:	Bill Lewey	Date:	8/25/2020
Sample ID:	EL-13	Tested By:	Bill Lewey, Mike Rozar	Date:	8/25/2020
Product:	Grade 40 Copper Clad Steel Wire Solid Bare #4 and #6 vs Equivalent Solid Copper: Grounding Electrode Conductor Equivalency Test	Sample Condition:	New		
Standard:	ASTM B910/910M Annealed Copper Clad Steel Wire				
Insulation: N/A - Bare		Jacket: N/A - Bare			

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Test Report Summary

Page	Test Performed	Date Completed	Pass/Fail
1	Grounding Electrode Conductor Test for Copper Clad Steel Grade 40	8/25/2020	**Pass**

Requirement:
#4 AWG Grade 40 Copper Clad Steel and #6 AWG Copper Clad Steel when compared to #4 solid copper and #6 solid copper for use as a grounding electrode conductor shall have equal ability to carry amperage during a ground fault condition.

Conclusion:
The ability of bare #4 AWG Copper Clad Steel Grade 40 and bare #6 AWG Copper Clad Steel Grade 40 performed equally to #4 AWG bare solid copper and #6 AWG bare solid copper when used as a grounding electrode conductor under a ground fault condition. The current measured proved equivalency.

Test Equipment Used

Item	Equipment Type	Equipment #	Cal. Due Date
1	Fluke 374FC Clamp Meter	AM-1	Nov 2020
2	Acme Electric 15KVA Transformer	T2535173S	N/A
3	Square D 60A / 600V Safety Interrupter	N/A	N/A
4	Eaton Service Panel	N/A	N/A
5	Eaton Type CH 20 Amp Breaker	N/A	N/A
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

VBU – Verify Before Use

N/A – Not Applicable

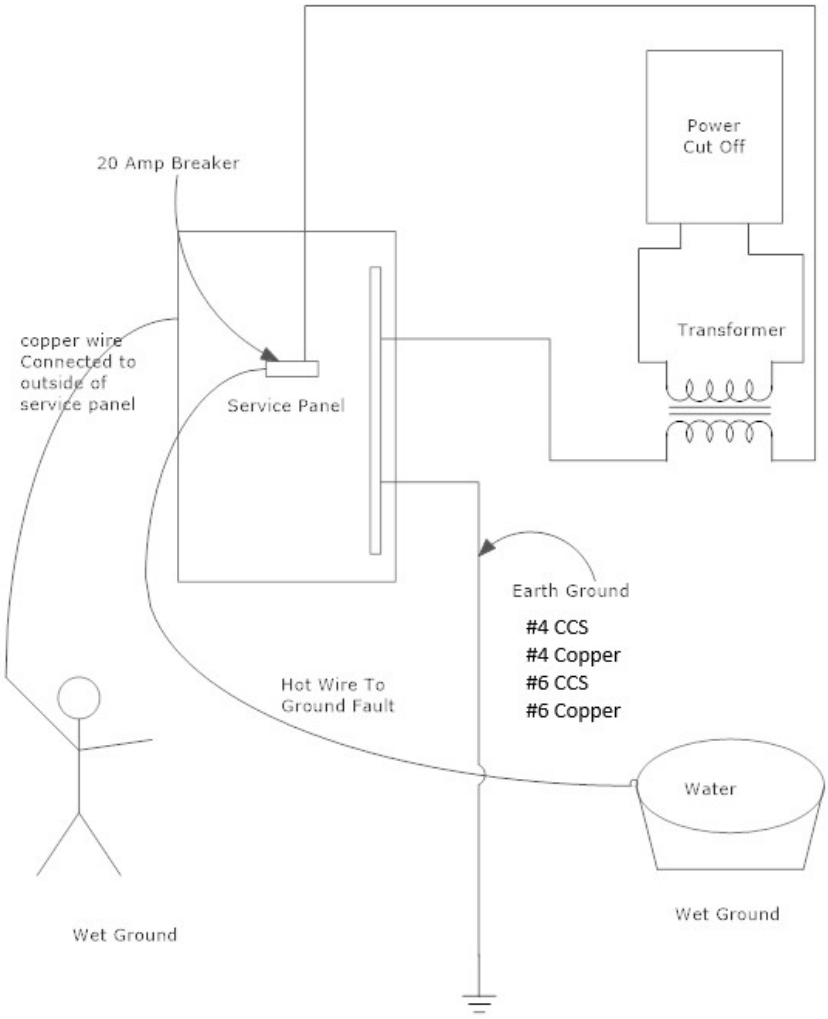
Sample Identification

Item	Description	Length/No. Rec'd
A	#4 AWG 40% Copper Clad Steel Bare	35 Ft
B	#4 AWG Solid Copper Bare	35 Ft
C	#6 AWG 40% Copper Clad Steel Bare	35 Ft
D	#6 AWG Solid Copper Bare	35 Ft
E		
F		

Grounding Electrode Conductor Test

Test Parameters:	
Conditioning:	No preconditioning.
Test Conductors:	1 each of #4 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #6 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #4 AWG Solid Bare copper grounding electrode conductor 1 each of #6 AWG Solid Bare copper grounding electrode conductor
Test Conductor Length:	Each conductor shall be 35 ft.
Test Circuit Configuration:	See schematic shown in Figure 1
Test Current:	Test current from 120 V / 20 A Residential Circuit
Method:	Testing was completed by creating a standard residential test circuit at 120V with 20A breaker wired to an intentional ground fault as shown in figure 1. The ground fault was created by connecting a hot wire from the breaker to a galvanized steel pan full of water and placing the pan on the wet ground. A conductor was also connected to the outside of the electrical panel and a Copper Plated Grounding Electrode (Copperweld Ground Rod) driven 6 inches into the wet ground to determine amount of current going through a grounded person touching the electrical panel during the ground fault condition. The ground fault and the grounded "man" were positioned 20 feet either side of the ground rod. The entire test area was soaked with water overnight using a sprinkler system When the ground fault was electrified, current measurements were taken from the ground fault conductor, the grounding electrode conductor and the grounded "man" conductor. For the four grounding electrode conductors tested, there was one test sequence for each. The current was measured for each. The objective: Compare the amperage measurements of the copper clad steel grounding electrode conductors to those of copper.

Figure 1



Results:			
Ground Conductor	**Fault Conductor Current**	**Current of the Grounding Electrode Conductor**	**Grounded Man Conductor Current**
#4 Copper	2.1 A	1.8 A	0.3 A
#4 40% CCS	2.1 A	1.8A	0.3 A
#6 Copper	1.7 A	1.6 A	0.1 A
#6 40% CCS	1.5 A	1.4 A	0.1 A

Requirement:
For equivalent sizes of Grade 40 Copper Clad steel vs. solid copper grounding conductors, the ability to carry amperage to ground during a ground fault condition is equal.

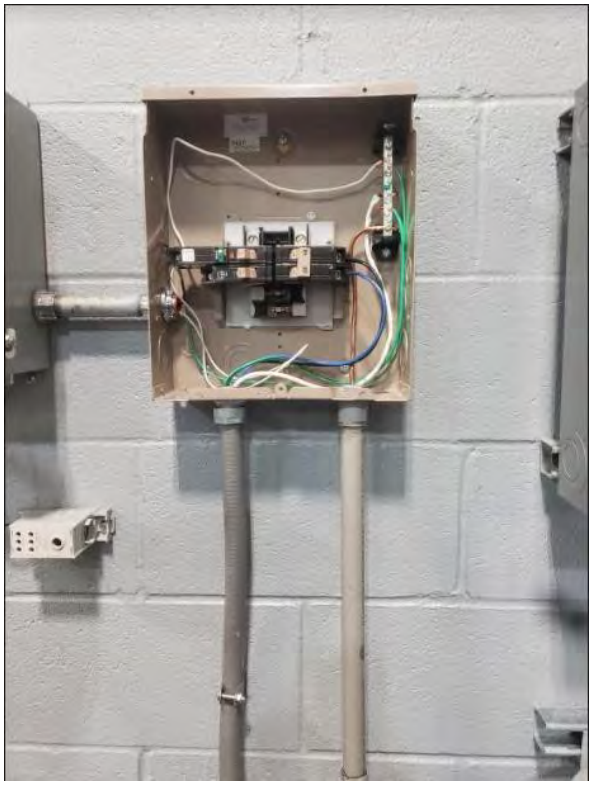
Comments:
____X__ (Pass) The product complies with all applicable requirements of this test. _____ (Fail) The product does not comply with the requirements of this test. **Test Date: 8/25/2020** **Tested By: Bill Lewey**

Environmental Conditions during Testing:

Humidity: % rh __74%_____ Ambient: °C___28_____

Test setup for the electrical service panel







Ground Rod with Grounding Conductor Attached



Ground Fault



Grounded “man”

Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]

The size of the grounding electrode conductor at the service, at each building or structure where supplied by a feeder(s) or branch circuit(s), or at a separately derived system of a grounded or ungrounded ac system shall not be less 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

Size of Largest Ungrounded Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil)			Size of Grounding Electrode Conductor (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum	-	Copper-Clad Steel or Copper	Aluminum or Copper-Clad Aluminum
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. Where 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.

Additional Proposed Changes

File Name	Description	Approved
CCS_Corrosion_paper_Rev2.pdf	50 Year Corrosion Study Grade 40 CCS	
TD002391.doc	UL 467 Short Circuit and UL 486A-B Mechanical Sequence Grade 40 CCS	

PL-03027_REP1.pdf	Fusing and Withstand Testing
CEL_-_13_Grounding_Conductor_Current_Test_002_.pdf	Graser 40CCS Conductivity Test Report. Lewey and Rozer

Statement of Problem and Substantiation for Public Input

COPPER-CLAD STEEL CONDUCTORS:

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 applicate 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 Inputs for This Document

Related Input	Relationship
Public Input No. 2459-NFPA 70-2020 [Section No. 250.52(A)(4)]	Copper-Clad Steel Grounding Conductors
Public Input No. 2514-NFPA 70-2020 [Section No. 550.16(C)(2)]	Copper-Clad Steel Grounding Conductors
Public Input No. 2459-NFPA 70-2020 [Section No. 250.52(A)(4)]	
Public Input No. 2460-NFPA 70-2020 [Section No. 250.53(E)]	
Public Input No. 2462-NFPA 70-2020 [Section No. 250.62]	
Public Input No. 2463-NFPA 70-2020 [Section No. 250.64(B)(1)]	
Public Input No. 2465-NFPA 70-2020 [Section No. 250.64(B)(2)]	
Public Input No. 2468-NFPA 70-2020 [Section No. 250.66(A)]	

Public Input No. 2470-NFPA 70-2020 [Section No. 250.66(B)]

Public Input No. 2476-NFPA 70-2020 [Section No. 250.166(A)]

Public Input No. 2481-NFPA 70-2020 [Section No. 250.190(B)]

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

Submitter Information Verification

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Affiliation: American Bimetallic Association
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City:
State:
Zip:
Submittal Date: Sun Aug 23 10:12:28 EDT 2020
Committee: NEC-P05

Testing done for the safety of our valued customer.

Global Circulation Laboratory Test Report

For Global Distribution

UL467 SHORT CIRCUIT & UL 486A-486B MECHANICAL SEQUENCE TESTS

YGHP29C2, YGHC2C2, YGHC26C26, YGHP34C29, YGHC29C29, YGHP34C34, YGHC34C34 HYTAP™ Connectors
YGL2C2, YGL29C29, YGL34C34 HYGRID™ Connectors
YGA4C2N, YGHA272N, YGA282N, YGHA302N HYLUG™ Connectors

5/8" and 3/4"Copper Clad Steel Ground Rod, #4AWG Solid, 4/0AWG Stranded, 7#7, and 19#8 COPPERWELD® 40% IACS Copper Clad Steel Conductors

PAT750XT-18V PATRIOT® Tool
with
UC, UO, U28RT, U29RT, U32RT, U997, PU998, and U1011 Die Sets

TD002391 REV B

Requested by / Date:	***Authorized by / Date:***	***Completed by / Date:***
C. Gandhi 12-Dec-2014	R Robicheau 12-Dec-2014	R Charpentier 06-Apr-2015
Engineering Approval / Date:	***Marketing Approval / Date:***	***Laboratory Approval / Date:***
R.Roman 20-Aug-2020	J Hogan 20-Aug-2020	R Charpentier 20-Aug-2020

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

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Burndy LLC 47 East Industrial Park Dr.
Manchester / New Hampshire / 03109
Tel: 603 647 5000 Fax: 603 647 5205

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PURPOSE OF TEST:

To determine if the Burndy HYTAP™, HYGRID™, and HYLUG™ Connectors can meet the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST REQUESTED:

UL486A-486B Mechanical Sequence
UL467 Short Time Current

TEST RESULTS:

Connector	Cable 1	Cable 2	Die	# of crimps	Securness	Pull	Short Time Current		
					Pass / Fail	Average Pull (lb)	Pass / Fail	Current (Amps)	Time (s)
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	U997	1	Pass	1021.3	Pass	1600	6
YGL2C2	#4 Solid CCS	#4 Solid CCS	U-O	1	Pass	1451.8	Pass	1600	6
YGHC2C2	#4 Solid CCS	#4 Solid CCS	U-C	1	Pass	1544.0	Pass	1600	6
YGA4C2N	#4 Solid CCS	n/a	U4CRT	1	Pass	814.0	Pass	1600	6
YGL29C29	7#7 STR CCS	7#7 STR CCS	U997	1	Pass	1643.2	Pass	4600	9
YGHC26C26	7#7 STRCCS	7#7 STR CCS	U-O	1	Pass	1239.4	Pass	4600	9
YGHA272N	7#7 STRCCS	n/a	U29RT	2	Pass	1574.0	Pass	4600	9
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PU998	1	Pass	1789.8	Pass	6100	9
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1849.8	Pass	6100	9
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1779.1	Pass	6100	9
YGA282N	4/0 AWG CCS	n/a	U28RT	2	Pass	2489.3	Pass	6100	9
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	U1011	3	Pass	2126.8	Pass	9000	9
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	U1011	3	Pass	2380.0	Pass	9000	9
YGL34C34	19#8 STRCCS	19#8 STR CCS	U1011	3	Pass	3158.3	Pass	9000	9
YGHC34C34	19#8 STR CCS	19#8 STR CCS	U1011	3	Pass	3812.1	Pass	9000	9
YGHA302N	19#8 STR CCS	n/a	U32RT	2	Pass	4792.2	Pass	9000	9

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CONCLUSIONS:

All samples tested met the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST PROCEDURES

The table below shows the connector / conductor combinations tested.

Connector	Cable 1	Cable 2	Tool	Die	# of Crimps
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	PAT750	U997	1
YGL2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-O	1
YGHC2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-C	1
YGA4C2N	#4 Solid CCS	n/a	PAT750	U4CRT	1
YGL29C29	7#7 STR CCS	7#7 STR CCS	PAT750	U997	1
YGHC26C26	7#7 STR CCS	7#7 STR CCS	PAT750	U-O	1
YGHA272N	7#7 STR CCS	n/a	PAT750	U997	2
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PAT750	PU998	1
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGA282N	4/0 AWG CCS	n/a	PAT750	U997	2
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	PAT750	U1011	3
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	PAT750	U1011	3
YGL34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHC34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHA302N	19#8 STR CCS	n/a	PAT750	U32RT	2

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All conductors were cut to twenty four (24) inch lengths.
All ground rod was pre-crimped with the appropriate pre-crimp die
5/8in Rod UPRECRIMP58
3/4in Rod UPRECRIMP34

Mechanical Sequence
Four samples of each set were secured to the Secureness tester, the height; weight and bushing size were as specified in UL486A-486B Table 26. Samples were rotated for thirty minutes at 9rpm. Samples were then subjected to a 1-minute pull to the value specified in UL486A-486B Table 27 and then to failure.

Short Time Current
Test samples were assembled in a series loop configuration then attached to a current controller as shown below. The test current and duration are listed below. After completion of the test, electrical continuity was checked with a digital multi-meter.

Test current values were derived from the equation Annex C of IEEE Std 837-2002. The diameter of the conductor(s) were measured and the cross-sectional area of the conductors was calculated.

Conductor	***Current Value (A)***	***Duration (sec)***
#4AWG Solid COPPERWELD® 40% IACS CCS	1600	6
4/0AWG 19 strand COPPERWELD® 40% IACS CCS,	6100	9
7#7 stranded COPPERWELD® 40% IACS CCS	4600	9
19#8 stranded COPPERWELD® 40% IACS CCS	9000	9

TEST EQUIPMENT LIST:

MANUFACTURER	MODEL	DESCRIPTION	SERIAL #	RANGE
FLUKE	79 III	DMM	70591301 (Rene)	AUTO
OHIO SEMITRONICS		CURRENT TRANSDUCER	NA	15000:5
SATEC	T5000	TABLE TOP	2038	5000 lbs
VIRTECH	NA	HIGH CURRENT	NA	12V / 12000A
MITUTOYO	505-675	DIAL CALIPER	08914565 (Rene)	6"

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CORROSION ON BURIED COPPER CLAD STEEL



Cece Syarif

Global Application Engineer

&

Anthony Hale

Manager, Utility Products, North America

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For more information, contact sales@copperweld.com.
The results and conclusions obtained from studies done by Copperweld are only applicable to Copper Clad Steel manufactured by Copperweld. Due to proprietary process used to produce the wire, the findings cannot be superimposed on any other copper-clad steel conductor.

254 Cotton Mill Rd, Fayetteville, TN 37334. Tel. (931) 433 – 7177

July 26, 2011

This paper compiles several studies and analysis regarding the corrosion performance of buried Copperweld® Copper-Clad-Steel (CCS) conductors. These range from the early 1900's with the invention of Copperweld® through the present day with studies performed by independent parties as well as Copperweld Company in-house testing. The purpose is to present the available information so that prospective users of Copperweld® CCS wire and strand can evaluate the corrosion resistance and expected performance within their specific application and area. Copperweld uses oxygen free copper in the manufacture of Copperweld® wire and strand. The copper surface of CCS is expected to oxidize and turn color ranging from green (patination) to brown and black the same as any solid copper wire or strand when exposed to environmental stimuli. Corrosion on exposed steel at the cut tip or end of the wire is also expected. The question to be answered is if the corrosion on either material or the interface between the copper and steel (galvanic reaction) will result in degradation of the wire as to make it unsuitable for use as a grounding conductor.

The oldest known underground corrosion study of bimetallic material was performed in the early 1900s[1]. This study focused on the corrosion behavior of Copperweld® CCS underground rod as well as other materials such as Copper and galvanized steel ground rod. The National Bureau of Standards (NBS) conducted an extensive underground corrosion study that involves 36,500 specimens which include 333 varieties of ferrous, nonferrous, and protective coating materials buried in 128 test locations throughout U.S in 1910 - 1955.

The study summarizes the service life of a ground rod as following:

10 mils copper coating – acceptable for service life up to 40 years

13 mils copper coating – acceptable for service life up to 50 years

Similarly, the Naval Civil Engineering Laboratory in collaboration with the National Association of Corrosion Engineers conducted a 7-year program of testing metal rods for electrical grounding to determine the galvanic corrosion effect. The three metals tested were stainless clad steel, copper-bonded steel (CCS), and galvanized steel. The result on the ⅝" CCS ground rod was as expected. The copper surface of the CCS was

virtually free of corrosion and the steel core has corroded at the tip approximately 2 inches down the length of the rod.

Copperweld Corporation is the inventor and sole manufacturer of Copperweld® Copper-bonded ground rods and Copperweld® wire and strand since 1915. The corrosion behavior of a Copperweld® ground rod is similar to the corrosion on Copperweld® wire and strand conductor. Both materials consist of copper permanently bonded to a steel core. All Copperweld® 40% CCS has a copper thickness of 10% of the overall diameter. For example, Copperweld® 4THOUGHT™ has a configuration of 19 strands of 0.1055 inch wires. It means that each strand has a copper thickness of 10.55 mils. Based on the NBS study, 4THOUGHT™ will have at least a minimum service life of 40 years.

Copperweld has also conducted a 5-year study of buried bare 21% conductivity (copper thickness is 3% of the diameter) Copperweld® CCS in 10 different soil conditions in association with Southwest Research Institute[2]. The study reported 100% surface oxidation and various degrees of deterioration of the steel core as expected after 5 years. The exposed steel on the tip of the wire rusted and formed "scab", as shown in Figure 1. The rust appeared to "seal-off" the un-oxidized material from the corrosive medium. The maximum depth of corrosion was 70% of the wire diameter.



Figure 1: Example of Underground Corrosion of Copper Clad Steel

Although the copper surface oxidation was heavy, the samples showed no signs of pits or holes in the copper cladding. The copper thickness of a severely oxidized 5-year sample showed no discernable difference when compared to an un-oxidized control sample that was not subjected to the corrosive environment. The mechanical and resistance testing

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resulted in negligible differences between 5-year samples and the control samples. Thus, the oxidation had no discernable impact on the strength or electrical performance of the wire.

An accelerated corrosion study based on ASTM B117 was conducted on bare CCS and solid Copper wires to evaluate copper surface corrosion. The wires were exposed to salt fog spray for 504 hours. As a result, corrosion on the CCS copper surface showed no significant difference as compared to the corrosion of copper wire.



(a) Copper Clad Steel (b) Copper

Figure 2: Patination of Copper Surface after 504 hours exposure to Salt Fog Spray

In February 2011, three separate sample strands of Copper Clad Steel were un-earthed and cut out from a substation built in Louisville, KY. The conductors were 40% conductivity, Low Carbon Steel, Dead Soft Annealed, 7 No. 5 (231,613 circular mil) and were installed in 1962.

Table 1: Physical properties of the three strands of Copperweld® conductor that had been buried underground for 48 years in a Kentucky substation

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			Strand 1	Strand 2	Strand 3
Conductor Type			40% Low Carbon Annealed		
Conductor Size			7 No. 5		
Cross Section Area		in^2	0.1819	0.1819	0.1819
Diameter of Single end		*inch*	0.1819	0.1819	0.1819
Diameter of Conductor		*inch*	0.5457	0.5457	0.5457
Copper Thickness	Min	*inch*	0.0142	0.0114	0.0134
	Max	*inch*	0.0213	0.0209	0.01975
% Concentricity			83.30%	77.30%	83.90%
Depth of corrosion	Min	*inch*	0.004	0.028	0.111
	Max	*inch*	0.781	0.859	0.484

The 1962 conductors were manufactured by Copperweld with a nominal copper thickness of 10% of its diameter. Figure 3 shows the copper thickness ranges from 11.4 – 21.3 mils and the concentricity of the conductor averaged at 81.5%. Current manufacturing improvements yield concentricity of copper thickness above 85%.

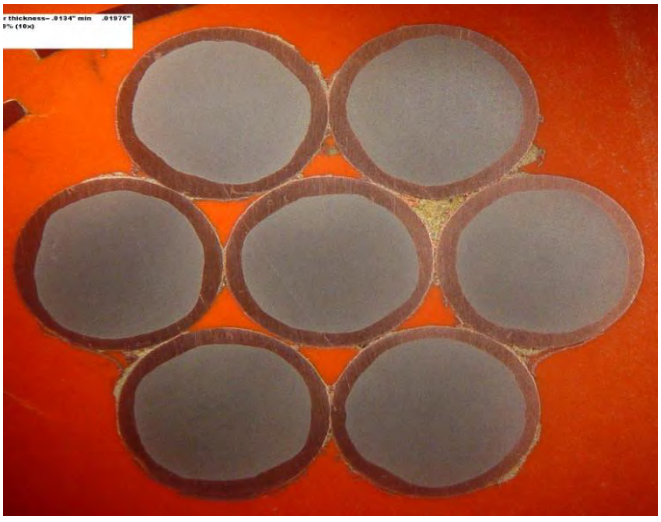


Figure 3: Copperweld® 40% LC DSA 7 No. 5 manufactured in 1962

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Figure 4a shows no visible corrosion observed other than oxidation and patination on the copper surface. At the ends of the wires, the corrosion occurred in the form of steel rust. The maximum depth of the corrosion is 0.859 inch with an average of 0.382 inch, as shown in Figure 4b.



Figure 4a: There is no visible corrosion between the copper and steel on all wires obtained from the substation in Kentucky.



Figure 4b: Corrosion occurred at the ends of the wires. Maximum penetration depth is 0.859 inch.

From all the corrosion studies above, there have not been reported or observed any galvanic corrosion at the interface of copper and steel. The process of cladding for

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Copperweld® ensures a metallurgical bond between the two metals. That metallurgical bond prevents any moisture from penetrating between the two metals precluding the corrosion process. Any propagation of corrosion on an area of exposed steel averages two times the diameter of the wire then stops. The corrosion rate of the copper surface is equivalent to that observed on standard solid copper wire and strand. Based on the results of these studies, it can be summarized that CCS can be expected to have a 50 plus year service life as buried grounding conductors.

REFERENCES:

1. Rempe, Chris. 7 July 2003. "A Technical Report on the Service Life of Ground Rod Electrodes".
2. Fox, Dustin, Belado, Chris, and Brossia, Sean. 23 September 2009. "The Effect of Corrosion on Tracer Wire with a Copper Clad Steel Center Conductor".

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Report ID: PL-03027 REP1
Revision: 0 Issued: 2020-04-15

Copper and CCS Wire Withstand Current and Fusing Current Tests

Copperweld Bimetallics, LLC



The Power of Trust. **The Future of Energy.**

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REPORT OF PERFORMANCE

CLIENT	Copperweld Bimetallics,LLC. 5141 Virginia Way, Suite 410 Brentwood, TN, United States 37027
TEST OBJECTS	Copper Clad Steel (CCS) Wires Manufacturer: Copperweld Bimetallics,LLC. Types: Scorpius Prototypes Part Nos.: 61 x 072 7 x 080 Condition: New Copper Conductor Manufacturer: Encore Wire Types: #4/0 AWG (19 strand) CU #6 AWG (single strand) CU Condition: New
TESTED BY	Powertech Labs Inc. 12388 - 88th Ave, Surrey, BC Canada V3W 7R7 www.powertechlabs.com
TEST DATE	2020-01-24 to 2020-01-25
TEST SPECIFICATION	Client Specified, with reference to IEEE Std 80-2013 and IEEE Std 837-2014

Powertech Labs Inc. does not accept any liability for any damages resulting from the use of this report. The results relate only to the item tested, and it is the responsibility of the manufacturer to maintain conformity of any object having the same designations. Information regarding the estimated measurement uncertainty is available upon request. The test report shall not be reproduced except in full, without written approval of Powertech Labs Inc.

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1 INTRODUCTION

At the request of Copperweld Bimetallics,LLC., withstand current and fusing current tests were performed on standard copper and copper clad steel (CCS) wires in accordance with specifications and procedures provided by the client. Reference was made to IEEE Std 80-2013 and IEEE Std 837-2014 as guides for determining current levels and durations for the tests.

The High Power Lab is accredited by the Standards Council of Canada to ISO 17025 for short-circuit testing.

2 TEST OBJECT INFORMATION

The test objects were identified by the client as follows:

Copper Clad Steel Wires (CCS)

Manufacturer:	Copperweld Bimetallics,LLC.
Types:	Scorpius Prototypes
Part Nos.:	61 x 072
	7 x 080
Condition:	New

Copper Conductor

Manufacturer:	Encore Wire
Types:	4/0 AWG (19 strand) CU
	#6 AWG (single strand) CU
Condition:	New

Conductor sample diameters and dc resistance values were measured by the laboratory before testing, as presented in Table 1.

3 GENERAL INFORMATION

3.1 Purpose

The purpose of the tests is to identify the current limits at short durations for standard copper and Copperweld CCS grounding wire products, and to determine if these products meet the applicable requirements of the referenced Standards.

3.2 Witnesses

Name	Company
Jeff Jordan	Copperweld Bimetallics,LLC.
Lora Aboulmouna	Copperweld Bimetallics,LLC.
Jason Smolko	Copperweld Bimetallics,LLC.
Ryan Hale	Copperweld Bimetallics,LLC.

3.3 Tests Performed

Test Standards/Specifications:

Withstand current tests were performed as requested by the client, with reference to the following Standards to determine the test levels:

IEEE Std 80-2013, Table 6 – Specification for the ultimate current carrying capacity of copper grounding cables using symmetrical current.

IEEE Std 837-2014, Clause 7.2 and Table 3 – Electromagnetic force (EMF) test

4 SHORT-CIRCUIT CURRENT TESTS

General Information:

Standard	Client's Specification, with reference to IEEE Std 80-2013 and IEEE Std 837-2014
Test Dates	2020-01-24 to 2020-01-25
Test Leader	Chris Morton

Environmental Conditions:

Ambient temperature	(7 – 9) °C
Relative Humidity	(95 – 99) %

Test Conditions:

Samples were tested in a covered test cell which was open on one side to the outdoor ambient conditions. During each test, one sample was connected horizontally between the laboratory source bus and ground bus, at a bus spacing of 48 inches, as shown in Figures 30 through 33. The samples were terminated using Burndy mechanical connectors, as shown in Figures 34 and 35. The length of each wire sample was the minimum length required to span the distance between the buses, and each sample was at approximately right angles (90°) to both the source and ground bus. Each sample was suspended in free air approximately 46 inches above the floor of the test cell. The temperature of the sample at the start of each test was the natural outdoor ambient temperature of the laboratory, except for tests performed to IEEE 837, where the sample was allowed to cool to less than 100 °C before the second shot.

All tests were performed at a power frequency of 60 Hz using the test circuit shown in Figure 1. Current was initiated by energizing a current limited source that was calibrated to provide the target current through the circuit. The rms current, current symmetry and duration of each test were specified by the client.

The test current was measured using a 300 kA_{peak} rated Rogowski coil (Powertech ID № 39444). The expanded uncertainty of the current measuring system is estimated as 2% (k=2).

Test Results:

The results of the tests are provided in Tables 2 through 5. Current and voltage waveforms for each test are provided in Figures 2 through 29.

The Encore #4/0 AWG Cu wire did not withstand the I^2t calculated from the current and duration specified in IEEE 80, Table 6, for a 500 ms duration (44 kA_{rms}). It was capable of carrying a maximum of 92% of this I^2t value without fusing.

The Encore #4/0 AWG Cu wire did not withstand the EMF current specified in IEEE 837, Table 3 (47 kA_{rms}). It was capable of carrying a maximum of 91% of this current value without failing.

The Copperweld Scorpius CCS 61 x 072 conductor exceeded the 500 ms rms withstand current requirement of IEEE 80, Table 6, and met the EMF current requirements of IEEE 837, Table 3, for a 4/0 conductor.

For the #6 AWG Cu conductor size the Standards did not have current values specified, so these were calculated using Equation (45) from IEEE 80 and Equation (C.1) from IEEE 837. The calculations are presented in Appendix D.

Both the Copperweld Scorpius CCS 7 x 080 conductor and the Encore #6 AWG Cu conductor met the 500 ms rms withstand current requirement of IEEE 80, Table 6 (5.29 kA_{rms}), and the EMF current requirements of IEEE 837, Table 3 (5.81 kA_{rms}), for a #6 AWG Cu conductor.

APPENDIX A – FUSING CURRENT TEST CIRCUIT AND DATA

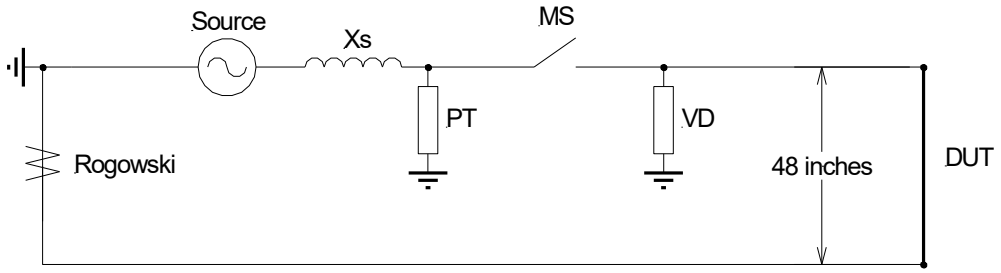


Figure 1: Test circuit schematic for all tests.

Notes:

1. X_S – Source current limiting reactance
2. MS – Making Switch
3. VD – Voltage measurement
4. Rogowski – Current measurement
5. DUT – Device Under Test

Table 1: Strand diameter and dc resistance measurements of sample conductors.

Wire Sample No.	Type	Strand Diameter [1] (in)		Conductor Diameter	Dc Resistance at 20°C
#		1	2	(in)	(μΩ/ft)
1	Encore Wire, 4/0 AWG, 19 strand CU	0.122	0.079	0.492	4.28
2	Encore Wire, 4/0 AWG, 19 strand CU	0.118	0.080	0.501	4.10
3	Encore Wire, 4/0 AWG, 19 strand CU	0.109	0.074	0.495	4.23
4	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.075	0.498	3.98
5	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.079	0.489	4.43
6	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.075	0.490	4.17
7	Encore Wire, 4/0 AWG, 19 strand CU	0.101	0.075	0.489	4.18
8	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.074	0.491	4.15
9	Encore Wire, 4/0 AWG, 19 strand CU	0.106	0.082	0.490	3.97
10	Encore Wire, 4/0 AWG, 19 strand CU	0.105	0.079	0.493	3.73
11	Scorpius 61 x 072 CCS	0.056	---	0.646	6.83
12	Scorpius 61 x 072 CCS	0.058	---	0.649	6.60
13	Scorpius 61 x 072 CCS	0.068	---	0.641	6.60
14	Scorpius 61 x 072 CCS	0.056	---	0.639	6.73
15	Scorpius 61 x 072 CCS	0.067	---	0.646	6.62
16	Scorpius 61 x 072 CCS	0.059	---	0.630	6.53
17	Scorpius 61 x 072 CCS	0.056	---	0.642	6.73
18	Scorpius 61 x 072 CCS	0.067	---	0.637	6.62
19	Scorpius 61 x 072 CCS	0.064	---	0.641	6.85
20	Scorpius 61 x 072 CCS	0.059	---	0.633	6.83
21	Encore Wire, #6 AWG, single strand CU	0.152	---	0.152	33.3
22	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
23	Encore Wire, #6 AWG, single strand CU	0.158	---	0.158	33.2
24	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.4
25	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.3
26	Encore Wire, #6 AWG, single strand CU	0.148	---	0.148	33.6
27	Encore Wire, #6 AWG, single strand CU	0.155	---	0.155	33.3
28	Encore Wire, #6 AWG, single strand CU	0.146	---	0.146	33.1
29	Encore Wire, #6 AWG, single strand CU	0.153	---	0.153	33.2
30	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
31	Scorpius 7 x 080 CCS	0.072	---	0.215	46.3
32	Scorpius 7 x 080 CCS	0.069	---	0.226	45.9
33	Scorpius 7 x 080 CCS	0.065	---	0.220	46.2
34	Scorpius 7 x 080 CCS	0.071	---	0.218	46.4
35	Scorpius 7 x 080 CCS	0.073	---	0.212	46.1
36	Scorpius 7 x 080 CCS	0.065	---	0.216	46.3
37	Scorpius 7 x 080 CCS	0.070	---	0.211	46.1

Note:

[1] Encore 4/0 AWG CU conductor had two sizes of strands, all remaining conductors had one size of strands. Strand and conductor diameters were measured using a digital caliper with a resolution of 0.001 in.

Table 2: Summary of tests on Encore 4/0 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
1	1	Run to fusing	3.85	41.7	60.0	530	923	2	Y
2	2	Withstand	3.85	41.8	62.5	509	889	3	N
3-1	3	EMF (IEEE 837)	4.24	48.0	130	262	826	4	N
3-2	3	EMF (IEEE 837)	4.26	48.0	130	127	503	5	Y
4	4	EMF (IEEE 837)	4.25	48.0	130	260	823	6	Y
5-1	5	EMF (IEEE 837)	4.20	47.4	129	262	808	7	N
5-2	5	EMF (IEEE 837)	4.19	47.4	128	9.9	77	8	Y
6-1	6	EMF (IEEE 837)	3.93	42.6	116	263	662	9	N
6-2	6	EMF (IEEE 837)	3.91	42.6	116	262	654	10	N

Table 3: Summary of tests on Copperweld Scorpius 61 x 072 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
7	11	Run to fusing	3.84	41.7	59.6	673	1173	11	Y
8	12	Run to fusing	4.25	48.1	69.8	500	1157	12	Y
9	13	Run to fusing	4.21	47.5	68.9	508	1150	13	Y
10	14	Withstand	4.09	46.2	66.2	508	1089	14	N
11-1	15	EMF (IEEE 837)	4.21	47.6	129	262	803	15	N
11-2	15	EMF (IEEE 837)	4.20	47.7	129	262	803	16	N
12-1	16	EMF (IEEE 837)	4.21	47.6	129	254	784	17	N
12-2	16	EMF (IEEE 837)	4.19	47.4	128	254	767	18	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

Table 4: Summary of tests on Encore #6 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
13	21	Run to fusing	3.90	5.18	7.36	607	16.3	19	Y
14	23	Run to fusing	3.90	5.18	7.57	600	16.1	20	Y
15	24	Run to fusing	4.27	5.68	8.15	500	16.1	21	Y
16-1	25	EMF (IEEE 837)	3.77	5.86	16.2	262	13.9	22	N
16-2	25	EMF (IEEE 837)	3.77	5.86	16.1	262	13.9	23	N

Table 5: Summary of tests on Copperweld Scorpius 7 x 080 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
17	31	Withstand	3.88	5.16	7.44	858	22.9	24	N
18	32	Run to fusing	3.89	5.16	7.43	908	24.2	25	Y
19	33	Run to fusing	4.48	7.00	10.3	493	24.1	26	Y
20	34	Run to fusing	4.41	6.91	10.2	502	23.9	27	Y
21-1	35	EMF (IEEE 837)	3.81	5.91	16.3	262	14.0	28	N
21-2	35	EMF (IEEE 837)	3.80	5.92	16.2	262	13.8	29	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

APPENDIX B – WAVEFORMS

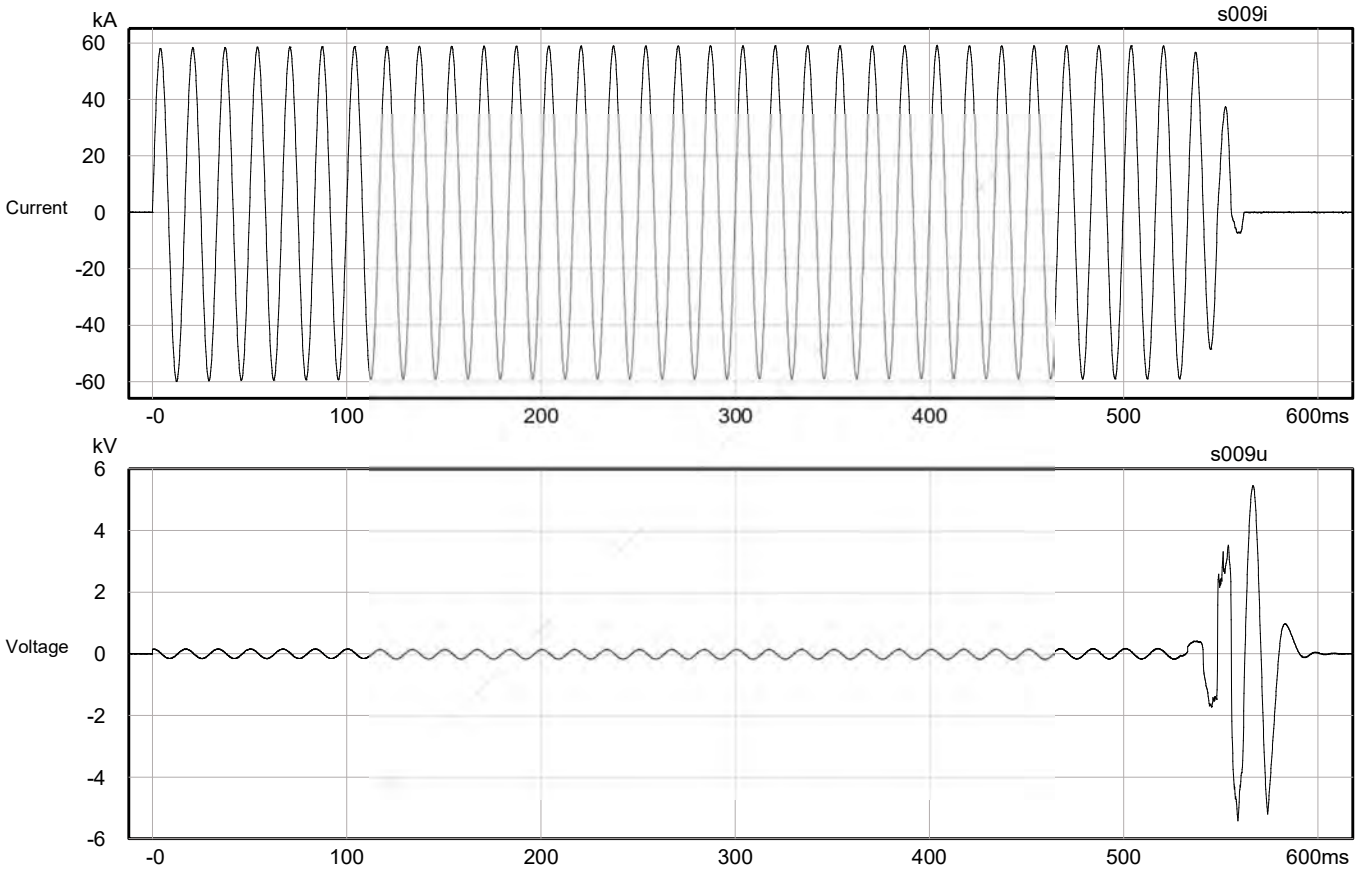


Figure 2: Waveforms for Test #1, Encore 4/0 AWG Sample 1.

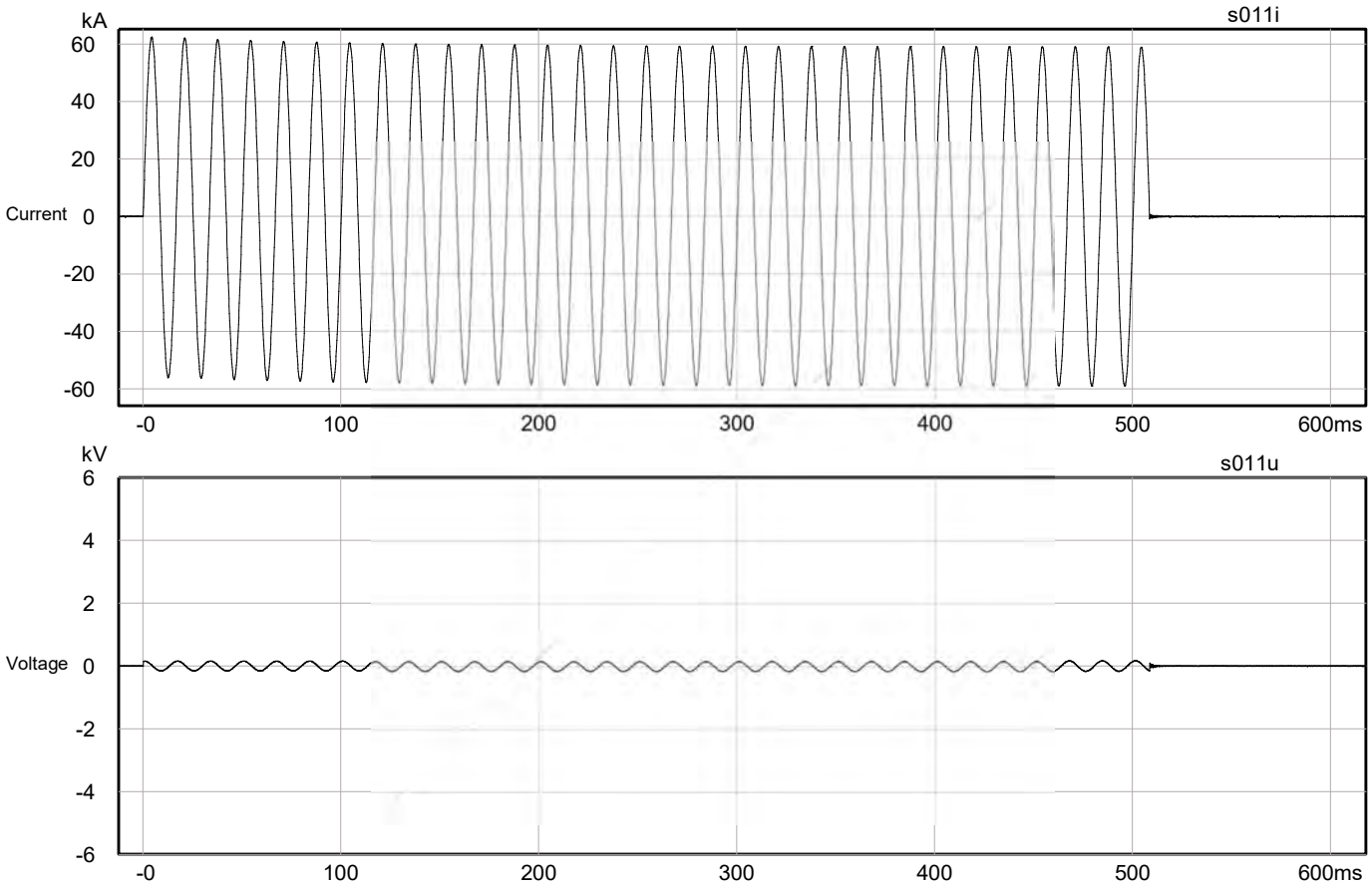


Figure 3: Waveforms for Test #2, Encore 4/0 AWG Sample 2.

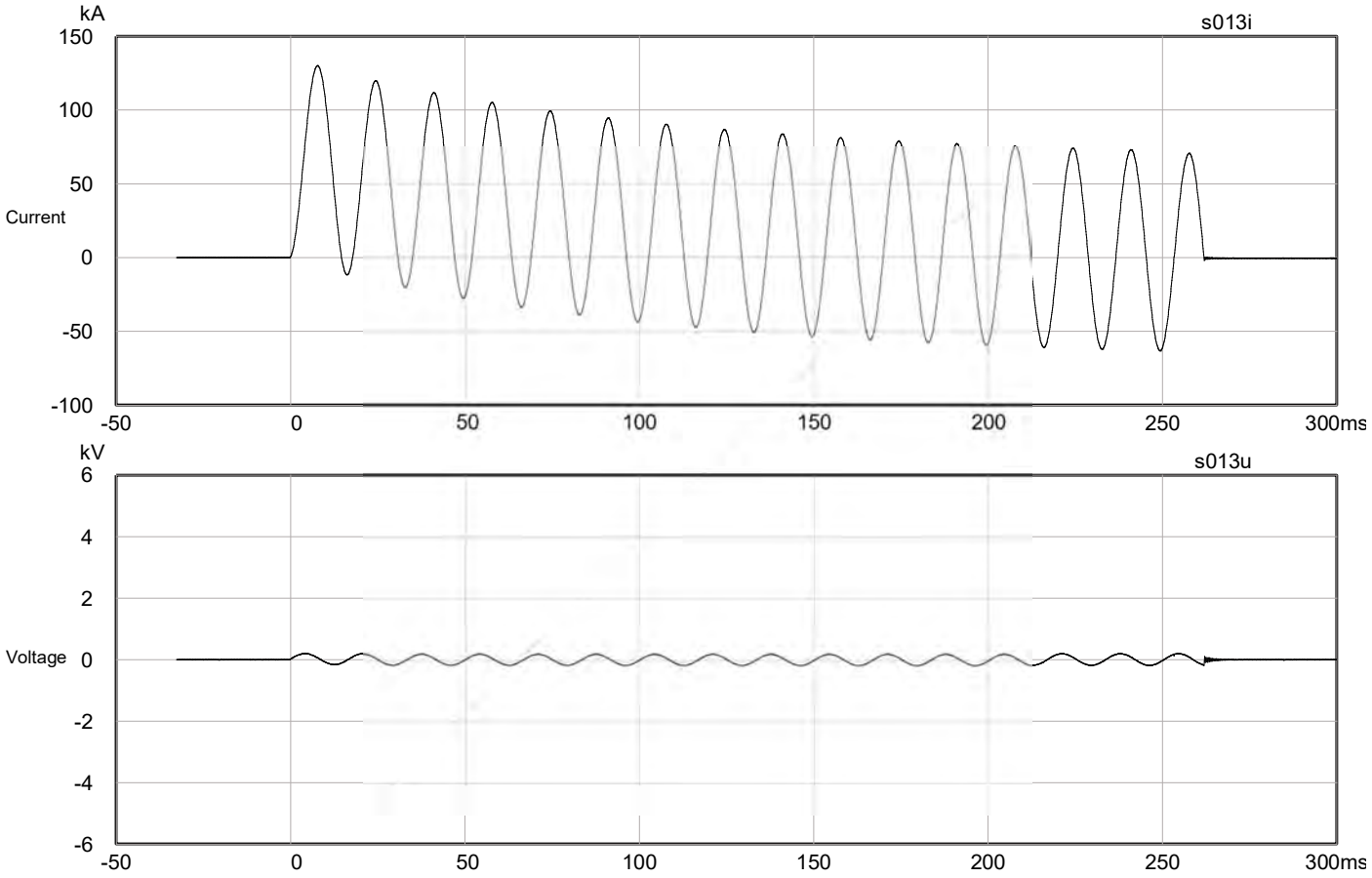


Figure 4: Waveforms for Test #3-1, Encore 4/0 AWG Sample 3.

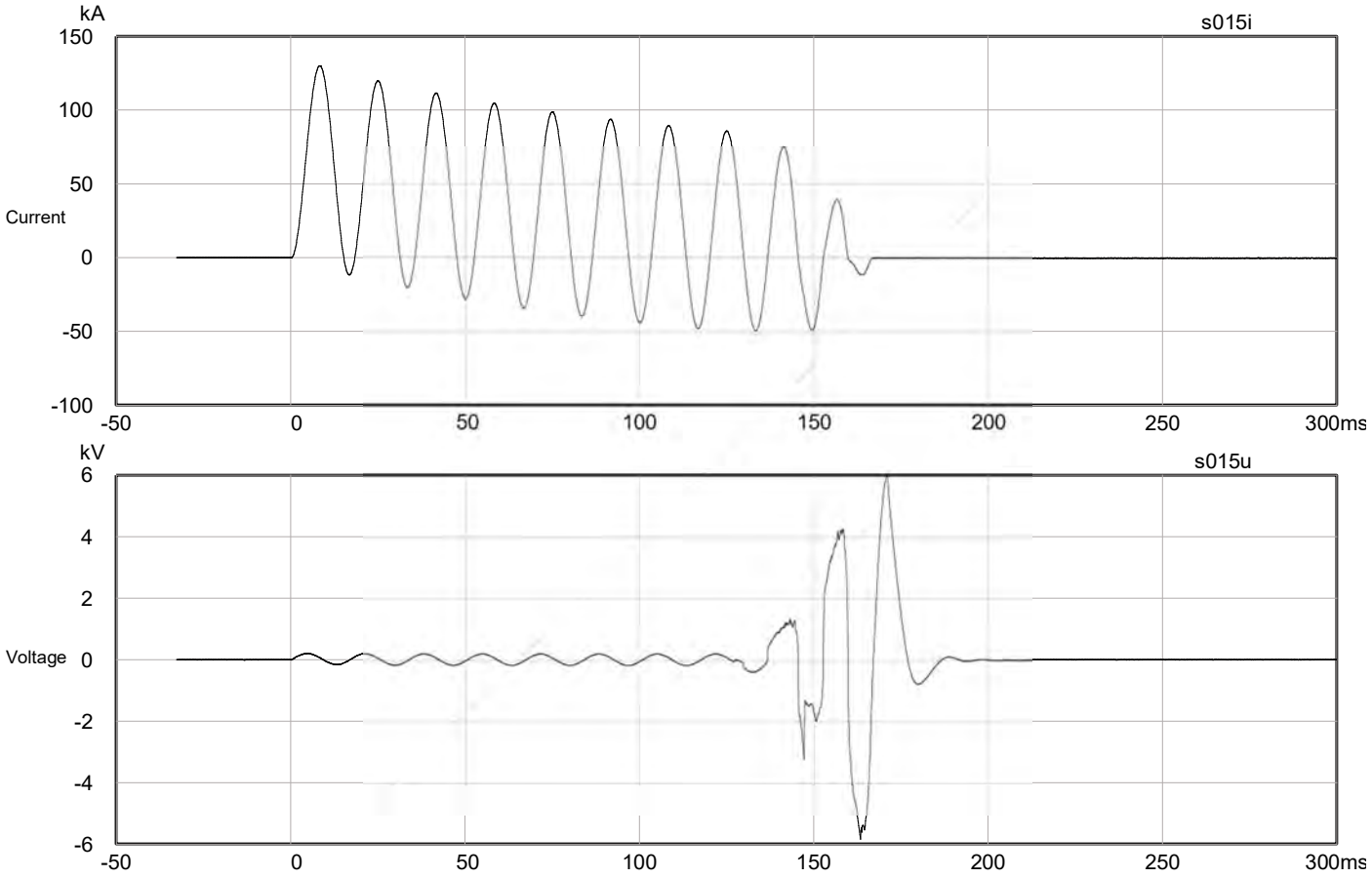


Figure 5: Waveforms for Test #3-2, Encore 4/0 AWG Sample 3.

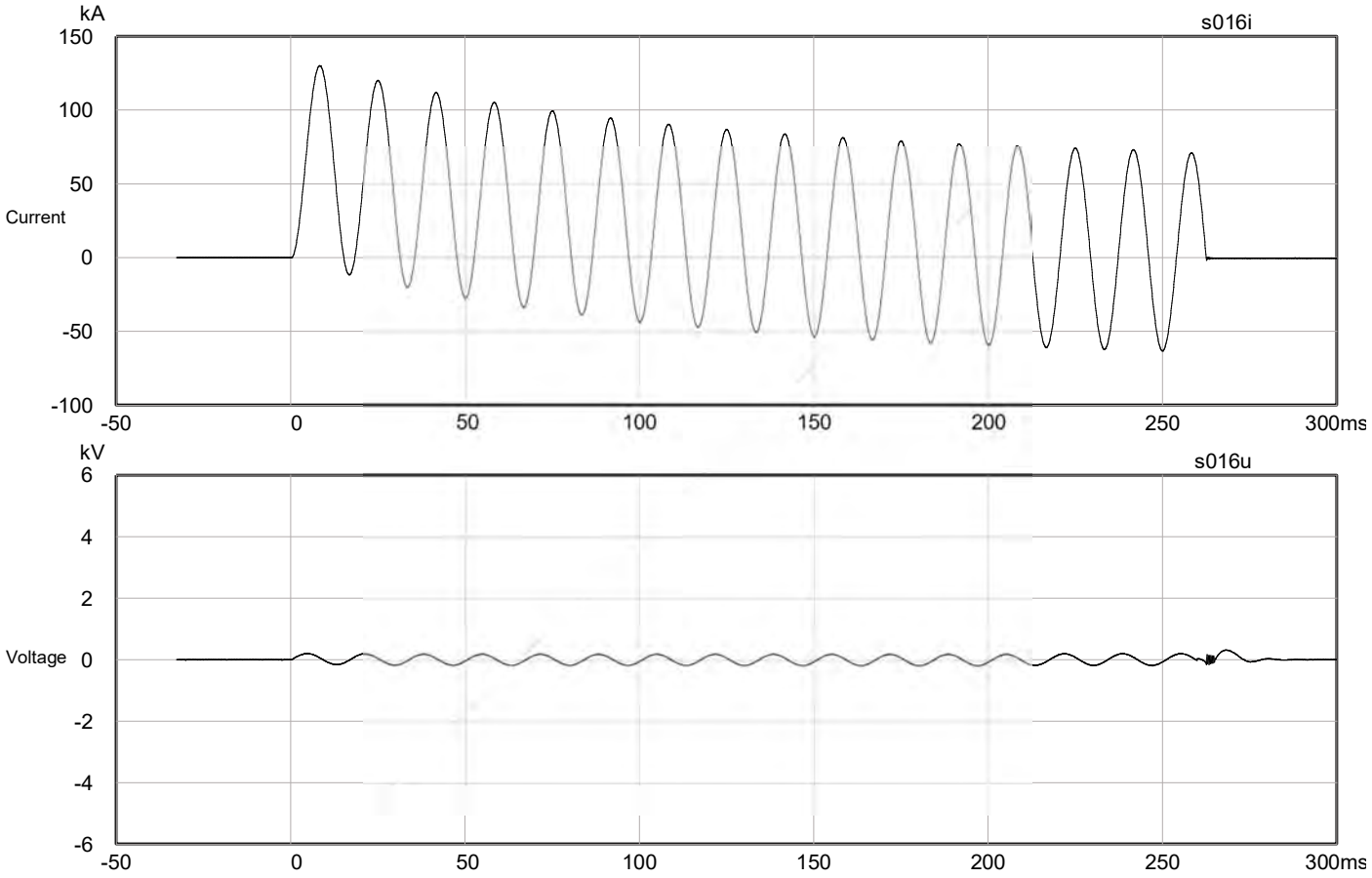


Figure 6: Waveforms for Test #4, Encore 4/0 AWG Sample 4.

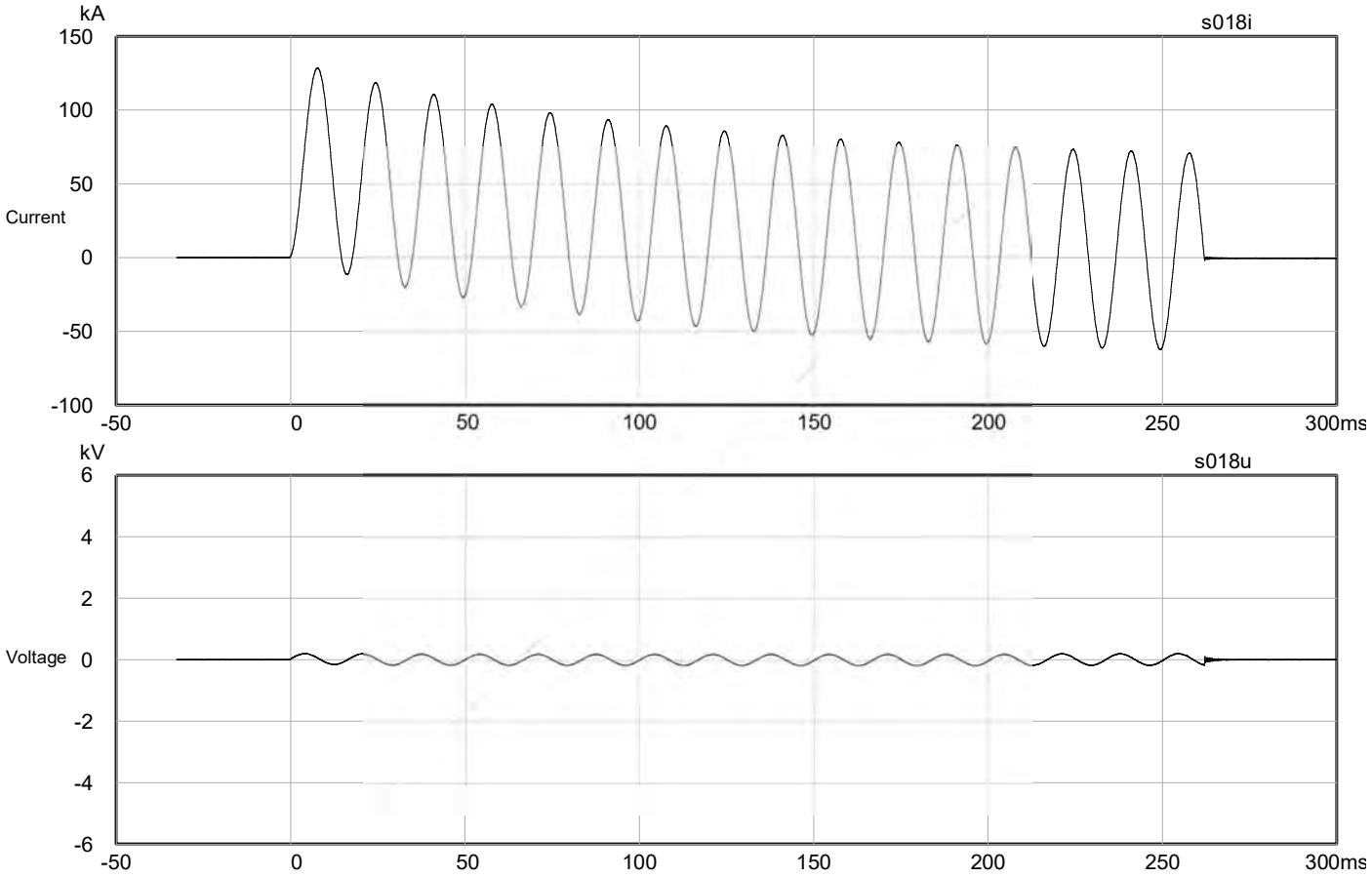


Figure 7: Waveforms for Test #5-1, Encore 4/0 AWG Sample 5.

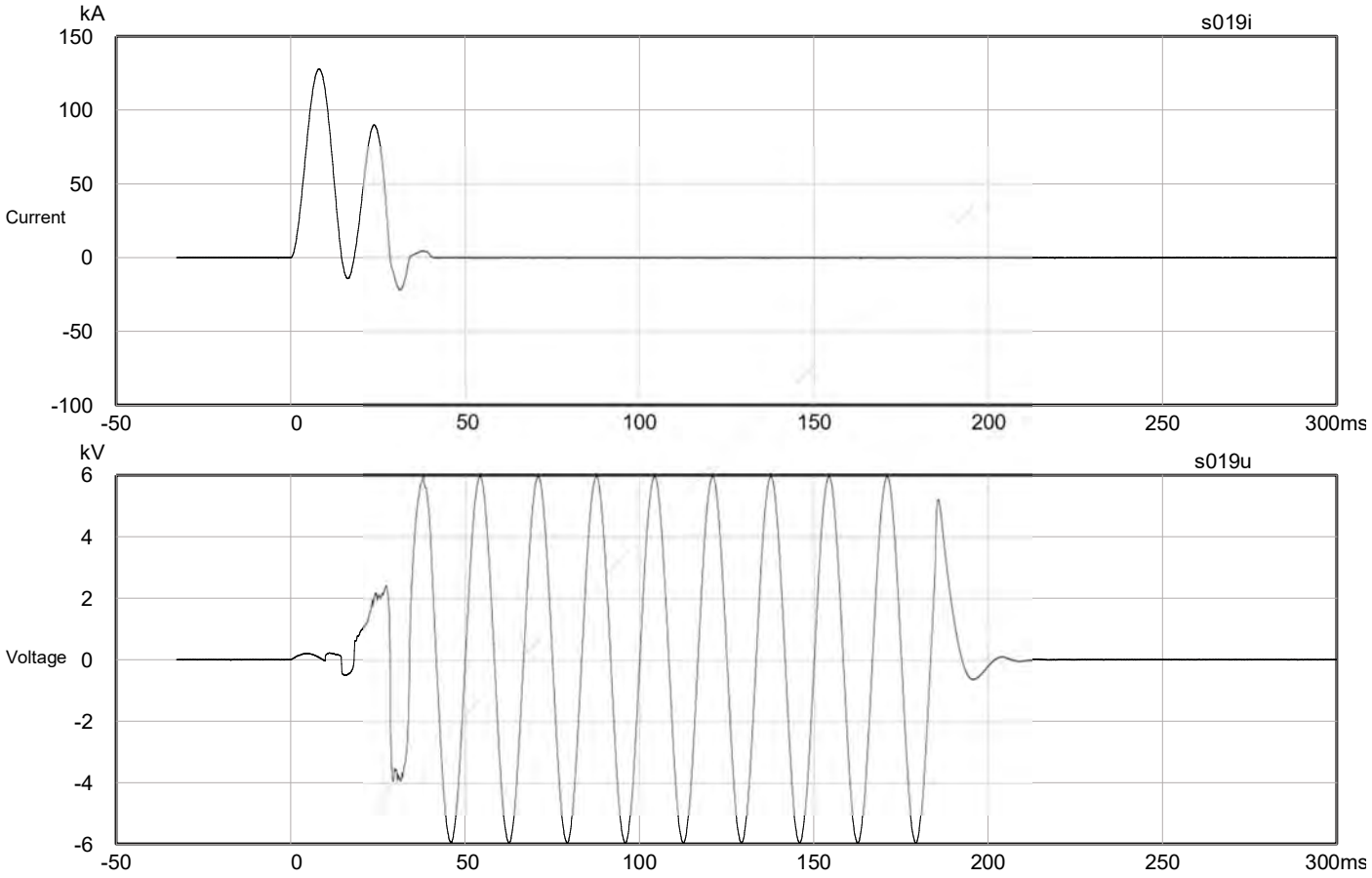


Figure 8: Waveforms for Test #5-2, Encore 4/0 AWG Sample 5.

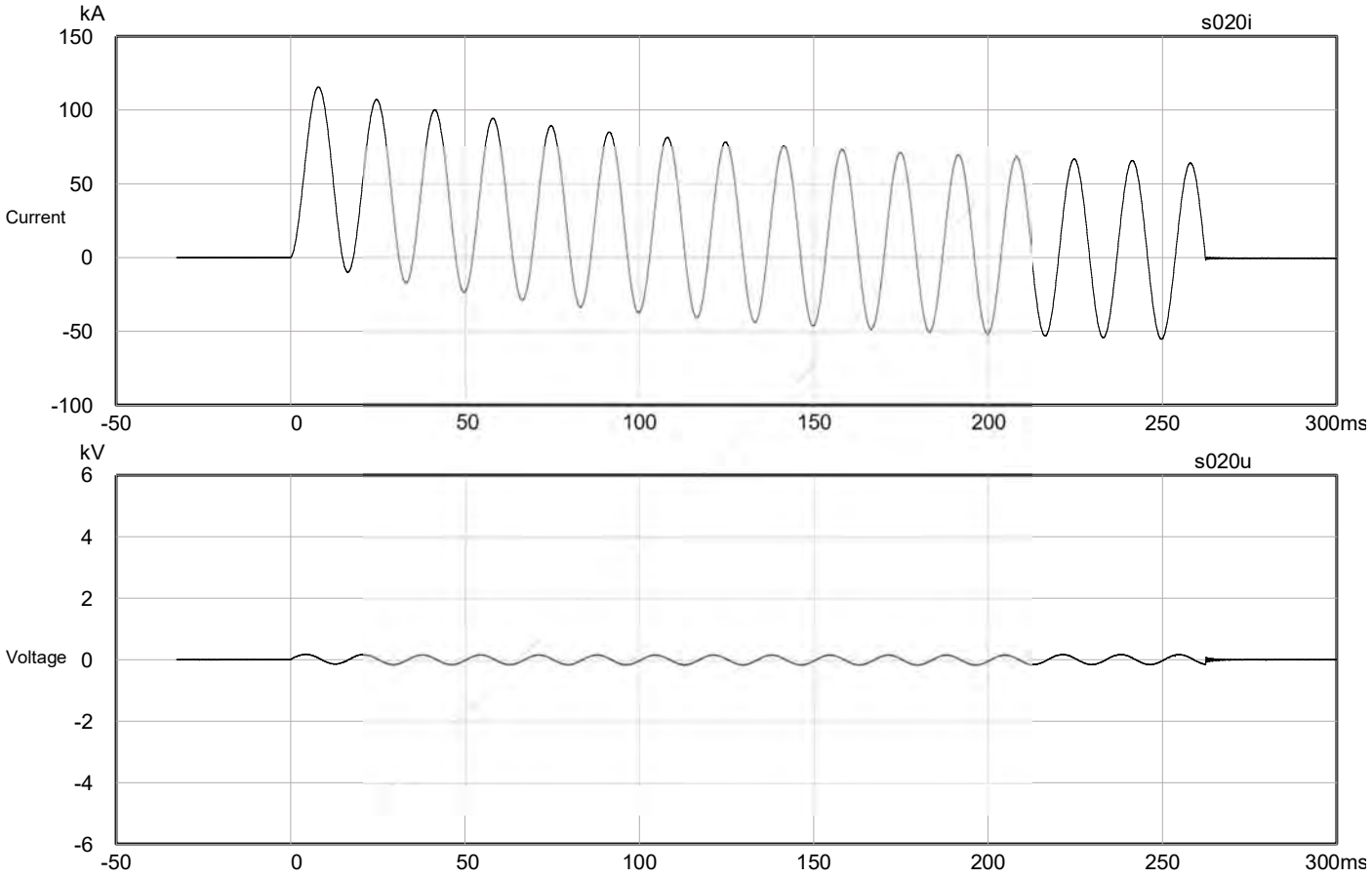


Figure 9: Waveforms for Test #6-1, Encore 4/0 AWG Sample 6.

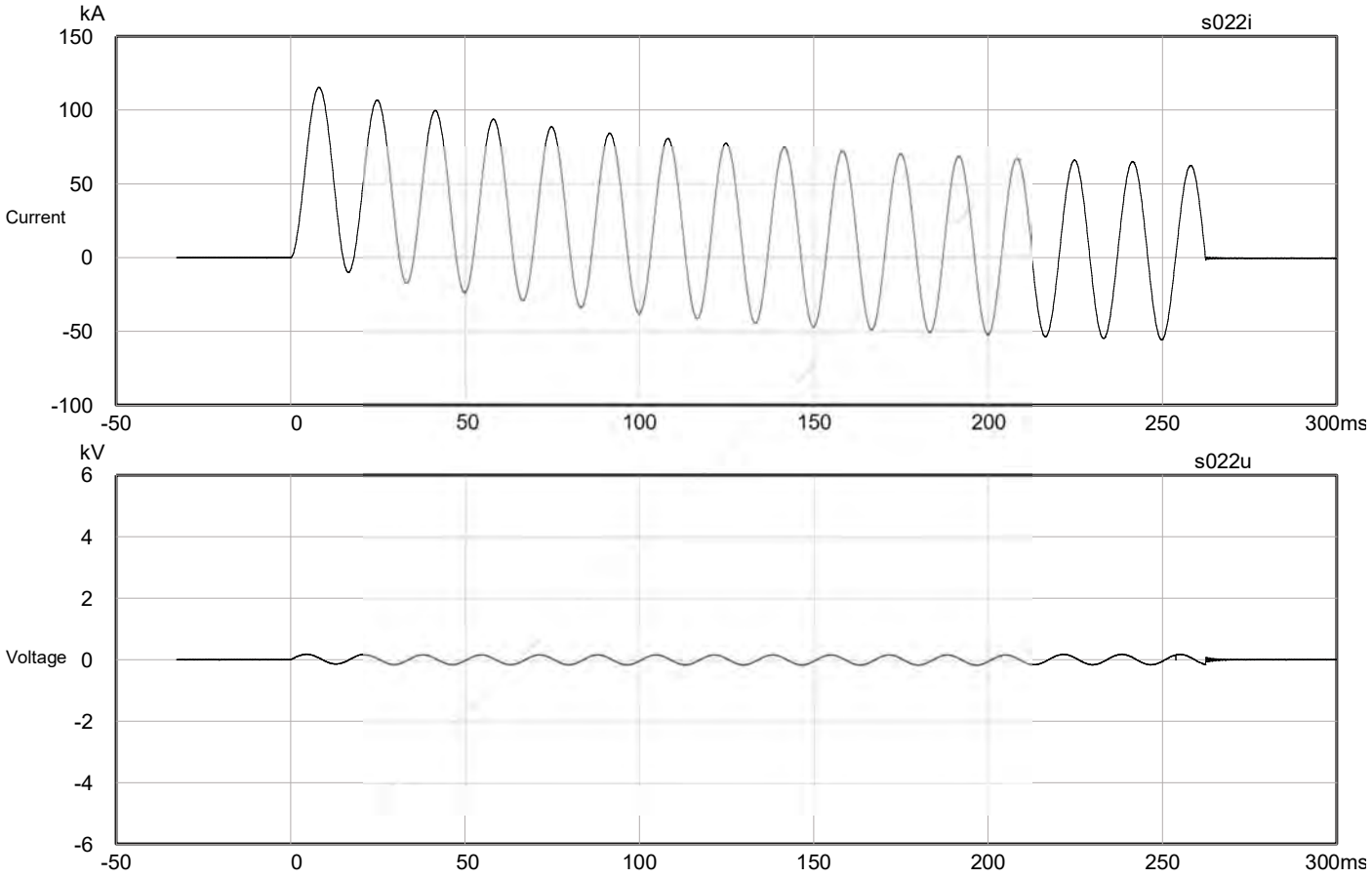


Figure 10: Waveforms for Test #6-2, Encore 4/0 AWG Sample 6.

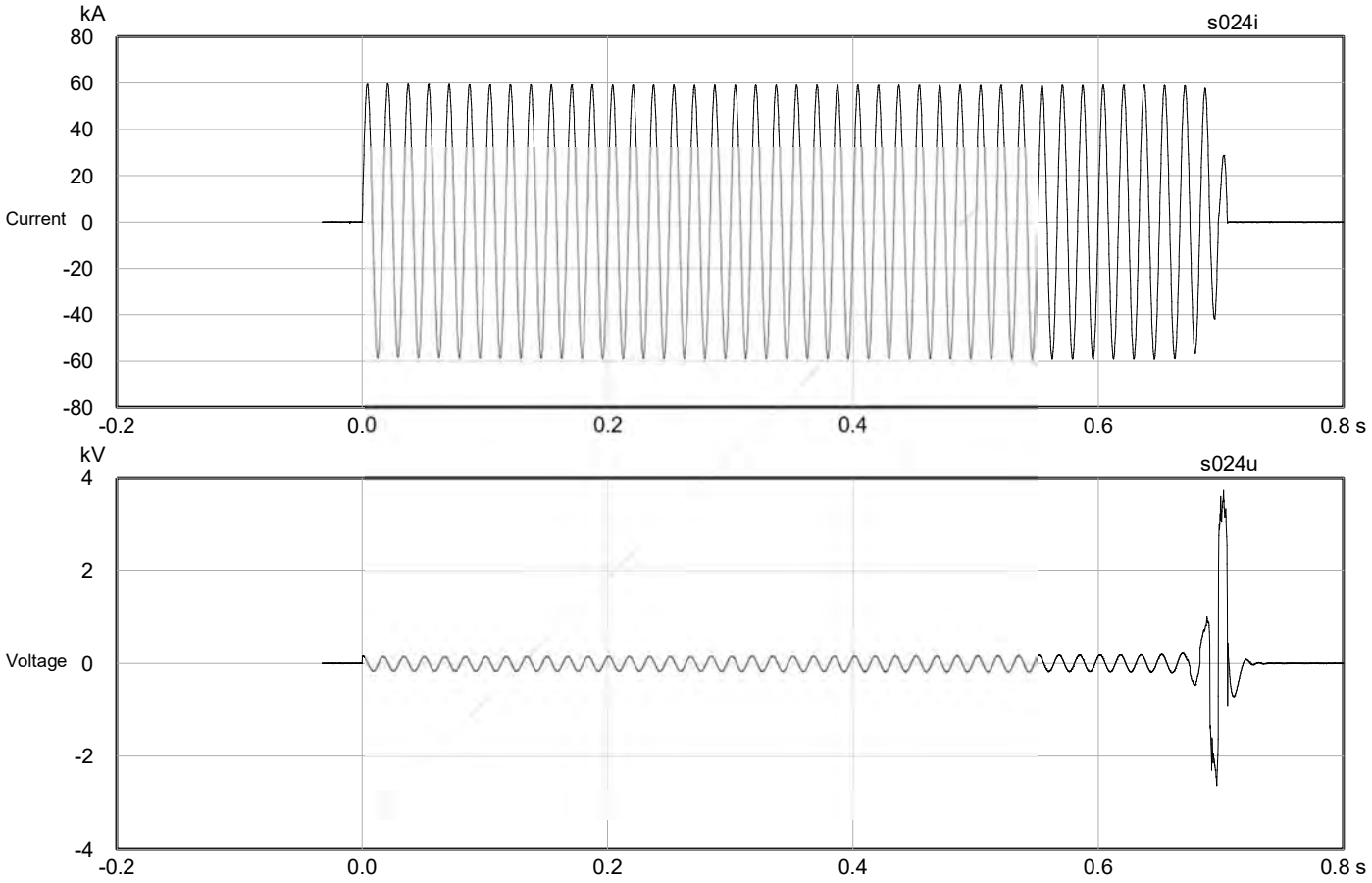


Figure 11: Waveforms for Test #7, Copperweld Scorpius 61 x 072 Sample 11.

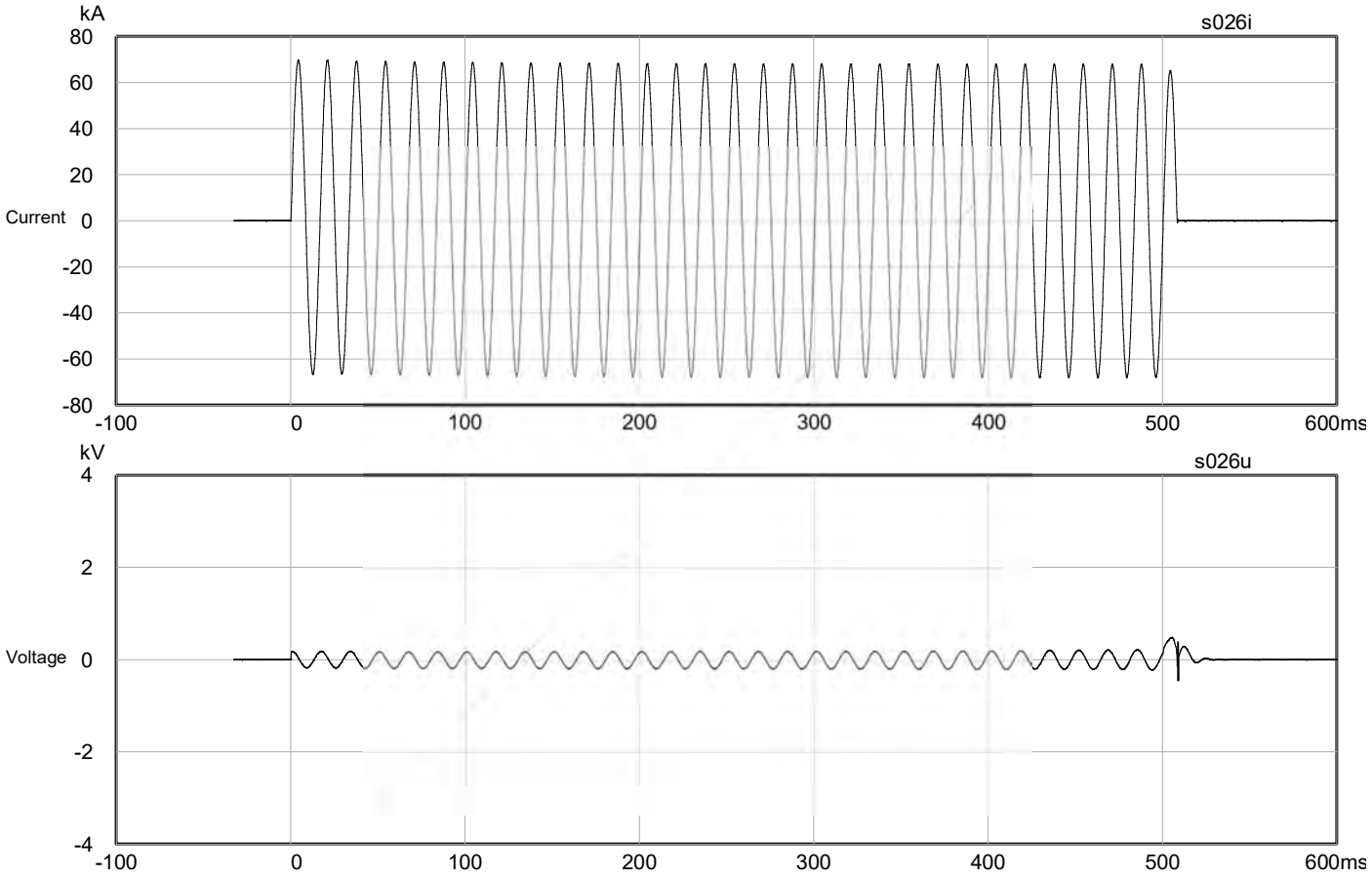


Figure 12: Waveforms for Test #6, Copperweld Scorpius 61 x 072 Sample 12.

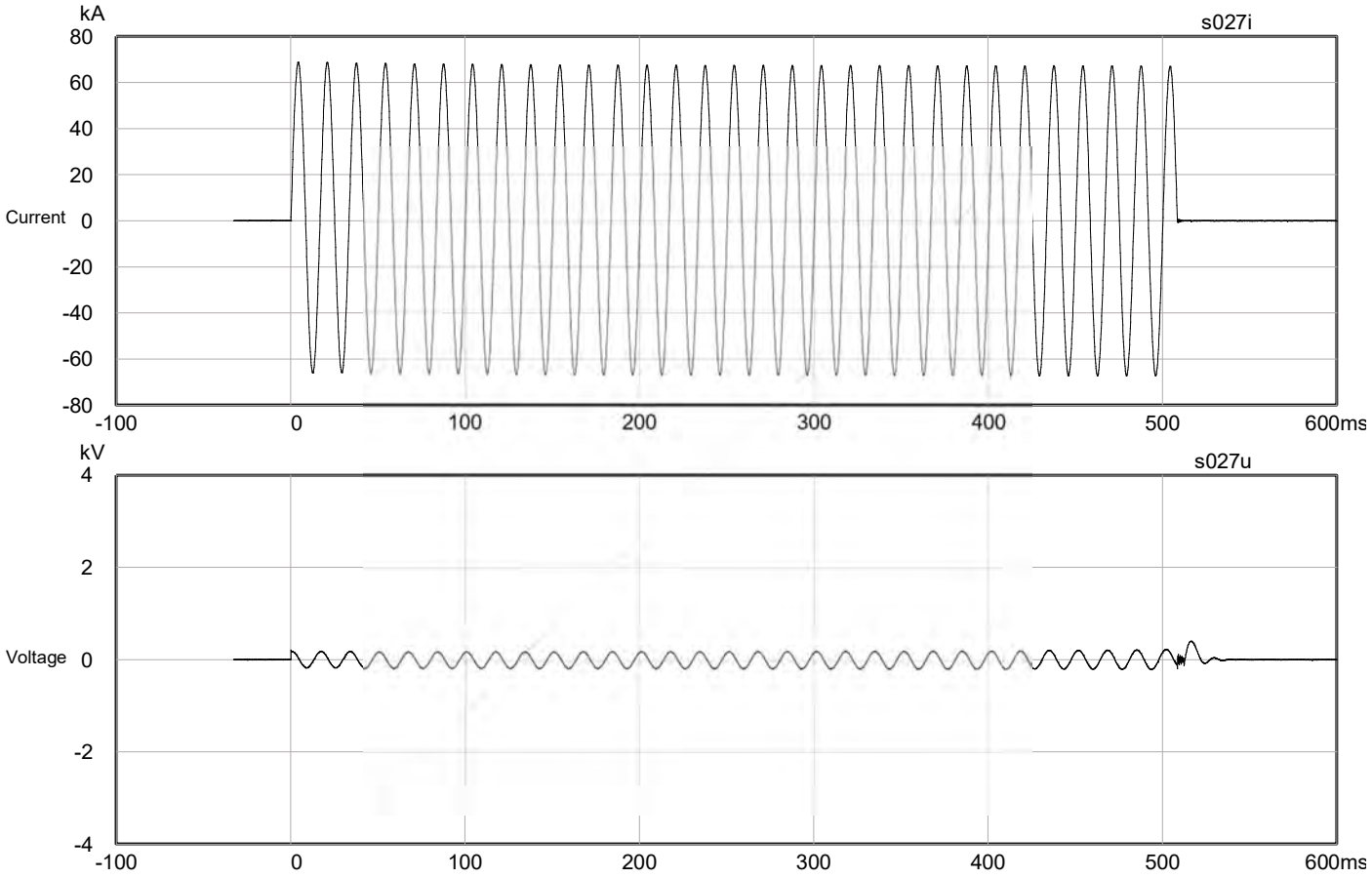


Figure 13: Waveforms for Test #9, Copperweld Scorpius 61 x 072 Sample 13.

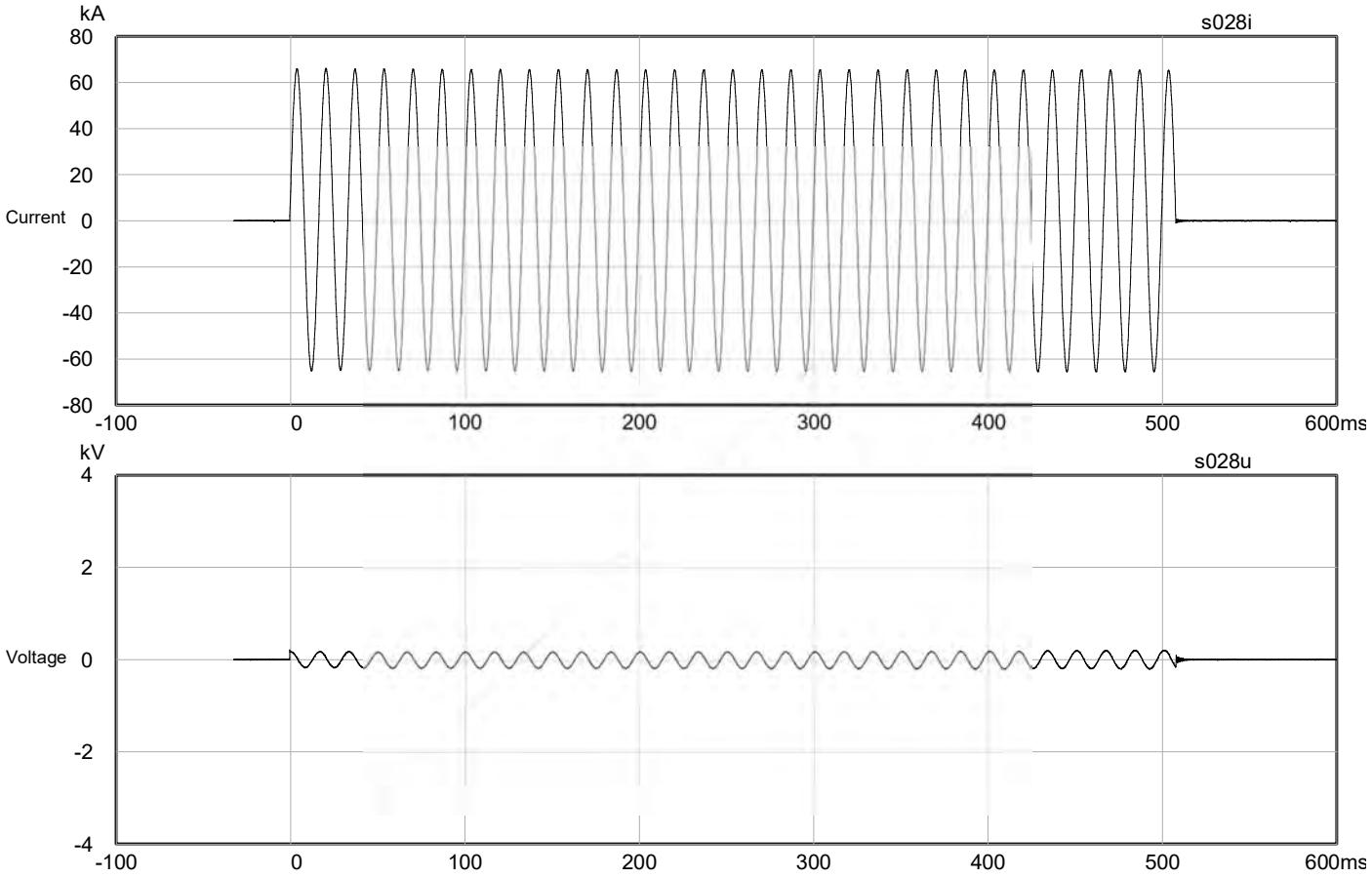


Figure 14: Waveforms for Test #10, Copperweld Scorpius 61 x 072 Sample 14.

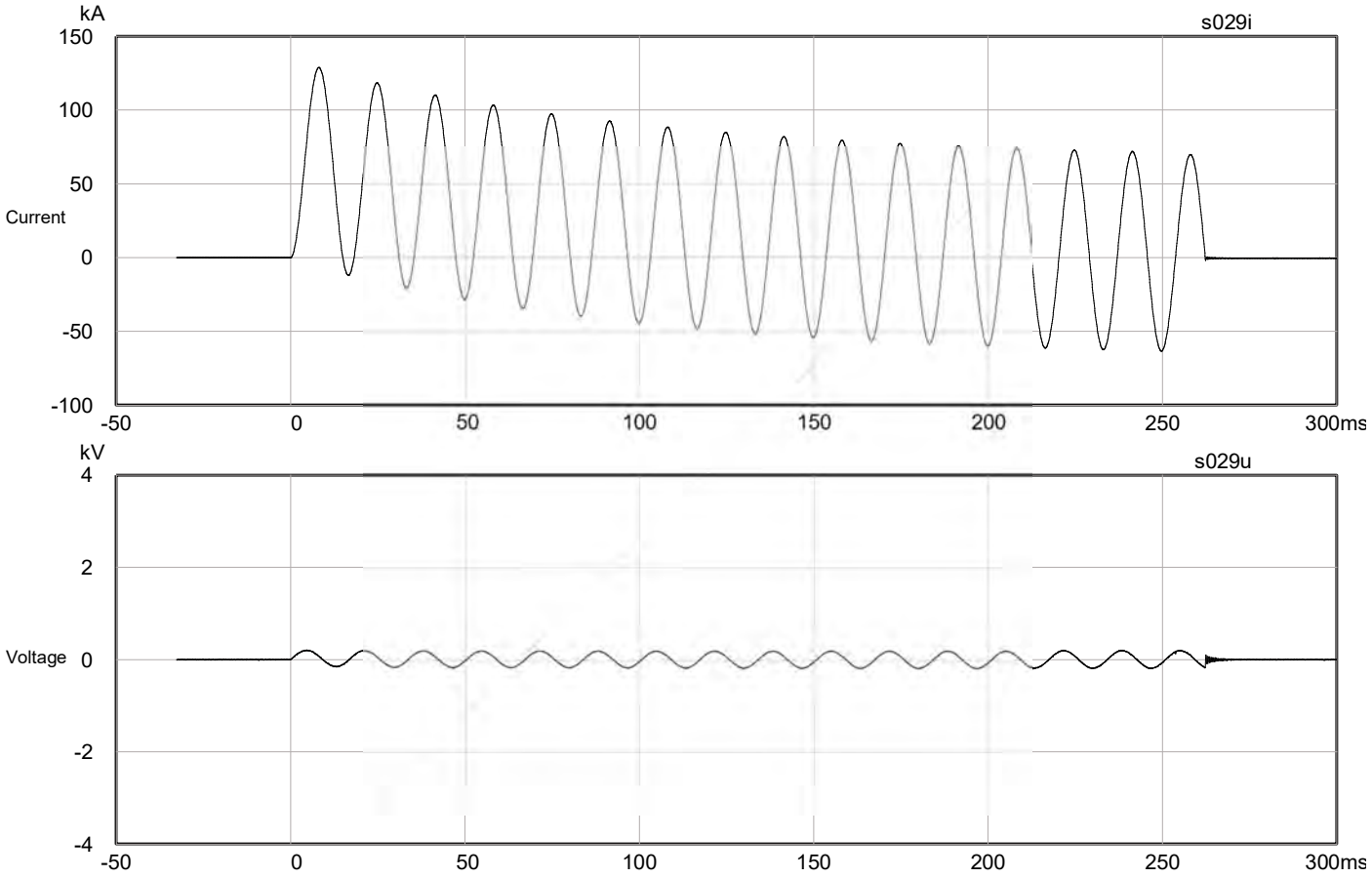


Figure 15: Waveforms for Test #11-1, Copperweld Scorpius 61 x 072 Sample 15.

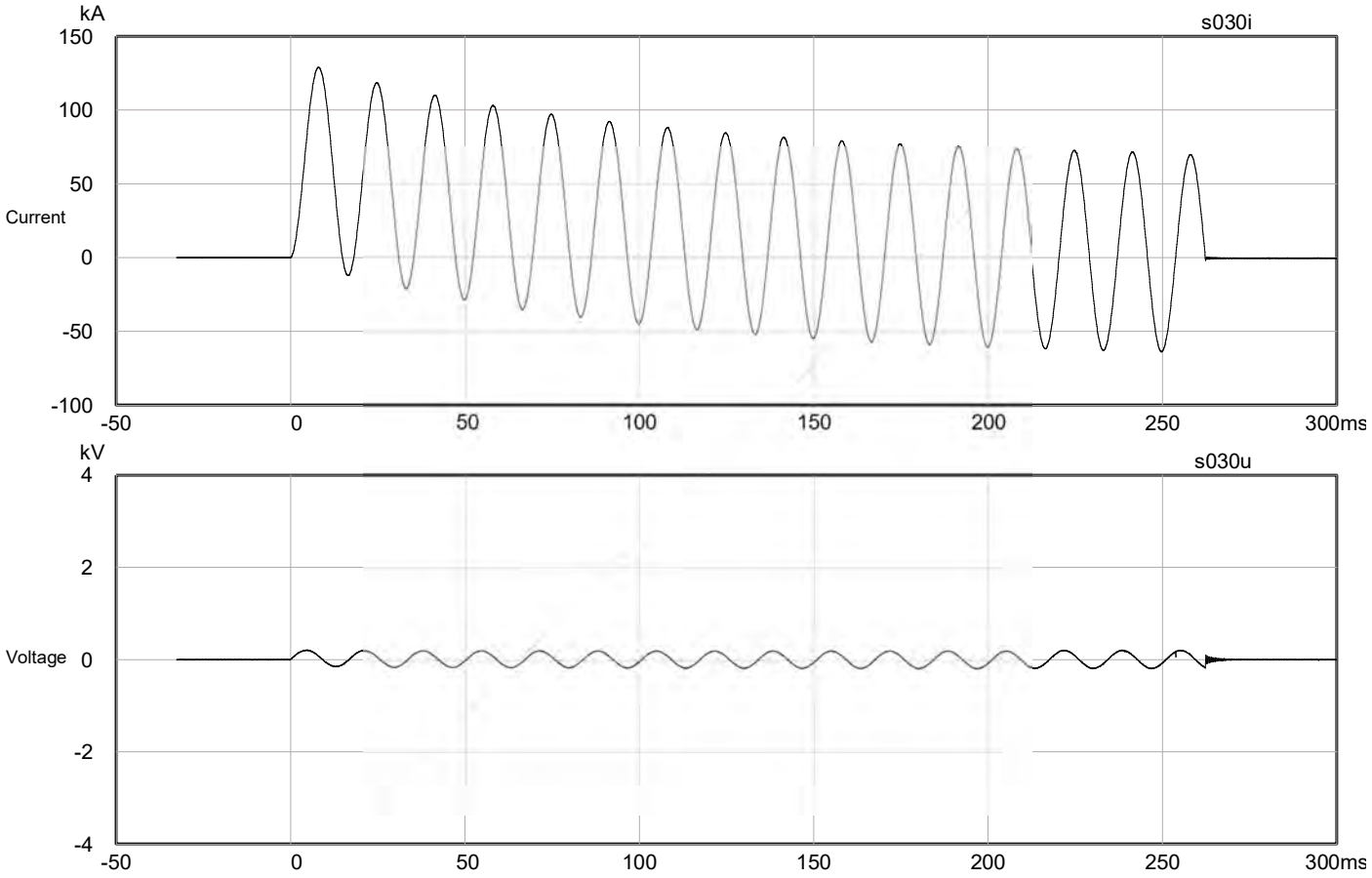


Figure 16: Waveforms for Test #11-2, Copperweld Scorpius 61 x 072 Sample 15.

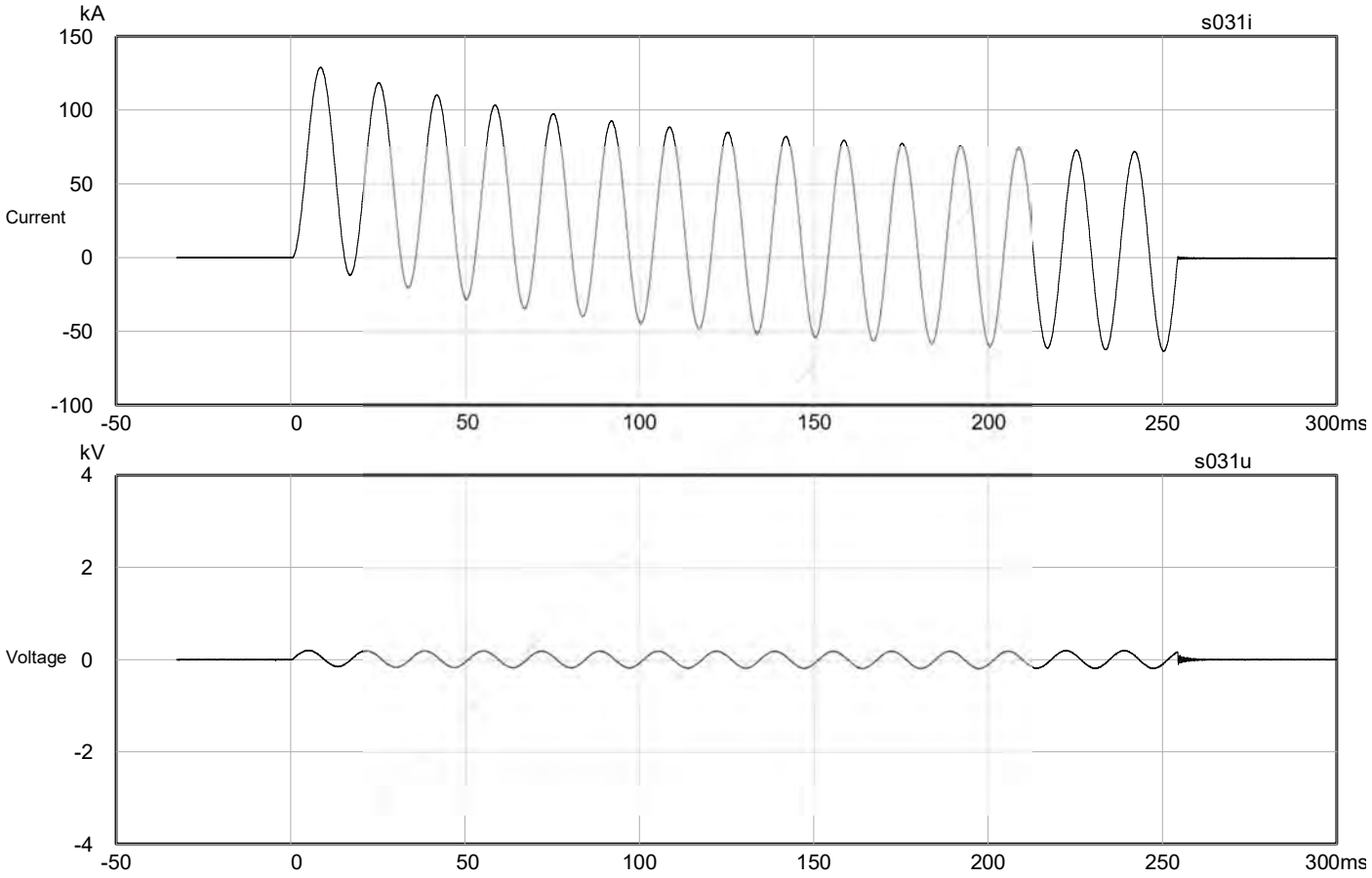


Figure 17: Waveforms for Test #12-1, Copperweld Scorpius 61 x 072 Sample 16.

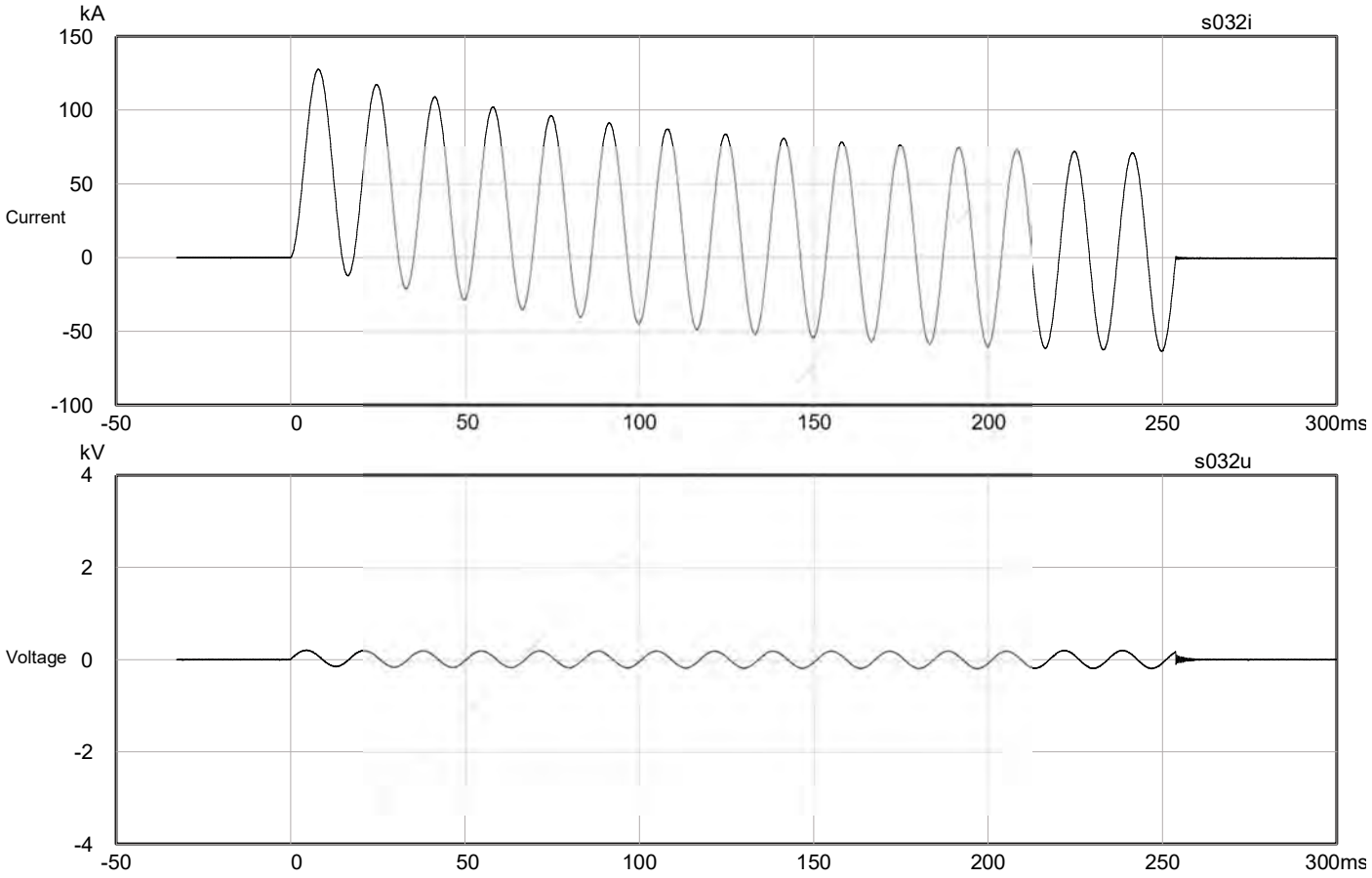


Figure 18: Waveforms for Test #12-2, Copperweld Scorpius 61 x 072 Sample 16.

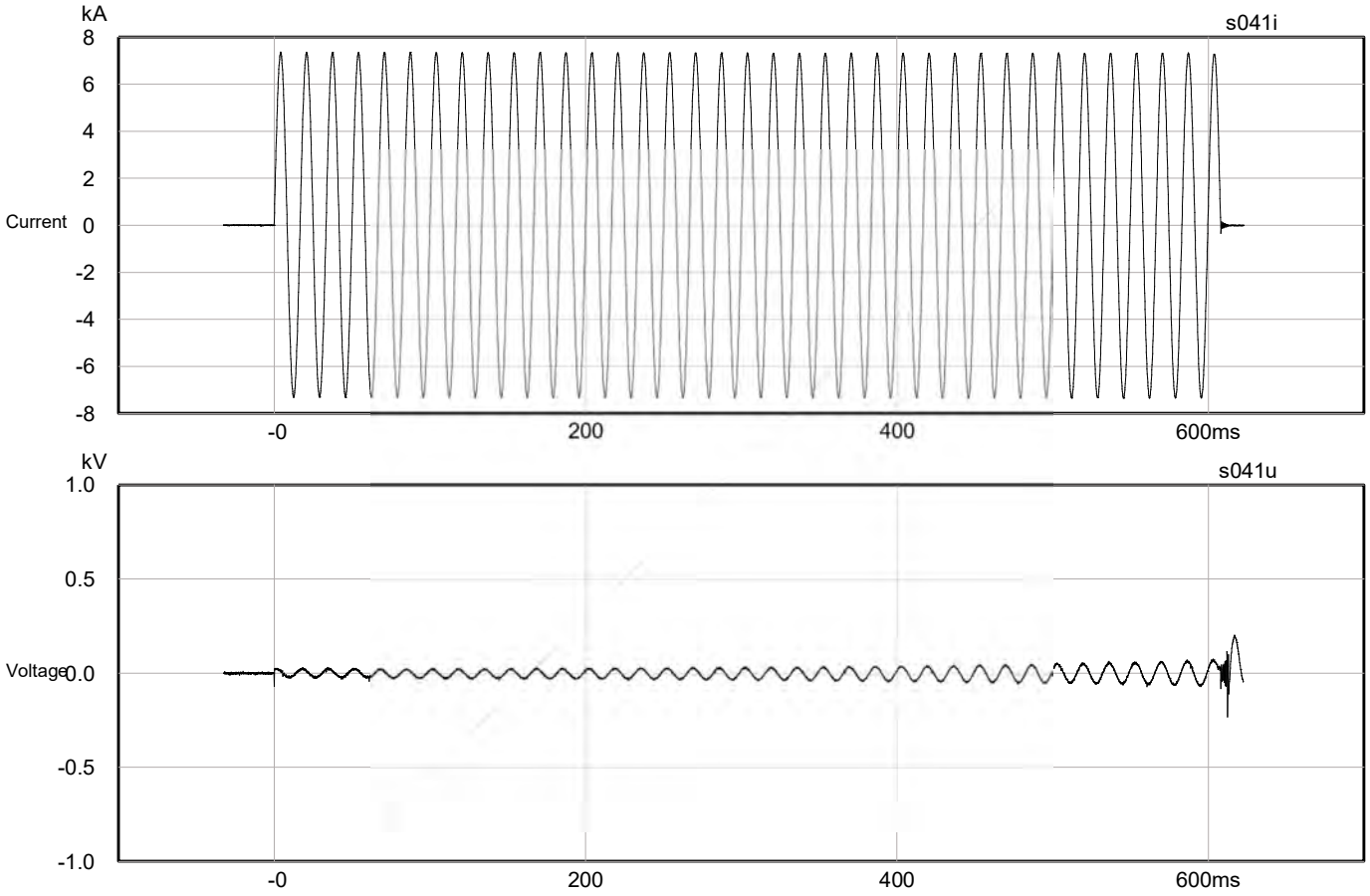


Figure 19: Waveforms for Test #13, Encore #6 AWG Sample 21.

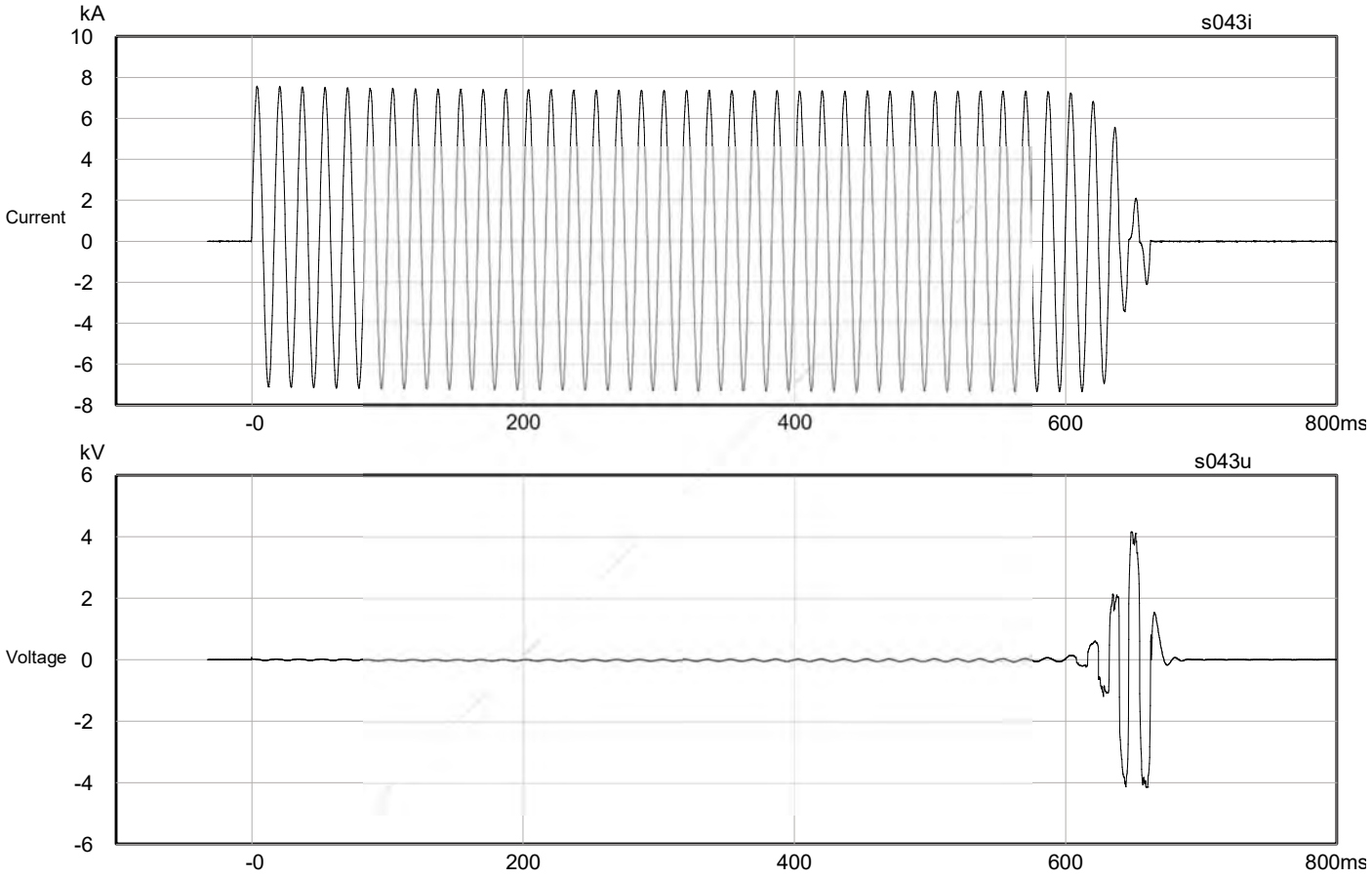


Figure 20: Waveforms for Test #14, Encore #6 AWG Sample 23.

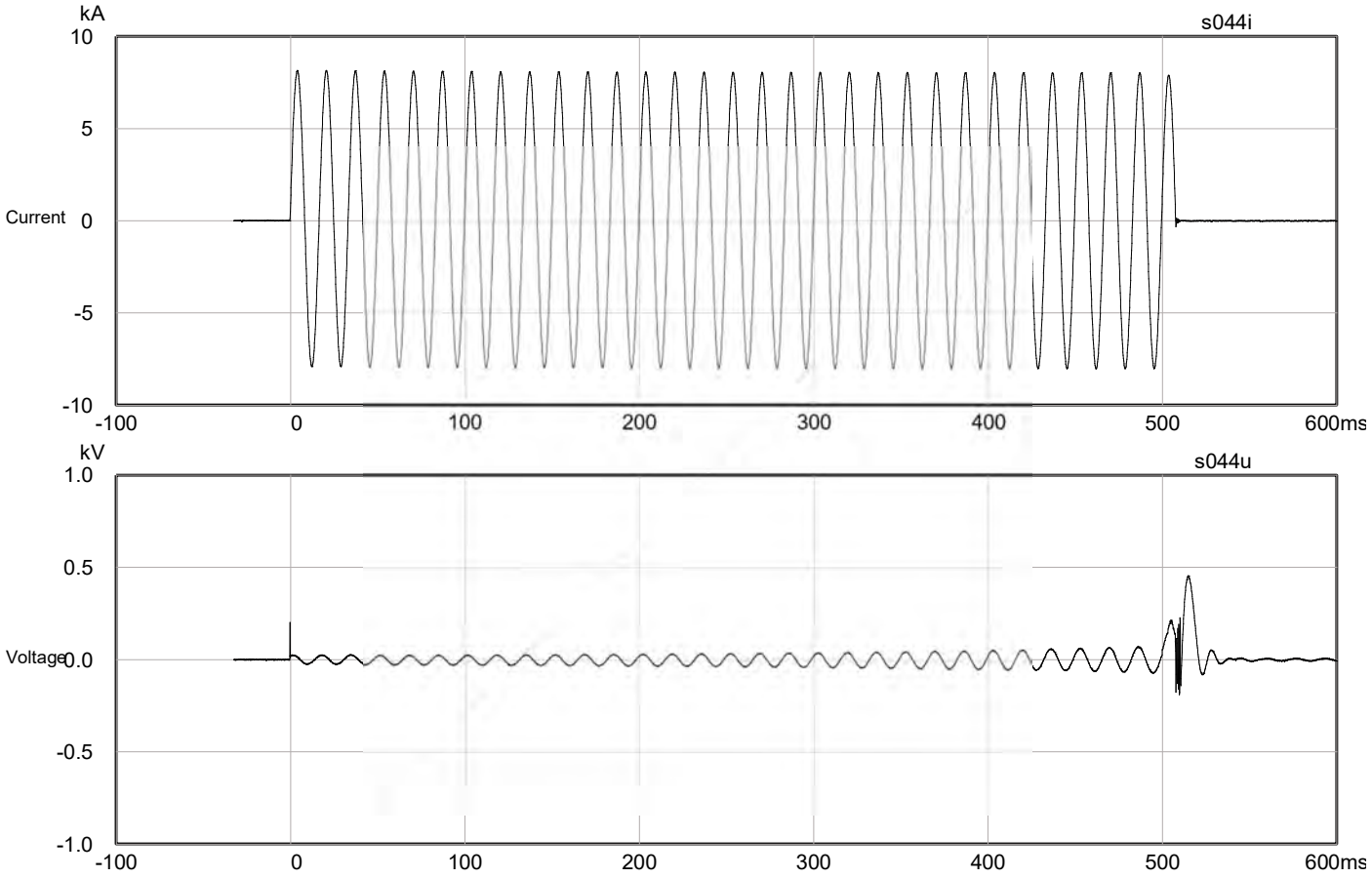


Figure 21: Waveforms for Test #15, Encore #6 AWG Sample 24.

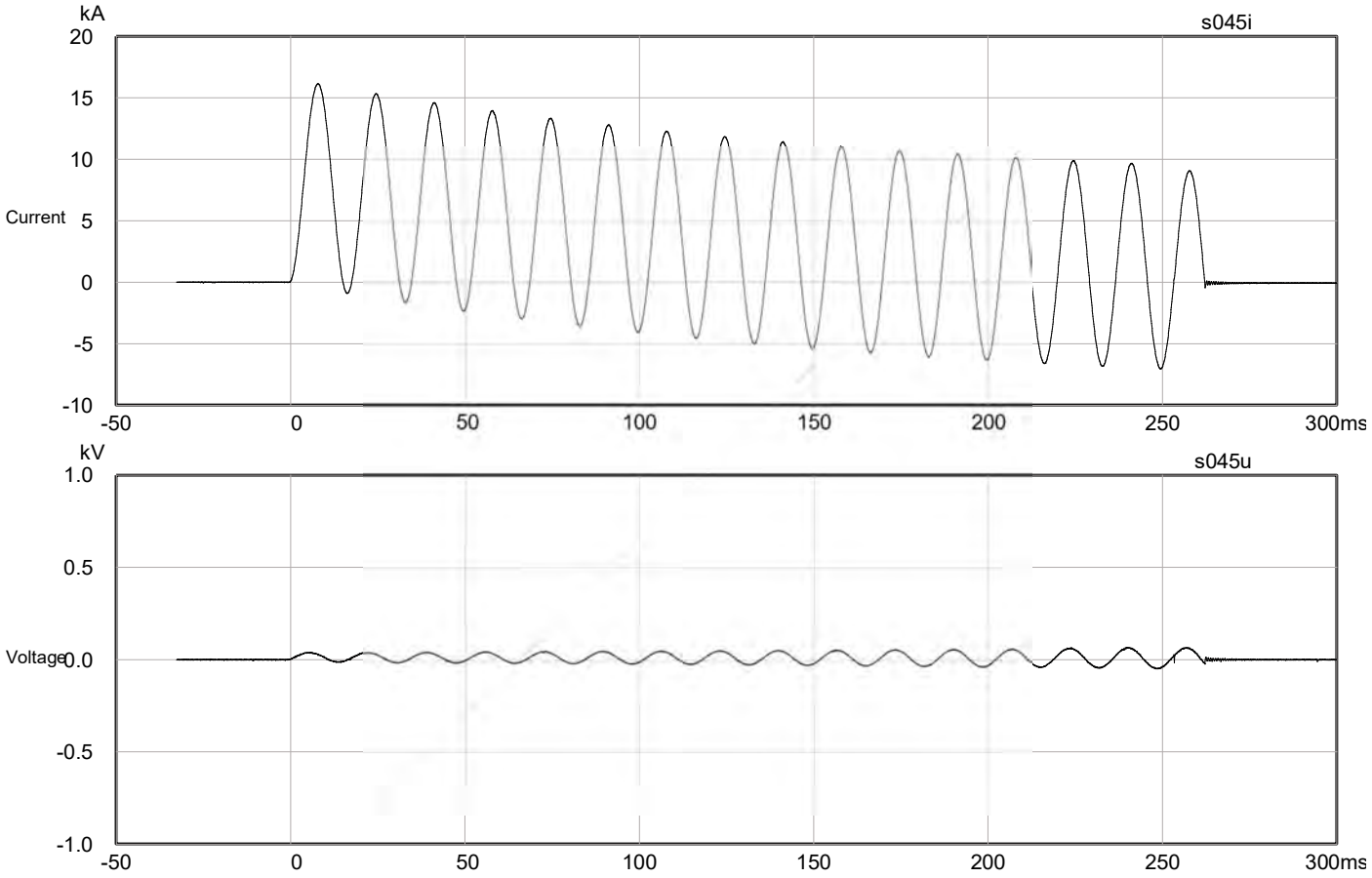


Figure 22: Waveforms for Test #16-1, Encore #6 AWG Sample 25.

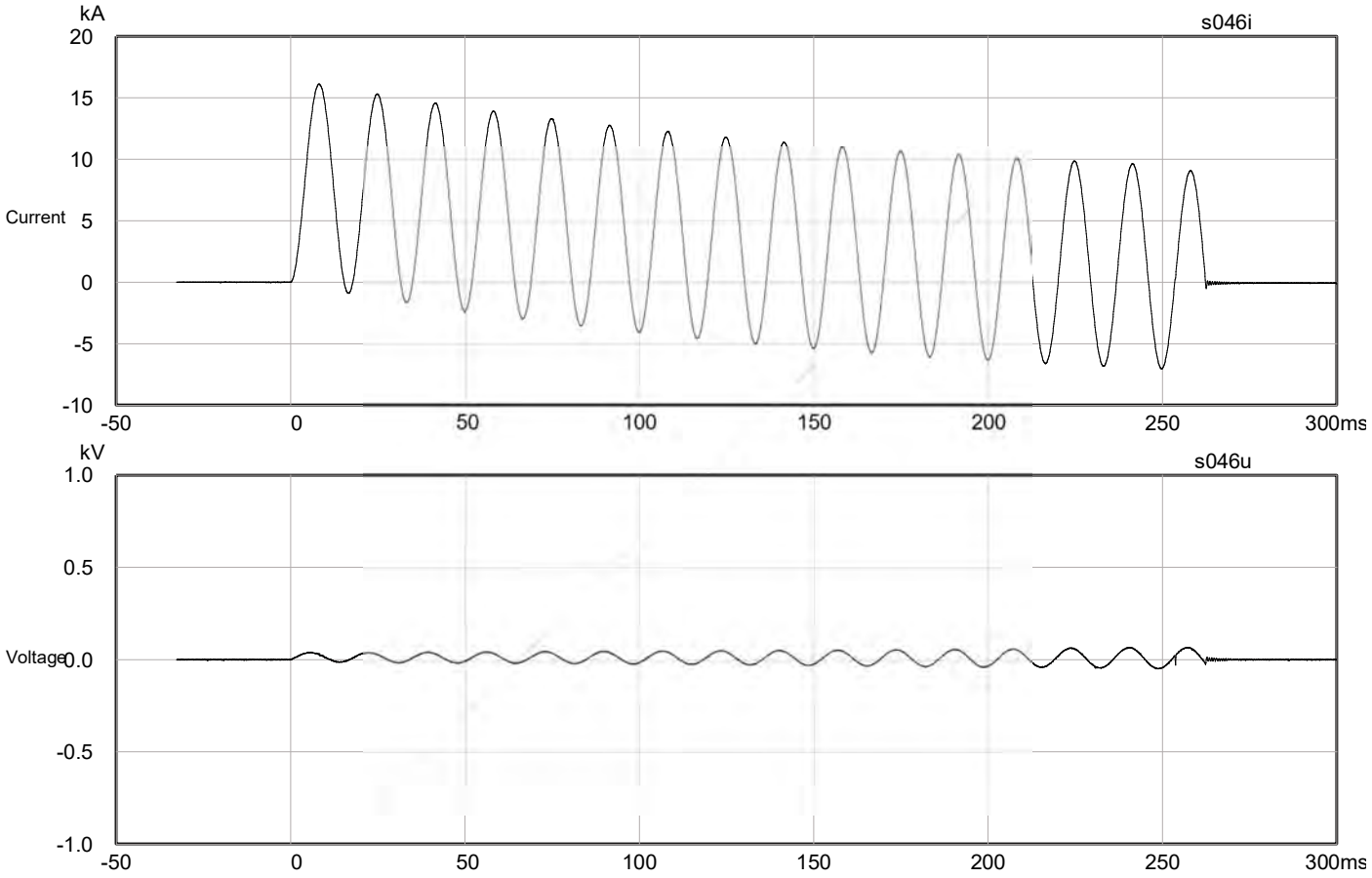


Figure 23: Waveforms for Test #16-2, Encore #6 AWG Sample 25.

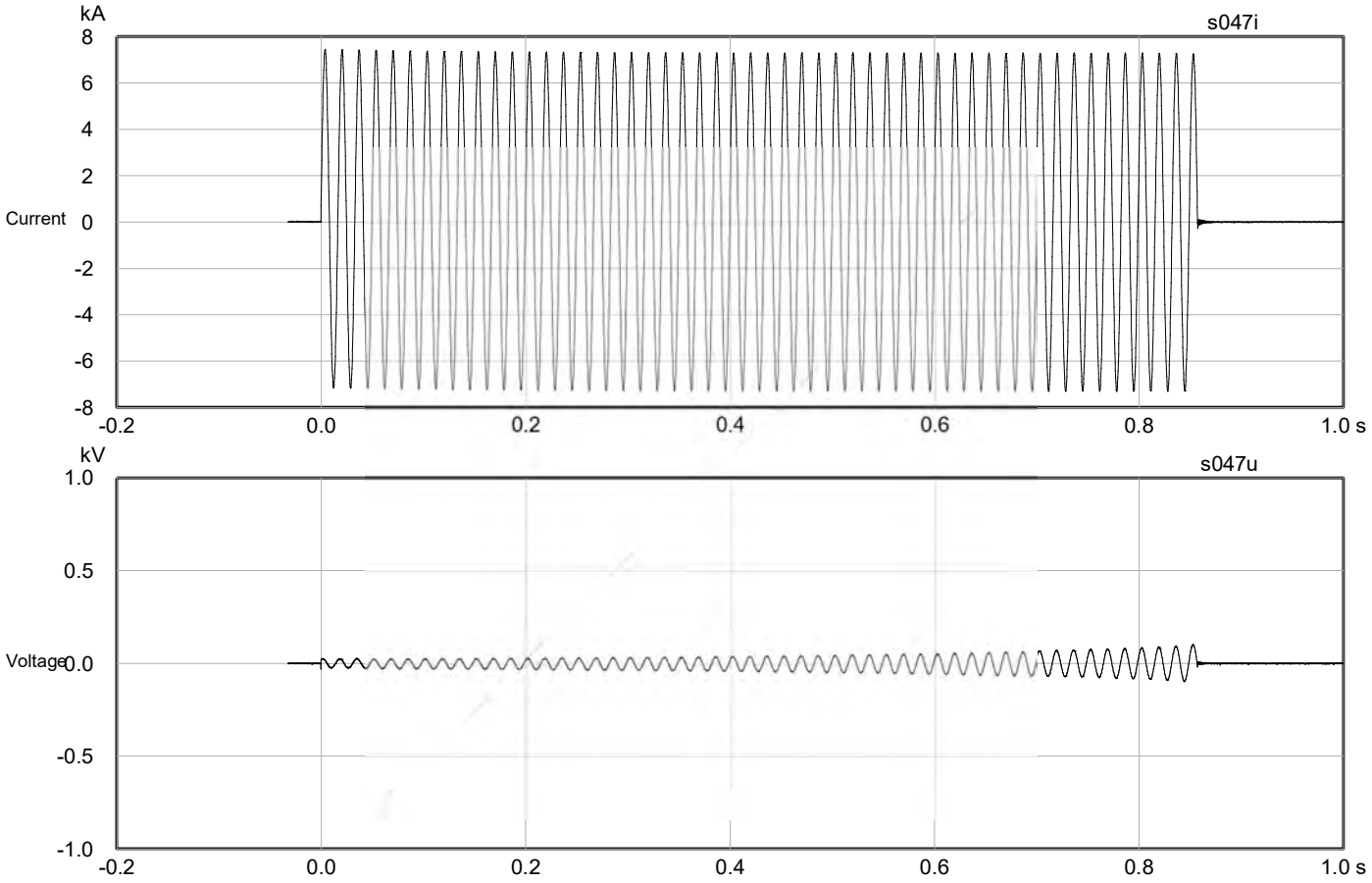


Figure 24: Waveforms for Test #17, Encore #6 AWG Sample 31.

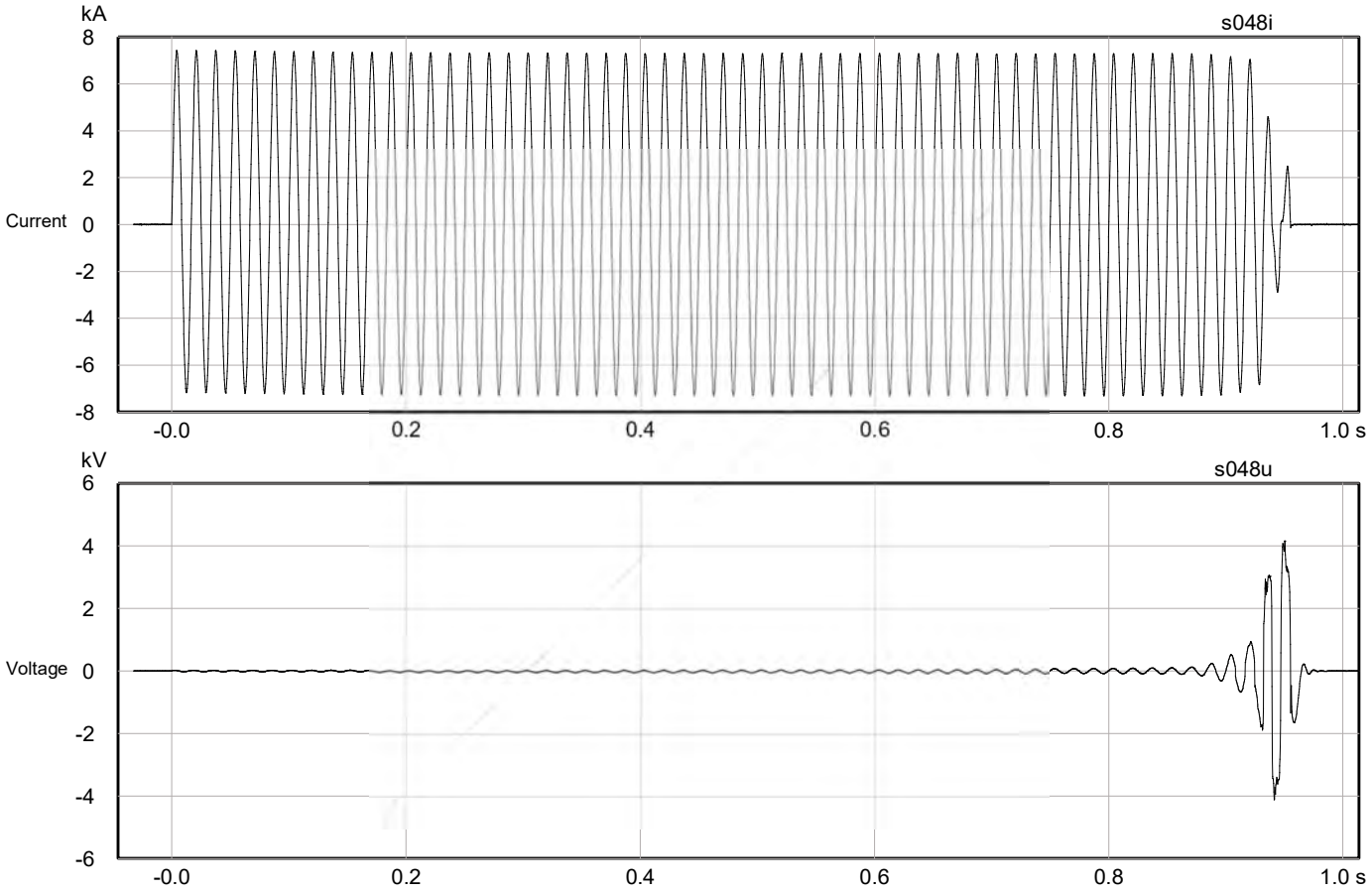


Figure 25: Waveforms for Test #18, Copperweld Scorpius 7 x 080 Sample 32.

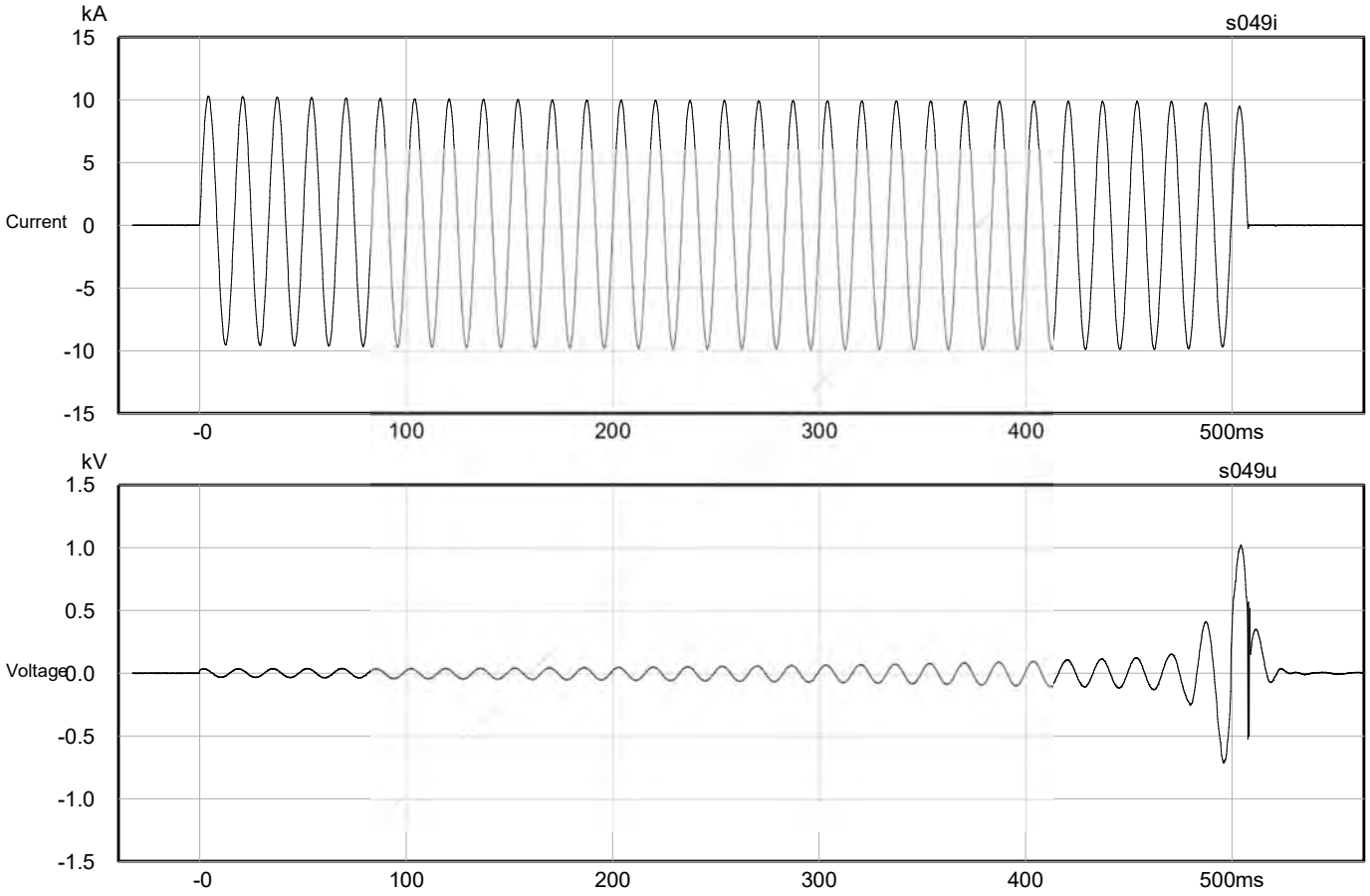


Figure 26: Waveforms for Test #19, Copperweld Scorpius 7 x 080 Sample 33.

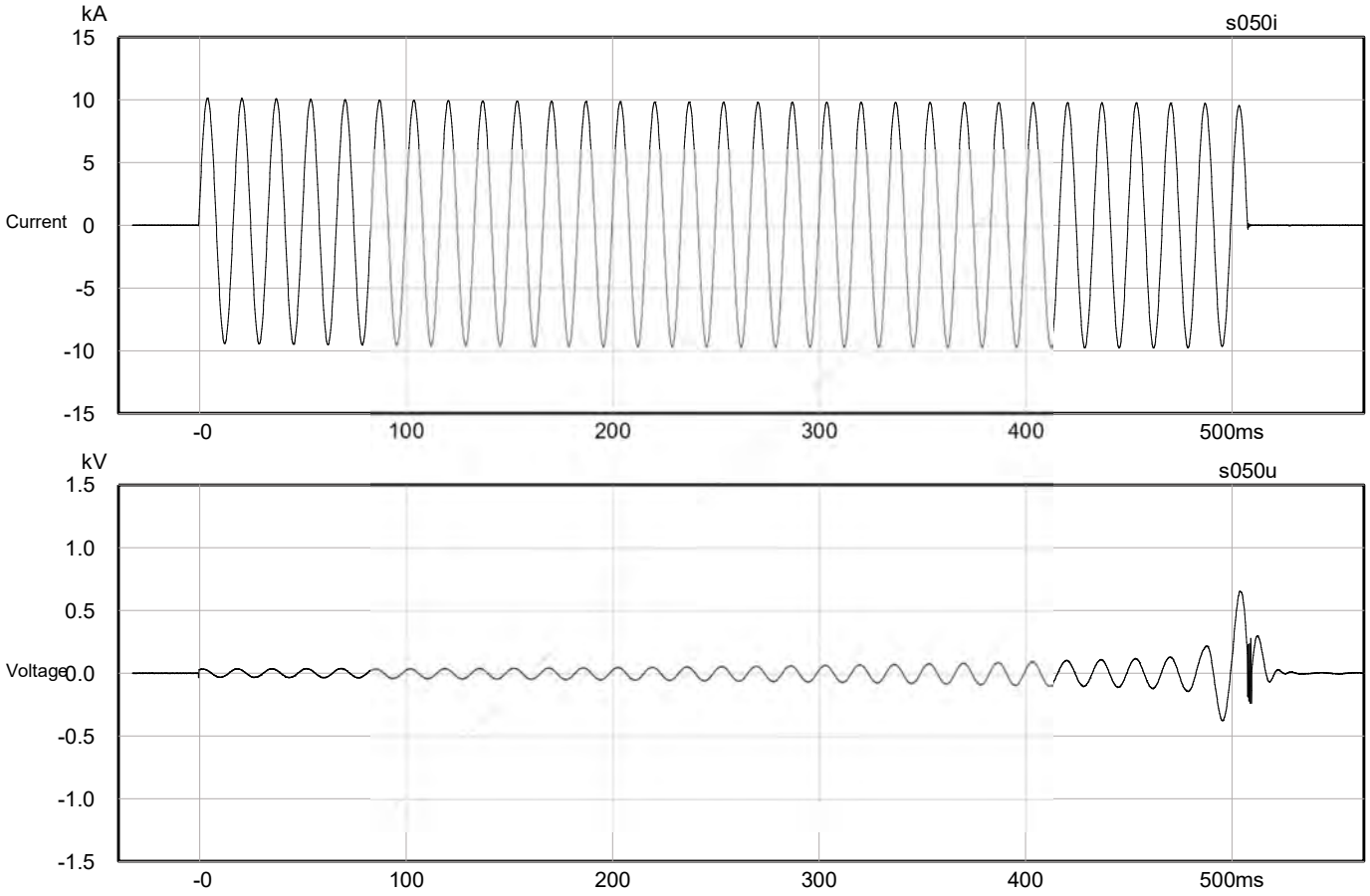


Figure 27: Waveforms for Test #20, Copperweld Scorpius 7 x 080 Sample 34.

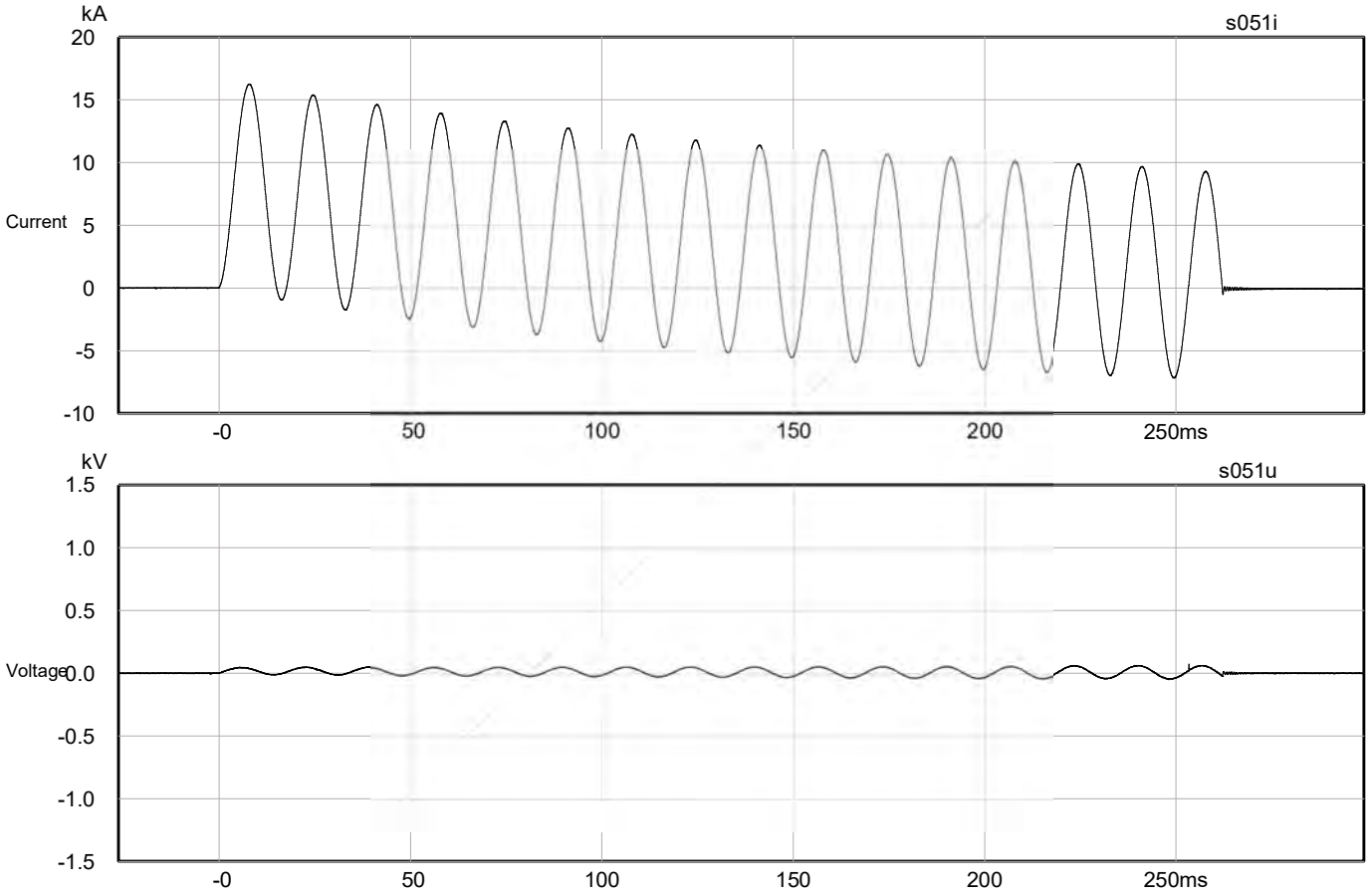


Figure 28: Waveforms for Test #21-1, Copperweld Scorpius 7 x 080 Sample 35.

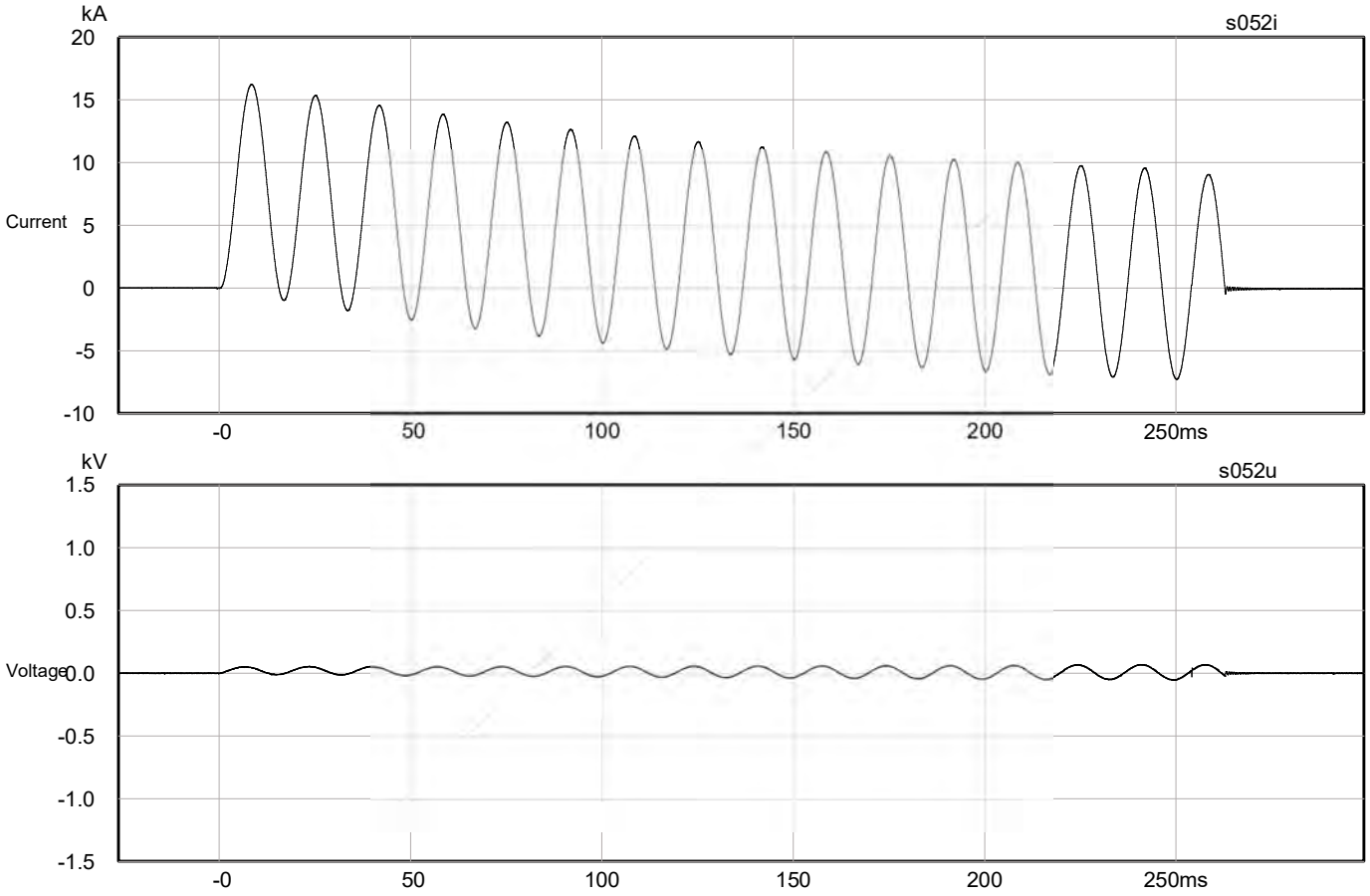


Figure 29: Waveforms for Test #21-2, Copperweld Scorpius 7 x 080 Sample 35.

APPENDIX C – PHOTOGRAPHS OF THE TEST OBJECTS



Figure 30: Test set up for the Encore 4/0 AWG Cu conductor. The power source bus is on the left and the ground bus is on the right.



Figure 31: Test set up for the Copperweld Scorpius 61 x 072 CCS conductor.



Figure 32: Test set up for the Encore #6 AWG Cu conductor.



Figure 33: Test set up for the Copperweld Scorpius 7 x 080 CCS conductor.

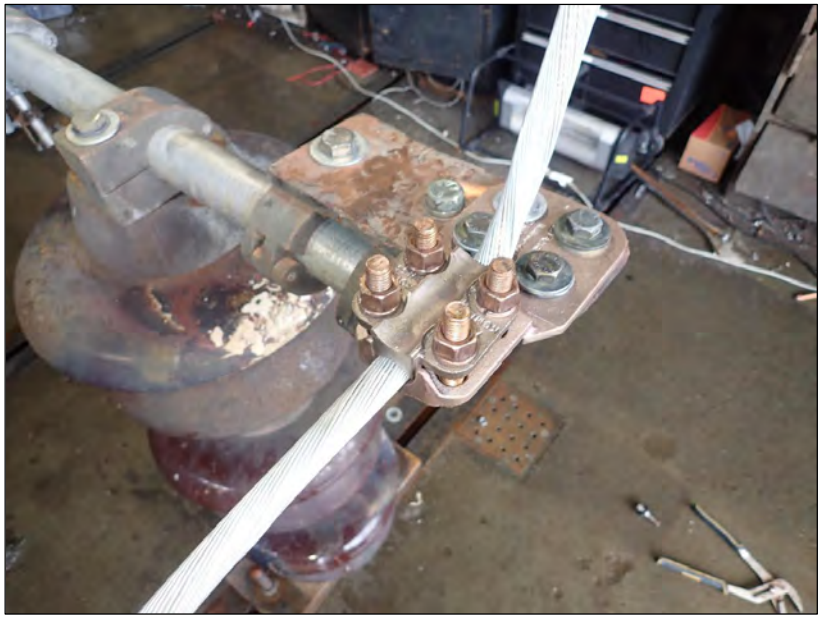


Figure 34: Typical Burndy terminal connector used to connect the Encore 4/0 AWG or Copperweld Scorpius 61 x 072 CCS conductors to the laboratory buses.



Figure 35: Typical Burndy terminal connector used to connect the Encore #6 AWG or Copperweld Scorpius 7 x 080 CCS conductors to the laboratory buses.

APPENDIX D – CALCUATIONS OF TEST CURRENT LEVELS FOR #6 AWG CU CONDUCTOR

Equation (45) in IEEE 80 and Equation (C.1) in IEEE 837 are the same, as follows:

$$I = A\sqrt{\left(\frac{TCAP\times 10^{-4}}{t_c\times\alpha_r\times\rho_r}\right)\ln\left(\frac{K_0+T_m}{K_0+T_a}\right)}$$

where

I is root mean square (rms) current in kA
A is conductor cross section in mm^2
T_m is maximum allowable temperature in °C
T_a is initial conductor temperature in °C
T_r is reference temperature for material constants in °C
α_0 is thermal coefficient of resistivity at 0 °C
α_r is thermal coefficient of resistivity at reference temperature T_r
ρ_r is resistivity of the ground conductor at reference temperature T_r in μΩ-cm
K_0 is $1/\alpha_0$, or $(1/\alpha_r)-T_r$ in °C
t_c is time of current flow in seconds (s)
TCAP is thermal capacity factor in joules/cm^3°C

This equation is used to calculate the short-circuit ampacity of a conductor based on it's material constants.

For IEEE 80, Table 6, the symmetrical rms fusing current for #6 AWG soft-drawn Cu conductor at 500 ms duration is determined to be:

$$\mathrm{I_{sym}} = (13.3)\sqrt{\frac{(3.4\mathrm{x}10^{-4})}{(0.5)(0.00393)(1.72)}\cdot\ln\left(\frac{(234+1083)}{(234+40)}\right)} = \boxed{5.29\ \mathrm{kA_{rms}}}$$

For IEEE 837, Table 3, the symmetrical rms fusing current for #6 AWG hard-drawn Cu conductor at 250 ms duration is determined to be:

$$\mathrm{I_{sym}} = (13.3)\sqrt{\frac{(3.4\mathrm{x}10^{-4})}{(0.25)(0.00381)(1.78)}\cdot\ln\left(\frac{(242+1084)}{(242+40)}\right)} = 7.41\ \mathrm{kA_{rms}}$$

From IEEE 837 Equation (C.4), the asymmetrical rms fusing current is:

$$\mathrm{I_{asym}} = \frac{(7.41\ \mathrm{kA})}{(1.148)} = 6.45\ \mathrm{kA_{rms}}$$

For the EMF described in IEEE 837, Clause 7.2, a value of 90% of the fusing current is used for conductors up to 4/0 AWG:

$$\mathrm{I_{EMF}} = (6.45)(0.9) = \boxed{5.81\ \mathrm{kA_{rms}}}$$

Copperweld Bimetallics Data Sheet Packet
Electrical Test Laboratory

Customer:	Copperweld Building Wire	Engineer:	Bill Lewey	Date:	8/25/2020
Sample ID:	EL-13	Tested By:	Bill Lewey, Mike Rozar	Date:	8/25/2020
Product:	Grade 40 Copper Clad Steel Wire Solid Bare #4 and #6 vs Equivalent Solid Copper: Grounding Electrode Conductor Equivalency Test	Sample Condition:	New		
Standard:	ASTM B910/910M Annealed Copper Clad Steel Wire				
Insulation: N/A - Bare		Jacket: N/A - Bare			

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Test Report Summary

Page	Test Performed	Date Completed	Pass/Fail
1	Grounding Electrode Conductor Test for Copper Clad Steel Grade 40	8/25/2020	**Pass**

Requirement:
#4 AWG Grade 40 Copper Clad Steel and #6 AWG Copper Clad Steel when compared to #4 solid copper and #6 solid copper for use as a grounding electrode conductor shall have equal ability to carry amperage during a ground fault condition.

Conclusion:
The ability of bare #4 AWG Copper Clad Steel Grade 40 and bare #6 AWG Copper Clad Steel Grade 40 performed equally to #4 AWG bare solid copper and #6 AWG bare solid copper when used as a grounding electrode conductor under a ground fault condition. The current measured proved equivalency.

Test Equipment Used

Item	Equipment Type	Equipment #	Cal. Due Date
1	Fluke 374FC Clamp Meter	AM-1	Nov 2020
2	Acme Electric 15KVA Transformer	T2535173S	N/A
3	Square D 60A / 600V Safety Interrupter	N/A	N/A
4	Eaton Service Panel	N/A	N/A
5	Eaton Type CH 20 Amp Breaker	N/A	N/A
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

VBU – Verify Before Use

N/A – Not Applicable

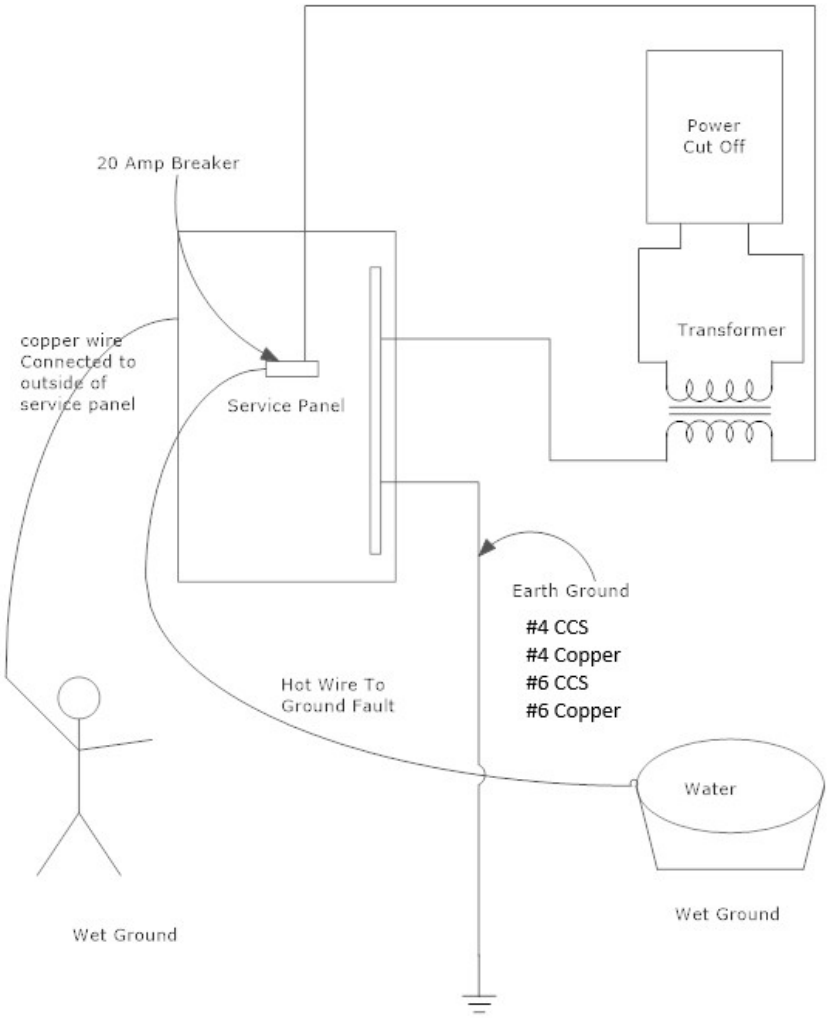
Sample Identification

Item	Description	Length/No. Rec'd
A	#4 AWG 40% Copper Clad Steel Bare	35 Ft
B	#4 AWG Solid Copper Bare	35 Ft
C	#6 AWG 40% Copper Clad Steel Bare	35 Ft
D	#6 AWG Solid Copper Bare	35 Ft
E		
F		

Grounding Electrode Conductor Test

Test Parameters:	
Conditioning:	No preconditioning.
Test Conductors:	1 each of #4 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #6 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #4 AWG Solid Bare copper grounding electrode conductor 1 each of #6 AWG Solid Bare copper grounding electrode conductor
Test Conductor Length:	Each conductor shall be 35 ft.
Test Circuit Configuration:	See schematic shown in Figure 1
Test Current:	Test current from 120 V / 20 A Residential Circuit
Method:	Testing was completed by creating a standard residential test circuit at 120V with 20A breaker wired to an intentional ground fault as shown in figure 1. The ground fault was created by connecting a hot wire from the breaker to a galvanized steel pan full of water and placing the pan on the wet ground. A conductor was also connected to the outside of the electrical panel and a Copper Plated Grounding Electrode (Copperweld Ground Rod) driven 6 inches into the wet ground to determine amount of current going through a grounded person touching the electrical panel during the ground fault condition. The ground fault and the grounded "man" were positioned 20 feet either side of the ground rod. The entire test area was soaked with water overnight using a sprinkler system When the ground fault was electrified, current measurements were taken from the ground fault conductor, the grounding electrode conductor and the grounded "man" conductor. For the four grounding electrode conductors tested, there was one test sequence for each. The current was measured for each. The objective: Compare the amperage measurements of the copper clad steel grounding electrode conductors to those of copper.

Figure 1



Results:			
Ground Conductor	**Fault Conductor Current**	**Current of the Grounding Electrode Conductor**	**Grounded Man Conductor Current**
#4 Copper	2.1 A	1.8 A	0.3 A
#4 40% CCS	2.1 A	1.8A	0.3 A
#6 Copper	1.7 A	1.6 A	0.1 A
#6 40% CCS	1.5 A	1.4 A	0.1 A

Requirement:
For equivalent sizes of Grade 40 Copper Clad steel vs. solid copper grounding conductors, the ability to carry amperage to ground during a ground fault condition is equal.

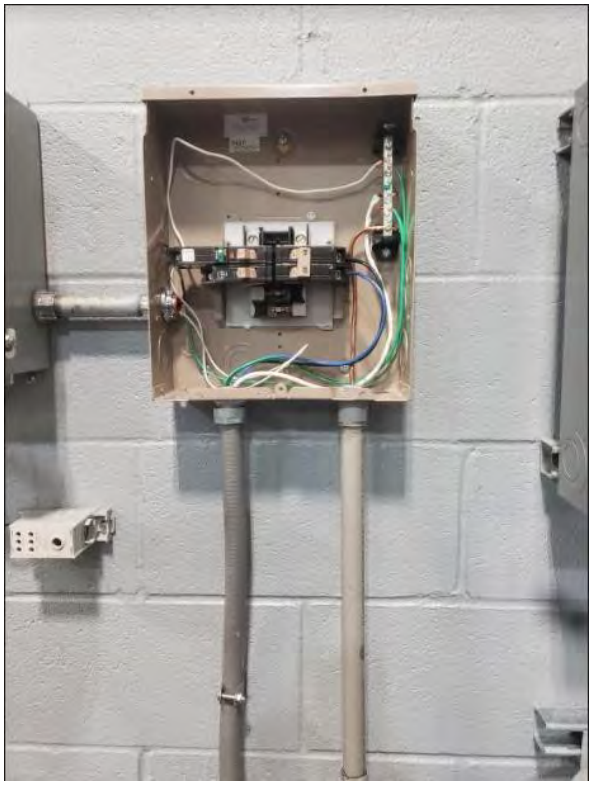
Comments:
____X__ (Pass) The product complies with all applicable requirements of this test. _____ (Fail) The product does not comply with the requirements of this test. **Test Date: 8/25/2020** **Tested By: Bill Lewey**

Environmental Conditions during Testing:

Humidity: % rh __74%_____ Ambient: °C___28_____

Test setup for the electrical service panel







Ground Rod with Grounding Conductor Attached



Ground Fault



Grounded “man”

Public Input No. 4576-NFPA 70-2020 [Section No. 250.68(A)]

(A) Accessibility.

All mechanical elements used to terminate a grounding electrode conductor or bonding jumper to a grounding electrode shall be accessible. Accessibilty to enclosures containing grounding electrode conductor connections shall not be prevented by locks or seals.

Exception No. 1: An encased or buried connection to a concrete-encased, driven, or buried grounding electrode shall not be required to be accessible.

Exception No. 2: Exothermic or irreversible compression connections used at terminations, together with the mechanical means used to attach such terminations to fireproofed structural metal whether or not the mechanical means is reversible, shall not be required to be accessible.

Statement of Problem and Substantiation for Public Input

The 2020 NEC changed the definition for "accessible (as applied to equipment)" by removing the references to locked doors, elevation or other effective means. Past proposals to CMP-5 to better clarify this section where locks or seals may be applied to service enclosures by the local utility were rejected on the basis that the definition of accessible already provided for that. In code change seminars it was stated that with the definition change there should not be any unintended consequences, but this is one of those unintended consequences. The local utility has the right and need to apply locks and seals to prevent unauthorized access to line side conductors. The purpose here is not to dispute that need.

Now with the definition change that language has been taken away. If the connection to the metal water pipe or other electrodes not exempted by the exceptions is necessary requiring access covers, then access to the service enclosures where the grounding electrode conductor is terminated is also necessary. The added text takes from the old definition of accessible and now brings it into this section. The owner, installer and inspector should always have access to the grounding electrode conductor connection(s) at any time and not be prevented from accessing due to seals or locks or have to setup a utility visit to access their equipment. The AHJ can use this requirement now to ensure the grounding electrode conductor installation is in a location that will not be sealed or locked limiting access.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4598-NFPA 70-2020 [Section No. 250.66]	Revised 260.66
Public Input No. 4653-NFPA 70-2020 [Section No. 250.104(C)]	Structural metal bonding
Public Input No. 4655-NFPA 70-2020 [Section No. 250.104(D)]	Separately derived system bonding

Submitter Information Verification

Submitter Full Name: Charles Mello
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Submittal Date:	Thu Sep 10 15:20:13 EDT 2020
Committee:	NEC-P05

Public Input No. 1018-NFPA 70-2020 [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 pipe, 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 pipe, 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 pipe, 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.

Additional Proposed Changes

File Name	Description	Approved
Water_pipe_measurements.pdf	water pipe measurements	

Statement of Problem and Substantiation for Public Input

This wording needs to be revised to clarify that the 5ft. measurement is to be taken "along the water pipe" rather than "as the crow flies". Making this measurement "as the crow flies" can result in

unlimited lengths of water piping being installed between the point of entrance of the water pipe and where the 5ft. measurement is taken. Presently so long as ANY part of the metal water piping system is within 5ft. of the point of entrance, it can be used for connection of grounding electrode conductors and bonding jumpers. This is true even if there is 100 ft. of water piping installed between the point of entrance and the location where the ground clamp is installed on the water pipe, provided the clamp is within 5ft "as the crow flies" of the point of entrance of the water pipe. I do not believe that is intent of this rule. I believe the intent of this rule is to make this 5ft. measurement "along the water pipe".

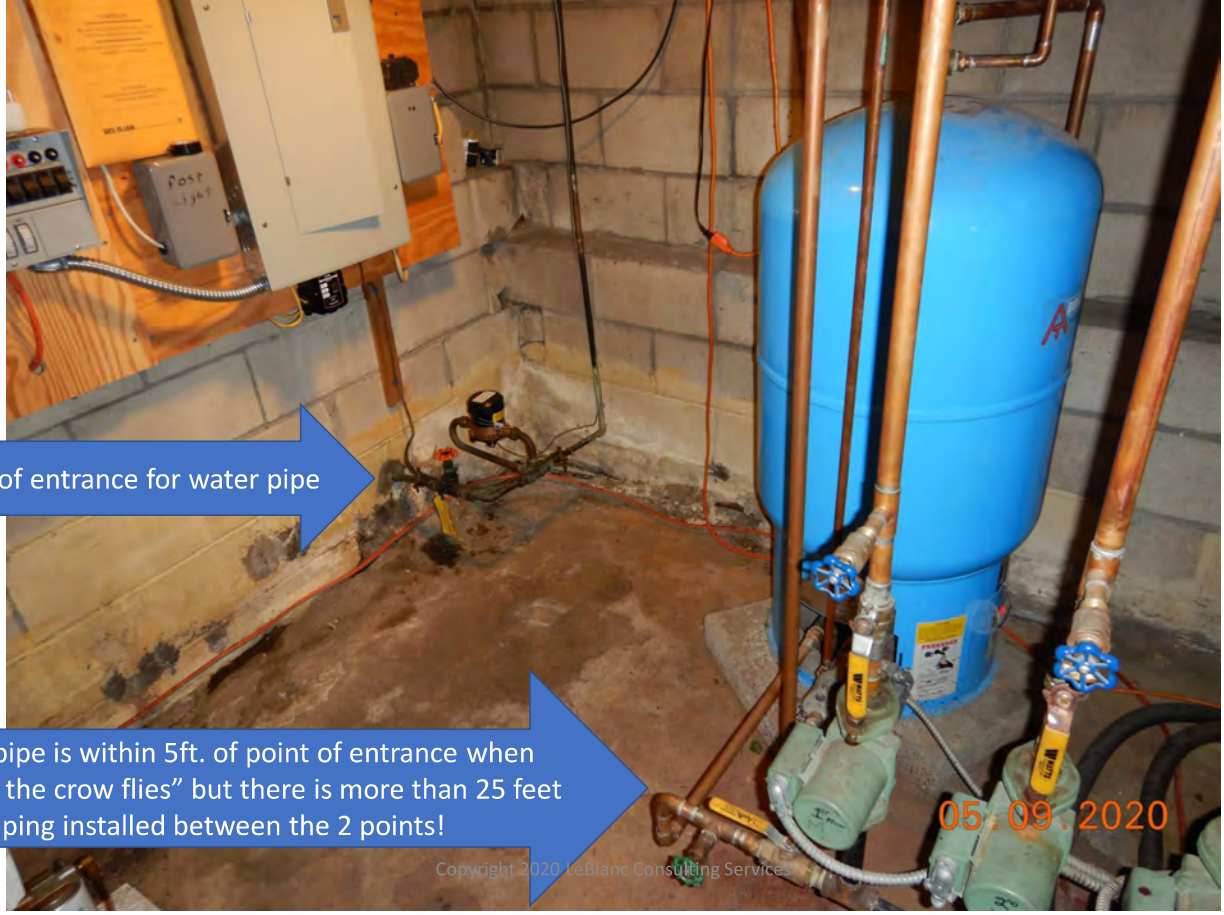
Submitter Information Verification

Submitter Full Name: Russ Leblanc
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Submittal Date: Sun May 10 09:59:48 EDT 2020
Committee: NEC-P05

250.68(C)(1) Measurements

- Should be measured “along the water pipe”!
- Should NOT be measured “as the crow flies”!

Copyright 2020 LeBlanc Consulting Services


Point of entrance for water pipe
This water pipe is within 5ft. of point of entrance when measured “as the crow flies” but there is more than 25 feet of piping installed between the 2 points!
05.09.2020
Copyright 2020 LeBlanc Consulting Services


Point of entrance for water pipe
This water pipe is within 5ft. of point of entrance when measured “as the crow flies” but there is more than 25 feet of piping installed between the 2 points!
05.09.2020
Copyright 2020 Leblanc Consulting Services



This water pipe is within 5ft. of point of entrance when measured “as the crow flies” but there is more than 25 feet of piping installed between the 2 points!

Copyright 2020 LeBlanc Consulting Services


Point of entrance for water pipe
DO NOT BOND HERE!
05.09.2020
Copyright 2020 Leblanc Consulting Services


Measure 5ft. “along the water pipe”!
Point of entrance for water pipe
05.09.2020
Copyright 2020 LeBlanc Consulting Services

Public Input No. 1208-NFPA 70-2020 [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 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 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 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 (clarify, define or state what a short section is) 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 Input

250.68 (C) Exception: Specify/Clarify Short Sections as Applied to Grounding Electrode Connections

Clarify, specify or define what a “short sections” is or is not as related to Section 250.68 (C) Exception permits “short sections” of interior water piping passing perpendicularly through walls, floors, or ceilings to be used as a grinding electrode conductor. The maximum length of a short section is not stated. Stating the maximum length of a short section will lessen ambiguity.

Submitter Information Verification

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Submittal Date: Sat May 23 07:53:30 EDT 2020
Committee: NEC-P05

Public Input No. 126-NFPA 70-2019 [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 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 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 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 grounding electrode installed in accordance with 250.52(A)(3) with an additional ~~rebar section~~ section of zinc galvanized or other electrically conductive coated steel reinforcing bars or rods 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 grounding electrode bonding jumpers in accordance with the following:

(4) The additional

~~rebar~~

a. section shall be continuous with the grounding electrode

~~rebar~~

a. or shall be connected to the grounding electrode

~~rebar and connected together~~

a. by the usual steel tie wires, exothermic welding, welding, or other effective means.

b. The

~~rebar~~

a. extension shall not be exposed to contact with the earth without corrosion protection.

~~Rebar~~

a. A concrete-encased grounding electrode of steel or iron or the extension shall not be used as a conductor to interconnect other electrodes of the

~~electrodes of~~

a. grounding electrode

~~systems~~

a. system .

Statement of Problem and Substantiation for Public Input

The term "rebar" is not appropriate to describe the concrete-encased grounding electrode as described in 250.52(A)(3) so it is proposed to revise it to that used in 250.52(A)(3).
Other proposed changes are intended to be editorial in nature rather than substantive.
(It appears that the output from the software used in this process has made the text disorganized. I apologize for this.)

Submitter Information Verification

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Submittal Date: Wed Nov 20 17:44:39 EST 2019
Committee: NEC-P05

Public Input No. 1413-NFPA 70-2020 [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 shall be permitted to extend the connection to an electrode(s) and the connection of the grounding electrode conductor . Interior metal water piping located more than 1.52 m (5 ft) from the point of entrance to the building shall not be used as a connection to the grounding electrode conductor or 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 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 Input

Add clarity that the GEC connection is also not permitted to be further than five feet from the point of entrance.

Submitter Information Verification

Submitter Full Name: Mike Holt

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Committee:	NEC-P05

Public Input No. 3426-NFPA 70-2020 [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 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 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 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 outside elements, weather, or 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 Input

This change is intended to add clarity and understanding that rebar needs protection if exposed to weather or in contact with earth.
The requirements in the building code requires that rebar or structural steel cannot be exposed to the elements that can be corrosive to steel (ICC, Chapter 19).
Exposure of reinforced concrete to chloride ions is the primary cause of premature corrosion of steel reinforcement. The intrusion of chloride ions present in deicing salts and seawater into reinforced concrete can cause steel corrosion if oxygen and moisture
are also available to sustain the reaction (America's Cement Manufacturers, 2019).
Exposed to earth or weather refers to direct exposure to moisture changes and not just to temperature

changes. Alternative methods of protecting the reinforcement form weather may be provided if they are equivalent to the additional concrete cover required by the Code (American Concrete Institute, ACI 318-11).

Note: Terra shows new text at 250.68(C)(3)(a), (b), and (c). The only proposed added text is at 250.68(C)(3)(b).

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Committee: NEC-P05

Public Input No. 3873-NFPA 70-2020 [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 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 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 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 *outside elements/weather or* 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 Input

This change is intended to add clarity and understanding that rebar needs protection if exposed to weather or in contact with earth.
The requirements in the building code requires that rebar or structural steel cannot be exposed to the elements that can be corrosive to steel (ICC, Chapter 19).
Exposure of reinforced concrete to chloride ions is the primary cause of premature corrosion of steel reinforcement. The intrusion of chloride ions present in deicing salts and seawater into reinforced concrete can cause steel corrosion if oxygen and moisture are also available to sustain the reaction (America's Cement Manufacturers, 2019).
Exposed to earth or weather refers to direct exposure to moisture changes and not just to temperature

changes. Alternative methods of protecting the reinforcement form weather may be provided if they are equivalent to the additional concrete cover required by the Code (American Concrete Institute, ACI 318-11).

Submitter Information Verification

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Submittal Date: Wed Sep 09 14:33:00 EDT 2020
Committee: NEC-P05

Public Input No. 4669-NFPA 70-2020 [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 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 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 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 Input

This section for the rebar is in the wrong location. The parent text of 250.68(C) is about connection points to electrodes and the ability to use metal water or structural metal as a conductor to interconnect electrodes. The rebar requirements properly belong in 250.53 where the other grounding electrode installation requirements are located. Having the rebar in this location has caused several misunderstandings about the possible use of the rebar as a mean to interconnect other electrodes. Removing it here and relocating to 250.53 as is being done in a related PI will resolve these issues.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4678-NFPA 70-2020 [Section No. 250.53]	Text relocated to new 250.53(G)
Public Input No. 4678-NFPA 70-2020 [Section No. 250.53]	

Submitter Information Verification

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Submittal Date: Thu Sep 10 16:36:28 EDT 2020
Committee: NEC-P05

Public Input No. 1178-NFPA 70-2020 [Section No. 250.70]

250.70 Methods of Grounding and Bonding Conductor Connection to Electrodes.

The grounding or bonding conductor shall be connected to the grounding electrode by exothermic welding, listed lugs, listed pressure connectors, listed clamps, or other listed means. Connections depending on solder shall not be used. Ground clamps shall be listed for the materials of the grounding electrode and the grounding electrode conductor and, where used on pipe, rod, or other buried electrodes, shall also be listed for direct soil burial or concrete encasement. Not more than one conductor shall be connected to the grounding electrode by a single clamp or fitting unless the clamp or fitting is listed for multiple conductors. One or more of the following methods shall be used:

(1) A pipe fitting, pipe plug, or other approved device screwed into a pipe or pipe fitting

(2) A listed bolted clamp of cast bronze or brass, or plain or malleable iron

(3) For indoor communications purposes only, a listed sheet metal strap-type ground clamp having a rigid metal base that seats on the electrode and having a strap of such material and dimensions that it is not likely to stretch during or after installation

(4) An equally substantial approved means

Statement of Problem and Substantiation for Public Input

The present wording literally allows only one connection method to be used. I certainly don't believe that the intent of this rule is to force installers to chose and use ONLY one of the specified methods. There is really no good reason to disallow using 2 of the methods, or 3 methods or even more. This revision is necessary to clarify that using more than one of the specified methods is also permitted.

Submitter Information Verification

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Submittal Date: Thu May 21 08:25:15 EDT 2020
Committee: NEC-P05

Public Input No. 127-NFPA 70-2019 [Section No. 250.70]

250.70 Methods of Grounding and Bonding Conductor Connection to Electrodes.

The grounding or bonding conductor shall be connected to the grounding electrode by exothermic welding, listed lugs, listed pressure connectors, listed clamps, or other listed means. Connections depending on solder shall not be used. Ground clamps shall be listed for the materials of the grounding electrode and the grounding electrode conductor and, where used on pipe, rod, or other buried electrodes, shall also be listed for direct soil burial or concrete encasement. Not more than one conductor shall be connected to the grounding electrode by a single clamp or fitting unless the clamp or fitting is listed for multiple conductors. One of the following methods shall be used:

(1) A ~~pipe fitting, pipe plug, or other approved device screwed into a pipe or pipe fitting~~ A

(2) listed bolted clamp of cast bronze or brass, or plain or malleable iron

(3) For indoor communications purposes only, a listed sheet metal strap-type ground clamp having a rigid metal base that seats on the electrode and having a strap of such material and dimensions that it is not likely to stretch during or after installation

(4) An equally substantial approved means

Statement of Problem and Substantiation for Public Input

So far as I can determine, there are no pipe fittings, pipe plugs or other approved device screwed into a pipe or pipe fitting that are suitable for connecting the grounding electrode conductor to a grounding electrode.
It seems this sentence is archaic.

Submitter Information Verification

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Submittal Date: Wed Nov 20 18:03:10 EST 2019
Committee: NEC-P05

Public Input No. 4543-NFPA 70-2020 [Section No. 250.70]

250.70 Methods of Grounding and Bonding Conductor Connection to Electrodes.

The grounding or bonding conductor shall be connected to the grounding electrode by exothermic welding, listed lugs, listed pressure connectors, listed clamps, or other listed means. Connections depending on solder shall not be used. Ground clamps shall be listed for the materials of the grounding electrode and the grounding electrode conductor and, where used on pipe, rod, or other buried electrodes, shall also be listed for direct soil burial or concrete encasement. Not more than one conductor shall be connected to the grounding electrode by a single clamp or fitting unless the clamp or fitting is listed for multiple conductors. One of the following methods shall be used:

(1) A pipe fitting, pipe plug, or other approved device screwed into a pipe or pipe fitting

(2) A listed bolted clamp of cast bronze or brass, or plain or malleable iron

(3) For indoor communications purposes only, a listed sheet metal strap-type ground clamp having a rigid metal base that seats on the electrode and having a strap of such material and dimensions that it is not likely to stretch during or after installation

(4) An equally substantial approved means

Informational Note:

Listed ground clamps that are identified for direct burial are also suitable for concrete encasement.

Statement of Problem and Substantiation for Public Input

Add an Informational Note to this section. As presently written, it infers that a listing for direct soil burial is different than a listing for concrete encasement because of the use of the word "or". Ground clamps that are identified for direct burial are also suitable for concrete encasement with no additional marking as they are evaluated to UL 467. I understand it is not generally desirable to over use informational notes but in this case, it provides very helpful information to the user.

Submitter Information Verification

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Submittal Date: Thu Sep 10 14:54:08 EDT 2020
Committee: NEC-P05

Public Input No. 1892-NFPA 70-2020 [Section No. 250.80]

250.80 Service Raceways and Enclosures.

Metal enclosures and raceways for service conductors and equipment shall be connected to the grounded ~~system~~ circuit conductor if the electrical system is grounded or to the grounding electrode conductor for electrical systems that are not grounded.

Exception: Metal components that are installed in a run of underground nonmetallic raceway(s) and are isolated from possible contact by a minimum cover of 450 mm (18 in.) to all parts of the metal components shall not be required to be connected to the grounded ~~system~~ circuit conductor, supply side bonding jumper, or grounding electrode conductor.

Statement of Problem and Substantiation for Public Input

The term "System Conductor" is used 12 times in the 2020 NEC and the usage is confined to Articles 100 and 250. In each instance of usage, it is describing a grounded conductor and in 11 of the 12 instances it is part of the term "Grounded System Conductor". The term "Circuit Conductor" is used 81 times throughout the 2020 NEC. The term "Grounded Circuit Conductor" is used 43 times throughout the 2020 NEC and 10 times in Article 250.

In Articles 100 and 250, it is not clear that there is a difference between a "Grounded System Conductor" and a "Grounded Circuit Conductor", these terms appear to be used interchangeably.

If it is not the intent that these terms be used interchangeably:

- Definitions should be provided as proposed in PIs 1881-NFPA 70-2020 and 1882-NFPA 70-2020 to delineate the unique features of a "System Conductor" versus those of a "Circuit Conductor“

- PIs 1883-NFPA 70-2020 , 1906-NFPA 70-2020 , 1892-NFPA 70-2020 , 1893-NFPA 70-2020 , 1904-NFPA 70-2020 , and 1905-NFPA 70-2020 should be disregarded

If it is the intent that the two terms are to be used interchangeably:

- All instances of "System Conductor" should be changed to "Circuit Conductor“

- PIs 1883-NFPA 70-2020 , 1906-NFPA 70-2020 , 1892-NFPA 70-2020 , 1893-NFPA 70-2020 , 1904-NFPA 70-2020 , and 1905-NFPA 70-2020 should be accepted to change instances of “system conductor” to “circuit conductor”

- PI 1881-NFPA 70-2020 may be helpful in this scenario to clarify the meaning of the term ”Circuit Conductor”

- Replacing all instances of "Circuit Conductor“ with "System Conductor" and defining the term "System Conductor" would accomplish the same goal. "Circuit Conductor“ is presently more used throughout the NEC, so the proposal above requires a smaller number of revisions.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1881-NFPA 70-2020 [New Definition after Definition: Conductor, Bare.]	
Public Input No. 1882-NFPA 70-2020 [New Definition after Definition: Conductor, Insulated.]	

Public Input No. 1883-NFPA 70-2020 [Definition: Grounded Conductor.]

Public Input No. 1893-NFPA 70-2020 [Section No. 250.84]

Public Input No. 1904-NFPA 70-2020 [Section No. 250.187(C)]

Public Input No. 1905-NFPA 70-2020 [Section No. 250.34(C)]

Public Input No. 1906-NFPA 70-2020 [Section No. 250.36(B)]

Public Input No. 1881-NFPA 70-2020 [New Definition after Definition: Conductor, Bare.]

Public Input No. 1882-NFPA 70-2020 [New Definition after Definition: Conductor, Insulated.]

Public Input No. 1883-NFPA 70-2020 [Definition: Grounded Conductor.]

Public Input No. 1893-NFPA 70-2020 [Section No. 250.84]

Public Input No. 1904-NFPA 70-2020 [Section No. 250.187(C)]

Public Input No. 1905-NFPA 70-2020 [Section No. 250.34(C)]

Public Input No. 1906-NFPA 70-2020 [Section No. 250.36(B)]

Submitter Information Verification

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Submittal Date: Tue Jul 14 09:14:44 EDT 2020
Committee: NEC-P05

Public Input No. 1893-NFPA 70-2020 [Section No. 250.84]

250.84 Underground Service Cable or Raceway.

(A) Underground Service Cable.

The sheath or armor of a continuous underground metal-sheathed or armored service cable system that is connected to the grounded ~~system~~ circuit conductor on the supply side shall not be required to be connected to the grounded ~~system~~ circuit conductor at the building or structure. The sheath or armor shall be permitted to be insulated from the interior metal raceway or piping.

(B) Underground Service Raceway Containing Cable.

An underground metal service raceway that contains a metal-sheathed or armored cable connected to the grounded ~~system~~ circuit conductor shall not be required to be connected to the grounded ~~system~~ circuit conductor at the building or structure. The sheath or armor shall be permitted to be insulated from the interior metal raceway or piping.

Statement of Problem and Substantiation for Public Input

The term "System Conductor" is used 12 times in the 2020 NEC and the usage is confined to Articles 100 and 250. In each instance of usage, it is describing a grounded conductor and in 11 of the 12 instances it is part of the term "Grounded System Conductor". The term "Circuit Conductor" is used 81 times throughout the 2020 NEC. The term "Grounded Circuit Conductor" is used 43 times throughout the 2020 NEC and 10 times in Article 250.

In Articles 100 and 250, it is not clear that there is a difference between a "Grounded System Conductor" and a "Grounded Circuit Conductor", these terms appear to be used interchangeably.

If it is not the intent that these terms be used interchangeably:

- Definitions should be provided as proposed in PIs 1881-NFPA 70-2020 and 1882-NFPA 70-2020 to delineate the unique features of a "System Conductor" versus those of a "Circuit Conductor“

- PIs 1883-NFPA 70-2020 , 1906-NFPA 70-2020 , 1892-NFPA 70-2020 , 1893-NFPA 70-2020 , 1904-NFPA 70-2020 , and 1905-NFPA 70-2020 should be disregarded

If it is the intent that the two terms are to be used interchangeably:

- All instances of "System Conductor" should be changed to "Circuit Conductor“

- PIs 1883-NFPA 70-2020 , 1906-NFPA 70-2020 , 1892-NFPA 70-2020 , 1893-NFPA 70-2020 , 1904-NFPA 70-2020 , and 1905-NFPA 70-2020 should be accepted to change instances of “system conductor” to “circuit conductor”

- PI 1881-NFPA 70-2020 may be helpful in this scenario to clarify the meaning of the term ”Circuit Conductor”

- Replacing all instances of "Circuit Conductor“ with "System Conductor" and defining the term "System Conductor" would accomplish the same goal. "Circuit Conductor“ is presently more used throughout the NEC, so the proposal above requires a smaller number of revisions.

Related Public Inputs for This Document

Related Input	Relationship

Public Input No. 1881-NFPA 70-2020 [New Definition after Definition: Conductor, Bare.]

Public Input No. 1882-NFPA 70-2020 [New Definition after Definition: Conductor, Insulated.]

Public Input No. 1883-NFPA 70-2020 [Definition: Grounded Conductor.]

Public Input No. 1906-NFPA 70-2020 [Section No. 250.36(B)]

Public Input No. 1904-NFPA 70-2020 [Section No. 250.187(C)]

Public Input No. 1905-NFPA 70-2020 [Section No. 250.34(C)]

Public Input No. 1892-NFPA 70-2020 [Section No. 250.80]

Public Input No. 1881-NFPA 70-2020 [New Definition after Definition: Conductor, Bare.]

Public Input No. 1882-NFPA 70-2020 [New Definition after Definition: Conductor, Insulated.]

Public Input No. 1883-NFPA 70-2020 [Definition: Grounded Conductor.]

Public Input No. 1892-NFPA 70-2020 [Section No. 250.80]

Public Input No. 1904-NFPA 70-2020 [Section No. 250.187(C)]

Public Input No. 1905-NFPA 70-2020 [Section No. 250.34(C)]

Public Input No. 1906-NFPA 70-2020 [Section No. 250.36(B)]

Submitter Information Verification

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Submittal Date: Tue Jul 14 09:23:50 EDT 2020
Committee: NEC-P05

Public Input No. 1729-NFPA 70-2020 [Section No. 250.92]

250.92 Services.

(A) Bonding of Equipment for Services.

The normally non–current-carrying metal parts of equipment indicated in 250.92(A)(1) and (A)(2) shall be bonded ~~together.~~ in accordance with 250.92(B).

(1) All raceways, cable trays, cablebus framework, auxiliary gutters, or service cable armor or sheath that enclose, contain, or support service conductors, except as permitted in 250.80

(2) All enclosures containing service conductors, including meter fittings, boxes, or the like, interposed in the service raceway or armor

(B) Method of Bonding at the Service.

Bonding jumpers meeting the requirements of this article shall be used around impaired connections, such as reducing washers or oversized, concentric, or eccentric knockouts. Standard locknuts or bushings shall not be the only means for the bonding required by this section but shall be permitted to be installed to make a mechanical connection of the raceway(s).

Electrical continuity at service equipment, service raceways, and service conductor enclosures shall be ensured by one of the following methods:

(1) Bonding equipment to the grounded service conductor in a manner provided in 250.8

(2) Connections using threaded couplings or listed threaded hubs on enclosures if made up wrenchtight

(3) Threadless couplings and connectors if made up tight for metal raceways and metal-clad cables

(4) Other listed devices, such as bonding-type locknuts, bushings, or bushings with bonding jumpers

Statement of Problem and Substantiation for Public Input

The intent of the rule is to bond these conductive parts to the grounded service conductor, not to bond the parts together. For example, if we had a metal nipple between the meter enclosure and service disconnect, we only need to bond one end of the nipple, not both ends.

Submitter Information Verification

Submitter Full Name: Mike Holt
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Submittal Date: Thu Jun 25 15:59:26 EDT 2020
Committee: NEC-P05

Public Input No. 1086-NFPA 70-2020 [Section No. 250.92(B)]

(B) Method of Bonding at the Service.

Bonding jumpers meeting the requirements of this article shall be used around impaired connections, such as reducing washers or oversized, concentric, or eccentric knockouts. Standard locknuts or bushings shall not be the only means for the bonding required by this section but shall be permitted to be installed to make a mechanical connection of the raceway(s).

Electrical continuity at service equipment, service raceways, and service conductor enclosures shall be ensured by one or more of the following methods:

(1) Bonding equipment to the grounded service conductor in a manner provided in 250.8

(2) Connections ~~using~~ made up wrenchtight using threaded couplings ~~or~~ , threaded entries, or listed threaded hubs on ~~enclosures if made up wrenchtight~~ enclosures

(3) Threadless couplings and connectors if made up tight for metal raceways and metal-clad cables

(4) Other listed devices, such as bonding-type locknuts, bushings, or bushings with bonding jumpers

Additional Proposed Changes

File Name	Description	Approved
3FBDE97B-6513-42A0-B0EC-3E2DDEB5B4FB.jpeg	raceway threaded into enclosure	
A7DDA673-8ABB-4223-8B8D-73659AEE9652.jpeg	threaded entry in box	
26D32C00-F834-43A7-8BD3-C87B77FCCF7E.jpeg	threaded entries	

Statement of Problem and Substantiation for Public Input

The literal wording presently requires installers to use only ONE method of bonding. I don't believe the intent of this rule is to allow only one type of bonding method. In some cases, raceways may be bonded to a service enclosure by being threaded into the enclosure, and on that same service, another raceway has bonding bushings and jumpers connected to the neutral to ensure continuity. Multiple bonding methods must be permitted to be used on services. This proposed revision will make this possible.
The revision to item (2) is necessary to recognize that many enclosures have threaded entries rather than threaded hubs. Presently threading a raceway directly into an enclosure having threaded entries is not permitted for bonding purposes at service equipment. I don’t believe the intent is to prohibit these types of threaded connections from serving as the required type of bonding. The order of the words were also changed simply for easier understanding and grammatical correctness.

Submitter Information Verification

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Submittal Date:	Sat May 16 08:12:59 EDT 2020
Committee:	NEC-P05






LARSON

Public Input No. 1446-NFPA 70-2020 [Section No. 250.94(A)]

(A) The Intersystem Bonding Termination Device.

An intersystem bonding termination (IBT) device 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 additional buildings or structures. 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) At the service equipment, building or structure disconnecting means, or metering equipment the intersystem bonding terminating device must be securely mounted and electrically connected to an enclosure for the service equipment, ~~to the meter enclosure~~ building or structure disconnecting means , or metering equipment , or to an exposed nonflexible metallic service raceway, or be mounted at one of these enclosures and be connected to the enclosure or to the grounding electrode conductor with a minimum 6 AWG copper conductor.

(5) At the disconnecting means for a building or structure, be securely mounted and electrically connected to the metallic enclosure for the building or structure disconnecting means, or be mounted at the disconnecting means and be connected to the metallic enclosure or to the grounding electrode conductor with a minimum 6 AWG copper conductor.

(6) The ~~terminals~~ intersystem bonding termination device shall be listed as grounding and bonding equipment.

Exception: In existing buildings or structures where any of the intersystem bonding and grounding electrode conductors required by 770.100(B)(2), 800.100(B)(2), 810.21(F)(2), 820.100, and 830.100 exist, installation of the intersystem bonding termination is not 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 additional buildings or structures by at least one of the following means:

(1) Exposed nonflexible metallic 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, 820.100, and 830.100 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 Input

The primary edit to this rule was to (4) to make it clear that it applies to other than service equipment.

Submitter Information Verification

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Submittal Date: Thu Jun 04 18:37:16 EDT 2020
Committee: NEC-P05

Public Input No. 262-NFPA 70-2020 [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 additional buildings or structures. 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) At the service equipment, be securely mounted and electrically connected to an enclosure for the service equipment, to the meter enclosure, or to an exposed nonflexible ~~metallic service~~ metal service raceway, or be mounted at one of these enclosures and be connected to the enclosure or to the grounding electrode conductor with a minimum 6 AWG copper conductor.

(5) At the disconnecting means for a building or structure, be securely mounted and electrically connected to the ~~metallic enclosure~~ metal enclosure for the building or structure disconnecting means, or be mounted at the disconnecting means and be connected to the ~~metallic enclosure~~ metal enclosure or to the grounding electrode conductor with a minimum 6 AWG copper conductor.

(6) The terminals shall be listed as grounding and bonding equipment.

Exception: In existing buildings or structures where any of the intersystem bonding and grounding electrode conductors required by 770.100(B)(2), 800.100(B)(2), 810.21(F)(2), 820.100, and 830.100 exist, installation of the intersystem bonding termination is not 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 additional buildings or structures by at least one of the following means:

(1) Exposed nonflexible ~~metallic raceways~~ 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~~ metal 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, 820.100, and 830.100 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 Input

The NEC style manual considers the term "metallic" as possibly unenforceable and vague, and

recommends using the term "metal" instead. In this case, I believe "metal" is the proper term.

Submitter Information Verification

Submitter Full Name: Nick Sasso
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Submittal Date: Wed Jan 08 19:55:20 EST 2020
Committee: NEC-P05

Public Input No. 3014-NFPA 70-2020 [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 additional buildings or structures. 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) At the service equipment, be securely mounted and electrically connected to an enclosure for the service equipment, to the meter enclosure, or to an exposed nonflexible metallic service raceway, or be mounted at one of these enclosures and be connected to the enclosure or to the grounding electrode conductor with a minimum 6 AWG copper conductor.

(5) At the disconnecting means for a building or structure, be securely mounted and electrically connected to the metallic enclosure for the building or structure disconnecting means, or be mounted at the disconnecting means and be connected to the metallic enclosure or to the grounding electrode conductor with a minimum 6 AWG copper conductor.

(6) The terminals shall be listed as grounding and bonding equipment.

Exception: In existing buildings or structures where 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 , ~~and 830.100 exist,~~ installation of the intersystem bonding termination is not 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 additional buildings or structures by at least one of the following means:

(1) Exposed nonflexible metallic 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~~, and 830.100 for~~ 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 Input

Consolidation efforts and section changes in Chapter 8 in the last code cycle have rearranged grounding and bonding requirements in Chapter 8 making the reference to Section 830.100 in the

Exception and Informational Note incorrect. There is no longer a Section 830.100 since the requirements of the old Section 830.100 are now contained within the new section 800.100.

Submitter Information Verification

Submitter Full Name: Trevor Bowmer
Organization: Telcordia (Ericsson)
Street Address:
City:
State:
Zip:
Submittal Date: Thu Sep 03 22:31:54 EDT 2020
Committee: NEC-P05

Public Input No. 1311-NFPA 70-2020 [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 sufficient 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).

Exception to (A) and (B): Means for connecting intersystem bonding conductors are not required where communications systems are not likely to be used.

~~Informational Note: The use of an IBT can reduce electrical noise on communication systems.~~

Statement of Problem and Substantiation for Public Input

Delete the Informational Note for three reasons: 1. There is no value in having a note explaining that the IBT can reduce electrical noise on communications systems. 2. I have a very good understanding of grounding and bonding and the IEEE Emerald book on “Sensitive Electronic Equipment”; in all of my forty years I have never seen anything that could possibly explain how the IBT reduces “noise.” 3. This note adds nothing for the user of the NEC, and if anything, it is a distraction since it cannot be explained.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Sun May 31 19:45:04 EDT 2020
Committee: NEC-P05

Public Input No. 1430-NFPA 70-2020 [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 sufficient 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 bonded to the service disconnecting means, feeder disconnecting means, or grounding electrode conductor with a minimum 6 AWG copper conductor.

Exception to (A) and (B): Means for connecting intersystem bonding conductors are not required where communications systems are not likely to be used.

Informational Note: The use of an IBT can reduce electrical noise on communication systems.

Statement of Problem and Substantiation for Public Input

There is no statement in 250.94 (B) as to where the busbar should be bonded to. Right now it reads as if even a free standing busbar would be sufficient to meet code. The intent would be to have it bonded similar to 250.94 (A) to put the systems bonded here at the same potential as the premises electrical system to prevent a hazard.

Submitter Information Verification

Submitter Full Name: Mason Flanagan
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Affiliation: Master Class A Electrician
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City:
State:
Zip:
Submittal Date: Wed Jun 03 08:42:15 EDT 2020
Committee: NEC-P05

Public Input No. 1445-NFPA 70-2020 [Section No. 250.94 [Excluding any Sub-Sections]]

Communications system bonding conductor terminations shall be connected in accordance with 250.94(A) or (B).

Statement of Problem and Substantiation for Public Input

Add the word 'conductor' to add clarity as to what termination the rule is related to.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
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City:
State:
Zip:
Submittal Date: Thu Jun 04 18:35:18 EDT 2020
Committee: NEC-P05

Public Input No. 1090-NFPA 70-2020 [Section No. 250.96(A)]

(A) General.

Metal raceways, cable trays, cable armor, cable sheath, enclosures, frames, fittings, and other metal non–current-carrying parts that are to serve as supply-side bonding jumpers or equipment grounding conductors, with or without the use of supplementary equipment grounding conductors, shall be bonded where necessary to ensure electrical continuity and the capacity to conduct safely any fault current likely to be imposed on them. Any nonconductive paint, enamel, or similar coating shall be removed at threads, contact points, and contact surfaces or shall be connected by means of fittings designed so as to make such removal unnecessary.

Statement of Problem and Substantiation for Public Input

Section 250.30(A)(2) permits nonflexible metal raceways to serve as supply-side bonding jumpers for separately derived systems. Where these raceways are used as supply-side bonding jumpers they too must be bonded "where necessary to ensure electrical continuity and the capacity to conduct safely any fault current likely to be imposed on them" in the same manner that raceways used as equipment grounding conductors must be. This proposed revision will close this "loophole" that presently exists for supply-side bonding jumpers.

Submitter Information Verification

Submitter Full Name: Russ Leblanc
Organization: Leblanc Consulting Services
Street Address:
City:
State:
Zip:
Submittal Date: Sat May 16 09:38:10 EDT 2020
Committee: NEC-P05

Public Input No. 2315-NFPA 70-2020 [Section No. 250.96(A)]

(A) General.

Metal raceways, cable trays, cable armor, cable sheath, enclosures, frames, fittings, and other metal non–current-carrying parts that are to serve as equipment grounding conductors, with or without the use of wire type supplementary equipment grounding conductors, shall be bonded where necessary to ensure electrical continuity and the capacity to conduct safely any fault current likely to be imposed on them. Any nonconductive paint, enamel, or similar coating shall be removed at threads, contact points, and contact surfaces or shall be connected by means of fittings designed so as to make such removal unnecessary.

Statement of Problem and Substantiation for Public Input

When the question is asked to explain or give an example of an equipment grounding conductor the answer is often a green conductor. As shown in 205.118 the term equipment grounding conductor (EGC) includes various types of materials including wire type conductors, metallic raceways, some cable jackets, etc. In code sections where the term equipment grounding conductor is used addressing a specific type of EGC, such as this case, wire type EGCs methods should be emphasized. This suggested change will help add clarity to the language of the code.

Submitter Information Verification

Submitter Full Name: Gary Beckstrand
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City:
State:
Zip:
Submittal Date: Fri Aug 14 12:39:53 EDT 2020
Committee: NEC-P05

Public Input No. 4549-NFPA 70-2020 [Section No. 250.97]

250.97 Bonding for Over 250 Volts to Ground .

For circuits of over 250 volts to ground, the electrical continuity of metal raceways and cables with metal sheaths that contain any conductor other than service conductors shall be ensured by one or more of the methods specified for services in 250.92(B), except for (B)(1).

Exception: Where oversized, concentric, or eccentric knockouts are not encountered, or where a box or enclosure with concentric or eccentric knockouts is listed to provide a reliable bonding connection, the following methods shall be permitted:

(1) Threadless couplings and connectors for cables with metal sheaths

(2) Two locknuts, on rigid metal conduit or intermediate metal conduit, one inside and one outside of boxes and cabinets

(3) Fittings with shoulders that seat firmly against the box or cabinet, such as electrical metallic tubing connectors, flexible metal conduit connectors, and cable connectors, with one locknut on the inside of boxes and cabinets

(4) Listed fittings

Statement of Problem and Substantiation for Public Input

Add the words "to Ground" to the title as shown. The section title should match the section requirement.

Submitter Information Verification

Submitter Full Name: Paul Dobrowsky
Organization: Innovative Technology Services
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Submittal Date: Thu Sep 10 14:58:11 EDT 2020
Committee: NEC-P05

Public Input No. 1252-NFPA 70-2020 [Section No. 250.100]

250.~~100~~ 100 Bonding in Hazardous (Classified) Locations.

(A) Bonding.

Regardless of the voltage of the electrical system, ~~the~~ the electrical continuity of non–current-carrying metal parts of electrical equipment, electrical metal raceways, ~~and other enclosures in~~ metal cable trays, metal-clad cable assemblies, and metallic enclosures containing electrical equipment in any hazardous (classified) location, as defined in 500.5, 505.5, and 506.5, shall be grounded and bonded in accordance by Article 250. Bonding shall be ensured by ~~any of~~ one or more of the following bonding methods ~~specified in 250.92(B) (2) through (B)(4).~~ :

(1) Threaded metal raceway couplings, listed cable connectors, or approved threaded hubs in enclosures where made up wrenchtight

(2) Threadless couplings and connectors are made up wrenchtight and the fittings are permitted by Articles 501, 502, 503, 504, 505, and 506

(3) Other devices listed for the location, such as bonding-type locknuts, protective metallic end bushings with lugs and the bonding jumpers are sized in accordance with 250.102.

One or more of these bonding methods shall be used whether or not equipment grounding conductors of the wire type are installed .

> ~~Informational Note: See 501.30 , 502.30 , 503.30 , 505.25 , or 506.25 for specific bonding requirements.~~

in the raceway or multiconductor cable assembly.

Locknut-bushing and double-locknut types of contacts shall not be depended on for bonding purposes, but bonding jumpers with approved fittings or other approved means of bonding shall be used. Such means of bonding shall apply to all intervening raceways, fittings, boxes, enclosures, and so forth between classified locations and the point of grounding for service equipment or point of grounding of a separately derived system.

Exception: The specific bonding means shall be required only to the nearest point where the main bonding jumper or supply-side bonding jumper is located on the line side of the building or structure disconnecting means as specified in 250.32(B), provided the branch-circuit overcurrent protection is located on the load side of the service or separately derived system disconnecting means.

(B) Flexible metal conduit.

Flexible metal conduit and liquidtight flexible metal conduit in hazardous (classified) locations shall include an external equipment bonding jumper of the wire type in compliance with 250.102 with connectors listed for grounding.

Statement of Problem and Substantiation for Public Input

Bonding for electrical equipment in hazardous locations is described throughout several other part of the Code. Presently in 250.100 it refers the user to 250.92(B)(2) through (4) as acceptable methods to ensure continuity of non-current-carrying parts in these locations. And, there is redundant verbiage in 501.30, 502.30 and 503.30, 505.25 and 506.25. Consolidating these requirements into Art. 250 would make the Code easier to use and eliminate redundant information. This is a companion proposal for proposals to delete Sections 501.30, 502.30 and 503.30, 505.25 and 506.25. In addition companion proposals are being submitted to correlate with this proposal for Sections 250.118(5) and (6), 348.60 and 350.60.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2129-NFPA 70-2020 [Section No. 348.60]	grounding and bonding of flexible metal conduit in hazardous locations
Public Input No. 2130-NFPA 70-2020 [Section No. 350.60]	grounding and bonding of liquidtight flexible metal conduit in hazardous locations
Public Input No. 2127-NFPA 70-2020 [Section No. 505.25]	
Public Input No. 2129-NFPA 70-2020 [Section No. 348.60]	
Public Input No. 2130-NFPA 70-2020 [Section No. 350.60]	
Public Input No. 2132-NFPA 70-2020 [Section No. 250.118]	

Submitter Information Verification

Submitter Full Name: Paul Guidry
Organization: Fluor Enterprises, Inc.
Affiliation: Associated Builders and Contractors
Street Address:
City:
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Zip:
Submittal Date: Sun May 24 18:50:52 EDT 2020
Committee: NEC-P05

Public Input No. 2471-NFPA 70-2020 [Section No. 250.102(A)]

(A) Material.

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

Additional Proposed Changes

File Name	Description	Approved
CCS_Corrosion_paper_Rev2.pdf	50 Year Corrosion Study Grade 40 CCS	
TD002391.doc	UL 467 Short Circuit and UL 486A-B Mechanical Sequence Testing Grade 40 CCS	
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

COPPER-CLAD STEEL CONDUCTORS:

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 applicate 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 Inputs for This Document

Related Input	Relationship
Public Input No. 2472-NFPA 70-2020 [Section No. 250.102(C)(2)]	Copper-Clad Steel Bonding 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 10:41:26 EDT 2020
Committee: NEC-P05

Testing done for the safety of our valued customer.

Global Circulation Laboratory Test Report

For Global Distribution

UL467 SHORT CIRCUIT & UL 486A-486B MECHANICAL SEQUENCE TESTS

YGHP29C2, YGHC2C2, YGHC26C26, YGHP34C29, YGHC29C29, YGHP34C34, YGHC34C34 HYTAP™ Connectors
YGL2C2, YGL29C29, YGL34C34 HYGRID™ Connectors
YGA4C2N, YGHA272N, YGA282N, YGHA302N HYLUG™ Connectors

5/8" and 3/4"Copper Clad Steel Ground Rod, #4AWG Solid, 4/0AWG Stranded, 7#7, and 19#8 COPPERWELD® 40% IACS Copper Clad Steel Conductors

PAT750XT-18V PATRIOT® Tool
with
UC, UO, U28RT, U29RT, U32RT, U997, PU998, and U1011 Die Sets

TD002391 REV B

Requested by / Date:	***Authorized by / Date:***	***Completed by / Date:***
C. Gandhi 12-Dec-2014	R Robicheau 12-Dec-2014	R Charpentier 06-Apr-2015
Engineering Approval / Date:	***Marketing Approval / Date:***	***Laboratory Approval / Date:***
R.Roman 20-Aug-2020	J Hogan 20-Aug-2020	R Charpentier 20-Aug-2020

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

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Burndy LLC 47 East Industrial Park Dr.
Manchester / New Hampshire / 03109
Tel: 603 647 5000 Fax: 603 647 5205

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

PURPOSE OF TEST:

To determine if the Burndy HYTAP™, HYGRID™, and HYLUG™ Connectors can meet the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST REQUESTED:

UL486A-486B Mechanical Sequence
UL467 Short Time Current

TEST RESULTS:

Connector	Cable 1	Cable 2	Die	# of crimps	Securness	Pull	Short Time Current		
					Pass / Fail	Average Pull (lb)	Pass / Fail	Current (Amps)	Time (s)
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	U997	1	Pass	1021.3	Pass	1600	6
YGL2C2	#4 Solid CCS	#4 Solid CCS	U-O	1	Pass	1451.8	Pass	1600	6
YGHC2C2	#4 Solid CCS	#4 Solid CCS	U-C	1	Pass	1544.0	Pass	1600	6
YGA4C2N	#4 Solid CCS	n/a	U4CRT	1	Pass	814.0	Pass	1600	6
YGL29C29	7#7 STR CCS	7#7 STR CCS	U997	1	Pass	1643.2	Pass	4600	9
YGHC26C26	7#7 STRCCS	7#7 STR CCS	U-O	1	Pass	1239.4	Pass	4600	9
YGHA272N	7#7 STRCCS	n/a	U29RT	2	Pass	1574.0	Pass	4600	9
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PU998	1	Pass	1789.8	Pass	6100	9
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1849.8	Pass	6100	9
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1779.1	Pass	6100	9
YGA282N	4/0 AWG CCS	n/a	U28RT	2	Pass	2489.3	Pass	6100	9
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	U1011	3	Pass	2126.8	Pass	9000	9
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	U1011	3	Pass	2380.0	Pass	9000	9
YGL34C34	19#8 STRCCS	19#8 STR CCS	U1011	3	Pass	3158.3	Pass	9000	9
YGHC34C34	19#8 STR CCS	19#8 STR CCS	U1011	3	Pass	3812.1	Pass	9000	9
YGHA302N	19#8 STR CCS	n/a	U32RT	2	Pass	4792.2	Pass	9000	9

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TD002391

Global Circulation Laboratory Test Report

For Global Distribution

CONCLUSIONS:

All samples tested met the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST PROCEDURES

The table below shows the connector / conductor combinations tested.

Connector	Cable 1	Cable 2	Tool	Die	# of Crimps
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	PAT750	U997	1
YGL2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-O	1
YGHC2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-C	1
YGA4C2N	#4 Solid CCS	n/a	PAT750	U4CRT	1
YGL29C29	7#7 STR CCS	7#7 STR CCS	PAT750	U997	1
YGHC26C26	7#7 STR CCS	7#7 STR CCS	PAT750	U-O	1
YGHA272N	7#7 STR CCS	n/a	PAT750	U997	2
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PAT750	PU998	1
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGA282N	4/0 AWG CCS	n/a	PAT750	U997	2
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	PAT750	U1011	3
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	PAT750	U1011	3
YGL34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHC34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHA302N	19#8 STR CCS	n/a	PAT750	U32RT	2

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TD002391

Global Circulation Laboratory Test Report

For Global Distribution

All conductors were cut to twenty four (24) inch lengths.
All ground rod was pre-crimped with the appropriate pre-crimp die
5/8in Rod UPRECRIMP58
3/4in Rod UPRECRIMP34

Mechanical Sequence
Four samples of each set were secured to the Secureness tester, the height; weight and bushing size were as specified in UL486A-486B Table 26. Samples were rotated for thirty minutes at 9rpm. Samples were then subjected to a 1-minute pull to the value specified in UL486A-486B Table 27 and then to failure.

Short Time Current
Test samples were assembled in a series loop configuration then attached to a current controller as shown below. The test current and duration are listed below. After completion of the test, electrical continuity was checked with a digital multi-meter.

Test current values were derived from the equation Annex C of IEEE Std 837-2002. The diameter of the conductor(s) were measured and the cross-sectional area of the conductors was calculated.

Conductor	***Current Value (A)***	***Duration (sec)***
#4AWG Solid COPPERWELD® 40% IACS CCS	1600	6
4/0AWG 19 strand COPPERWELD® 40% IACS CCS,	6100	9
7#7 stranded COPPERWELD® 40% IACS CCS	4600	9
19#8 stranded COPPERWELD® 40% IACS CCS	9000	9

TEST EQUIPMENT LIST:

MANUFACTURER	MODEL	DESCRIPTION	SERIAL #	RANGE
FLUKE	79 III	DMM	70591301 (Rene)	AUTO
OHIO SEMITRONICS		CURRENT TRANSDUCER	NA	15000:5
SATEC	T5000	TABLE TOP	2038	5000 lbs
VIRTECH	NA	HIGH CURRENT	NA	12V / 12000A
MITUTOYO	505-675	DIAL CALIPER	08914565 (Rene)	6"

Burndy LLC 47 East Industrial Park Dr.
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CORROSION ON BURIED COPPER CLAD STEEL



Cece Syarif

Global Application Engineer

&

Anthony Hale

Manager, Utility Products, North America

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For more information, contact sales@copperweld.com.
The results and conclusions obtained from studies done by Copperweld are only applicable to Copper Clad Steel manufactured by Copperweld. Due to proprietary process used to produce the wire, the findings cannot be superimposed on any other copper-clad steel conductor.

254 Cotton Mill Rd, Fayetteville, TN 37334. Tel. (931) 433 – 7177

July 26, 2011

This paper compiles several studies and analysis regarding the corrosion performance of buried Copperweld® Copper-Clad-Steel (CCS) conductors. These range from the early 1900's with the invention of Copperweld® through the present day with studies performed by independent parties as well as Copperweld Company in-house testing. The purpose is to present the available information so that prospective users of Copperweld® CCS wire and strand can evaluate the corrosion resistance and expected performance within their specific application and area. Copperweld uses oxygen free copper in the manufacture of Copperweld® wire and strand. The copper surface of CCS is expected to oxidize and turn color ranging from green (patination) to brown and black the same as any solid copper wire or strand when exposed to environmental stimuli. Corrosion on exposed steel at the cut tip or end of the wire is also expected. The question to be answered is if the corrosion on either material or the interface between the copper and steel (galvanic reaction) will result in degradation of the wire as to make it unsuitable for use as a grounding conductor.

The oldest known underground corrosion study of bimetallic material was performed in the early 1900s[1]. This study focused on the corrosion behavior of Copperweld® CCS underground rod as well as other materials such as Copper and galvanized steel ground rod. The National Bureau of Standards (NBS) conducted an extensive underground corrosion study that involves 36,500 specimens which include 333 varieties of ferrous, nonferrous, and protective coating materials buried in 128 test locations throughout U.S in 1910 - 1955.

The study summarizes the service life of a ground rod as following:

10 mils copper coating – acceptable for service life up to 40 years

13 mils copper coating – acceptable for service life up to 50 years

Similarly, the Naval Civil Engineering Laboratory in collaboration with the National Association of Corrosion Engineers conducted a 7-year program of testing metal rods for electrical grounding to determine the galvanic corrosion effect. The three metals tested were stainless clad steel, copper-bonded steel (CCS), and galvanized steel. The result on the ⅝" CCS ground rod was as expected. The copper surface of the CCS was

virtually free of corrosion and the steel core has corroded at the tip approximately 2 inches down the length of the rod.

Copperweld Corporation is the inventor and sole manufacturer of Copperweld® Copper-bonded ground rods and Copperweld® wire and strand since 1915. The corrosion behavior of a Copperweld® ground rod is similar to the corrosion on Copperweld® wire and strand conductor. Both materials consist of copper permanently bonded to a steel core. All Copperweld® 40% CCS has a copper thickness of 10% of the overall diameter. For example, Copperweld® 4THOUGHT™ has a configuration of 19 strands of 0.1055 inch wires. It means that each strand has a copper thickness of 10.55 mils. Based on the NBS study, 4THOUGHT™ will have at least a minimum service life of 40 years.

Copperweld has also conducted a 5-year study of buried bare 21% conductivity (copper thickness is 3% of the diameter) Copperweld® CCS in 10 different soil conditions in association with Southwest Research Institute[2]. The study reported 100% surface oxidation and various degrees of deterioration of the steel core as expected after 5 years. The exposed steel on the tip of the wire rusted and formed "scab", as shown in Figure 1. The rust appeared to "seal-off" the un-oxidized material from the corrosive medium. The maximum depth of corrosion was 70% of the wire diameter.



Figure 1: Example of Underground Corrosion of Copper Clad Steel

Although the copper surface oxidation was heavy, the samples showed no signs of pits or holes in the copper cladding. The copper thickness of a severely oxidized 5-year sample showed no discernable difference when compared to an un-oxidized control sample that was not subjected to the corrosive environment. The mechanical and resistance testing

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resulted in negligible differences between 5-year samples and the control samples. Thus, the oxidation had no discernable impact on the strength or electrical performance of the wire.

An accelerated corrosion study based on ASTM B117 was conducted on bare CCS and solid Copper wires to evaluate copper surface corrosion. The wires were exposed to salt fog spray for 504 hours. As a result, corrosion on the CCS copper surface showed no significant difference as compared to the corrosion of copper wire.



(a) Copper Clad Steel (b) Copper

Figure 2: Patination of Copper Surface after 504 hours exposure to Salt Fog Spray

In February 2011, three separate sample strands of Copper Clad Steel were un-earthed and cut out from a substation built in Louisville, KY. The conductors were 40% conductivity, Low Carbon Steel, Dead Soft Annealed, 7 No. 5 (231,613 circular mil) and were installed in 1962.

Table 1: Physical properties of the three strands of Copperweld® conductor that had been buried underground for 48 years in a Kentucky substation

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			Strand 1	Strand 2	Strand 3
Conductor Type			40% Low Carbon Annealed		
Conductor Size			7 No. 5		
Cross Section Area		in^2	0.1819	0.1819	0.1819
Diameter of Single end		*inch*	0.1819	0.1819	0.1819
Diameter of Conductor		*inch*	0.5457	0.5457	0.5457
Copper Thickness	Min	*inch*	0.0142	0.0114	0.0134
	Max	*inch*	0.0213	0.0209	0.01975
% Concentricity			83.30%	77.30%	83.90%
Depth of corrosion	Min	*inch*	0.004	0.028	0.111
	Max	*inch*	0.781	0.859	0.484

The 1962 conductors were manufactured by Copperweld with a nominal copper thickness of 10% of its diameter. Figure 3 shows the copper thickness ranges from 11.4 – 21.3 mils and the concentricity of the conductor averaged at 81.5%. Current manufacturing improvements yield concentricity of copper thickness above 85%.

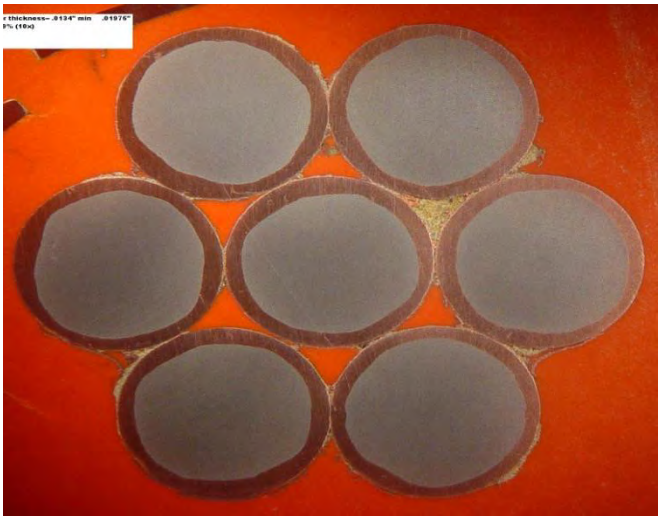


Figure 3: Copperweld® 40% LC DSA 7 No. 5 manufactured in 1962

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Figure 4a shows no visible corrosion observed other than oxidation and patination on the copper surface. At the ends of the wires, the corrosion occurred in the form of steel rust. The maximum depth of the corrosion is 0.859 inch with an average of 0.382 inch, as shown in Figure 4b.



Figure 4a: There is no visible corrosion between the copper and steel on all wires obtained from the substation in Kentucky.



Figure 4b: Corrosion occurred at the ends of the wires. Maximum penetration depth is 0.859 inch.

From all the corrosion studies above, there have not been reported or observed any galvanic corrosion at the interface of copper and steel. The process of cladding for

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Copperweld® ensures a metallurgical bond between the two metals. That metallurgical bond prevents any moisture from penetrating between the two metals precluding the corrosion process. Any propagation of corrosion on an area of exposed steel averages two times the diameter of the wire then stops. The corrosion rate of the copper surface is equivalent to that observed on standard solid copper wire and strand. Based on the results of these studies, it can be summarized that CCS can be expected to have a 50 plus year service life as buried grounding conductors.

REFERENCES:

1. Rempe, Chris. 7 July 2003. "A Technical Report on the Service Life of Ground Rod Electrodes".
2. Fox, Dustin, Belado, Chris, and Brossia, Sean. 23 September 2009. "The Effect of Corrosion on Tracer Wire with a Copper Clad Steel Center Conductor".

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Revision: 0 Issued: 2020-04-15

Copper and CCS Wire Withstand Current and Fusing Current Tests

Copperweld Bimetallics, LLC



The Power of Trust. **The Future of Energy.**

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REPORT OF PERFORMANCE

CLIENT	Copperweld Bimetallics,LLC. 5141 Virginia Way, Suite 410 Brentwood, TN, United States 37027
TEST OBJECTS	Copper Clad Steel (CCS) Wires Manufacturer: Copperweld Bimetallics,LLC. Types: Scorpius Prototypes Part Nos.: 61 x 072 7 x 080 Condition: New Copper Conductor Manufacturer: Encore Wire Types: #4/0 AWG (19 strand) CU #6 AWG (single strand) CU Condition: New
TESTED BY	Powertech Labs Inc. 12388 - 88th Ave, Surrey, BC Canada V3W 7R7 www.powertechlabs.com
TEST DATE	2020-01-24 to 2020-01-25
TEST SPECIFICATION	Client Specified, with reference to IEEE Std 80-2013 and IEEE Std 837-2014

Powertech Labs Inc. does not accept any liability for any damages resulting from the use of this report. The results relate only to the item tested, and it is the responsibility of the manufacturer to maintain conformity of any object having the same designations. Information regarding the estimated measurement uncertainty is available upon request. The test report shall not be reproduced except in full, without written approval of Powertech Labs Inc.

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1 INTRODUCTION

At the request of Copperweld Bimetallics,LLC., withstand current and fusing current tests were performed on standard copper and copper clad steel (CCS) wires in accordance with specifications and procedures provided by the client. Reference was made to IEEE Std 80-2013 and IEEE Std 837-2014 as guides for determining current levels and durations for the tests.

The High Power Lab is accredited by the Standards Council of Canada to ISO 17025 for short-circuit testing.

2 TEST OBJECT INFORMATION

The test objects were identified by the client as follows:

Copper Clad Steel Wires (CCS)

Manufacturer:	Copperweld Bimetallics,LLC.
Types:	Scorpius Prototypes
Part Nos.:	61 x 072
	7 x 080
Condition:	New

Copper Conductor

Manufacturer:	Encore Wire
Types:	4/0 AWG (19 strand) CU
	#6 AWG (single strand) CU
Condition:	New

Conductor sample diameters and dc resistance values were measured by the laboratory before testing, as presented in Table 1.

3 GENERAL INFORMATION

3.1 Purpose

The purpose of the tests is to identify the current limits at short durations for standard copper and Copperweld CCS grounding wire products, and to determine if these products meet the applicable requirements of the referenced Standards.

3.2 Witnesses

Name	Company
Jeff Jordan	Copperweld Bimetallics,LLC.
Lora Aboulmouna	Copperweld Bimetallics,LLC.
Jason Smolko	Copperweld Bimetallics,LLC.
Ryan Hale	Copperweld Bimetallics,LLC.

3.3 Tests Performed

Test Standards/Specifications:

Withstand current tests were performed as requested by the client, with reference to the following Standards to determine the test levels:

IEEE Std 80-2013, Table 6 – Specification for the ultimate current carrying capacity of copper grounding cables using symmetrical current.

IEEE Std 837-2014, Clause 7.2 and Table 3 – Electromagnetic force (EMF) test

4 SHORT-CIRCUIT CURRENT TESTS

General Information:

Standard	Client's Specification, with reference to IEEE Std 80-2013 and IEEE Std 837-2014
Test Dates	2020-01-24 to 2020-01-25
Test Leader	Chris Morton

Environmental Conditions:

Ambient temperature	(7 – 9) °C
Relative Humidity	(95 – 99) %

Test Conditions:

Samples were tested in a covered test cell which was open on one side to the outdoor ambient conditions. During each test, one sample was connected horizontally between the laboratory source bus and ground bus, at a bus spacing of 48 inches, as shown in Figures 30 through 33. The samples were terminated using Burndy mechanical connectors, as shown in Figures 34 and 35. The length of each wire sample was the minimum length required to span the distance between the buses, and each sample was at approximately right angles (90°) to both the source and ground bus. Each sample was suspended in free air approximately 46 inches above the floor of the test cell. The temperature of the sample at the start of each test was the natural outdoor ambient temperature of the laboratory, except for tests performed to IEEE 837, where the sample was allowed to cool to less than 100 °C before the second shot.

All tests were performed at a power frequency of 60 Hz using the test circuit shown in Figure 1. Current was initiated by energizing a current limited source that was calibrated to provide the target current through the circuit. The rms current, current symmetry and duration of each test were specified by the client.

The test current was measured using a 300 kA_{peak} rated Rogowski coil (Powertech ID № 39444). The expanded uncertainty of the current measuring system is estimated as 2% (k=2).

Test Results:

The results of the tests are provided in Tables 2 through 5. Current and voltage waveforms for each test are provided in Figures 2 through 29.

The Encore #4/0 AWG Cu wire did not withstand the I^2t calculated from the current and duration specified in IEEE 80, Table 6, for a 500 ms duration (44 kA_{rms}). It was capable of carrying a maximum of 92% of this I^2t value without fusing.

The Encore #4/0 AWG Cu wire did not withstand the EMF current specified in IEEE 837, Table 3 (47 kA_{rms}). It was capable of carrying a maximum of 91% of this current value without failing.

The Copperweld Scorpius CCS 61 x 072 conductor exceeded the 500 ms rms withstand current requirement of IEEE 80, Table 6, and met the EMF current requirements of IEEE 837, Table 3, for a 4/0 conductor.

For the #6 AWG Cu conductor size the Standards did not have current values specified, so these were calculated using Equation (45) from IEEE 80 and Equation (C.1) from IEEE 837. The calculations are presented in Appendix D.

Both the Copperweld Scorpius CCS 7 x 080 conductor and the Encore #6 AWG Cu conductor met the 500 ms rms withstand current requirement of IEEE 80, Table 6 (5.29 kA_{rms}), and the EMF current requirements of IEEE 837, Table 3 (5.81 kA_{rms}), for a #6 AWG Cu conductor.

APPENDIX A – FUSING CURRENT TEST CIRCUIT AND DATA

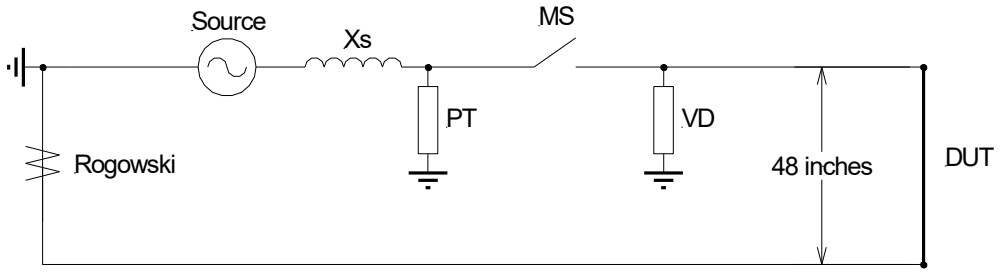


Figure 1: Test circuit schematic for all tests.

Notes:

1. X_S – Source current limiting reactance
2. MS – Making Switch
3. VD – Voltage measurement
4. Rogowski – Current measurement
5. DUT – Device Under Test

Table 1: Strand diameter and dc resistance measurements of sample conductors.

Wire Sample No.	Type	Strand Diameter [1] (in)		Conductor Diameter	Dc Resistance at 20°C
#		1	2	(in)	(μΩ/ft)
1	Encore Wire, 4/0 AWG, 19 strand CU	0.122	0.079	0.492	4.28
2	Encore Wire, 4/0 AWG, 19 strand CU	0.118	0.080	0.501	4.10
3	Encore Wire, 4/0 AWG, 19 strand CU	0.109	0.074	0.495	4.23
4	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.075	0.498	3.98
5	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.079	0.489	4.43
6	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.075	0.490	4.17
7	Encore Wire, 4/0 AWG, 19 strand CU	0.101	0.075	0.489	4.18
8	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.074	0.491	4.15
9	Encore Wire, 4/0 AWG, 19 strand CU	0.106	0.082	0.490	3.97
10	Encore Wire, 4/0 AWG, 19 strand CU	0.105	0.079	0.493	3.73
11	Scorpius 61 x 072 CCS	0.056	---	0.646	6.83
12	Scorpius 61 x 072 CCS	0.058	---	0.649	6.60
13	Scorpius 61 x 072 CCS	0.068	---	0.641	6.60
14	Scorpius 61 x 072 CCS	0.056	---	0.639	6.73
15	Scorpius 61 x 072 CCS	0.067	---	0.646	6.62
16	Scorpius 61 x 072 CCS	0.059	---	0.630	6.53
17	Scorpius 61 x 072 CCS	0.056	---	0.642	6.73
18	Scorpius 61 x 072 CCS	0.067	---	0.637	6.62
19	Scorpius 61 x 072 CCS	0.064	---	0.641	6.85
20	Scorpius 61 x 072 CCS	0.059	---	0.633	6.83
21	Encore Wire, #6 AWG, single strand CU	0.152	---	0.152	33.3
22	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
23	Encore Wire, #6 AWG, single strand CU	0.158	---	0.158	33.2
24	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.4
25	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.3
26	Encore Wire, #6 AWG, single strand CU	0.148	---	0.148	33.6
27	Encore Wire, #6 AWG, single strand CU	0.155	---	0.155	33.3
28	Encore Wire, #6 AWG, single strand CU	0.146	---	0.146	33.1
29	Encore Wire, #6 AWG, single strand CU	0.153	---	0.153	33.2
30	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
31	Scorpius 7 x 080 CCS	0.072	---	0.215	46.3
32	Scorpius 7 x 080 CCS	0.069	---	0.226	45.9
33	Scorpius 7 x 080 CCS	0.065	---	0.220	46.2
34	Scorpius 7 x 080 CCS	0.071	---	0.218	46.4
35	Scorpius 7 x 080 CCS	0.073	---	0.212	46.1
36	Scorpius 7 x 080 CCS	0.065	---	0.216	46.3
37	Scorpius 7 x 080 CCS	0.070	---	0.211	46.1

Note:

[1] Encore 4/0 AWG CU conductor had two sizes of strands, all remaining conductors had one size of strands. Strand and conductor diameters were measured using a digital caliper with a resolution of 0.001 in.

Table 2: Summary of tests on Encore 4/0 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
1	1	Run to fusing	3.85	41.7	60.0	530	923	2	Y
2	2	Withstand	3.85	41.8	62.5	509	889	3	N
3-1	3	EMF (IEEE 837)	4.24	48.0	130	262	826	4	N
3-2	3	EMF (IEEE 837)	4.26	48.0	130	127	503	5	Y
4	4	EMF (IEEE 837)	4.25	48.0	130	260	823	6	Y
5-1	5	EMF (IEEE 837)	4.20	47.4	129	262	808	7	N
5-2	5	EMF (IEEE 837)	4.19	47.4	128	9.9	77	8	Y
6-1	6	EMF (IEEE 837)	3.93	42.6	116	263	662	9	N
6-2	6	EMF (IEEE 837)	3.91	42.6	116	262	654	10	N

Table 3: Summary of tests on Copperweld Scorpius 61 x 072 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
7	11	Run to fusing	3.84	41.7	59.6	673	1173	11	Y
8	12	Run to fusing	4.25	48.1	69.8	500	1157	12	Y
9	13	Run to fusing	4.21	47.5	68.9	508	1150	13	Y
10	14	Withstand	4.09	46.2	66.2	508	1089	14	N
11-1	15	EMF (IEEE 837)	4.21	47.6	129	262	803	15	N
11-2	15	EMF (IEEE 837)	4.20	47.7	129	262	803	16	N
12-1	16	EMF (IEEE 837)	4.21	47.6	129	254	784	17	N
12-2	16	EMF (IEEE 837)	4.19	47.4	128	254	767	18	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

Table 4: Summary of tests on Encore #6 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
13	21	Run to fusing	3.90	5.18	7.36	607	16.3	19	Y
14	23	Run to fusing	3.90	5.18	7.57	600	16.1	20	Y
15	24	Run to fusing	4.27	5.68	8.15	500	16.1	21	Y
16-1	25	EMF (IEEE 837)	3.77	5.86	16.2	262	13.9	22	N
16-2	25	EMF (IEEE 837)	3.77	5.86	16.1	262	13.9	23	N

Table 5: Summary of tests on Copperweld Scorpius 7 x 080 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
17	31	Withstand	3.88	5.16	7.44	858	22.9	24	N
18	32	Run to fusing	3.89	5.16	7.43	908	24.2	25	Y
19	33	Run to fusing	4.48	7.00	10.3	493	24.1	26	Y
20	34	Run to fusing	4.41	6.91	10.2	502	23.9	27	Y
21-1	35	EMF (IEEE 837)	3.81	5.91	16.3	262	14.0	28	N
21-2	35	EMF (IEEE 837)	3.80	5.92	16.2	262	13.8	29	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

APPENDIX B – WAVEFORMS

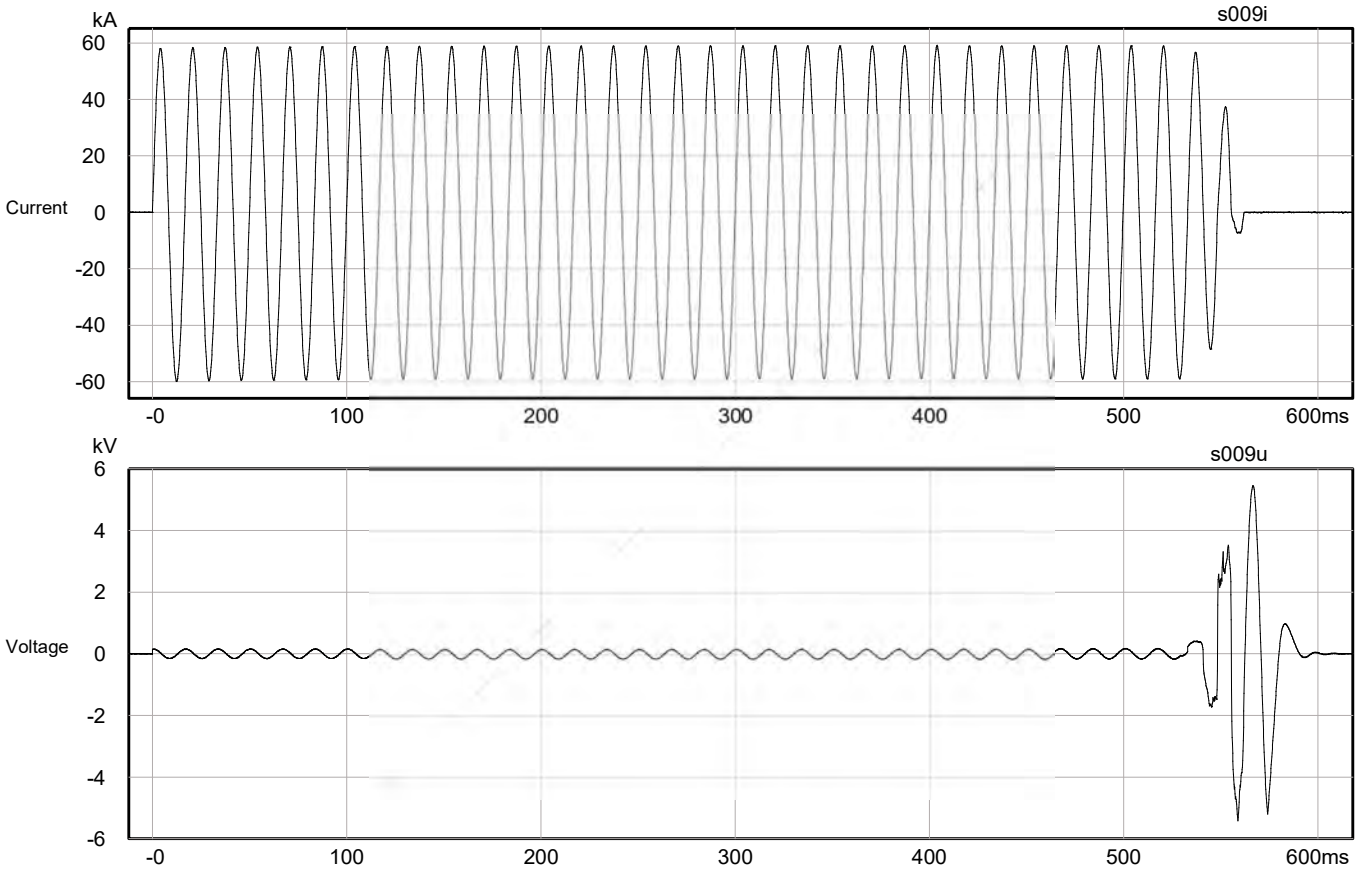


Figure 2: Waveforms for Test #1, Encore 4/0 AWG Sample 1.

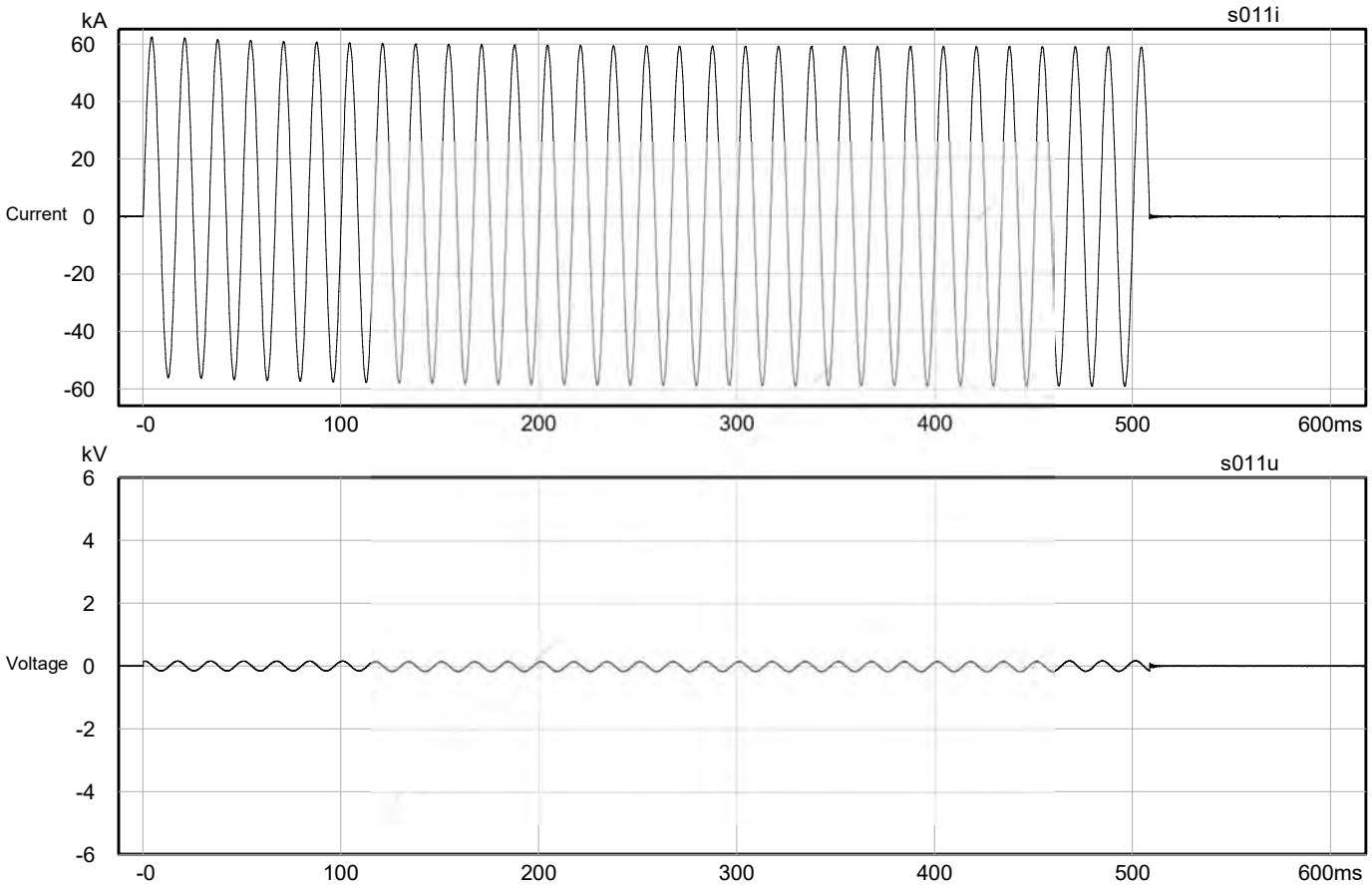


Figure 3: Waveforms for Test #2, Encore 4/0 AWG Sample 2.

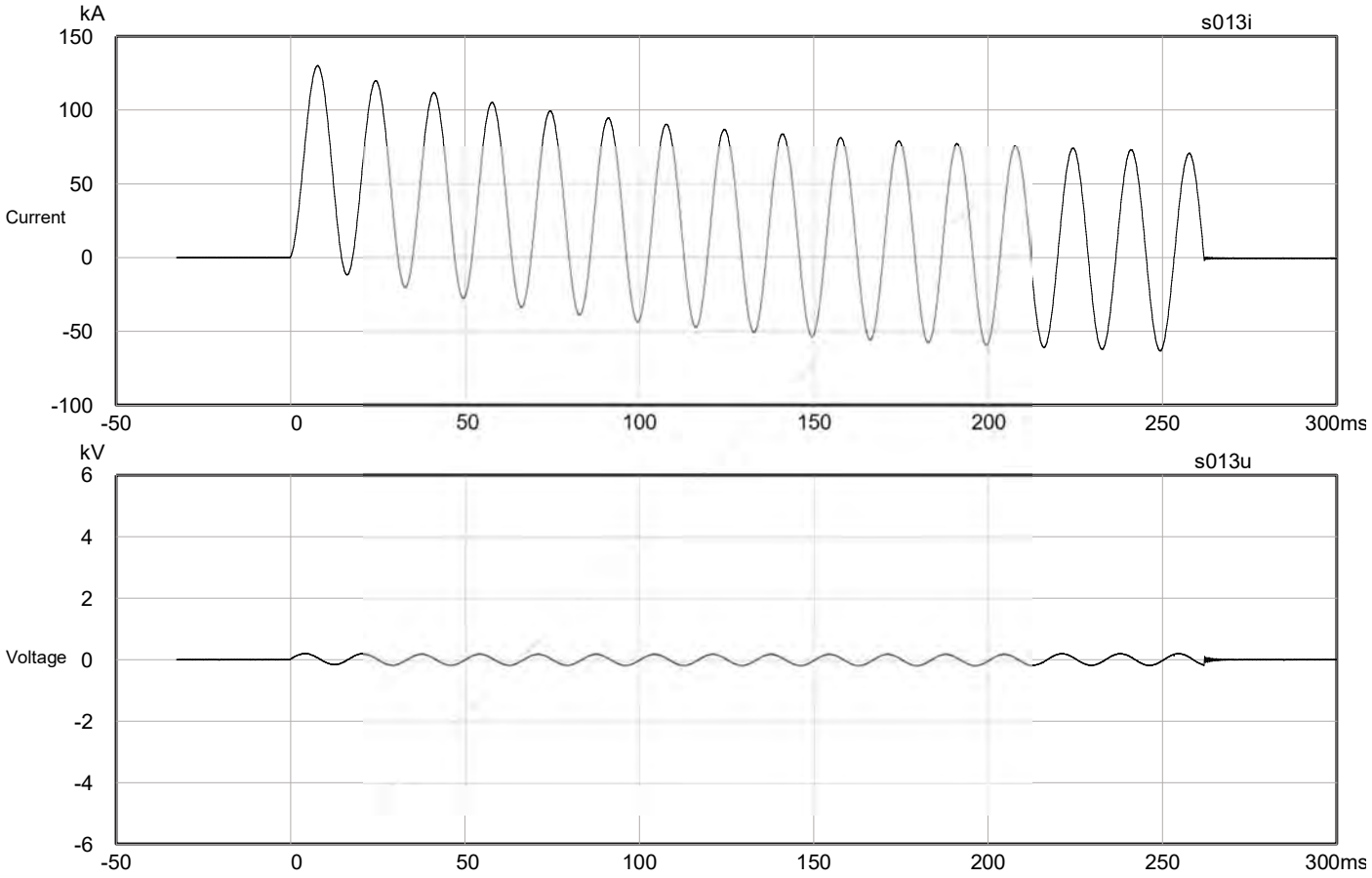


Figure 4: Waveforms for Test #3-1, Encore 4/0 AWG Sample 3.

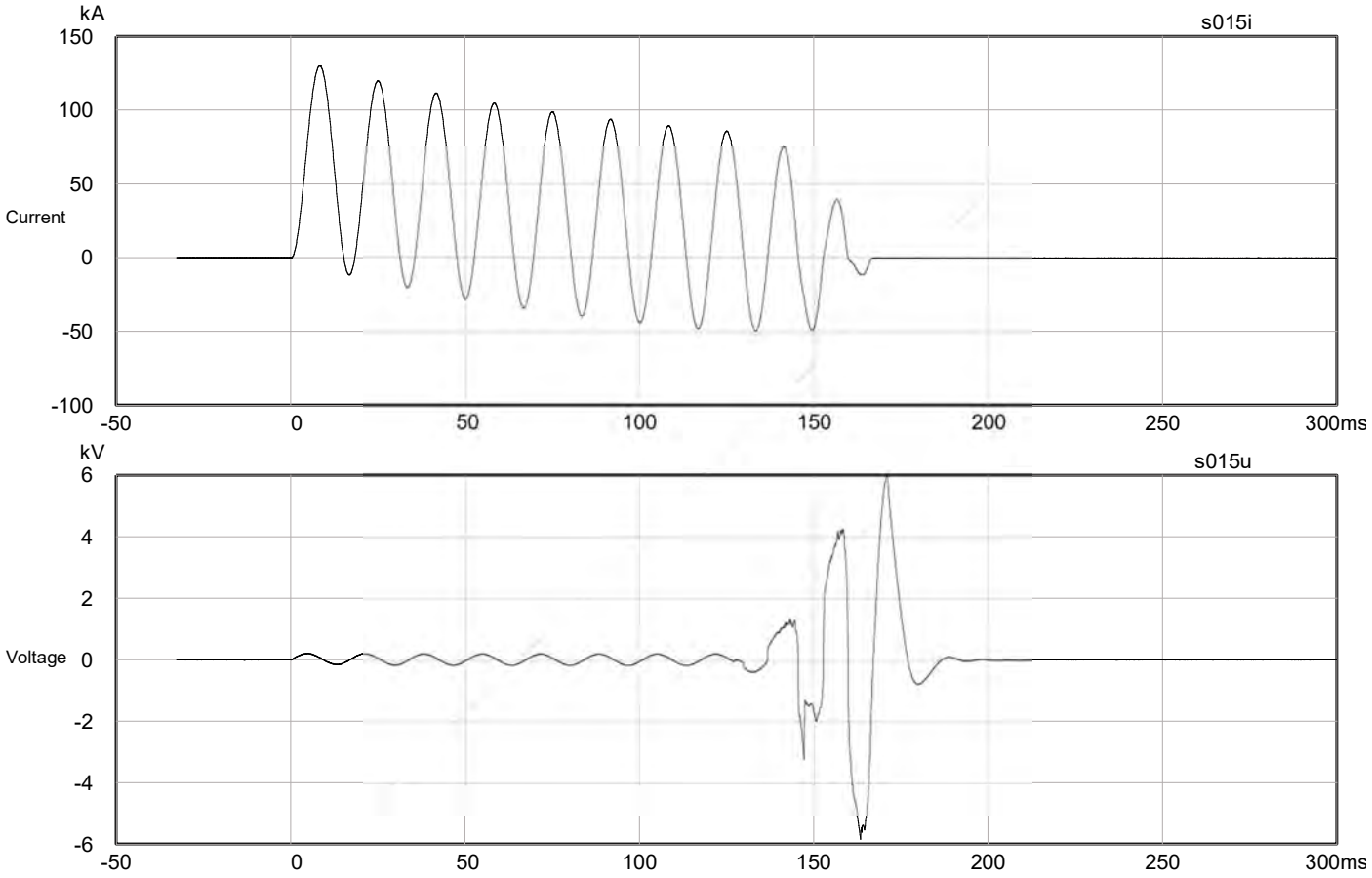


Figure 5: Waveforms for Test #3-2, Encore 4/0 AWG Sample 3.

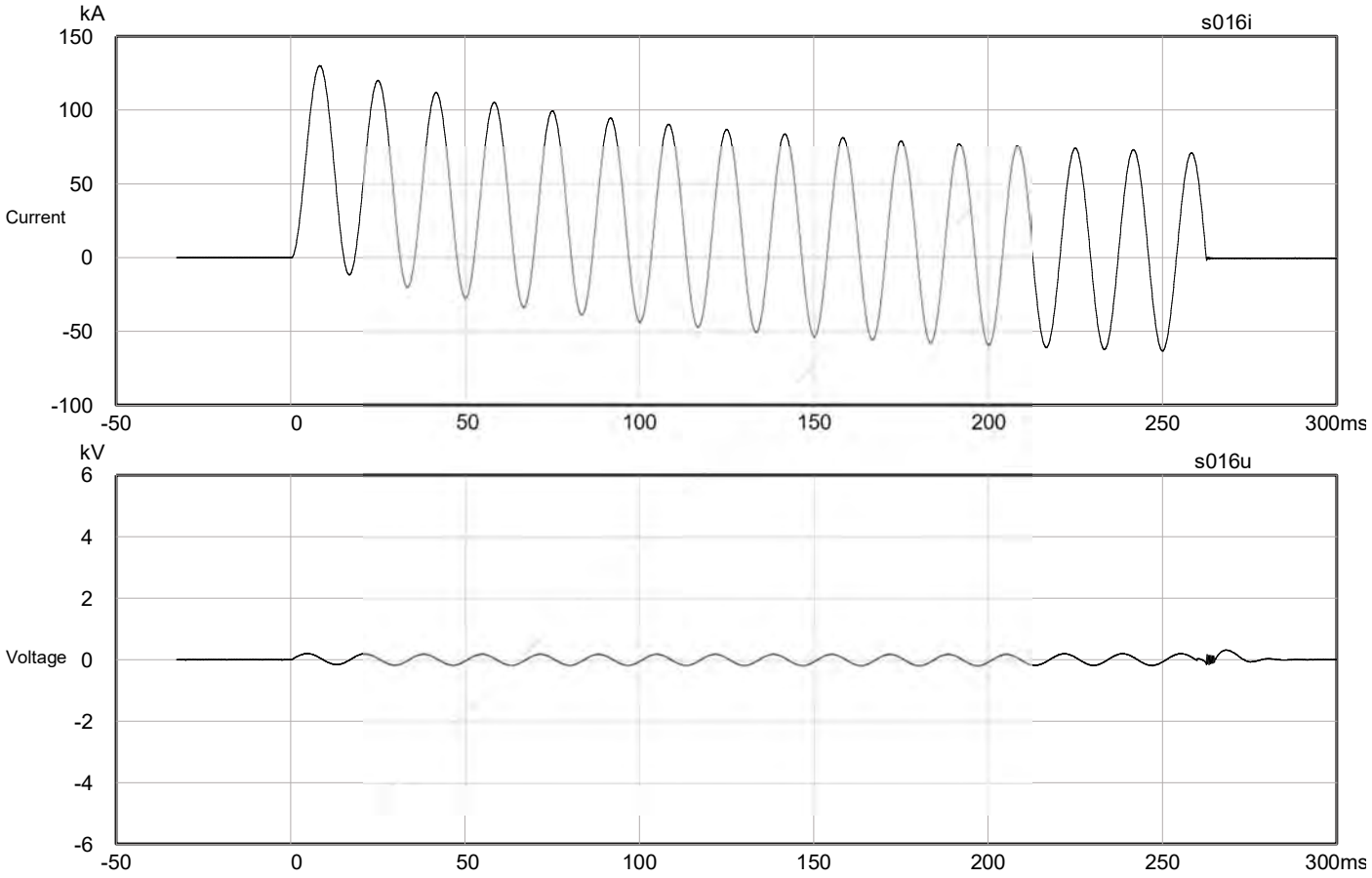


Figure 6: Waveforms for Test #4, Encore 4/0 AWG Sample 4.

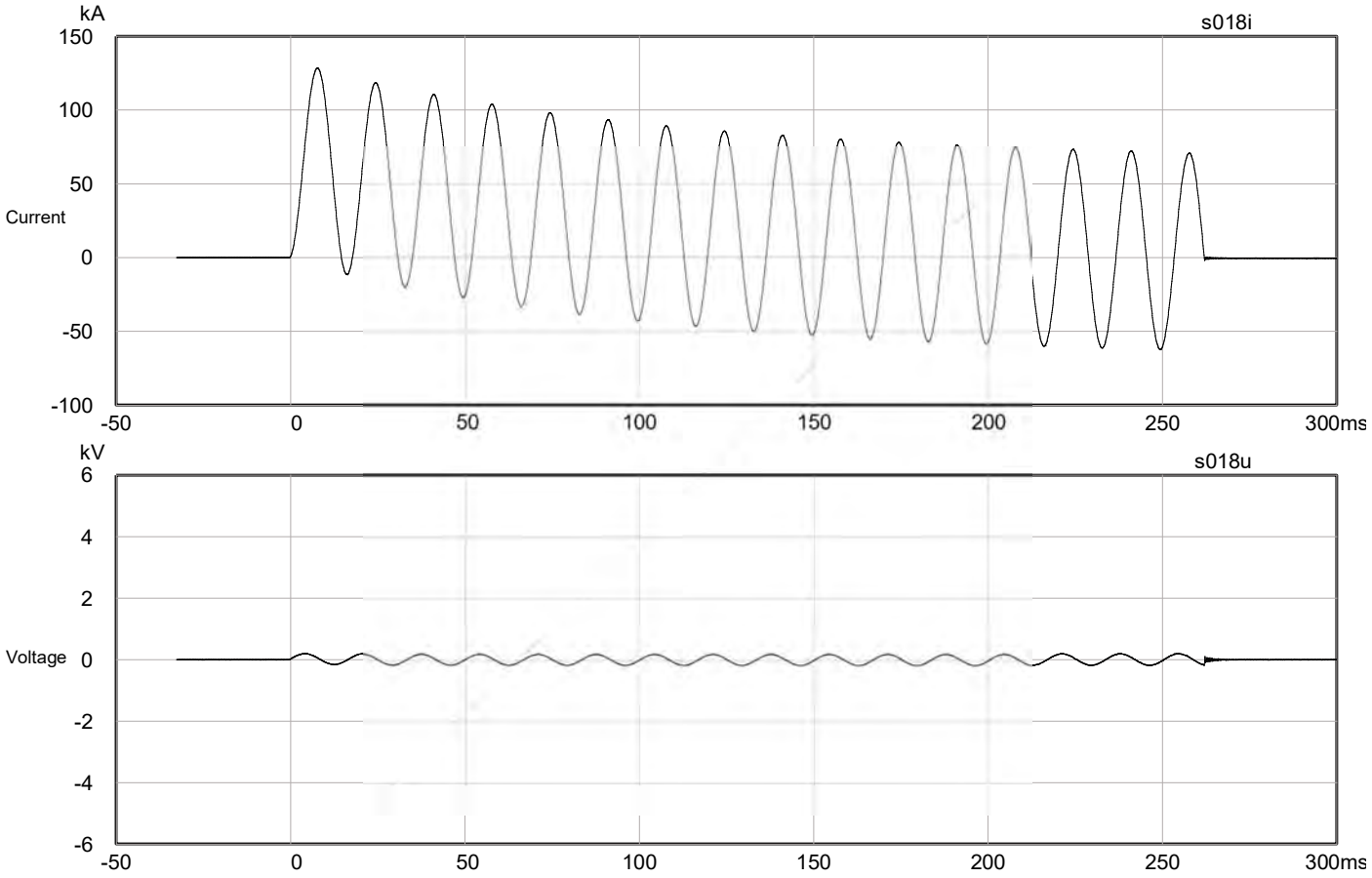


Figure 7: Waveforms for Test #5-1, Encore 4/0 AWG Sample 5.

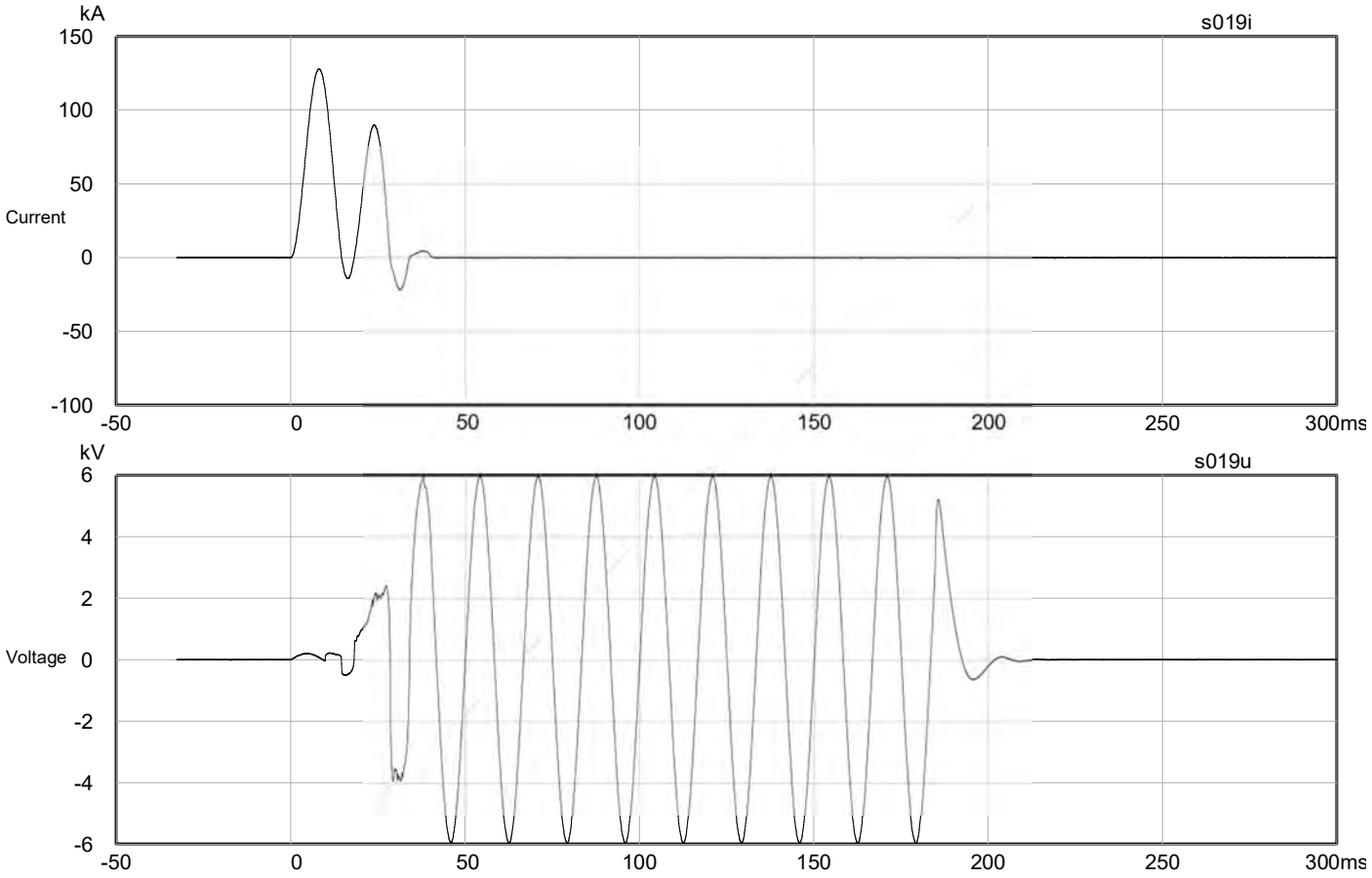


Figure 8: Waveforms for Test #5-2, Encore 4/0 AWG Sample 5.

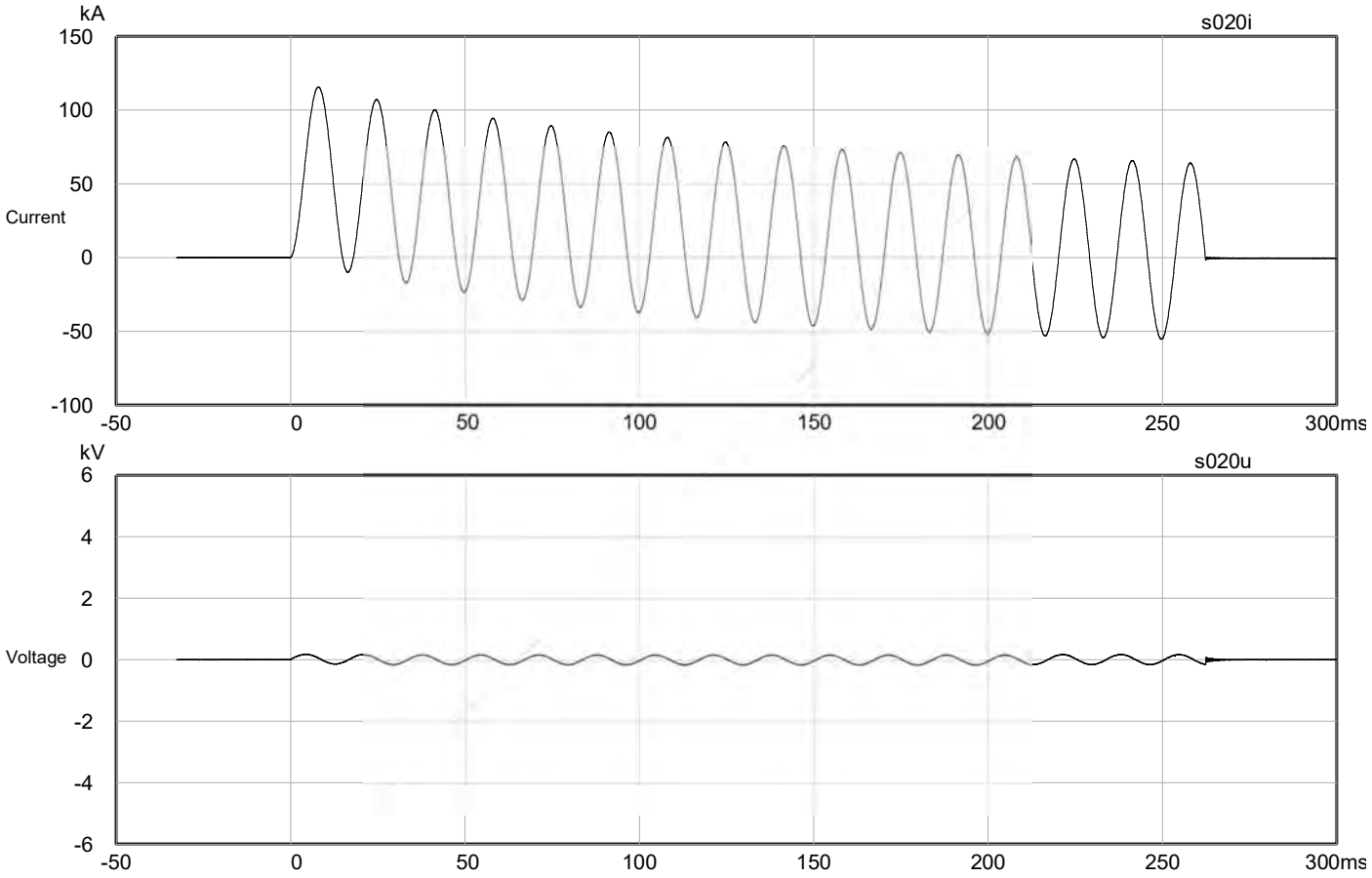


Figure 9: Waveforms for Test #6-1, Encore 4/0 AWG Sample 6.

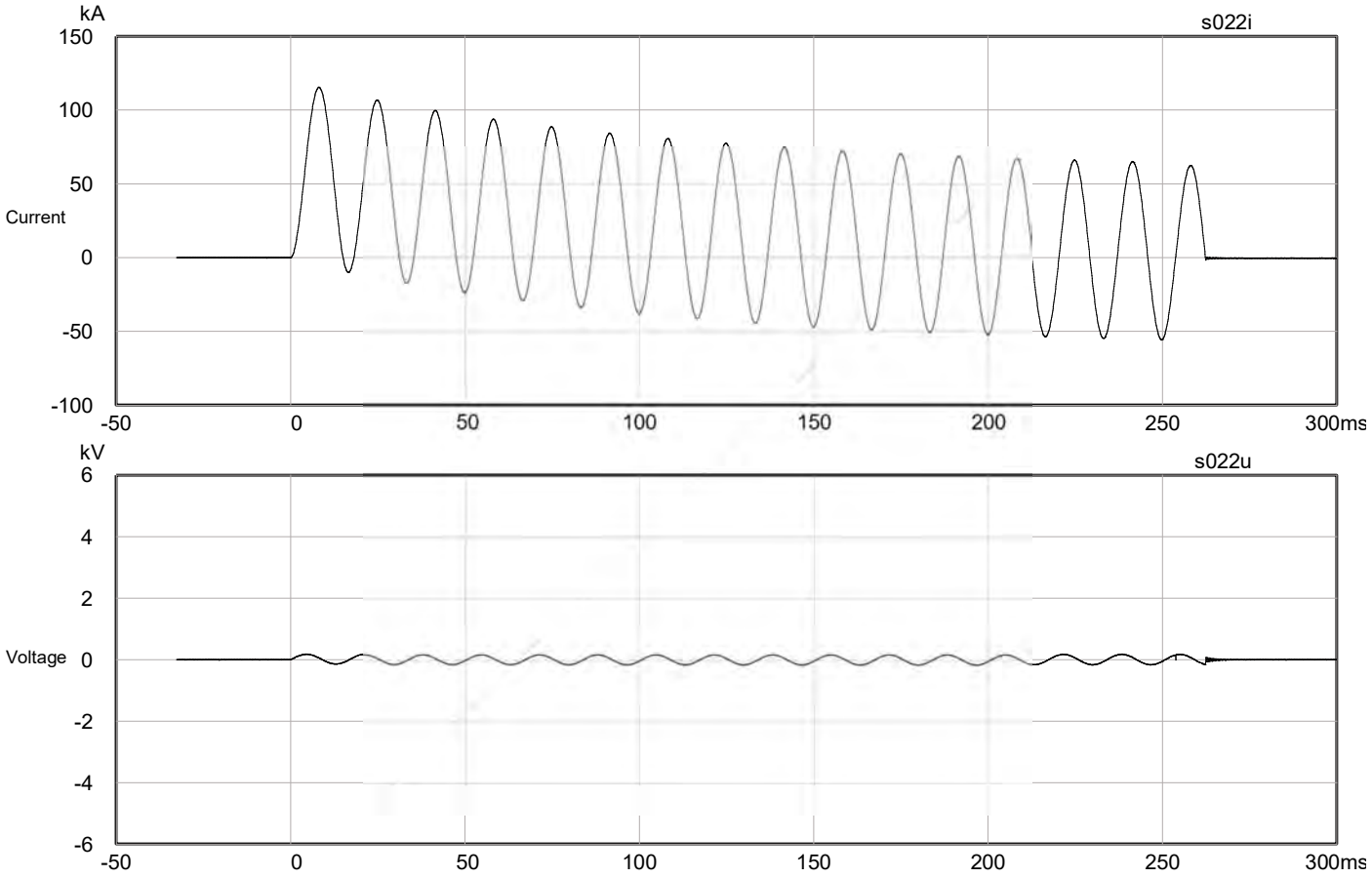


Figure 10: Waveforms for Test #6-2, Encore 4/0 AWG Sample 6.

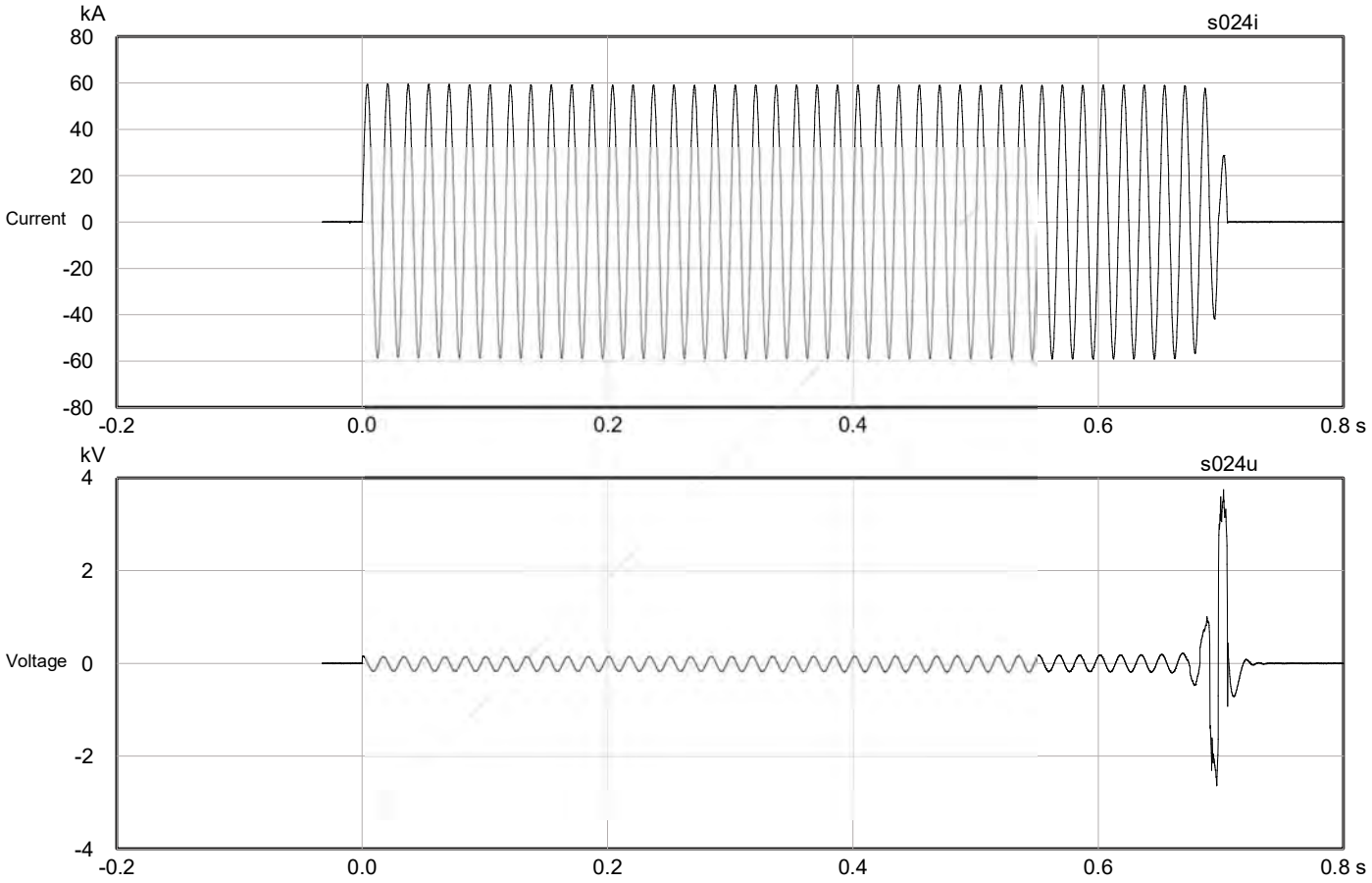


Figure 11: Waveforms for Test #7, Copperweld Scorpius 61 x 072 Sample 11.

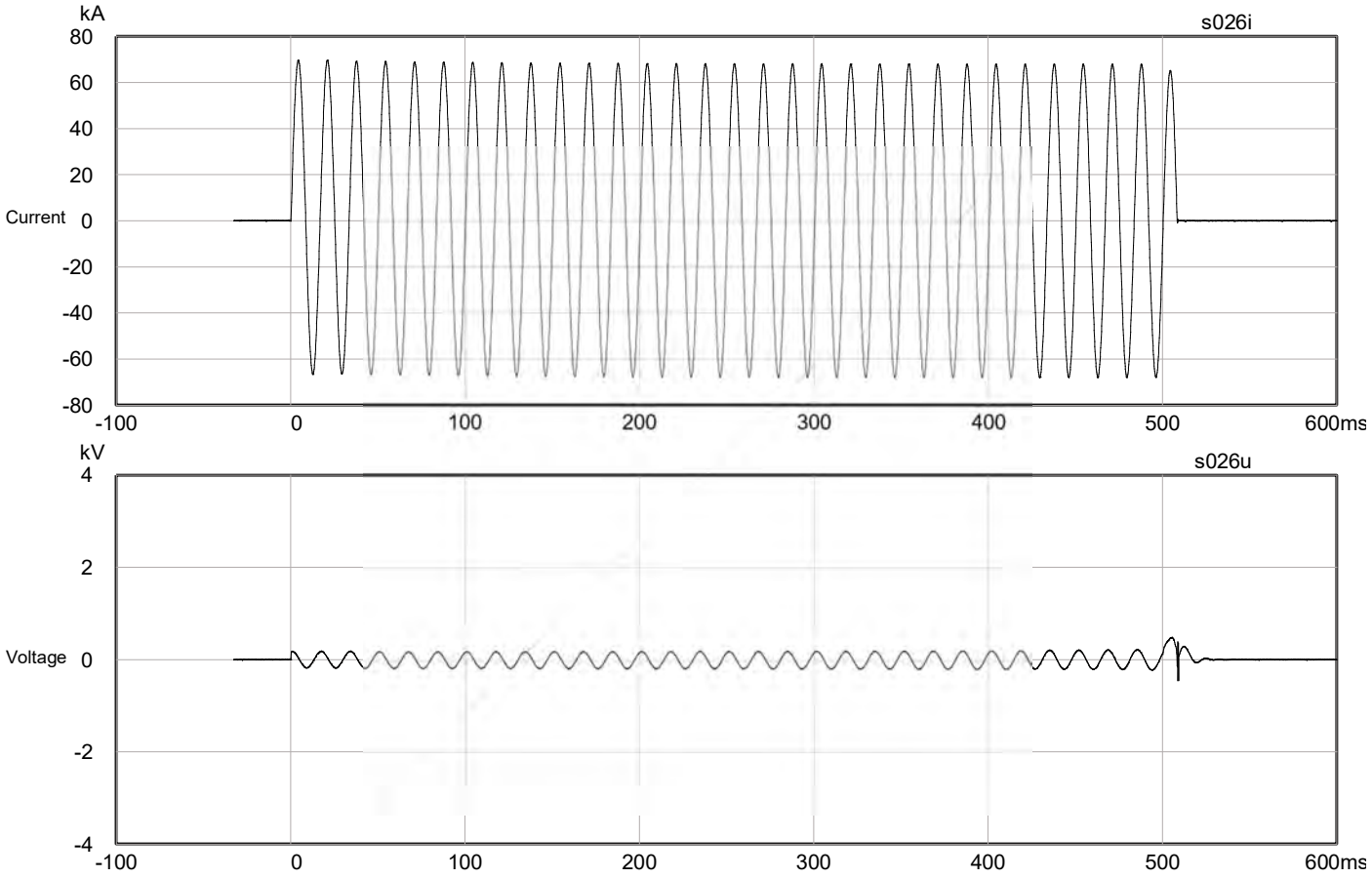


Figure 12: Waveforms for Test #6, Copperweld Scorpius 61 x 072 Sample 12.

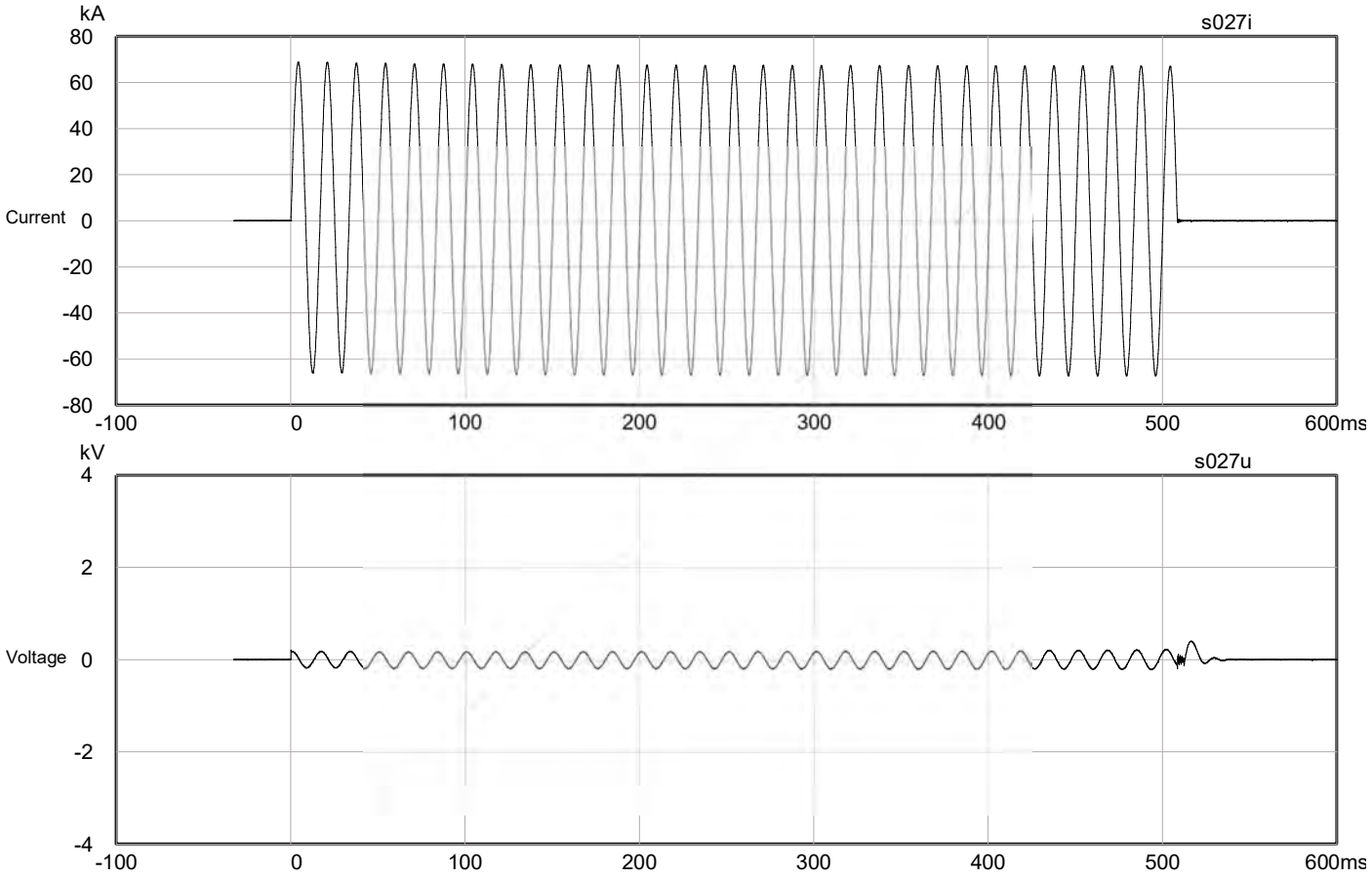


Figure 13: Waveforms for Test #9, Copperweld Scorpius 61 x 072 Sample 13.

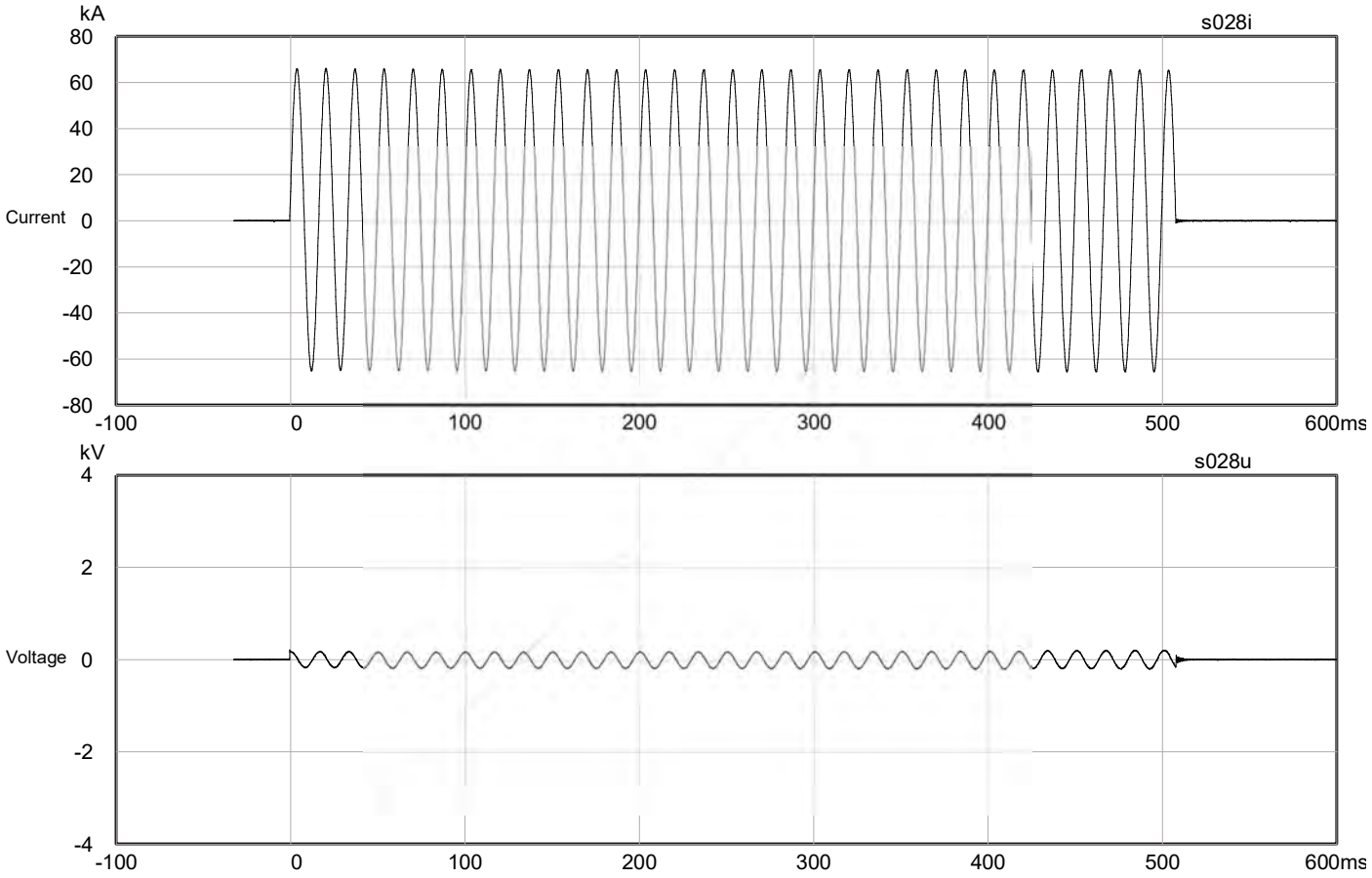


Figure 14: Waveforms for Test #10, Copperweld Scorpius 61 x 072 Sample 14.

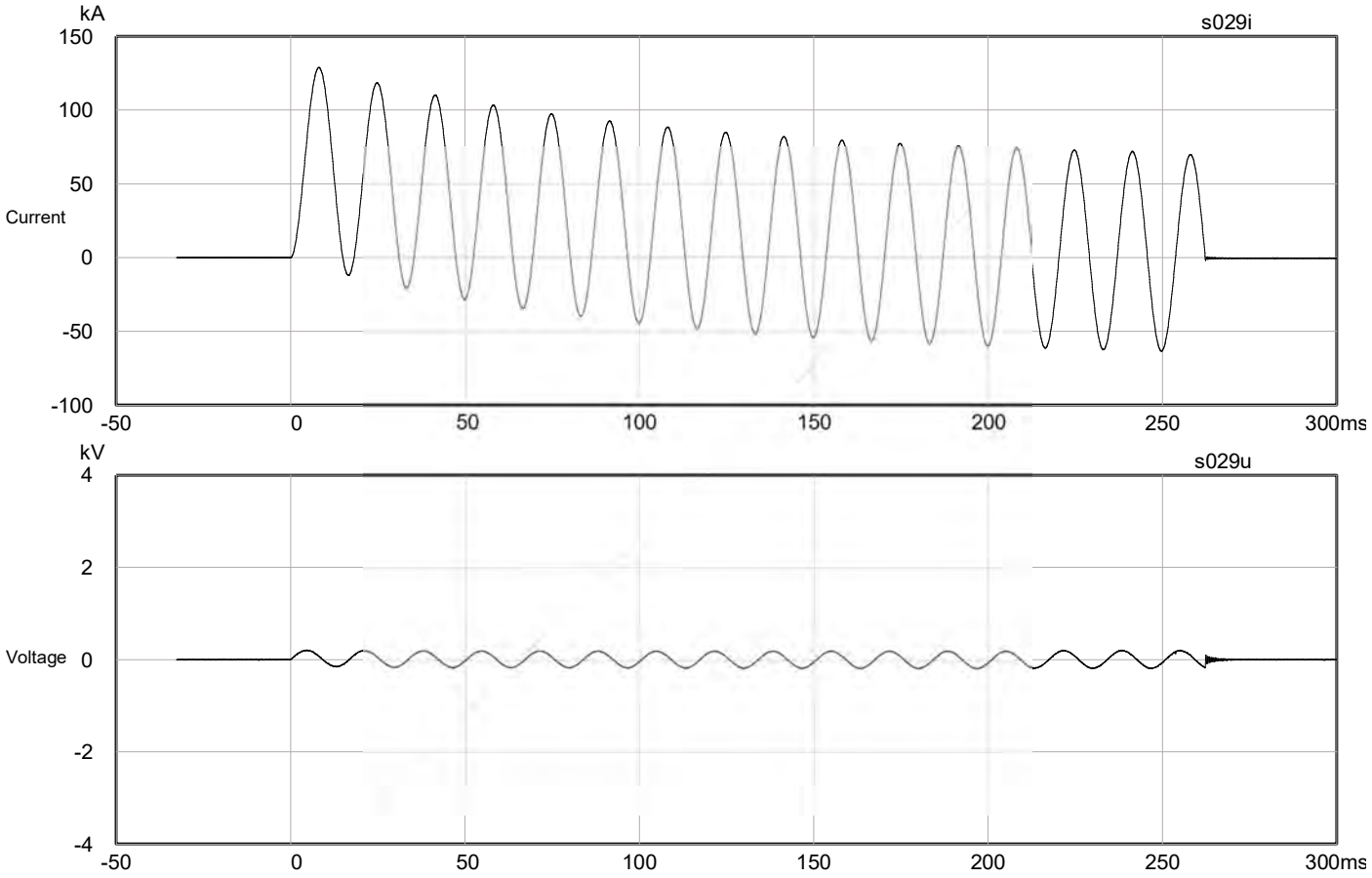


Figure 15: Waveforms for Test #11-1, Copperweld Scorpius 61 x 072 Sample 15.

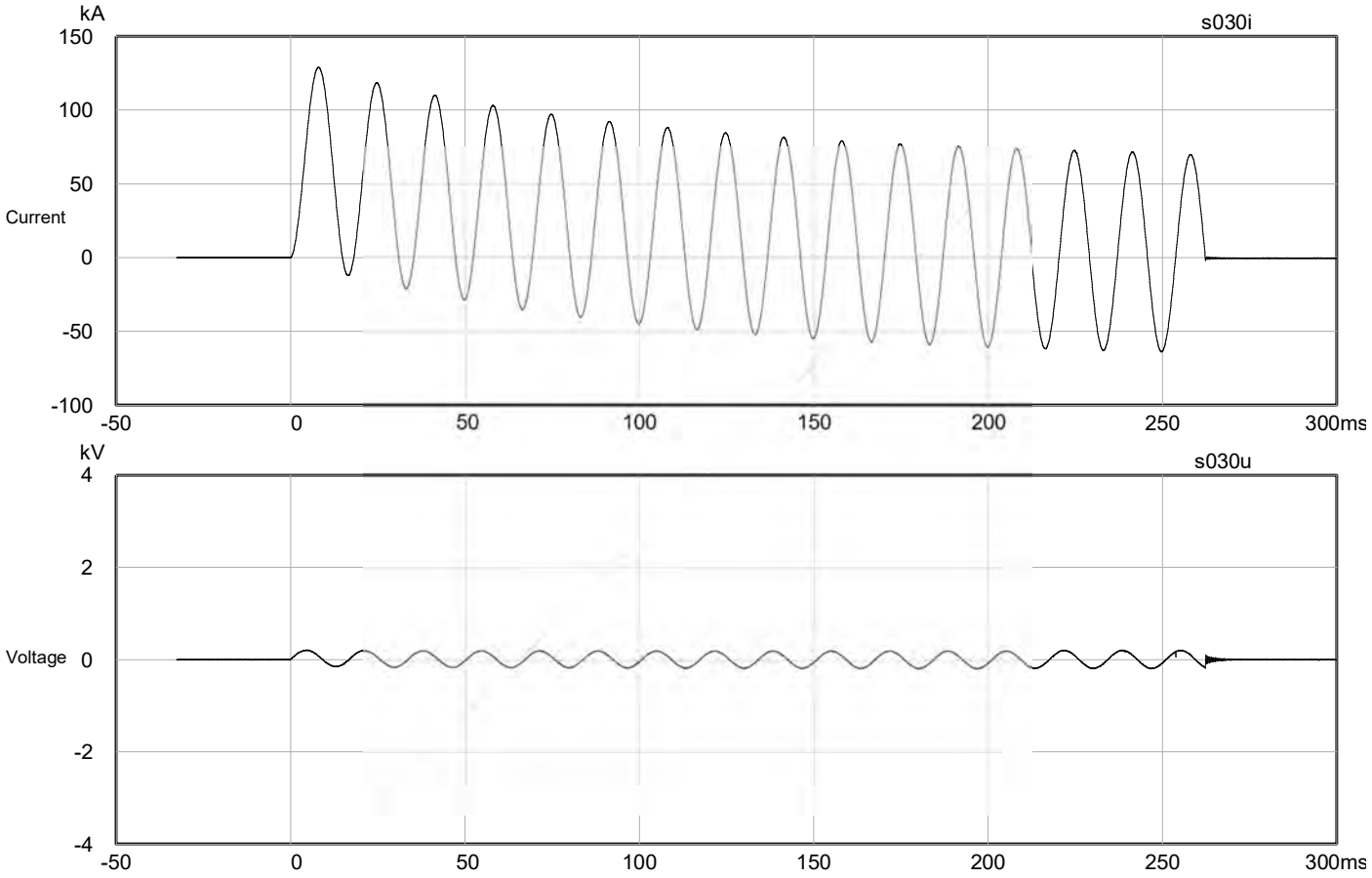


Figure 16: Waveforms for Test #11-2, Copperweld Scorpius 61 x 072 Sample 15.

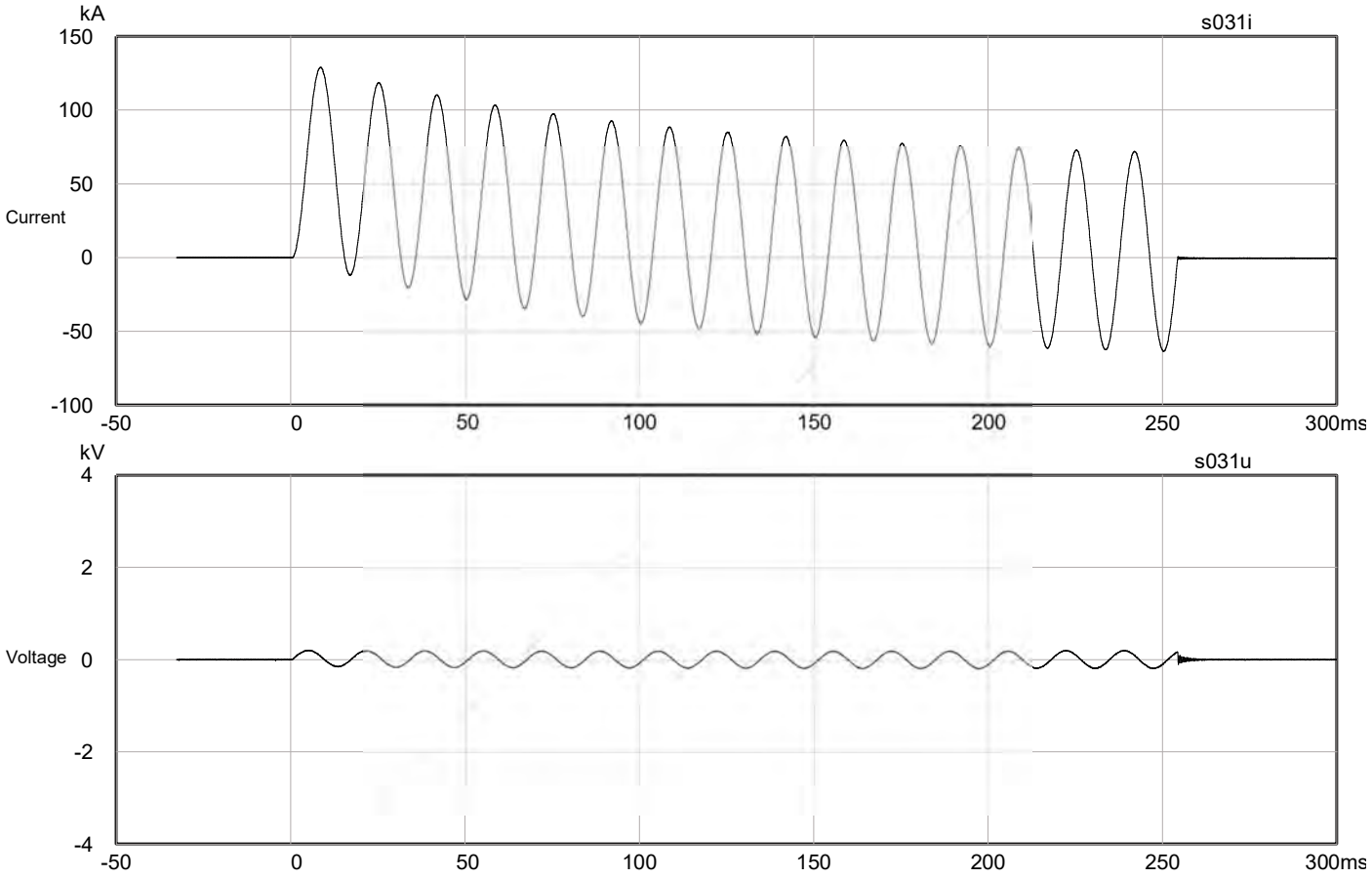


Figure 17: Waveforms for Test #12-1, Copperweld Scorpius 61 x 072 Sample 16.

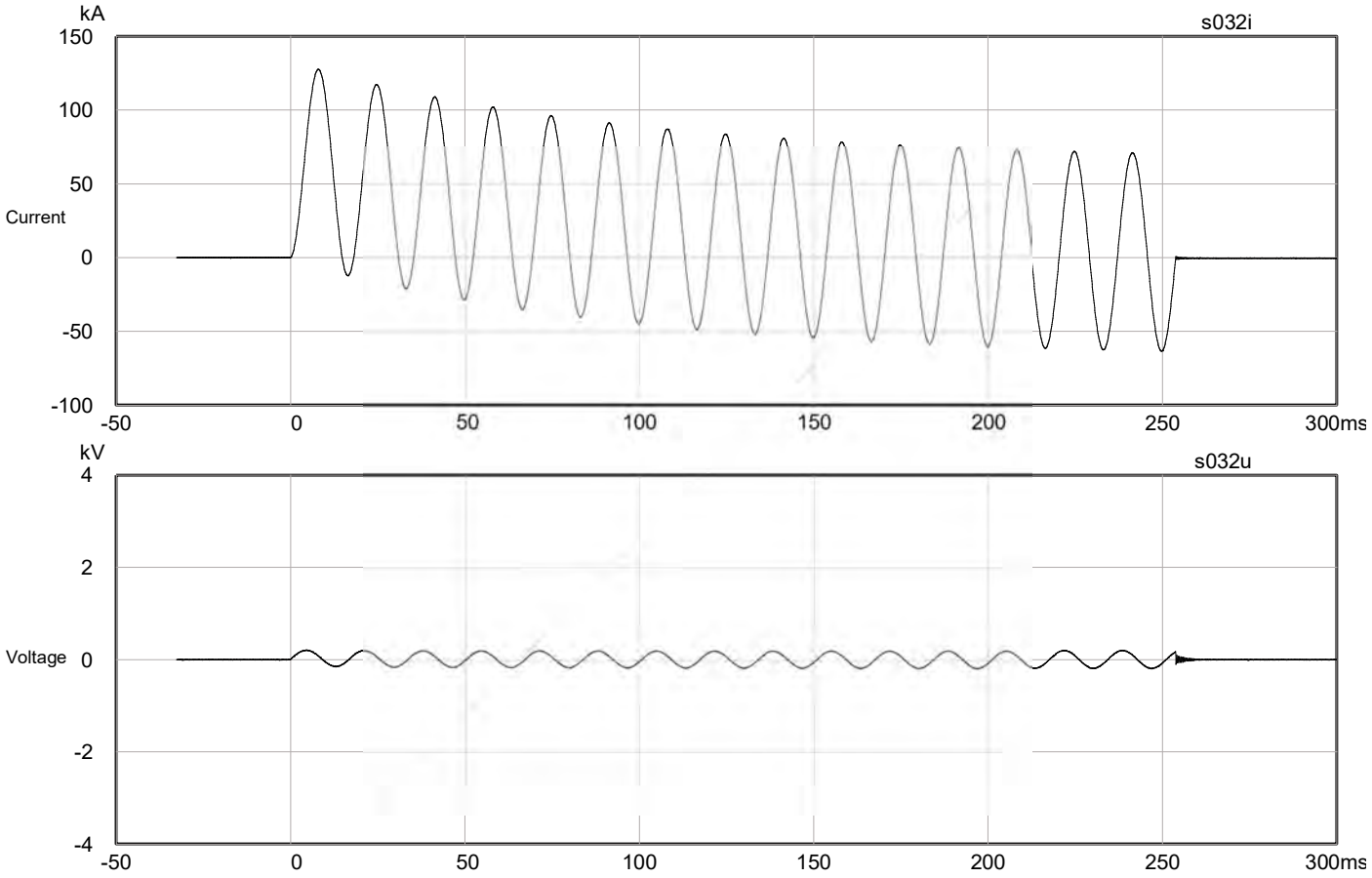


Figure 18: Waveforms for Test #12-2, Copperweld Scorpius 61 x 072 Sample 16.

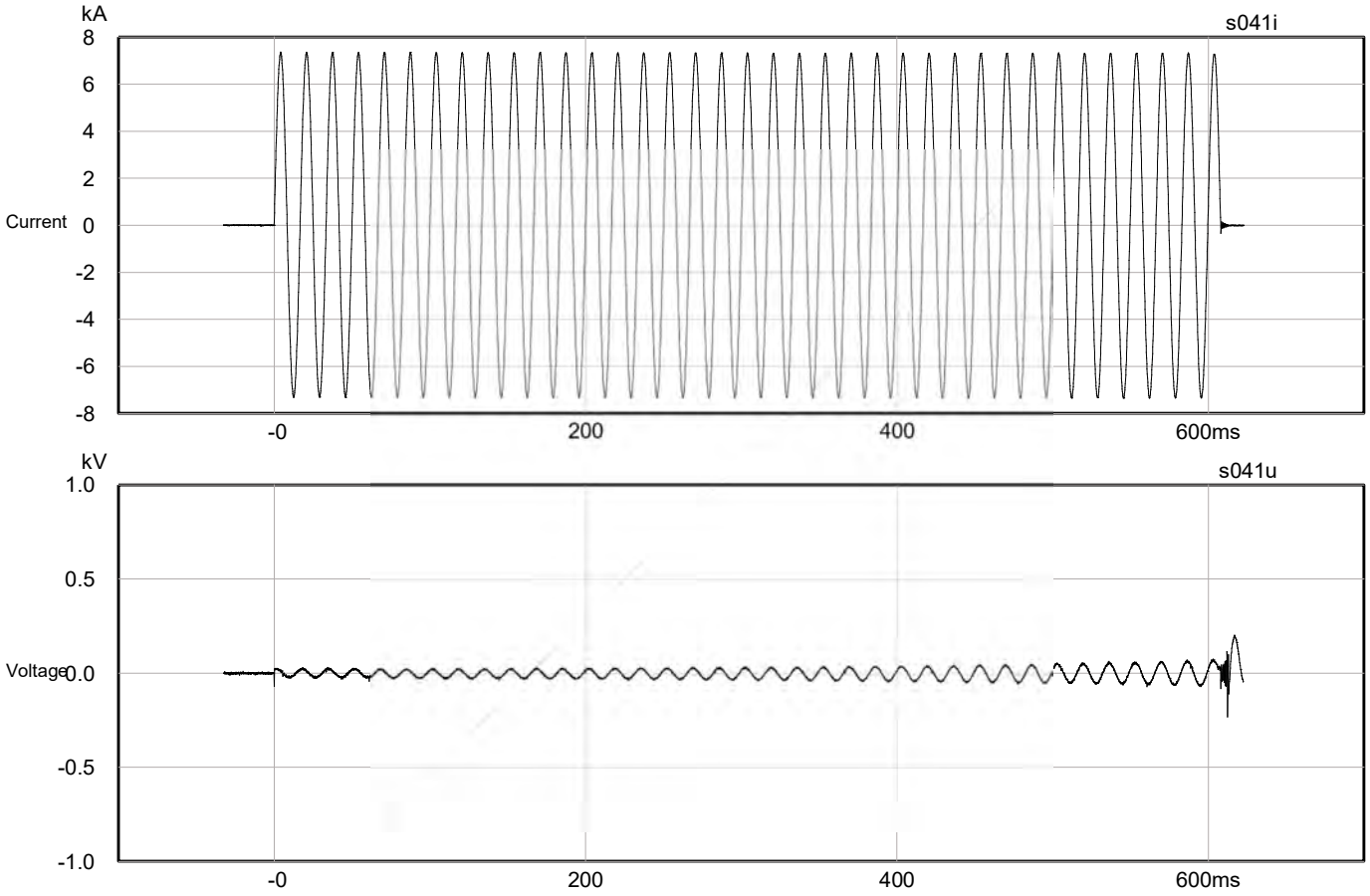


Figure 19: Waveforms for Test #13, Encore #6 AWG Sample 21.

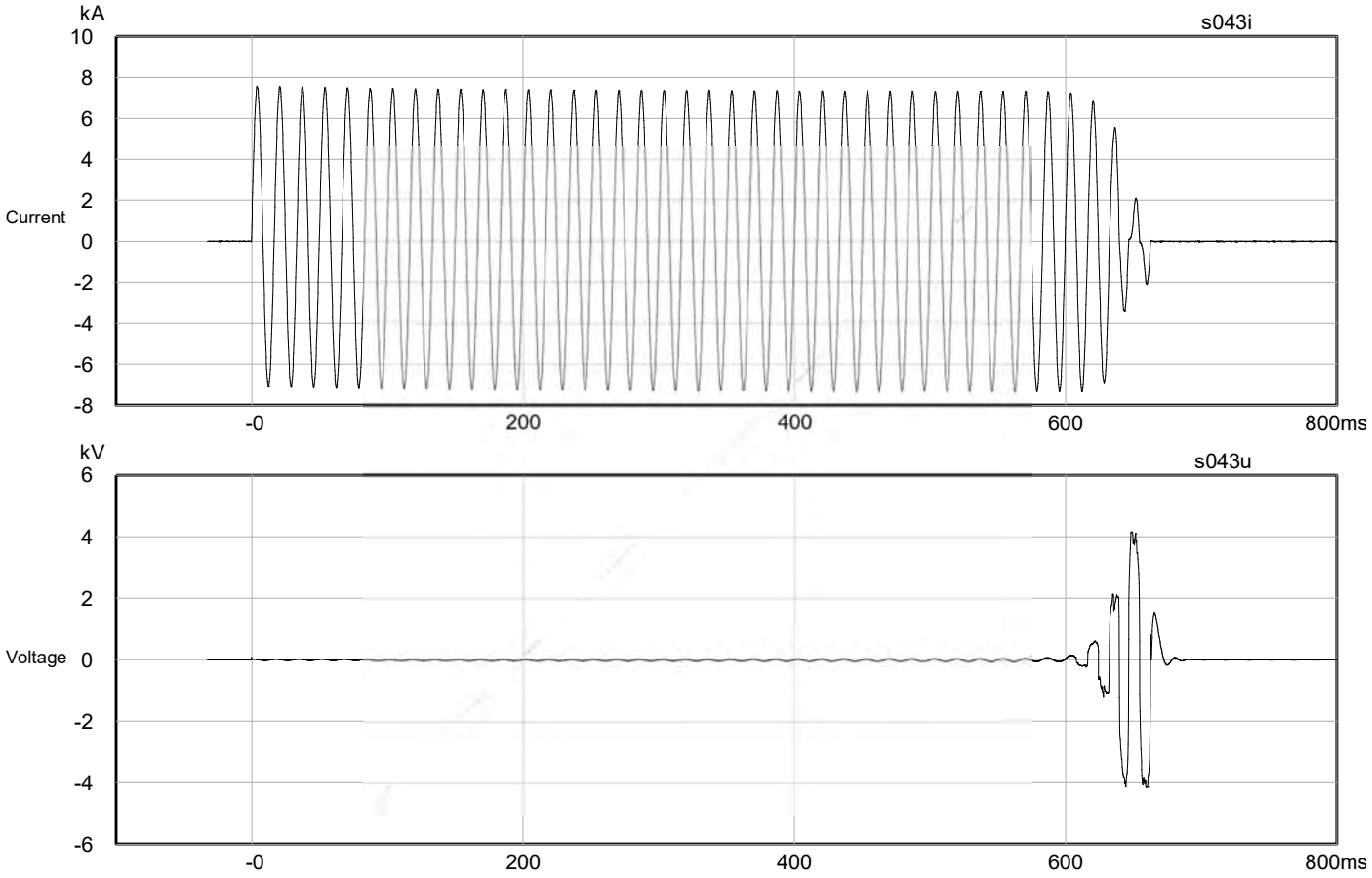


Figure 20: Waveforms for Test #14, Encore #6 AWG Sample 23.

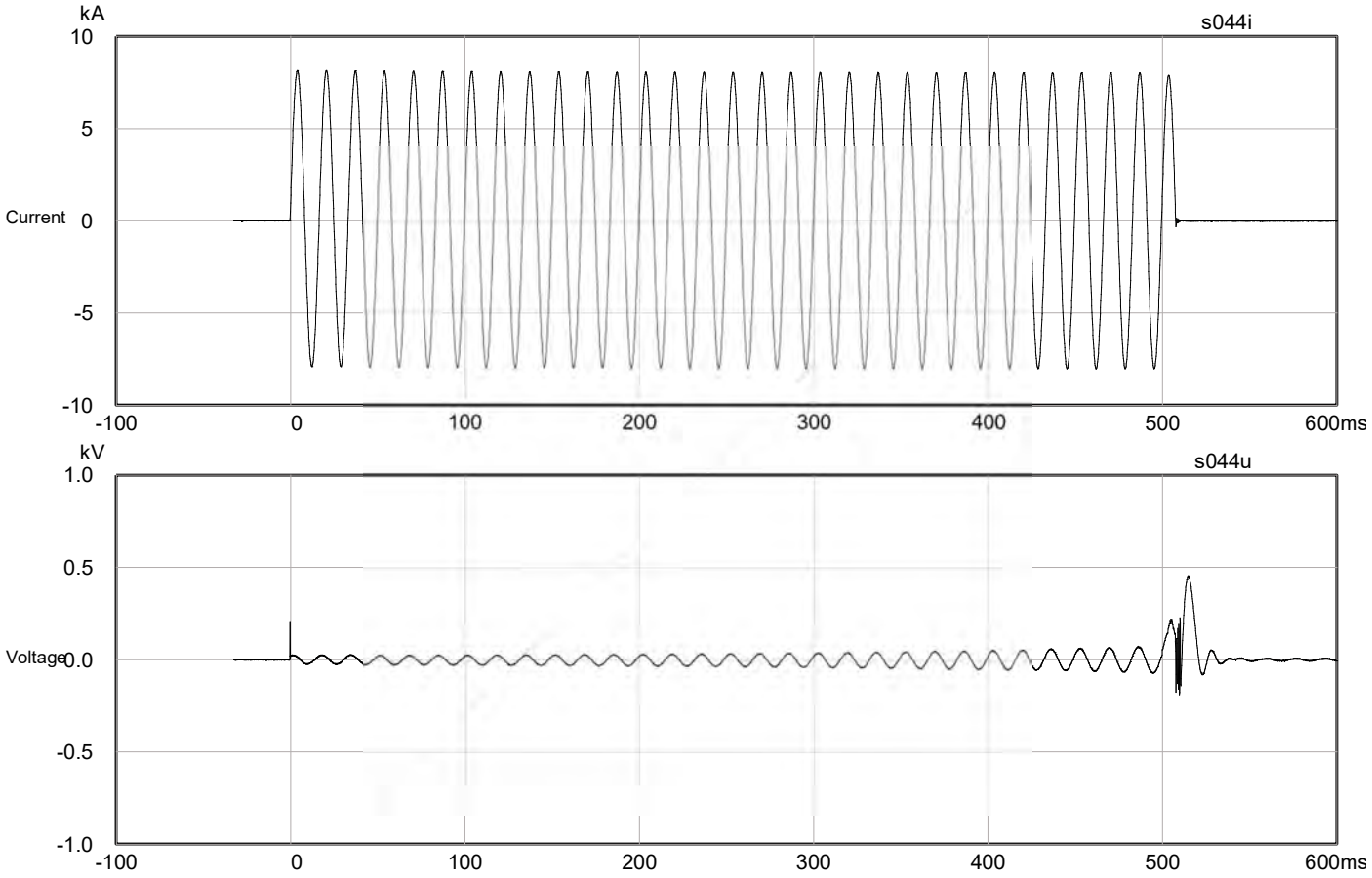


Figure 21: Waveforms for Test #15, Encore #6 AWG Sample 24.

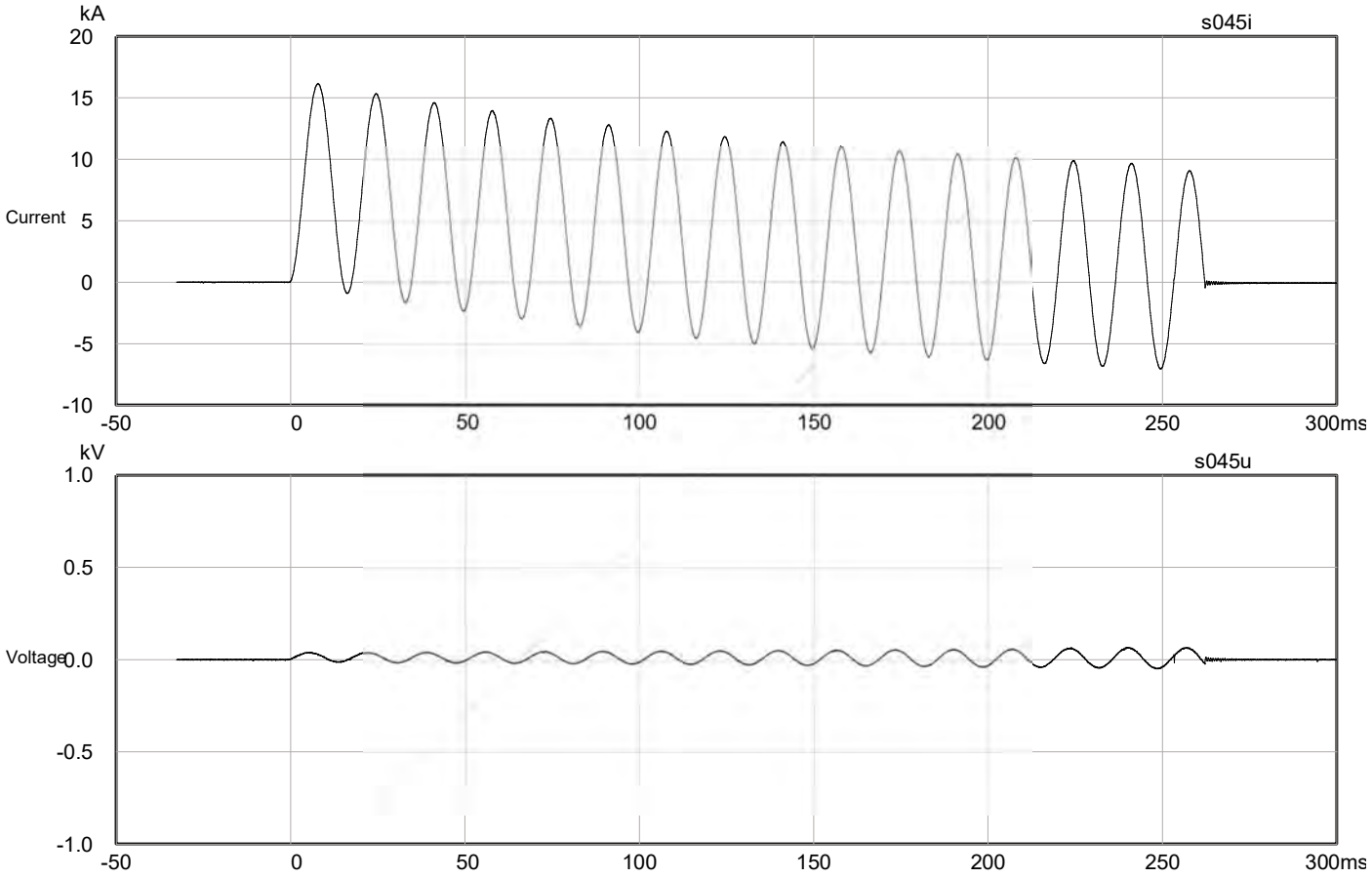


Figure 22: Waveforms for Test #16-1, Encore #6 AWG Sample 25.

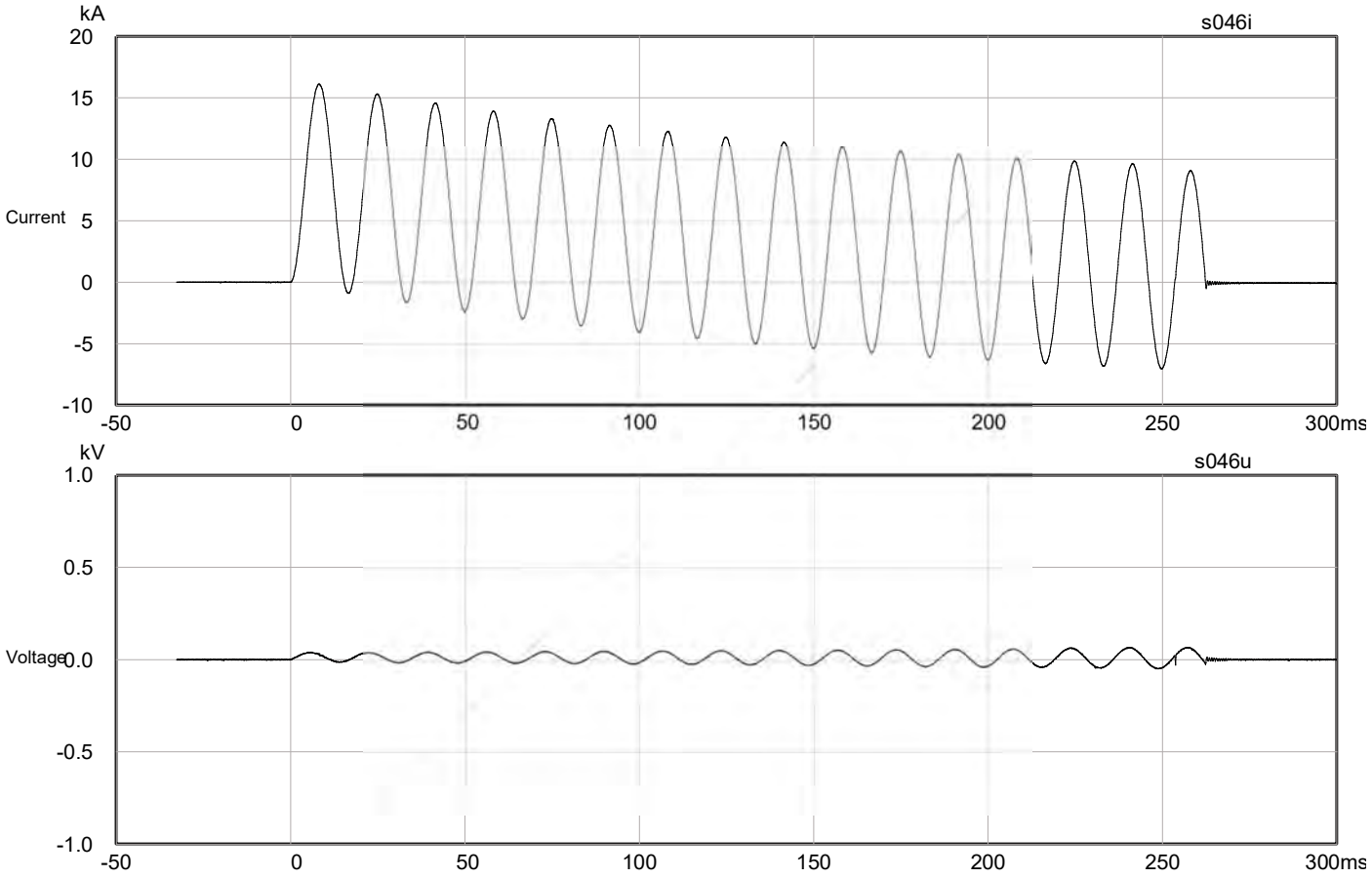


Figure 23: Waveforms for Test #16-2, Encore #6 AWG Sample 25.

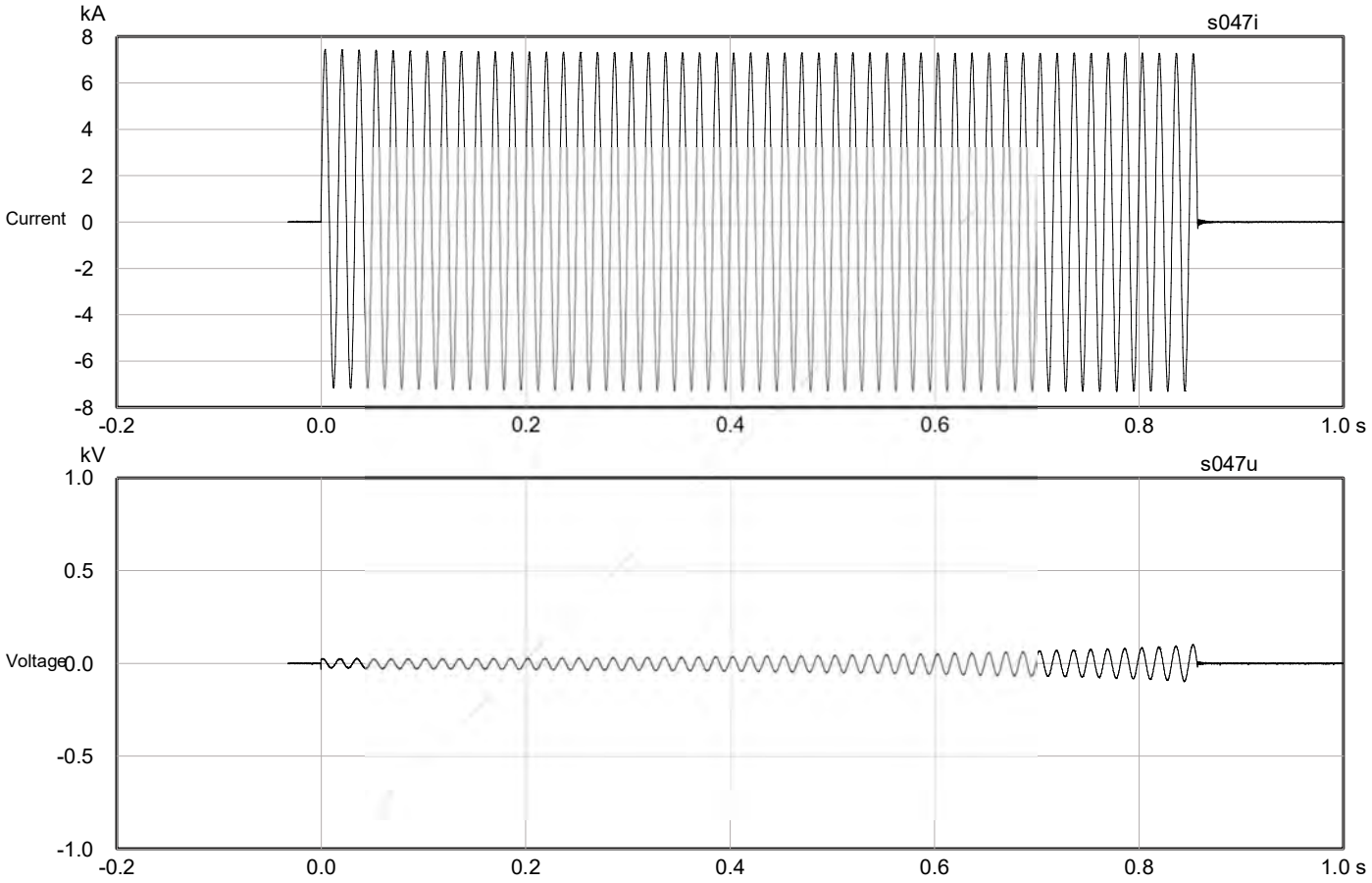


Figure 24: Waveforms for Test #17, Encore #6 AWG Sample 31.

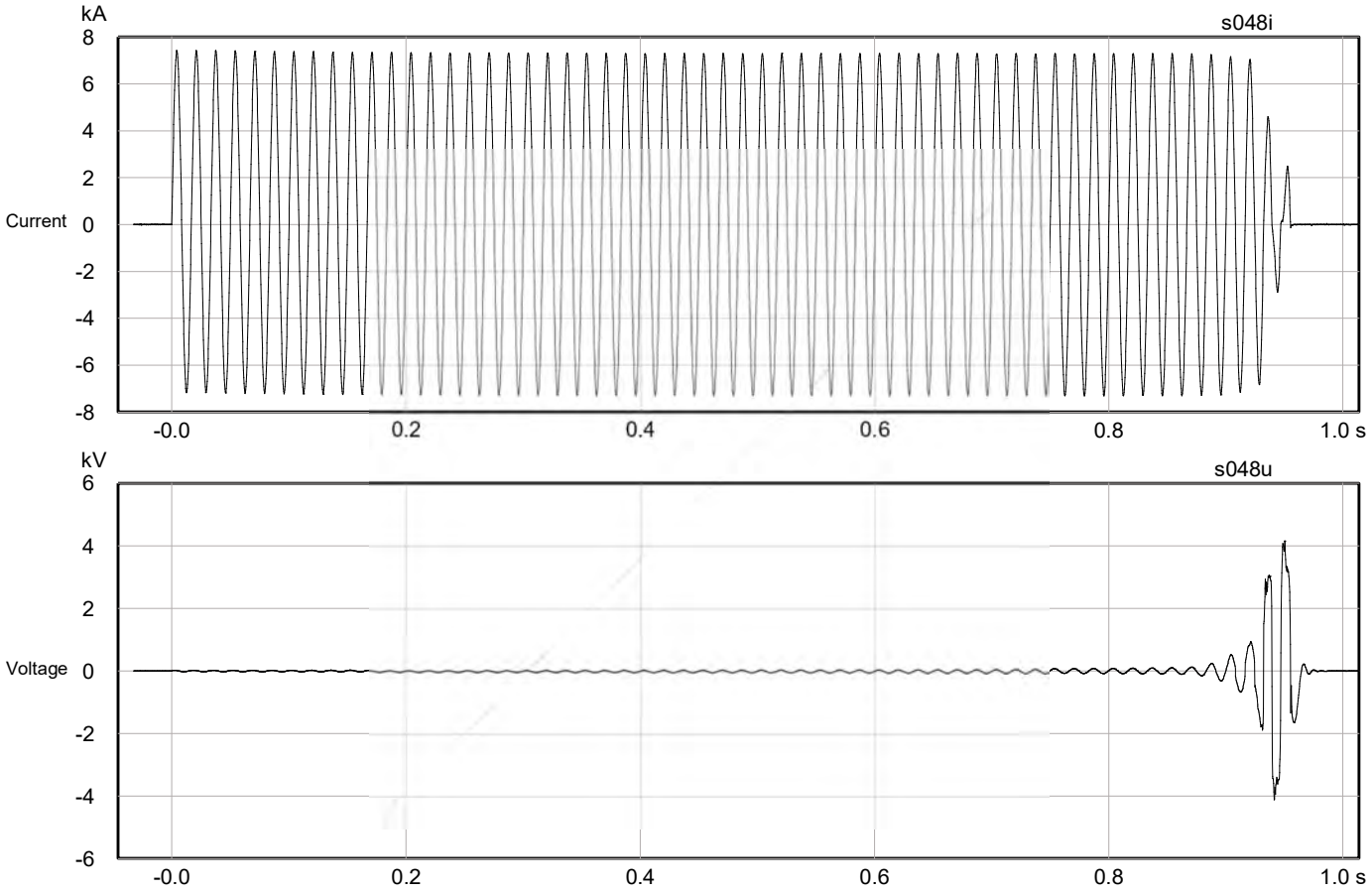


Figure 25: Waveforms for Test #18, Copperweld Scorpius 7 x 080 Sample 32.

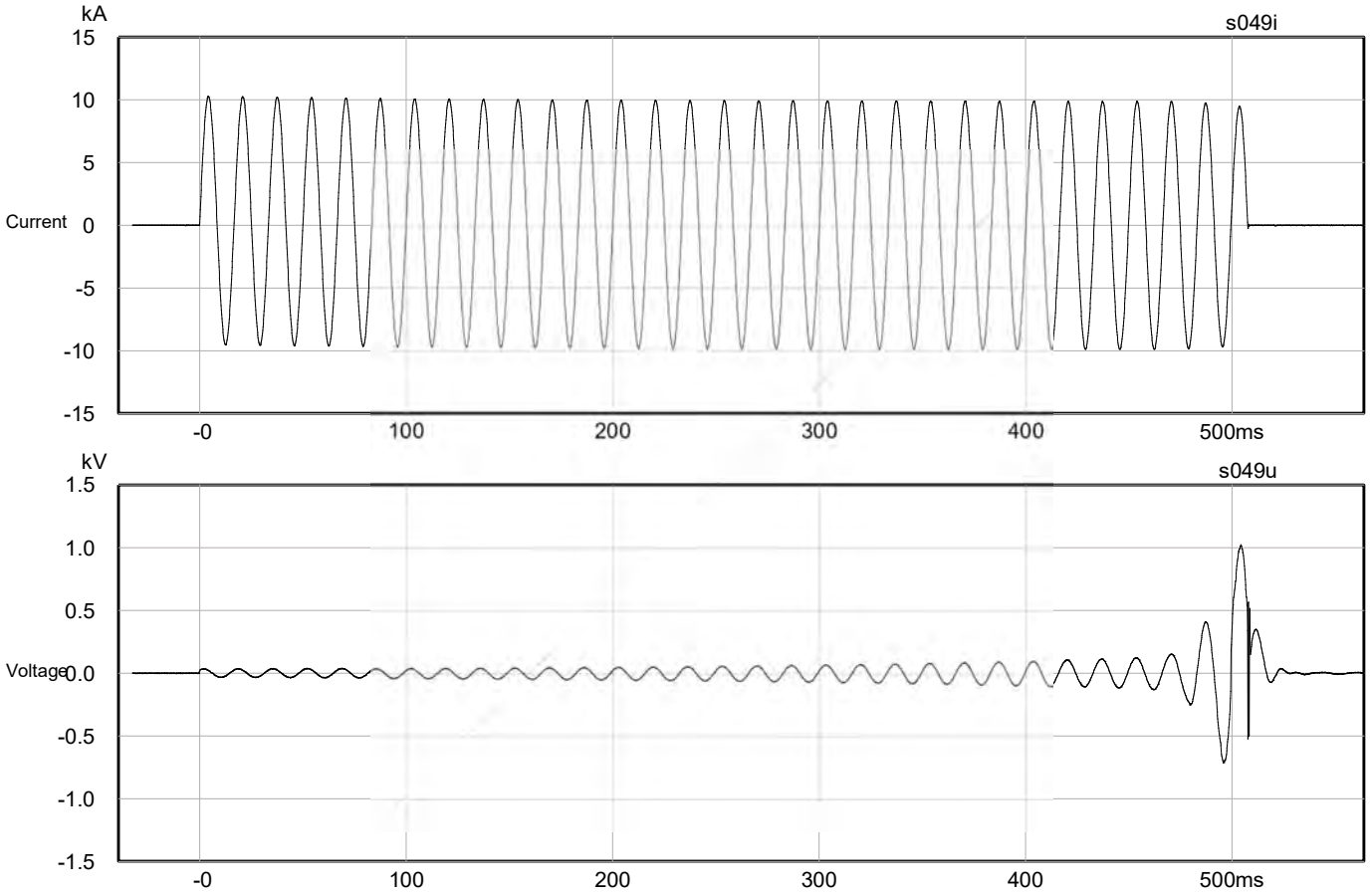


Figure 26: Waveforms for Test #19, Copperweld Scorpius 7 x 080 Sample 33.

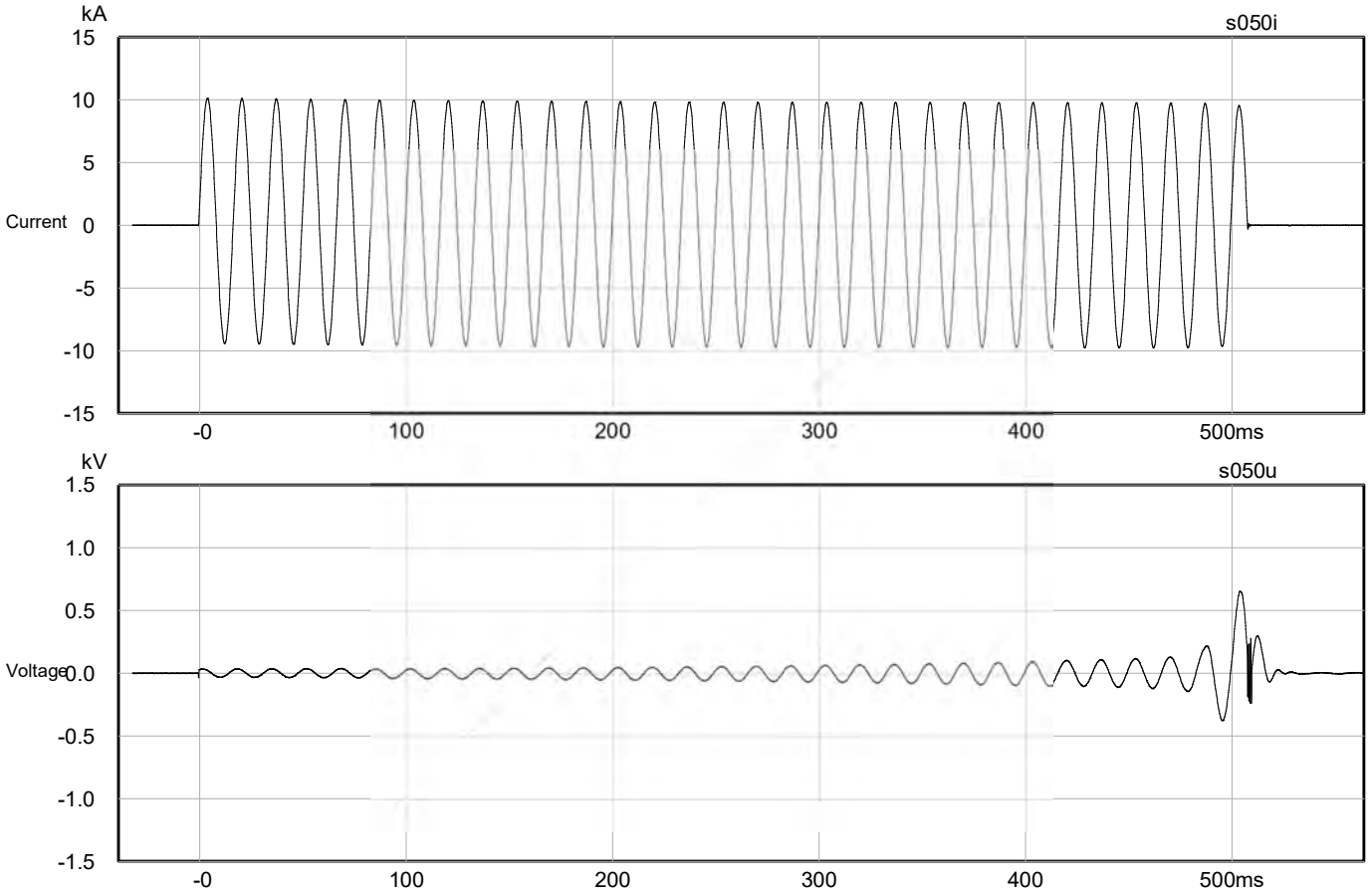


Figure 27: Waveforms for Test #20, Copperweld Scorpius 7 x 080 Sample 34.

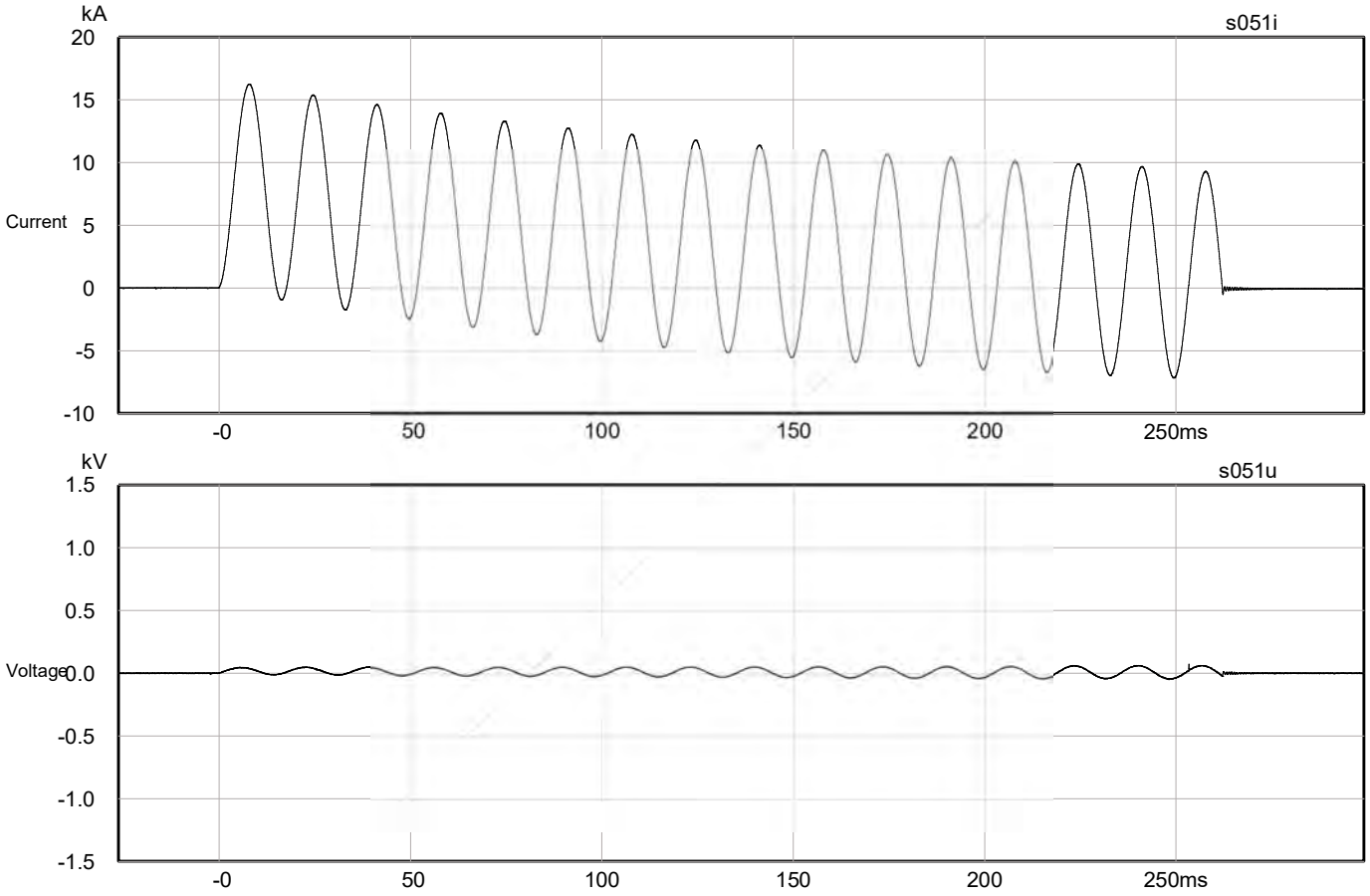


Figure 28: Waveforms for Test #21-1, Copperweld Scorpius 7 x 080 Sample 35.

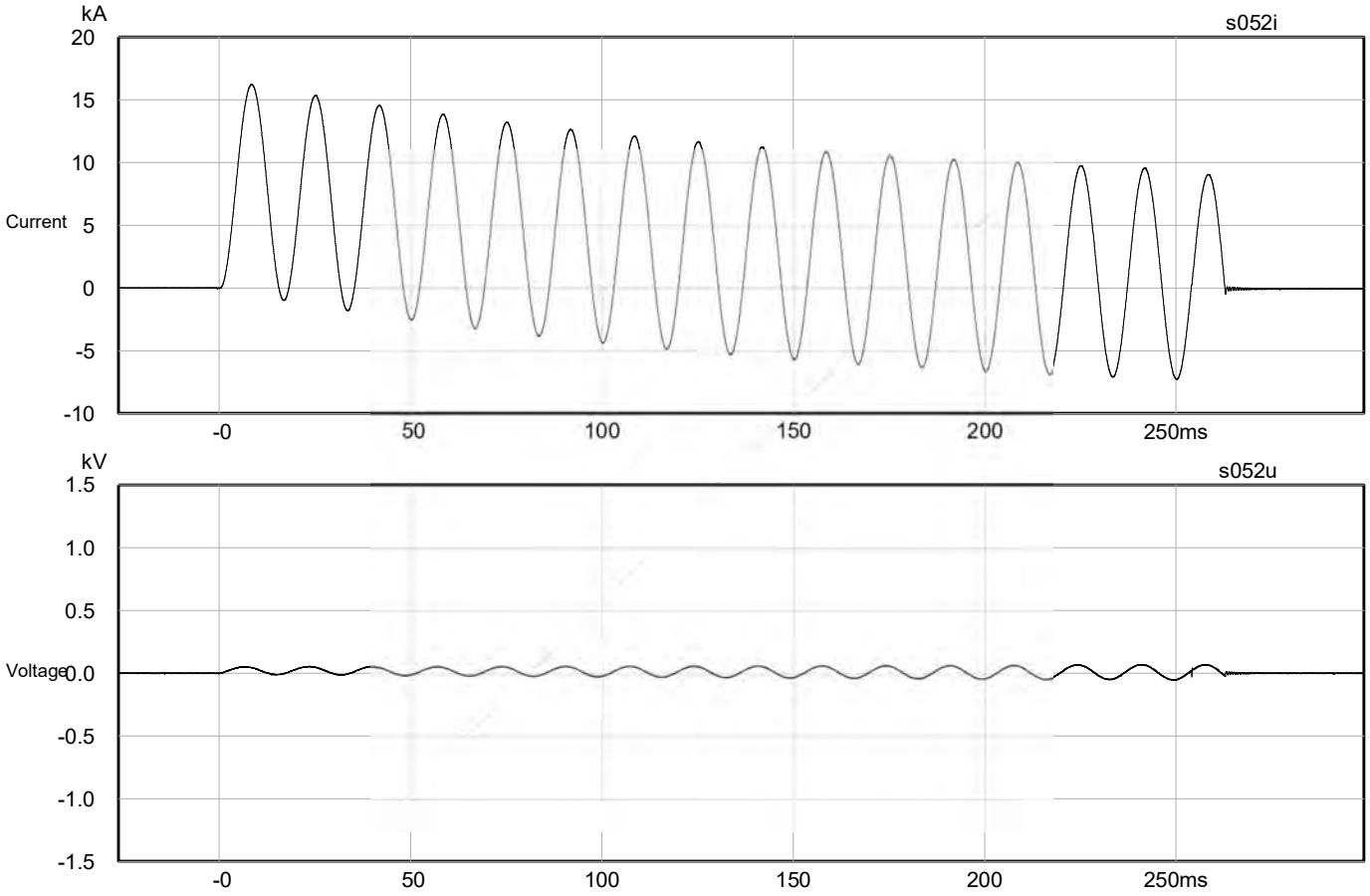


Figure 29: Waveforms for Test #21-2, Copperweld Scorpius 7 x 080 Sample 35.

APPENDIX C – PHOTOGRAPHS OF THE TEST OBJECTS



Figure 30: Test set up for the Encore 4/0 AWG Cu conductor. The power source bus is on the left and the ground bus is on the right.



Figure 31: Test set up for the Copperweld Scorpius 61 x 072 CCS conductor.



Figure 32: Test set up for the Encore #6 AWG Cu conductor.



Figure 33: Test set up for the Copperweld Scorpius 7 x 080 CCS conductor.

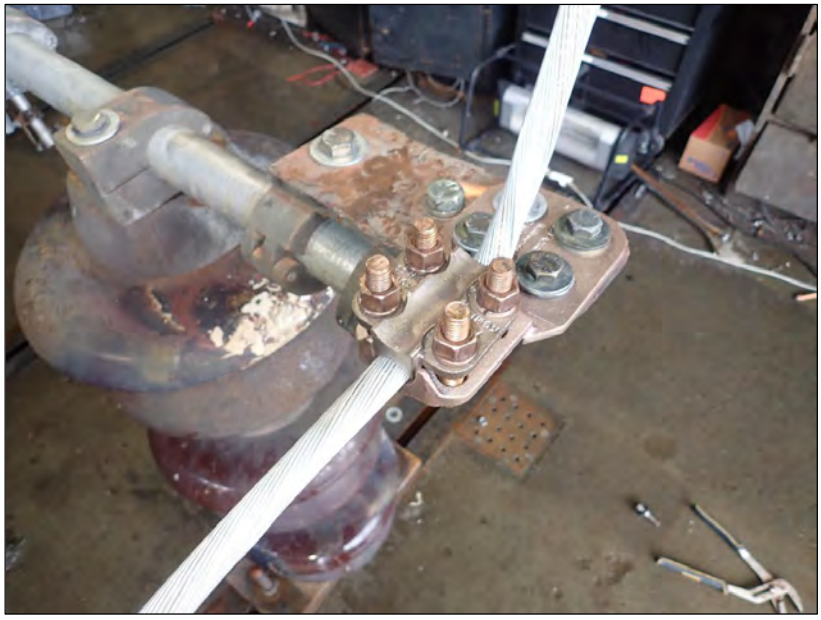


Figure 34: Typical Burndy terminal connector used to connect the Encore 4/0 AWG or Copperweld Scorpius 61 x 072 CCS conductors to the laboratory buses.



Figure 35: Typical Burndy terminal connector used to connect the Encore #6 AWG or Copperweld Scorpius 7 x 080 CCS conductors to the laboratory buses.

APPENDIX D – CALCUATIONS OF TEST CURRENT LEVELS FOR #6 AWG CU CONDUCTOR

Equation (45) in IEEE 80 and Equation (C.1) in IEEE 837 are the same, as follows:

$$I = A\sqrt{\left(\frac{TCAP\times10^{-4}}{t_c\times\alpha_r\times\rho_r}\right)\ln\left(\frac{K_0+T_m}{K_0+T_a}\right)}$$

where

I is root mean square (rms) current in kA
A is conductor cross section in mm^2
T_m is maximum allowable temperature in °C
T_a is initial conductor temperature in °C
T_r is reference temperature for material constants in °C
α_0 is thermal coefficient of resistivity at 0 °C
α_r is thermal coefficient of resistivity at reference temperature T_r
ρ_r is resistivity of the ground conductor at reference temperature T_r in μΩ-cm
K_0 is $1/\alpha_0$, or $(1/\alpha_r)-T_r$ in °C
t_c is time of current flow in seconds (s)
TCAP is thermal capacity factor in joules/cm^3°C

This equation is used to calculate the short-circuit ampacity of a conductor based on it's material constants.

For IEEE 80, Table 6, the symmetrical rms fusing current for #6 AWG soft-drawn Cu conductor at 500 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.5)(0.00393)(1.72)}\cdot\ln\left(\frac{(234+1083)}{(234+40)}\right)} = \boxed{5.29\ kA_{rms}}$$

For IEEE 837, Table 3, the symmetrical rms fusing current for #6 AWG hard-drawn Cu conductor at 250 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.25)(0.00381)(1.78)}\cdot\ln\left(\frac{(242+1084)}{(242+40)}\right)} = 7.41\ kA_{rms}$$

From IEEE 837 Equation (C.4), the asymmetrical rms fusing current is:

$$I_{asym} = \frac{(7.41\ kA)}{(1.148)} = 6.45\ kA_{rms}$$

For the EMF described in IEEE 837, Clause 7.2, a value of 90% of the fusing current is used for conductors up to 4/0 AWG:

$$I_{EMF} = (6.45)(0.9) = \boxed{5.81\ kA_{rms}}$$

Copperweld Bimetallics Data Sheet Packet
Electrical Test Laboratory

Customer:	Copperweld Building Wire	Engineer:	Bill Lewey	Date:	8/25/2020
Sample ID:	EL-13	Tested By:	Bill Lewey, Mike Rozar	Date:	8/25/2020
Product:	Grade 40 Copper Clad Steel Wire Solid Bare #4 and #6 vs Equivalent Solid Copper: Grounding Electrode Conductor Equivalency Test	Sample Condition:	New		
Standard:	ASTM B910/910M Annealed Copper Clad Steel Wire				
Insulation: N/A - Bare		Jacket: N/A - Bare			

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Test Report Summary

Page	Test Performed	Date Completed	Pass/Fail
1	Grounding Electrode Conductor Test for Copper Clad Steel Grade 40	8/25/2020	**Pass**

Requirement:
#4 AWG Grade 40 Copper Clad Steel and #6 AWG Copper Clad Steel when compared to #4 solid copper and #6 solid copper for use as a grounding electrode conductor shall have equal ability to carry amperage during a ground fault condition.

Conclusion:
The ability of bare #4 AWG Copper Clad Steel Grade 40 and bare #6 AWG Copper Clad Steel Grade 40 performed equally to #4 AWG bare solid copper and #6 AWG bare solid copper when used as a grounding electrode conductor under a ground fault condition. The current measured proved equivalency.

Test Equipment Used

Item	Equipment Type	Equipment #	Cal. Due Date
1	Fluke 374FC Clamp Meter	AM-1	Nov 2020
2	Acme Electric 15KVA Transformer	T2535173S	N/A
3	Square D 60A / 600V Safety Interrupter	N/A	N/A
4	Eaton Service Panel	N/A	N/A
5	Eaton Type CH 20 Amp Breaker	N/A	N/A
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

VBU – Verify Before Use

N/A – Not Applicable

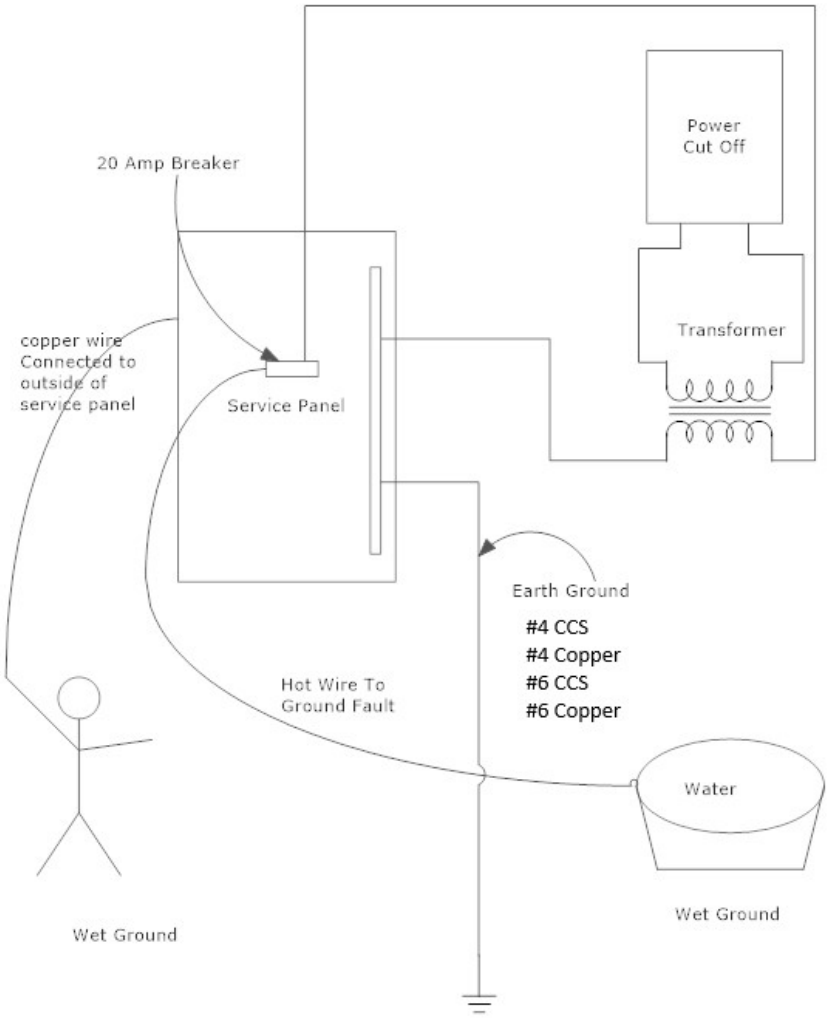
Sample Identification

Item	Description	Length/No. Rec'd
A	#4 AWG 40% Copper Clad Steel Bare	35 Ft
B	#4 AWG Solid Copper Bare	35 Ft
C	#6 AWG 40% Copper Clad Steel Bare	35 Ft
D	#6 AWG Solid Copper Bare	35 Ft
E		
F		

Grounding Electrode Conductor Test

Test Parameters:	
Conditioning:	No preconditioning.
Test Conductors:	1 each of #4 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #6 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #4 AWG Solid Bare copper grounding electrode conductor 1 each of #6 AWG Solid Bare copper grounding electrode conductor
Test Conductor Length:	Each conductor shall be 35 ft.
Test Circuit Configuration:	See schematic shown in Figure 1
Test Current:	Test current from 120 V / 20 A Residential Circuit
Method:	Testing was completed by creating a standard residential test circuit at 120V with 20A breaker wired to an intentional ground fault as shown in figure 1. The ground fault was created by connecting a hot wire from the breaker to a galvanized steel pan full of water and placing the pan on the wet ground. A conductor was also connected to the outside of the electrical panel and a Copper Plated Grounding Electrode (Copperweld Ground Rod) driven 6 inches into the wet ground to determine amount of current going through a grounded person touching the electrical panel during the ground fault condition. The ground fault and the grounded "man" were positioned 20 feet either side of the ground rod. The entire test area was soaked with water overnight using a sprinkler system When the ground fault was electrified, current measurements were taken from the ground fault conductor, the grounding electrode conductor and the grounded "man" conductor. For the four grounding electrode conductors tested, there was one test sequence for each. The current was measured for each. The objective: Compare the amperage measurements of the copper clad steel grounding electrode conductors to those of copper.

Figure 1



Results:			
Ground Conductor	**Fault Conductor Current**	**Current of the Grounding Electrode Conductor**	**Grounded Man Conductor Current**
#4 Copper	2.1 A	1.8 A	0.3 A
#4 40% CCS	2.1 A	1.8A	0.3 A
#6 Copper	1.7 A	1.6 A	0.1 A
#6 40% CCS	1.5 A	1.4 A	0.1 A

Requirement:
For equivalent sizes of Grade 40 Copper Clad steel vs. solid copper grounding conductors, the ability to carry amperage to ground during a ground fault condition is equal.

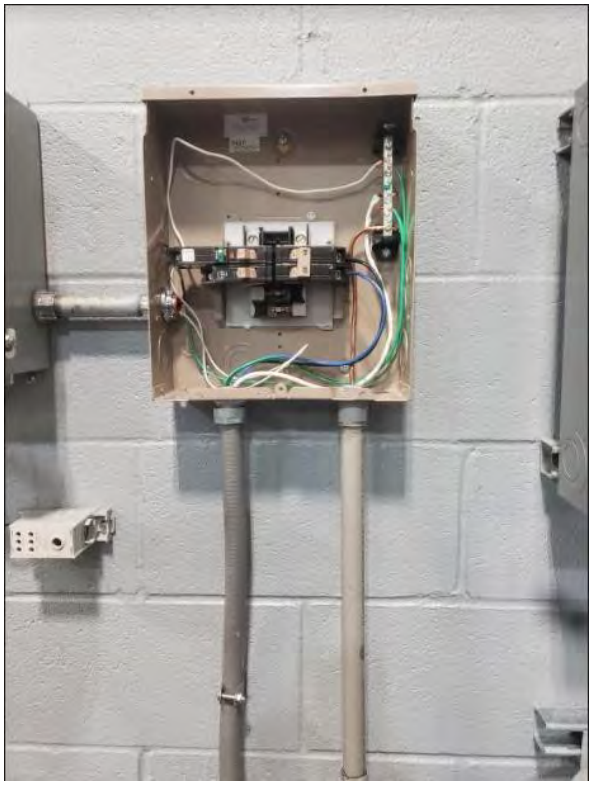
Comments:
____X__ (Pass) The product complies with all applicable requirements of this test. _____ (Fail) The product does not comply with the requirements of this test. **Test Date: 8/25/2020** **Tested By: Bill Lewey**

Environmental Conditions during Testing:

Humidity: % rh __74%_____ Ambient: °C___28_____

Test setup for the electrical service panel







Ground Rod with Grounding Conductor Attached



Ground Fault



Grounded “man”

Public Input No. 1054-NFPA 70-2020 [Section No. 250.102(C)(2)]

(2) Size for Parallel Conductor Installations in Two or More Raceways or Cables.

Where the ungrounded supply conductors are paralleled in two or more raceways or cables, and an individual supply-side bonding jumper is used for bonding these raceways or cables, the size of the supply-side bonding jumper for each raceway or cable shall be selected from Table 250.102(C)(1) based on the size of the ungrounded supply conductors in each raceway or cable. A single supply-side bonding jumper installed for bonding two or more raceways or cables shall be sized in accordance with 250.102(C)(1).

Where supply side bonding jumpers are routed along with ungrounded supply conductors in parallel and within the two or more raceways, the supply side bonding jumpers shall divvy equally and be routed in each raceway and be sized in accordance with 250.102C1 based on the size of the ungrounded conductors in each raceway or cable.

Informational Note No. 1: The term *supply conductors* includes ungrounded conductors that do not have overcurrent protection on their supply side and terminate at service equipment or the first disconnecting means of a separately derived system.

Informational Note No. 2: See Chapter 9, Table 8, for the circular mil area of conductors 18 AWG through 4/0 AWG.

Table 250.102(C)(1) Grounded Conductor, Main Bonding Jumper, System Bonding Jumper, and Supply-Side Bonding Jumper for Alternating-Current Systems

Size of Largest Ungrounded Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil)		Size of Grounded Conductor or Bonding Jumper* (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum
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	See Notes 1 and 2.	

Notes:

1. If the ungrounded supply conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum, the grounded conductor or bonding jumper shall have an area not less than 12½ percent of the area of the largest ungrounded supply conductor or equivalent area for parallel supply conductors. The grounded conductor or bonding jumper shall not be required to be larger than the largest ungrounded conductor or set of ungrounded conductors.

2. If the ungrounded supply conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum and if the ungrounded supply conductors and the bonding jumper are of different materials (copper, aluminum, or copper-clad aluminum), the minimum size of the grounded conductor or bonding jumper shall be based on the assumed use of ungrounded supply conductors of the same material as the grounded conductor or bonding jumper and will have an ampacity equivalent to that of the installed ungrounded supply conductors.

3. If multiple sets of service-entrance conductors are used as permitted in 230.40, Exception No. 2, or if multiple sets of ungrounded supply conductors are installed for a separately derived system, the equivalent size of the largest ungrounded supply conductor(s) shall be determined by the largest sum of the areas of the corresponding conductors of each set.

4. If there are no service-entrance conductors, the supply conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.

*For the purposes of applying this table and its notes, the term *bonding jumper* refers to main bonding jumpers, system bonding jumpers, and supply-side bonding jumpers.

Statement of Problem and Substantiation for Public Input

This is similar to 250.122F and for the same reasoning. Paralleling supply side bonding jumpers this way facilitates ungrounded conductors in cancelling highly inductive fault currents.

Presently, 250.102C2 language does not prevent someone from routing a supply side bonding jumper through line side raceways; nor should it. I do know it is unnecessary to route through metal raceways in order to bond. The bond for those raceways may derive from either of the metal enclosures that the raceways are connecting using supply side bonding jumpers or utilizing 250.142A grounded conductor bonding. I believe the closest reference to call the practice a violation would be 250.4A5 but even that never says there can't be a parallel ground or bond path. The idea being, the parallel paths of the metal raceway and the supply side bonding jumper within may be regarded as a greater impedance with those two different routes imposing on each other in the event of a ground fault, creating a choking affect.

Adding the new NEC language I've shown for 250.102C would prevent an electrician from routing a supply side bonding jumper(s) in less than each parallel raceway. The alternative is to add NEC language that prohibits routing supply side bonding jumpers through service metal raceways unnecessarily but I don't agree with this as the title of 250.102C2 already implies compliance.

Now a whole other discussion is in store: 'Non-metallic raceways between metal service enclosures'. Now the supply side bonding jumper is required within the raceway(s) between enclosures to meet 250.80 and 250.92B if the grounded conductor wasn't serving that purpose (250.142A) and it wouldn't if main bonding jumpers weren't installed at meter enclosures, line side gutters, and the like.

Main bonding jumpers are required at each service disconnect metal enclosure but not the other line side enclosures. Possibly, a utility company doesn't want that main bonding jumper in the meter enclosure or current transformer enclosure. Possibly, 250.92B already infers no non-metallic raceways are permitted for service conductors (I don't think it does) but that would be inconsistent with something like 230.30B or 230.43.

My newly proposed 250.102A2 language covers both metallic and non-metallic service raceways. The highest fault currents of an electrical installation are at the service and I think it's important that parallel supply side bonding jumpers should divvy into each raceway when they are routed within those raceways.

Submitter Information Verification

Submitter Full Name: Norman Feck
Organization: State of Colorado
Street Address:
City:
State:
Zip:
Submittal Date: Wed May 13 17:01:24 EDT 2020
Committee: NEC-P05

Public Input No. 128-NFPA 70-2019 [Section No. 250.102(C)(2)]

(2) Size for Parallel Conductor Installations in Two or More Raceways or Cables.

Where the ungrounded supply conductors are paralleled in two or more raceways or cables, and an individual supply-side bonding jumper is used for bonding these raceways or cables, the size of the supply-side bonding jumper for each raceway or cable shall be selected from Table 250.102(C)(1) based on the size of the ungrounded supply conductors in each raceway or cable. A single supply-side bonding jumper installed for bonding two or more raceways or cables shall be sized in accordance with 250.102(C)(1).

Informational Note No. 1: The term *supply conductors* includes ungrounded conductors that do not have overcurrent protection on their supply side and terminate at service equipment or the first disconnecting means of a separately derived system.

Informational Note No. 2: See Chapter 9, Table 8, for the circular mil area of conductors 18 AWG through 4/0 AWG.

Table 250.102(C)(1) Grounded Conductor, Main Bonding Jumper, System Bonding Jumper, and Supply-Side Bonding Jumper for Alternating-Current Systems

Size of Largest Ungrounded Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil)		Size of Grounded Conductor or Bonding Jumper* (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum
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	See Notes 1 and 2.	

Notes:

1. If the circular-mil area of one or the sum of a set of ungrounded supply conductors that are connected in parallel is or are larger than 1100 kcmil copper or 1750 kcmil aluminum, the grounded conductor or bonding jumper shall have an area not less than 12½ percent of the area of the largest ungrounded supply conductor or equivalent area for parallel supply conductors. The grounded conductor or bonding jumper shall not be required to be larger than the largest ungrounded conductor or set of ungrounded conductors.

2. If the circular-mil area of one or the sum of a set of ungrounded supply conductors that are connected in parallel is or are larger than 1100 kcmil copper or 1750 kcmil aluminum and if the ungrounded supply conductors and the bonding jumper are of different materials (copper, aluminum, or copper-clad aluminum), the minimum size of the grounded conductor or bonding jumper shall be based on the assumed use of ungrounded supply conductors of the same material as the grounded conductor or bonding jumper ~~and will have~~ that has an ampacity equivalent to that of the installed ungrounded supply conductors.

3. ~~If multiple sets of service-entrance conductors are used as permitted in 230.40, Exception No. 2, or if multiple sets of ungrounded supply conductors are installed for a separately derived system, the equivalent size of the largest ungrounded supply conductor(s) shall be determined by the largest sum of the areas of the corresponding conductors of each set.4. If~~ If there are no service-entrance conductors, the supply conductor size shall be determined by the largest of the equivalent size of the largest service-entrance conductor required for the load to be served or for the rating of the overcurrent device .

*For the purposes of applying this table and its notes, the term *bonding jumper* refers to main bonding jumpers, system bonding jumpers, and supply-side bonding jumpers.

Statement of Problem and Substantiation for Public Input

By including the requirement for using the circular mil area of single or sets of conductors in parallel, in Notes 1 and 2, the existing note 3 is no longer needed.
In addition, it is necessary to add text to the existing Note 4 related to the rating of an overcurrent device. It is common to install service conductors that are larger than the load to comply with 230.90(A) for the rating of an overcurrent device.

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Public Input No. 2029-NFPA 70-2020 [Section No. 250.102(C)(2)]

(2) Size for Parallel Conductor Installations in Two or More Raceways or Cables.

Where the ungrounded supply conductors are paralleled in two or more raceways or cables, and an individual supply-side bonding jumper is used for bonding these raceways or cables, the size of the supply-side bonding jumper for each raceway or cable shall be selected from Table 250.102(C)(1) based on the size of the ungrounded supply conductors in each raceway or cable. A single supply-side bonding jumper installed for bonding two or more raceways or cables shall be sized in accordance with 250.102(C)(1).

Informational Note No. 1: The term *supply conductors* includes ungrounded conductors that do not have overcurrent protection on their supply side and terminate at service equipment or the first disconnecting means of a separately derived system.

Informational Note No. 2: See Chapter 9, Table 8, for the circular mil area of conductors 18 AWG through 4/0 AWG.

Table 250.102(C)(1) Grounded Conductor, Main Bonding Jumper, System Bonding Jumper, and Supply-Side Bonding Jumper for Alternating-Current Systems

Size of Largest Ungrounded Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil)			Size of Grounded Conductor or Bonding Jumper * (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum		Copper	Aluminum or Copper-Clad Aluminum
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	-	See Notes 1 and 2.	

Notes:

1. If the ungrounded supply conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum, the grounded conductor or bonding jumper shall have an area not less than 12½ percent of the area of the largest ungrounded supply conductor or equivalent area for parallel supply conductors. The grounded conductor or bonding jumper shall not be required to be larger than the largest ungrounded conductor or set of ungrounded conductors.

2. If the ungrounded supply conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum and if the ungrounded supply conductors and the bonding jumper are of different materials (copper, aluminum, or copper-clad aluminum), the minimum size of the grounded conductor or bonding jumper shall be based on the assumed use of ungrounded supply conductors of the same material as the grounded conductor or bonding jumper and will have an ampacity equivalent to that of the installed ungrounded supply conductors.

3. If multiple sets of service-entrance conductors are used as permitted in 230.40, Exception No. 2, or if multiple sets of ungrounded supply conductors are installed for a separately derived system, the equivalent size of the largest ungrounded supply conductor(s) shall be determined by the largest sum of the areas of the corresponding conductors of each set.

4. If there are no service-entrance conductors, the supply conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.

~~*For the purposes of applying this table and its notes, the term *bonding jumper* refers to main bonding jumpers, system bonding jumpers, and supply-side bonding jumpers.~~

Statement of Problem and Substantiation for Public Input

Delete the * and associated note. This table also applies to the sizing of the bonding jumper required for metal water piping systems, other metal piping systems and structural metal as required by 250.104(A), (B) and (C). The bonding jumper used for these applications is not a main bonding jumper, system bonding jumper, or supply side bonding jumper. It is simply a bonding jumper.

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Committee: NEC-P05

Public Input No. 2472-NFPA 70-2020 [Section No. 250.102(C)(2)]

(2) Size for Parallel Conductor Installations in Two or More Raceways or Cables.

Where the ungrounded supply conductors are paralleled in two or more raceways or cables, and an individual supply-side bonding jumper is used for bonding these raceways or cables, the size of the supply-side bonding jumper for each raceway or cable shall be selected from Table 250.102(C)(1) based on the size of the ungrounded supply conductors in each raceway or cable. A single supply-side bonding jumper installed for bonding two or more raceways or cables shall be sized in accordance with 250.102(C)(1).

Informational Note No. 1: The term *supply conductors* includes ungrounded conductors that do not have overcurrent protection on their supply side and terminate at service equipment or the first disconnecting means of a separately derived system.

Informational Note No. 2: See Chapter 9, Table 8, for the circular mil area of conductors 18 AWG through 4/0 AWG.

Table 250.102(C)(1) Grounded Conductor, Main Bonding Jumper, System Bonding Jumper, and Supply-Side Bonding Jumper for Alternating-Current Systems

Size of Largest Ungrounded Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil)			Size of Grounded Conductor or Bonding Jumper* (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum		Copper-Clad Steel or Copper	Aluminum or Copper-Clad Aluminum
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	-	See Notes 1 and 2.	

Notes:

1. If the ungrounded supply conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum, the grounded conductor or bonding jumper shall have an area not less than 12½ percent of the area of the largest ungrounded supply conductor or equivalent area for parallel supply conductors. The grounded conductor or bonding jumper shall not be required to be larger than the largest ungrounded conductor or set of ungrounded conductors.

2. If the ungrounded supply conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum and if the ungrounded supply conductors and the bonding jumper are of different materials (copper, aluminum, or copper-clad aluminum), the minimum size of the grounded conductor or bonding jumper shall be based on the assumed use of ungrounded supply conductors of the same material as the grounded conductor or bonding jumper and will have an ampacity equivalent to that of the installed ungrounded supply conductors.

3. If multiple sets of service-entrance conductors are used as permitted in 230.40, Exception No. 2, or if multiple sets of ungrounded supply conductors are installed for a separately derived system, the equivalent size of the largest ungrounded supply conductor(s) shall be determined by the largest sum of the areas of the corresponding conductors of each set.

4. If there are no service-entrance conductors, the supply conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.

*For the purposes of applying this table and its notes, the term *bonding jumper* refers to main bonding jumpers, system bonding jumpers, and supply-side bonding jumpers.

Additional Proposed Changes

File Name	Description	Approved
CCS_Corrosion_paper_Rev2.pdf	50 Year Corrosion Study Grade 40 CCS	
TD002391.doc	UL 467 Short Circuit and UL 486A-B Mechanical Sequence Grade 40 CCS	
PL-03027_REP1.pdf	Fusion 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

COPPER-CLAD STEEL CONDUCTORS:

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 applicate 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 Inputs for This Document

Related Input	Relationship
Public Input No. 2460-NFPA 70-2020 [Section No. 250.53(E)]	Copper-Clad Steel Bonding Conductors
Public Input No. 2460-NFPA 70-2020 [Section No. 250.53(E)]	
Public Input No. 2471-NFPA 70-2020 [Section No. 250.102(A)]	
Public Input No. 2474-NFPA 70-2020 [Section No. 250.166 [Excluding any Sub-Sections]]	

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

Public Input No. 2493-NFPA 70-2020 [Section No. 770.100(D)]

Public Input No. 2512-NFPA 70-2020 [Section No. 770.106(B)]

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Committee: NEC-P05

Testing done for the safety of our valued customer.

Global Circulation Laboratory Test Report

For Global Distribution

UL467 SHORT CIRCUIT & UL 486A-486B MECHANICAL SEQUENCE TESTS

YGHP29C2, YGHC2C2, YGHC26C26, YGHP34C29, YGHC29C29, YGHP34C34, YGHC34C34 HYTAP™ Connectors
YGL2C2, YGL29C29, YGL34C34 HYGRID™ Connectors
YGA4C2N, YGHA272N, YGA282N, YGHA302N HYLUG™ Connectors

5/8" and 3/4"Copper Clad Steel Ground Rod, #4AWG Solid, 4/0AWG Stranded, 7#7, and 19#8 COPPERWELD® 40% IACS Copper Clad Steel Conductors

PAT750XT-18V PATRIOT® Tool
with
UC, UO, U28RT, U29RT, U32RT, U997, PU998, and U1011 Die Sets

TD002391 REV B

Requested by / Date:	***Authorized by / Date:***	***Completed by / Date:***
C. Gandhi 12-Dec-2014	R Robicheau 12-Dec-2014	R Charpentier 06-Apr-2015
Engineering Approval / Date:	***Marketing Approval / Date:***	***Laboratory Approval / Date:***
R.Roman 20-Aug-2020	J Hogan 20-Aug-2020	R Charpentier 20-Aug-2020

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

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Burndy LLC 47 East Industrial Park Dr.
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Tel: 603 647 5000 Fax: 603 647 5205

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

PURPOSE OF TEST:

To determine if the Burndy HYTAP™, HYGRID™, and HYLUG™ Connectors can meet the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST REQUESTED:

UL486A-486B Mechanical Sequence
UL467 Short Time Current

TEST RESULTS:

Connector	Cable 1	Cable 2	Die	# of crimps	Securness	Pull	Short Time Current		
					Pass / Fail	Average Pull (lb)	Pass / Fail	Current (Amps)	Time (s)
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	U997	1	Pass	1021.3	Pass	1600	6
YGL2C2	#4 Solid CCS	#4 Solid CCS	U-O	1	Pass	1451.8	Pass	1600	6
YGHC2C2	#4 Solid CCS	#4 Solid CCS	U-C	1	Pass	1544.0	Pass	1600	6
YGA4C2N	#4 Solid CCS	n/a	U4CRT	1	Pass	814.0	Pass	1600	6
YGL29C29	7#7 STR CCS	7#7 STR CCS	U997	1	Pass	1643.2	Pass	4600	9
YGHC26C26	7#7 STRCCS	7#7 STR CCS	U-O	1	Pass	1239.4	Pass	4600	9
YGHA272N	7#7 STRCCS	n/a	U29RT	2	Pass	1574.0	Pass	4600	9
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PU998	1	Pass	1789.8	Pass	6100	9
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1849.8	Pass	6100	9
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1779.1	Pass	6100	9
YGA282N	4/0 AWG CCS	n/a	U28RT	2	Pass	2489.3	Pass	6100	9
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	U1011	3	Pass	2126.8	Pass	9000	9
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	U1011	3	Pass	2380.0	Pass	9000	9
YGL34C34	19#8 STRCCS	19#8 STR CCS	U1011	3	Pass	3158.3	Pass	9000	9
YGHC34C34	19#8 STR CCS	19#8 STR CCS	U1011	3	Pass	3812.1	Pass	9000	9
YGHA302N	19#8 STR CCS	n/a	U32RT	2	Pass	4792.2	Pass	9000	9

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TD002391

Global Circulation Laboratory Test Report

For Global Distribution

CONCLUSIONS:

All samples tested met the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST PROCEDURES

The table below shows the connector / conductor combinations tested.

Connector	Cable 1	Cable 2	Tool	Die	# of Crimps
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	PAT750	U997	1
YGL2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-O	1
YGHC2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-C	1
YGA4C2N	#4 Solid CCS	n/a	PAT750	U4CRT	1
YGL29C29	7#7 STR CCS	7#7 STR CCS	PAT750	U997	1
YGHC26C26	7#7 STR CCS	7#7 STR CCS	PAT750	U-O	1
YGHA272N	7#7 STR CCS	n/a	PAT750	U997	2
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PAT750	PU998	1
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGA282N	4/0 AWG CCS	n/a	PAT750	U997	2
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	PAT750	U1011	3
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	PAT750	U1011	3
YGL34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHC34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHA302N	19#8 STR CCS	n/a	PAT750	U32RT	2

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TD002391

Global Circulation Laboratory Test Report

For Global Distribution

All conductors were cut to twenty four (24) inch lengths.
All ground rod was pre-crimped with the appropriate pre-crimp die
5/8in Rod UPRECRIMP58
3/4in Rod UPRECRIMP34

Mechanical Sequence
Four samples of each set were secured to the Secureness tester, the height; weight and bushing size were as specified in UL486A-486B Table 26. Samples were rotated for thirty minutes at 9rpm. Samples were then subjected to a 1-minute pull to the value specified in UL486A-486B Table 27 and then to failure.

Short Time Current
Test samples were assembled in a series loop configuration then attached to a current controller as shown below. The test current and duration are listed below. After completion of the test, electrical continuity was checked with a digital multi-meter.

Test current values were derived from the equation Annex C of IEEE Std 837-2002. The diameter of the conductor(s) were measured and the cross-sectional area of the conductors was calculated.

Conductor	***Current Value (A)***	***Duration (sec)***
#4AWG Solid COPPERWELD® 40% IACS CCS	1600	6
4/0AWG 19 strand COPPERWELD® 40% IACS CCS,	6100	9
7#7 stranded COPPERWELD® 40% IACS CCS	4600	9
19#8 stranded COPPERWELD® 40% IACS CCS	9000	9

TEST EQUIPMENT LIST:

MANUFACTURER	MODEL	DESCRIPTION	SERIAL #	RANGE
FLUKE	79 III	DMM	70591301 (Rene)	AUTO
OHIO SEMITRONICS		CURRENT TRANSDUCER	NA	15000:5
SATEC	T5000	TABLE TOP	2038	5000 lbs
VIRTECH	NA	HIGH CURRENT	NA	12V / 12000A
MITUTOYO	505-675	DIAL CALIPER	08914565 (Rene)	6"

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CORROSION ON BURIED COPPER CLAD STEEL



Cece Syarif

Global Application Engineer

&

Anthony Hale

Manager, Utility Products, North America

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For more information, contact sales@copperweld.com.
The results and conclusions obtained from studies done by Copperweld are only applicable to Copper Clad Steel manufactured by Copperweld. Due to proprietary process used to produce the wire, the findings cannot be superimposed on any other copper-clad steel conductor.

254 Cotton Mill Rd, Fayetteville, TN 37334. Tel. (931) 433 – 7177

July 26, 2011

This paper compiles several studies and analysis regarding the corrosion performance of buried Copperweld® Copper-Clad-Steel (CCS) conductors. These range from the early 1900's with the invention of Copperweld® through the present day with studies performed by independent parties as well as Copperweld Company in-house testing. The purpose is to present the available information so that prospective users of Copperweld® CCS wire and strand can evaluate the corrosion resistance and expected performance within their specific application and area. Copperweld uses oxygen free copper in the manufacture of Copperweld® wire and strand. The copper surface of CCS is expected to oxidize and turn color ranging from green (patination) to brown and black the same as any solid copper wire or strand when exposed to environmental stimuli. Corrosion on exposed steel at the cut tip or end of the wire is also expected. The question to be answered is if the corrosion on either material or the interface between the copper and steel (galvanic reaction) will result in degradation of the wire as to make it unsuitable for use as a grounding conductor.

The oldest known underground corrosion study of bimetallic material was performed in the early 1900s[1]. This study focused on the corrosion behavior of Copperweld® CCS underground rod as well as other materials such as Copper and galvanized steel ground rod. The National Bureau of Standards (NBS) conducted an extensive underground corrosion study that involves 36,500 specimens which include 333 varieties of ferrous, nonferrous, and protective coating materials buried in 128 test locations throughout U.S in 1910 - 1955.

The study summarizes the service life of a ground rod as following:

10 mils copper coating – acceptable for service life up to 40 years

13 mils copper coating – acceptable for service life up to 50 years

Similarly, the Naval Civil Engineering Laboratory in collaboration with the National Association of Corrosion Engineers conducted a 7-year program of testing metal rods for electrical grounding to determine the galvanic corrosion effect. The three metals tested were stainless clad steel, copper-bonded steel (CCS), and galvanized steel. The result on the ⅝" CCS ground rod was as expected. The copper surface of the CCS was

virtually free of corrosion and the steel core has corroded at the tip approximately 2 inches down the length of the rod.

Copperweld Corporation is the inventor and sole manufacturer of Copperweld® Copper-bonded ground rods and Copperweld® wire and strand since 1915. The corrosion behavior of a Copperweld® ground rod is similar to the corrosion on Copperweld® wire and strand conductor. Both materials consist of copper permanently bonded to a steel core. All Copperweld® 40% CCS has a copper thickness of 10% of the overall diameter. For example, Copperweld® 4THOUGHT™ has a configuration of 19 strands of 0.1055 inch wires. It means that each strand has a copper thickness of 10.55 mils. Based on the NBS study, 4THOUGHT™ will have at least a minimum service life of 40 years.

Copperweld has also conducted a 5-year study of buried bare 21% conductivity (copper thickness is 3% of the diameter) Copperweld® CCS in 10 different soil conditions in association with Southwest Research Institute[2]. The study reported 100% surface oxidation and various degrees of deterioration of the steel core as expected after 5 years. The exposed steel on the tip of the wire rusted and formed "scab", as shown in Figure 1. The rust appeared to "seal-off" the un-oxidized material from the corrosive medium. The maximum depth of corrosion was 70% of the wire diameter.



Figure 1: Example of Underground Corrosion of Copper Clad Steel

Although the copper surface oxidation was heavy, the samples showed no signs of pits or holes in the copper cladding. The copper thickness of a severely oxidized 5-year sample showed no discernable difference when compared to an un-oxidized control sample that was not subjected to the corrosive environment. The mechanical and resistance testing

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resulted in negligible differences between 5-year samples and the control samples. Thus, the oxidation had no discernable impact on the strength or electrical performance of the wire.

An accelerated corrosion study based on ASTM B117 was conducted on bare CCS and solid Copper wires to evaluate copper surface corrosion. The wires were exposed to salt fog spray for 504 hours. As a result, corrosion on the CCS copper surface showed no significant difference as compared to the corrosion of copper wire.



(a) Copper Clad Steel (b) Copper

Figure 2: Patination of Copper Surface after 504 hours exposure to Salt Fog Spray

In February 2011, three separate sample strands of Copper Clad Steel were un-earthed and cut out from a substation built in Louisville, KY. The conductors were 40% conductivity, Low Carbon Steel, Dead Soft Annealed, 7 No. 5 (231,613 circular mil) and were installed in 1962.

Table 1: Physical properties of the three strands of Copperweld® conductor that had been buried underground for 48 years in a Kentucky substation

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			Strand 1	Strand 2	Strand 3
Conductor Type			40% Low Carbon Annealed		
Conductor Size			7 No. 5		
Cross Section Area		in^2	0.1819	0.1819	0.1819
Diameter of Single end		*inch*	0.1819	0.1819	0.1819
Diameter of Conductor		*inch*	0.5457	0.5457	0.5457
Copper Thickness	Min	*inch*	0.0142	0.0114	0.0134
	Max	*inch*	0.0213	0.0209	0.01975
% Concentricity			83.30%	77.30%	83.90%
Depth of corrosion	Min	*inch*	0.004	0.028	0.111
	Max	*inch*	0.781	0.859	0.484

The 1962 conductors were manufactured by Copperweld with a nominal copper thickness of 10% of its diameter. Figure 3 shows the copper thickness ranges from 11.4 – 21.3 mils and the concentricity of the conductor averaged at 81.5%. Current manufacturing improvements yield concentricity of copper thickness above 85%.

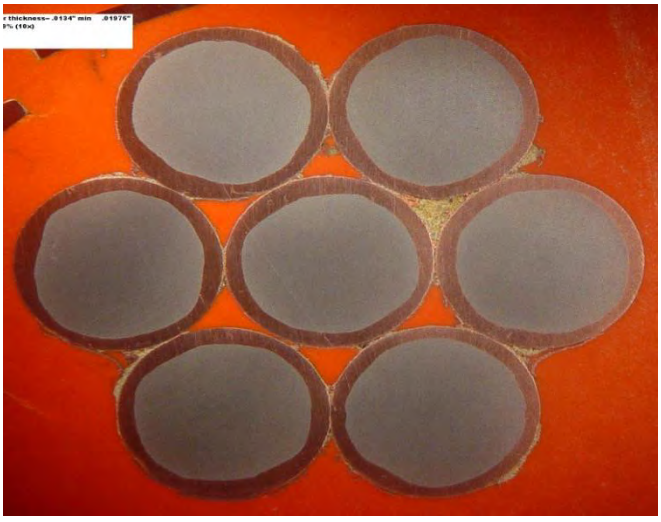


Figure 3: Copperweld® 40% LC DSA 7 No. 5 manufactured in 1962

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Figure 4a shows no visible corrosion observed other than oxidation and patination on the copper surface. At the ends of the wires, the corrosion occurred in the form of steel rust. The maximum depth of the corrosion is 0.859 inch with an average of 0.382 inch, as shown in Figure 4b.



Figure 4a: There is no visible corrosion between the copper and steel on all wires obtained from the substation in Kentucky.



Figure 4b: Corrosion occurred at the ends of the wires. Maximum penetration depth is 0.859 inch.

From all the corrosion studies above, there have not been reported or observed any galvanic corrosion at the interface of copper and steel. The process of cladding for

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Copperweld® ensures a metallurgical bond between the two metals. That metallurgical bond prevents any moisture from penetrating between the two metals precluding the corrosion process. Any propagation of corrosion on an area of exposed steel averages two times the diameter of the wire then stops. The corrosion rate of the copper surface is equivalent to that observed on standard solid copper wire and strand. Based on the results of these studies, it can be summarized that CCS can be expected to have a 50 plus year service life as buried grounding conductors.

REFERENCES:

1. Rempe, Chris. 7 July 2003. "A Technical Report on the Service Life of Ground Rod Electrodes".
2. Fox, Dustin, Belado, Chris, and Brossia, Sean. 23 September 2009. "The Effect of Corrosion on Tracer Wire with a Copper Clad Steel Center Conductor".

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Revision: 0 Issued: 2020-04-15

Copper and CCS Wire Withstand Current and Fusing Current Tests

Copperweld Bimetallics, LLC



The Power of Trust. **The Future of Energy.**

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REPORT OF PERFORMANCE

CLIENT	Copperweld Bimetallics,LLC. 5141 Virginia Way, Suite 410 Brentwood, TN, United States 37027
TEST OBJECTS	Copper Clad Steel (CCS) Wires Manufacturer: Copperweld Bimetallics,LLC. Types: Scorpius Prototypes Part Nos.: 61 x 072 7 x 080 Condition: New Copper Conductor Manufacturer: Encore Wire Types: #4/0 AWG (19 strand) CU #6 AWG (single strand) CU Condition: New
TESTED BY	Powertech Labs Inc. 12388 - 88th Ave, Surrey, BC Canada V3W 7R7 www.powertechlabs.com
TEST DATE	2020-01-24 to 2020-01-25
TEST SPECIFICATION	Client Specified, with reference to IEEE Std 80-2013 and IEEE Std 837-2014

Powertech Labs Inc. does not accept any liability for any damages resulting from the use of this report. The results relate only to the item tested, and it is the responsibility of the manufacturer to maintain conformity of any object having the same designations. Information regarding the estimated measurement uncertainty is available upon request. The test report shall not be reproduced except in full, without written approval of Powertech Labs Inc.

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1 INTRODUCTION

At the request of Copperweld Bimetallics,LLC., withstand current and fusing current tests were performed on standard copper and copper clad steel (CCS) wires in accordance with specifications and procedures provided by the client. Reference was made to IEEE Std 80-2013 and IEEE Std 837-2014 as guides for determining current levels and durations for the tests.

The High Power Lab is accredited by the Standards Council of Canada to ISO 17025 for short-circuit testing.

2 TEST OBJECT INFORMATION

The test objects were identified by the client as follows:

Copper Clad Steel Wires (CCS)

Manufacturer:	Copperweld Bimetallics,LLC.
Types:	Scorpius Prototypes
Part Nos.:	61 x 072
	7 x 080
Condition:	New

Copper Conductor

Manufacturer:	Encore Wire
Types:	4/0 AWG (19 strand) CU
	#6 AWG (single strand) CU
Condition:	New

Conductor sample diameters and dc resistance values were measured by the laboratory before testing, as presented in Table 1.

3 GENERAL INFORMATION

3.1 Purpose

The purpose of the tests is to identify the current limits at short durations for standard copper and Copperweld CCS grounding wire products, and to determine if these products meet the applicable requirements of the referenced Standards.

3.2 Witnesses

Name	Company
Jeff Jordan	Copperweld Bimetallics,LLC.
Lora Aboulmouna	Copperweld Bimetallics,LLC.
Jason Smolko	Copperweld Bimetallics,LLC.
Ryan Hale	Copperweld Bimetallics,LLC.

3.3 Tests Performed

Test Standards/Specifications:

Withstand current tests were performed as requested by the client, with reference to the following Standards to determine the test levels:

IEEE Std 80-2013, Table 6 – Specification for the ultimate current carrying capacity of copper grounding cables using symmetrical current.

IEEE Std 837-2014, Clause 7.2 and Table 3 – Electromagnetic force (EMF) test

4 SHORT-CIRCUIT CURRENT TESTS

General Information:

Standard	Client's Specification, with reference to IEEE Std 80-2013 and IEEE Std 837-2014
Test Dates	2020-01-24 to 2020-01-25
Test Leader	Chris Morton

Environmental Conditions:

Ambient temperature	(7 – 9) °C
Relative Humidity	(95 – 99) %

Test Conditions:

Samples were tested in a covered test cell which was open on one side to the outdoor ambient conditions. During each test, one sample was connected horizontally between the laboratory source bus and ground bus, at a bus spacing of 48 inches, as shown in Figures 30 through 33. The samples were terminated using Burndy mechanical connectors, as shown in Figures 34 and 35. The length of each wire sample was the minimum length required to span the distance between the buses, and each sample was at approximately right angles (90°) to both the source and ground bus. Each sample was suspended in free air approximately 46 inches above the floor of the test cell. The temperature of the sample at the start of each test was the natural outdoor ambient temperature of the laboratory, except for tests performed to IEEE 837, where the sample was allowed to cool to less than 100 °C before the second shot.

All tests were performed at a power frequency of 60 Hz using the test circuit shown in Figure 1. Current was initiated by energizing a current limited source that was calibrated to provide the target current through the circuit. The rms current, current symmetry and duration of each test were specified by the client.

The test current was measured using a 300 kA_{peak} rated Rogowski coil (Powertech ID № 39444). The expanded uncertainty of the current measuring system is estimated as 2% (k=2).

Test Results:

The results of the tests are provided in Tables 2 through 5. Current and voltage waveforms for each test are provided in Figures 2 through 29.

The Encore #4/0 AWG Cu wire did not withstand the I^2t calculated from the current and duration specified in IEEE 80, Table 6, for a 500 ms duration (44 kA_{rms}). It was capable of carrying a maximum of 92% of this I^2t value without fusing.

The Encore #4/0 AWG Cu wire did not withstand the EMF current specified in IEEE 837, Table 3 (47 kA_{rms}). It was capable of carrying a maximum of 91% of this current value without failing.

The Copperweld Scorpius CCS 61 x 072 conductor exceeded the 500 ms rms withstand current requirement of IEEE 80, Table 6, and met the EMF current requirements of IEEE 837, Table 3, for a 4/0 conductor.

For the #6 AWG Cu conductor size the Standards did not have current values specified, so these were calculated using Equation (45) from IEEE 80 and Equation (C.1) from IEEE 837. The calculations are presented in Appendix D.

Both the Copperweld Scorpius CCS 7 x 080 conductor and the Encore #6 AWG Cu conductor met the 500 ms rms withstand current requirement of IEEE 80, Table 6 (5.29 kA_{rms}), and the EMF current requirements of IEEE 837, Table 3 (5.81 kA_{rms}), for a #6 AWG Cu conductor.

APPENDIX A – FUSING CURRENT TEST CIRCUIT AND DATA

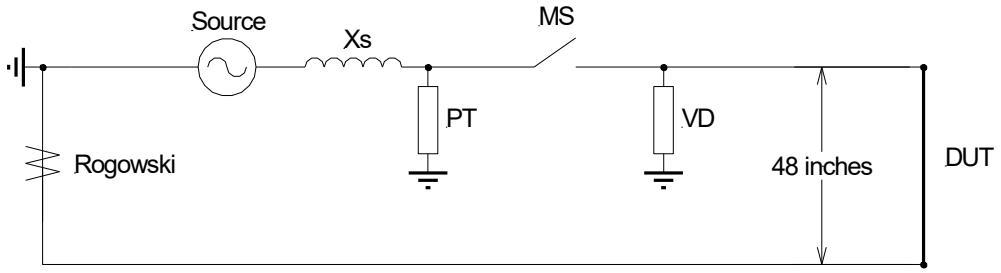


Figure 1: Test circuit schematic for all tests.

Notes:

1. X_S – Source current limiting reactance
2. MS – Making Switch
3. VD – Voltage measurement
4. Rogowski – Current measurement
5. DUT – Device Under Test

Table 1: Strand diameter and dc resistance measurements of sample conductors.

Wire Sample No.	Type	Strand Diameter [1] (in)		Conductor Diameter	Dc Resistance at 20°C
#		1	2	(in)	(μΩ/ft)
1	Encore Wire, 4/0 AWG, 19 strand CU	0.122	0.079	0.492	4.28
2	Encore Wire, 4/0 AWG, 19 strand CU	0.118	0.080	0.501	4.10
3	Encore Wire, 4/0 AWG, 19 strand CU	0.109	0.074	0.495	4.23
4	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.075	0.498	3.98
5	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.079	0.489	4.43
6	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.075	0.490	4.17
7	Encore Wire, 4/0 AWG, 19 strand CU	0.101	0.075	0.489	4.18
8	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.074	0.491	4.15
9	Encore Wire, 4/0 AWG, 19 strand CU	0.106	0.082	0.490	3.97
10	Encore Wire, 4/0 AWG, 19 strand CU	0.105	0.079	0.493	3.73
11	Scorpius 61 x 072 CCS	0.056	---	0.646	6.83
12	Scorpius 61 x 072 CCS	0.058	---	0.649	6.60
13	Scorpius 61 x 072 CCS	0.068	---	0.641	6.60
14	Scorpius 61 x 072 CCS	0.056	---	0.639	6.73
15	Scorpius 61 x 072 CCS	0.067	---	0.646	6.62
16	Scorpius 61 x 072 CCS	0.059	---	0.630	6.53
17	Scorpius 61 x 072 CCS	0.056	---	0.642	6.73
18	Scorpius 61 x 072 CCS	0.067	---	0.637	6.62
19	Scorpius 61 x 072 CCS	0.064	---	0.641	6.85
20	Scorpius 61 x 072 CCS	0.059	---	0.633	6.83
21	Encore Wire, #6 AWG, single strand CU	0.152	---	0.152	33.3
22	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
23	Encore Wire, #6 AWG, single strand CU	0.158	---	0.158	33.2
24	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.4
25	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.3
26	Encore Wire, #6 AWG, single strand CU	0.148	---	0.148	33.6
27	Encore Wire, #6 AWG, single strand CU	0.155	---	0.155	33.3
28	Encore Wire, #6 AWG, single strand CU	0.146	---	0.146	33.1
29	Encore Wire, #6 AWG, single strand CU	0.153	---	0.153	33.2
30	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
31	Scorpius 7 x 080 CCS	0.072	---	0.215	46.3
32	Scorpius 7 x 080 CCS	0.069	---	0.226	45.9
33	Scorpius 7 x 080 CCS	0.065	---	0.220	46.2
34	Scorpius 7 x 080 CCS	0.071	---	0.218	46.4
35	Scorpius 7 x 080 CCS	0.073	---	0.212	46.1
36	Scorpius 7 x 080 CCS	0.065	---	0.216	46.3
37	Scorpius 7 x 080 CCS	0.070	---	0.211	46.1

Note:

[1] Encore 4/0 AWG CU conductor had two sizes of strands, all remaining conductors had one size of strands. Strand and conductor diameters were measured using a digital caliper with a resolution of 0.001 in.

Table 2: Summary of tests on Encore 4/0 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
1	1	Run to fusing	3.85	41.7	60.0	530	923	2	Y
2	2	Withstand	3.85	41.8	62.5	509	889	3	N
3-1	3	EMF (IEEE 837)	4.24	48.0	130	262	826	4	N
3-2	3	EMF (IEEE 837)	4.26	48.0	130	127	503	5	Y
4	4	EMF (IEEE 837)	4.25	48.0	130	260	823	6	Y
5-1	5	EMF (IEEE 837)	4.20	47.4	129	262	808	7	N
5-2	5	EMF (IEEE 837)	4.19	47.4	128	9.9	77	8	Y
6-1	6	EMF (IEEE 837)	3.93	42.6	116	263	662	9	N
6-2	6	EMF (IEEE 837)	3.91	42.6	116	262	654	10	N

Table 3: Summary of tests on Copperweld Scorpius 61 x 072 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
7	11	Run to fusing	3.84	41.7	59.6	673	1173	11	Y
8	12	Run to fusing	4.25	48.1	69.8	500	1157	12	Y
9	13	Run to fusing	4.21	47.5	68.9	508	1150	13	Y
10	14	Withstand	4.09	46.2	66.2	508	1089	14	N
11-1	15	EMF (IEEE 837)	4.21	47.6	129	262	803	15	N
11-2	15	EMF (IEEE 837)	4.20	47.7	129	262	803	16	N
12-1	16	EMF (IEEE 837)	4.21	47.6	129	254	784	17	N
12-2	16	EMF (IEEE 837)	4.19	47.4	128	254	767	18	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

Table 4: Summary of tests on Encore #6 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
13	21	Run to fusing	3.90	5.18	7.36	607	16.3	19	Y
14	23	Run to fusing	3.90	5.18	7.57	600	16.1	20	Y
15	24	Run to fusing	4.27	5.68	8.15	500	16.1	21	Y
16-1	25	EMF (IEEE 837)	3.77	5.86	16.2	262	13.9	22	N
16-2	25	EMF (IEEE 837)	3.77	5.86	16.1	262	13.9	23	N

Table 5: Summary of tests on Copperweld Scorpius 7 x 080 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
17	31	Withstand	3.88	5.16	7.44	858	22.9	24	N
18	32	Run to fusing	3.89	5.16	7.43	908	24.2	25	Y
19	33	Run to fusing	4.48	7.00	10.3	493	24.1	26	Y
20	34	Run to fusing	4.41	6.91	10.2	502	23.9	27	Y
21-1	35	EMF (IEEE 837)	3.81	5.91	16.3	262	14.0	28	N
21-2	35	EMF (IEEE 837)	3.80	5.92	16.2	262	13.8	29	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

APPENDIX B – WAVEFORMS

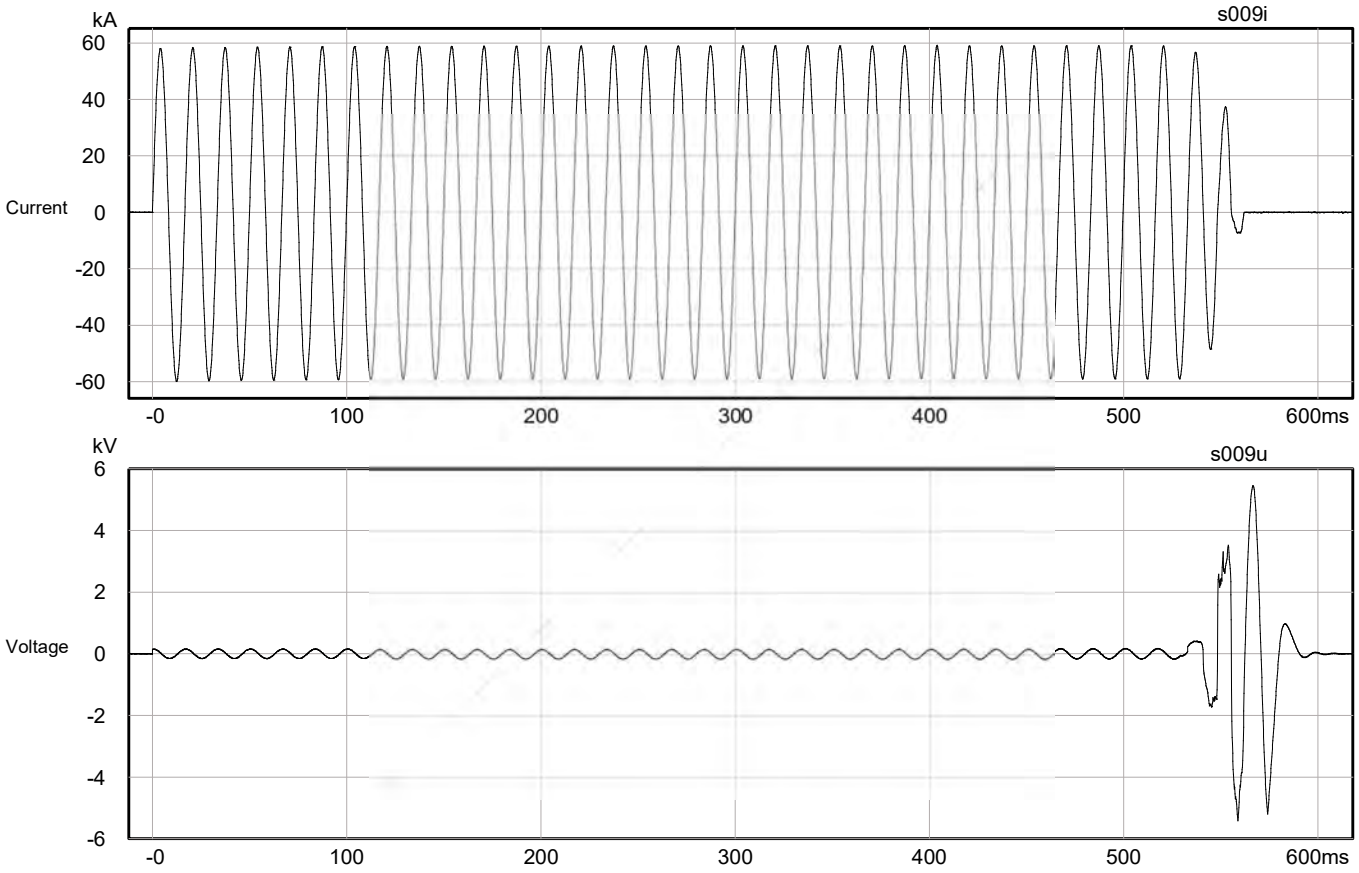


Figure 2: Waveforms for Test #1, Encore 4/0 AWG Sample 1.

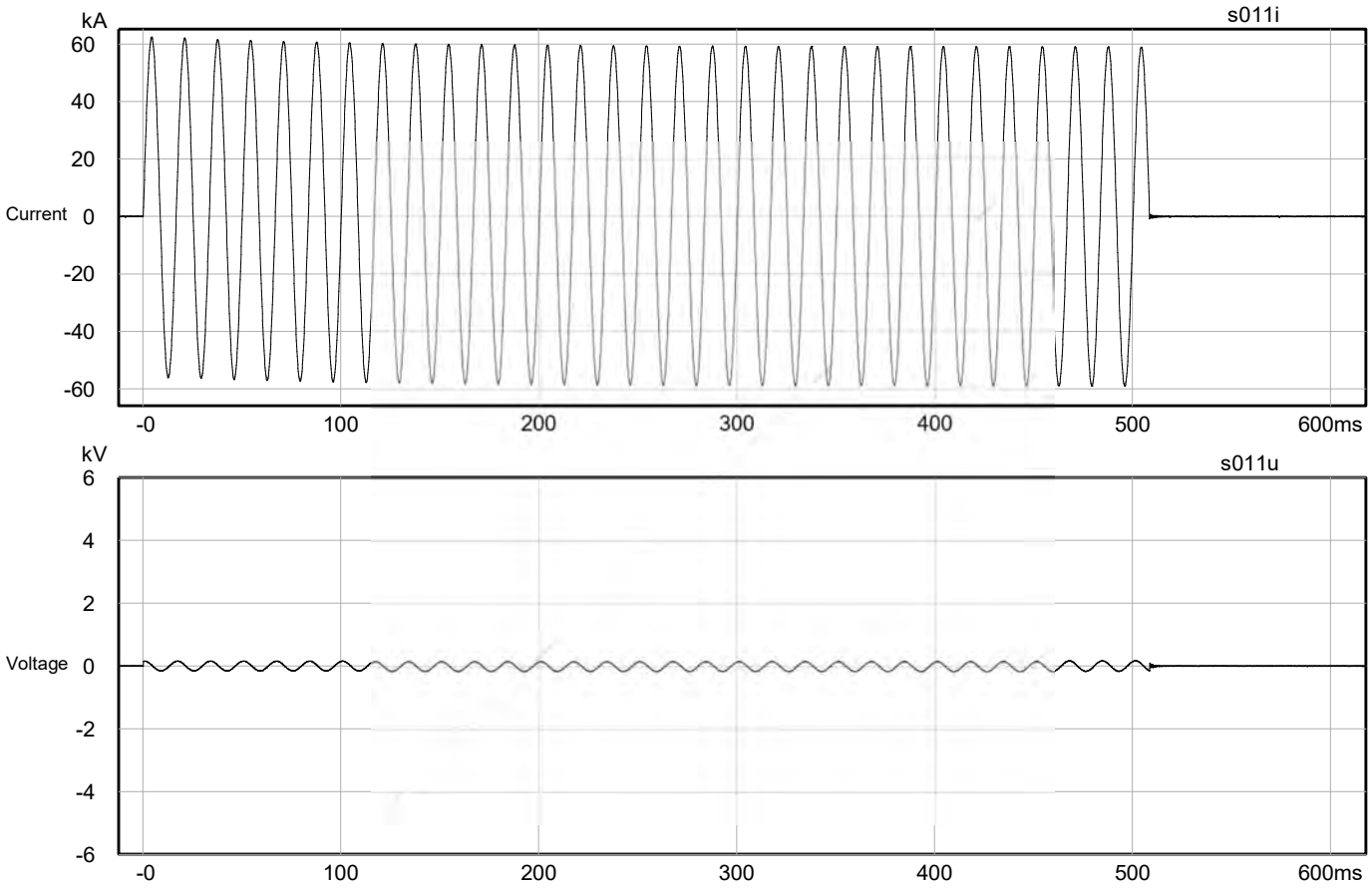


Figure 3: Waveforms for Test #2, Encore 4/0 AWG Sample 2.

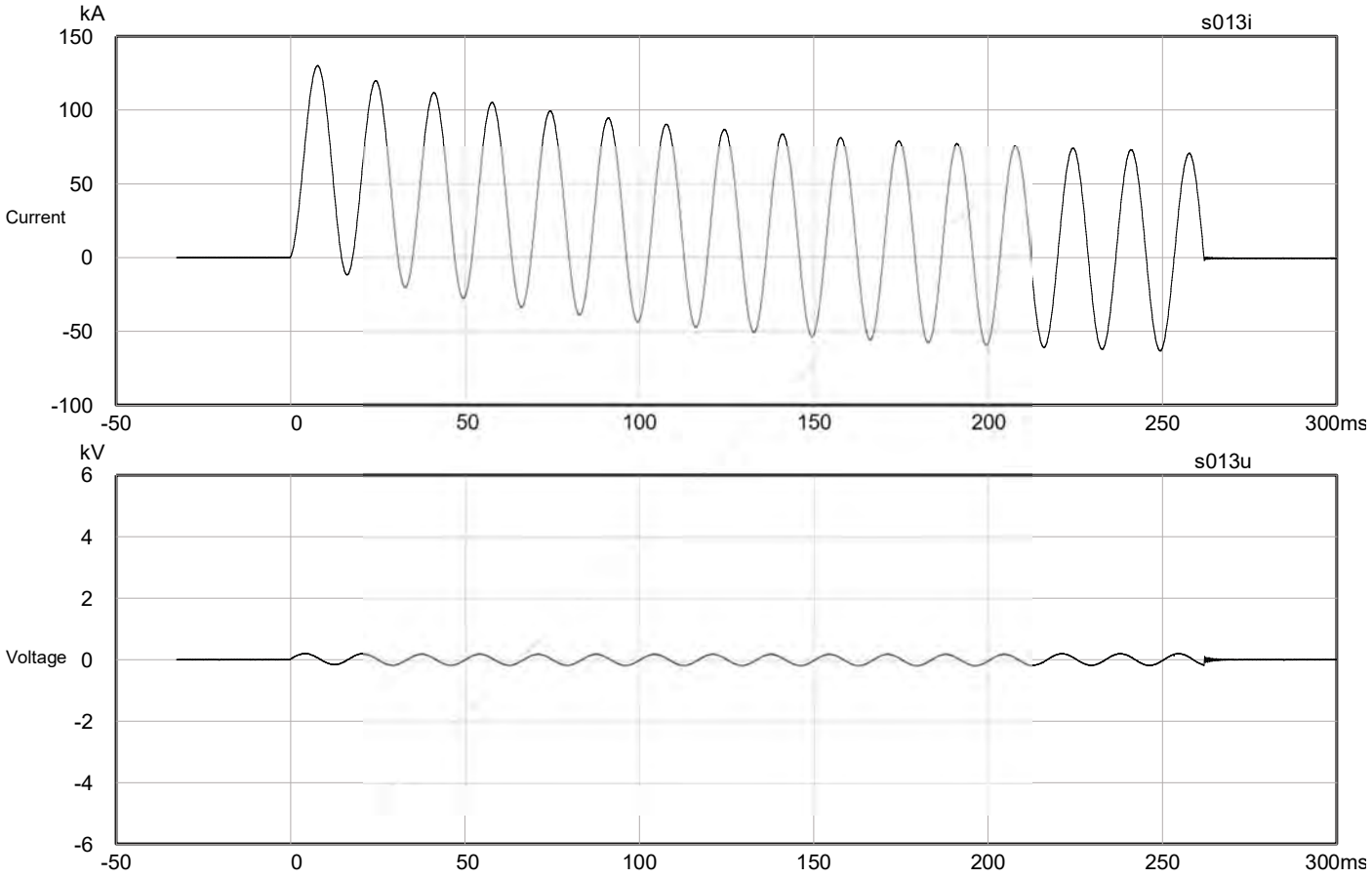


Figure 4: Waveforms for Test #3-1, Encore 4/0 AWG Sample 3.

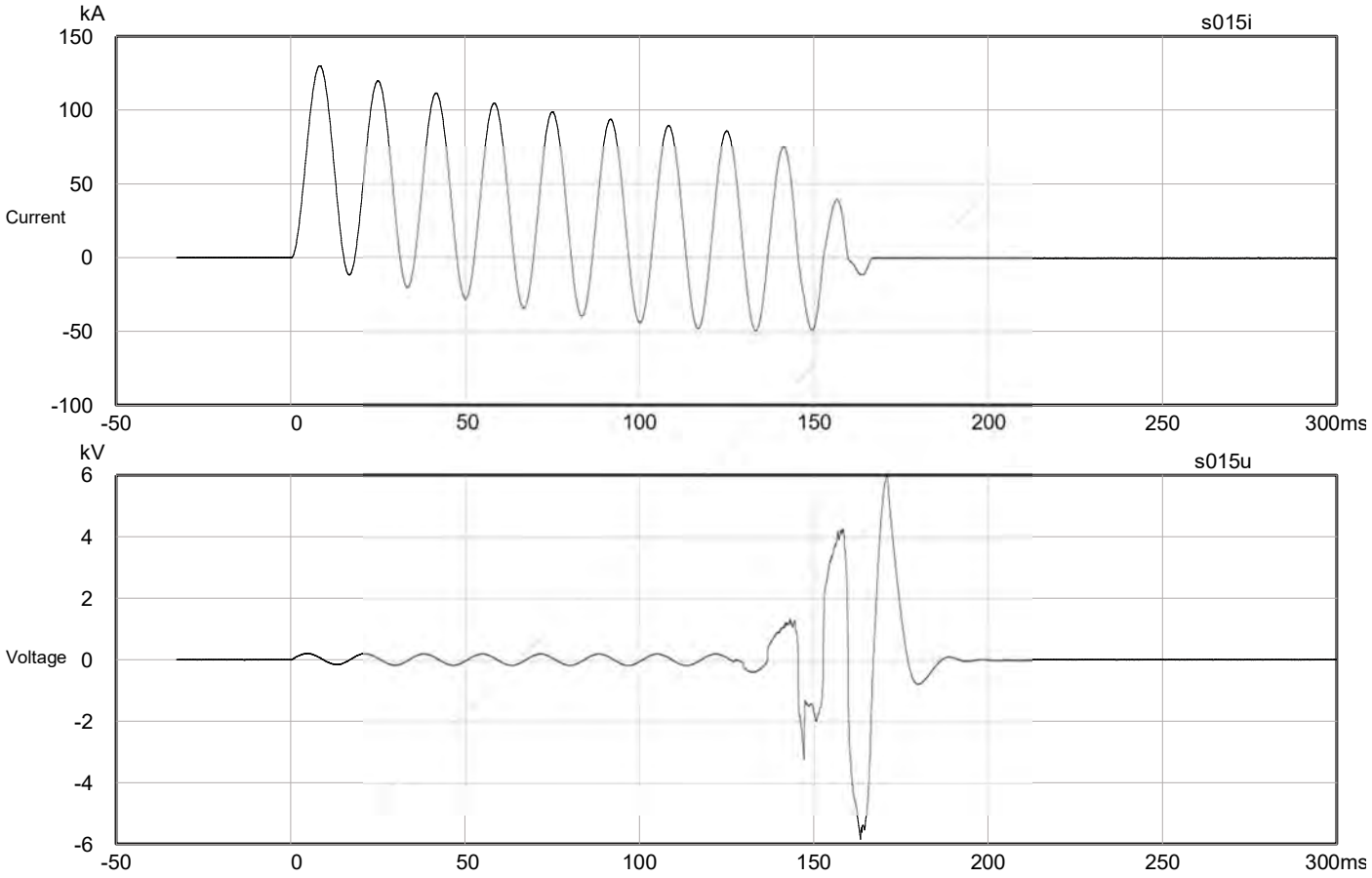


Figure 5: Waveforms for Test #3-2, Encore 4/0 AWG Sample 3.

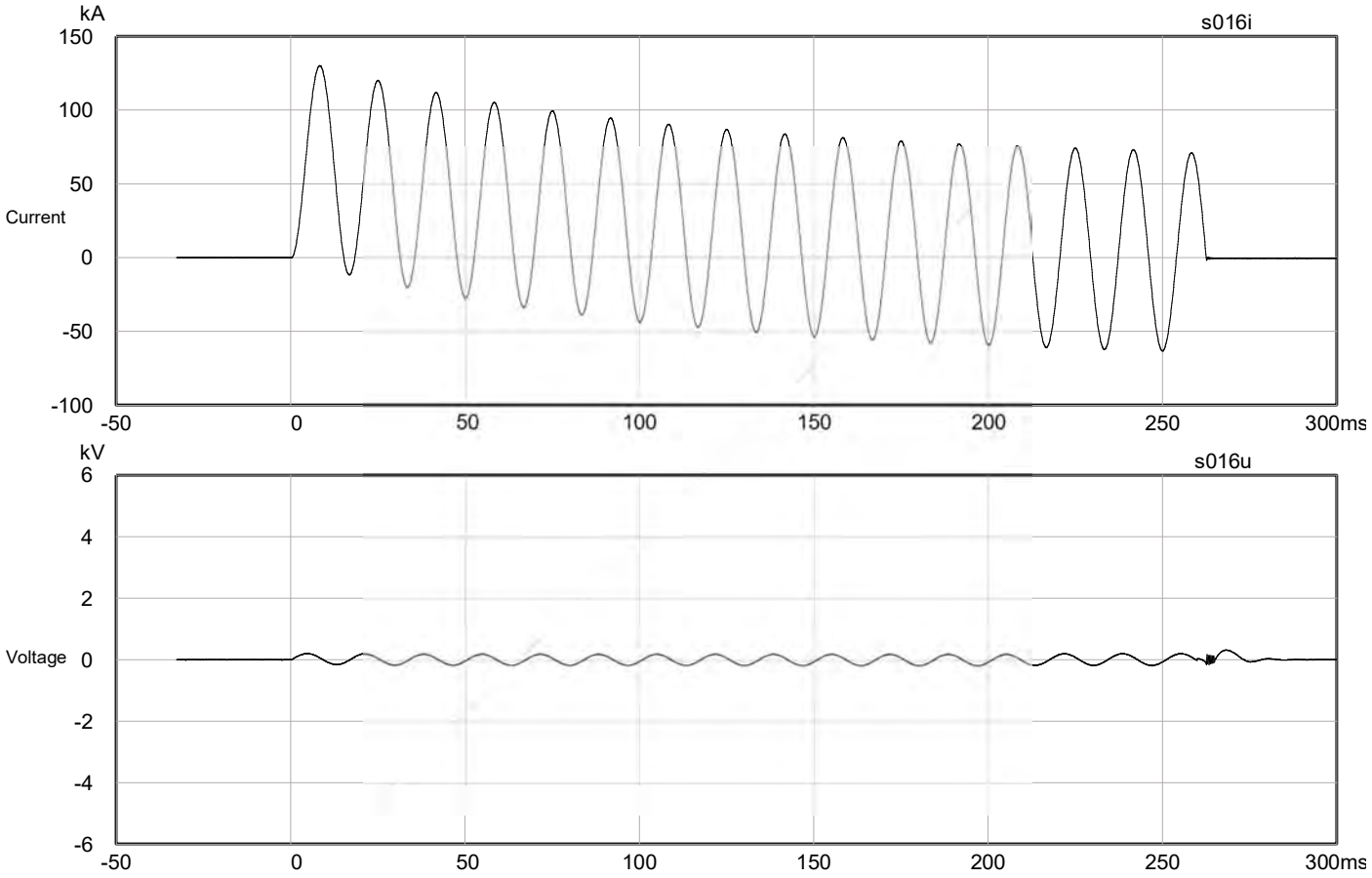


Figure 6: Waveforms for Test #4, Encore 4/0 AWG Sample 4.

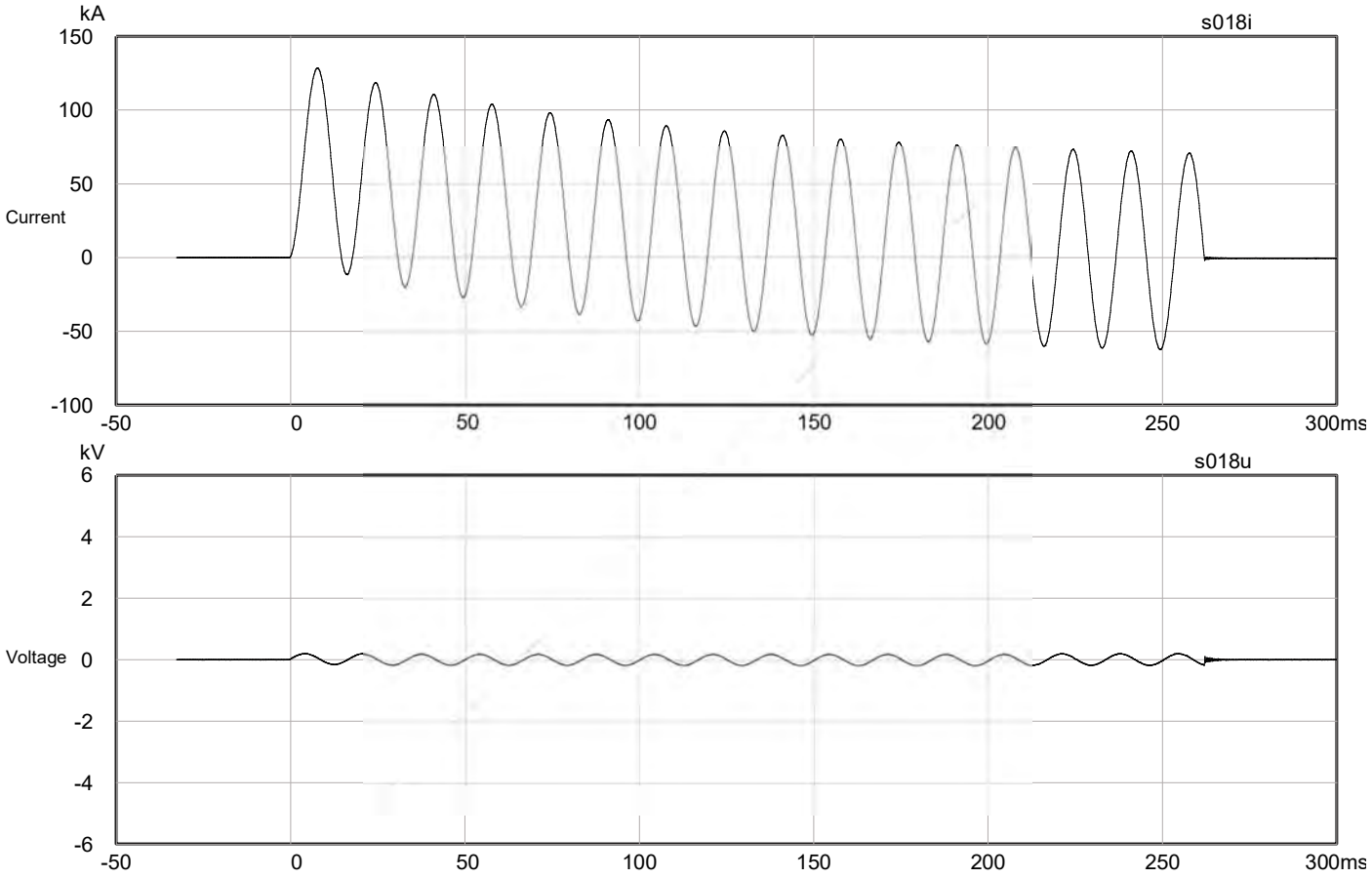


Figure 7: Waveforms for Test #5-1, Encore 4/0 AWG Sample 5.

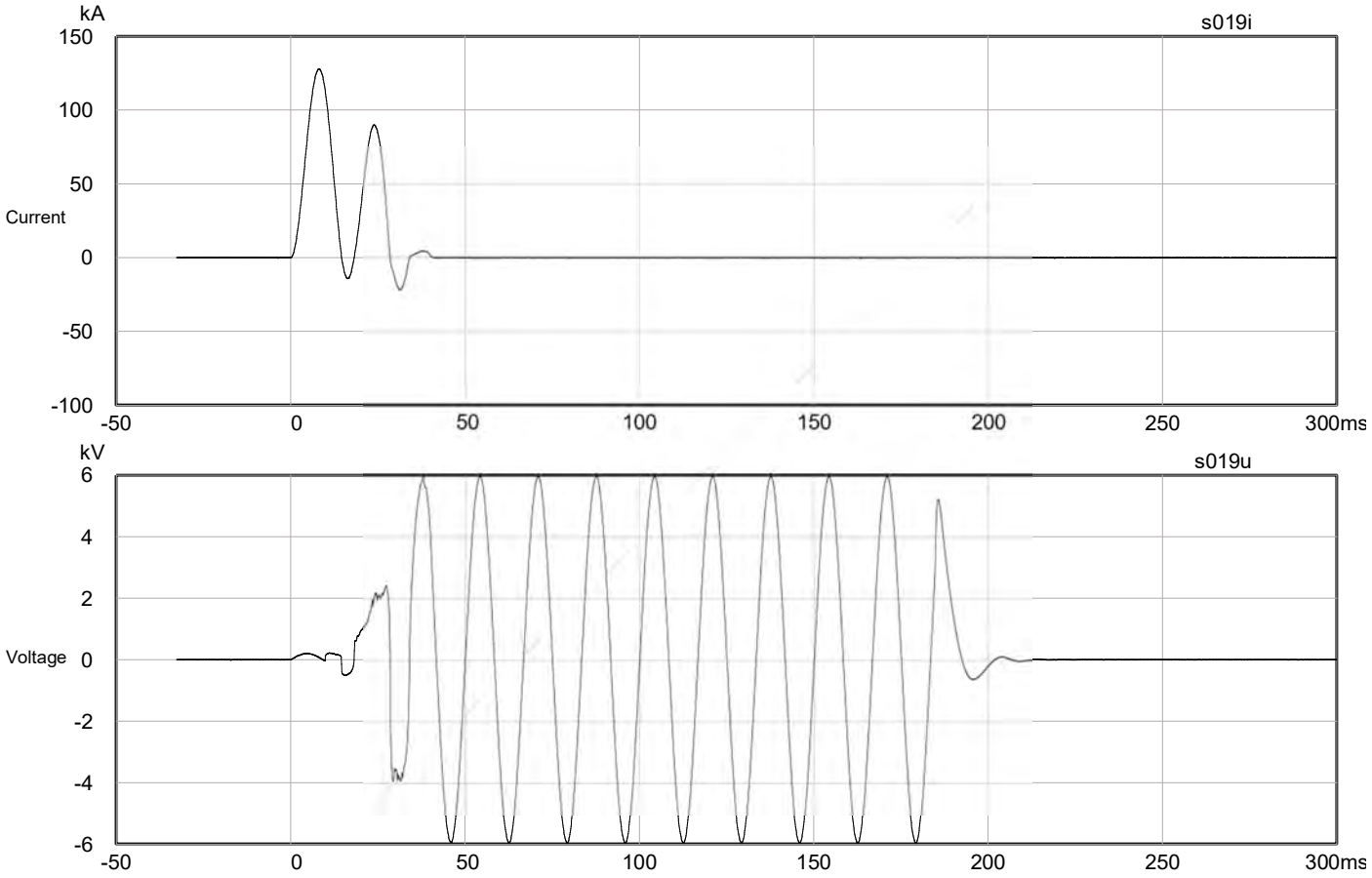


Figure 8: Waveforms for Test #5-2, Encore 4/0 AWG Sample 5.

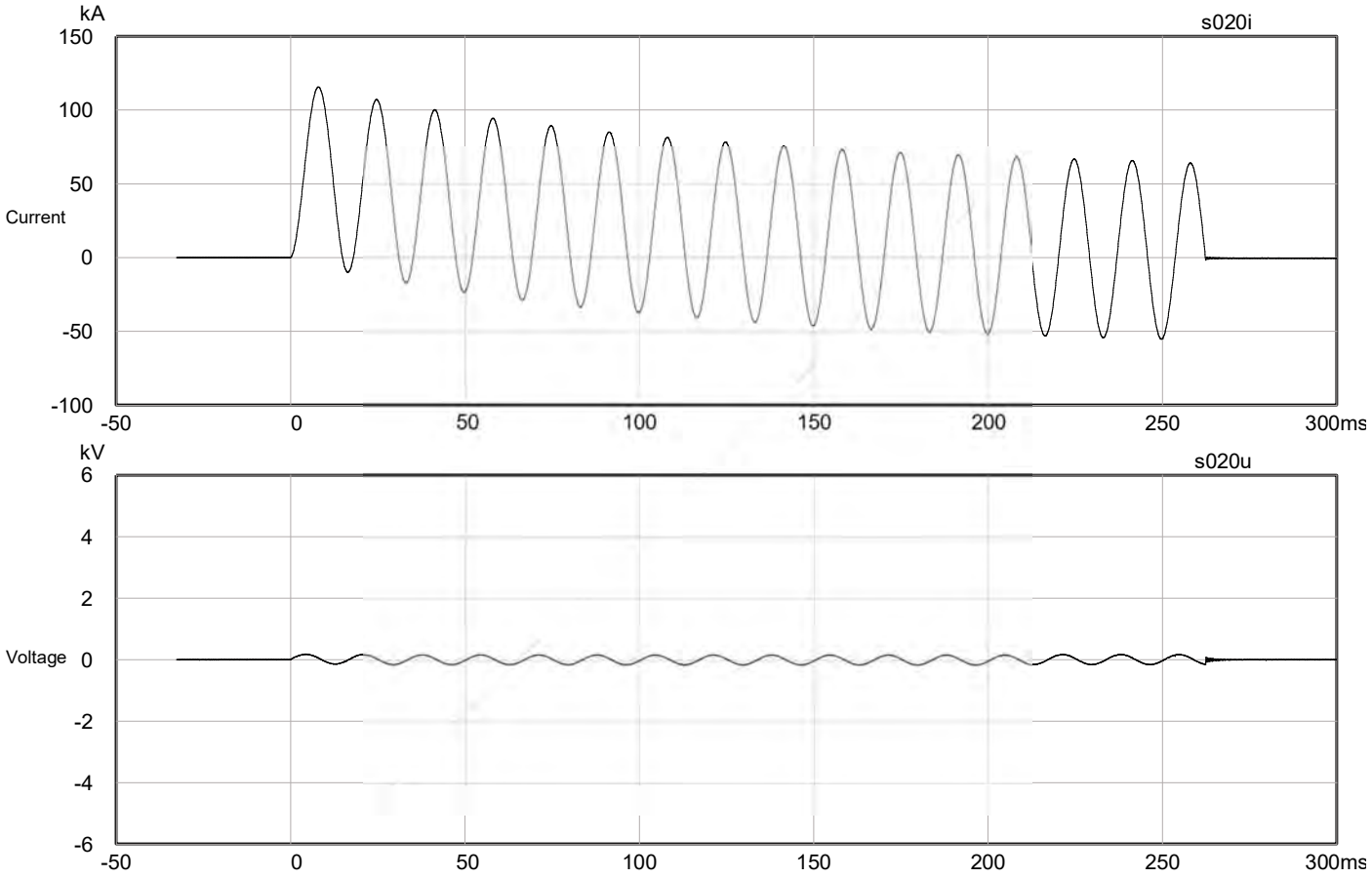


Figure 9: Waveforms for Test #6-1, Encore 4/0 AWG Sample 6.

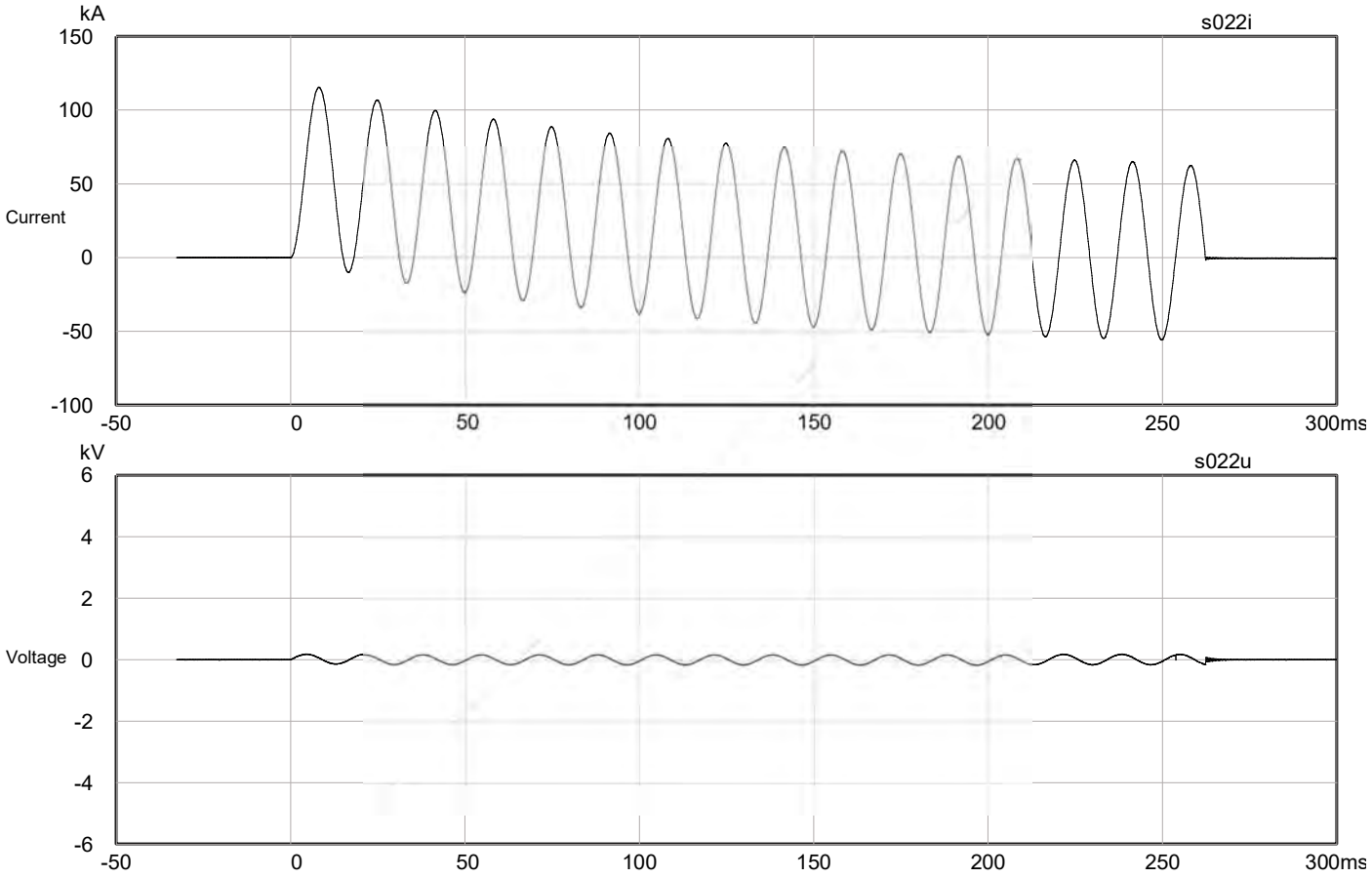


Figure 10: Waveforms for Test #6-2, Encore 4/0 AWG Sample 6.

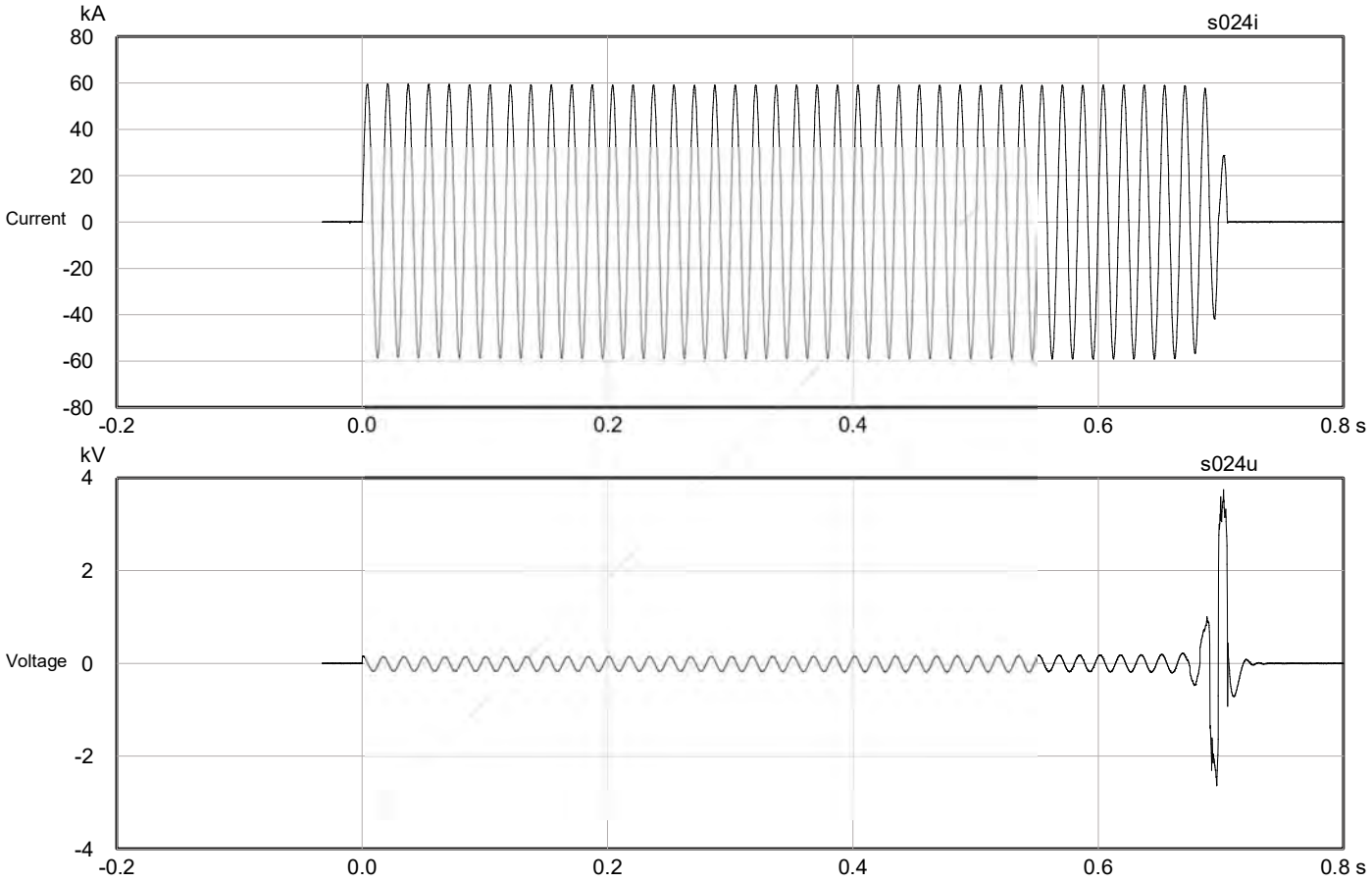


Figure 11: Waveforms for Test #7, Copperweld Scorpius 61 x 072 Sample 11.

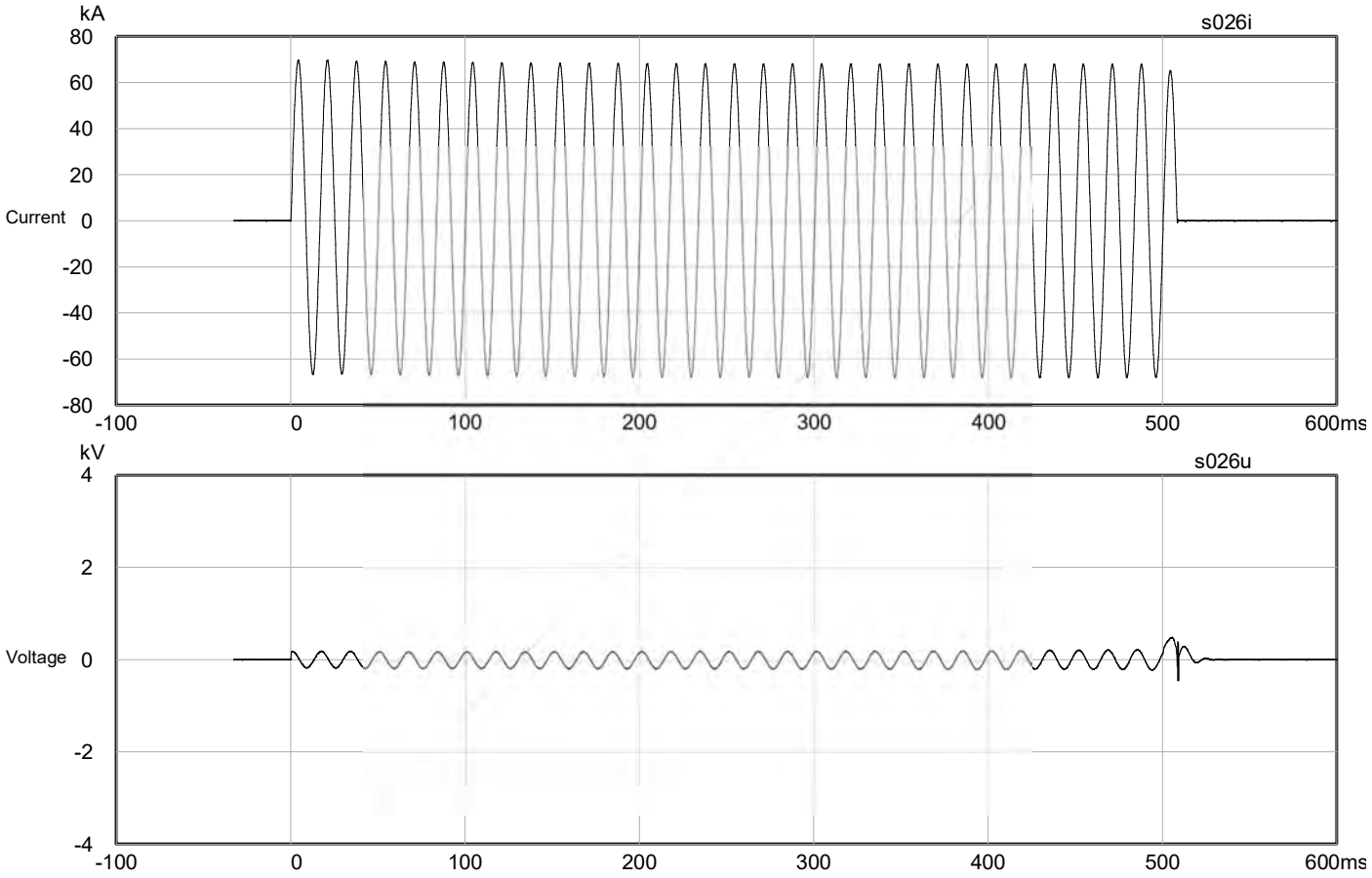


Figure 12: Waveforms for Test #6, Copperweld Scorpius 61 x 072 Sample 12.

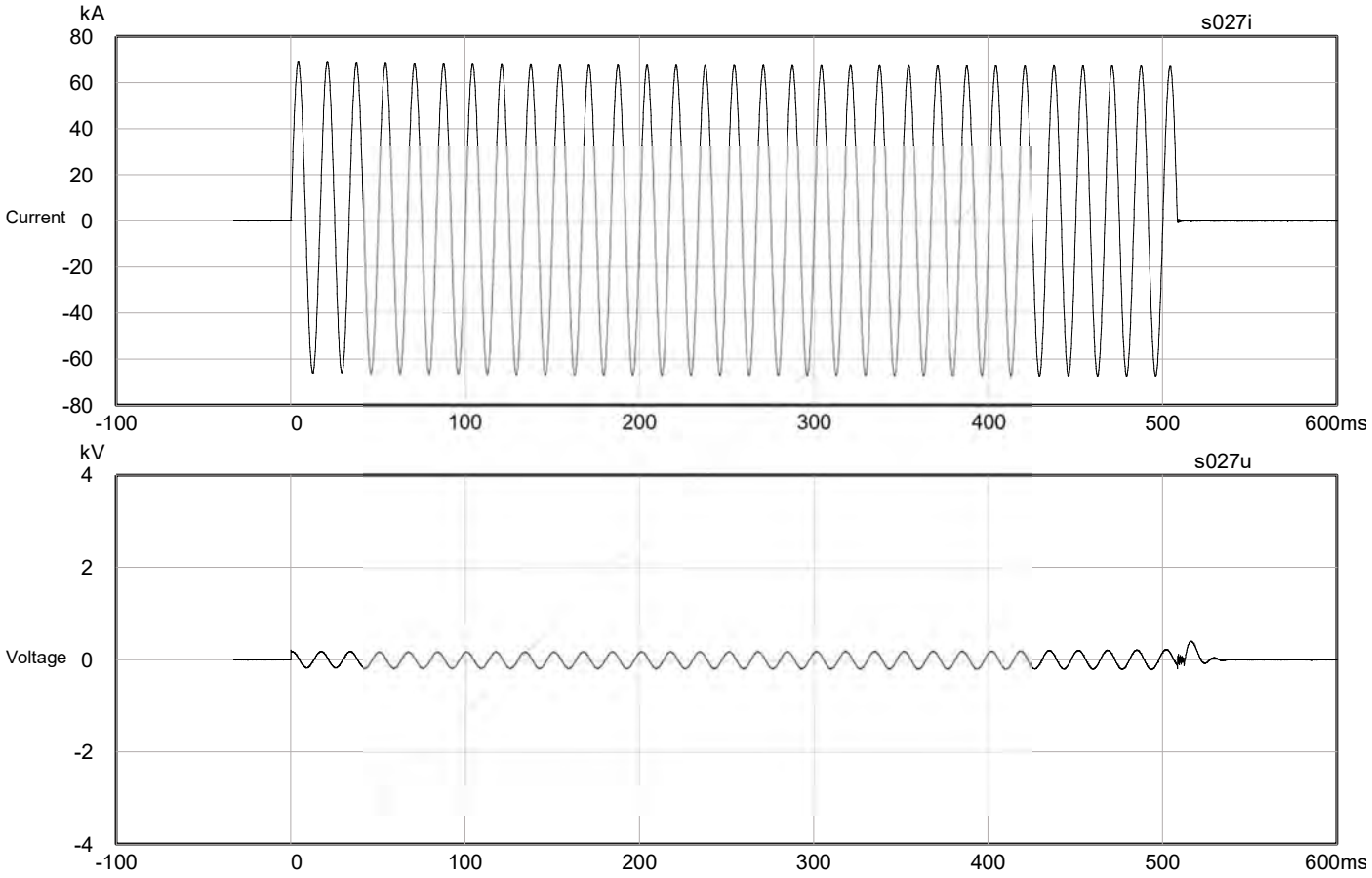


Figure 13: Waveforms for Test #9, Copperweld Scorpius 61 x 072 Sample 13.

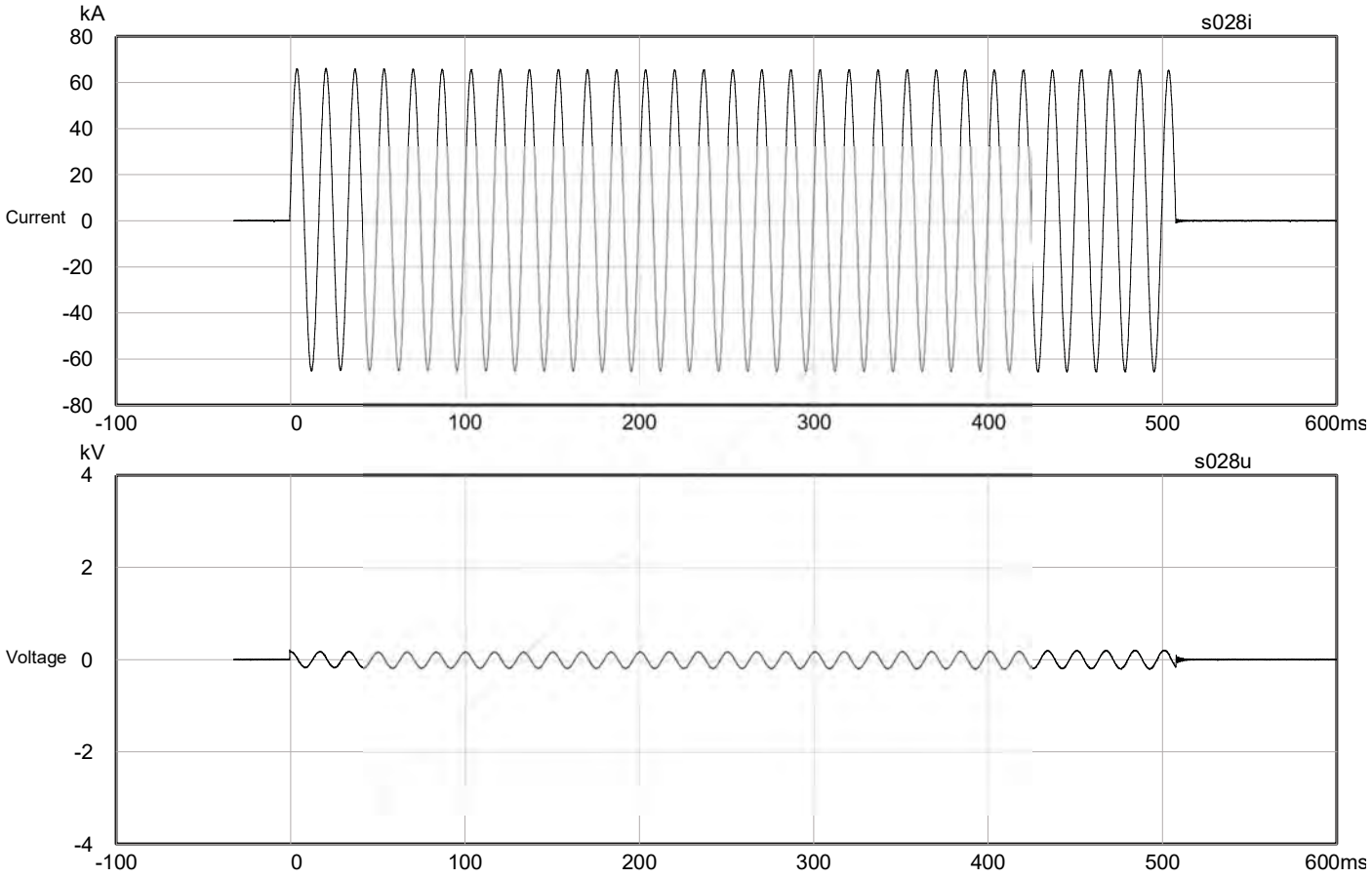


Figure 14: Waveforms for Test #10, Copperweld Scorpius 61 x 072 Sample 14.

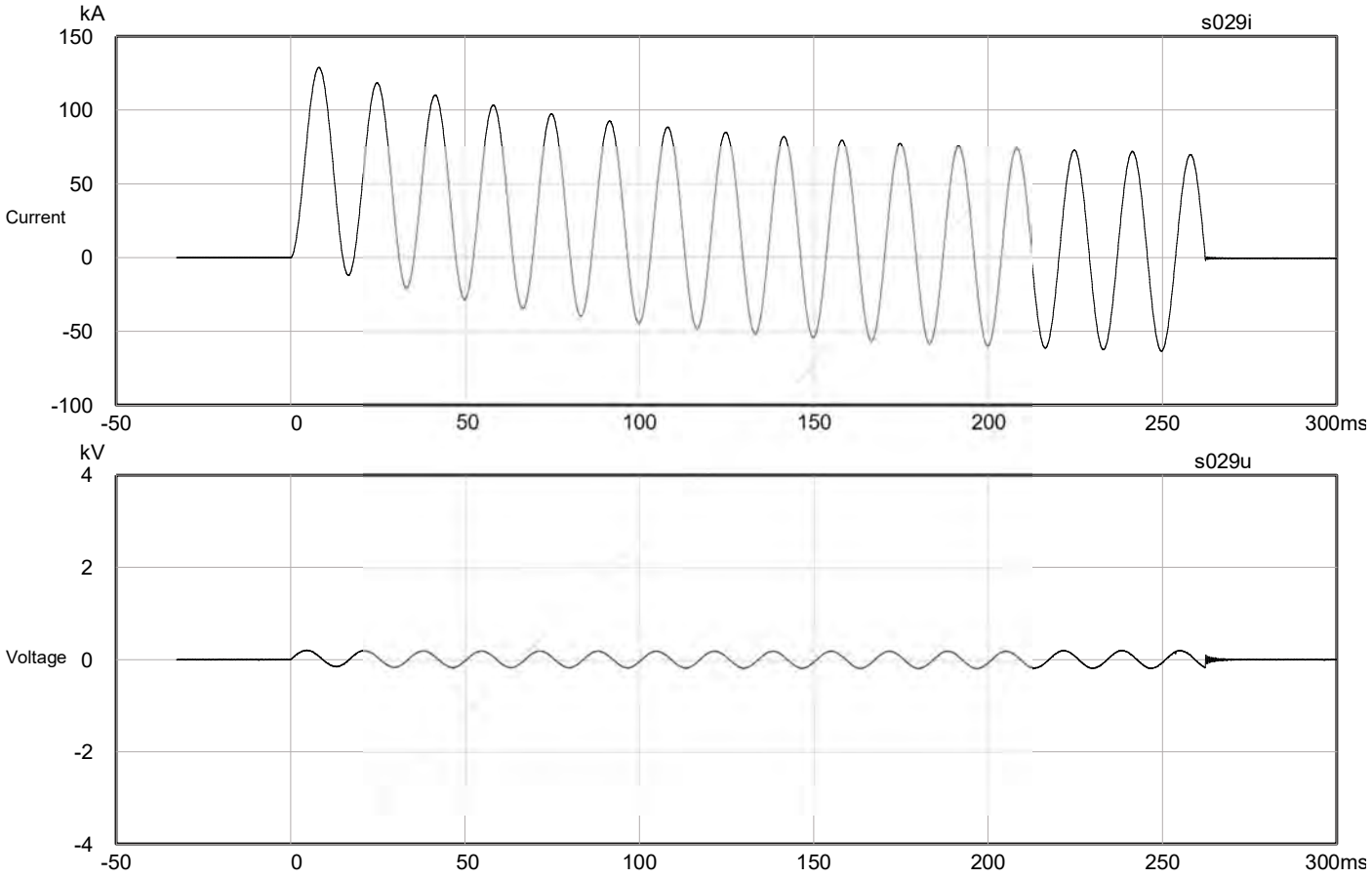


Figure 15: Waveforms for Test #11-1, Copperweld Scorpius 61 x 072 Sample 15.

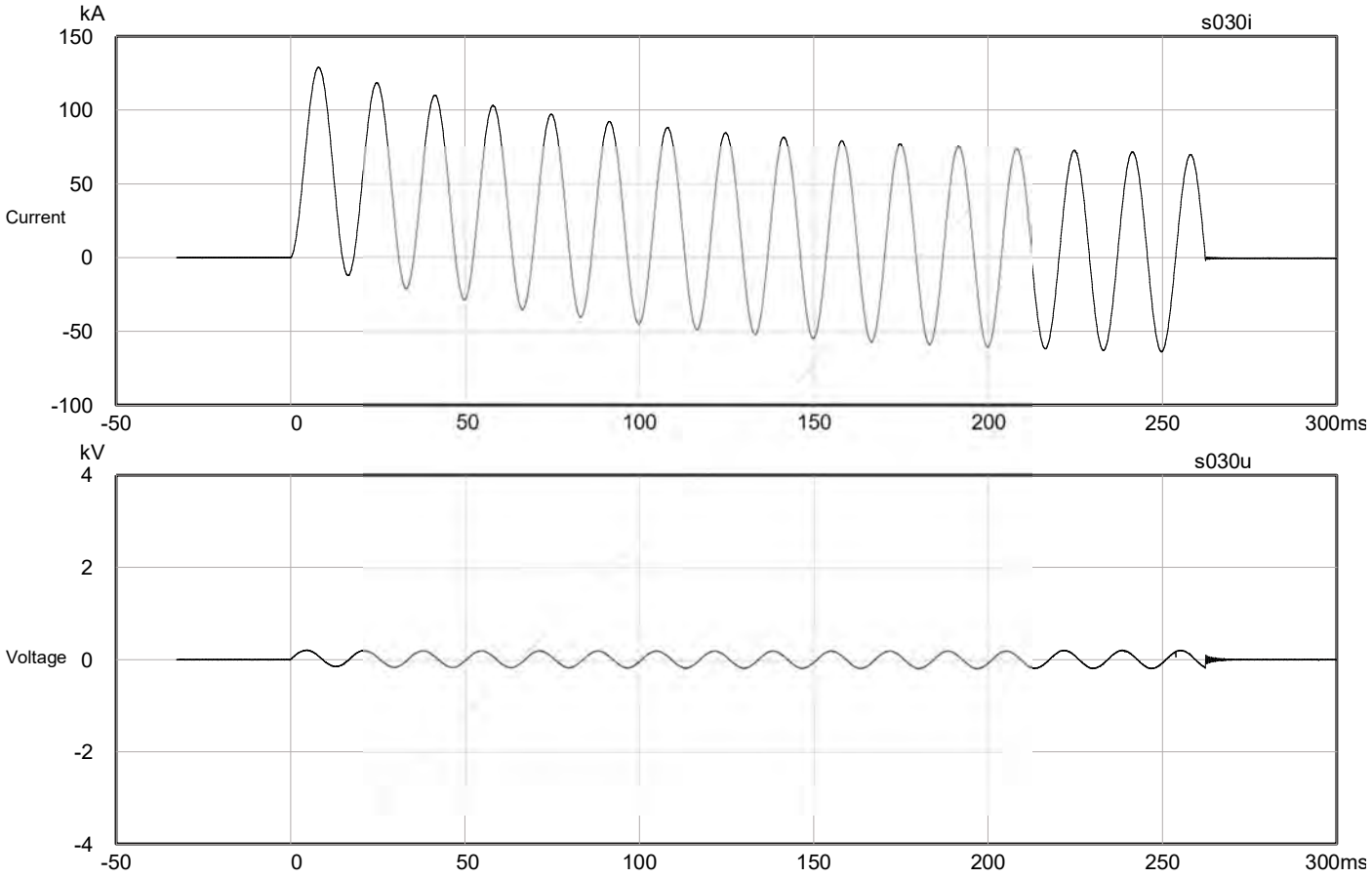


Figure 16: Waveforms for Test #11-2, Copperweld Scorpius 61 x 072 Sample 15.

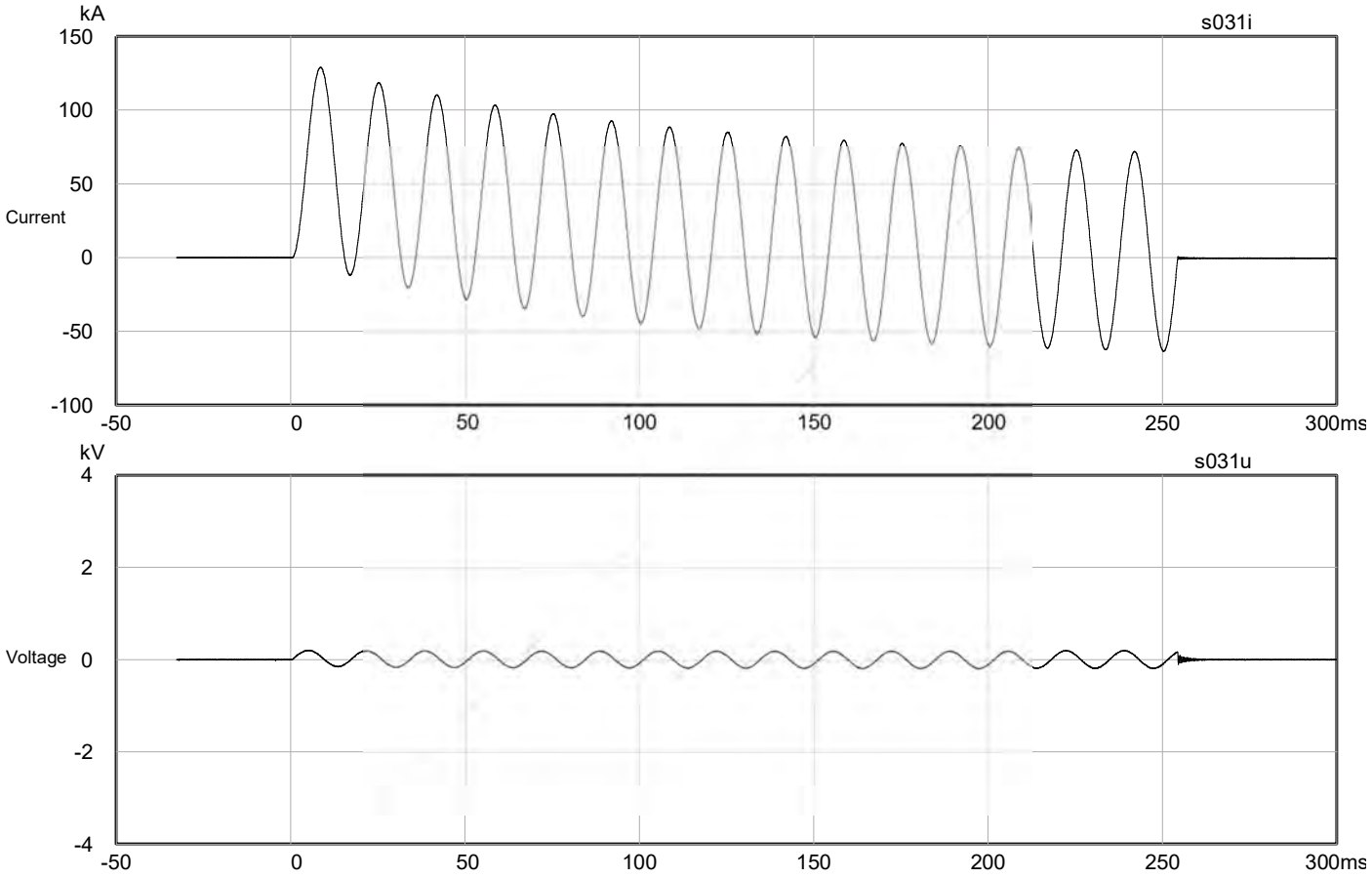


Figure 17: Waveforms for Test #12-1, Copperweld Scorpius 61 x 072 Sample 16.

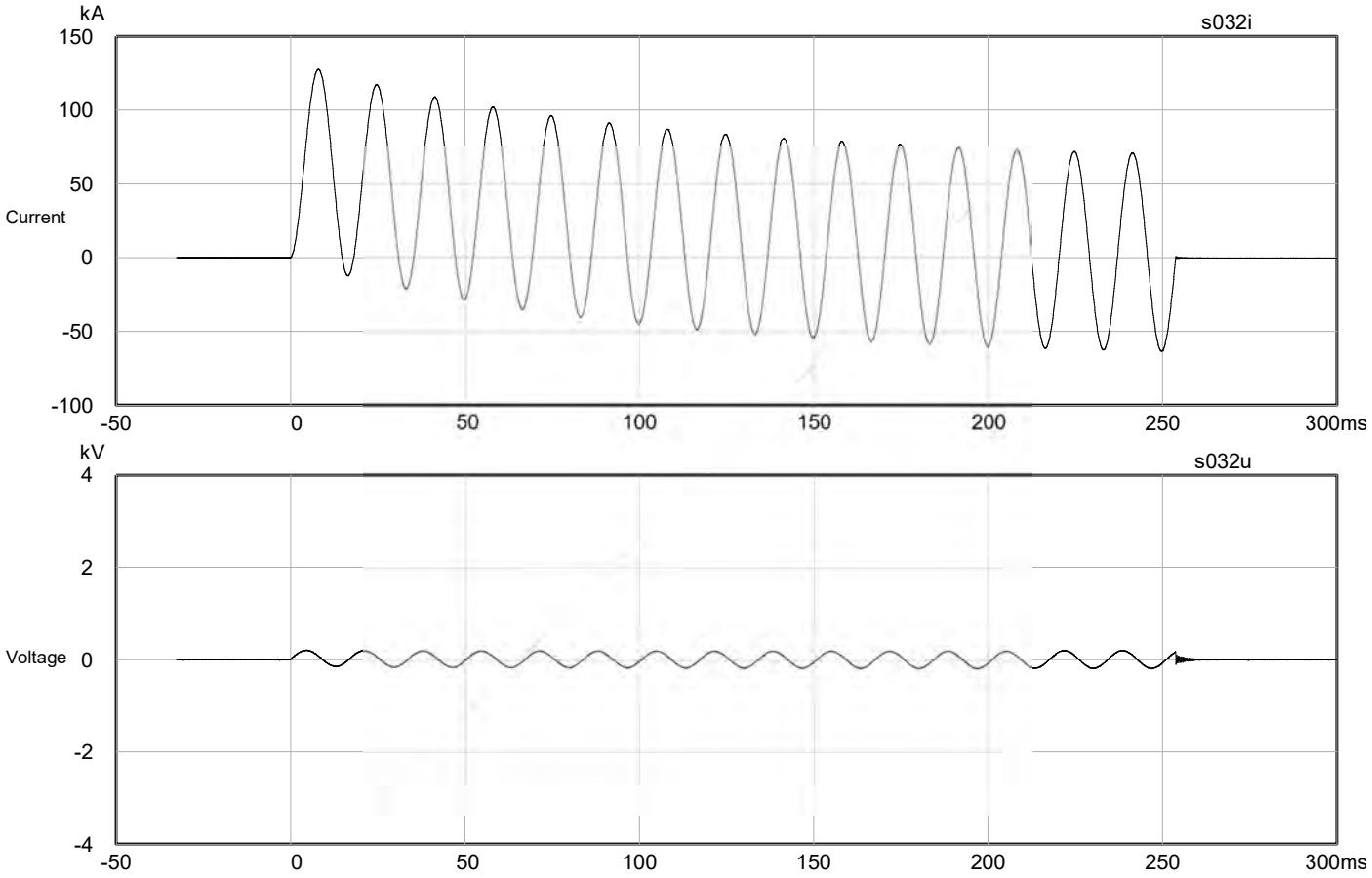


Figure 18: Waveforms for Test #12-2, Copperweld Scorpius 61 x 072 Sample 16.

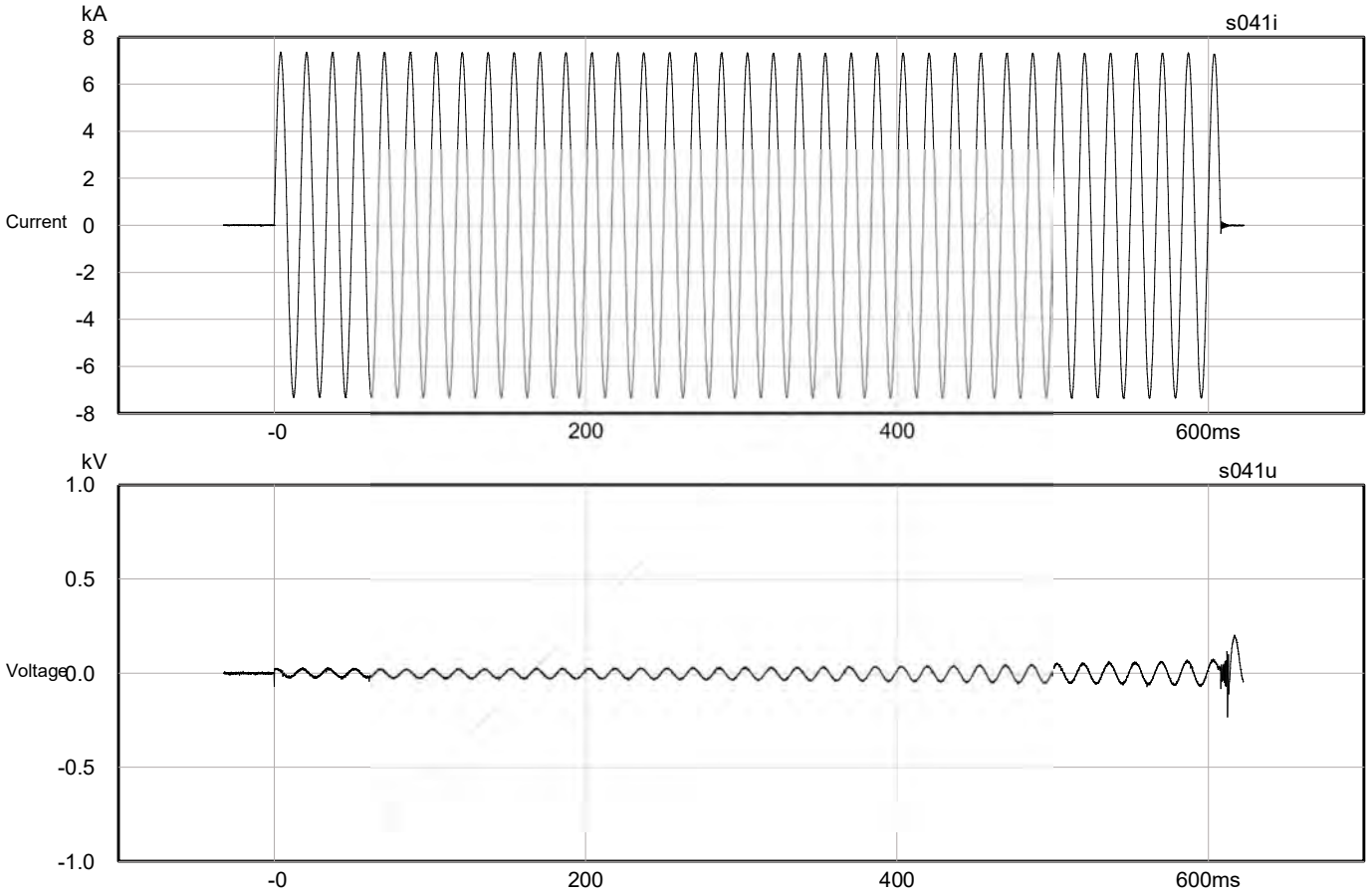


Figure 19: Waveforms for Test #13, Encore #6 AWG Sample 21.

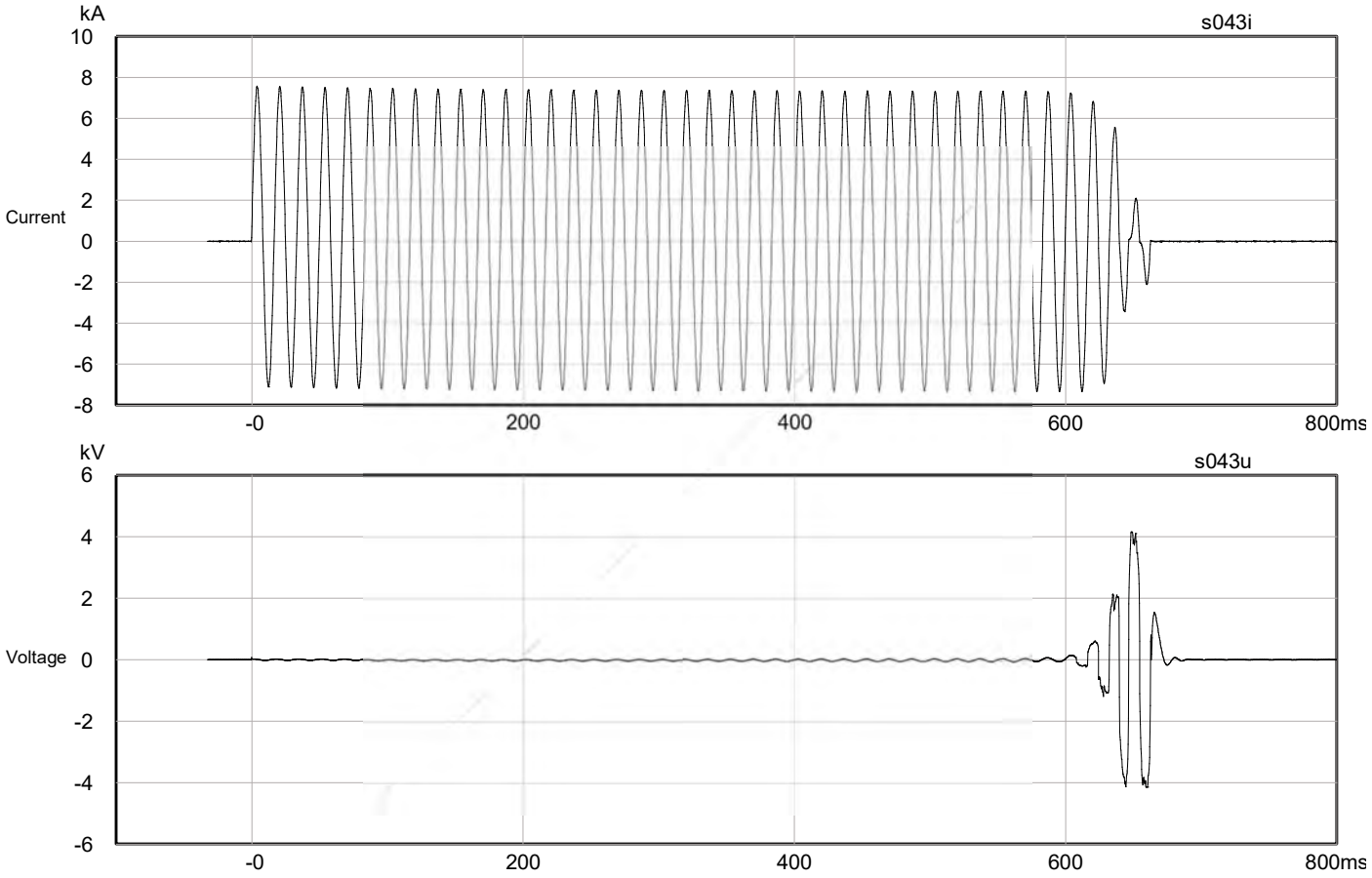


Figure 20: Waveforms for Test #14, Encore #6 AWG Sample 23.

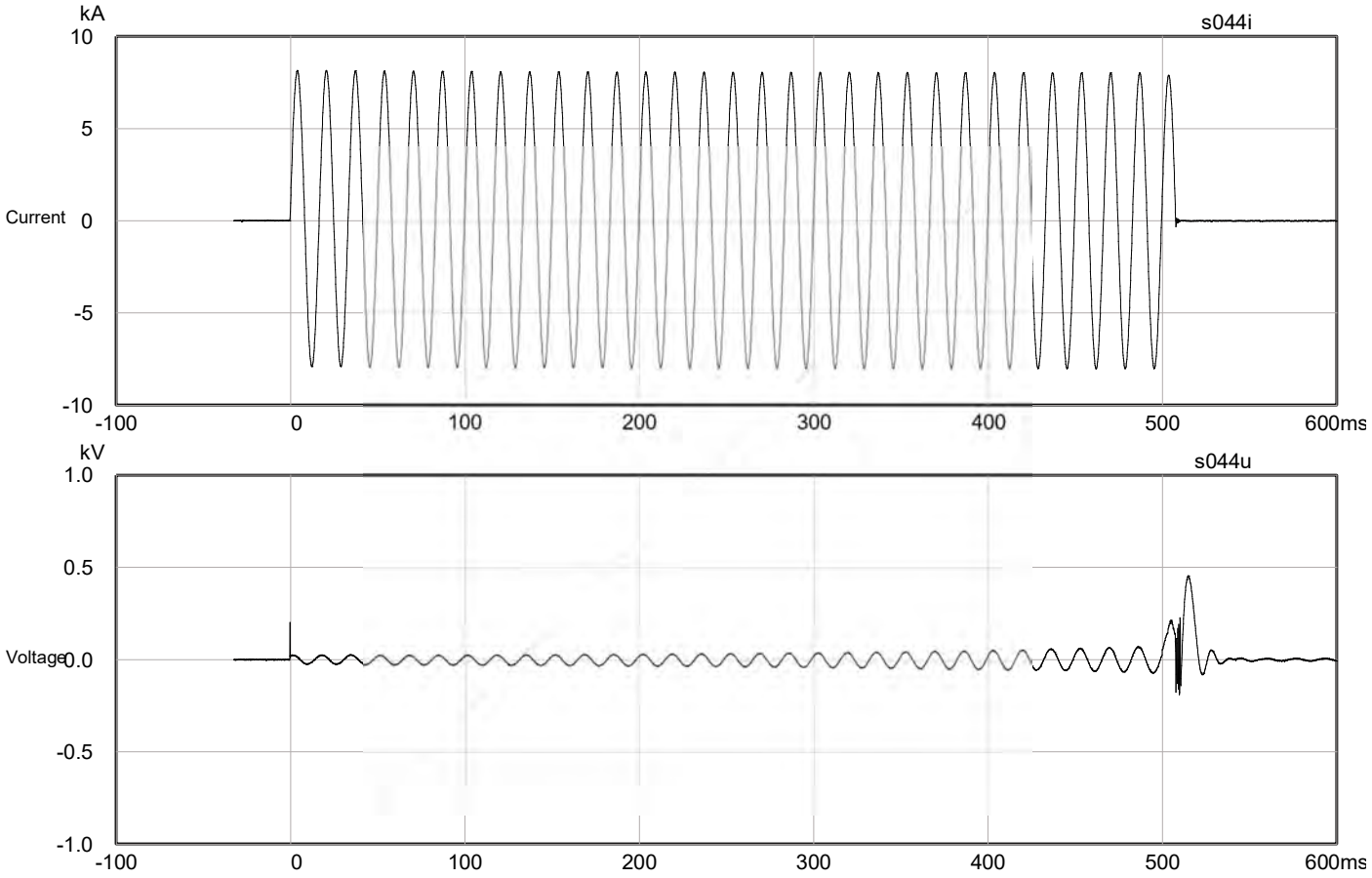


Figure 21: Waveforms for Test #15, Encore #6 AWG Sample 24.

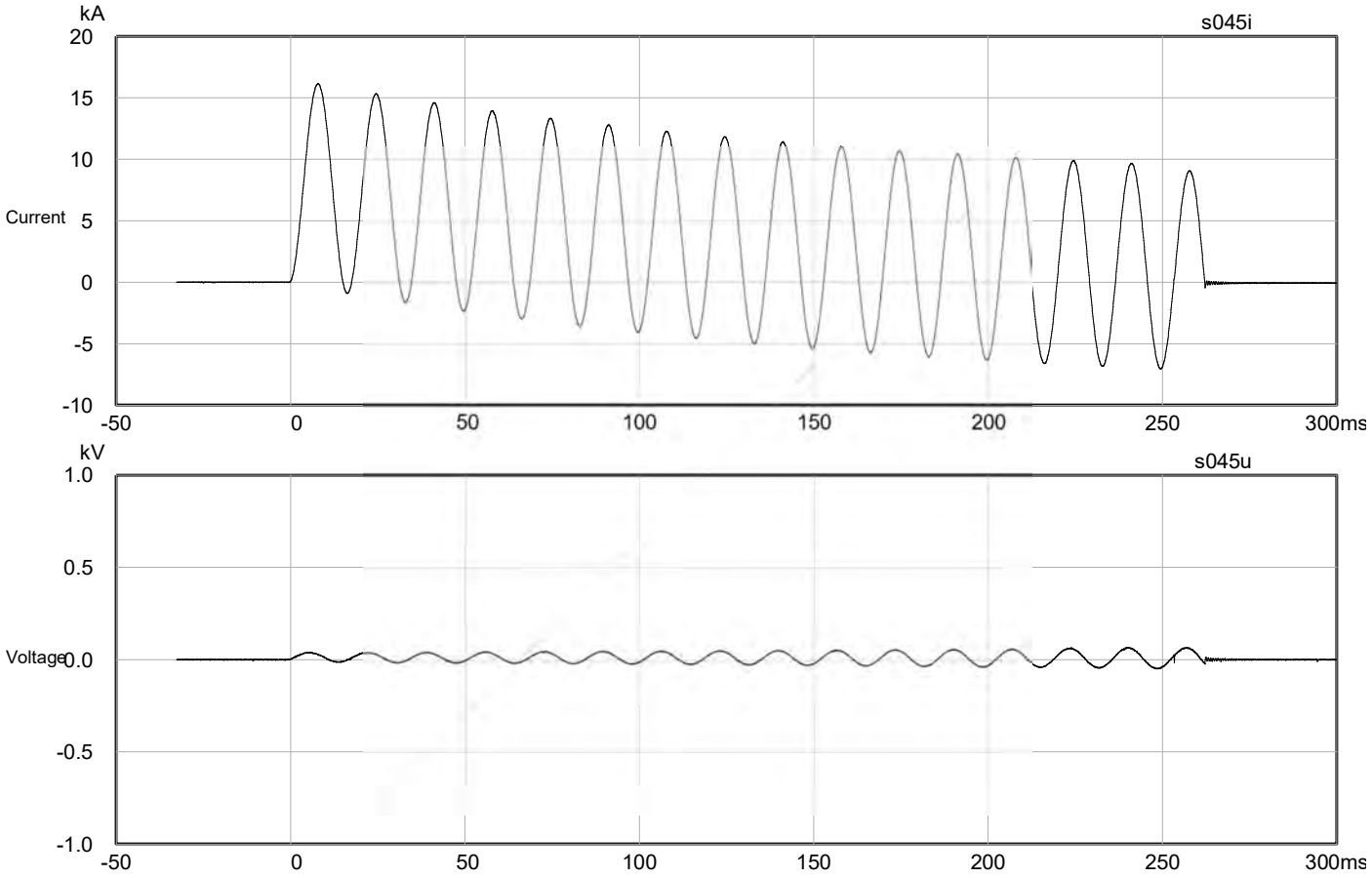


Figure 22: Waveforms for Test #16-1, Encore #6 AWG Sample 25.

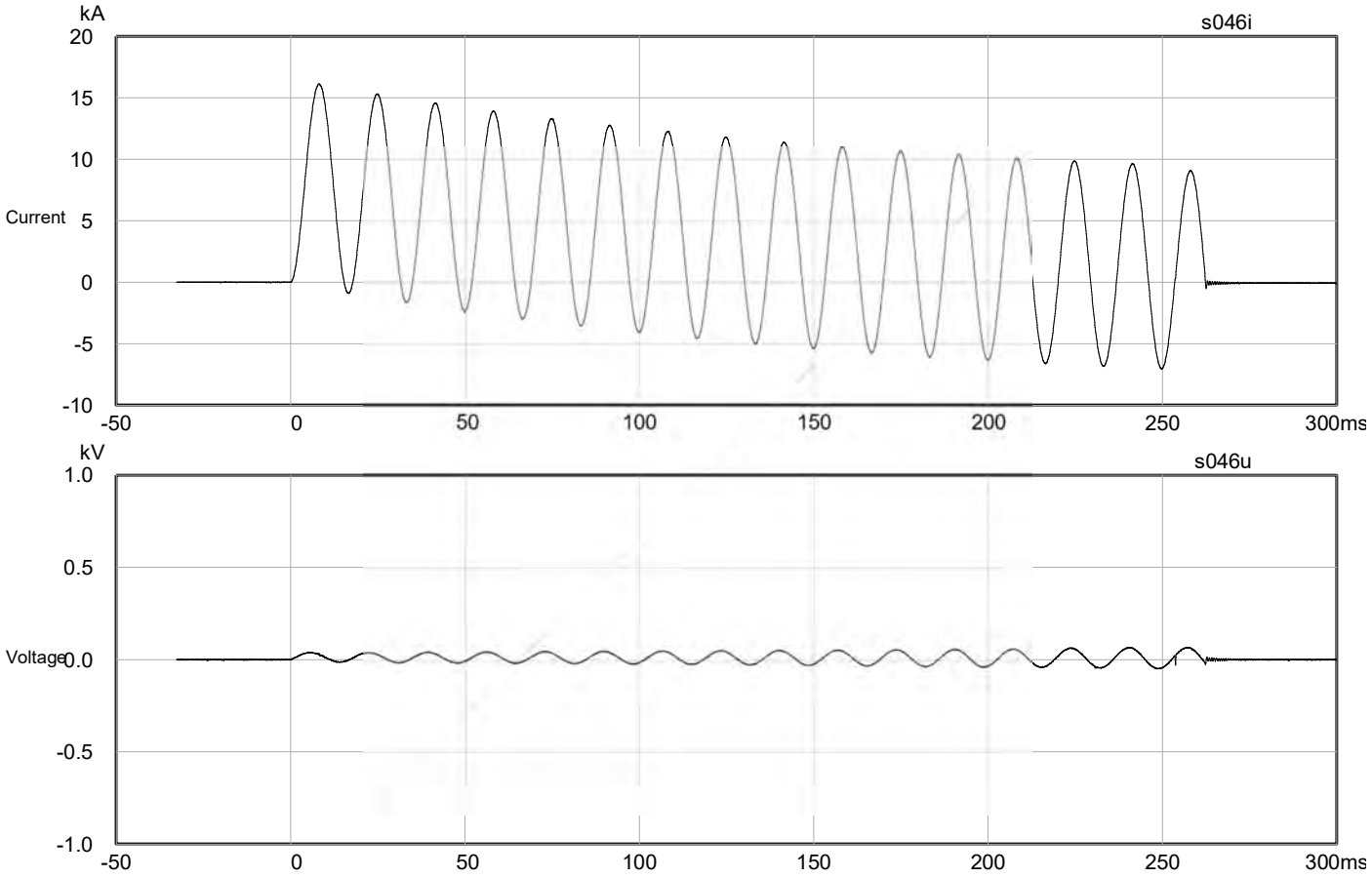


Figure 23: Waveforms for Test #16-2, Encore #6 AWG Sample 25.

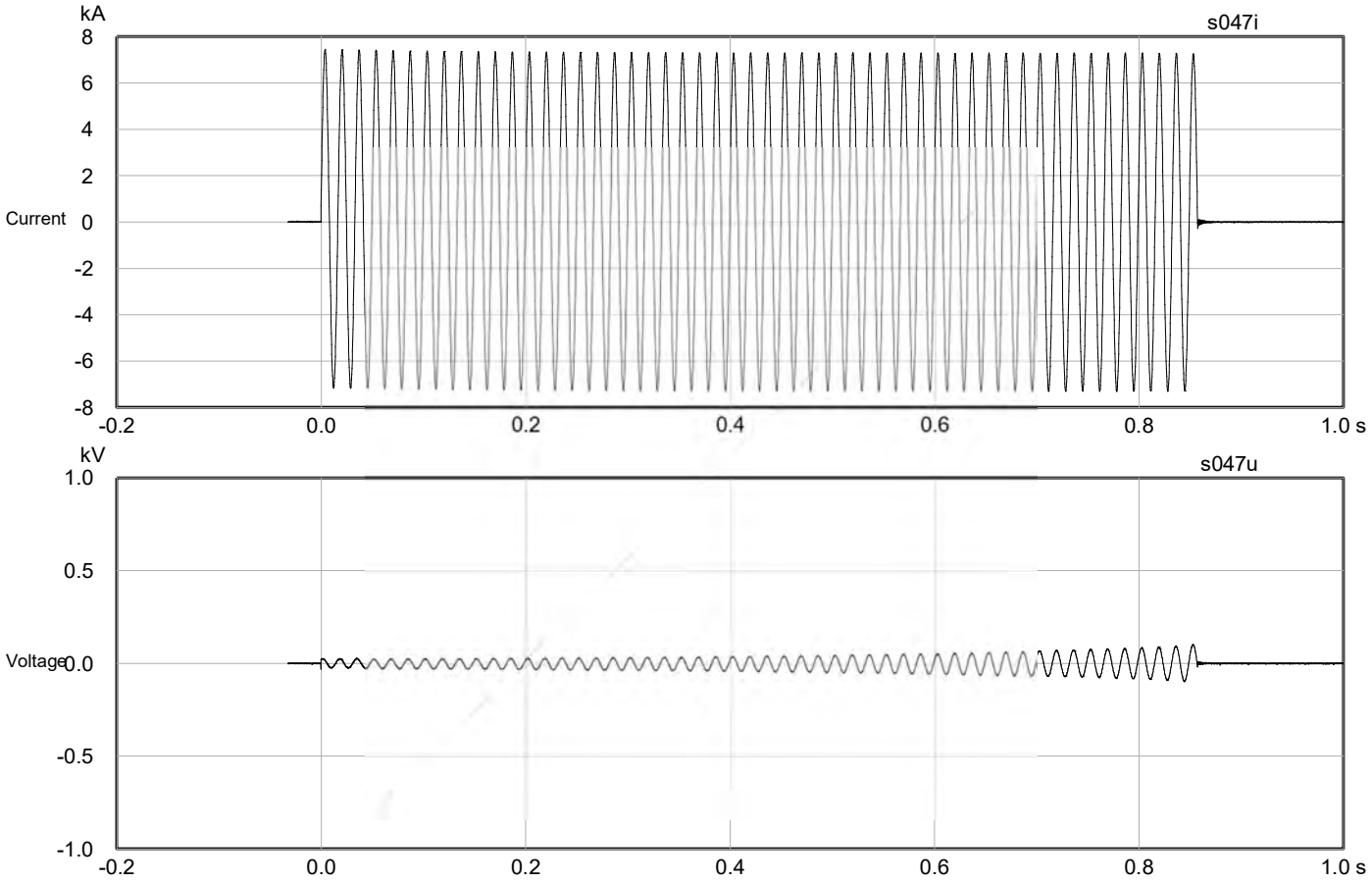


Figure 24: Waveforms for Test #17, Encore #6 AWG Sample 31.

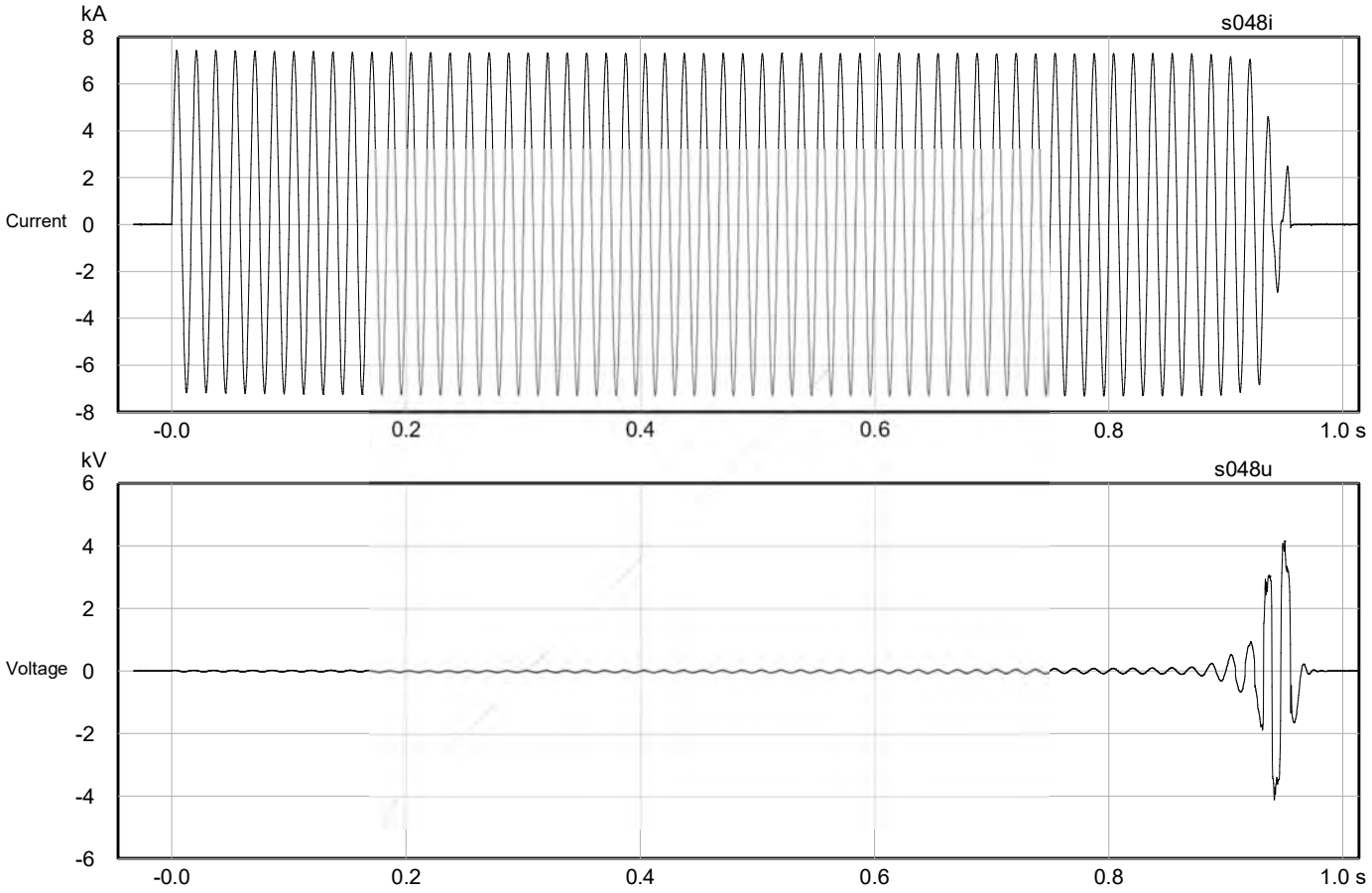


Figure 25: Waveforms for Test #18, Copperweld Scorpius 7 x 080 Sample 32.

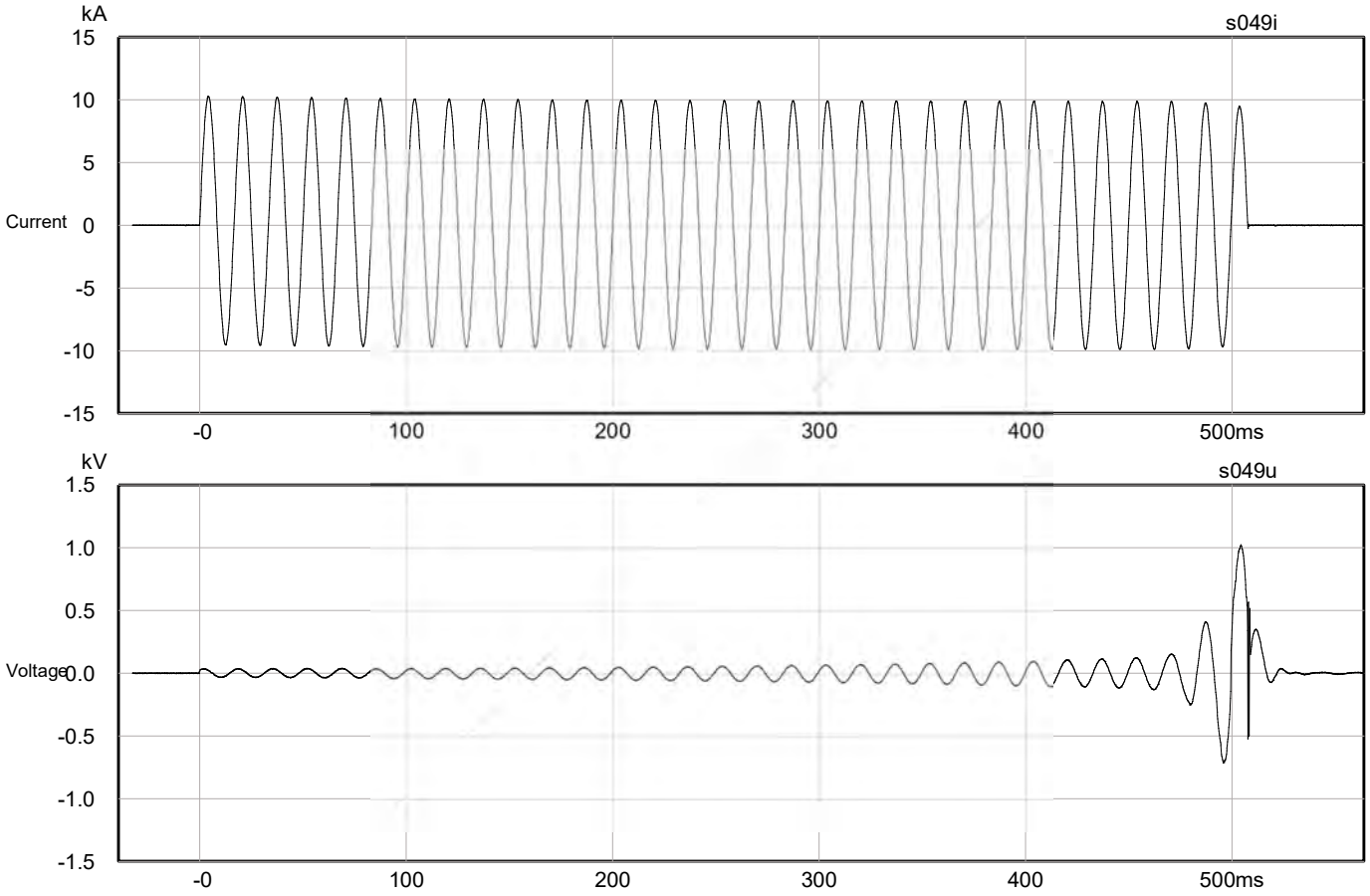


Figure 26: Waveforms for Test #19, Copperweld Scorpius 7 x 080 Sample 33.

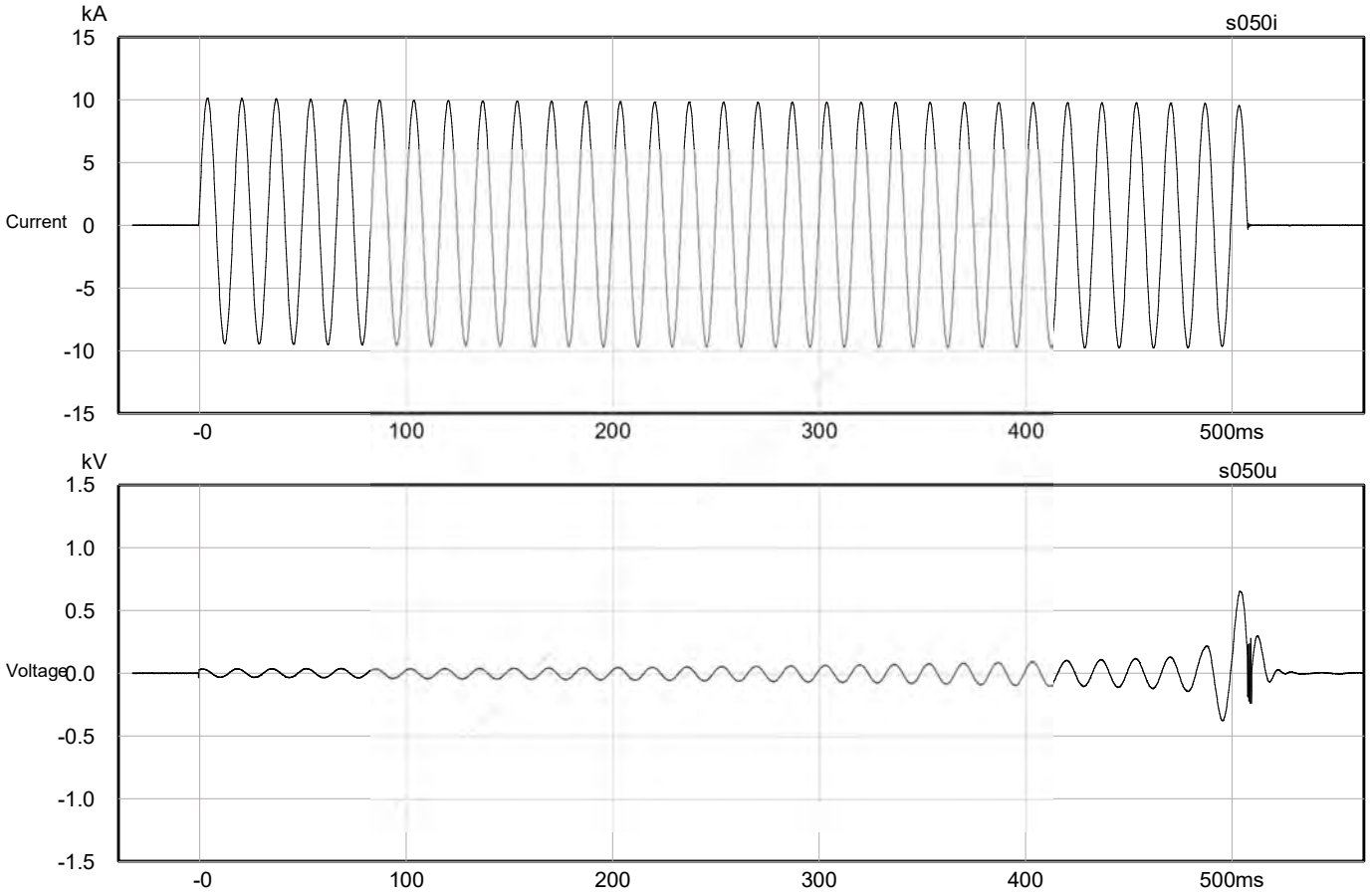


Figure 27: Waveforms for Test #20, Copperweld Scorpius 7 x 080 Sample 34.

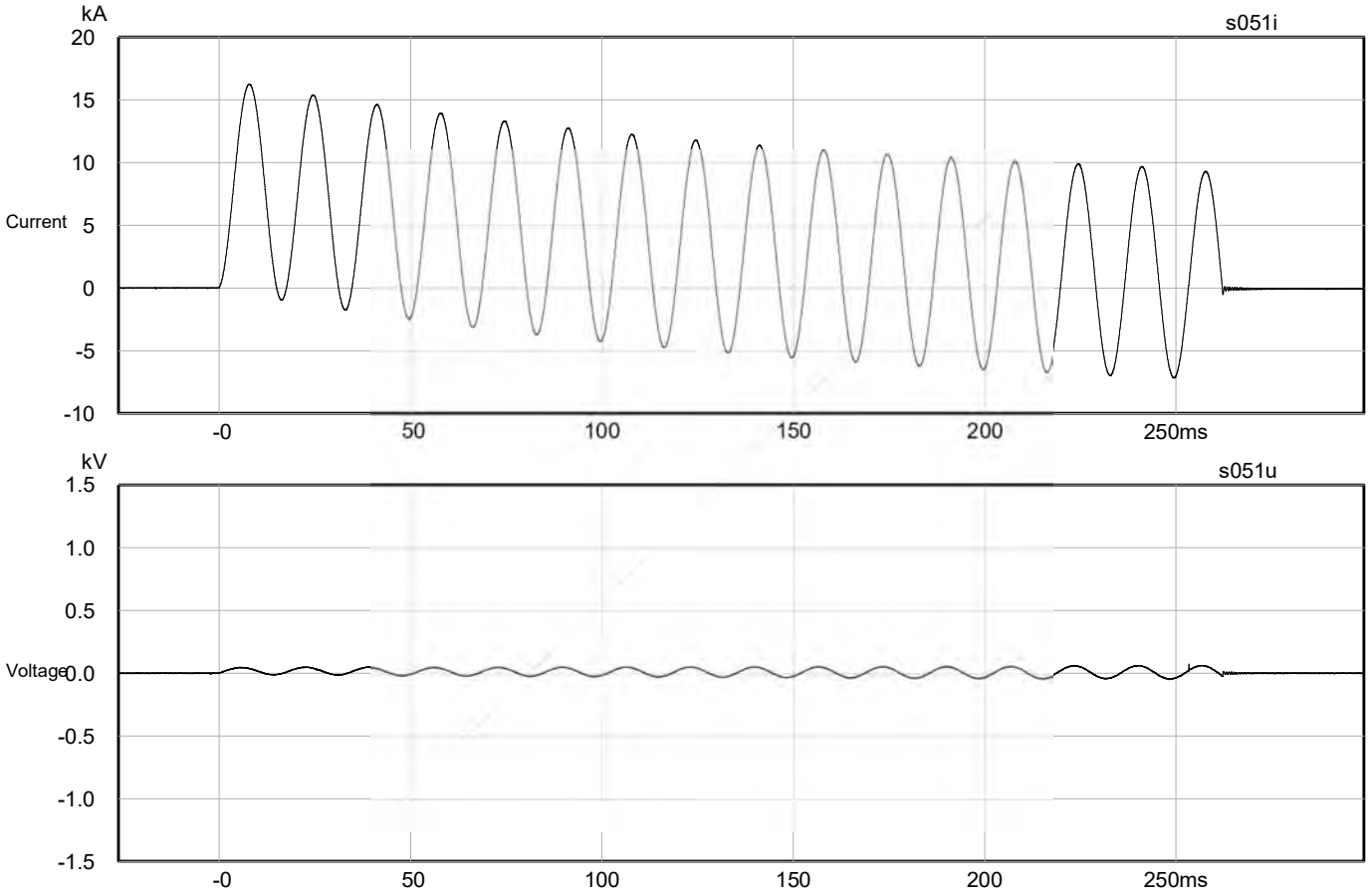


Figure 28: Waveforms for Test #21-1, Copperweld Scorpius 7 x 080 Sample 35.

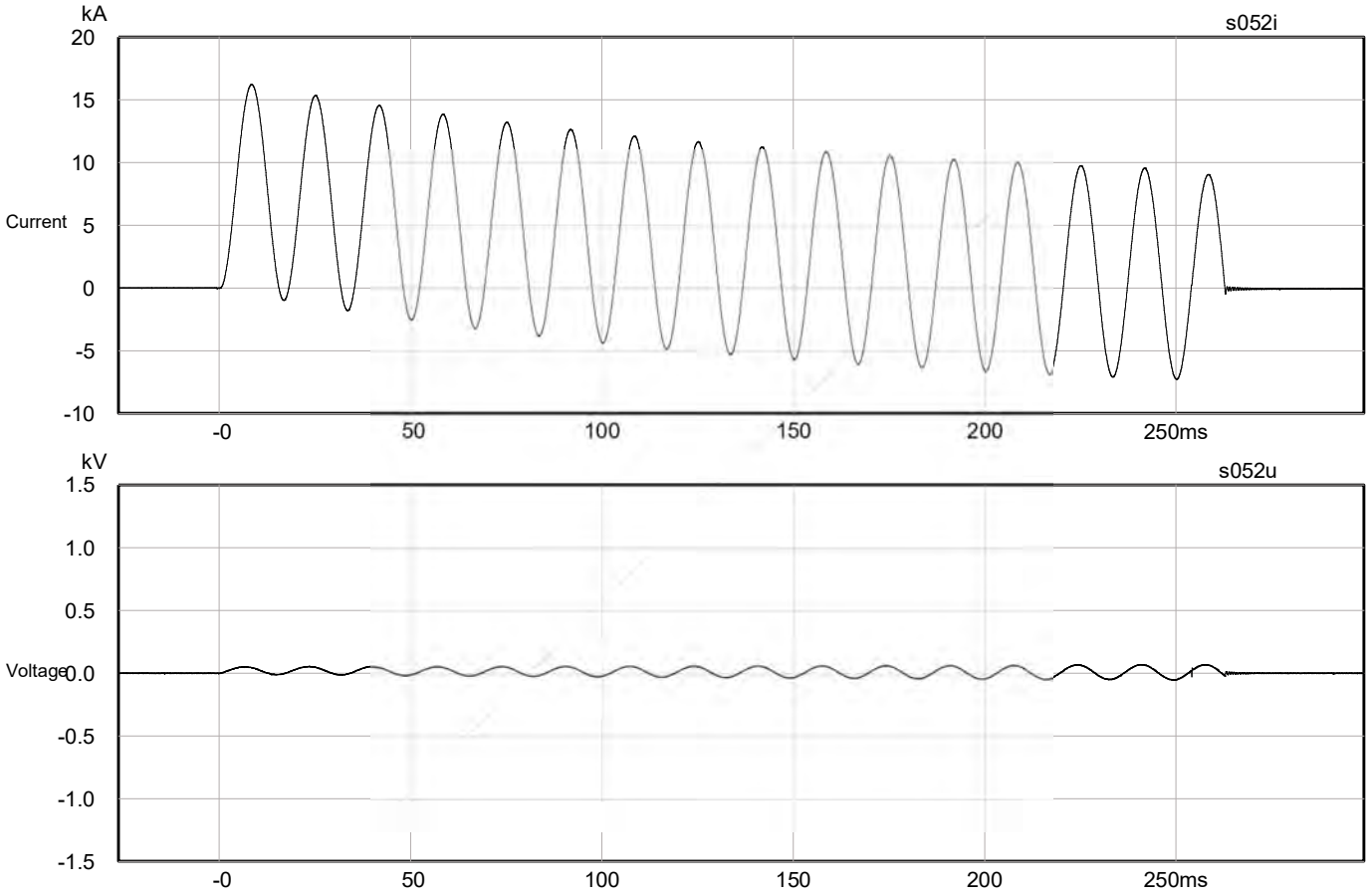


Figure 29: Waveforms for Test #21-2, Copperweld Scorpius 7 x 080 Sample 35.

APPENDIX C – PHOTOGRAPHS OF THE TEST OBJECTS



Figure 30: Test set up for the Encore 4/0 AWG Cu conductor. The power source bus is on the left and the ground bus is on the right.



Figure 31: Test set up for the Copperweld Scorpius 61 x 072 CCS conductor.



Figure 32: Test set up for the Encore #6 AWG Cu conductor.



Figure 33: Test set up for the Copperweld Scorpius 7 x 080 CCS conductor.

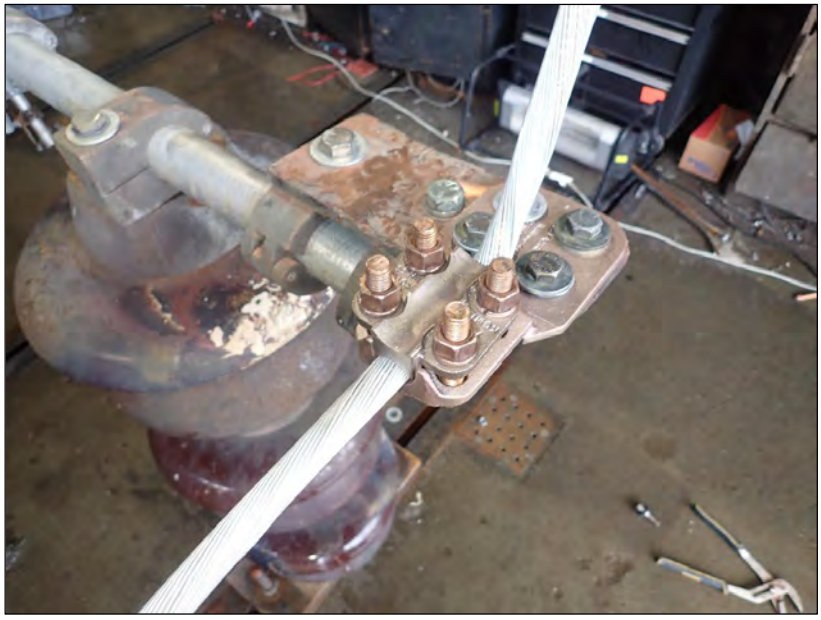


Figure 34: Typical Burndy terminal connector used to connect the Encore 4/0 AWG or Copperweld Scorpius 61 x 072 CCS conductors to the laboratory buses.



Figure 35: Typical Burndy terminal connector used to connect the Encore #6 AWG or Copperweld Scorpius 7 x 080 CCS conductors to the laboratory buses.

APPENDIX D – CALCUATIONS OF TEST CURRENT LEVELS FOR #6 AWG CU CONDUCTOR

Equation (45) in IEEE 80 and Equation (C.1) in IEEE 837 are the same, as follows:

$$I = A\sqrt{\left(\frac{TCAP\times10^{-4}}{t_c\times\alpha_r\times\rho_r}\right)\ln\left(\frac{K_0+T_m}{K_0+T_a}\right)}$$

where

I is root mean square (rms) current in kA
A is conductor cross section in mm^2
T_m is maximum allowable temperature in °C
T_a is initial conductor temperature in °C
T_r is reference temperature for material constants in °C
α_0 is thermal coefficient of resistivity at 0 °C
α_r is thermal coefficient of resistivity at reference temperature T_r
ρ_r is resistivity of the ground conductor at reference temperature T_r in μΩ-cm
K_0 is $1/\alpha_0$, or $(1/\alpha_r)-T_r$ in °C
t_c is time of current flow in seconds (s)
TCAP is thermal capacity factor in joules/cm^3°C

This equation is used to calculate the short-circuit ampacity of a conductor based on it's material constants.

For IEEE 80, Table 6, the symmetrical rms fusing current for #6 AWG soft-drawn Cu conductor at 500 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.5)(0.00393)(1.72)}\cdot\ln\left(\frac{(234+1083)}{(234+40)}\right)} = \boxed{5.29\ kA_{rms}}$$

For IEEE 837, Table 3, the symmetrical rms fusing current for #6 AWG hard-drawn Cu conductor at 250 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.25)(0.00381)(1.78)}\cdot\ln\left(\frac{(242+1084)}{(242+40)}\right)} = 7.41\ kA_{rms}$$

From IEEE 837 Equation (C.4), the asymmetrical rms fusing current is:

$$I_{asym} = \frac{(7.41\ kA)}{(1.148)} = 6.45\ kA_{rms}$$

For the EMF described in IEEE 837, Clause 7.2, a value of 90% of the fusing current is used for conductors up to 4/0 AWG:

$$I_{EMF} = (6.45)(0.9) = \boxed{5.81\ kA_{rms}}$$

Copperweld Bimetallics Data Sheet Packet
Electrical Test Laboratory

Customer:	Copperweld Building Wire	Engineer:	Bill Lewey	Date:	8/25/2020
Sample ID:	EL-13	Tested By:	Bill Lewey, Mike Rozar	Date:	8/25/2020
Product:	Grade 40 Copper Clad Steel Wire Solid Bare #4 and #6 vs Equivalent Solid Copper: Grounding Electrode Conductor Equivalency Test	Sample Condition:	New		
Standard:	ASTM B910/910M Annealed Copper Clad Steel Wire				
Insulation: N/A - Bare		Jacket: N/A - Bare			

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Test Report Summary

Page	Test Performed	Date Completed	Pass/Fail
1	Grounding Electrode Conductor Test for Copper Clad Steel Grade 40	8/25/2020	**Pass**

Requirement:
#4 AWG Grade 40 Copper Clad Steel and #6 AWG Copper Clad Steel when compared to #4 solid copper and #6 solid copper for use as a grounding electrode conductor shall have equal ability to carry amperage during a ground fault condition.

Conclusion:
The ability of bare #4 AWG Copper Clad Steel Grade 40 and bare #6 AWG Copper Clad Steel Grade 40 performed equally to #4 AWG bare solid copper and #6 AWG bare solid copper when used as a grounding electrode conductor under a ground fault condition. The current measured proved equivalency.

Test Equipment Used

Item	Equipment Type	Equipment #	Cal. Due Date
1	Fluke 374FC Clamp Meter	AM-1	Nov 2020
2	Acme Electric 15KVA Transformer	T2535173S	N/A
3	Square D 60A / 600V Safety Interrupter	N/A	N/A
4	Eaton Service Panel	N/A	N/A
5	Eaton Type CH 20 Amp Breaker	N/A	N/A
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

VBU – Verify Before Use

N/A – Not Applicable

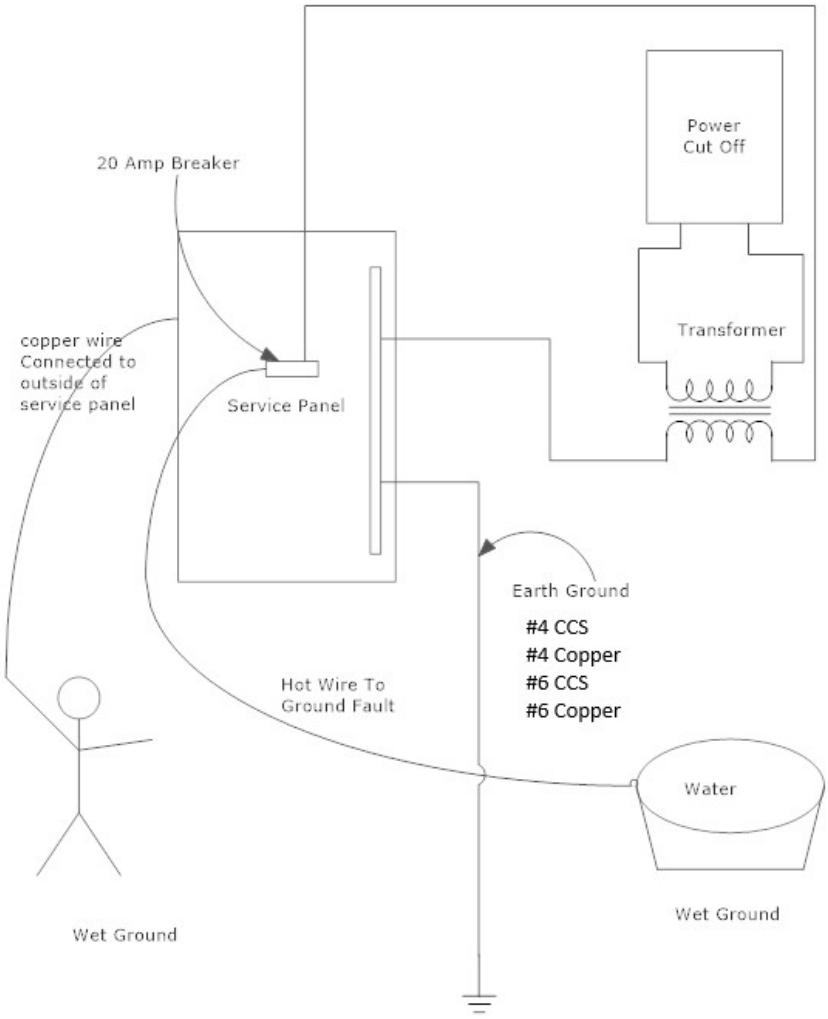
Sample Identification

Item	Description	Length/No. Rec'd
A	#4 AWG 40% Copper Clad Steel Bare	35 Ft
B	#4 AWG Solid Copper Bare	35 Ft
C	#6 AWG 40% Copper Clad Steel Bare	35 Ft
D	#6 AWG Solid Copper Bare	35 Ft
E		
F		

Grounding Electrode Conductor Test

Test Parameters:	
Conditioning:	No preconditioning.
Test Conductors:	1 each of #4 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #6 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #4 AWG Solid Bare copper grounding electrode conductor 1 each of #6 AWG Solid Bare copper grounding electrode conductor
Test Conductor Length:	Each conductor shall be 35 ft.
Test Circuit Configuration:	See schematic shown in Figure 1
Test Current:	Test current from 120 V / 20 A Residential Circuit
Method:	Testing was completed by creating a standard residential test circuit at 120V with 20A breaker wired to an intentional ground fault as shown in figure 1. The ground fault was created by connecting a hot wire from the breaker to a galvanized steel pan full of water and placing the pan on the wet ground. A conductor was also connected to the outside of the electrical panel and a Copper Plated Grounding Electrode (Copperweld Ground Rod) driven 6 inches into the wet ground to determine amount of current going through a grounded person touching the electrical panel during the ground fault condition. The ground fault and the grounded "man" were positioned 20 feet either side of the ground rod. The entire test area was soaked with water overnight using a sprinkler system When the ground fault was electrified, current measurements were taken from the ground fault conductor, the grounding electrode conductor and the grounded "man" conductor. For the four grounding electrode conductors tested, there was one test sequence for each. The current was measured for each. The objective: Compare the amperage measurements of the copper clad steel grounding electrode conductors to those of copper.

Figure 1



Results:			
Ground Conductor	**Fault Conductor Current**	**Current of the Grounding Electrode Conductor**	**Grounded Man Conductor Current**
#4 Copper	2.1 A	1.8 A	0.3 A
#4 40% CCS	2.1 A	1.8A	0.3 A
#6 Copper	1.7 A	1.6 A	0.1 A
#6 40% CCS	1.5 A	1.4 A	0.1 A

Requirement:
For equivalent sizes of Grade 40 Copper Clad steel vs. solid copper grounding conductors, the ability to carry amperage to ground during a ground fault condition is equal.

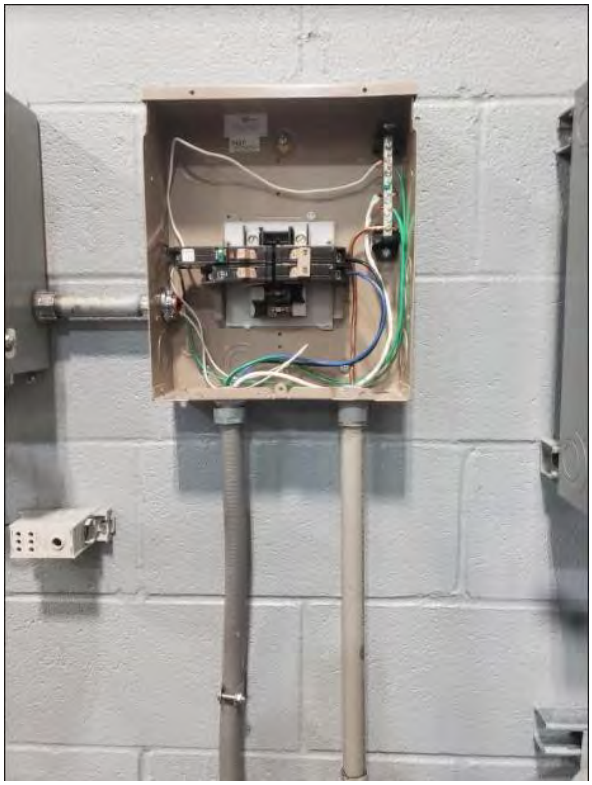
Comments:
____X__ (Pass) The product complies with all applicable requirements of this test. _____ (Fail) The product does not comply with the requirements of this test. **Test Date: 8/25/2020** **Tested By: Bill Lewey**

Environmental Conditions during Testing:

Humidity: % rh __74%_____ Ambient: °C___28_____

Test setup for the electrical service panel







Ground Rod with Grounding Conductor Attached



Ground Fault



Grounded “man”

Public Input No. 3823-NFPA 70-2020 [Section No. 250.102(C)(2)]

(2) Size for Parallel Conductor Installations in Two or More Raceways or Cables.

Where the ungrounded supply conductors are paralleled in two or more raceways or cables, ~~and~~ the supply-side bonding jumper shall be sized in accordance with (1) or (2) as follows:

(1) If an individual supply-side bonding jumper is used for bonding ~~these raceways or cables~~ to each individual raceway or cable , the size of the supply-side bonding jumper for each raceway or cable shall be selected from Table 250.102(C)(1) based on the size of the ungrounded supply conductors in each raceway or cable. ~~A single~~

(2) If a single or common supply-side bonding jumper is installed for bonding two or more raceways or cables, it shall be sized in accordance with 250.102(C)(1).

Informational Note No. 1: The term *supply conductors* includes ungrounded conductors that do not have overcurrent protection on their supply side and terminate at service equipment or the first disconnecting means of a separately derived system.

Informational Note No. 2: See Chapter 9, Table 8, for the circular mil area of conductors 18 AWG through 4/0 AWG.

Table 250.102(C)(1) Grounded Conductor, Main Bonding Jumper, System Bonding Jumper, and Supply-Side Bonding Jumper for Alternating-Current Systems

Size of Largest Ungrounded Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil)		Size of Grounded Conductor or Bonding Jumper* (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum
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	See Notes 1 and 2.	

Notes:

1. If the ungrounded supply conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum, the grounded conductor or bonding jumper shall have an area not less than 12½ percent of the area of the largest ungrounded supply conductor or equivalent area for parallel supply conductors. The grounded conductor or bonding jumper shall not be required to be larger than the largest ungrounded conductor or set of ungrounded conductors.

2. If the ungrounded supply conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum and if the ungrounded supply conductors and the bonding jumper are of different materials (copper, aluminum, or copper-clad aluminum), the minimum size of the grounded conductor or bonding jumper shall be based on the assumed use of ungrounded supply conductors of the same material as the grounded conductor or bonding jumper and will have an ampacity equivalent to that of the installed ungrounded supply conductors.

3. If multiple sets of service-entrance conductors are used as permitted in 230.40, Exception No. 2, or if multiple sets of ungrounded supply conductors are installed for a separately derived system, the equivalent size of the largest ungrounded supply conductor(s) shall be determined by the largest sum of the areas of the corresponding conductors of each set.

4. If there are no service-entrance conductors, the supply conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.

*For the purposes of applying this table and its notes, the term *bonding jumper* refers to main

bonding jumpers, system bonding jumpers, and supply-side bonding jumpers.

Statement of Problem and Substantiation for Public Input

This paragraph is somewhat confusing in that there are actually two different requirements or methods that are allowed to be used when sizing the supply-side bonding jumper. The last sentence in the paragraph sometimes gets missed and the bonding jumper may not get sized correctly if they daisy chain from raceway to raceway. By placing each of the methods that are allowed into two list items it may help in understanding how to size the supply-side bonding jumper in the two different scenarios that can be used. This would help in the usability of this section 250.102.

Submitter Information Verification

Submitter Full Name: Darryl Hill
Organization: Wichita Electrical JATC
Street Address:
City:
State:
Zip:
Submittal Date: Wed Sep 09 13:39:57 EDT 2020
Committee: NEC-P05

Public Input No. 129-NFPA 70-2019 [Section No. 250.102(E)(1)]

(1) Inside a Raceway or an Enclosure.

If installed inside a raceway, equipment bonding jumpers and bonding jumpers or conductors shall be permitted to be of the length required or necessary and shall comply with the requirements of 250.119 and 250.148.

Statement of Problem and Substantiation for Public Input

This PI is intended to clarify that the length limitation of 250.102(E)(2) does not apply if the conductors are installed inside a raceway.

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Wed Nov 20 18:48:11 EST 2019
Committee: NEC-P05

Public Input No. 4631-NFPA 70-2020 [Section No. 250.104(A)]

(A) Metal Water Piping.

The metal water piping system shall be bonded as required in 250.104(A)(1), (A)(2), or (A)(3).

(1) General.

Metal water piping system(s) installed in or attached to a building or structure shall be bonded to any of the following:

(1) Service equipment enclosure

(2) Grounded conductor at the service

(3) Grounding electrode conductor, if of sufficient size

(4) One or more grounding electrodes used, if the grounding electrode conductor or bonding jumper to the grounding electrode is of sufficient size

The bonding jumper(s) shall be installed in accordance with 250.64(A), 250.64(B), and 250.64(E). The points of attachment of the bonding jumper(s) shall be accessible. The bonding jumper(s) shall be sized in accordance with Table 250.~~102(C)(1) except that it shall not be required to be larger than 3/0 copper or 250 kcmil aluminum or copper-clad aluminum and except~~ 66 except as permitted in 250.104(A)(2) and 250.104(A)(3).

(2) Buildings of Multiple Occupancy.

In buildings of multiple occupancy where the metal water piping system(s) installed in or attached to a building or structure for the individual occupancies is metallically isolated from all other occupancies by use of nonmetallic water piping, the metal water piping system(s) for each occupancy shall be permitted to be bonded to the equipment grounding terminal of the switchgear, switchboard, or panelboard enclosure (other than service equipment) supplying that occupancy. The bonding jumper shall be sized in accordance with 250.~~102(D)~~ 66 .

(3) Buildings or Structures Supplied by a Feeder(s) or Branch Circuit(s).

The metal water piping system(s) installed in or attached to a building or structure shall be bonded to any of the following:

(1) Building or structure disconnecting means enclosure where located at the building or structure

(2) Equipment grounding conductor run with the supply conductors

(3) One or more grounding electrodes used

The bonding jumper(s) shall be sized in accordance with 250.~~102(D)~~ 66 . The bonding jumper shall not be required to be larger than the largest ungrounded feeder or branch-circuit conductor supplying the building or structure.

Statement of Problem and Substantiation for Public Input

Starting with the 2008 NEC cycle, CMP-5 has done an excellent job to separate requirements for grounding (connection to earth) and bonding (connection together and capable to carry ground fault current). Part of this was the creation of the new Table 250.120(C)(1) and designating this table for certain bonding conductors and the grounded (neutral) conductor where these will need to carry ground fault current. There is an asterix note that clarifies that Table 250.102(C) bonding conductor are for the main bonding jumper, system bonding jumper, and supply side bonding jumper. This greatly simplified the various sections with the 12 1/2 percent rule and other similar parts into one location.

In the past couple of cycles CMP-5 has also made changes to other "bonding conductors" that are not necessarily intended to primarily carry ground fault current. This is possibly a case of making something fit where it really does not. The change for the metal water pipe bonding from 250.104(A) is an example where what seemed to be a logical change (this is a bonding conductor) to reference Table 250.102(C)(1). But now there is a bonding jumper that is not one of those listed in the table note. The next cycle this change then resulted another change needed to establish a limit of the size to 3/0 copper or 250 kcmil aluminum. Therefore, the size is really right back to Table 260.66. In earlier cycles CMP-5 made a concerted decision to not reference Table 250.122 either directly or through a reference to 250.102(D). 250.102(D) is for “equipment bonding jumpers on the load side or an overcurrent device” and by definition this is to maintain continuity between equipment grounding conductors. This section does not apply for bonding of metal water systems to the electrical panel. The sizes in 250.122 are based on an overcurrent device which can in fact cause the water pipe bonding conductor to be larger that what a grounding electrode conductor to the same water pipe is required to be. Again, is this to bond to maintain equal potential or is it part of the effective ground fault current path? It is also noted that previously 250.136 and now 250.121(B) specifically prohibit the structural metal frame of a building from being used as an equipment grounding conductor to carry ground fault current.

There was no good technical reason that the original requirement referencing Table 250.66 was incorrect, just the fact that the table title and text seemed to limit this to just grounding electrode conductors. A related change fixes the issue with Table 250.66, similar to what was done for Table 250.102(C)(1) to include the grounding electrode conductor along with the grounding electrode bonding conductors that 250.53(C) reference to Table 250.66, and the water pipe and structural metal bonding conductors.

If the bonding conductor is part of the effective ground fault current path, then is should be sized to Table 250.102(C)(1) and related requirements. If the bonding conductor is there to connect two or more electrodes together or to bond the water pipe or structural metal primarily to maintain equal potential to the electrical system, then it should be sized to Table 250.66.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4481-NFPA 70-2020 [New Part after II.]	
Public Input No. 4598-NFPA 70-2020 [Section No. 250.66]	
Public Input No. 4653-NFPA 70-2020 [Section No. 250.104(C)]	

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Submittal Date: Thu Sep 10 16:02:56 EDT 2020
Committee: NEC-P05

Public Input No. 2380-NFPA 70-2020 [Section No. 250.104(A)(1)]

(1) General.

Metal water piping system(s) installed in or attached to a building or structure shall be bonded to any of the following:

(1) Service equipment enclosure

(2) Grounded conductor at the service

(3) Grounding electrode conductor, if of sufficient size

(4) One or more grounding electrodes used, if the grounding electrode conductor or bonding jumper to the grounding electrode is of sufficient size

The bonding jumper(s) shall be installed in accordance with 250.64(A), 250.64(B), ~~and~~ 250.64(E) and 250 .68. The points of attachment of the bonding jumper(s) shall be accessible. The bonding jumper(s) shall be sized in accordance with Table 250.102(C)(1) except that it shall not be required to be larger than 3/0 copper or 250 kcmil aluminum or copper-clad aluminum and except as permitted in 250.104(A)(2) and 250.104(A)(3).

Statement of Problem and Substantiation for Public Input

this section give no guidance as to the location and effectiveness of the bonding taking place. If a fault current not sufficient to trip an OCPD was to flow on the water pipe a person removing a filter or a value could bridge the gap an be harmed by the flow of current. Following the installation rules of the GEC/bonding jumper would minimize the risk.

Submitter Information Verification

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Submittal Date: Tue Aug 18 14:13:27 EDT 2020
Committee: NEC-P05

Public Input No. 4250-NFPA 70-2020 [Section No. 250.104(C)]

(C) Structural Metal.

Exposed structural metal that is interconnected to form a metal building frame, is not intentionally grounded or bonded, and is likely to become energized shall be bonded to any of the following:

(1) Service equipment enclosure

(2) Grounded conductor at the service

(3) Disconnecting means for buildings or structures supplied by a feeder or branch circuit

(4) Grounding electrode conductor, if of sufficient size

(5) One or more grounding electrodes used, if the grounding electrode conductor or bonding jumper to the grounding electrode is of sufficient size

The bonding conductor(s) or jumper(s) shall be sized in accordance with Table 250.102(C)(1), except that it shall not be required to be larger than 3/0 AWG copper or 250 kcmil aluminum or copper-clad aluminum, and installed in accordance with 250.64(A), 250.64(B), and 250.64(E). The points of attachment of the bonding jumper(s) shall be accessible unless installed in compliance with 250.68(A) Exception No. 2.

Statement of Problem and Substantiation for Public Input

In 250.104(C) there is an issue that need to be corrected when using the wording 3/0 copper. It should appear as 3/0 AWG copper

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Committee: NEC-P05

Public Input No. 4653-NFPA 70-2020 [Section No. 250.104(C)]

(C) Structural Metal.

Exposed structural metal that is interconnected to form a metal building frame, is not intentionally grounded or bonded, and is likely to become energized shall be bonded to any of the following:

(1) Service equipment enclosure

(2) Grounded conductor at the service

(3) Disconnecting means for buildings or structures supplied by a feeder or branch circuit

(4) Grounding electrode conductor, if of sufficient size

(5) One or more grounding electrodes used, if the grounding electrode conductor or bonding jumper to the grounding electrode is of sufficient size

The bonding conductor(s) or jumper(s) shall be sized in accordance with Table 250.~~102(C)(1)~~ , ~~except that it shall not be required to be larger than 3/0 copper or 250 kcmil aluminum or copper-clad aluminum,~~ 66 , and installed in accordance with 250.64(A), 250.64(B), and 250.64(E). The points of attachment of the bonding jumper(s) shall be accessible unless installed in compliance with 250.68(A) Exception No. 2.

Statement of Problem and Substantiation for Public Input

Starting with the 2008 NEC cycle, CMP-5 has done an excellent job to separate requirements for grounding (connection to earth) and bonding (connection together and capable to carry ground fault current). Part of this was the creation of the new Table 250.120(C)(1) and designating this table for certain bonding conductors and the grounded (neutral) conductor where these will need to carry ground fault current. There is an asterix note that clarifies that Table 250.102(C) bonding conductor are for the main bonding jumper, system bonding jumper, and supply side bonding jumper. This greatly simplified the various sections with the 12 1/2 percent rule and other similar parts into one location.

In the past couple of cycles CMP-5 has also made changes to other "bonding conductors" that are not necessarily intended to primarily carry ground fault current. This is possibly a case of making something fit where it really does not. The change for the metal water pipe bonding from 250.104(A) is an example where what seemed to be a logical change (this is a bonding conductor) to reference Table 250.102(C)(1). But now there is a bonding jumper that is not one of those listed in the table note. The next cycle this change then resulted another change needed to establish a limit of the size to 3/0 copper or 250 kcmil aluminum. Therefore, the size is really right back to Table 260.66. In earlier cycles CMP-5 made a concerted decision to not reference Table 250.122 either directly or through a reference to 250.102(D). 250.102(D) is for “equipment bonding jumpers on the load side or an overcurrent device” and by definition this is to maintain continuity between equipment grounding conductors. This section does not apply for bonding of metal water systems to the electrical panel. The sizes in 250.122 are based on an overcurrent device which can in fact cause the water pipe bonding conductor to be larger that what a grounding electrode conductor to the same water pipe is required to be. Again, is this to bond to maintain equal potential or is it part of the effective ground fault current path? It is also noted that previously 250.136 and now 250.121(B) specifically prohibit the structural metal frame of a building from being used as an equipment grounding conductor to carry ground fault current.

There was no good technical reason that the original requirement referencing Table 250.66 was incorrect, just the fact that the table title and text seemed to limit this to just grounding electrode conductors. A related change fixes the issue with Table 250.66, similar to what was done for Table 250.102(C)(1) to include the grounding electrode conductor along with the grounding electrode bonding conductors that 250.53(C) reference to Table 250.66, and the water pipe and structural metal

bonding conductors.

If the bonding conductor is part of the effective ground fault current path, then is should be sized to Table 250.102(C)(1) and related requirements. If the bonding conductor is there to connect two or more electrodes together or to bond the water pipe or structural metal primarily to maintain equal potential to the electrical system, then it should be sized to Table 250.66.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4598-NFPA 70-2020 [Section No. 250.66]	Revised 250.66
Public Input No. 4631-NFPA 70-2020 [Section No. 250.104(A)]	Water pipe bonding
Public Input No. 4655-NFPA 70-2020 [Section No. 250.104(D)]	Separately derived system bonding
Public Input No. 4481-NFPA 70-2020 [New Part after II.]	
Public Input No. 4576-NFPA 70-2020 [Section No. 250.68(A)]	
Public Input No. 4598-NFPA 70-2020 [Section No. 250.66]	

Submitter Information Verification

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Submittal Date: Thu Sep 10 16:19:19 EDT 2020
Committee: NEC-P05

Public Input No. 1180-NFPA 70-2020 [Section No. 250.104(D)]

(D) Separately Derived Systems.

Metal water piping systems and structural metal that is interconnected to form a building frame shall be bonded to separately derived systems in accordance with 250.104(D)(1) through 250.104(D)(3).

(1) Metal Water Piping System(s).

The grounded conductor of each separately derived system shall be bonded to the nearest available point of the metal water piping system(s) in the area served by each separately derived system. This connection shall be made at the same point on the separately derived system where the grounding electrode conductor is connected. Each bonding jumper shall be sized in accordance with Table 250.102(C)(1) based on the largest ungrounded conductor of the separately derived system except that it shall not be required to be larger than 3/0 copper or 250 kcmil aluminum or copper-clad aluminum.

Exception No. 1: A separate bonding jumper to the metal water piping system shall not be required if the metal water piping system is used as the grounding electrode ~~for the~~ as specified in 250.52(A)(1), or the grounding electrode connection as permitted in 250.68(C) for the separately derived system and the water piping system is in the area served.

Exception No. 2: A separate water piping bonding jumper shall not be required if the metal frame of a building or structure is used as the grounding electrode ~~for a separately~~ as specified in 250.52(A)(2), or the grounding electrode connection as permitted in 250.68(C) for the separately derived system and is bonded to the metal water piping in the area served by the separately derived system.

(2) Structural Metal.

If exposed structural metal that is interconnected to form the building frame exists in the area served by the separately derived system, it shall be bonded to the grounded conductor of each separately derived system. This connection shall be made at the same point on the separately derived system where the grounding electrode conductor is connected. Each bonding jumper shall be sized in accordance with Table 250.102(C)(1) based on the largest ungrounded conductor of the separately derived system except that it shall not be required to be larger than 3/0 copper or 250 kcmil aluminum or copper-clad aluminum.

Exception No. 1: A separate bonding jumper to the building structural metal shall not be required if the metal frame of a building or structure is used as the grounding electrode ~~for the~~ as specified in 250.52(A)(2),or the grounding electrode connection as permitted in 250.68(C) for the separately derived system.

Exception No. 2: A separate bonding jumper to the building structural metal shall not be required if the water piping of a building or structure is used as the grounding electrode ~~for a separately~~ as specified in 250.52(A)(1), or the grounding electrode connection as permitted in 250.68(C) for the separately derived system and is bonded to the building structural metal in the area served by the separately derived system.

(3) Common Grounding Electrode Conductor.

If a common grounding electrode conductor is installed for multiple separately derived systems as permitted by 250.30(A)(6), and exposed structural metal that is interconnected to form the building frame or interior metal piping exists in the area served by the separately derived system, the metal piping and the structural metal member shall be bonded to the common grounding electrode conductor in the area served by the separately derived system.

Exception: A separate bonding jumper from each derived system to metal water piping and to structural metal members shall not be required if the metal water piping and the structural metal members in the area served by the separately derived system are bonded to the common grounding electrode conductor.

Statement of Problem and Substantiation for Public Input

These revisions are needed to make the distinction between the underground portion of metal water pipes and in-ground metal building frames described in Sections 250.52(A)(1) and (2) that actually meet the definition of a “grounding electrode” per Article 100, and the aboveground portions of metal water piping and metal building frames that do NOT meet the definition of “grounding electrode” per Article 100, but are permitted to be used to “extend the connection to an electrode” as permitted in Section 250.68(C). The present wording literally only recognizes the use of underground water pipe electrodes and in-ground metal building frame electrodes as described in 250.52(A)(1) and (2). The use of above ground metal water pipes and metal building frames as specified in 250.68(C) should also be recognized. This revision will recognize the use of electrodes actually in the earth and connections extended to those electrodes by use of the above ground portions.

Submitter Information Verification

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Submittal Date: Thu May 21 08:40:30 EDT 2020
Committee: NEC-P05

Public Input No. 4249-NFPA 70-2020 [Section No. 250.104(D)]

(D) Separately Derived Systems.

Metal water piping systems and structural metal that is interconnected to form a building frame shall be bonded to separately derived systems in accordance with 250.104(D)(1) through 250.104(D)(3).

(1) Metal Water Piping System(s).

The grounded conductor of each separately derived system shall be bonded to the nearest available point of the metal water piping system(s) in the area served by each separately derived system. This connection shall be made at the same point on the separately derived system where the grounding electrode conductor is connected. Each bonding jumper shall be sized in accordance with Table 250.102(C)(1) based on the largest ungrounded conductor of the separately derived system except that it shall not be required to be larger than 3/0 AWG copper or 250 kcmil aluminum or copper-clad aluminum.

Exception No. 1: A separate bonding jumper to the metal water piping system shall not be required if the metal water piping system is used as the grounding electrode for the separately derived system and the water piping system is in the area served.

Exception No. 2: A separate water piping bonding jumper shall not be required if the metal frame of a building or structure is used as the grounding electrode for a separately derived system and is bonded to the metal water piping in the area served by the separately derived system.

(2) Structural Metal.

If exposed structural metal that is interconnected to form the building frame exists in the area served by the separately derived system, it shall be bonded to the grounded conductor of each separately derived system. This connection shall be made at the same point on the separately derived system where the grounding electrode conductor is connected. Each bonding jumper shall be sized in accordance with Table 250.102(C)(1) based on the largest ungrounded conductor of the separately derived system except that it shall not be required to be larger than 3/0 AWG copper or 250 kcmil aluminum or copper-clad aluminum.

Exception No. 1: A separate bonding jumper to the building structural metal shall not be required if the metal frame of a building or structure is used as the grounding electrode for the separately derived system.

Exception No. 2: A separate bonding jumper to the building structural metal shall not be required if the water piping of a building or structure is used as the grounding electrode for a separately derived system and is bonded to the building structural metal in the area served by the separately derived system.

(3) Common Grounding Electrode Conductor.

If a common grounding electrode conductor is installed for multiple separately derived systems as permitted by 250.30(A)(6), and exposed structural metal that is interconnected to form the building frame or interior metal piping exists in the area served by the separately derived system, the metal piping and the structural metal member shall be bonded to the common grounding electrode conductor in the area served by the separately derived system.

Exception: A separate bonding jumper from each derived system to metal water piping and to structural metal members shall not be required if the metal water piping and the structural metal members in the area served by the separately derived system are bonded to the common grounding electrode conductor.

Statement of Problem and Substantiation for Public Input

Throughout 250.104(D) there are some issues that need to be corrected when using the wording 3/0 copper.

It appears in the text as 3/0 copper. It should appear as 3/0 AWG copper. This change needs to made in 250.104(D)(1) and 250.104(D)(2).

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Committee: NEC-P05

Public Input No. 4655-NFPA 70-2020 [Section No. 250.104(D)]

(D) Separately Derived Systems.

Metal water piping systems and structural metal that is interconnected to form a building frame shall be bonded to separately derived systems in accordance with 250.104(D)(1) through 250.104(D)(3).

(1) Metal Water Piping System(s).

The grounded conductor of each separately derived system shall be bonded to the nearest available point of the metal water piping system(s) in the area served by each separately derived system. This connection shall be made at the same point on the separately derived system where the grounding electrode conductor is connected. Each bonding jumper shall be sized in accordance with Table 250.~~102(C)(1)~~ ~~based~~ 66 based on the largest ungrounded conductor of the separately derived system~~ except that it shall not be required to be larger than 3/0 copper or 250 kcmil aluminum or copper-clad aluminum~~ .

Exception No. 1: A separate bonding jumper to the metal water piping system shall not be required if the metal water piping system is used as the grounding electrode for the separately derived system and the water piping system is in the area served.

Exception No. 2: A separate water piping bonding jumper shall not be required if the metal frame of a building or structure is used as the grounding electrode for a separately derived system and is bonded to the metal water piping in the area served by the separately derived system.

(2) Structural Metal.

If exposed structural metal that is interconnected to form the building frame exists in the area served by the separately derived system, it shall be bonded to the grounded conductor of each separately derived system. This connection shall be made at the same point on the separately derived system where the grounding electrode conductor is connected. Each bonding jumper shall be sized in accordance with Table 250.~~102(C)(1)~~ 66 based on the largest ungrounded conductor of the separately derived system~~ except that it shall not be required to be larger than 3/0 copper or 250 kcmil aluminum or copper-clad aluminum~~ .

Exception No. 1: A separate bonding jumper to the building structural metal shall not be required if the metal frame of a building or structure is used as the grounding electrode for the separately derived system.

Exception No. 2: A separate bonding jumper to the building structural metal shall not be required if the water piping of a building or structure is used as the grounding electrode for a separately derived system and is bonded to the building structural metal in the area served by the separately derived system.

(3) Common Grounding Electrode Conductor.

If a common grounding electrode conductor is installed for multiple separately derived systems as permitted by 250.30(A)(6), and exposed structural metal that is interconnected to form the building frame or interior metal piping exists in the area served by the separately derived system, the metal piping and the structural metal member shall be bonded to the common grounding electrode conductor in the area served by the separately derived system.

Exception: A separate bonding jumper from each derived system to metal water piping and to structural metal members shall not be required if the metal water piping and the structural metal members in the area served by the separately derived system are bonded to the common grounding electrode conductor.

Statement of Problem and Substantiation for Public Input

Starting with the 2008 NEC cycle, CMP-5 has done an excellent job to separate requirements for grounding (connection to earth) and bonding (connection together and capable to carry ground fault current). Part of this was the creation of the new Table 250.120(C)(1) and designating this table for certain bonding conductors and the grounded (neutral) conductor where these will need to carry ground fault current. There is an asterix note that clarifies that Table 250.102(C) bonding conductor are for the main bonding jumper, system bonding jumper, and supply side bonding jumper. This greatly simplified the various sections with the 12 1/2 percent rule and other similar parts into one location.

In the past couple of cycles CMP-5 has also made changes to other "bonding conductors" that are not necessarily intended to primarily carry ground fault current. This is possibly a case of making something fit where it really does not. The change for the metal water pipe bonding from 250.104(A) is an example where what seemed to be a logical change (this is a bonding conductor) to reference Table 250.102(C)(1). But now there is a bonding jumper that is not one of those listed in the table note. The next cycle this change then resulted another change needed to establish a limit of the size to 3/0 copper or 250 kcmil aluminum. Therefore, the size is really right back to Table 260.66. Similar changes happened in 250.104(D) for separately derived systems. Why reference 250.66 for the grounding electrode conductor and then reference Table 250.102(C)(1) for the water pipe or structure metal bonding conductor when that same conductor may be serving both purposes. Again, is this to bond to maintain equal potential or is it part of the effective ground fault current path? It is also noted that previously 250.136 and now 250.121(B) specifically prohibit the structural metal frame of a building from being used as an equipment grounding conductor to carry ground fault current.

There was no good technical reason that the original requirement referencing Table 250.66 was incorrect, just the fact that the table title and text seemed to limit this to just grounding electrode conductors. A related change fixes the issue with Table 250.66, similar to what was done for Table 250.102(C)(1) to include the grounding electrode conductor along with the grounding electrode bonding conductors that 250.53(C) reference to Table 250.66, and the water pipe and structural metal bonding conductors.

If the bonding conductor is part of the effective ground fault current path, then is should be sized to Table 250.102(C)(1) and related requirements. If the bonding conductor is there to connect two or more electrodes together or to bond the water pipe or structural metal primarily to maintain equal potential to the electrical system, then it should be sized to Table 250.66.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4576-NFPA 70-2020 [Section No. 250.68(A)]	
Public Input No. 4598-NFPA 70-2020 [Section No. 250.66]	
Public Input No. 4653-NFPA 70-2020 [Section No. 250.104(C)]	

Submitter Information Verification

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Submittal Date: Thu Sep 10 16:21:10 EDT 2020
Committee: NEC-P05

Public Input No. 1259-NFPA 70-2020 [Section No. 250.104(D)(3)]

(3) Common Grounding Electrode Conductor.

If a common grounding electrode conductor is installed for multiple separately derived systems as permitted by 250.30(A)(6), and exposed structural metal that is interconnected to form the building frame or interior metal water piping exists in the area served by the separately derived system, the metal water piping and the structural metal member shall be bonded to the common grounding electrode conductor in the area served by the separately derived system.

Exception: A separate bonding jumper from each derived system to metal water piping and to structural metal members shall not be required if the metal water piping and the structural metal members in the area served by the separately derived system are bonded to the common grounding electrode conductor.

Additional Proposed Changes

File Name	Description	Approved
DSCN1416.JPG	metal piping systems	
DSCN2856.JPG	metal piping systems 2	

Statement of Problem and Substantiation for Public Input

Interior metal WATER piping should be specified here rather than simply metal piping. Only metal water piping is required to be bonded in Sections 250.104(A)(1), 250.104(A)(2), 250.104(A)(3), and 250.104(D)(1) regardless if it is "likely to become energized". Other metal piping is only required to be bonded if it is "likely to become energized" as specified in Section 250.104(B). Yet for some reason, the present wording in 250.104(D)(3) requires ALL metal piping including water piping, gas piping, compressed air piping, piping for oxygen, nitrogen, nitrous oxide, vacuum lines, medical air, exhaust lines, drain pipes, sewer pipes, oil pipes and so on, and so forth regardless of whether these piping systems are "likely to become energized". Please see photos I have provided showing metal piping systems presently required to be bonded by this Section even if the piping is not likely to become energized. I believe this may be a simple error that has been overlooked. I really can't imagine any good reason to require bonding of drain pipes or sewer pipes or any other pipes that are not likely to become energized. This revision will clarify this rule and align the bonding of water pipes with the parent text in Section 250.104(D) which mentions water piping systems as the only metal piping system requiring bonding, as well as other rules requiring bonding of metal water piping systems.

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Committee: NEC-P05


OXYGEN
NITROGEN
OXYGEN
NITROUS OXIDE

VACUUM
NATURAL GAS
ACID WASTE

Public Input No. 2381-NFPA 70-2020 [Section No. 250.106]

250.106 Lightning Protection Systems.

The lightning protection system ground terminals shall be permitted to 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 780-2017, *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 780-2017, *Standard for the Installation of Lightning Protection Systems*.

Statement of Problem and Substantiation for Public Input

There is a lot of controversy in the practice of mandating the lightning system attachment to the building grounding electrode system. This is based on creating a pathway into the premises wiring system and in addition, the effect it can have on concrete containing water in a concrete encased electrode application. If no building grounding electrode exist the lightning system is sufficiently grounded so why mandated this, let the end user or engineer make the call.

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Committee: NEC-P05

Public Input No. 1409-NFPA 70-2020 [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. Metal covers and metal fittings attached to these metal enclosures shall be considered as being connected to ~~bonding jumpers or equipment grounding conductors, or both~~ the effective ground-fault current path .

Statement of Problem and Substantiation for Public Input

My edits are not technical, just an attempt to make the language a little easer to understand and apply.

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Submittal Date: Tue Jun 02 12:20:59 EDT 2020
Committee: NEC-P05

Public Input No. 2030-NFPA 70-2020 [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. Metal covers, mud rings, extension rings and metal fittings attached to these metal enclosures shall be considered as being connected to bonding jumpers or equipment grounding conductors, or both.

Statement of Problem and Substantiation for Public Input

This PI would add the terms "mud rings" and "extension rings" to clarify that these items are permitted to serve as the required connection to the circuit equipment grounding conductor. The existing language using the only the term "cover" does not include "mud rings" or "extension rings". As with boxes, mud rings and extension rings have been used for decades as part of the equipment grounding path.

Submitter Information Verification

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Submittal Date: Sun Jul 26 12:04:36 EDT 2020
Committee: NEC-P05

Public Input No. 3904-NFPA 70-2020 [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. Metal covers and metal fittings attached to these metal enclosures shall be considered as being connected to 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 Input

This 2020 new rule directly conflicts with 250.97 that requires enhanced measures to assure an appropriate fault current return path by enabling an enclosure interposition in the return path by right. Other rules require wired equipment grounding return paths including parts of articles 517 and 680 for just two. Admittedly these are in chapters capable of amending Chapter two, but the principle must be clearly established that if a rule calls for a wired bonding path, then that rule trumps this one.

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Submittal Date: Wed Sep 09 15:14:44 EDT 2020
Committee: NEC-P05

Public Input No. 3810-NFPA 70-2020 [Section No. 250.110]

250.110 Equipment Fastened in Place (Fixed) or Connected by Permanent Wiring Methods.

Exposed, normally non–current-carrying metal parts of fixed equipment supplied by or enclosing conductors or components that are likely to become energized shall be connected to an equipment grounding conductor under any of the following conditions:

(1) Where within 2.5 m (8 ft) vertically or 1.5 m (5 ft) horizontally of ground or grounded metal objects and subject to contact by persons

(2) Where located in a wet or damp location and not isolated

(3) Where in electrical contact with metal

(4) Where in a hazardous (classified) location ~~as covered by Articles 500 through 517~~

(5) Where supplied by a wiring method that provides an equipment grounding conductor, except as permitted by 250.86, Exception No. 2, for short sections of metal enclosures

(6) Where equipment operates with any terminal at over 150 volts to ground

Exception No. 1: If exempted by special permission, the metal frame of electrically heated appliances that have the frame permanently and effectively insulated from ground shall not be required to be grounded.

Exception No. 2: Distribution apparatus, such as transformer and capacitor cases, mounted on wooden poles at a height exceeding 2.5 m (8 ft) above ground or grade level shall not be required to be grounded.

Exception No. 3: Listed equipment protected by a system of double insulation, or its equivalent, shall not be required to be connected to the equipment grounding conductor. Where such a system is employed, the equipment shall be distinctively marked.

Statement of Problem and Substantiation for Public Input

Section 4.1.4 of the 2020 NEC(r) Style Manual prohibits references to entire articles with the exception of Article 100. It is proposed to delete the references to Article 500-517 as it is unnecessary reference as it is clear in 90.3 that the special occupancy chapters would apply accordingly. It is recommended that this PI also be submitted to CMP14 for information and/or comment.

Submitter Information Verification

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Submittal Date: Wed Sep 09 13:21:11 EDT 2020
Committee: NEC-P05

Public Input No. 1209-NFPA 70-2020 [New Section after 250.112(J)]

Icemaker Standalone Appliance

Icemaker Standalone Appliance

Statement of Problem and Substantiation for Public Input

Icemakers standalone type appliances – add a requirement that standalone appliance type icemakers are to be connected to an equipment grounding conductor. A consequence of the icemaker design and function is the frequent introduction of water on floors and on the equipment. Standalone appliance type icemakers are typically subjected to elevated physical damage (from vandalism, impacts, etc.) Users of icemakers often come into contact with moisture/water for example; stepping into puddles of water from spilled ice or condensate on the floor as a result of the refrigeration cycle. Requiring standalone appliance type icemakers to be connected to an equipment grounding conductor will help ensure a reliable/safe path for fault current.

Submitter Information Verification

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Submittal Date: Sat May 23 07:59:47 EDT 2020
Committee: NEC-P05

Public Input No. 1210-NFPA 70-2020 [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(2) through (4) shall not be required to be connected to an equipment grounding conductor where protected by a system of double insulation or its equivalent. Double insulated equipment shall be distinctively marked.

(1) In hazardous (classified) locations (see Articles 500 through 517)

(2) Where operated at over 150 volts to ground

Exception No. 1 to (2): Motors, where 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

(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

(15) 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

(16) Tools likely to be used in wet or conductive locations

Exception: Tools and portable handlamps and portable luminaires likely to be used in wet or conductive locations shall not be required to be connected to an equipment grounding conductor where supplied through an isolating transformer with an ungrounded secondary of not over 50 volts.

Statement of Problem and Substantiation for Public Input

Icemakers – add a requirement that icemakers are to be connected to an equipment grounding conductor. A consequence of the icemaker design and function is the frequent introduction of water on floors and on the equipment. Users of icemakers often come into contact with moisture/water for example; stepping into puddles of water from spilled ice or condensate on the floor as a result of the refrigeration cycle. Requiring icemakers to be connected to an equipment grounding conductor will help ensure a reliable/safe path for fault current.

Existing language of article 250.114 (3) and (4) covers specific equipment that by function or design share hazardous that are not dissimilar from those of icemakers through design/function/outcome.

Submitter Information Verification

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Submittal Date: Sat May 23 08:04:34 EDT 2020
Committee: NEC-P05

Public Input No. 3268-NFPA 70-2020 [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(2) through (4) shall not be required to be connected to an equipment grounding conductor where protected by a system of double insulation or its equivalent. Double insulated equipment shall be distinctively marked.

(1) In hazardous (classified) locations (see Articles 500 through 517)

(2) Where operated at over 150 volts to ground

Exception No. 1 to (2): Motors, where 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, 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

(9) Exception: The equipment listed in 250.114(3) shall not be required to be connected to an equipment grounding conductor where supplied by a recepacle installed per 406.5(D)(2)(b) or (c).

(10) In other than residential occupancies:

(11) Refrigerators, freezers, and air conditioners

(12) Clothes-washing, clothes-drying, and dish-washing machines; information technology equipment; sump pumps; and electrical aquarium equipment

(13) Hand-held motor-operated tools, stationary and fixed motor-operated tools, and light industrial motor-operated tools

(14) Motor-operated appliances of the following types: hedge clippers, lawn mowers, snow blowers, and wet scrubbers

(15) Portable handlamps and portable luminaires

(16) 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

(17) Tools likely to be used in wet or conductive locations

Exception : Tools and portable handlamps and portable luminaires likely to be used in wet or conductive locations shall not be required to be connected to an equipment grounding conductor where supplied through an isolating transformer with an ungrounded secondary of not over 50 volts.

Statement of Problem and Substantiation for Public Input

This rule discourages the increased safety that is provided where an existing 2 wire receptacle is replaced using the provisions of 406.5(D)(2)(b0 or (c) as under the existing rules you still must have an EGC for the equipment listed in 250.114(3). If you are not permitted to used that equipment on the GFCI protected replacement receptacle, there is no real reason to replace the 2 wire receptacle. Even without the installation of an EGC, the use of GFCI protection increases the safety of the installation as compared to the continued use of the two wire receptacle.
Note the change is to add an exception and not a new list item (f). Teraview would not let me add an exception and underlined all of the list items.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3269-NFPA 70-2020 [Section No. 406.4(D)(2)]	deletes IN reference to this section
Public Input No. 3269-NFPA 70-2020 [Section No. 406.4(D)(2)]	

Submitter Information Verification

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Submittal Date: Mon Sep 07 13:18:21 EDT 2020
Committee: NEC-P05

Public Input No. 3814-NFPA 70-2020 [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(2) through (4) shall not be required to be connected to an equipment grounding conductor where protected by a system of double insulation or its equivalent. Double insulated equipment shall be distinctively marked.

(1) In hazardous (classified) locations ~~(see Articles 500 through 517)~~

(2) Where operated at over 150 volts to ground

Exception No. 1 to (2): Motors, where 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, 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

(9) In other than residential occupancies:

(10) Refrigerators, freezers, 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

(15) 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

(16) Tools likely to be used in wet or conductive locations

Exception: Tools and portable handlamps and portable luminaires likely to be used in wet or conductive locations shall not be required to be connected to an equipment grounding conductor where supplied through an isolating transformer with an ungrounded secondary of not over 50 volts.

Statement of Problem and Substantiation for Public Input

Section 4.1.4 of the 2020 NEC(r) Style Manual prohibits references to entire articles with the exception of Article 100. It is proposed to delete the reference to Articles 500-517 as Section 90.3 makes it clear that the special occupancy articles modify this section and would apply. It is recommended that this PI also be submitted to CMP14 for information and/or comment.

Submitter Information Verification

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Submittal Date: Wed Sep 09 13:24:27 EDT 2020
Committee: NEC-P05

Public Input No. 2132-NFPA 70-2020 [Section No. 250.118]

250.118 Types of Equipment Grounding Conductors.

The 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 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 used to connect equipment where flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation, a wire-type equipment grounding conductor shall be installed.

(11) The conduit is not installed in a hazardous (classified) location.

(12) Listed liquidtight flexible metal conduit meeting all the following conditions:

(13) The conduit is terminated in listed fittings.

(14) For metric designators 12 through 16 (trade sizes 3/8 through 1/2), the circuit conductors contained in the conduit are protected by overcurrent devices rated at 20 amperes or less.

(15) For metric designators 21 through 35 (trade sizes 3/4 through 1 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 3/8 through 1/2) in the effective ground-fault current path.

(16) 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).

(17) If used to connect equipment where flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation, a wire-type equipment grounding conductor shall be installed.

(18) The conduit is not installed in a hazardous (classified) location.

(19) Flexible metallic tubing where the tubing is terminated in listed fittings and meeting the following conditions:

(20) The circuit conductors contained in the tubing are protected by overcurrent devices rated at 20 amperes or less.

(21) 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).

(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: For a definition of *effective ground-fault current path*, see Article 100.

Statement of Problem and Substantiation for Public Input

This is a companion proposal to several being submitted to require the use of a wire type equipment grounding conductor or bonding jumper for FMC and LFMC installed in hazardous (classified) locations.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1252-NFPA 70-2020 [Section No. 250.100]	
Public Input No. 2129-NFPA 70-2020 [Section No. 348.60]	
Public Input No. 2130-NFPA 70-2020 [Section No. 350.60]	
Public Input No. 2124-NFPA 70-2020 [Section No. 501.30]	
Public Input No. 2125-NFPA 70-2020 [Section No. 502.30]	
Public Input No. 2126-NFPA 70-2020 [Section No. 503.30]	
Public Input No. 2127-NFPA 70-2020 [Section No. 505.25]	
Public Input No. 2131-NFPA 70-2020 [Section No. 506.25]	

Submitter Information Verification

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Submittal Date: Sun Aug 02 12:46:26 EDT 2020
Committee: NEC-P05

Public Input No. 2388-NFPA 70-2020 [Section No. 250.118]

250.118 Types of Equipment Grounding Conductors.

~~The~~ Each equipment grounding ~~conductor run with or enclosing the circuit conductors shall~~ method shall provide an effective ground fault path and 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 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 used to connect equipment where flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation, a wire-type equipment grounding conductor 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 3/8 through 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 3/4 through 1 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 3/8 through 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 used to connect equipment where flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation, a wire-type equipment grounding conductor shall be installed.

(17) Flexible metallic tubing where 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: For a definition of *effective ground-fault current path*, see Article 100.

Statement of Problem and Substantiation for Public Input

Not all EGC are enclosing the circuit conductors like a cable tray.the way it is written a conductor of wire type would only apply when it encloses the circuit conductors, the word method can easily describe all method including the raceway and cable tray type.

Submitter Information Verification

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Submittal Date: Tue Aug 18 15:20:40 EDT 2020
Committee: NEC-P05

Public Input No. 2940-NFPA 70-2020 [Section No. 250.118]

250.118 Types of Equipment Grounding Conductors.

The 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 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 used to connect equipment where flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation, a wire-type equipment grounding conductor 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 3/8 through 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 3/4 through 1 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 3/8 through 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 used to connect equipment where flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation, a wire-type equipment grounding conductor shall be installed.

(17) For liquidtight flexible metal conduit containing a stainless steel core, a wire-type equipment grounding conductor shall be installed with the circuit conductors.

(18) Flexible metallic tubing where 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) Armor of Type AC cable as provided in 320.108.

(22) The copper sheath of mineral-insulated, metal-sheathed cable Type MI.

(23) Type MC cable that provides an effective ground-fault current path in accordance with one or more of the following:

(24) It contains an insulated or uninsulated equipment grounding conductor in compliance with 250.118 (1).

(25) 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

(26) 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

(27) Cable trays as permitted in 392.10 and 392.60.

(28) Cablebus framework as permitted in 370.60(1).

(29) Other listed electrically continuous metal raceways and listed auxiliary gutters.

(30) Surface metal raceways listed for grounding.

Informational Note: For a definition of *effective ground-fault current path*, see Article 100.

Statement of Problem and Substantiation for Public Input

Only (f) was added to 250.118(6).
Stainless steel core can result in a poor ground-fault current path because stainless steel has a higher resistivity than other metals used in flexible conduit. To overcome this, and allow the use of liquid tight flexible stainless steel and its excellent corrosion resistance properties in wire protection devices, a separate grounding conductor should be required to be installed in all installations.

Submitter Information Verification

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Submittal Date: Thu Sep 03 13:18:48 EDT 2020
Committee: NEC-P05

Public Input No. 4303-NFPA 70-2020 [Section No. 250.118]

250.118 Types of Equipment Grounding Conductors.

(A) Types Permitted. _ The 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 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 used to connect equipment where flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation, a wire-type equipment grounding conductor 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 3/8 through 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 3/4 through 1 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 3/8 through 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 used to connect equipment where flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation, a wire-type equipment grounding conductor shall be installed.

(17) Flexible metallic tubing where 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: For a definition of *effective ground-fault current path*, see Article 100.

(B) Not Permitted for Use as Equipment Grounding Conductors. The following items shall not be used as an equipment grounding conductor:

(1) Grounding electrode conductor(s).

Exception: A wire-type equipment grounding conductor installed in compliance with 250.6(A) and the applicable requirements for both the equipment grounding conductor and the grounding electrode conductor in Parts II, III, and VI of this article shall be permitted to serve as both an equipment grounding conductor and a grounding electrode conductor.

(2) Structural metal frame of a building or structure.

Statement of Problem and Substantiation for Public Input

Section 250.121 of the 2020 NEC is titled "Restricted Use of Equipment Grounding Conductors" but only partially addresses use of the equipment grounding conductor. (A) seems to address the fact that the equipment grounding conductor and the grounding electrode conductor are not interchangeable unless the conditions of the exception are met. (B) addresses an item that cannot be used as the EGC, not a restricted use for the EGC.

This PI recommends relocating this language to Section 250.118 which contains the items permitted to be used as equipment grounding conductors. The proposed change mirrors previous action by the committee taken in Section 250.52 regarding what can and what cannot be used as a grounding electrode conductor. By creating two first level subdivisions this material is located in the same place while keeping the requirements in tact. This will increase the readability and usability of the Code. A subsequent PI will be submitted to recommend deletion of Section 250.121 if this PI is accepted by the committee.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4330-NFPA 70-2020 [Section No. 250.121]	This PI is directly tied to PI #4330.
Public Input No. 4330-NFPA 70-2020 [Section No. 250.121]	

Submitter Information Verification

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Submittal Date: Thu Sep 10 09:50:50 EDT 2020
Committee: NEC-P05

Public Input No. 1002-NFPA 70-2020 [Section No. 250.119]

250.119 Identification of Equipment Grounding Conductors and Supply-Side Bonding Jumpers .

Unless required elsewhere in this *Code,* equipment grounding conductors, and supply-side bonding jumpers shall be permitted to be bare, covered, or insulated. Individually covered or insulated equipment grounding ~~conductors~~ conductors and supply-side bonding jumpers, 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. 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 be permitted to be used for system bonding jumpers, main bonding jumpers, and grounding electrode 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 where 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: 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: 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.

(A) Conductors 4 AWG and Larger.

Equipment grounding conductors, and supply-side bonding jumpers 4 AWG and larger shall comply with 250.119(A)(1) and (A)(2).

(1) An insulated or covered conductor 4 AWG and larger shall be permitted, at the time of installation, to be permanently identified as an equipment grounding conductor, or supply-side bonding jumper at each end and at every point where the conductor is accessible.

Exception: Conductors 4 AWG and larger shall not be required to be marked in conduit bodies that contain no splices or unused hubs.

(2) Identification shall encircle the conductor and shall be accomplished by one of the following:

(3) Stripping the insulation or covering from the entire exposed length

(4) Coloring the insulation or covering green at the termination

(5) Marking the insulation or covering with green tape or green adhesive labels at the termination

(B) Multiconductor Cable.

One or more insulated conductors in a multiconductor cable, at the time of installation, shall be permitted to be permanently identified as equipment grounding conductors, or supply-side bonding jumpers at each end and at every point where the conductors are accessible by one of the following means:

(1) Stripping the insulation from the entire exposed length.

(2) Coloring the exposed insulation green.

(3) Marking the exposed insulation with green tape or green adhesive labels. Identification shall encircle the conductor.

(C) Flexible Cord.

Equipment grounding conductors and supply-side bonding jumpers in flexible cords shall be insulated and shall have a continuous outer finish that is either green or green with one or more yellow stripes.

Additional Proposed Changes

File Name	Description	Approved
E2B2C2B2-48E4-46D9-97C0-E4CD6D352496.jpeg	LFMC as an equipment grounding conductor.	

Statement of Problem and Substantiation for Public Input

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

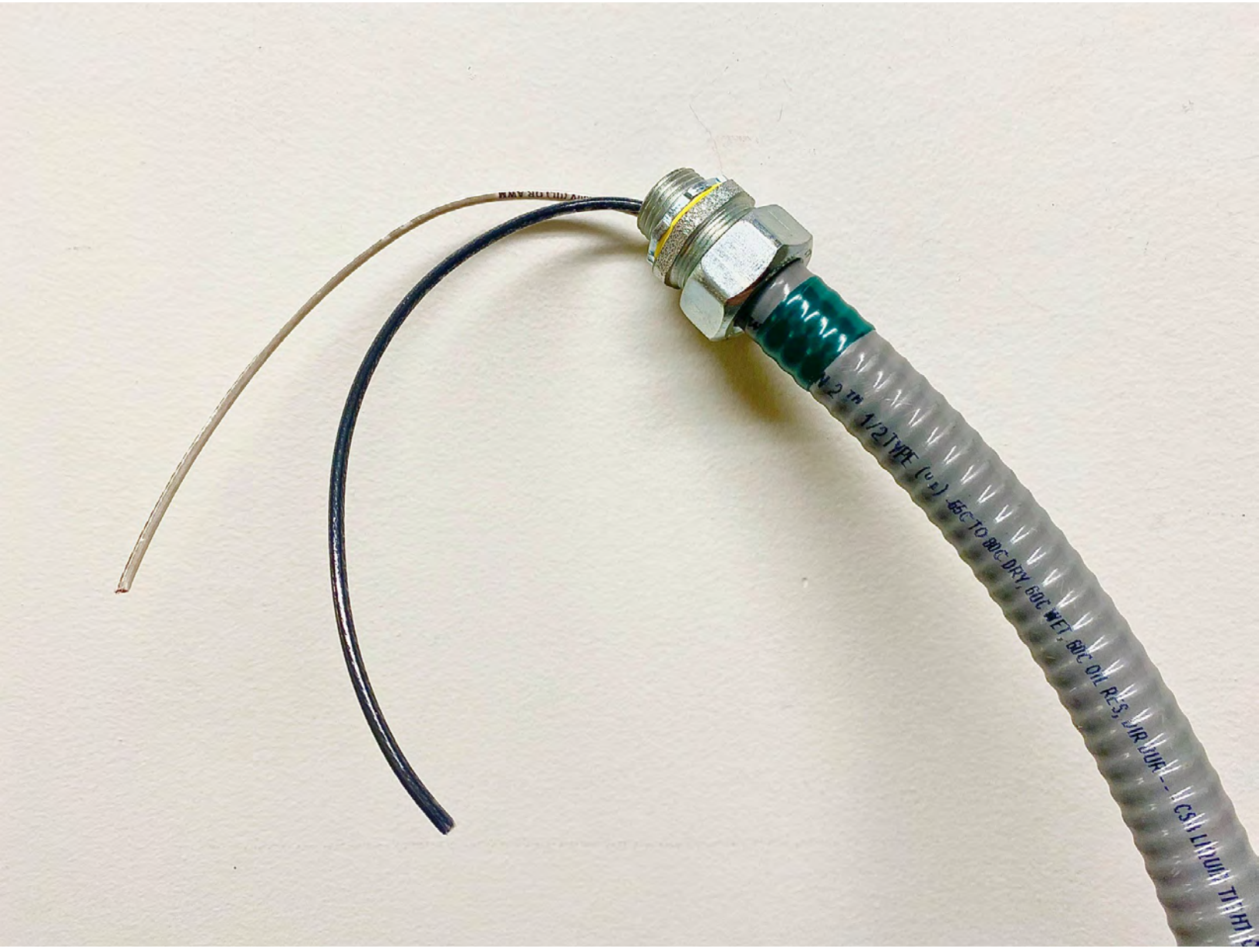
Related Public Inputs for This Document

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

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

Submitter Information Verification

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Submittal Date: Fri May 08 08:57:46 EDT 2020
Committee: NEC-P05


1/2 TYPE (UL) -55C TO 80C DRY, 60C WET, 80C OIL RES, VW-1 UL

Public Input No. 2373-NFPA 70-2020 [Section No. 250.119]

250.119 Identification of Equipment Grounding Conductors.

Informational Note: see 200.6, 210.5, 215.12, 455.6(B), and 517.160(A)(5) for conductor identification and posting requirements that may apply.

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 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 where 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: 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: 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.

(A) Conductors 4 AWG and Larger.

Equipment grounding conductors 4 AWG and larger shall comply with 250.119(A)(1) and (A)(2).

(1) An insulated or covered conductor 4 AWG and larger shall be permitted, at the time of installation, to be permanently identified as an equipment grounding conductor at each end and at every point where the conductor is accessible.

Exception: Conductors 4 AWG and larger shall not be required to be marked in conduit bodies that contain no splices or unused hubs.

(2) Identification shall encircle the conductor and shall be accomplished by one of the following:

(3) Stripping the insulation or covering from the entire exposed length

(4) Coloring the insulation or covering green at the termination

(5) Marking the insulation or covering with green tape or green adhesive labels at the termination

(B) Multiconductor Cable.

One or more insulated conductors in a multiconductor cable, at the time of installation, shall be permitted to be permanently identified as equipment grounding conductors at each end and at every point where the conductors are accessible by one of the following means:

(1) Stripping the insulation from the entire exposed length.

(2) Coloring the exposed insulation green.

(3) Marking the exposed insulation with green tape or green adhesive labels. Identification shall encircle the conductor.

(C) Flexible Cord.

Equipment grounding conductors in flexible cords shall be insulated and shall have a continuous outer finish that is either green or green with one or more yellow stripes.

Statement of Problem and Substantiation for Public Input

The code has other conductor identification and posting requirements on the topic of facility-wide consistency of conductor marking by voltage system and by phase. A portion of these other codes likely always apply to this application of 250.119. And, each of the separate code requirements on this topic should correlate each other to facilitate consistency across a facility; 200.6 [grounded phase conductors], 210.5 [branch conductors], 215.12 [feeder conductors], 250.119 [equipment grounding conductors], 455.6(B) for conductors of manufactured phases, and 517.160(A)(5) [Isolated Power Systems].

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2368-NFPA 70-2020 [Section No. 455.6(B)]	similar issue and edit
Public Input No. 2370-NFPA 70-2020 [Section No. 200.6]	similar issue and edit
Public Input No. 2371-NFPA 70-2020 [Section No. 210.5]	similar issue and edit
Public Input No. 2372-NFPA 70-2020 [Section No. 215.12]	similar issue and edit
Public Input No. 2374-NFPA 70-2020 [Section No. 517.160(A)(5)]	similar issue and edit
Public Input No. 2368-NFPA 70-2020 [Section No. 455.6(B)]	
Public Input No. 2370-NFPA 70-2020 [Section No. 200.6]	
Public Input No. 2371-NFPA 70-2020 [Section No. 210.5]	
Public Input No. 2372-NFPA 70-2020 [Section No. 215.12]	
Public Input No. 2374-NFPA 70-2020 [Section No. 517.160(A)(5)]	

Submitter Information Verification

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Submittal Date: Tue Aug 18 11:16:09 EDT 2020
Committee: NEC-P05

Public Input No. 2393-NFPA 70-2020 [Section No. 250.119]

250.119 Identification of Equipment Grounding ~~Conductors~~ Methods .

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 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 where 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: 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: 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.

(A) Conductors 4 AWG and Larger.

Equipment grounding conductors 4 AWG and larger shall comply with 250.119(A)(1) and (A)(2).

(1) An insulated or covered conductor 4 AWG and larger shall be permitted, at the time of installation, to be permanently identified as an equipment grounding conductor at each end and at every point where the conductor is accessible.

Exception: Conductors 4 AWG and larger shall not be required to be marked in conduit bodies that contain no splices or unused hubs.

(2) Identification shall encircle the conductor and shall be accomplished by one of the following:

(3) Stripping the insulation or covering from the entire exposed length

(4) Coloring the insulation or covering green at the termination

(5) Marking the insulation or covering with green tape or green adhesive labels at the termination

(B) Multiconductor Cable.

One or more insulated conductors in a multiconductor cable, at the time of installation, shall be permitted to be permanently identified as equipment grounding conductors at each end and at every point where the conductors are accessible by one of the following means:

(1) Stripping the insulation from the entire exposed length.

(2) Coloring the exposed insulation green.

(3) Marking the exposed insulation with green tape or green adhesive labels. Identification shall encircle the conductor.

(C) Flexible Cord.

Equipment grounding conductors in flexible cords shall be insulated and shall have a continuous outer finish that is either green or green with one or more yellow stripes.

Statement of Problem and Substantiation for Public Input

not all equipment grounding methods are conductors this change acknowledges this

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2391-NFPA 70-2020 [Section No. 250.119 [Excluding any Sub-Sections]]	

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
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Submittal Date: Tue Aug 18 15:46:39 EDT 2020
Committee: NEC-P05

Public Input No. 2291-NFPA 70-2020 [Section No. 250.119(A)]

(A) Conductors 4 AWG and Larger.

Equipment grounding conductors 4 AWG and larger shall comply with 250.119(A)(1) and (A)(2).

(1) An insulated or covered conductor 4 AWG and larger shall ~~be permitted~~ , at the time of installation, ~~to~~ be permanently identified as an equipment grounding conductor at each end and at every point where the conductor is accessible.

Exception: Conductors 4 AWG and larger shall not be required to be marked in conduit bodies that contain no splices or unused hubs.

(2) Identification shall encircle the conductor and shall be accomplished by one of the following:

(3) Stripping the insulation or covering from the entire exposed length

(4) Coloring the insulation or covering green at the termination

(5) Marking the insulation or covering with green tape or green adhesive labels at the termination

Statement of Problem and Substantiation for Public Input

wording of 250.119(A) infers mandatory compliance to 50.119(A)(1), but 50.119(A)(1) is a non-mandatory permission rather than a requirement. Revise to affirm intent which is that 50.119(A)(1) is required.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2292-NFPA 70-2020 [Section No. 250.119(B)]	
Public Input No. 2292-NFPA 70-2020 [Section No. 250.119(B)]	

Submitter Information Verification

Submitter Full Name: John Blissett
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Submittal Date: Thu Aug 13 17:00:11 EDT 2020
Committee: NEC-P05

Public Input No. 2722-NFPA 70-2020 [Section No. 250.119(A)]

(A) Conductors ~~4 AWG~~ 8 AWG and Larger.

Equipment grounding conductors ~~4 AWG~~ 8 AWG and larger shall comply with 250.119(A)(1) and (A)(2).

(1) An insulated or covered conductor ~~4 AWG~~ 8 AWG and larger shall be permitted, at the time of installation, to be permanently identified as an equipment grounding conductor at each end and at every point where the conductor is accessible.

Exception: Conductors ~~4 AWG~~ 8 AWG and larger shall not be required to be marked in conduit bodies that contain no splices or unused hubs.

(2) Identification shall encircle the conductor and shall be accomplished by one of the following:

(3) Stripping the insulation or covering from the entire exposed length

(4) Coloring the insulation or covering green at the termination

(5) Marking the insulation or covering with green tape or green adhesive labels at the termination

Statement of Problem and Substantiation for Public Input

Changing the size from 4 AWG to 8 AWG will clear up a long standing code violations of the wrong size conductor being re-identified, the standard size wire that has a color other that black is number 10 AWG. Green.This results in a number 8 or 6 AWG black conductor being re-identified instead of the correct colored wire being installed in the first place.
It is time for the code language to change that aligns with what is being installed in the field simply because it is what is most readily available to the electrician.
When you look at section 210.5 (C)(1) which is branch circuits that are supplied from more than one Nominal voltage System the branch circuits are allowed to be re-identified by marking tape with no size limitation and I think that the same should apply now to 250.119

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Committee: NEC-P05

Public Input No. 2292-NFPA 70-2020 [Section No. 250.119(B)]

(B) Multiconductor Cable.

One or more insulated conductors in a multiconductor cable, at the time of installation, shall be ~~permitted to be~~ permanently identified as equipment grounding conductors at each end and at every point where the conductors are accessible by one of the following means:

(1) Stripping the insulation from the entire exposed length.

(2) Coloring the exposed insulation green.

(3) Marking the exposed insulation with green tape or green adhesive labels. Identification shall encircle the conductor.

Statement of Problem and Substantiation for Public Input

What is meant as a requirement is written to be optional.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2291-NFPA 70-2020 [Section No. 250.119(A)]	
Public Input No. 2291-NFPA 70-2020 [Section No. 250.119(A)]	

Submitter Information Verification

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Committee: NEC-P05

Public Input No. 130-NFPA 70-2019 [Section No. 250.119 [Excluding any Sub-Sections]]

(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 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 where 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: 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: 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 Input

Adding an (A) General to the opening paragraph is important to clarify that the rules in this paragraph apply to equipment grounding conductors that are both smaller than 4 AWG as well as to those that are covered in the existing (A) Conductors 4 AWG and Larger.
Renumber the existing (A) to (B), (B) to (C), and (C) to (D).

Submitter Information Verification

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Submittal Date: Wed Nov 20 18:56:12 EST 2019
Committee: NEC-P05

Public Input No. 235-NFPA 70-2020 [Section No. 250.119 [Excluding any Sub-Sections]]

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 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*~~

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 where 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: Conductors with green insulation shall be permitted to be used as ungrounded signal conductors for Types CL3P, CL2P, CL3R, CL2R, CL3, CL2, CL3X, CL2X, and substitute cables installed in accordance with 725.154(A) .

Exception No. 2: Conductors with green insulation shall be permitted to be used as ungrounded signal conductors for Types FPLP, FPLR, FPL, and substitute cables installed in accordance with 760.154(A).

Exception No. 3: Conductors with green insulation shall be permitted to be used as ungrounded signal conductors for Types CMP, CMR, CMG, CM, CMX, BLP, BMR, BLR, BM, BL, BMU, BLU and BLX.

Exception No. 4 : 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*~~

5 : 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 Input

The purpose of this PI is to remove CONFLICTS IN THE CODE.

Section 725.3(P) permits all Class 2 and Class 3 cables to have green wires used as ungrounded signal conductors.

Section 760.3()) permits all power-limited fire alarm 3 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.

Acceptance of the text recommended by this PI will remove the conflicts in 250.119 with Articles 725, 760 and Chapter 8.

Submitter Information Verification

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Submittal Date: Thu Jan 02 13:06:28 EST 2020
Committee: NEC-P05

Public Input No. 2391-NFPA 70-2020 [Section No. 250.119 [Excluding any Sub-Sections]]

Unless required elsewhere in this *Code,* equipment grounding ~~conductors~~ methods shall be permitted to be bare, covered, or insulated. Individually covered or insulated equipment grounding ~~conductors~~ of the wire-type method 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 where 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: 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: 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 Input

RMC comes covered in PVC, LTFMC is covered in PVC these method do not require identification however the wire type does. This edit clarifies the deference of the methods and when the identification applies

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2393-NFPA 70-2020 [Section No. 250.119]	

Submitter Information Verification

Submitter Full Name: Alfio Torrisi
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Committee: NEC-P05

Public Input No. 3909-NFPA 70-2020 [Section No. 250.119 [Excluding any Sub-Sections]]

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 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 where 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:~~ 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 Input

Exception No. 1 does not correlate with 725.3(P) and 760.3(O) which state:

“725.3(P) Identification of Equipment Grounding Conductors.
Equipment grounding conductors shall be identified in accordance with 250.119.
Exception: Conductors with green insulation shall be permitted to be used as ungrounded signal conductors for Types CL3P, CL2P, CL3R, CL2R, CL3, CL2, CL3X, CL2X, and substitute cables installed in accordance with 725.154(A).”

“760.3(O) Identification of Equipment Grounding Conductors.
Equipment grounding conductors shall be identified in accordance with 250.119.
Exception: Conductors with green insulation shall be permitted to be used as ungrounded signal conductors for Types FPLP, FPLR, FPL, and substitute cables installed in accordance with 760.154(A).”

Since 90.3 Arrangement states that, “Chapters 5, 6, and 7 apply to special occupancies, special equipment, or other special conditions and may supplement or modify the requirements in Chapters 1 through 7.”, the simplest way to achieve correlation is to delete Exception No. 1 in 250.119.

Submitter Information Verification

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Submittal Date:	Wed Sep 09 15:19:14 EDT 2020
Committee:	NEC-P05

Public Input No. 2097-NFPA 70-2020 [Section No. 250.120(A)]

(A) Raceway, Cable Trays, Cable Armor, Cablebus, or Cable Sheaths.

Where it consists of a raceway, cable tray, cable armor, cablebus framework, or cable sheath or where 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 use with the type raceway or cable used. All connections, joints, and fittings shall be made tight using suitable tools.

Informational Note: See the UL ~~guide information on FHIT systems~~ Guide Information for Electrical Circuit Integrity Systems (FHIT) for equipment grounding conductors installed in a raceway that are part of ~~an~~ a listed electrical circuit protective system or a listed fire-~~rated cable listed to maintain circuit integrity~~ resistive cable system .

Statement of Problem and Substantiation for Public Input

This proposed update is made to update the document title from the UL Guide Information on FHIT to the current title, Guide Information for Electrical Circuit Integrity Systems(FHIT). This public input is a result of the Correlating Committee Task Group for Circuit Integrity Cable efforts to correlate information on Circuit Integrity (-CI) cable throughout the NEC®. Members of the task group included Blake Shugarman from UL – Principal Engineer for Circuit Integrity Systems, Larry Shudak from UL - Principal Engineer for Life Safety Technologies and member of NFPA 72, Anthony Tassone from UL – Principal Engineer Seasonal and Holiday Decorative Products and Telecommunications Cables - CMP16, Jim Conrad from Marmon Innovation and Technology Group – CMP13, George Straniero from AFC Cable Systems – CMP6, CMP3, and CC, Paul Casparro from IBEW – CMP3, and Rich Holub from DuPont – CMP14 and CC.

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Committee: NEC-P05

Public Input No. 293-NFPA 70-2020 [Section No. 250.120(C)]

(C) Equipment Grounding Conductors Smaller Than 6 AWG.

Where not routed with circuit conductors as permitted in 250.130(C) and 250.134(A) Exception No. 2, equipment grounding conductors smaller than 6 AWG shall be protected from physical damage by an ~~identified~~ approved sleeve, raceway ~~or~~ , cable armor ~~unless installed within hollow spaces of the framing members of buildings or structures and where not subject to physical damage~~ or other approved means .

Statement of Problem and Substantiation for Public Input

A sleeve is not a raceway and only needs approval this method is used in several other articles as protection from PD for many wiring methods and they also have "other approved means" as a way to protect for PD this application is no different. A common method of physical protection is to install a wiring method concealing. This also allows more flexibility as the installation of the EGC could use several method of protection in a single run.

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Submittal Date: Wed Jan 15 12:17:08 EST 2020
Committee: NEC-P05

Public Input No. 3324-NFPA 70-2020 [Section No. 250.120(C)]

(C) Equipment Grounding Conductors Smaller Than 6 AWG.

Where not routed with circuit conductors as permitted in 250.130(C) and 250.134(A 1) Exception No. 2, equipment grounding conductors smaller than 6 AWG shall be protected from physical damage by an identified raceway or cable armor unless installed within hollow spaces of the framing members of buildings or structures and where not subject to physical damage.

Statement of Problem and Substantiation for Public Input

Section 250.134 subsections were renumbered in 2020 NEC from Letters to Numbers. The reference in 250.120(C), Equipment Grounding Conductors Smaller Than 6 AWG was changes to reflect the renumbering. Correct reference is 250.134(1).

Submitter Information Verification

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Committee: NEC-P05

Public Input No. 4330-NFPA 70-2020 [Section No. 250.121]

~~**250.121** Restricted Use of Equipment Grounding Conductors.~~

~~**(A)** Grounding Electrode Conductor.~~

~~An equipment grounding conductor shall not be used as a grounding electrode conductor.~~

~~*Exception: A wire-type equipment grounding conductor installed in compliance with 250.6(A) and the applicable requirements for both the equipment grounding conductor and the grounding electrode conductor in Parts II, III, and VI of this article shall be permitted to serve as both an equipment grounding conductor and a grounding electrode conductor.*~~

~~**(B)** Metal Frame of Building or Structure.~~

~~The structural metal frame of a building or structure shall not be used as an equipment grounding conductor.~~

Statement of Problem and Substantiation for Public Input

Section 250.121 is titled "Restricted Use of Equipment Grounding Conductors", but only partially addresses that topic. Subdivision (A) states the equipment grounding conductor (EGC) is not to be used as a grounding electrode conductor (GEC) unless complying with the exception. It is my understanding that the committee was clarifying the EGC and GEC are not interchangeable. Subdivision (B) gives an item (metal frames) that can't be used for the EGC, not a restricted use of the EGC.

This PI recommends relocating this information to Section 250.118 under a newly created first level subdivision (B) titled "Not Permitted For Use As Equipment Grounding Conductors". This will require creation of a new first level subdivision (A) titled "Permitted for Use as Equipment Grounding Conductors." This is similar in concept to the structure of Section 250.52 (A & B). Then, with the requirements relocated, existing 250.121 can be deleted. A user of the Code will then be able to turn to Section 250.118 and find what can and can't be used as an EGC in a system. This will increase clarity and usability.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 4303-NFPA 70-2020 [Section No. 250.118]	Directly tied to one another.
Public Input No. 4303-NFPA 70-2020 [Section No. 250.118]	

Submitter Information Verification

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Submittal Date: Thu Sep 10 10:17:45 EDT 2020
Committee: NEC-P05

Public Input No. 227-NFPA 70-2019 [Section No. 250.121(A)]

(A) Grounding Electrode Conductor.

~~An equipment~~ A grounding electrode conductor shall not be used as ~~a~~ an equipment grounding ~~electrode~~ conductor.

Exception: ~~A~~ A Feeder suppling a Panelboard, Swithboard or MCC equipment with a wire-type equipment grounding conductor installed in compliance with 250.6(A) and the applicable requirements for both the equipment grounding conductor and the grounding electrode conductor in Parts II, III, and VI of this article shall be permitted to serve as both an equipment grounding conductor and a grounding electrode conductor. A warning lable shall be placed on the equipment stating

WARNING

SHOCK HAZARD EXISTS IF GROUNDING

ELECTRODE CONDUCTOR OR EQUIPMENT GROUNDING CONDUCTOR IS REMOVES WHILE MAIN SERVICE OR BUILDING DISCONNECT IS ENERGIZED

Statement of Problem and Substantiation for Public Input

The title states GEC then talks about an EGC! this is in the inconstant with the title stick with the subject, then give the exception. this exception is not practical for Branch circuit installations because of the 300.3 EGC requirement and 250. The same hazard exists in the stand-by and emergency systems when installed as a non separately derived system these system have a warring label installed for the hazard because of this a warring label should be installed at this lactation for the same purpose. It should also be required here

Submitter Information Verification

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Submittal Date: Mon Dec 30 12:52:00 EST 2019
Committee: NEC-P05

Public Input No. 366-NFPA 70-2020 [Section No. 250.121(A)]

(A) Grounding Electrode Conductor.

An equipment grounding conductor shall not be used as a grounding electrode conductor.

~~*Exception: A wire-type equipment grounding conductor installed in compliance with 250.6(A) and the applicable requirements for both the equipment grounding conductor and the grounding electrode conductor in Parts II, III, and VI of this article shall be permitted to serve as both an equipment grounding conductor and a grounding electrode conductor.*~~

Statement of Problem and Substantiation for Public Input

The exception is 98% theoretical in nature and 2% practical (if that).

The exception serves to confuse and confound both journeyman and master electricians.

The exception serves to CREATE problems in the field for the AHJs and electrical inspectors who have to deal with the fallout. This language really needs to be stricken, and default back to the 2011 language that did not include the exception. The exception serves no real-life purpose other than to impose a greater burden on electrical inspectors who have the duty to correct the system grounding and equipment grounding violations.

Furthermore the exception violates the style manual, section 3.3 writing style, which states the following:
"Writing rules in long sentences full of commas, dependent clauses, and parenthetical expressions often creates confusion and misunderstanding..."

To say, "installed in compliance with 250.6(A) and the applicable requirements for both the equipment grounding conductor and the grounding electrode conductor in Parts II, III, and VI of this article..." is incomprehensible, excessive, and impossible to understand. It is truly incomprehensible.

"Parts II, III, and VI of this article..?" Seriously?
If the language is not stricken, how about an Informational Note citing a real life example of how a grounding electrode conductor can be used as an equipment grounding conductor?

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 367-NFPA 70-2020 [Section No. 250.121(A)]	
Public Input No. 367-NFPA 70-2020 [Section No. 250.121(A)]	

Submitter Information Verification

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Submittal Date:	Sat Jan 25 16:00:13 EST 2020
Committee:	NEC-P05

Public Input No. 367-NFPA 70-2020 [Section No. 250.121(A)]

(A) Grounding Electrode Conductor.

An equipment grounding conductor shall not be used as a grounding electrode conductor.

Exception: A wire-type equipment grounding conductor installed in compliance with 250.6(A) and the applicable requirements for both the equipment grounding conductor and the grounding electrode conductor in Parts II, III, and VI of this article shall be permitted to serve as both an equipment grounding conductor and a grounding electrode conductor. If this exception is to be used, a grounding detail shall be provided to the AHJ prior to the installation.

Statement of Problem and Substantiation for Public Input

Theoretical possibilities do not make for good code language. The exception is 98% theoretical in nature and 2% practical (if that).

The exception serves to confuse and confound both journeyman and master electricians.

The exception serves to CREATE problems in the field for AHJs and electrical inspectors who have to deal with the fallout. This language really needs to be stricken, and default back to the 2011 language that did not include the exception. The exception serves no real-life purpose other than to impose a greater burden on electrical inspectors who have the duty to correct the system grounding and equipment grounding violations.

Assuming that there is some real-life example of how this exception can be used, a detail should be supplied to the AHJ prior to the installation. It is not unheard of that the NEC require a diagram or detail; please see 215.5: "If required by the authority having jurisdiction, a diagram showing feeder details shall be provided prior to the installation of the feeders..."

This proposed language will eliminate the added burden placed on the electrical inspector in the field of having to correct the additional grounding violations created as a result of the exception being added.
I feel that the exception should really be stricken. But if the panel isn't going to do that, then the added language needs to be placed as part of this exception.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 366-NFPA 70-2020 [Section No. 250.121(A)]	
Public Input No. 366-NFPA 70-2020 [Section No. 250.121(A)]	

Submitter Information Verification

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Committee:	NEC-P05

Public Input No. 1836-NFPA 70-2020 [Section No. 250.122]

250.122 Size of Equipment Grounding Conductors of the Wire Type .

(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 circuit 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).

Equipment grounding conductors shall be permitted to be sectioned within a multiconductor cable, provided the combined circular mil area complies with Table 250.122.

Informational Note: Metal raceways, metal cables, other metal wiring methods, and auxiliary gutters in accordance with 250.118 or cable trays complying with 392.60 (B) are permitted as the equipment grounding conductor.

(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 by a qualified person to provide an effective ground fault current path in accordance with 250.4(A)(5) or (B)(4).

(C) Multiple Circuits.

A single equipment grounding conductor shall be permitted to be installed for multiple circuits that are installed in the same raceway, cable, trench, or cable tray. It shall be sized from Table 250.122 for the largest overcurrent device protecting circuit conductors in the raceway, cable, trench, or cable tray. Equipment grounding conductors installed in cable trays shall meet the minimum requirements of 392.10(B)(1)(c).

(D) Motor Circuits.

Equipment grounding conductors for motor circuits shall be sized in accordance with 250.122(D)(1) or (D)(2).

(1) General.

The equipment grounding conductor size shall not be smaller than determined by 250.122(A)based on the rating of the branch-circuit short-circuit and ground-fault protective device.

(2) Instantaneous-Trip Circuit Breaker and Motor Short-Circuit Protector.

If the overcurrent device is an instantaneous-trip circuit breaker or a motor short-circuit protector, the equipment grounding conductor shall be sized not smaller than that given by 250.122(A) using the maximum permitted rating of a dual element time-delay fuse selected for branch-circuit short-circuit and ground-fault protection in accordance with 430.52(C)(1), Exception No. 1.

(E) Flexible Cord and Fixture Wire.

The equipment grounding conductor in a flexible cord with the largest circuit conductor 10 AWG or smaller, and the equipment grounding conductor used with fixture wires of any size in accordance with 240.5, shall not be smaller than 18 AWG copper and shall not be smaller than the circuit conductors. The equipment grounding conductor in a flexible cord with a circuit conductor larger than 10 AWG shall be sized in accordance with Table 250.122.

(F) Conductors in Parallel.

For circuits of parallel conductors as permitted in 310.10(G), the equipment grounding conductor shall be installed in accordance with 250.122(F)(1) or (F)(2).

(1) Conductor Installations in Raceways, Auxiliary Gutters, or Cable Trays.

(a) *Single Raceway or Cable Tray, Auxiliary Gutter, or Cable Tray*. If circuit conductors are connected in parallel in the same raceway, auxiliary gutter, or cable tray, a single wire-type conductor shall be permitted as the equipment grounding conductor. The wire-type equipment grounding conductor shall be sized in accordance with 250.122, based on the overcurrent protective device for the feeder or branch circuit.

(b) *Multiple Raceways*. If conductors are installed in multiple raceways and are connected in parallel, a wire-type equipment grounding conductor, if used, shall be installed in each raceway and shall be connected in parallel. The equipment grounding conductor installed in each raceway shall be sized in accordance with 250.122 based on the rating of the overcurrent protective device for the feeder or branch circuit.

(c) *Wire-Type Equipment Grounding Conductors in Cable Trays.* Wire-type equipment grounding conductors installed in cable trays shall meet the minimum requirements of 392.10(B)(1)(c).

~~*Metal Raceways, Auxiliary Gutters, or Cable Trays.* Metal raceways or auxiliary gutters in accordance with 250.118 or cable trays complying with 392.60~~

~~(~~

~~B) shall be permitted as the equipment grounding conductor.~~

~~(~~ **2)** Multiconductor Cables.

(a) Except as provided in 250.122(F)(2)(c) for raceway or cable tray installations, the equipment grounding conductor in each multiconductor cable shall be sized in accordance with 250.122 based on the overcurrent protective device for the feeder or branch circuit.

(b) If circuit conductors of multiconductor cables are connected in parallel, the equipment grounding conductor(s) in each cable shall be connected in parallel.

(c) If multiconductor cables are paralleled in the same raceway, auxiliary gutter, or cable tray, a single equipment grounding conductor that is sized in accordance with 250.122 shall be permitted in combination with the equipment grounding conductors provided within the multiconductor cables and shall all be connected together.

(d) Equipment grounding conductors installed in cable trays shall meet the minimum requirements of 392.10(B)(1)(c). Cable trays complying with 392.60(B), metal raceways in accordance with 250.118, or auxiliary gutters shall be permitted as the equipment grounding conductor.

(G) Feeder Taps.

Equipment grounding conductors installed with feeder taps shall not be smaller than shown in Table 250.122 based on the rating of the overcurrent device ahead of the feeder on the supply side ahead of the tap but shall not be required to be larger than the tap conductors.

Table 250.122 Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)	Size (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum*
15	14	12
20	12	10
60	10	8
100	8	6
200	6	4
300	4	2
400	3	1
500	2	1/0
600	1	2/0
800	1/0	3/0
1000	2/0	4/0
1200	3/0	250
1600	4/0	350
2000	250	400
2500	350	600
3000	400	600
4000	500	750
5000	700	1250
6000	800	1250

Note: Where necessary to comply with 250.4(A)(5) or (B)(4), the equipment grounding conductor shall be sized larger than given in this table.

*See installation restrictions in 250.120.

Statement of Problem and Substantiation for Public Input

Relocate text contained in 250.122(F)(1)(B) "Metal raceways or auxiliary gutters in accordance with 250.118 or cable trays complying with 392.60(B) shall be permitted as the equipment grounding conductor.' to the parent paragraphi.

Submitter Information Verification

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Submittal Date:	Fri Jul 10 12:27:29 EDT 2020
Committee:	NEC-P05

Public Input No. 2737-NFPA 70-2020 [Section No. 250.122]

250.122 Size of Equipment Grounding Conductors.

(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 circuit 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).

Equipment grounding conductors shall be permitted to be sectioned within a multiconductor cable, provided the combined circular mil area complies with Table 250.122.

(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 by a qualified person to provide an effective ground fault current path in accordance with 250.4(A)(5) or (B)(4).*~~

~~**(C)** Multiple Circuits.~~

~~A single equipment grounding conductor shall be permitted to be installed for multiple circuits that are installed in the same raceway, cable, trench, or cable tray. It shall be sized from Table 250.122 for the largest overcurrent device protecting circuit conductors in the raceway, cable, trench, or cable tray. Equipment grounding conductors installed in cable trays shall meet the minimum requirements of 392.10(B)(1)(c) .~~

(~~D~~ C) Motor Circuits.

Equipment grounding conductors for motor circuits shall be sized in accordance with 250.122(D)(1) or (D)(2).

(1) General.

The equipment grounding conductor size shall not be smaller than determined by 250.122(A)based on the rating of the branch-circuit short-circuit and ground-fault protective device.

(2) Instantaneous-Trip Circuit Breaker and Motor Short-Circuit Protector.

If the overcurrent device is an instantaneous-trip circuit breaker or a motor short-circuit protector, the equipment grounding conductor shall be sized not smaller than that given by 250.122(A) using the maximum permitted rating of a dual element time-delay fuse selected for branch-circuit short-circuit and ground-fault protection in accordance with 430.52(C)(1), Exception No. 1.

(~~E~~ D) Flexible Cord and Fixture Wire.

The equipment grounding conductor in a flexible cord with the largest circuit conductor 10 AWG or smaller, and the equipment grounding conductor used with fixture wires of any size in accordance with 240.5, shall not be smaller than 18 AWG copper and shall not be smaller than the circuit conductors. The equipment grounding conductor in a flexible cord with a circuit conductor larger than 10 AWG shall be sized in accordance with Table 250.122.

(~~F~~ E) – _ Conductors in Parallel.

For circuits of parallel conductors as permitted in 310.10(G), the equipment grounding conductor shall be installed in accordance with 250.122(F)(1) or (F)(2).

(1) Conductor Installations in Raceways, Auxiliary Gutters, or Cable Trays.

(a) *Single Raceway or Cable Tray, Auxiliary Gutter*, *or Cable Tray*. If circuit conductors are connected in parallel in the same raceway, auxiliary gutter, or cable tray, a single wire-type conductor shall be permitted as the equipment grounding conductor. The wire-type equipment grounding conductor shall be sized in accordance with 250.122, based on the overcurrent protective device for the feeder or branch circuit.

(b) *Multiple Raceways*. If conductors are installed in multiple raceways and are connected in parallel, a wire-type equipment grounding conductor, if used, shall be installed in each raceway and shall be connected in parallel. The equipment grounding conductor installed in each raceway shall be sized in accordance with 250.122 based on the rating of the overcurrent protective device for the feeder or branch circuit.

(c) *Wire-Type Equipment Grounding Conductors in Cable Trays.* Wire-type equipment grounding conductors installed in cable trays shall meet the minimum requirements of 392.10(B)(1)(c).

(d) *Metal Raceways, Auxiliary Gutters, or Cable Trays.* Metal raceways or auxiliary gutters in accordance with 250.118 or cable trays complying with 392.60(B) shall be permitted as the equipment grounding conductor.

(2) Multiconductor Cables.

(a) Except as provided in 250.122(F)(2)(c) for raceway or cable tray installations, the equipment grounding conductor in each multiconductor cable shall be sized in accordance with 250.122 based on the overcurrent protective device for the feeder or branch circuit.

(b) If circuit conductors of multiconductor cables are connected in parallel, the equipment grounding conductor(s) in each cable shall be connected in parallel.

(c) If multiconductor cables are paralleled in the same raceway, auxiliary gutter, or cable tray, a single equipment grounding conductor that is sized in accordance with 250.122 shall be permitted in combination with the equipment grounding conductors provided within the multiconductor cables and shall all be connected together.

(d) Equipment grounding conductors installed in cable trays shall meet the minimum requirements of 392.10(B)(1)(c). Cable trays complying with 392.60(B), metal raceways in accordance with 250.118, or auxiliary gutters shall be permitted as the equipment grounding conductor.

(G F) Feeder Taps.

Equipment grounding conductors installed with feeder taps shall not be smaller than shown in Table 250.122 based on the rating of the overcurrent device ahead of the feeder on the supply side ahead of the tap but shall not be required to be larger than the tap conductors.

Table 250.122 Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)	Size (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum*
15	14	12
20	12	10
60	10	8
100	8	6
200	6	4
300	4	2
400	3	1
500	2	1/0
600	1	2/0
800	1/0	3/0
1000	2/0	4/0
1200	3/0	250
1600	4/0	350
2000	250	400
2500	350	600
3000	400	600
4000	500	750
5000	700	1250
6000	800	1250

Note: Where necessary to comply with 250.4(A)(5) or (B)(4), the equipment grounding conductor shall be sized larger than given in this table.

*See installation restrictions in 250.120.

Statement of Problem and Substantiation for Public Input

Delete existing section 250.122(B) then renumber the subsequent sections.
250.122(B) has been, and continues to be virtually unusable by installers and unenforceable by inspectors. Here are just a few examples...assuming all 75 degree C conductors: a 50amp breaker with 8AWG circuit wires and 10AWG EGC= code compliant, but a 40amp, 35amp, 30amp, 25amp, 20amp, or 15amp breaker with same 8AWG circuit wires and 10AWG EGC could be a violation if circuit wires were increased in size for voltage drop or some other design. Does this make any sense at all? How can an AHJ determine what's a violation or not? Next example: a 100amp breaker with 3AWG circuit wires and 8AWG EGC = code compliant, but a 90amp, 80amp, 70amp, 60amp, 50amp,

45amp, 40amp, 35amp, 30amp, 25amp, 20amp, or even a 15amp breaker with same 3AWG circuit wires and 8AWG EGC could be a violation if circuit wires were increased in size by design. Does this make any sense at all? No it does not. Next example: a 225amp breaker with 4/0 circuit wires and 4AWG EGC = code compliant, but a 200amp, 175amp, 150amp, 125amp, 110amp, 100amp, 90amp, 80amp, 70amp, 60amp, 50amp, 45amp, 40amp, 35amp, 30amp, 25amp, 20amp or even 15amp breaker with same 4/0 circuit wires and 4AWG EGC could be a violation if circuit wires were increased in size by design. This makes absolutely no sense at all. Last example: a 400amp breaker with 500kcmil circuit wires and 3AWG EGC = code compliant, but a 350amp, 300amp, 250amp, 225amp, 200amp, 175amp, 150amp, 125amp, 110amp, 100amp, 90amp, 80amp, 70amp, 60amp, 50amp, 45amp, 40amp, 35amp, 30amp, 25amp, 20amp, or even a 15amp breaker with same 500kcmil circuit wires and 3AWG EGC could be a violation if circuit wires were increased in size by design. I could give 10000 more examples, but I think I may have made my point. Does this EGC sizing requirement make any sense at all? No it does not. It also demonstrates that there is no real safety concern if an EGC is NOT increased in size proportionately to the circuit conductors. How does one reconcile the fact that any size EGC could potentially be a violation when installed on a circuit with an overcurrent device SMALLER than specified in Table 250.122? An 800kcmil EGC is ok for a 6000amp circuit, but could be a violation on a 15amp circuit!!!!! It's time to completely scrap this rule!

Submitter Information Verification

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Committee: NEC-P05

Public Input No. 4569-NFPA 70-2020 [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 circuit 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).

Equipment grounding conductors shall be permitted to be sectioned within a multiconductor cable, provided the combined circular mil area complies with Table 250.122.

Exception: When a branch circuit is protected by a GFCI or GFPE, 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.

Statement of Problem and Substantiation for Public Input

A GFCI or GFPE will detect current flowing on the equipment grounding conductor and prevent a 12AWG conductor from being damaged in the event of a short circuit. Reducing the size of the equipment grounding conductor will save material cost, save labor cost, reduce the carbon footprint of new construction—all without sacrificing safety.

A GFCI is required by UL 943 to trip within 25 milliseconds at leakage currents greater than 0.264 amperes which is well within the operating limits of 12AWG conductors. A GFPE may have fixed or adjustable leakage current trip thresholds, but can be set to trip well within operating limits of 12AWG conductors.

Submitter Information Verification

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Submittal Date: Thu Sep 10 15:15:51 EDT 2020
Committee: NEC-P05

Public Input No. 1127-NFPA 70-2020 [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 by a qualified person to provide an effective ground fault current path in accordance with 250.4(A)(5) or (B)(4)~~

Choosing not to use allowances as provided for in 240.4(B) shall not be considered as increasing conductor size .

Statement of Problem and Substantiation for Public Input

The existing exception gives way too much control to the design professional. This proposal would help design professionals provide what they call a "full size" conductor for their installations without the requirement for up sizing the equipment grounding conductor unnecessarily.

Submitter Information Verification

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Affiliation: City of Deltona
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Zip:
Submittal Date: Mon May 18 13:35:13 EDT 2020
Committee: NEC-P05

Public Input No. 131-NFPA 70-2019 [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 by a qualified person to provide an effective ground fault current path in accordance with 250.4(A)(5) or (B)(4).*~~

Statement of Problem and Substantiation for Public Input

This exception was added to the 2020 NEC without proper substantiation. There is no requirement for any method to be used to determine the adequate size of an equipment grounding conductor.
In addition, there is no requirement that any documentation be provided to the owner and electrical inspector to prove that the equipment grounding conductor that is determined by the qualified person is adequate.

Submitter Information Verification

Submitter Full Name: Phil Simmons
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Zip:
Submittal Date: Wed Nov 20 19:02:28 EST 2019
Committee: NEC-P05

Public Input No. 16-NFPA 70-2019 [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 No. 1 : Equipment grounding conductors shall be permitted to be sized by a qualified person to provide an effective ground fault current path in accordance with 250.4(A)(5) or (B)(4).

Exception No. 2: Equipment grounding conductors shall not be required to be increased in size when the ungrounded conductors are protected by ground-fault protection of equipment or ground-fault circuit interrupter protection at their source

Statement of Problem and Substantiation for Public Input

GFPE and GFCI protection provides a level of protection below the ampere rating of branch and feeder conductors which will also provide the protection for the EGC should the ungrounded conductor be increased for any reason.

Submitter Information Verification

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Submittal Date: Fri Nov 01 18:11:11 EDT 2019
Committee: NEC-P05

Public Input No. 520-NFPA 70-2020 [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 by a qualified person to provide an effective ground fault current path in accordance with 250.4(A)(5) or (B)(4).*~~ *Informational Note: A minimum ampacity of ungrounded conductors as determined by applying correction factors to ampacity table values does not constitute an increase in size from minimum.*

Statement of Problem and Substantiation for Public Input

1. It is ill-advised to limit a minimum ampacity determination to a certain obvious sections, as there may be others that also have an impact that are not as obvious. The existing rule from 2017 and before was clear enough, an informational note should be all the explanation needed.
2. The exception writes quite the blank check for any "qualified person" to simply ignore the rule and say "it's fine because I said it's fine", because at the end of the day that's exactly what the exception says. 250.4 should be the backing for an engineer to require more robust grounding, not a launching pad for stupid electricians like me to skate and say "the breaker should trip just fine."

Submitter Information Verification

Submitter Full Name: George Stolz
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Submittal Date: Sat Feb 22 22:27:41 EST 2020
Committee: NEC-P05

Public Input No. 2233-NFPA 70-2020 [Section No. 250.122(D)]

(D) ~~Motor~~ Motors and Air-Conditioning Circuits.

(1) Motors. Equipment grounding conductors ~~for motor circuits~~ shall be sized in accordance with 250.122(D)(1)(a) or (D)(~~2~~ 1)(b) .

(~~1~~ a) General.

The equipment grounding conductor size shall not be smaller than determined by 250.122(A) based on the rating of the branch-circuit short-circuit and ground-fault protective device in accordance with 430 .52.

(~~2~~ b) Instantaneous-Trip Circuit Breaker and Motor Short-Circuit Protector.

If the overcurrent device is an instantaneous-trip circuit breaker or a motor short-circuit protector, the equipment grounding conductor shall be sized not smaller than that given by 250.122(A) using the maximum permitted rating of a dual element time-delay fuse selected for branch-circuit short-circuit and ground-fault protection in accordance with 430.52(C)(1), Exception No. 1.

(2) Air-Conditioning Equipment. The equipment grounding conductor size shall not be smaller than determined by 250.122(A) based on the rating of the branch-circuit short-circuit and ground-fault protective device in accordance with 440.22.

Statement of Problem and Substantiation for Public Input

The rules contained in 250.122(D) need to also apply to air-conditioning equipment, for the same reasons they apply to motors. The reason 250.122(D) is in the NEC is because protection for the motor is base on ground-fault and short-circuit conditions, not overload [430.52]. Add a (2) section for air-conditioning provides the rules on sizing the EGC for this type of equipment based on short-circuit and ground-fault conductions, not overload.

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
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Submittal Date: Wed Aug 12 09:41:03 EDT 2020
Committee: NEC-P05

Public Input No. 1591-NFPA 70-2020 [Section No. 250.122(F)(1)]

(1) Conductor Installations in Raceways, Auxiliary Gutters, or Cable Trays.

(a) *Single Raceway or Cable Tray, Auxiliary Gutter, or Cable Tray*. If circuit conductors are connected in parallel in the same raceway, auxiliary gutter, or cable tray, a single wire-type conductor shall be permitted as the equipment grounding conductor. The wire-type equipment grounding conductor shall be sized in accordance with 250.122, based on the overcurrent protective device for the feeder or branch circuit.

(b) *Multiple Raceways*. If conductors are installed in multiple raceways and are connected in parallel, a wire-type equipment grounding conductor, if used, shall be installed in each raceway and shall be connected in parallel. The equipment grounding conductor installed in each raceway shall be sized in accordance with 250.122 based on the rating of the overcurrent protective device for the feeder or branch circuit, but in no case shall they be required to be larger than the circuit conductors in each raceway .

(c) *Wire-Type Equipment Grounding Conductors in Cable Trays.* Wire-type equipment grounding conductors installed in cable trays shall meet the minimum requirements of 392.10(B)(1)(c).

(d) *Metal Raceways, Auxiliary Gutters, or Cable Trays.* Metal raceways or auxiliary gutters in accordance with 250.118 or cable trays complying with 392.60(B) shall be permitted as the equipment grounding conductor.

Statement of Problem and Substantiation for Public Input

The text "but in no case shall they be required to be larger than the circuit conductors supplying the equipment." is the current text contained in 250.122(A). It is a rare event when the EGCs per Table 250.122 would be larger than the circuit conductors, but this would occur when a 4000A switchboard is wired with 12 sets of 600kcmil AL rated 340A per Table 310.16 for the ungrounded conductors, and contain a 750kcmil AL EGC per Table 250.122. I understand the logic of requiring the full size EGC for each parallel set of conductors (not that we follow that logic for service raceways), but if there was a fault in a single raceway, what value is there to require an EGC lager than the circuit conductors?

Submitter Information Verification

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Organization: Mike Holt Enterprises Inc
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Submittal Date: Mon Jun 22 18:10:04 EDT 2020
Committee: NEC-P05

Public Input No. 2773-NFPA 70-2020 [Section No. 250.122(F)(1)]

(1) Conductor Installations in Raceways, Auxiliary Gutters, or Cable Trays.

(a) *Single Raceway or Cable Tray, Auxiliary Gutter, or Cable Tray*. If circuit conductors are connected in parallel in the same raceway, auxiliary gutter, or cable tray, a single wire-type conductor shall be permitted as the equipment grounding conductor. The wire-type equipment grounding conductor shall be sized in accordance with 250.122, based on the overcurrent protective device for the feeder or branch circuit.

(b) *Multiple Raceways*. If conductors are installed in multiple raceways and are connected in parallel, a wire-type equipment grounding conductor, if used, shall be installed in each raceway and shall be connected in parallel. The equipment grounding conductor installed in each raceway shall be sized in accordance with 250.122 based on the rating of the overcurrent protective device for the feeder or branch circuit.

(c) *Wire-Type Equipment Grounding Conductors in Cable Trays.* Wire-type equipment grounding conductors installed in cable trays shall meet the minimum requirements of 392.10(B)(1)(c).

(d) *Metal Raceways, Auxiliary Gutters, or Cable Trays.* Metal raceways or auxiliary gutters in accordance with 250.118 or cable trays complying with 392.60(B) shall be permitted as the equipment grounding conductor.

(e) The equipment grounding conductor shall be sized per 250.122 (A)

Statement of Problem and Substantiation for Public Input

The current wording leads to situations where the equipment grounding conductor could be larger than the phase conductors. An example would be 1/0 phase conductors would require 3/0 copper egc's in each parallel raceway. It should follow 250.122 a and allow for it to be no larger than the phase conductors.

Submitter Information Verification

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Submittal Date: Mon Aug 31 15:27:14 EDT 2020
Committee: NEC-P05

Public Input No. 594-NFPA 70-2020 [Section No. 250.122(F)(1)]

(1) Conductor Installations in Raceways, Auxiliary Gutters, or Cable Trays.

(a) *Single Raceway or Cable Tray, Auxiliary Gutter, or Cable Tray*. If circuit conductors are connected in parallel in the same raceway, auxiliary gutter, or cable tray, a single wire-type conductor shall be permitted as the equipment grounding conductor. The wire-type equipment grounding conductor shall be sized in accordance with 250.122, based on the overcurrent protective device for the feeder or branch circuit.

(b) *Multiple Raceways*. If conductors are installed in multiple raceways and are connected in parallel, a wire-type equipment grounding conductor, if used, shall be installed in each raceway and shall be connected in parallel. The equipment grounding conductor installed in each raceway shall be sized in accordance with Table 250.122 based on the rating of the overcurrent protective device for the feeder or branch circuit except as adjusted where necessary in compliance with 250 .122(B) or 250.122 (D).

(c) *Wire-Type Equipment Grounding Conductors in Cable Trays.* Wire-type equipment grounding conductors installed in cable trays shall meet the minimum requirements of 392.10(B)(1)(c).

(d) *Metal Raceways, Auxiliary Gutters, or Cable Trays.* Metal raceways or auxiliary gutters in accordance with 250.118 or cable trays complying with 392.60(B) shall be permitted as the equipment grounding conductor.

Statement of Problem and Substantiation for Public Input

Greetings Code making Panel Members -

There seems to be a lot of confusion on how to size the EGC when installed in parallel in multiple raceways. In speaking with NFPA and Staff on this issue it was agreed that 250.122(F)(1)(b) should supercede the requirements in 250.122(A) which states that the EGC shall not be required to be larger than the circuit conductors. So I am going to paint you a scenario in hopes that CMP 5 will clear up this confusing with either a public statement or change to the section for clarity.

You have (12) Sets of PVC Conduit with (1) set of 600 kcmil Al serving per raceway as feeders to a 4000A remote distribution system.

This feeder is protected by a 4000A OCPD and based on T250.122 and 250.122(F)(1)(b) the EGC in each raceway is to be 750 kcmil based on the OCPD.

250.122(F)(1)(b) states each raceway is to have that EGC sized per 250.122. So here is the question.

Since 250.122(A) states "The equipment grounding conductor of the "wire type" shall not be required to be larger than the circuit conductors supplying the equipment."

So the largest conductors in each raceway is 600 kcmil does the EGC in each raceway have to be 750 kcmil based on the 4000A OCPD? or does 250.122(A) apply to just the conductors that in each raceway which are only 600 kcmil thus making 250.122(A) say the EGC only has to be 600 kcmil.

Here is the response from NFPA on this subject:

"Thank you for your inquiry on the 2020 NEC®

Based on the description provided the installation is a single 4000 ampere feeder circuit that is

installed using conductors in parallel in multiple raceways. Section 250.122 (F) (1) (b) covers conductors in parallel and specifies that each raceway contain an equipment grounding conductor based on the rating of the overcurrent device protecting the circuit conductors, in this case a 4000 ampere OCPD.
Based on the requirement in 250.122 (F) (1) (b) covering this specific method of installation, where a wire type equipment grounding conductors is installed, it's size shall be based on Table 250.122 and is required to be installed in each of the parallel raceways.
While the total size of the EGC exceeds the total size of the phase conductors, Section 250.122 (F) (1) (b) requires wire-type equipment grounding conductors to be fully sized in each raceway."

In closing, as you can see we have an issue here. Because 250.122(F)(1)(b) points you back to 250.122, and that brings (A) into play, it says the EGC never has to be larger than the largest ungrounded conductor.

Now, we know that some folks will say, without documentation mind you, that the 600 kcmil is large enough BUT we also know that even though they are connected in parallel per 310.10(G) they are not really being used in parallel like we do with ungrounded conductors used to equally divide current and obtain a higher ampacity value. We are simply installing them in parallel per 310.10(G) knowing they do not act in parallel under a single raceway fault condition which is why they have always been sized fully in each raceway. The truth is they are full sized because of a potential ground-fault in any of the raceways between one or more conductors at the same potential time. In fact, the likelihood of multiple conductors faulting out due to an accident or specific incident is more probable than a single ungrounded conductor.

We need to clarify if 250.122(A) applies to 250.122(F)(1)(b) or not.

Submitter Information Verification

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Submittal Date:	Tue Mar 03 15:28:04 EST 2020
Committee:	NEC-P05

Public Input No. 4379-NFPA 70-2020 [Section No. 250.130(C)]

(C) ~~Nongrounding Receptacle Replacement or Branch Circuit Extensions.~~

~~The equipment grounding conductor of~~

Equipment Grounding for Existing Installations.

For existing installations where a means to connect to an equipment grounding conductor does not exist in an enclosure or the wiring method does not include an equipment grounding conductor, a grounding-type switch, grounding-type receptacle, or a branch-circuit extension shall be permitted to be ~~connected~~ grounded by connection 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 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 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: See 406.4(D) for the use of a ground-fault circuit-interrupting type of receptacle.

Statement of Problem and Substantiation for Public Input

Where non-grounding receptacles are replaced with grounding-type receptacles and no grounding means exists in the enclosure, Section 250.130(C) provides options for an equipment grounding conductor to be "fished" to ground the replacement receptacle. Section 404.9(B) requires snap switches to be connected to an equipment grounding conductor, but an exception allows a replacement switch to be supplied through a GFCI where a grounding means is not available in an exiting enclosure. If the replacement switch were supplied under the provisions of 250.130(C) there would be no need for GFCI protection but the current requirement only addresses replacement of receptacles. If a decision has been made to install equipment grounding conductors as per Section 250.130(C) in an existing dwelling, the installed EGC should be able to serve switches and receptacles alike.

Submitter Information Verification

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Submittal Date: Thu Sep 10 11:32:10 EDT 2020

Committee: NEC-P05

Public Input No. 145-NFPA 70-2019 [Section No. 250.132]

250.132 Short Sections of Raceway or Cable .

Isolated sections of metal raceway or cable armor, if required to be connected to an equipment grounding conductor, shall be connected in accordance with 250.134.

Statement of Problem and Substantiation for Public Input

Greetings CMP 5 Members -

This proposed change aims to align the section heading with the code language. The language in 250.132 refers also to cables so it stands to reason that should also be in the section heading since cables are not raceways.

Submitter Information Verification

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Submittal Date: Mon Nov 25 16:09:22 EST 2019
Committee: NEC-P05

Public Input No. 1594-NFPA 70-2020 [Section No. 250.134]

250.134 Equipment Fastened in Place or Connected by Permanent Wiring Methods (Fixed).

Unless connected to the grounded circuit conductor as permitted by 250.32, 250.140, and 250.142, non–current-carrying metal parts of equipment, raceways, and other enclosures ~~, if grounded,~~ shall be connected to ~~an~~ any equipment grounding conductor by one of the following methods:

(1) By connecting to any of the equipment grounding conductors permitted by 250.118(2) through (14)

(2) By connecting to an equipment grounding conductor of the wire type that is contained within the same raceway, contained within the same cable, or otherwise run with the circuit conductors

Exception No. 1: As provided in 250.130(C), the equipment grounding conductor shall be permitted to be run separately from the circuit conductors.

Exception No. 2: For dc circuits, the equipment grounding conductor shall be permitted to be run separately from the circuit conductors

Informational Note No. 1: See 250.102 and 250.168 for equipment bonding jumper requirements.

Informational Note No. 2: See 400.10 for use of flexible cords and flexible cables for fixed equipment.

Statement of Problem and Substantiation for Public Input

The metal parts of all equipment is required to be grounded, weather the system is a grounded or ungrounded system. Removal of the text removes the question as to when the metal parts might not need to be grounded. Let's just have the text clear without any question.

Submitter Information Verification

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Submittal Date: Mon Jun 22 18:49:52 EDT 2020
Committee: NEC-P05

Public Input No. 1312-NFPA 70-2020 [Section No. 250.136]

250.136 Equipment Secured to ~~Grounded~~ Metal ~~Supports~~ Rack or Structure .

Electrical equipment secured to and in electrical contact with a metal rack or structure provided for its support shall be permitted to be considered as being connected to an equipment grounding conductor if the metal rack or structure is connected to an equipment grounding conductor by one of the means indicated in 250.134.

Statement of Problem and Substantiation for Public Input

Revise the title to 250.136 so that it reflects the content of the rule (metal rack and structure). The rule states: "Electrical equipment secured to and in electrical contact with a metal rack or structure provided for its support shall be permitted to be considered as being connected to an equipment grounding conductor if the metal rack or structure is connected to an equipment grounding conductor by one of the means indicated in 250.134."

Submitter Information Verification

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Organization: Mike Holt Enterprises Inc
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Submittal Date: Sun May 31 20:03:28 EDT 2020
Committee: NEC-P05

Public Input No. 2473-NFPA 70-2020 [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 where 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~~ 8 AWG copper-clad aluminum or 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.

Statement of Problem and Substantiation for Public Input

COPPER-CLAD ALUMINUM CONDUCTORS:

Please Consult Sections 110.14 Electrical Connections and 110.5 Conductor Materials. Copper-Clad Aluminum as a conductor material should not be excluded for this application. With aluminum and copper, Copper-Clad Aluminum is only one of three conductor materials for general wiring permitted by the NEC. This PI aims to correct an inconsistency in correlation between Articles. It aims to bring safe alternatives to users of this Code. The NFPA Standards Council created in August 2019 a special Bimetals Task Group to in part bring attention to correlation issues effecting Copper-Clad Aluminum, as well as to study expanding its range of applications in 2023. In a coordinated effort, the Bimetals Task Group will submit 19 Public Inputs in this cycle addressing these matters.

Submitter Information Verification

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Submittal Date: Sun Aug 23 10:51:40 EDT 2020
Committee: NEC-P05

Public Input No. 3571-NFPA 70-2020 [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 where 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.

(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.

Statement of Problem and Substantiation for Public Input

This public input is submitted to recognize and address an issue that occurs where homeowners install optional standby systems. We all know that in older homes there are ranges, ovens and dryers etc. that were installed with Type SE cable and the grounded conductor is used to ground the frames of the equipment supplied. That is seen readily in the requirements of 250.142(B) and 250.140.

When a SUSE rated transfer switch is installed upstream of existing service equipment, modifications are required as that panelboard is no longer service equipment, it is feeder supplied. The requirements in list item (3) of the Exception to the general requirements of 250.140, mandate that the branch circuit must originate in service equipment. This rule (when first added to the NEC) never took into account this scenario. There is no logical reason to retain the requirement in list item (3) of the Exception to the general requirements of 250.140, and mandate that the branch circuit must originate in service equipment. Where the existing service equipment is modified and the existing branch circuit using Type SE cable (for a range as an example) has the concentric conductor terminated on the grounded conductor terminal block, there are no safety concerns whatsoever.

Leaving this as written creates a nightmare for installers and inspectors. There are tens of thousands, perhaps hundreds of thousands of installations already installed in a manner described in this PI. This is simply recognizing a practice that has played out for many years and no safety issues or concerns are created. Requiring homeowners to rip open walls and ceilings to replace these branch circuits with no safety benefit, just because they are installing an optional standby system is not substantiated.

Those branch circuits have been installed for decades without any safety issues whatsoever.

If CMP-5 chooses two resolve this PI, I respectfully request that they answer in detail the following question. Stating that this is a long standing requirement just doesn't work. If this PI is resolved, CMP-5 needs to explain in detail how such an installation creates a concern.

It is important to note that this deals only with existing installations.

What safety issues are created where the concentric conductor from an existing Type SE cable is properly terminated on a grounded conductor terminal bar that is isolated from the enclosure and is connected to an insulated grounded conductor which originates in a SUSE rated transfer switch?

Submitter Information Verification

Submitter Full Name: James Dollard
Organization: IBEW Local Union 98
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Submittal Date: Wed Sep 09 08:07:35 EDT 2020
Committee: NEC-P05

Public Input No. 3853-NFPA 70-2020 [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 where ~~an~~ a separate equipment grounding conductor is not present in the outlet or junction box, , the grounded conductor of branch circuits shall be permitted to serve as both the grounded conductor and the equipment grounding c onductor. T he frames of exisitng electric ranges, wall-mounted ovens, counter-mounted cooking units, clothes dryers, and outlet or junction boxes that are ~~part of~~ connected to the existing 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.

(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 the next level distribution equipment , such as a panelboard, downstream tow ard the load .

(4) Grounding contacts of receptacles furnished as part of the equipment are bonded to the equipment.

Statement of Problem and Substantiation for Public Input

This revision is an effort to address a gap in the NEC. As currently written, the exception is incomplete and does not provide practical relief from this rule without creating significant and unnecessary hardship. The exception should address situations such as service upgrades, generator installations that include transfer equipment, and multifamily dwelling unit occupancies where the older existing stype SE Cables are existing and operational for dwelling units and are connected to the grounded conductor at the panelboard within ewach dwelling unit. The suggested text was derived from 230.67 (which was new in 2020) that addresses installations of surge protective devices at a panelboard within a dwelling unit (next level of distribution equipment that is downstream toward the load. The development of this exception originally was intended to provide practical relief from the requirement to separate neutrals and equipment grounding conductors on the load side of the service equipment (not new). The exception did not go far enough and has introduce problems for inspection jurisdictions that are being resolved by local modification (variances) to the general rule. The relief is warranted as there does not appear to be documents safety concerns or problems form allowing these existing installations to remain without requiring complete rewiring of these individual branch circuits.

Submitter Information Verification

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Submittal Date:	Wed Sep 09 14:01:03 EDT 2020
Committee:	NEC-P05

Public Input No. 4020-NFPA 70-2020 [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 where 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.

(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-cicuit installations only where the equipment supplies a dwelling unit(s) and there is no equipment grounding conductor present at 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 the conditions specified in (1), (2) and (4) of Exception No. 1 are met, the grounded condutor of the circuit supplying the appliance(s) is part of a nonmetallic sheathed cable and it is insulated of coverd within the supply enclosure so that it does not make contact with any normally non-current-carrying metal parts.

Statement of Problem and Substantiation for Public Input

The proposed new exception is intended to address situations where a whole house, service rated, transfer switch is installed between the meter enclosure and the existing panelboard enclosure. Because the existing load center (formally the service equipment) is now feeder supplied equipment, which is on the load side of the service disconnecting means (the service rated transfer switch), the grounded conductor is not permitted to be used part of the effective ground-fault current pathway. Therefore, any existing 3-wire range and dryer circuits must be replaced with 4-wire circuits. 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 now normally non-current-carrying. By stating the uninsulated conductor can be “covered” it will be clear that methods such as taping or using shrink tubing as means of preventing contact with normally non-current-carrying metal parts is permitted. Having to replace these nonmetallic sheathed cables, receptacles and appliance cords can present significant hardships for the dwelling unit owners which often result in a limited optional standby system. The proposed new exception provides a safe alternative to having to replace the existing 3-wire nonmetallic sheathed cables and equipment or install a limited standby system.

Submitter Information Verification

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Submittal Date:	Wed Sep 09 17:46:19 EDT 2020
Committee:	NEC-P05

Public Input No. 4693-NFPA 70-2020 [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 where 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.

(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~~ in an existing panelboard .

(4) Grounding contacts of receptacles furnished as part of the equipment are bonded to the equipment.

Statement of Problem and Substantiation for Public Input

In many cases, services are replaced, modified, or upgraded because of additional load, equipment failure, or an optional standby system is installed. Where the original service enclosure is located on the load side of the new service equipment, those existing range and/or dryer circuits may no longer be supplied from the service. In most cases, the new service will now be required to be located on the outside of the home. This revision will allow that existing circuit to remain in place and add no hazard.

Submitter Information Verification

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Submittal Date: Thu Sep 10 16:53:44 EDT 2020
Committee: NEC-P05

Public Input No. 1314-NFPA 70-2020 [Section No. 250.144]

250.144 Multiple Circuit Connections.

Where equipment is ~~grounded and is~~ supplied by ~~separate connection to~~ more than one circuit ~~or grounded premises wiring system~~ , an equipment grounding conductor termination shall be provided for each such connection as specified in 250.134 and 250.138.

Statement of Problem and Substantiation for Public Input

Reference to 'grounded' or 'grounded premises wiring system' make the rule more complex than it's needed. My PI is to simply the rule to make it easier to understand and apply.

Submitter Information Verification

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Submittal Date: Sun May 31 20:10:07 EDT 2020
Committee: NEC-P05

Public Input No. 1315-NFPA 70-2020 [New Section after 250.146]

TITLE OF NEW CONTENT

250.147 Bonding Metal Faceplates

Metal faceplates shall be bonded to the circuit equipment grounding conductor by the metal mounting screw(s) securing the faceplate to a metal yoke or strap of a receptacle, switch, or metal outlet box.

Statement of Problem and Substantiation for Public Input

The simple concept of bonding a metal faceplate is managed in many different ways by different Code Panels. Examples: Switches [404.9(B)] - "Metal faceplates shall be bonded to the equipment grounding conductor." Receptacles [406.6(B)] - "Metal faceplates shall be grounded." Health Care (receptacles only) [517.13(B)(1)(4)] - " Metal faceplates, by means of a metal mounting screw(s) securing the faceplate to a metal yoke or strap of a receptacle or to a metal outlet box." The industry would really appreciate it if this rule were contained in Article 250.

Submitter Information Verification

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Submittal Date: Sun May 31 20:15:18 EDT 2020
Committee: NEC-P05

Public Input No. 1601-NFPA 70-2020 [Section No. 250.148]

250.148 Continuity of Equipment Grounding Conductors and Attachment in Boxes.

If circuit conductors are spliced within a box or terminated on equipment within or supported by a box, all wire-type equipment grounding conductor(s) associated with any of those circuit conductors shall be connected ~~within~~ in the box ~~or~~ and to the box in accordance with 250.8 and 250.148(A) through (D).

Exception: The equipment grounding conductor permitted in 250.146(D) shall not be required to be connected to the other equipment grounding conductors or to the box.

(A) Connections and Splices.

Connections and splices shall be made in accordance with 110.14(B) except that insulation shall not be required.

(B) Equipment Grounding Conductor Continuity.

The arrangement of equipment grounding conductor grounding connections shall be such that the disconnection or the removal of a luminaire, receptacle, or other device fed from the box does not interrupt the electrical continuity of the equipment grounding conductor(s) ~~providing an~~ that provides the required effective ground-fault current path.

(C) Metal Boxes.

A connection used for no other purpose shall be made between the metal box and the equipment grounding conductor(s) ~~in accordance with 250~~ . ~~8.~~

(D) Nonmetallic Boxes.

One or more equipment grounding conductors brought into a nonmetallic outlet box shall be arranged such that a connection can be made to any fitting or device in that box requiring connection to an equipment grounding conductor.

Statement of Problem and Substantiation for Public Input

Slight “tweaking” of the text to clarify the intent clearer and remove the redundant reference to 250.8.

Submitter Information Verification

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Submittal Date: Mon Jun 22 19:42:43 EDT 2020
Committee: NEC-P05

Public Input No. 1053-NFPA 70-2020 [Section No. 250.148 [Excluding any Sub-Sections]]

If circuit conductors are spliced within a box or terminated on equipment within or supported by a box, all wire-type equipment grounding conductor(s) ~~associated with any of those circuit~~ regardless of their association with any circuit conductors shall be connected within the box or to the box in accordance with 250.8 and 250.148(A) through (D).

Exception: The equipment grounding conductor permitted in 250.146(D) shall not be required to be connected to the other equipment grounding conductors or to the box.

Statement of Problem and Substantiation for Public Input

As currently worded, the paragraph has the subject of conductors spliced in the box, then goes on to state "equipment grounding conductors associated with those conductors". Which conductors? Those that are spliced. In previous explanations the CMP stated it is the intent for all equipment grounding conductors to be connected together, not just those that are associated with the spliced conductors. This wording makes the intent more clear.

Submitter Information Verification

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Submittal Date: Wed May 13 16:58:23 EDT 2020
Committee: NEC-P05

Public Input No. 122-NFPA 70-2019 [Section No. 250.148 [Excluding any Sub-Sections]]

If circuit conductors are spliced within ~~a box~~ an enclosure or terminated on equipment within or supported by ~~a box~~ an enclosure , all wire-type equipment grounding conductor(s) associated with any of those circuit conductors shall be connected within the ~~box~~ enclosure or to the ~~box~~ enclosure in accordance with 250.8 and 250.148(A) through (D).

Exception: The equipment grounding conductor permitted in 250.146(D) shall not be required to be connected to the other equipment grounding conductors or to the box.

Statement of Problem and Substantiation for Public Input

Not all enclosures are boxes, using the more general term provides clarity as to when this requirement is applicable to installations.

Submitter Information Verification

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Submittal Date: Wed Nov 20 12:42:44 EST 2019
Committee: NEC-P05

Public Input No. 4612-NFPA 70-2020 [Section No. 250.148 [Excluding any Sub-Sections]]

If circuit conductors are spliced within a box or terminated on equipment within or supported by a box, all wire-type equipment ~~grounding conductor(s) associated with any of those circuit conductors shall be connected within the box or to the box~~ grounding conductor connections shall be made in accordance with 250.8 ~~and 250.~~ 148(A) through (D).

Exception: The equipment grounding conductor permitted in 250.146(D) shall not be required to be connected to the other equipment grounding conductors or to the box.

Statement of Problem and Substantiation for Public Input

I've been told by very smart people that the wording does not match what the panel intended it to mean. I believe the CMP5 consensus for the 2020 NEC was that if multiple circuits of different ampacities with different overcurrent protection devices were in the same nonmetallic enclosure only the equipment grounding conductors for each circuit needed to be connected together. The word "all" was deleted in the second draft based on that concept. For example, if a 15-ampere circuit with a 14 AWG EGC and a 100-ampere circuit with an 8 AWG EGC are in the same nonmetallic enclosure the 14 and 8 do not need to be connected together. Each circuits EGC continuity needs to have continuity to the equipment supplied but connecting all EGC's present is not required in a nonmetallic enclosure. This modified wording is an attempt to accomplish that. The present opening paragraph (charging wording) essentially states that suitable devices must be used and references 250.8. That requirement does not need to be repeated.

Submitter Information Verification

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Submittal Date: Thu Sep 10 15:50:35 EDT 2020
Committee: NEC-P05

Public Input No. 2476-NFPA 70-2020 [Section No. 250.166(A)]

(A) Not Smaller Than the Neutral Conductor.

Where 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~~ 8 AWG copper-clad steel or copper or ~~6 AWG~~ 6 AWG copper-clad aluminum or aluminum .

Additional Proposed Changes

File Name	Description	Approved
CCS_Corrosion_paper_Rev2.pdf	50 Year Corrosion Study Grade 40 CCS	
TD002391.doc	UL 467 Short Circuit and UL 486A-B Mechanical Sequence Testing Grade 40 CCS	
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

COPPER-CLAD ALUMINUM CONDUCTORS:

Please Consult Sections 110.14 Electrical Connections and 110.5 Conductor Materials. Copper-Clad Aluminum as a conductor material should not be excluded for this application. With aluminum and copper, Copper-Clad Aluminum is only one of three conductor materials for general wiring permitted by the NEC. Copper-Clad Aluminum is referenced as a GEC in Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems. This Public Input aims to correct an inconsistency in correlation between sections and articles. It aims to bring safe alternatives to users of this Code. The NFPA Standards Council created in August 2019 a special Bimetals Task Group to in part bring attention to correlation issues effecting Copper-Clad Aluminum, as well as to study expanding its range of applications in 2023. In a coordinated effort, the Bimetals Task Group will submit 19 Public Inputs in this cycle addressing these matters.

COPPER-CLAD STEEL CONDUCTORS:

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 applicate 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 Inputs for This Document

Related Input	Relationship
Public Input No. 2462-NFPA 70-2020 [Section No. 250.62]	Copper-Clad Steel Grounding Conductors
Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]	Copper-Clad Steel Grounding Conductors

Submitter Information Verification

Submitter Full Name: Peter Graser
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Affiliation: American Bimetallic Association
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 23 12:46:05 EDT 2020
Committee: NEC-P05

Testing done for the safety of our valued customer.

Global Circulation Laboratory Test Report

For Global Distribution

UL467 SHORT CIRCUIT & UL 486A-486B MECHANICAL SEQUENCE TESTS

YGHP29C2, YGHC2C2, YGHC26C26, YGHP34C29, YGHC29C29, YGHP34C34, YGHC34C34 HYTAP™ Connectors
YGL2C2, YGL29C29, YGL34C34 HYGRID™ Connectors
YGA4C2N, YGHA272N, YGA282N, YGHA302N HYLUG™ Connectors

5/8" and 3/4"Copper Clad Steel Ground Rod, #4AWG Solid, 4/0AWG Stranded, 7#7, and 19#8 COPPERWELD® 40% IACS Copper Clad Steel Conductors

PAT750XT-18V PATRIOT® Tool
with
UC, UO, U28RT, U29RT, U32RT, U997, PU998, and U1011 Die Sets

TD002391 REV B

Requested by / Date:	***Authorized by / Date:***	***Completed by / Date:***
C. Gandhi 12-Dec-2014	R Robicheau 12-Dec-2014	R Charpentier 06-Apr-2015
Engineering Approval / Date:	***Marketing Approval / Date:***	***Laboratory Approval / Date:***
R.Roman 20-Aug-2020	J Hogan 20-Aug-2020	R Charpentier 20-Aug-2020

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

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TEST EQUIPMENT : 5

Burndy LLC 47 East Industrial Park Dr.
Manchester / New Hampshire / 03109
Tel: 603 647 5000 Fax: 603 647 5205

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

PURPOSE OF TEST:

To determine if the Burndy HYTAP™, HYGRID™, and HYLUG™ Connectors can meet the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST REQUESTED:

UL486A-486B Mechanical Sequence
UL467 Short Time Current

TEST RESULTS:

Connector	Cable 1	Cable 2	Die	# of crimps	Securness	Pull	Short Time Current		
					Pass / Fail	Average Pull (lb)	Pass / Fail	Current (Amps)	Time (s)
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	U997	1	Pass	1021.3	Pass	1600	6
YGL2C2	#4 Solid CCS	#4 Solid CCS	U-O	1	Pass	1451.8	Pass	1600	6
YGHC2C2	#4 Solid CCS	#4 Solid CCS	U-C	1	Pass	1544.0	Pass	1600	6
YGA4C2N	#4 Solid CCS	n/a	U4CRT	1	Pass	814.0	Pass	1600	6
YGL29C29	7#7 STR CCS	7#7 STR CCS	U997	1	Pass	1643.2	Pass	4600	9
YGHC26C26	7#7 STRCCS	7#7 STR CCS	U-O	1	Pass	1239.4	Pass	4600	9
YGHA272N	7#7 STRCCS	n/a	U29RT	2	Pass	1574.0	Pass	4600	9
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PU998	1	Pass	1789.8	Pass	6100	9
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1849.8	Pass	6100	9
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1779.1	Pass	6100	9
YGA282N	4/0 AWG CCS	n/a	U28RT	2	Pass	2489.3	Pass	6100	9
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	U1011	3	Pass	2126.8	Pass	9000	9
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	U1011	3	Pass	2380.0	Pass	9000	9
YGL34C34	19#8 STRCCS	19#8 STR CCS	U1011	3	Pass	3158.3	Pass	9000	9
YGHC34C34	19#8 STR CCS	19#8 STR CCS	U1011	3	Pass	3812.1	Pass	9000	9
YGHA302N	19#8 STR CCS	n/a	U32RT	2	Pass	4792.2	Pass	9000	9

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TD002391

Global Circulation Laboratory Test Report

For Global Distribution

CONCLUSIONS:

All samples tested met the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST PROCEDURES

The table below shows the connector / conductor combinations tested.

Connector	Cable 1	Cable 2	Tool	Die	# of Crimps
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	PAT750	U997	1
YGL2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-O	1
YGHC2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-C	1
YGA4C2N	#4 Solid CCS	n/a	PAT750	U4CRT	1
YGL29C29	7#7 STR CCS	7#7 STR CCS	PAT750	U997	1
YGHC26C26	7#7 STR CCS	7#7 STR CCS	PAT750	U-O	1
YGHA272N	7#7 STR CCS	n/a	PAT750	U997	2
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PAT750	PU998	1
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGA282N	4/0 AWG CCS	n/a	PAT750	U997	2
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	PAT750	U1011	3
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	PAT750	U1011	3
YGL34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHC34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHA302N	19#8 STR CCS	n/a	PAT750	U32RT	2

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TD002391

Global Circulation Laboratory Test Report

For Global Distribution

All conductors were cut to twenty four (24) inch lengths.
All ground rod was pre-crimped with the appropriate pre-crimp die
5/8in Rod UPRECRIMP58
3/4in Rod UPRECRIMP34

Mechanical Sequence
Four samples of each set were secured to the Secureness tester, the height; weight and bushing size were as specified in UL486A-486B Table 26. Samples were rotated for thirty minutes at 9rpm. Samples were then subjected to a 1-minute pull to the value specified in UL486A-486B Table 27 and then to failure.

Short Time Current
Test samples were assembled in a series loop configuration then attached to a current controller as shown below. The test current and duration are listed below. After completion of the test, electrical continuity was checked with a digital multi-meter.

Test current values were derived from the equation Annex C of IEEE Std 837-2002. The diameter of the conductor(s) were measured and the cross-sectional area of the conductors was calculated.

Conductor	***Current Value (A)***	***Duration (sec)***
#4AWG Solid COPPERWELD® 40% IACS CCS	1600	6
4/0AWG 19 strand COPPERWELD® 40% IACS CCS,	6100	9
7#7 stranded COPPERWELD® 40% IACS CCS	4600	9
19#8 stranded COPPERWELD® 40% IACS CCS	9000	9

TEST EQUIPMENT LIST:

MANUFACTURER	MODEL	DESCRIPTION	SERIAL #	RANGE
FLUKE	79 III	DMM	70591301 (Rene)	AUTO
OHIO SEMITRONICS		CURRENT TRANSDUCER	NA	15000:5
SATEC	T5000	TABLE TOP	2038	5000 lbs
VIRTECH	NA	HIGH CURRENT	NA	12V / 12000A
MITUTOYO	505-675	DIAL CALIPER	08914565 (Rene)	6"

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CORROSION ON BURIED COPPER CLAD STEEL



Cece Syarif

Global Application Engineer

&

Anthony Hale

Manager, Utility Products, North America

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For more information, contact sales@copperweld.com.
The results and conclusions obtained from studies done by Copperweld are only applicable to Copper Clad Steel manufactured by Copperweld. Due to proprietary process used to produce the wire, the findings cannot be superimposed on any other copper-clad steel conductor.

254 Cotton Mill Rd, Fayetteville, TN 37334. Tel. (931) 433 – 7177

July 26, 2011

This paper compiles several studies and analysis regarding the corrosion performance of buried Copperweld® Copper-Clad-Steel (CCS) conductors. These range from the early 1900's with the invention of Copperweld® through the present day with studies performed by independent parties as well as Copperweld Company in-house testing. The purpose is to present the available information so that prospective users of Copperweld® CCS wire and strand can evaluate the corrosion resistance and expected performance within their specific application and area. Copperweld uses oxygen free copper in the manufacture of Copperweld® wire and strand. The copper surface of CCS is expected to oxidize and turn color ranging from green (patination) to brown and black the same as any solid copper wire or strand when exposed to environmental stimuli. Corrosion on exposed steel at the cut tip or end of the wire is also expected. The question to be answered is if the corrosion on either material or the interface between the copper and steel (galvanic reaction) will result in degradation of the wire as to make it unsuitable for use as a grounding conductor.

The oldest known underground corrosion study of bimetallic material was performed in the early 1900s[1]. This study focused on the corrosion behavior of Copperweld® CCS underground rod as well as other materials such as Copper and galvanized steel ground rod. The National Bureau of Standards (NBS) conducted an extensive underground corrosion study that involves 36,500 specimens which include 333 varieties of ferrous, nonferrous, and protective coating materials buried in 128 test locations throughout U.S in 1910 - 1955.

The study summarizes the service life of a ground rod as following:

10 mils copper coating – acceptable for service life up to 40 years

13 mils copper coating – acceptable for service life up to 50 years

Similarly, the Naval Civil Engineering Laboratory in collaboration with the National Association of Corrosion Engineers conducted a 7-year program of testing metal rods for electrical grounding to determine the galvanic corrosion effect. The three metals tested were stainless clad steel, copper-bonded steel (CCS), and galvanized steel. The result on the ⅝" CCS ground rod was as expected. The copper surface of the CCS was

virtually free of corrosion and the steel core has corroded at the tip approximately 2 inches down the length of the rod.

Copperweld Corporation is the inventor and sole manufacturer of Copperweld® Copper-bonded ground rods and Copperweld® wire and strand since 1915. The corrosion behavior of a Copperweld® ground rod is similar to the corrosion on Copperweld® wire and strand conductor. Both materials consist of copper permanently bonded to a steel core. All Copperweld® 40% CCS has a copper thickness of 10% of the overall diameter. For example, Copperweld® 4THOUGHT™ has a configuration of 19 strands of 0.1055 inch wires. It means that each strand has a copper thickness of 10.55 mils. Based on the NBS study, 4THOUGHT™ will have at least a minimum service life of 40 years.

Copperweld has also conducted a 5-year study of buried bare 21% conductivity (copper thickness is 3% of the diameter) Copperweld® CCS in 10 different soil conditions in association with Southwest Research Institute[2]. The study reported 100% surface oxidation and various degrees of deterioration of the steel core as expected after 5 years. The exposed steel on the tip of the wire rusted and formed "scab", as shown in Figure 1. The rust appeared to "seal-off" the un-oxidized material from the corrosive medium. The maximum depth of corrosion was 70% of the wire diameter.



Figure 1: Example of Underground Corrosion of Copper Clad Steel

Although the copper surface oxidation was heavy, the samples showed no signs of pits or holes in the copper cladding. The copper thickness of a severely oxidized 5-year sample showed no discernable difference when compared to an un-oxidized control sample that was not subjected to the corrosive environment. The mechanical and resistance testing

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resulted in negligible differences between 5-year samples and the control samples. Thus, the oxidation had no discernable impact on the strength or electrical performance of the wire.

An accelerated corrosion study based on ASTM B117 was conducted on bare CCS and solid Copper wires to evaluate copper surface corrosion. The wires were exposed to salt fog spray for 504 hours. As a result, corrosion on the CCS copper surface showed no significant difference as compared to the corrosion of copper wire.



(a) Copper Clad Steel (b) Copper

Figure 2: Patination of Copper Surface after 504 hours exposure to Salt Fog Spray

In February 2011, three separate sample strands of Copper Clad Steel were un-earthed and cut out from a substation built in Louisville, KY. The conductors were 40% conductivity, Low Carbon Steel, Dead Soft Annealed, 7 No. 5 (231,613 circular mil) and were installed in 1962.

Table 1: Physical properties of the three strands of Copperweld® conductor that had been buried underground for 48 years in a Kentucky substation

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			Strand 1	Strand 2	Strand 3
Conductor Type			40% Low Carbon Annealed		
Conductor Size			7 No. 5		
Cross Section Area		in^2	0.1819	0.1819	0.1819
Diameter of Single end		*inch*	0.1819	0.1819	0.1819
Diameter of Conductor		*inch*	0.5457	0.5457	0.5457
Copper Thickness	Min	*inch*	0.0142	0.0114	0.0134
	Max	*inch*	0.0213	0.0209	0.01975
% Concentricity			83.30%	77.30%	83.90%
Depth of corrosion	Min	*inch*	0.004	0.028	0.111
	Max	*inch*	0.781	0.859	0.484

The 1962 conductors were manufactured by Copperweld with a nominal copper thickness of 10% of its diameter. Figure 3 shows the copper thickness ranges from 11.4 – 21.3 mils and the concentricity of the conductor averaged at 81.5%. Current manufacturing improvements yield concentricity of copper thickness above 85%.

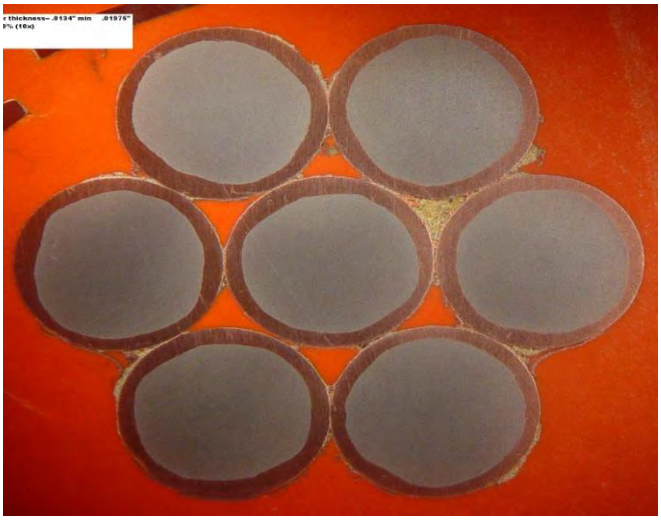


Figure 3: Copperweld® 40% LC DSA 7 No. 5 manufactured in 1962

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Figure 4a shows no visible corrosion observed other than oxidation and patination on the copper surface. At the ends of the wires, the corrosion occurred in the form of steel rust. The maximum depth of the corrosion is 0.859 inch with an average of 0.382 inch, as shown in Figure 4b.



Figure 4a: There is no visible corrosion between the copper and steel on all wires obtained from the substation in Kentucky.



Figure 4b: Corrosion occurred at the ends of the wires. Maximum penetration depth is 0.859 inch.

From all the corrosion studies above, there have not been reported or observed any galvanic corrosion at the interface of copper and steel. The process of cladding for

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Copperweld® ensures a metallurgical bond between the two metals. That metallurgical bond prevents any moisture from penetrating between the two metals precluding the corrosion process. Any propagation of corrosion on an area of exposed steel averages two times the diameter of the wire then stops. The corrosion rate of the copper surface is equivalent to that observed on standard solid copper wire and strand. Based on the results of these studies, it can be summarized that CCS can be expected to have a 50 plus year service life as buried grounding conductors.

REFERENCES:

1. Rempe, Chris. 7 July 2003. "A Technical Report on the Service Life of Ground Rod Electrodes".
2. Fox, Dustin, Belado, Chris, and Brossia, Sean. 23 September 2009. "The Effect of Corrosion on Tracer Wire with a Copper Clad Steel Center Conductor".

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Revision: 0 Issued: 2020-04-15

Copper and CCS Wire Withstand Current and Fusing Current Tests

Copperweld Bimetallics, LLC



The Power of Trust. **The Future of Energy.**

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REPORT OF PERFORMANCE

CLIENT	Copperweld Bimetallics,LLC. 5141 Virginia Way, Suite 410 Brentwood, TN, United States 37027
TEST OBJECTS	Copper Clad Steel (CCS) Wires Manufacturer: Copperweld Bimetallics,LLC. Types: Scorpius Prototypes Part Nos.: 61 x 072 7 x 080 Condition: New Copper Conductor Manufacturer: Encore Wire Types: #4/0 AWG (19 strand) CU #6 AWG (single strand) CU Condition: New
TESTED BY	Powertech Labs Inc. 12388 - 88th Ave, Surrey, BC Canada V3W 7R7 www.powertechlabs.com
TEST DATE	2020-01-24 to 2020-01-25
TEST SPECIFICATION	Client Specified, with reference to IEEE Std 80-2013 and IEEE Std 837-2014

Powertech Labs Inc. does not accept any liability for any damages resulting from the use of this report. The results relate only to the item tested, and it is the responsibility of the manufacturer to maintain conformity of any object having the same designations. Information regarding the estimated measurement uncertainty is available upon request. The test report shall not be reproduced except in full, without written approval of Powertech Labs Inc.

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1 INTRODUCTION

At the request of Copperweld Bimetallics,LLC., withstand current and fusing current tests were performed on standard copper and copper clad steel (CCS) wires in accordance with specifications and procedures provided by the client. Reference was made to IEEE Std 80-2013 and IEEE Std 837-2014 as guides for determining current levels and durations for the tests.

The High Power Lab is accredited by the Standards Council of Canada to ISO 17025 for short-circuit testing.

2 TEST OBJECT INFORMATION

The test objects were identified by the client as follows:

Copper Clad Steel Wires (CCS)

Manufacturer:	Copperweld Bimetallics,LLC.
Types:	Scorpius Prototypes
Part Nos.:	61 x 072
	7 x 080
Condition:	New

Copper Conductor

Manufacturer:	Encore Wire
Types:	4/0 AWG (19 strand) CU
	#6 AWG (single strand) CU
Condition:	New

Conductor sample diameters and dc resistance values were measured by the laboratory before testing, as presented in Table 1.

3 GENERAL INFORMATION

3.1 Purpose

The purpose of the tests is to identify the current limits at short durations for standard copper and Copperweld CCS grounding wire products, and to determine if these products meet the applicable requirements of the referenced Standards.

3.2 Witnesses

Name	Company
Jeff Jordan	Copperweld Bimetallics,LLC.
Lora Aboulmouna	Copperweld Bimetallics,LLC.
Jason Smolko	Copperweld Bimetallics,LLC.
Ryan Hale	Copperweld Bimetallics,LLC.

3.3 Tests Performed

Test Standards/Specifications:

Withstand current tests were performed as requested by the client, with reference to the following Standards to determine the test levels:

IEEE Std 80-2013, Table 6 – Specification for the ultimate current carrying capacity of copper grounding cables using symmetrical current.

IEEE Std 837-2014, Clause 7.2 and Table 3 – Electromagnetic force (EMF) test

4 SHORT-CIRCUIT CURRENT TESTS

General Information:

Standard	Client's Specification, with reference to IEEE Std 80-2013 and IEEE Std 837-2014
Test Dates	2020-01-24 to 2020-01-25
Test Leader	Chris Morton

Environmental Conditions:

Ambient temperature	(7 – 9) °C
Relative Humidity	(95 – 99) %

Test Conditions:

Samples were tested in a covered test cell which was open on one side to the outdoor ambient conditions. During each test, one sample was connected horizontally between the laboratory source bus and ground bus, at a bus spacing of 48 inches, as shown in Figures 30 through 33. The samples were terminated using Burndy mechanical connectors, as shown in Figures 34 and 35. The length of each wire sample was the minimum length required to span the distance between the buses, and each sample was at approximately right angles (90°) to both the source and ground bus. Each sample was suspended in free air approximately 46 inches above the floor of the test cell. The temperature of the sample at the start of each test was the natural outdoor ambient temperature of the laboratory, except for tests performed to IEEE 837, where the sample was allowed to cool to less than 100 °C before the second shot.

All tests were performed at a power frequency of 60 Hz using the test circuit shown in Figure 1. Current was initiated by energizing a current limited source that was calibrated to provide the target current through the circuit. The rms current, current symmetry and duration of each test were specified by the client.

The test current was measured using a 300 kA_{peak} rated Rogowski coil (Powertech ID № 39444). The expanded uncertainty of the current measuring system is estimated as 2% (k=2).

Test Results:

The results of the tests are provided in Tables 2 through 5. Current and voltage waveforms for each test are provided in Figures 2 through 29.

The Encore #4/0 AWG Cu wire did not withstand the I^2t calculated from the current and duration specified in IEEE 80, Table 6, for a 500 ms duration (44 kA_{rms}). It was capable of carrying a maximum of 92% of this I^2t value without fusing.

The Encore #4/0 AWG Cu wire did not withstand the EMF current specified in IEEE 837, Table 3 (47 kA_{rms}). It was capable of carrying a maximum of 91% of this current value without failing.

The Copperweld Scorpius CCS 61 x 072 conductor exceeded the 500 ms rms withstand current requirement of IEEE 80, Table 6, and met the EMF current requirements of IEEE 837, Table 3, for a 4/0 conductor.

For the #6 AWG Cu conductor size the Standards did not have current values specified, so these were calculated using Equation (45) from IEEE 80 and Equation (C.1) from IEEE 837. The calculations are presented in Appendix D.

Both the Copperweld Scorpius CCS 7 x 080 conductor and the Encore #6 AWG Cu conductor met the 500 ms rms withstand current requirement of IEEE 80, Table 6 (5.29 kA_{rms}), and the EMF current requirements of IEEE 837, Table 3 (5.81 kA_{rms}), for a #6 AWG Cu conductor.

APPENDIX A – FUSING CURRENT TEST CIRCUIT AND DATA

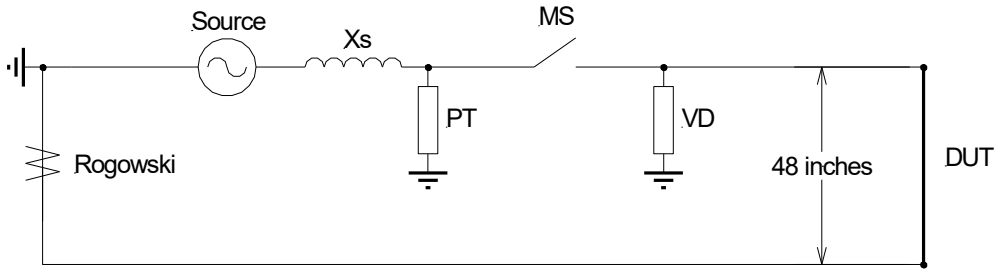


Figure 1: Test circuit schematic for all tests.

Notes:

1. X_S – Source current limiting reactance
2. MS – Making Switch
3. VD – Voltage measurement
4. Rogowski – Current measurement
5. DUT – Device Under Test

Table 1: Strand diameter and dc resistance measurements of sample conductors.

Wire Sample No.	Type	Strand Diameter [1] (in)		Conductor Diameter	Dc Resistance at 20°C
#		1	2	(in)	(μΩ/ft)
1	Encore Wire, 4/0 AWG, 19 strand CU	0.122	0.079	0.492	4.28
2	Encore Wire, 4/0 AWG, 19 strand CU	0.118	0.080	0.501	4.10
3	Encore Wire, 4/0 AWG, 19 strand CU	0.109	0.074	0.495	4.23
4	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.075	0.498	3.98
5	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.079	0.489	4.43
6	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.075	0.490	4.17
7	Encore Wire, 4/0 AWG, 19 strand CU	0.101	0.075	0.489	4.18
8	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.074	0.491	4.15
9	Encore Wire, 4/0 AWG, 19 strand CU	0.106	0.082	0.490	3.97
10	Encore Wire, 4/0 AWG, 19 strand CU	0.105	0.079	0.493	3.73
11	Scorpius 61 x 072 CCS	0.056	---	0.646	6.83
12	Scorpius 61 x 072 CCS	0.058	---	0.649	6.60
13	Scorpius 61 x 072 CCS	0.068	---	0.641	6.60
14	Scorpius 61 x 072 CCS	0.056	---	0.639	6.73
15	Scorpius 61 x 072 CCS	0.067	---	0.646	6.62
16	Scorpius 61 x 072 CCS	0.059	---	0.630	6.53
17	Scorpius 61 x 072 CCS	0.056	---	0.642	6.73
18	Scorpius 61 x 072 CCS	0.067	---	0.637	6.62
19	Scorpius 61 x 072 CCS	0.064	---	0.641	6.85
20	Scorpius 61 x 072 CCS	0.059	---	0.633	6.83
21	Encore Wire, #6 AWG, single strand CU	0.152	---	0.152	33.3
22	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
23	Encore Wire, #6 AWG, single strand CU	0.158	---	0.158	33.2
24	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.4
25	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.3
26	Encore Wire, #6 AWG, single strand CU	0.148	---	0.148	33.6
27	Encore Wire, #6 AWG, single strand CU	0.155	---	0.155	33.3
28	Encore Wire, #6 AWG, single strand CU	0.146	---	0.146	33.1
29	Encore Wire, #6 AWG, single strand CU	0.153	---	0.153	33.2
30	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
31	Scorpius 7 x 080 CCS	0.072	---	0.215	46.3
32	Scorpius 7 x 080 CCS	0.069	---	0.226	45.9
33	Scorpius 7 x 080 CCS	0.065	---	0.220	46.2
34	Scorpius 7 x 080 CCS	0.071	---	0.218	46.4
35	Scorpius 7 x 080 CCS	0.073	---	0.212	46.1
36	Scorpius 7 x 080 CCS	0.065	---	0.216	46.3
37	Scorpius 7 x 080 CCS	0.070	---	0.211	46.1

Note:

[1] Encore 4/0 AWG CU conductor had two sizes of strands, all remaining conductors had one size of strands. Strand and conductor diameters were measured using a digital caliper with a resolution of 0.001 in.

Table 2: Summary of tests on Encore 4/0 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
1	1	Run to fusing	3.85	41.7	60.0	530	923	2	Y
2	2	Withstand	3.85	41.8	62.5	509	889	3	N
3-1	3	EMF (IEEE 837)	4.24	48.0	130	262	826	4	N
3-2	3	EMF (IEEE 837)	4.26	48.0	130	127	503	5	Y
4	4	EMF (IEEE 837)	4.25	48.0	130	260	823	6	Y
5-1	5	EMF (IEEE 837)	4.20	47.4	129	262	808	7	N
5-2	5	EMF (IEEE 837)	4.19	47.4	128	9.9	77	8	Y
6-1	6	EMF (IEEE 837)	3.93	42.6	116	263	662	9	N
6-2	6	EMF (IEEE 837)	3.91	42.6	116	262	654	10	N

Table 3: Summary of tests on Copperweld Scorpius 61 x 072 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
7	11	Run to fusing	3.84	41.7	59.6	673	1173	11	Y
8	12	Run to fusing	4.25	48.1	69.8	500	1157	12	Y
9	13	Run to fusing	4.21	47.5	68.9	508	1150	13	Y
10	14	Withstand	4.09	46.2	66.2	508	1089	14	N
11-1	15	EMF (IEEE 837)	4.21	47.6	129	262	803	15	N
11-2	15	EMF (IEEE 837)	4.20	47.7	129	262	803	16	N
12-1	16	EMF (IEEE 837)	4.21	47.6	129	254	784	17	N
12-2	16	EMF (IEEE 837)	4.19	47.4	128	254	767	18	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

Table 4: Summary of tests on Encore #6 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
13	21	Run to fusing	3.90	5.18	7.36	607	16.3	19	Y
14	23	Run to fusing	3.90	5.18	7.57	600	16.1	20	Y
15	24	Run to fusing	4.27	5.68	8.15	500	16.1	21	Y
16-1	25	EMF (IEEE 837)	3.77	5.86	16.2	262	13.9	22	N
16-2	25	EMF (IEEE 837)	3.77	5.86	16.1	262	13.9	23	N

Table 5: Summary of tests on Copperweld Scorpius 7 x 080 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
17	31	Withstand	3.88	5.16	7.44	858	22.9	24	N
18	32	Run to fusing	3.89	5.16	7.43	908	24.2	25	Y
19	33	Run to fusing	4.48	7.00	10.3	493	24.1	26	Y
20	34	Run to fusing	4.41	6.91	10.2	502	23.9	27	Y
21-1	35	EMF (IEEE 837)	3.81	5.91	16.3	262	14.0	28	N
21-2	35	EMF (IEEE 837)	3.80	5.92	16.2	262	13.8	29	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

APPENDIX B – WAVEFORMS

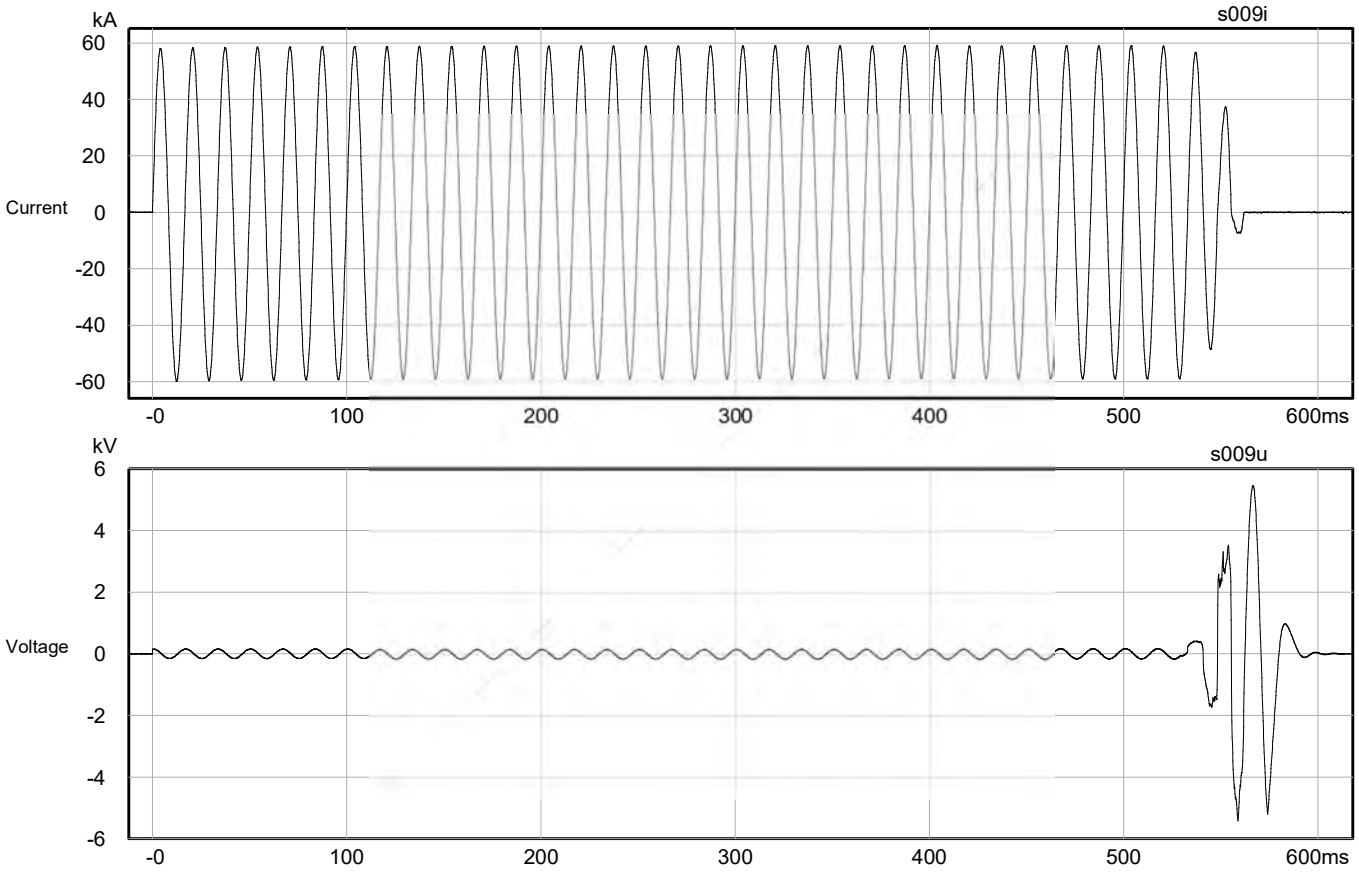


Figure 2: Waveforms for Test #1, Encore 4/0 AWG Sample 1.

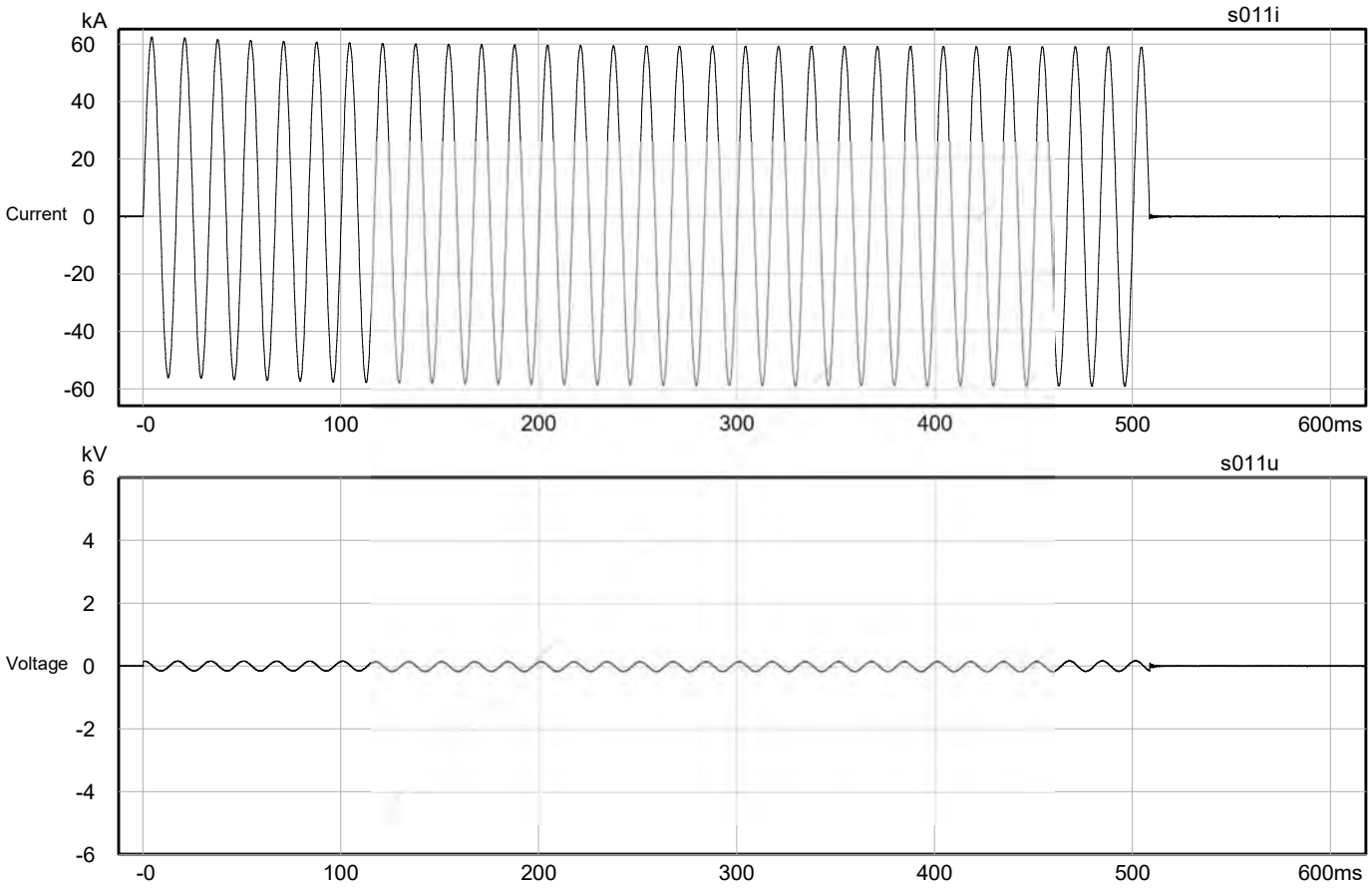


Figure 3: Waveforms for Test #2, Encore 4/0 AWG Sample 2.

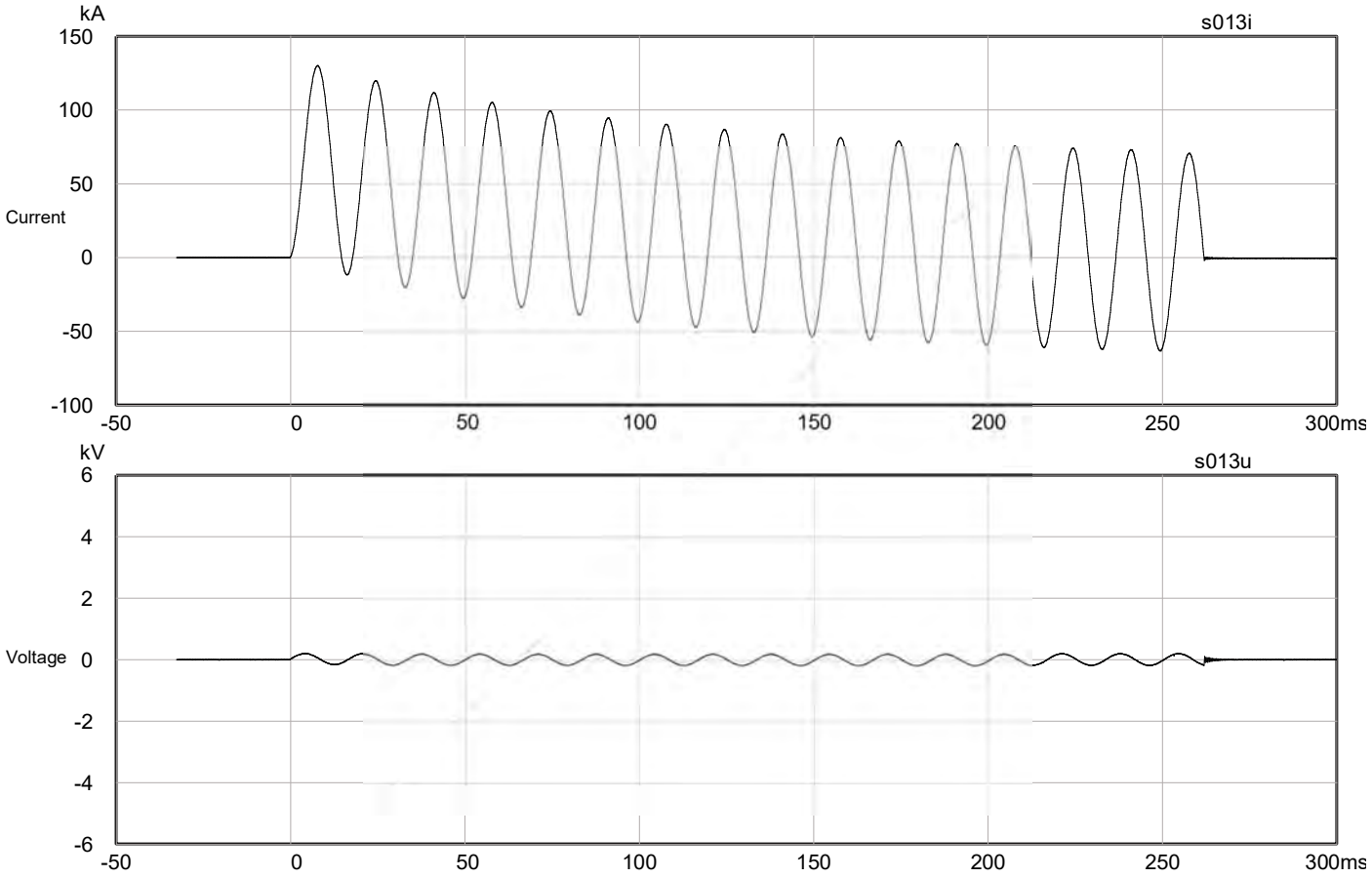


Figure 4: Waveforms for Test #3-1, Encore 4/0 AWG Sample 3.

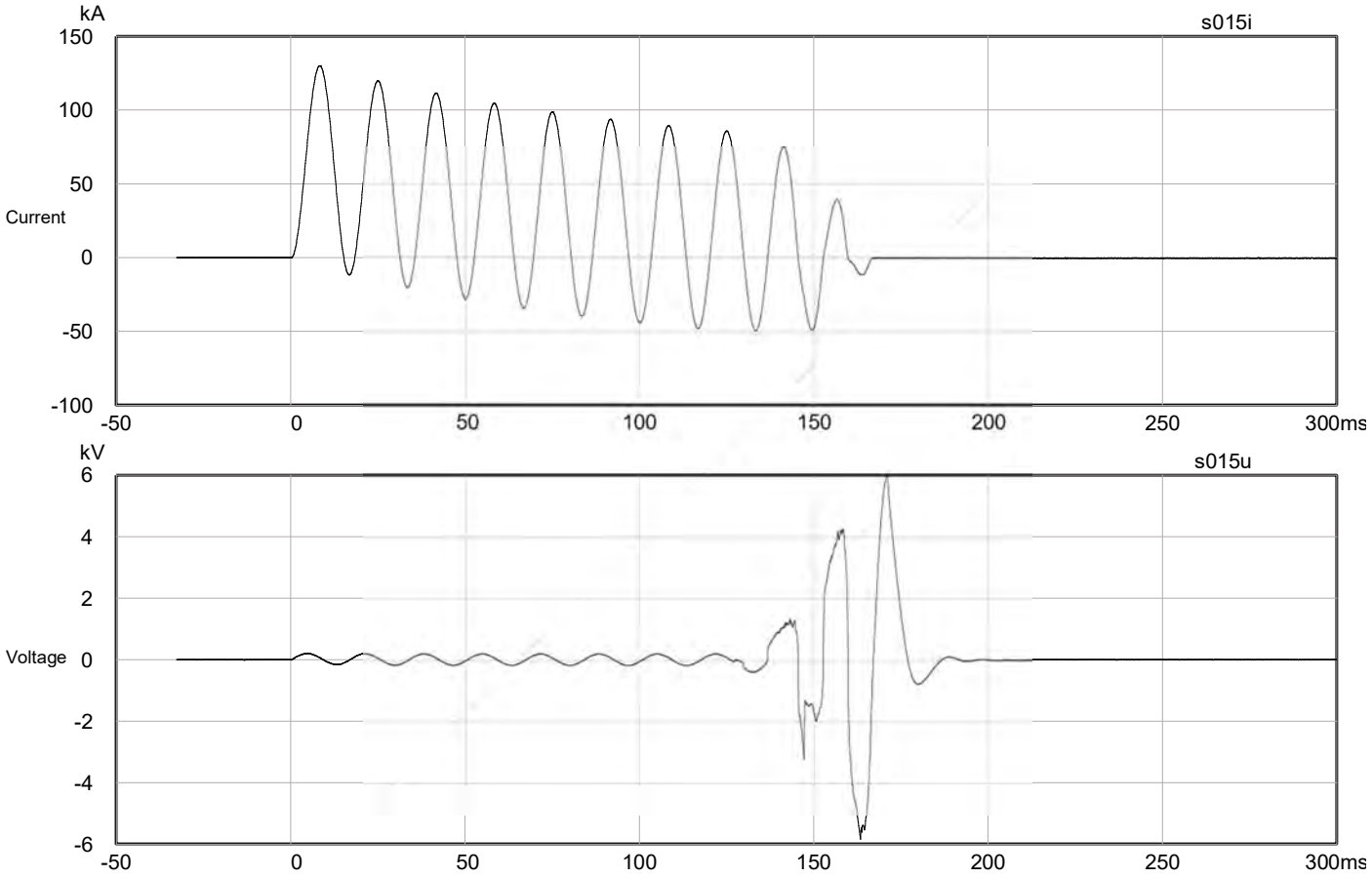


Figure 5: Waveforms for Test #3-2, Encore 4/0 AWG Sample 3.

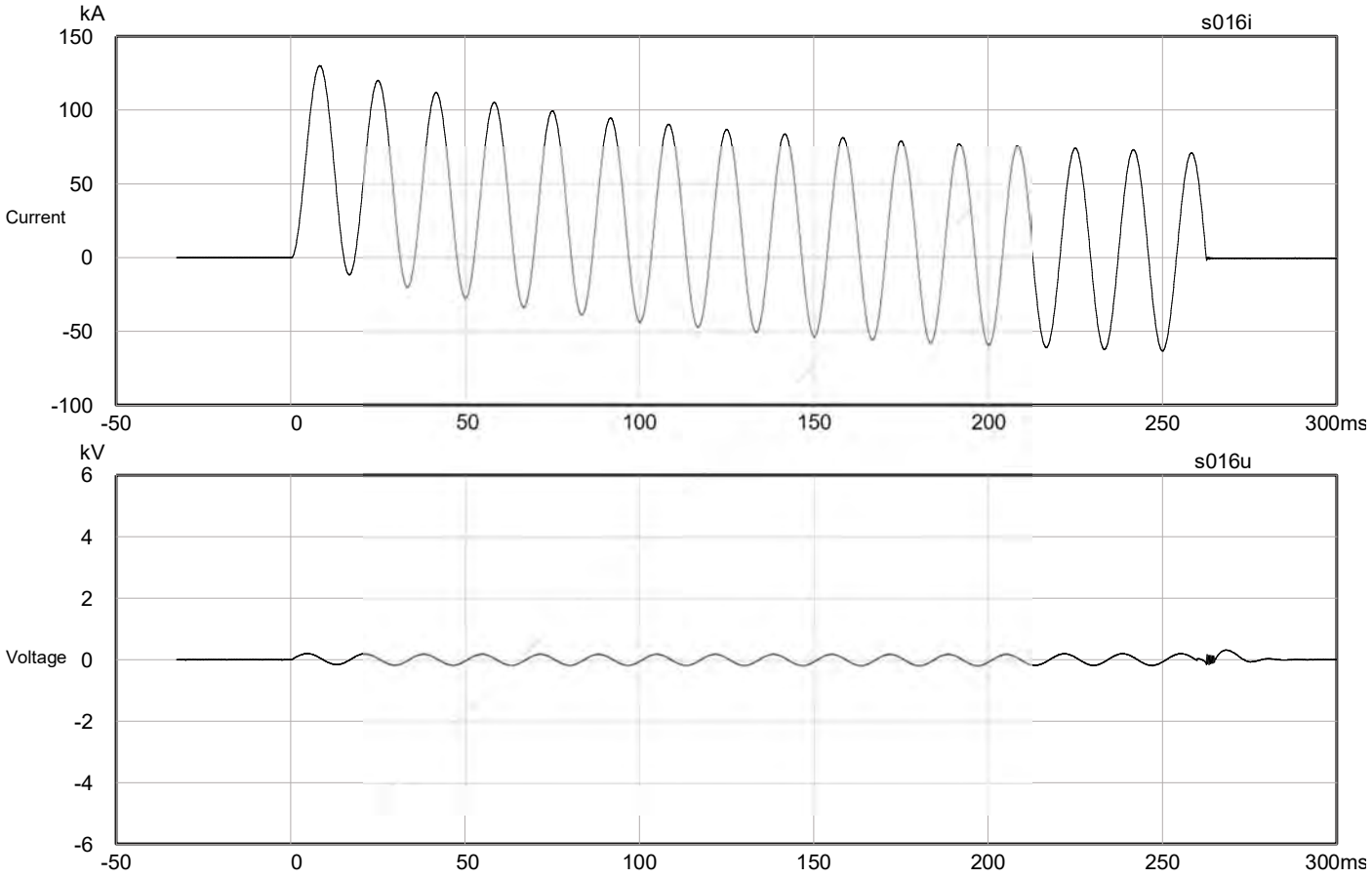


Figure 6: Waveforms for Test #4, Encore 4/0 AWG Sample 4.

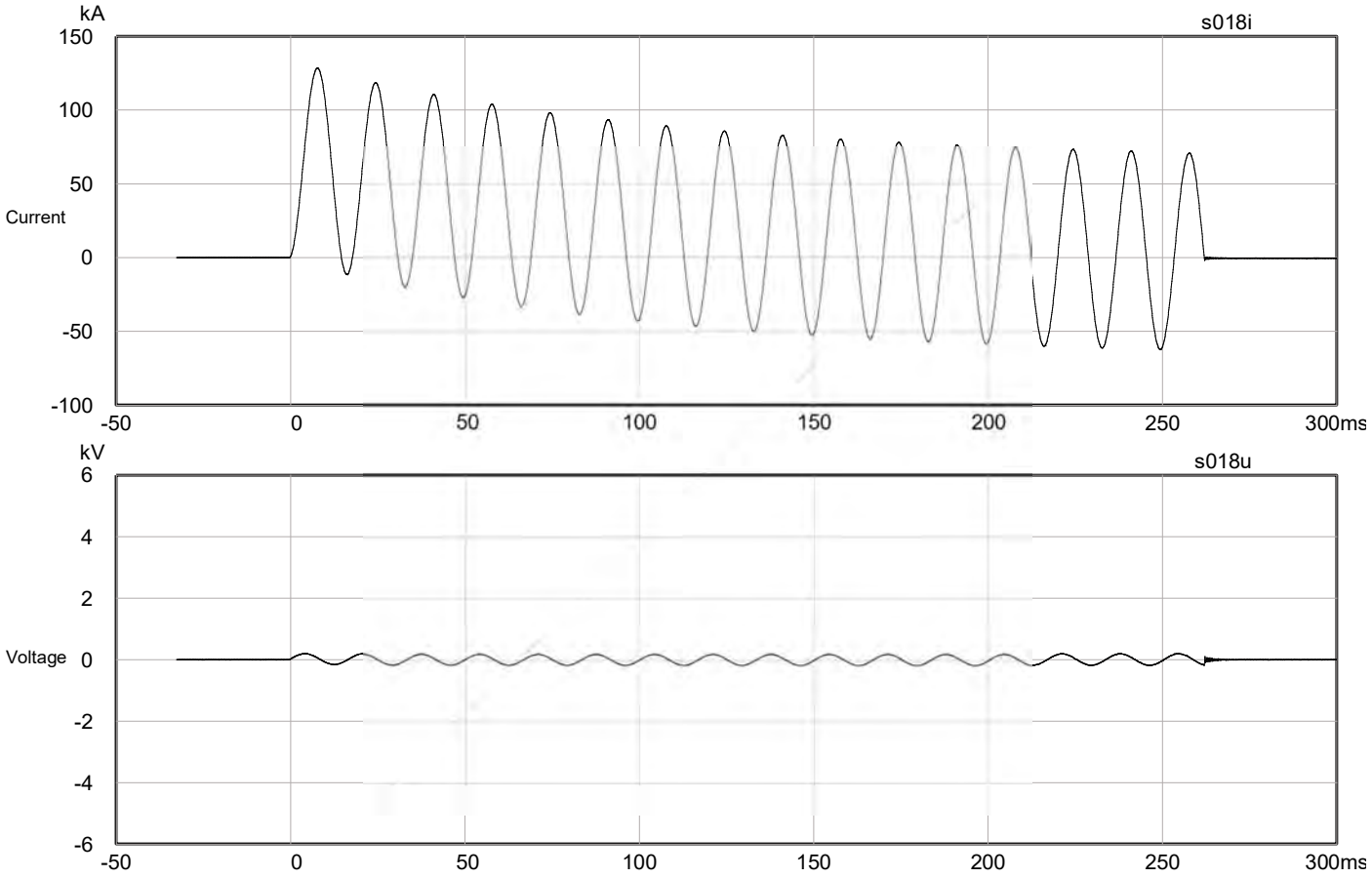


Figure 7: Waveforms for Test #5-1, Encore 4/0 AWG Sample 5.

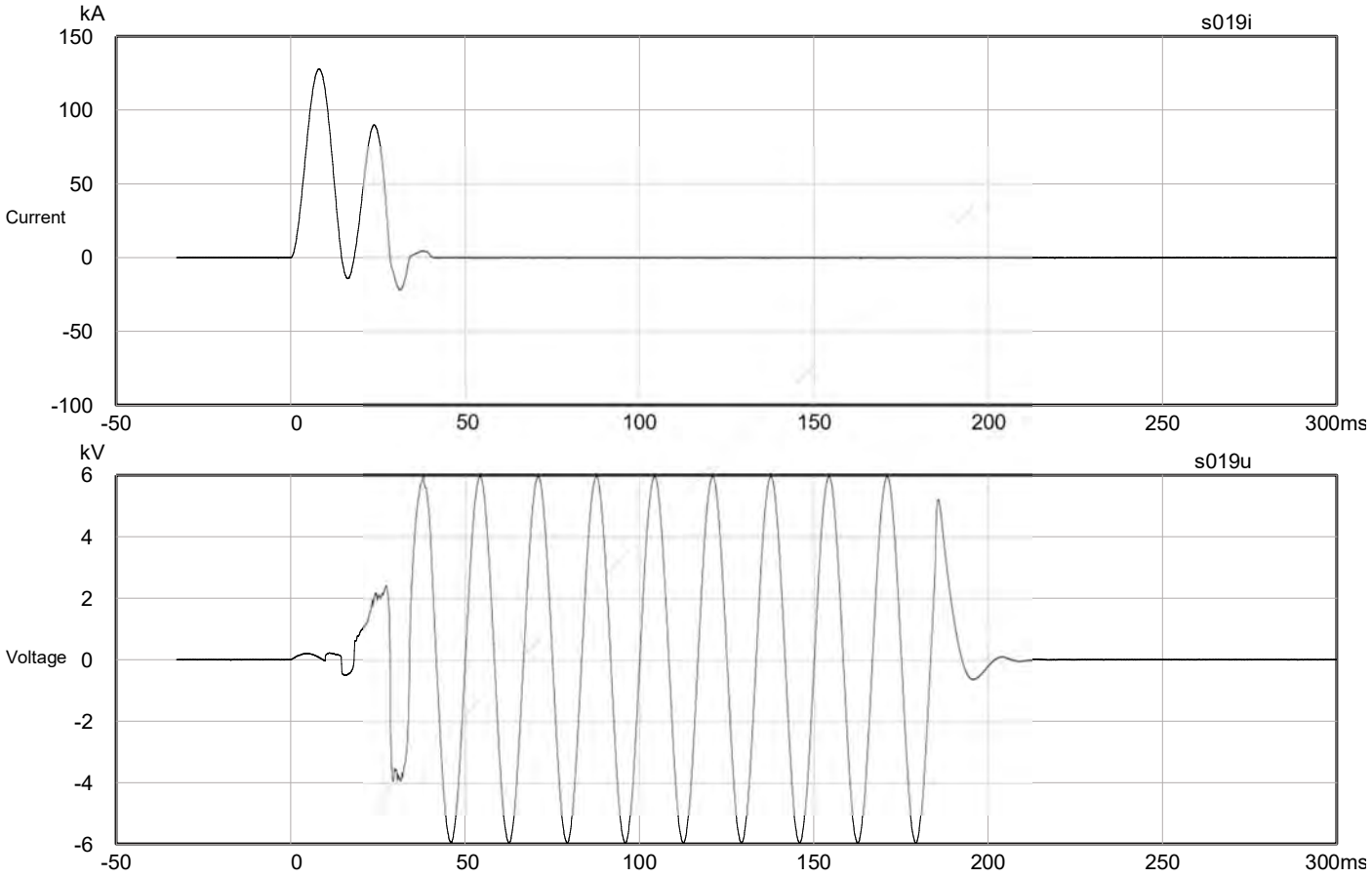


Figure 8: Waveforms for Test #5-2, Encore 4/0 AWG Sample 5.

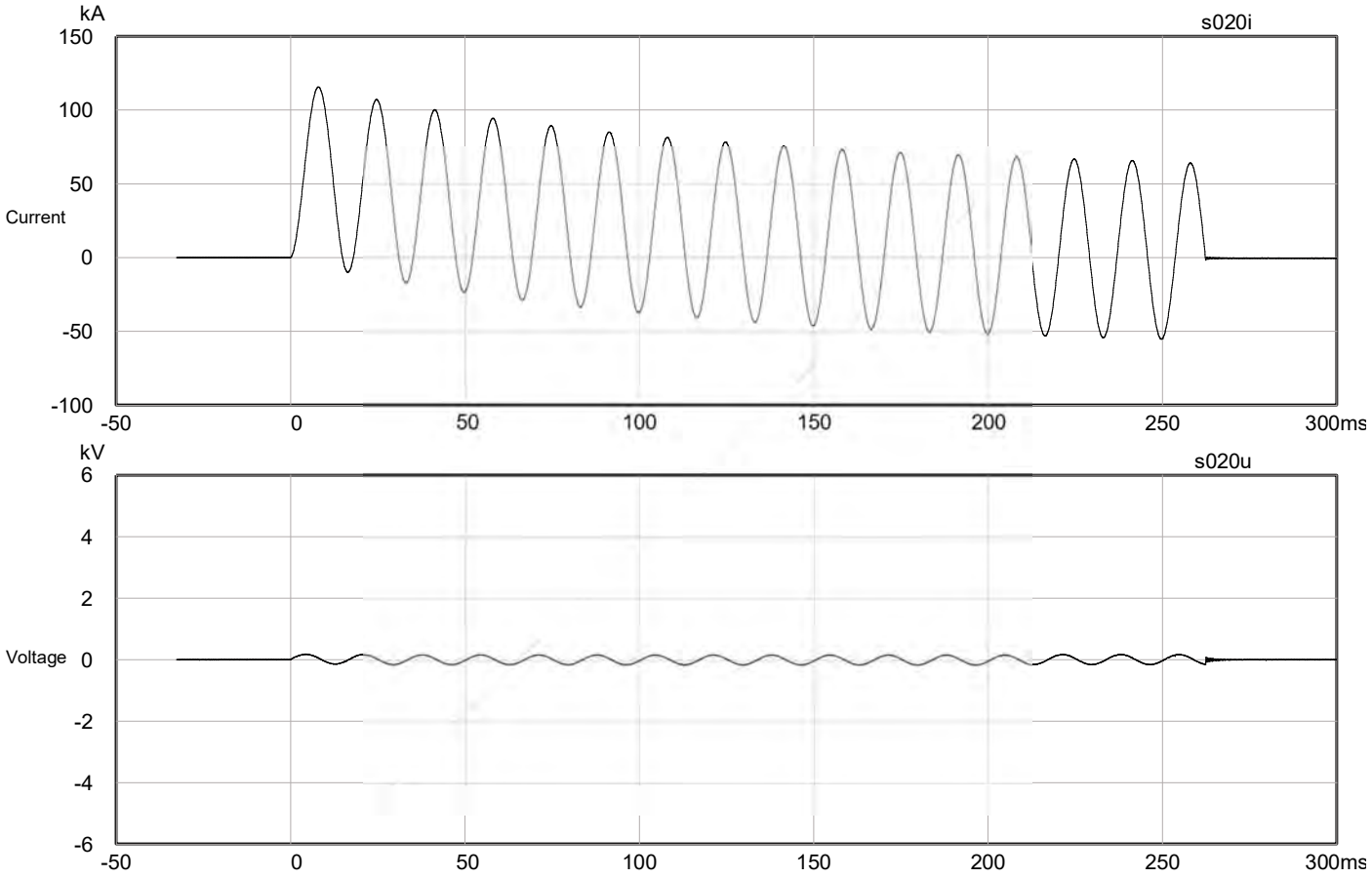


Figure 9: Waveforms for Test #6-1, Encore 4/0 AWG Sample 6.

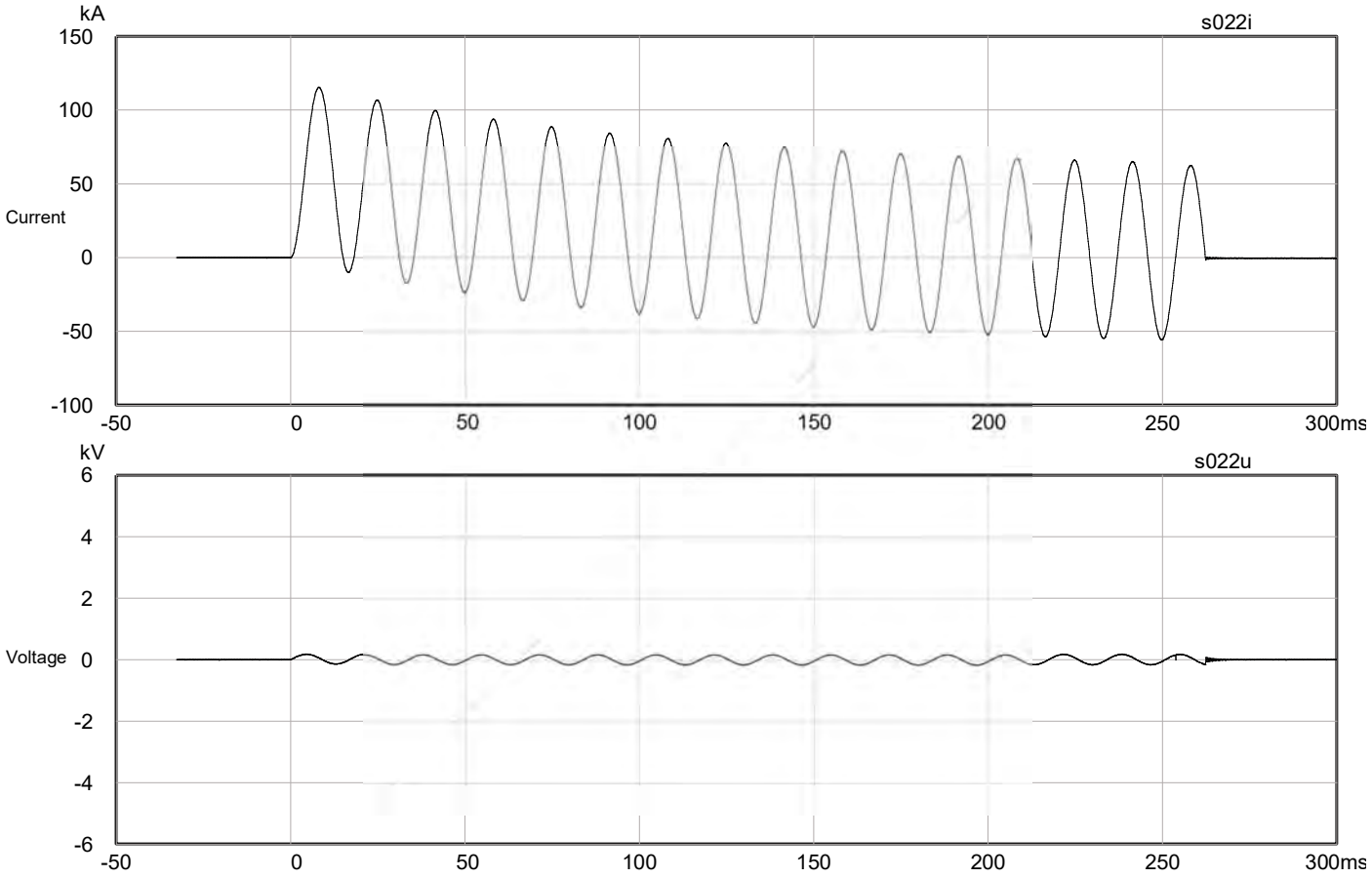


Figure 10: Waveforms for Test #6-2, Encore 4/0 AWG Sample 6.

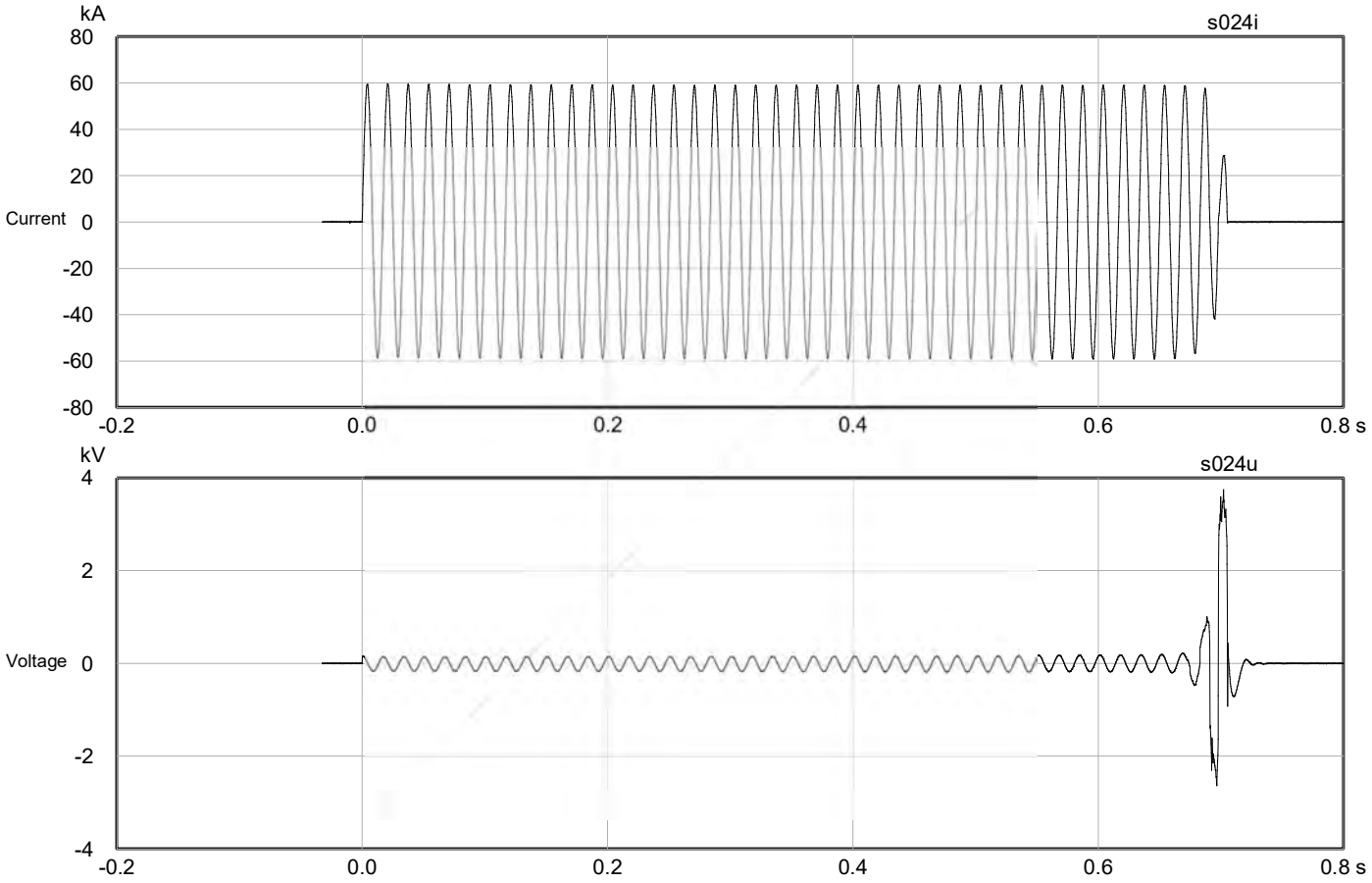


Figure 11: Waveforms for Test #7, Copperweld Scorpius 61 x 072 Sample 11.

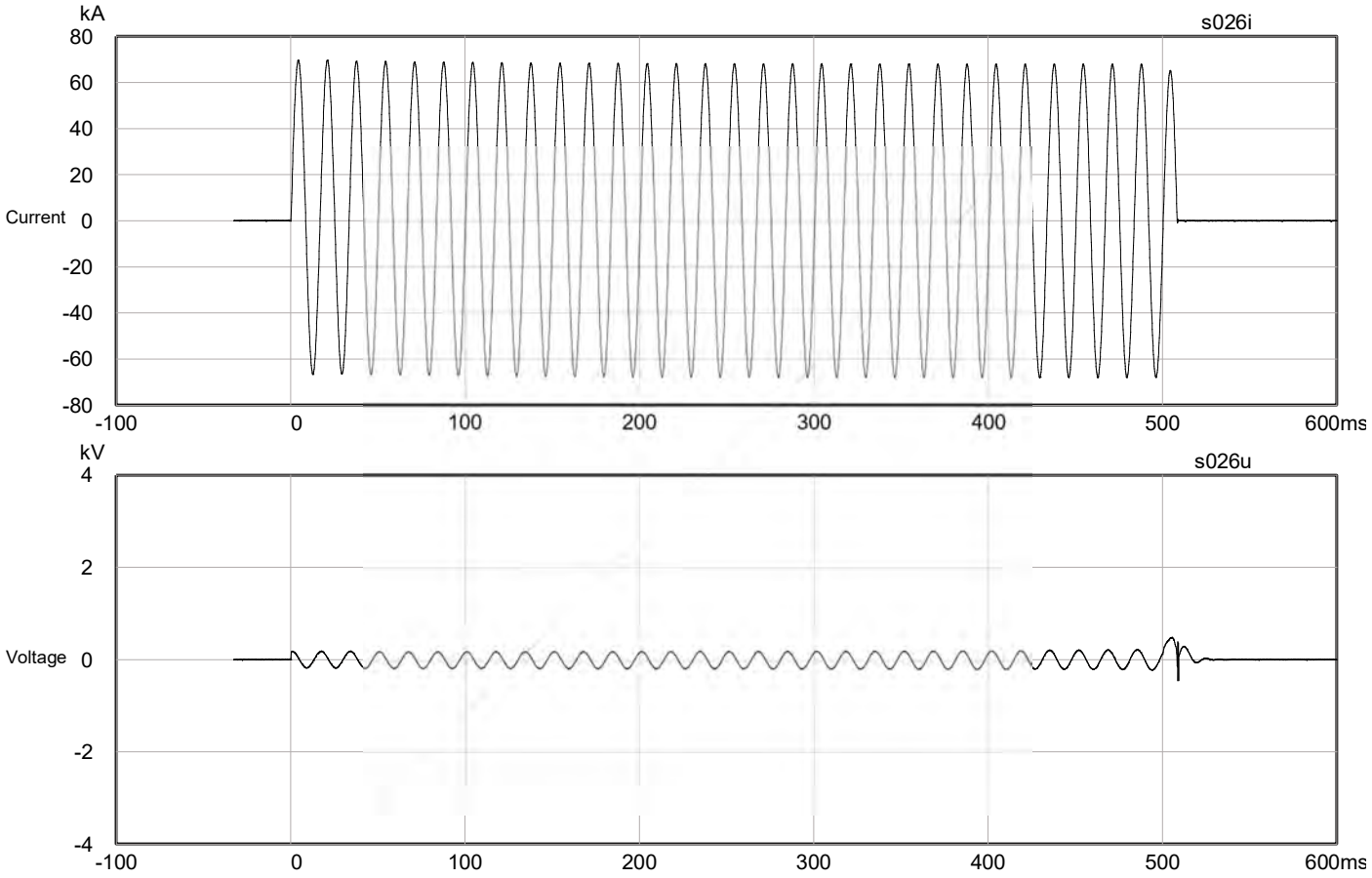


Figure 12: Waveforms for Test #6, Copperweld Scorpius 61 x 072 Sample 12.

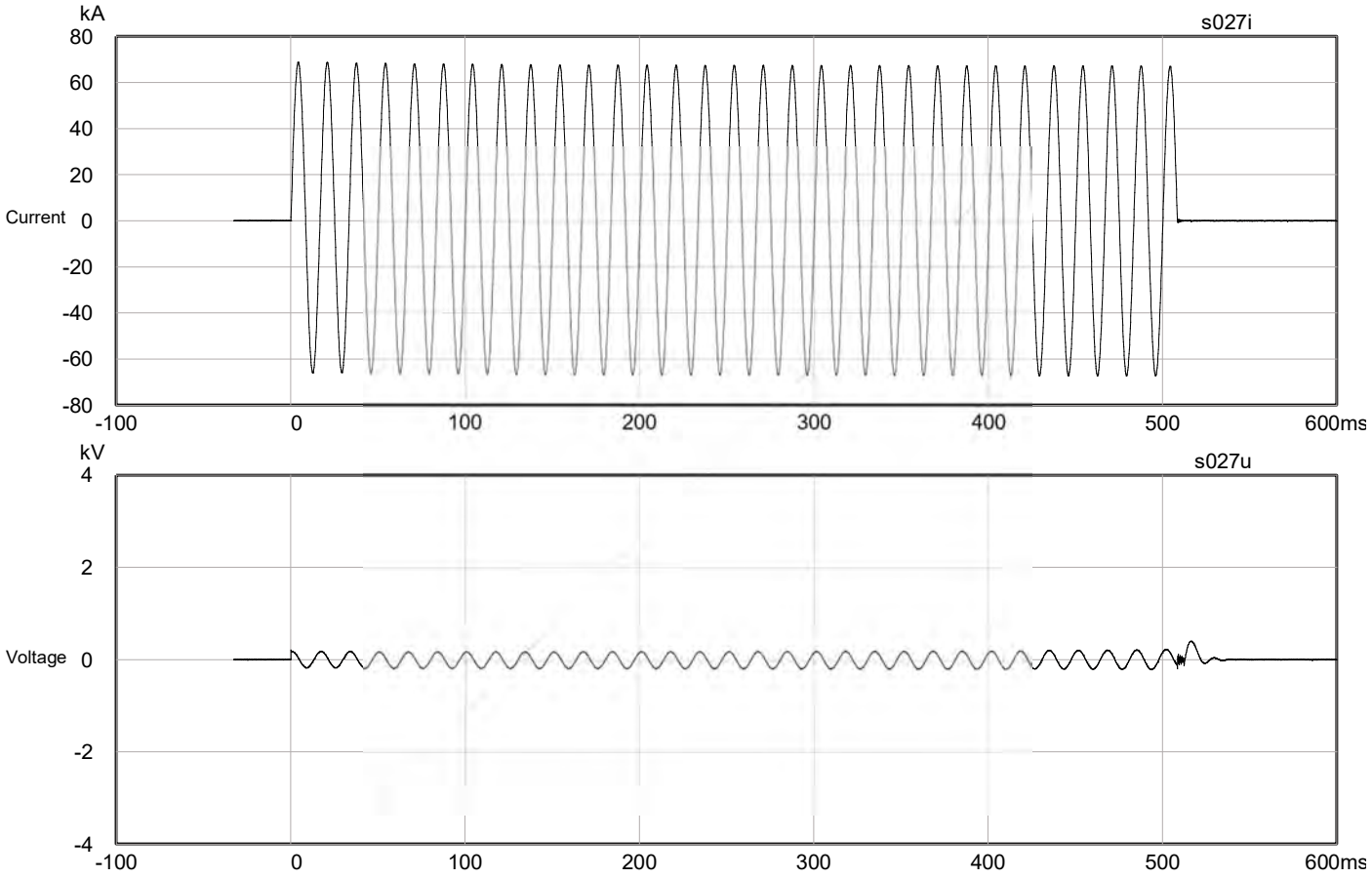


Figure 13: Waveforms for Test #9, Copperweld Scorpius 61 x 072 Sample 13.

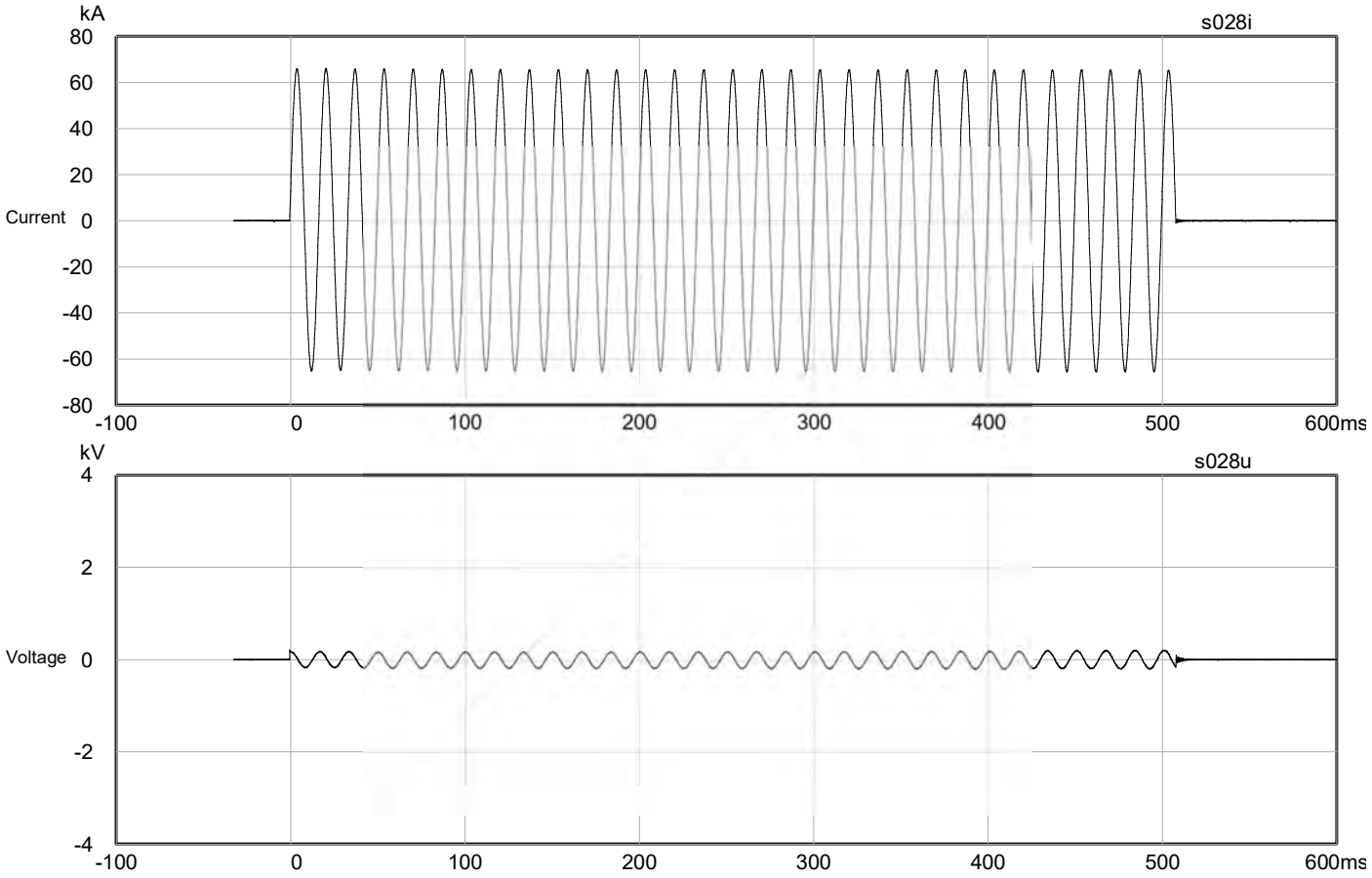


Figure 14: Waveforms for Test #10, Copperweld Scorpius 61 x 072 Sample 14.

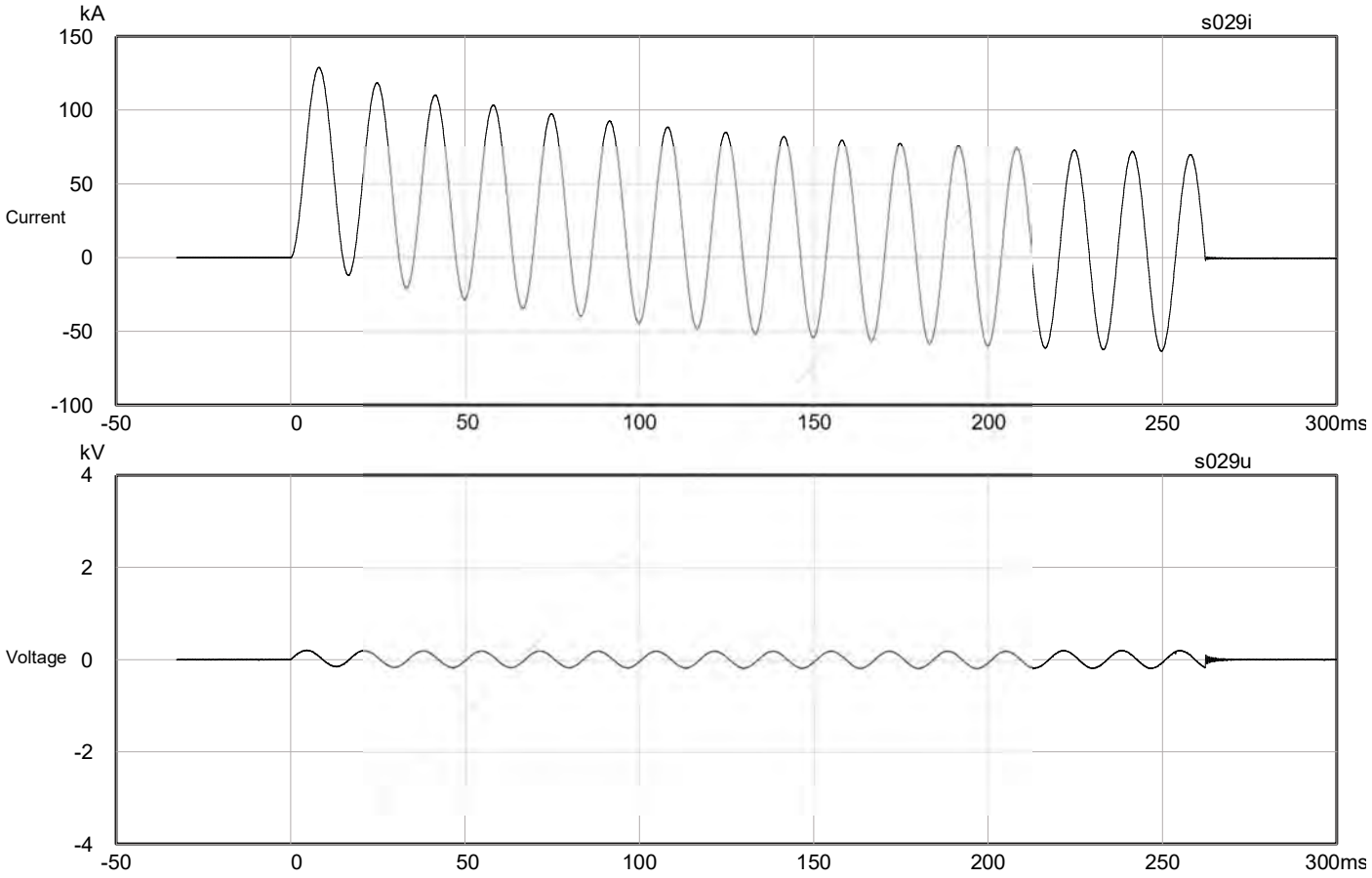


Figure 15: Waveforms for Test #11-1, Copperweld Scorpius 61 x 072 Sample 15.

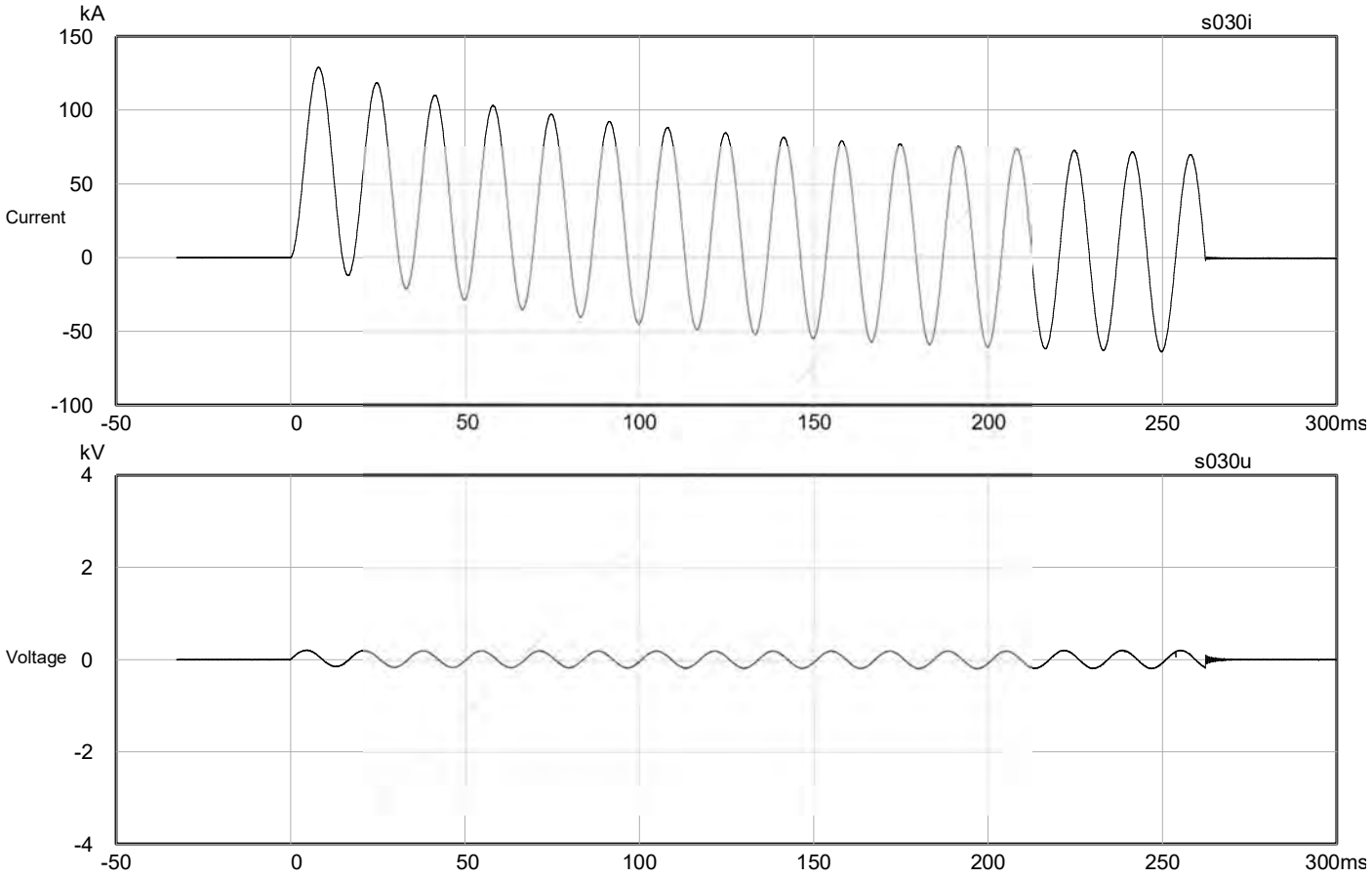


Figure 16: Waveforms for Test #11-2, Copperweld Scorpius 61 x 072 Sample 15.

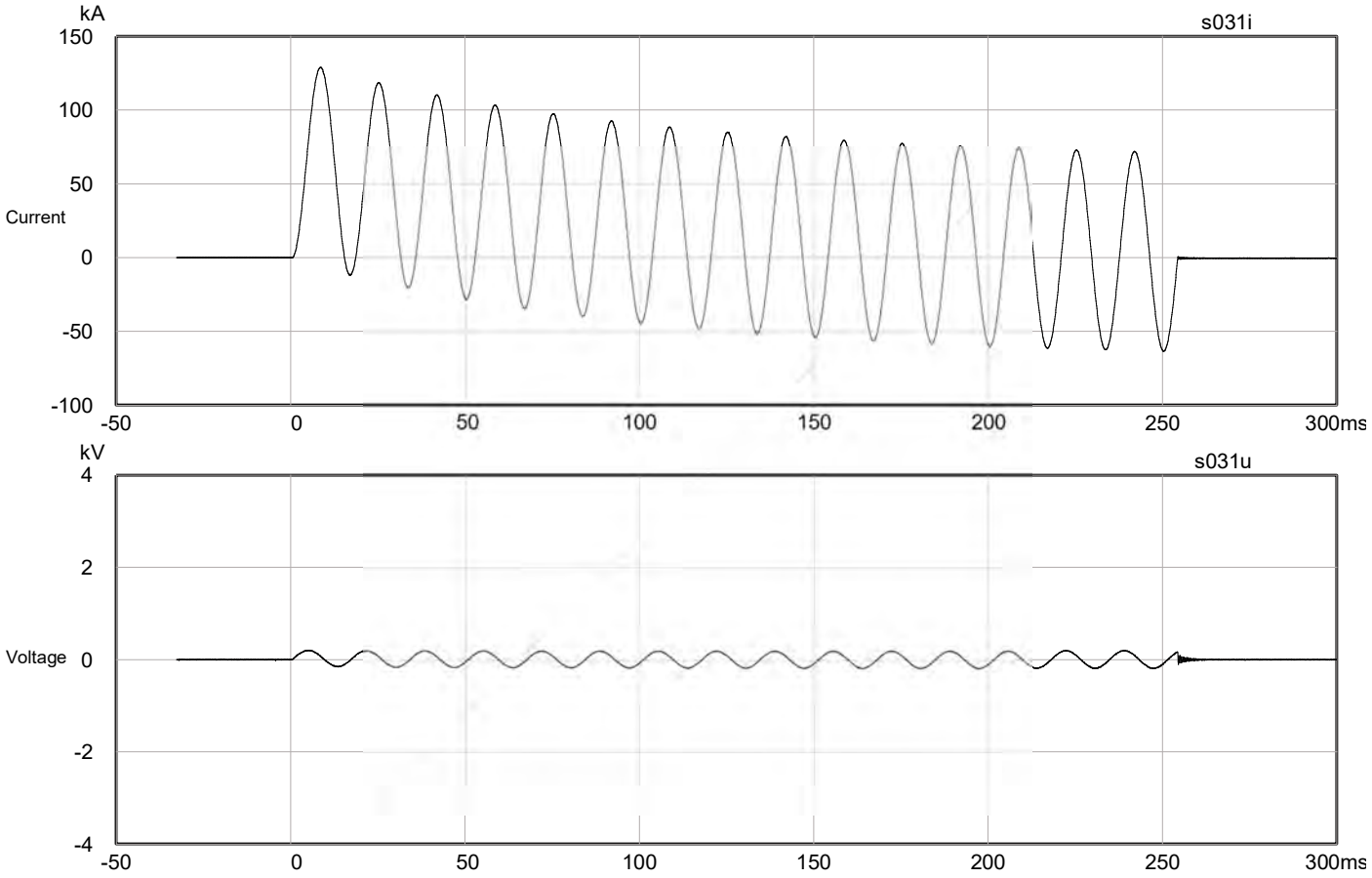


Figure 17: Waveforms for Test #12-1, Copperweld Scorpius 61 x 072 Sample 16.

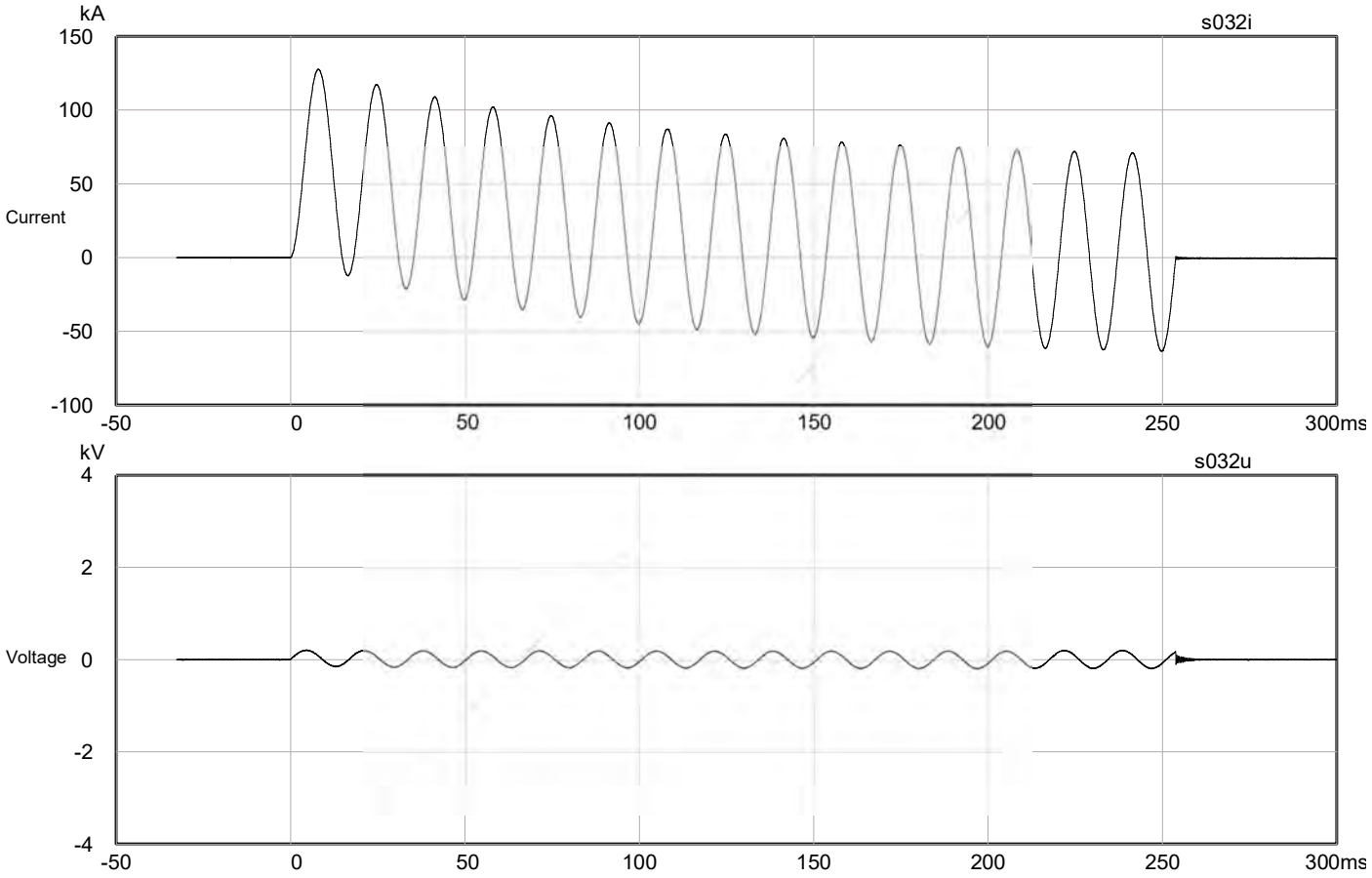


Figure 18: Waveforms for Test #12-2, Copperweld Scorpius 61 x 072 Sample 16.

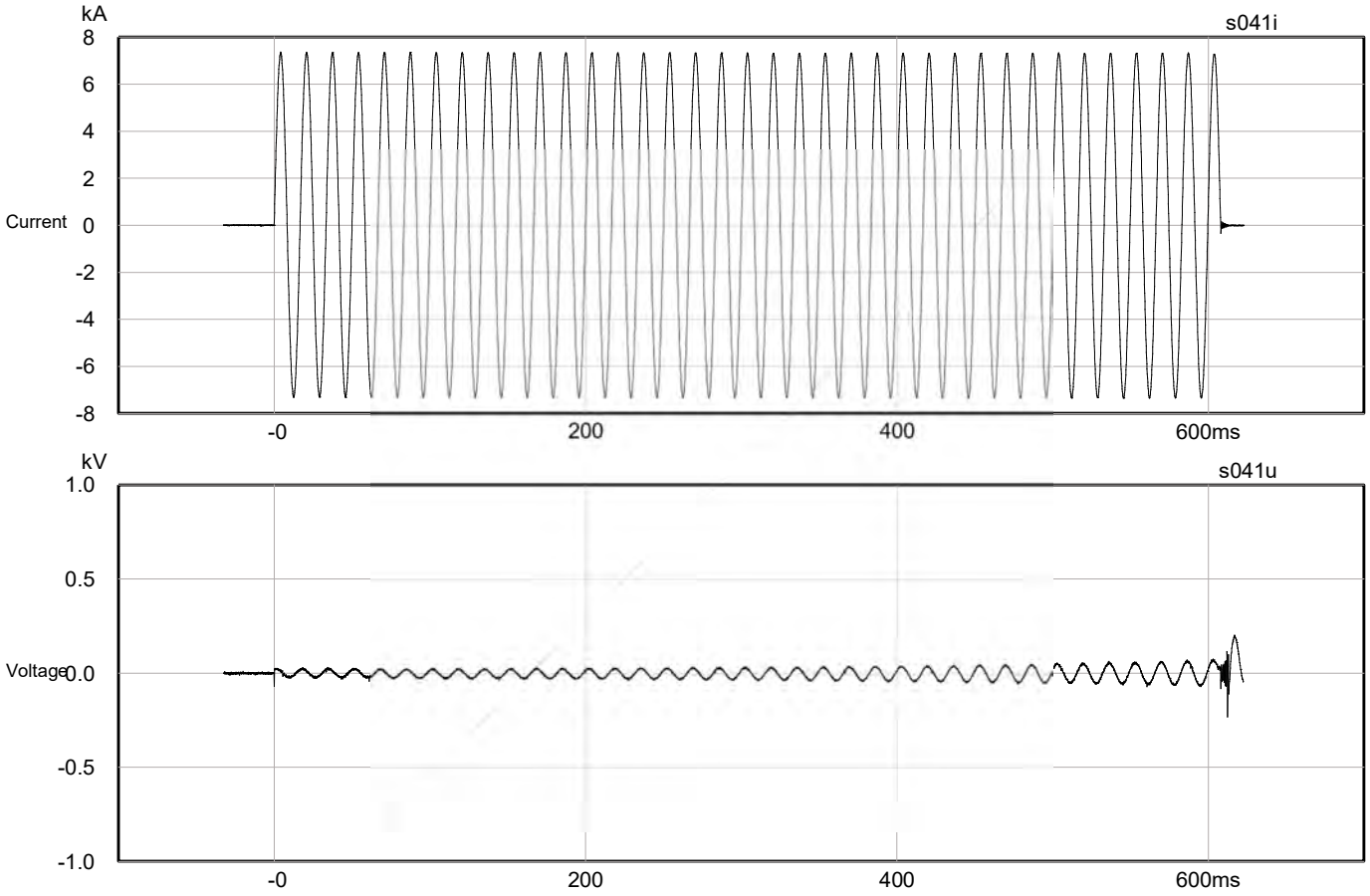


Figure 19: Waveforms for Test #13, Encore #6 AWG Sample 21.

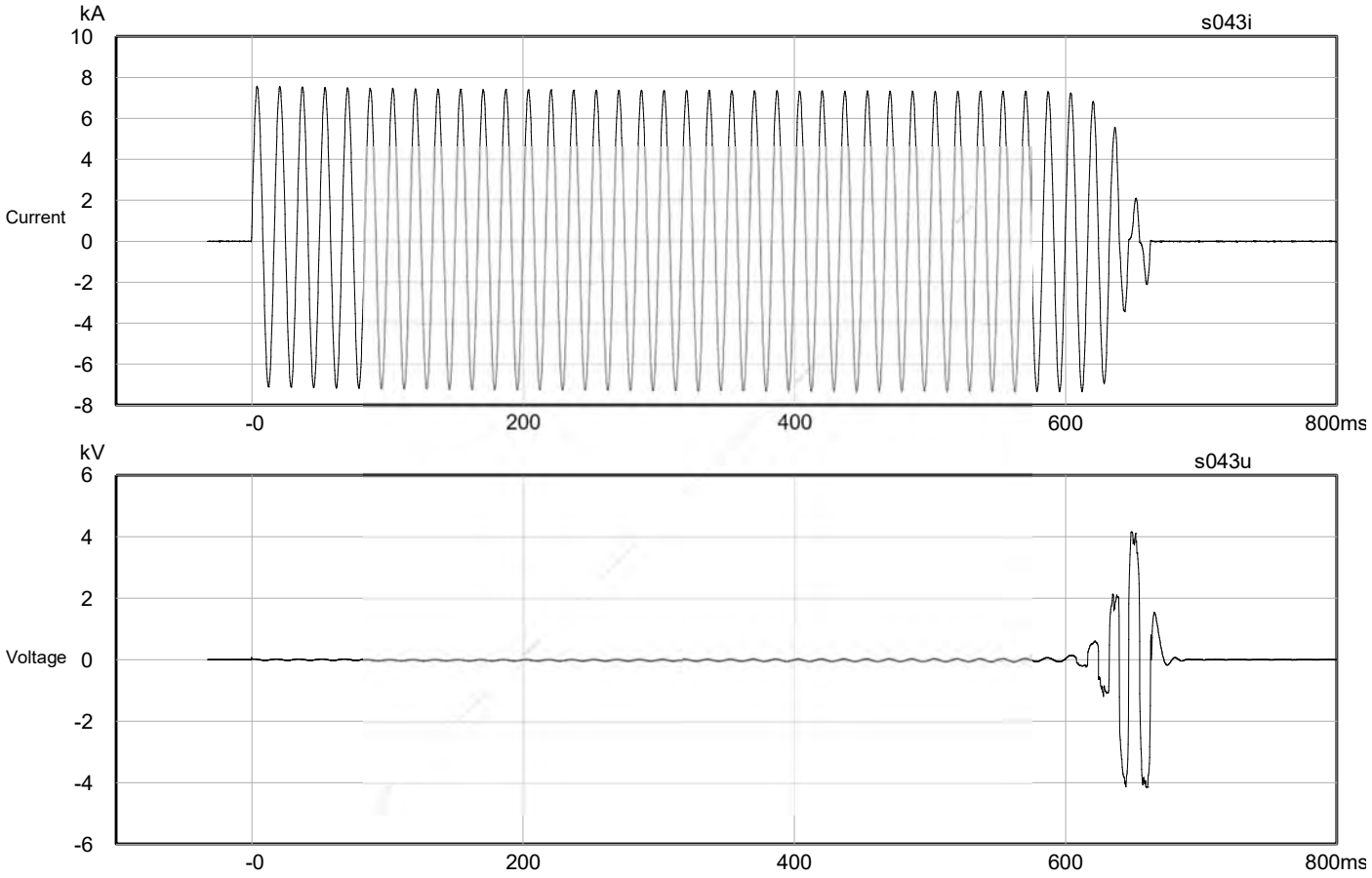


Figure 20: Waveforms for Test #14, Encore #6 AWG Sample 23.

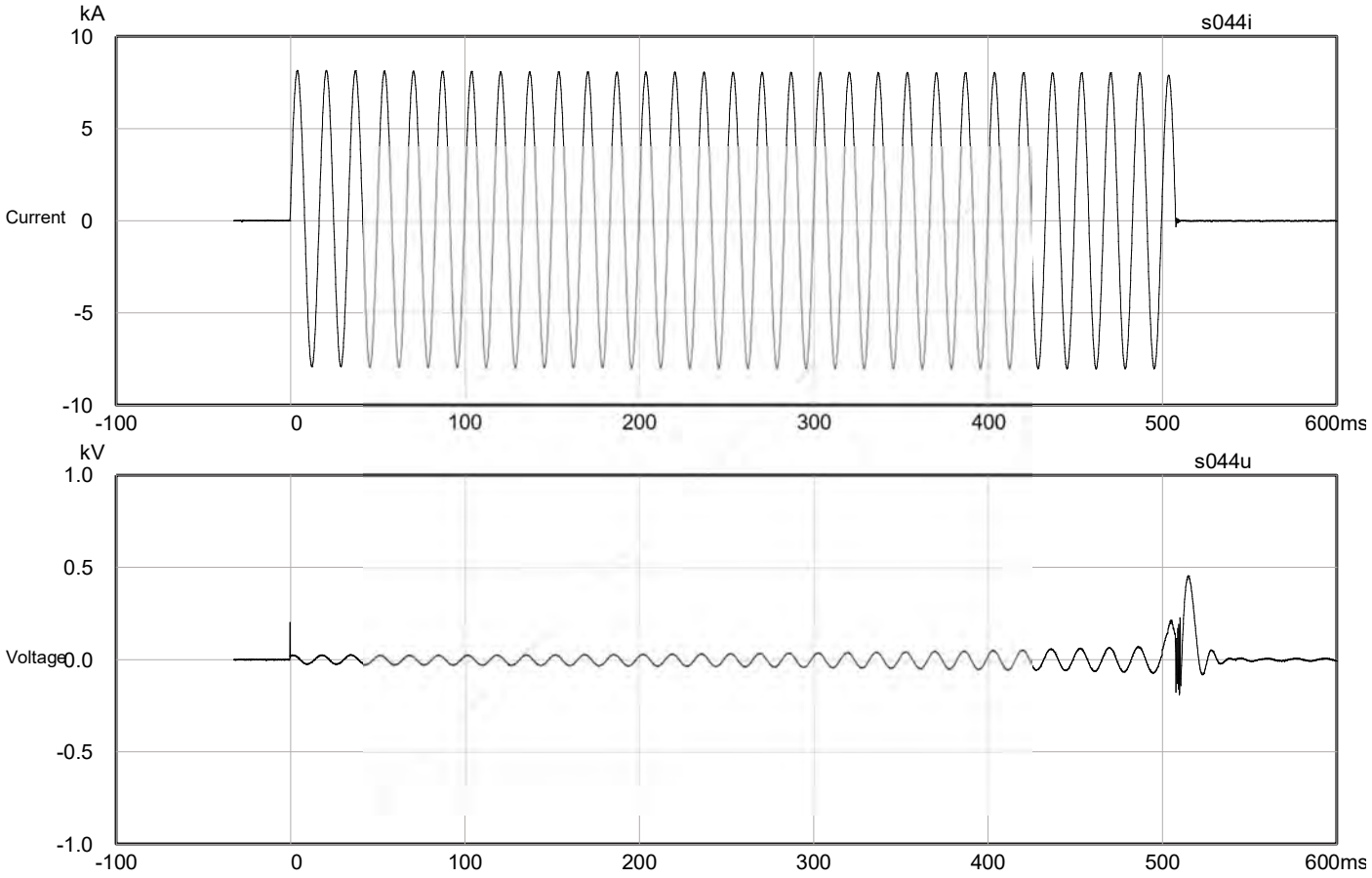


Figure 21: Waveforms for Test #15, Encore #6 AWG Sample 24.

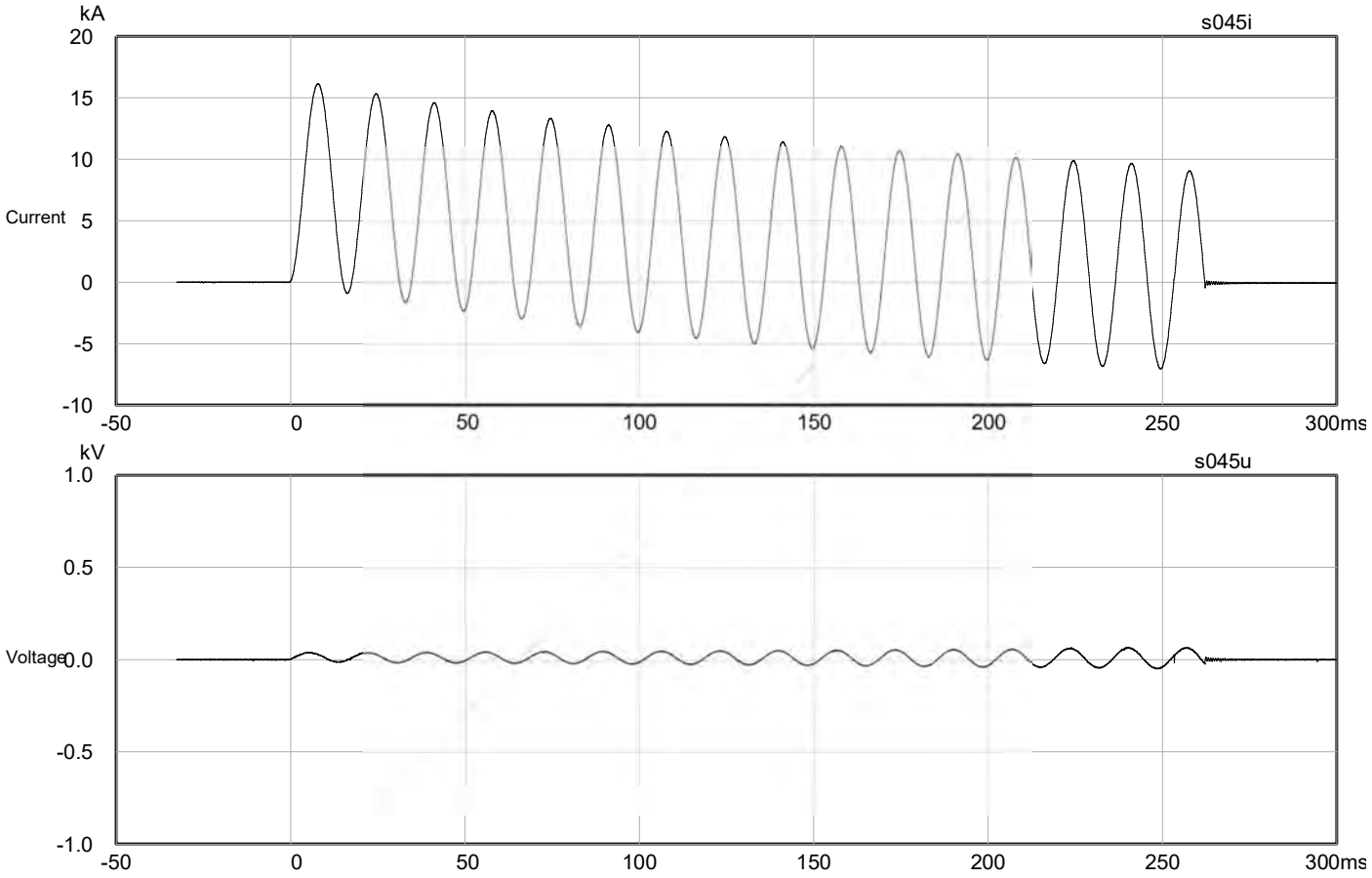


Figure 22: Waveforms for Test #16-1, Encore #6 AWG Sample 25.

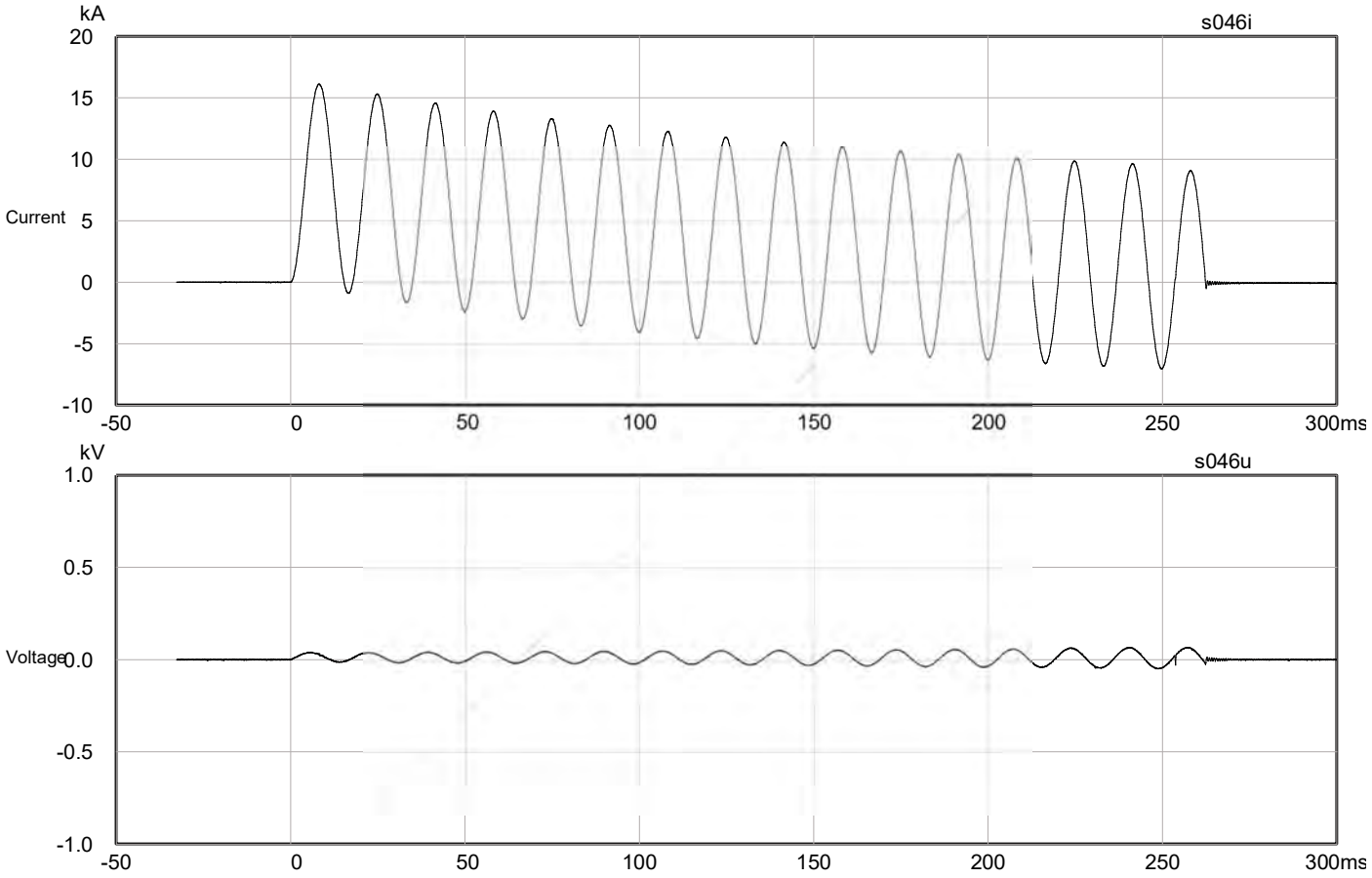


Figure 23: Waveforms for Test #16-2, Encore #6 AWG Sample 25.

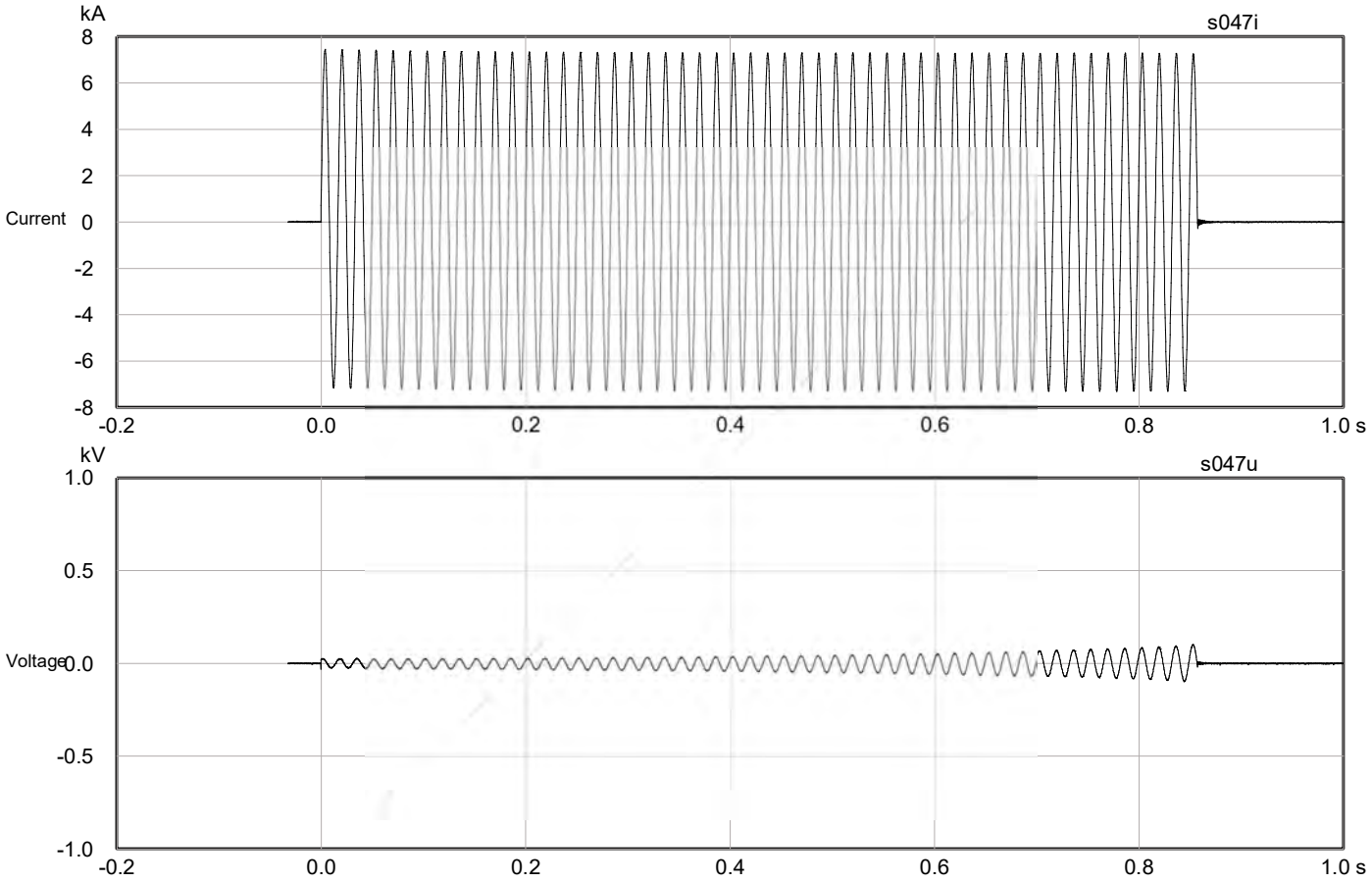


Figure 24: Waveforms for Test #17, Encore #6 AWG Sample 31.

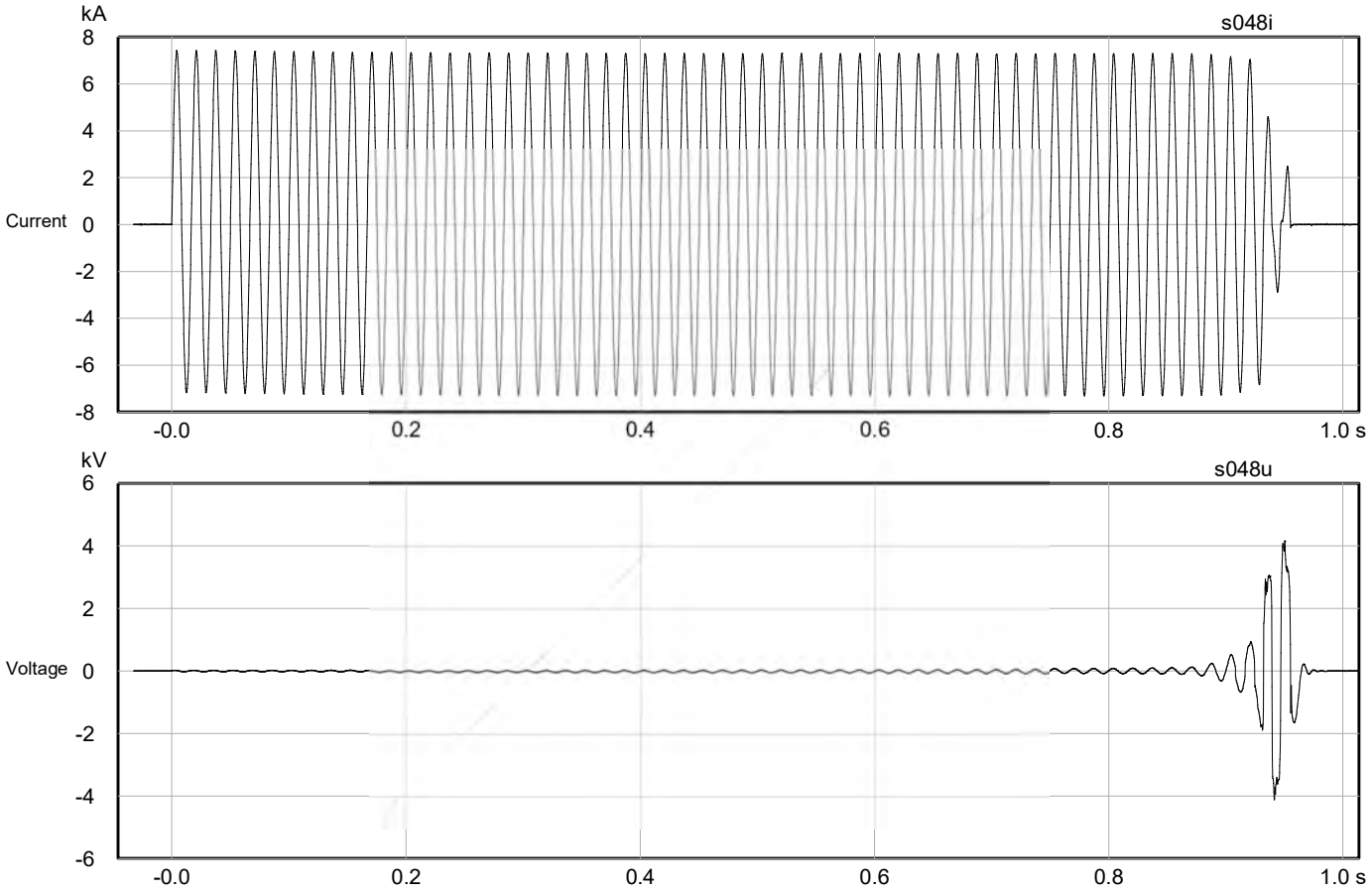


Figure 25: Waveforms for Test #18, Copperweld Scorpius 7 x 080 Sample 32.

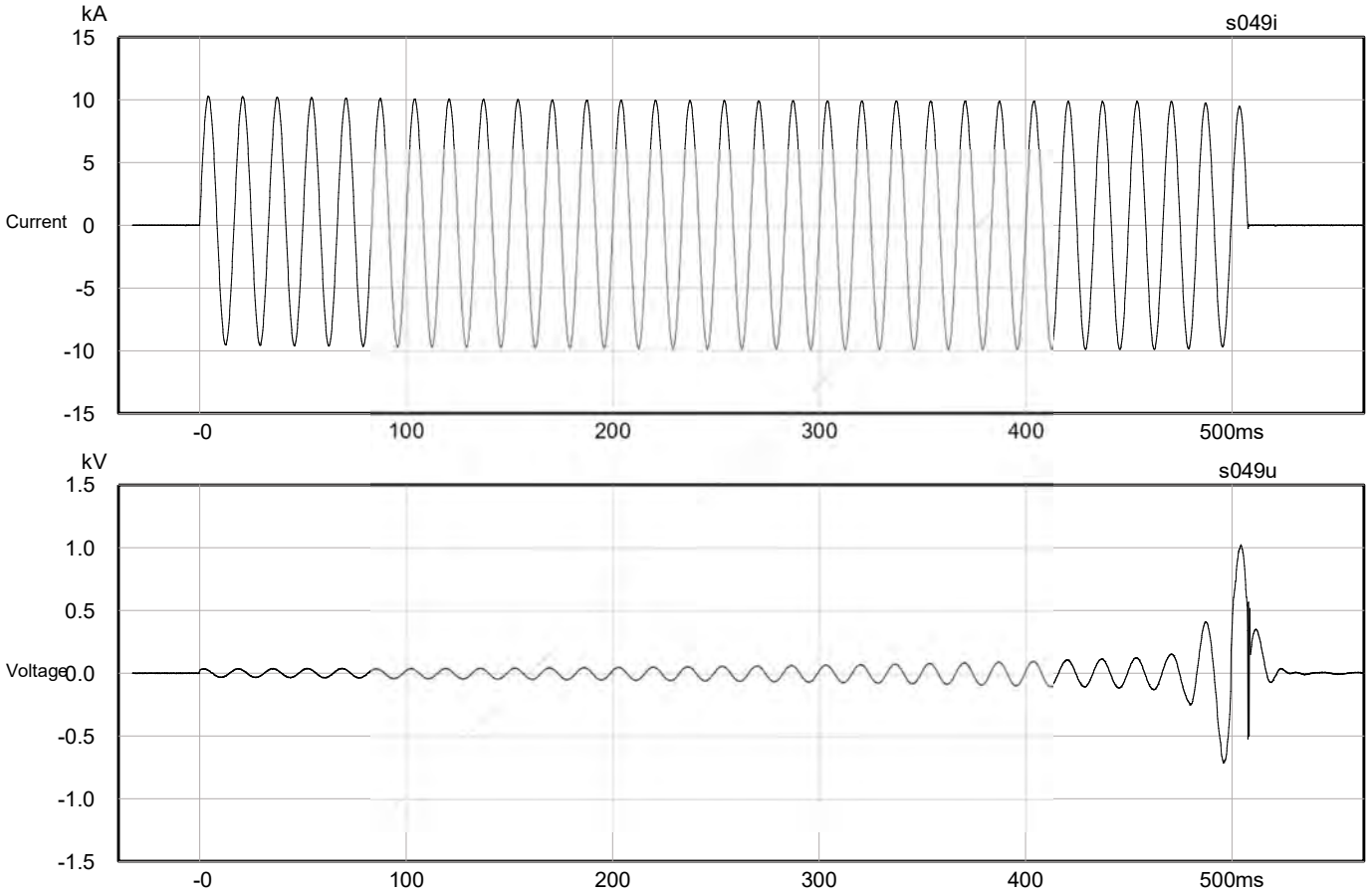


Figure 26: Waveforms for Test #19, Copperweld Scorpius 7 x 080 Sample 33.

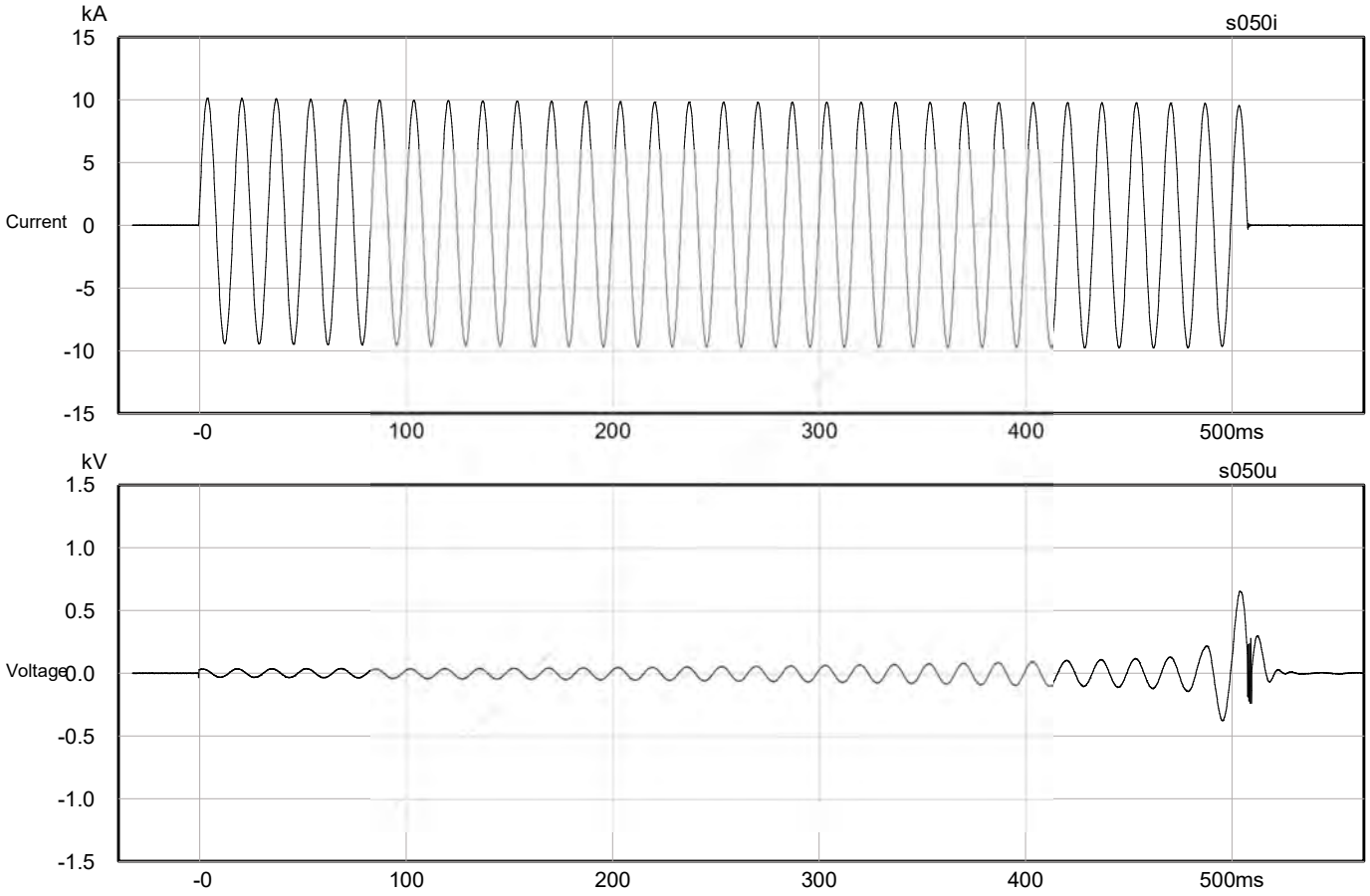


Figure 27: Waveforms for Test #20, Copperweld Scorpius 7 x 080 Sample 34.

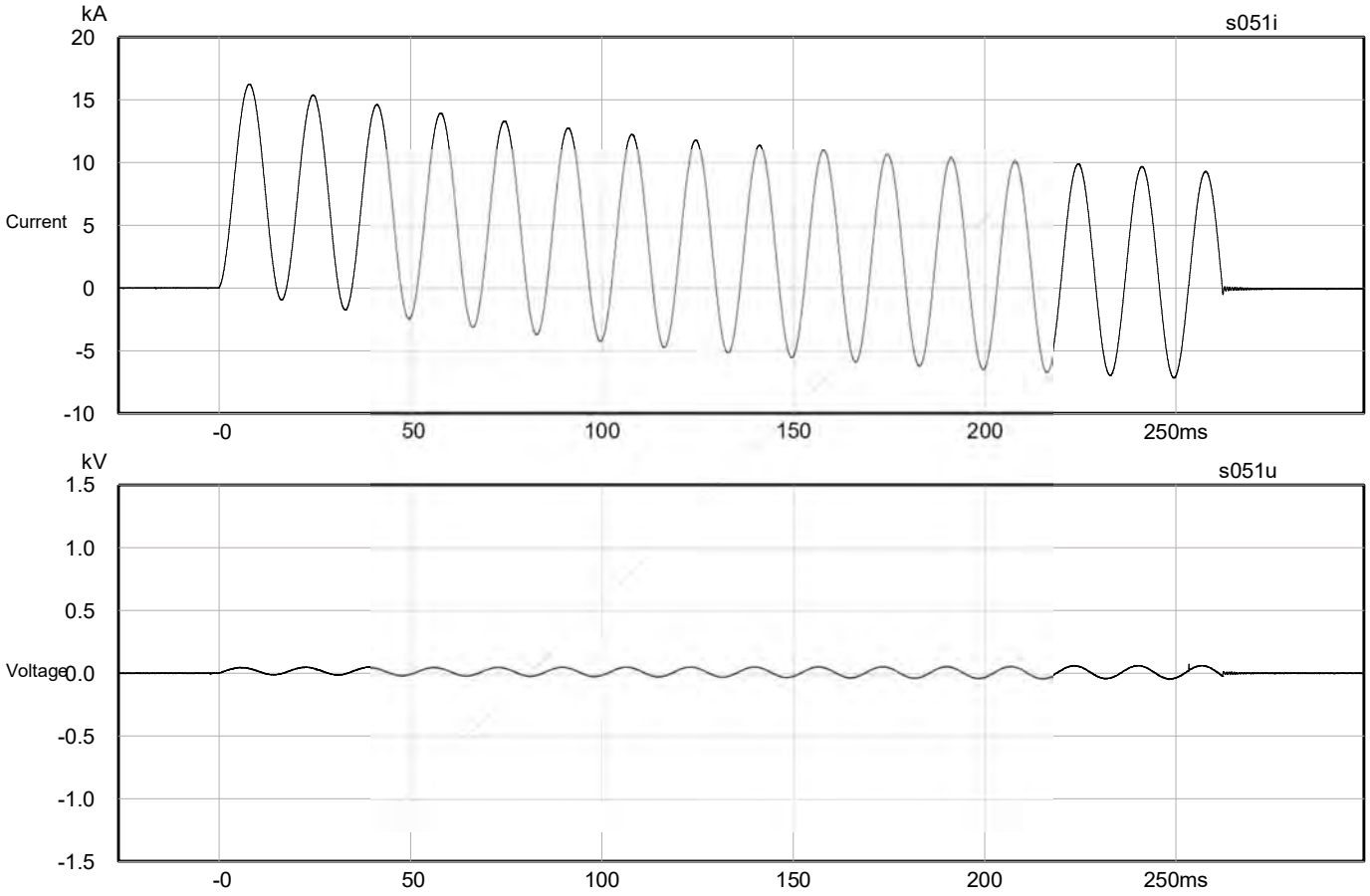


Figure 28: Waveforms for Test #21-1, Copperweld Scorpius 7 x 080 Sample 35.

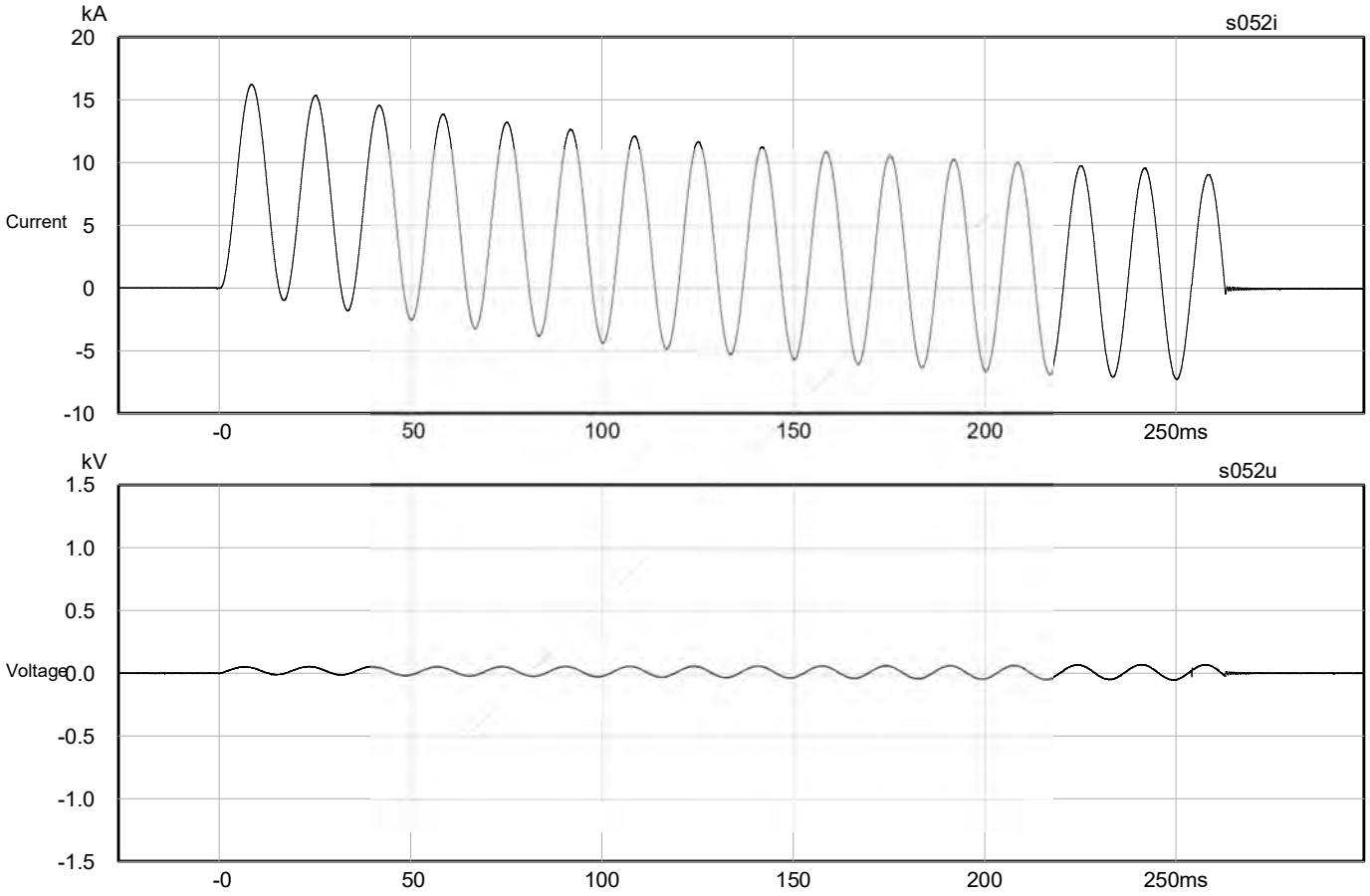


Figure 29: Waveforms for Test #21-2, Copperweld Scorpius 7 x 080 Sample 35.

APPENDIX C – PHOTOGRAPHS OF THE TEST OBJECTS



Figure 30: Test set up for the Encore 4/0 AWG Cu conductor. The power source bus is on the left and the ground bus is on the right.



Figure 31: Test set up for the Copperweld Scorpius 61 x 072 CCS conductor.



Figure 32: Test set up for the Encore #6 AWG Cu conductor.



Figure 33: Test set up for the Copperweld Scorpius 7 x 080 CCS conductor.

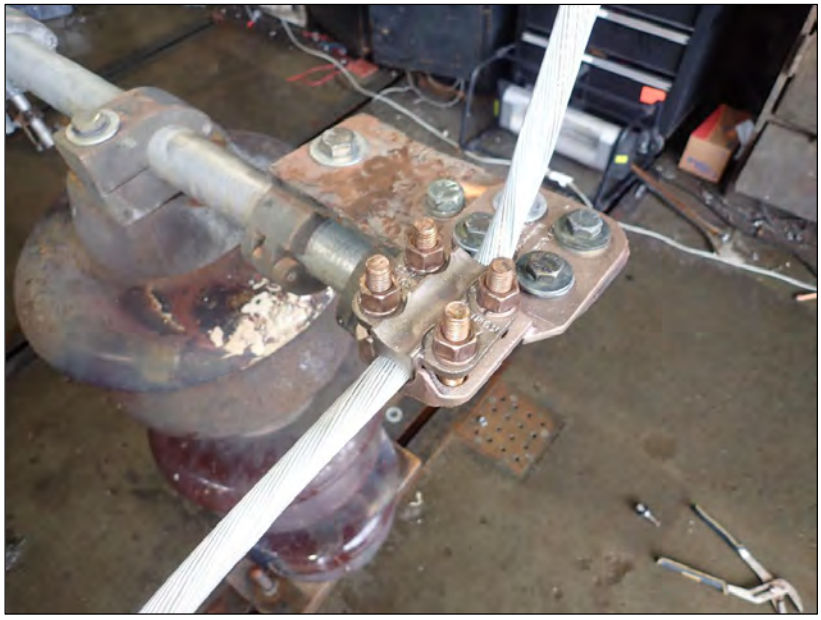


Figure 34: Typical Burndy terminal connector used to connect the Encore 4/0 AWG or Copperweld Scorpius 61 x 072 CCS conductors to the laboratory buses.



Figure 35: Typical Burndy terminal connector used to connect the Encore #6 AWG or Copperweld Scorpius 7 x 080 CCS conductors to the laboratory buses.

APPENDIX D – CALCUATIONS OF TEST CURRENT LEVELS FOR #6 AWG CU CONDUCTOR

Equation (45) in IEEE 80 and Equation (C.1) in IEEE 837 are the same, as follows:

$$I = A\sqrt{\left(\frac{TCAP\times10^{-4}}{t_c\times\alpha_r\times\rho_r}\right)\ln\left(\frac{K_0+T_m}{K_0+T_a}\right)}$$

where

I is root mean square (rms) current in kA
A is conductor cross section in mm^2
T_m is maximum allowable temperature in °C
T_a is initial conductor temperature in °C
T_r is reference temperature for material constants in °C
α_0 is thermal coefficient of resistivity at 0 °C
α_r is thermal coefficient of resistivity at reference temperature T_r
ρ_r is resistivity of the ground conductor at reference temperature T_r in μΩ-cm
K_0 is $1/\alpha_0$, or $(1/\alpha_r)-T_r$ in °C
t_c is time of current flow in seconds (s)
TCAP is thermal capacity factor in joules/cm^3°C

This equation is used to calculate the short-circuit ampacity of a conductor based on it's material constants.

For IEEE 80, Table 6, the symmetrical rms fusing current for #6 AWG soft-drawn Cu conductor at 500 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.5)(0.00393)(1.72)}\cdot\ln\left(\frac{(234+1083)}{(234+40)}\right)} = \boxed{5.29\ kA_{rms}}$$

For IEEE 837, Table 3, the symmetrical rms fusing current for #6 AWG hard-drawn Cu conductor at 250 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.25)(0.00381)(1.78)}\cdot\ln\left(\frac{(242+1084)}{(242+40)}\right)} = 7.41\ kA_{rms}$$

From IEEE 837 Equation (C.4), the asymmetrical rms fusing current is:

$$I_{asym} = \frac{(7.41\ kA)}{(1.148)} = 6.45\ kA_{rms}$$

For the EMF described in IEEE 837, Clause 7.2, a value of 90% of the fusing current is used for conductors up to 4/0 AWG:

$$I_{EMF} = (6.45)(0.9) = \boxed{5.81\ kA_{rms}}$$

Copperweld Bimetallics Data Sheet Packet
Electrical Test Laboratory

Customer:	Copperweld Building Wire	Engineer:	Bill Lewey	Date:	8/25/2020
Sample ID:	EL-13	Tested By:	Bill Lewey, Mike Rozar	Date:	8/25/2020
Product:	Grade 40 Copper Clad Steel Wire Solid Bare #4 and #6 vs Equivalent Solid Copper: Grounding Electrode Conductor Equivalency Test	Sample Condition:	New		
Standard:	ASTM B910/910M Annealed Copper Clad Steel Wire				
Insulation: N/A - Bare		Jacket: N/A - Bare			

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Test Report Summary

Page	Test Performed	Date Completed	Pass/Fail
1	Grounding Electrode Conductor Test for Copper Clad Steel Grade 40	8/25/2020	**Pass**

Requirement:
#4 AWG Grade 40 Copper Clad Steel and #6 AWG Copper Clad Steel when compared to #4 solid copper and #6 solid copper for use as a grounding electrode conductor shall have equal ability to carry amperage during a ground fault condition.

Conclusion:
The ability of bare #4 AWG Copper Clad Steel Grade 40 and bare #6 AWG Copper Clad Steel Grade 40 performed equally to #4 AWG bare solid copper and #6 AWG bare solid copper when used as a grounding electrode conductor under a ground fault condition. The current measured proved equivalency.

Test Equipment Used

Item	Equipment Type	Equipment #	Cal. Due Date
1	Fluke 374FC Clamp Meter	AM-1	Nov 2020
2	Acme Electric 15KVA Transformer	T2535173S	N/A
3	Square D 60A / 600V Safety Interrupter	N/A	N/A
4	Eaton Service Panel	N/A	N/A
5	Eaton Type CH 20 Amp Breaker	N/A	N/A
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

VBU – Verify Before Use

N/A – Not Applicable

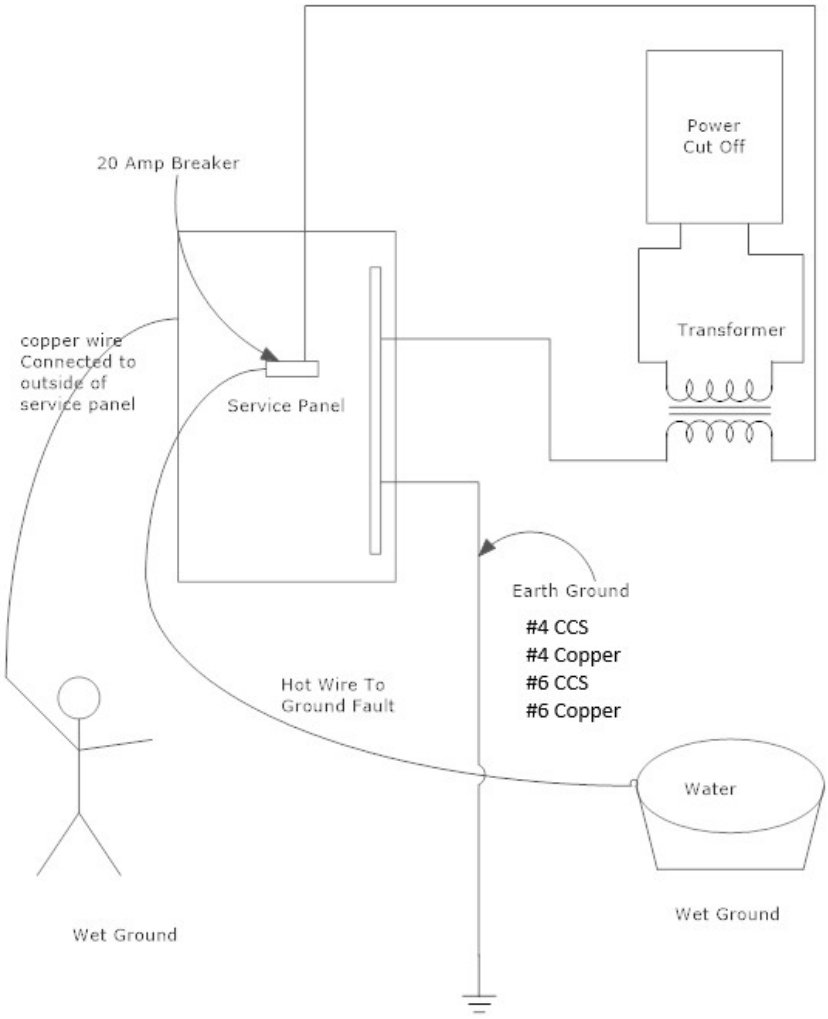
Sample Identification

Item	Description	Length/No. Rec'd
A	#4 AWG 40% Copper Clad Steel Bare	35 Ft
B	#4 AWG Solid Copper Bare	35 Ft
C	#6 AWG 40% Copper Clad Steel Bare	35 Ft
D	#6 AWG Solid Copper Bare	35 Ft
E		
F		

Grounding Electrode Conductor Test

Test Parameters:	
Conditioning:	No preconditioning.
Test Conductors:	1 each of #4 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #6 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #4 AWG Solid Bare copper grounding electrode conductor 1 each of #6 AWG Solid Bare copper grounding electrode conductor
Test Conductor Length:	Each conductor shall be 35 ft.
Test Circuit Configuration:	See schematic shown in Figure 1
Test Current:	Test current from 120 V / 20 A Residential Circuit
Method:	Testing was completed by creating a standard residential test circuit at 120V with 20A breaker wired to an intentional ground fault as shown in figure 1. The ground fault was created by connecting a hot wire from the breaker to a galvanized steel pan full of water and placing the pan on the wet ground. A conductor was also connected to the outside of the electrical panel and a Copper Plated Grounding Electrode (Copperweld Ground Rod) driven 6 inches into the wet ground to determine amount of current going through a grounded person touching the electrical panel during the ground fault condition. The ground fault and the grounded "man" were positioned 20 feet either side of the ground rod. The entire test area was soaked with water overnight using a sprinkler system When the ground fault was electrified, current measurements were taken from the ground fault conductor, the grounding electrode conductor and the grounded "man" conductor. For the four grounding electrode conductors tested, there was one test sequence for each. The current was measured for each. The objective: Compare the amperage measurements of the copper clad steel grounding electrode conductors to those of copper.

Figure 1



Results:			
Ground Conductor	**Fault Conductor Current**	**Current of the Grounding Electrode Conductor**	**Grounded Man Conductor Current**
#4 Copper	2.1 A	1.8 A	0.3 A
#4 40% CCS	2.1 A	1.8A	0.3 A
#6 Copper	1.7 A	1.6 A	0.1 A
#6 40% CCS	1.5 A	1.4 A	0.1 A

Requirement:
For equivalent sizes of Grade 40 Copper Clad steel vs. solid copper grounding conductors, the ability to carry amperage to ground during a ground fault condition is equal.

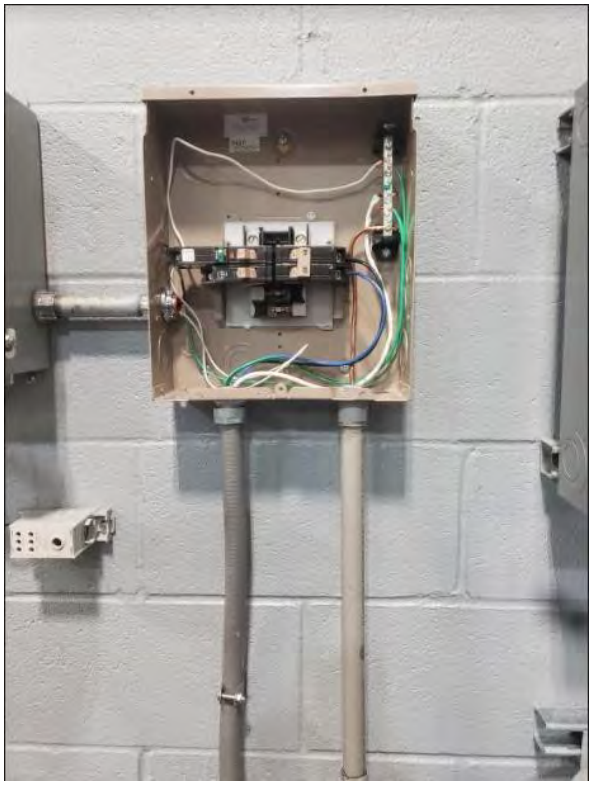
Comments:
____X__ (Pass) The product complies with all applicable requirements of this test. _____ (Fail) The product does not comply with the requirements of this test. **Test Date: 8/25/2020** **Tested By: Bill Lewey**

Environmental Conditions during Testing:

Humidity: % rh __74%_____ Ambient: °C___28_____

Test setup for the electrical service panel







Ground Rod with Grounding Conductor Attached



Ground Fault



Grounded “man”

Public Input No. 2477-NFPA 70-2020 [Section No. 250.166(B)]

(B) Not Smaller Than the Largest Conductor.

Where 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~~ 8 AWG copper-clad steel or copper or ~~6 AWG~~ 6 AWG copper-clad aluminum or aluminum .

Statement of Problem and Substantiation for Public Input

Please consult Attached Test Reports to Public Input 2474 for Section 250.166

COPPER-CLAD ALUMINUM CONDUCTORS:

Please Consult Sections 110.14 Electrical Connections and 110.5 Conductor Materials. Copper-Clad Aluminum as a conductor material should not be excluded for this application. With aluminum and copper, Copper-Clad Aluminum is only one of three conductor materials for general wiring permitted by the NEC. Copper-Clad Aluminum is referenced as a GEC in Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems. This PI aims to correct an inconsistency in correlation between sections and articles. It aims to bring safe alternatives to users of this Code. The NFPA Standards Council created in August 2019 a special Bimetals Task Group to in part bring attention to correlation issues effecting Copper-Clad Aluminum, as well as to study expanding its range of applications in 2023. In a coordinated effort, the Bimetals Task Group will submit 19 Public Inputs in this cycle addressing these matters.

COPPER-CLAD STEEL CONDUCTORS:

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 applicate 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 Inputs for This Document

Related Input	Relationship
Public Input No. 2474-NFPA 70-2020 [Section No. 250.166 [Excluding any Sub-Sections]]	

Submitter Information Verification

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State:
Zip:
Submittal Date: Sun Aug 23 13:04:02 EDT 2020
Committee: NEC-P05

Public Input No. 2478-NFPA 70-2020 [Section No. 250.166(C)]

(C) Connected to Rod, Pipe, or Plate Electrodes.

Where 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~~ 6 AWG copper-clad steel or copper wire or ~~4 AWG~~ 4 AWG copper-clad aluminum or aluminum wire.

Statement of Problem and Substantiation for Public Input

Please consult Attached Test Reports to Public Input 2474 for Section 250.166

COPPER-CLAD ALUMINUM CONDUCTORS:

Please Consult Sections 110.14 Electrical Connections and 110.5 Conductor Materials. Copper-Clad Aluminum as a conductor material should not be excluded for this application. With aluminum and copper, Copper-Clad Aluminum is only one of three conductor materials for general wiring permitted by the NEC. Copper-Clad Aluminum is referenced as a GEC in Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems. This PI aims to correct an inconsistency in correlation between sections and articles. It aims to bring safe alternatives to users of this Code. The NFPA Standards Council created in August 2019 a special Bimetals Task Group to in part bring attention to correlation issues effecting Copper-Clad Aluminum, as well as to study expanding its range of applications in 2023. In a coordinated effort, the Bimetals Task Group will submit 19 Public Inputs in this cycle addressing these matters.

COPPER-CLAD STEEL CONDUCTORS:

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 applicate 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 Inputs for This Document

Related Input	Relationship
Public Input No. 2474-NFPA 70-2020 [Section No. 250.166 [Excluding any Sub-Sections]]	

Submitter Information Verification

Submitter Full Name: Peter Graser
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Affiliation: American Bimetallic Association
Street Address:
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Zip:
Submittal Date: Sun Aug 23 13:15:13 EDT 2020
Committee: NEC-P05

Public Input No. 2479-NFPA 70-2020 [Section No. 250.166(D)]

(D) Connected to a Concrete-Encased Electrode.

Where 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~~ 4 AWG copper-clad steel or copper ~~wire~~ .

Statement of Problem and Substantiation for Public Input

Please consult Attached Test Reports to Public Input 2474 for Section 250.166

COPPER-CLAD STEEL CONDUCTORS:

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 applicate 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 Inputs for This Document

Related Input	Relationship
Public Input No. 2474-NFPA 70-2020 [Section No. 250.166 [Excluding any Sub-Sections]]	

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
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Street Address:	
City:	
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Submittal Date:	Sun Aug 23 13:18:28 EDT 2020
Committee:	NEC-P05

Public Input No. 2474-NFPA 70-2020 [Section No. 250.166 [Excluding any Sub-Sections]]

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 or copper or 250 ~~kcmil~~ kcmil copper-clad aluminum or aluminum .

Additional Proposed Changes

File Name	Description	Approved
CCS_Corrosion_paper_Rev2.pdf	50 Year Corrosion Study Grade 40 CCS	
TD002391.doc	UL 467 Short Circuit and UL 486A-B Mechanical Sequence Grade 40 CCS	
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

COPPER-CLAD ALUMINUM CONDUCTORS:

Please Consult Sections 110.14 Electrical Connections and 110.5 Conductor Materials. Copper-Clad Aluminum as a conductor material should not be excluded for this application. With aluminum and copper, Copper-Clad Aluminum is only one of three conductor materials for general wiring permitted by the NEC. Copper-Clad Aluminum is also referenced in Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems as a GEC. This PI aims to correct an inconsistency in correlation between sections and articles. It aims to bring safe alternatives to users of this Code. The NFPA Standards Council created in August 2019 a special Bimetals Task Group to in part bring attention to correlation issues effecting Copper-Clad Aluminum, as well as to study expanding its range of applications in 2023. In a coordinated effort, the Bimetals Task Group will submit 19 Public Inputs in this cycle addressing these matters.

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within the grounding electrode system.

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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 applicate 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 Inputs for This Document

Related Input	Relationship
Public Input No. 2462-NFPA 70-2020 [Section No. 250.62]	
Public Input No. 2470-NFPA 70-2020 [Section No. 250.66(B)]	
Public Input No. 2472-NFPA 70-2020 [Section No. 250.102(C)(2)]	
Public Input No. 2477-NFPA 70-2020 [Section No. 250.166(B)]	
Public Input No. 2478-NFPA 70-2020 [Section No. 250.166(C)]	
Public Input No. 2479-NFPA 70-2020 [Section No. 250.166(D)]	

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
Affiliation: American Bimetallic Association
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 23 11:01:20 EDT 2020
Committee: NEC-P05

Testing done for the safety of our valued customer.

Global Circulation Laboratory Test Report

For Global Distribution

UL467 SHORT CIRCUIT & UL 486A-486B MECHANICAL SEQUENCE TESTS

YGHP29C2, YGHC2C2, YGHC26C26, YGHP34C29, YGHC29C29, YGHP34C34, YGHC34C34 HYTAP™ Connectors
YGL2C2, YGL29C29, YGL34C34 HYGRID™ Connectors
YGA4C2N, YGHA272N, YGA282N, YGHA302N HYLUG™ Connectors

5/8" and 3/4"Copper Clad Steel Ground Rod, #4AWG Solid, 4/0AWG Stranded, 7#7, and 19#8 COPPERWELD® 40% IACS Copper Clad Steel Conductors

PAT750XT-18V PATRIOT® Tool
with
UC, UO, U28RT, U29RT, U32RT, U997, PU998, and U1011 Die Sets

TD002391 REV B

Requested by / Date:	***Authorized by / Date:***	***Completed by / Date:***
C. Gandhi 12-Dec-2014	R Robicheau 12-Dec-2014	R Charpentier 06-Apr-2015
Engineering Approval / Date:	***Marketing Approval / Date:***	***Laboratory Approval / Date:***
R.Roman 20-Aug-2020	J Hogan 20-Aug-2020	R Charpentier 20-Aug-2020

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

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TEST REQUESTED: 3
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CONCLUSIONS: 4
ENGINEERING COMMENTS: 4
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TEST EQUIPMENT : 5

Burndy LLC 47 East Industrial Park Dr.
Manchester / New Hampshire / 03109
Tel: 603 647 5000 Fax: 603 647 5205

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

PURPOSE OF TEST:

To determine if the Burndy HYTAP™, HYGRID™, and HYLUG™ Connectors can meet the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST REQUESTED:

UL486A-486B Mechanical Sequence
UL467 Short Time Current

TEST RESULTS:

Connector	Cable 1	Cable 2	Die	# of crimps	Securness	Pull	Short Time Current		
					Pass / Fail	Average Pull (lb)	Pass / Fail	Current (Amps)	Time (s)
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	U997	1	Pass	1021.3	Pass	1600	6
YGL2C2	#4 Solid CCS	#4 Solid CCS	U-O	1	Pass	1451.8	Pass	1600	6
YGHC2C2	#4 Solid CCS	#4 Solid CCS	U-C	1	Pass	1544.0	Pass	1600	6
YGA4C2N	#4 Solid CCS	n/a	U4CRT	1	Pass	814.0	Pass	1600	6
YGL29C29	7#7 STR CCS	7#7 STR CCS	U997	1	Pass	1643.2	Pass	4600	9
YGHC26C26	7#7 STRCCS	7#7 STR CCS	U-O	1	Pass	1239.4	Pass	4600	9
YGHA272N	7#7 STRCCS	n/a	U29RT	2	Pass	1574.0	Pass	4600	9
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PU998	1	Pass	1789.8	Pass	6100	9
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1849.8	Pass	6100	9
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1779.1	Pass	6100	9
YGA282N	4/0 AWG CCS	n/a	U28RT	2	Pass	2489.3	Pass	6100	9
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	U1011	3	Pass	2126.8	Pass	9000	9
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	U1011	3	Pass	2380.0	Pass	9000	9
YGL34C34	19#8 STRCCS	19#8 STR CCS	U1011	3	Pass	3158.3	Pass	9000	9
YGHC34C34	19#8 STR CCS	19#8 STR CCS	U1011	3	Pass	3812.1	Pass	9000	9
YGHA302N	19#8 STR CCS	n/a	U32RT	2	Pass	4792.2	Pass	9000	9

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TD002391

Global Circulation Laboratory Test Report

For Global Distribution

CONCLUSIONS:

All samples tested met the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST PROCEDURES

The table below shows the connector / conductor combinations tested.

Connector	Cable 1	Cable 2	Tool	Die	# of Crimps
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	PAT750	U997	1
YGL2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-O	1
YGHC2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-C	1
YGA4C2N	#4 Solid CCS	n/a	PAT750	U4CRT	1
YGL29C29	7#7 STR CCS	7#7 STR CCS	PAT750	U997	1
YGHC26C26	7#7 STR CCS	7#7 STR CCS	PAT750	U-O	1
YGHA272N	7#7 STR CCS	n/a	PAT750	U997	2
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PAT750	PU998	1
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGA282N	4/0 AWG CCS	n/a	PAT750	U997	2
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	PAT750	U1011	3
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	PAT750	U1011	3
YGL34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHC34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHA302N	19#8 STR CCS	n/a	PAT750	U32RT	2

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Global Circulation Laboratory Test Report

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All conductors were cut to twenty four (24) inch lengths.
All ground rod was pre-crimped with the appropriate pre-crimp die
5/8in Rod UPRECRIMP58
3/4in Rod UPRECRIMP34

Mechanical Sequence
Four samples of each set were secured to the Secureness tester, the height; weight and bushing size were as specified in UL486A-486B Table 26. Samples were rotated for thirty minutes at 9rpm. Samples were then subjected to a 1-minute pull to the value specified in UL486A-486B Table 27 and then to failure.

Short Time Current
Test samples were assembled in a series loop configuration then attached to a current controller as shown below. The test current and duration are listed below. After completion of the test, electrical continuity was checked with a digital multi-meter.

Test current values were derived from the equation Annex C of IEEE Std 837-2002. The diameter of the conductor(s) were measured and the cross-sectional area of the conductors was calculated.

Conductor	***Current Value (A)***	***Duration (sec)***
#4AWG Solid COPPERWELD® 40% IACS CCS	1600	6
4/0AWG 19 strand COPPERWELD® 40% IACS CCS,	6100	9
7#7 stranded COPPERWELD® 40% IACS CCS	4600	9
19#8 stranded COPPERWELD® 40% IACS CCS	9000	9

TEST EQUIPMENT LIST:

MANUFACTURER	MODEL	DESCRIPTION	SERIAL #	RANGE
FLUKE	79 III	DMM	70591301 (Rene)	AUTO
OHIO SEMITRONICS		CURRENT TRANSDUCER	NA	15000:5
SATEC	T5000	TABLE TOP	2038	5000 lbs
VIRTECH	NA	HIGH CURRENT	NA	12V / 12000A
MITUTOYO	505-675	DIAL CALIPER	08914565 (Rene)	6"

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CORROSION ON BURIED COPPER CLAD STEEL



Cece Syarif

Global Application Engineer

&

Anthony Hale

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The results and conclusions obtained from studies done by Copperweld are only applicable to Copper Clad Steel manufactured by Copperweld. Due to proprietary process used to produce the wire, the findings cannot be superimposed on any other copper-clad steel conductor.

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July 26, 2011

This paper compiles several studies and analysis regarding the corrosion performance of buried Copperweld® Copper-Clad-Steel (CCS) conductors. These range from the early 1900's with the invention of Copperweld® through the present day with studies performed by independent parties as well as Copperweld Company in-house testing. The purpose is to present the available information so that prospective users of Copperweld® CCS wire and strand can evaluate the corrosion resistance and expected performance within their specific application and area. Copperweld uses oxygen free copper in the manufacture of Copperweld® wire and strand. The copper surface of CCS is expected to oxidize and turn color ranging from green (patination) to brown and black the same as any solid copper wire or strand when exposed to environmental stimuli. Corrosion on exposed steel at the cut tip or end of the wire is also expected. The question to be answered is if the corrosion on either material or the interface between the copper and steel (galvanic reaction) will result in degradation of the wire as to make it unsuitable for use as a grounding conductor.

The oldest known underground corrosion study of bimetallic material was performed in the early 1900s[1]. This study focused on the corrosion behavior of Copperweld® CCS underground rod as well as other materials such as Copper and galvanized steel ground rod. The National Bureau of Standards (NBS) conducted an extensive underground corrosion study that involves 36,500 specimens which include 333 varieties of ferrous, nonferrous, and protective coating materials buried in 128 test locations throughout U.S in 1910 - 1955.

The study summarizes the service life of a ground rod as following:

10 mils copper coating – acceptable for service life up to 40 years

13 mils copper coating – acceptable for service life up to 50 years

Similarly, the Naval Civil Engineering Laboratory in collaboration with the National Association of Corrosion Engineers conducted a 7-year program of testing metal rods for electrical grounding to determine the galvanic corrosion effect. The three metals tested were stainless clad steel, copper-bonded steel (CCS), and galvanized steel. The result on the ⅝" CCS ground rod was as expected. The copper surface of the CCS was

virtually free of corrosion and the steel core has corroded at the tip approximately 2 inches down the length of the rod.

Copperweld Corporation is the inventor and sole manufacturer of Copperweld® Copper-bonded ground rods and Copperweld® wire and strand since 1915. The corrosion behavior of a Copperweld® ground rod is similar to the corrosion on Copperweld® wire and strand conductor. Both materials consist of copper permanently bonded to a steel core. All Copperweld® 40% CCS has a copper thickness of 10% of the overall diameter. For example, Copperweld® 4THOUGHT™ has a configuration of 19 strands of 0.1055 inch wires. It means that each strand has a copper thickness of 10.55 mils. Based on the NBS study, 4THOUGHT™ will have at least a minimum service life of 40 years.

Copperweld has also conducted a 5-year study of buried bare 21% conductivity (copper thickness is 3% of the diameter) Copperweld® CCS in 10 different soil conditions in association with Southwest Research Institute[2]. The study reported 100% surface oxidation and various degrees of deterioration of the steel core as expected after 5 years. The exposed steel on the tip of the wire rusted and formed "scab", as shown in Figure 1. The rust appeared to "seal-off" the un-oxidized material from the corrosive medium. The maximum depth of corrosion was 70% of the wire diameter.



Figure 1: Example of Underground Corrosion of Copper Clad Steel

Although the copper surface oxidation was heavy, the samples showed no signs of pits or holes in the copper cladding. The copper thickness of a severely oxidized 5-year sample showed no discernable difference when compared to an un-oxidized control sample that was not subjected to the corrosive environment. The mechanical and resistance testing

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resulted in negligible differences between 5-year samples and the control samples. Thus, the oxidation had no discernable impact on the strength or electrical performance of the wire.

An accelerated corrosion study based on ASTM B117 was conducted on bare CCS and solid Copper wires to evaluate copper surface corrosion. The wires were exposed to salt fog spray for 504 hours. As a result, corrosion on the CCS copper surface showed no significant difference as compared to the corrosion of copper wire.



(a) Copper Clad Steel (b) Copper

Figure 2: Patination of Copper Surface after 504 hours exposure to Salt Fog Spray

In February 2011, three separate sample strands of Copper Clad Steel were un-earthed and cut out from a substation built in Louisville, KY. The conductors were 40% conductivity, Low Carbon Steel, Dead Soft Annealed, 7 No. 5 (231,613 circular mil) and were installed in 1962.

Table 1: Physical properties of the three strands of Copperweld® conductor that had been buried underground for 48 years in a Kentucky substation

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			Strand 1	Strand 2	Strand 3
Conductor Type			40% Low Carbon Annealed		
Conductor Size			7 No. 5		
Cross Section Area		in^2	0.1819	0.1819	0.1819
Diameter of Single end		*inch*	0.1819	0.1819	0.1819
Diameter of Conductor		*inch*	0.5457	0.5457	0.5457
Copper Thickness	Min	*inch*	0.0142	0.0114	0.0134
	Max	*inch*	0.0213	0.0209	0.01975
% Concentricity			83.30%	77.30%	83.90%
Depth of corrosion	Min	*inch*	0.004	0.028	0.111
	Max	*inch*	0.781	0.859	0.484

The 1962 conductors were manufactured by Copperweld with a nominal copper thickness of 10% of its diameter. Figure 3 shows the copper thickness ranges from 11.4 – 21.3 mils and the concentricity of the conductor averaged at 81.5%. Current manufacturing improvements yield concentricity of copper thickness above 85%.

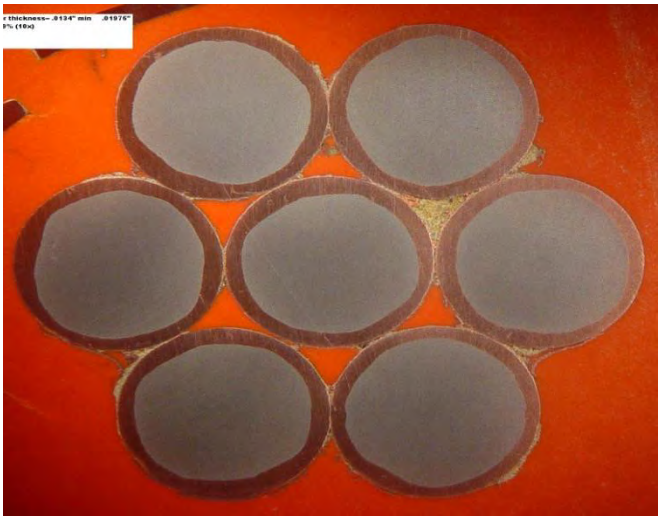


Figure 3: Copperweld® 40% LC DSA 7 No. 5 manufactured in 1962

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Figure 4a shows no visible corrosion observed other than oxidation and patination on the copper surface. At the ends of the wires, the corrosion occurred in the form of steel rust. The maximum depth of the corrosion is 0.859 inch with an average of 0.382 inch, as shown in Figure 4b.



Figure 4a: There is no visible corrosion between the copper and steel on all wires obtained from the substation in Kentucky.



Figure 4b: Corrosion occurred at the ends of the wires. Maximum penetration depth is 0.859 inch.

From all the corrosion studies above, there have not been reported or observed any galvanic corrosion at the interface of copper and steel. The process of cladding for

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Copperweld® ensures a metallurgical bond between the two metals. That metallurgical bond prevents any moisture from penetrating between the two metals precluding the corrosion process. Any propagation of corrosion on an area of exposed steel averages two times the diameter of the wire then stops. The corrosion rate of the copper surface is equivalent to that observed on standard solid copper wire and strand. Based on the results of these studies, it can be summarized that CCS can be expected to have a 50 plus year service life as buried grounding conductors.

REFERENCES:

1. Rempe, Chris. 7 July 2003. "A Technical Report on the Service Life of Ground Rod Electrodes".
2. Fox, Dustin, Belado, Chris, and Brossia, Sean. 23 September 2009. "The Effect of Corrosion on Tracer Wire with a Copper Clad Steel Center Conductor".

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Revision: 0 Issued: 2020-04-15

Copper and CCS Wire Withstand Current and Fusing Current Tests

Copperweld Bimetallics, LLC



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REPORT OF PERFORMANCE

CLIENT	Copperweld Bimetallics,LLC. 5141 Virginia Way, Suite 410 Brentwood, TN, United States 37027
TEST OBJECTS	Copper Clad Steel (CCS) Wires Manufacturer: Copperweld Bimetallics,LLC. Types: Scorpius Prototypes Part Nos.: 61 x 072 7 x 080 Condition: New Copper Conductor Manufacturer: Encore Wire Types: #4/0 AWG (19 strand) CU #6 AWG (single strand) CU Condition: New
TESTED BY	Powertech Labs Inc. 12388 - 88th Ave, Surrey, BC Canada V3W 7R7 www.powertechlabs.com
TEST DATE	2020-01-24 to 2020-01-25
TEST SPECIFICATION	Client Specified, with reference to IEEE Std 80-2013 and IEEE Std 837-2014

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1 INTRODUCTION

At the request of Copperweld Bimetallics,LLC., withstand current and fusing current tests were performed on standard copper and copper clad steel (CCS) wires in accordance with specifications and procedures provided by the client. Reference was made to IEEE Std 80-2013 and IEEE Std 837-2014 as guides for determining current levels and durations for the tests.

The High Power Lab is accredited by the Standards Council of Canada to ISO 17025 for short-circuit testing.

2 TEST OBJECT INFORMATION

The test objects were identified by the client as follows:

Copper Clad Steel Wires (CCS)

Manufacturer:	Copperweld Bimetallics,LLC.
Types:	Scorpius Prototypes
Part Nos.:	61 x 072
	7 x 080
Condition:	New

Copper Conductor

Manufacturer:	Encore Wire
Types:	4/0 AWG (19 strand) CU
	#6 AWG (single strand) CU
Condition:	New

Conductor sample diameters and dc resistance values were measured by the laboratory before testing, as presented in Table 1.

3 GENERAL INFORMATION

3.1 Purpose

The purpose of the tests is to identify the current limits at short durations for standard copper and Copperweld CCS grounding wire products, and to determine if these products meet the applicable requirements of the referenced Standards.

3.2 Witnesses

Name	Company
Jeff Jordan	Copperweld Bimetallics,LLC.
Lora Aboulmouna	Copperweld Bimetallics,LLC.
Jason Smolko	Copperweld Bimetallics,LLC.
Ryan Hale	Copperweld Bimetallics,LLC.

3.3 Tests Performed

Test Standards/Specifications:

Withstand current tests were performed as requested by the client, with reference to the following Standards to determine the test levels:

IEEE Std 80-2013, Table 6 – Specification for the ultimate current carrying capacity of copper grounding cables using symmetrical current.

IEEE Std 837-2014, Clause 7.2 and Table 3 – Electromagnetic force (EMF) test

4 SHORT-CIRCUIT CURRENT TESTS

General Information:

Standard	Client's Specification, with reference to IEEE Std 80-2013 and IEEE Std 837-2014
Test Dates	2020-01-24 to 2020-01-25
Test Leader	Chris Morton

Environmental Conditions:

Ambient temperature	(7 – 9) °C
Relative Humidity	(95 – 99) %

Test Conditions:

Samples were tested in a covered test cell which was open on one side to the outdoor ambient conditions. During each test, one sample was connected horizontally between the laboratory source bus and ground bus, at a bus spacing of 48 inches, as shown in Figures 30 through 33. The samples were terminated using Burndy mechanical connectors, as shown in Figures 34 and 35. The length of each wire sample was the minimum length required to span the distance between the buses, and each sample was at approximately right angles (90°) to both the source and ground bus. Each sample was suspended in free air approximately 46 inches above the floor of the test cell. The temperature of the sample at the start of each test was the natural outdoor ambient temperature of the laboratory, except for tests performed to IEEE 837, where the sample was allowed to cool to less than 100 °C before the second shot.

All tests were performed at a power frequency of 60 Hz using the test circuit shown in Figure 1. Current was initiated by energizing a current limited source that was calibrated to provide the target current through the circuit. The rms current, current symmetry and duration of each test were specified by the client.

The test current was measured using a 300 kA_{peak} rated Rogowski coil (Powertech ID № 39444). The expanded uncertainty of the current measuring system is estimated as 2% (k=2).

Test Results:

The results of the tests are provided in Tables 2 through 5. Current and voltage waveforms for each test are provided in Figures 2 through 29.

The Encore #4/0 AWG Cu wire did not withstand the I^2t calculated from the current and duration specified in IEEE 80, Table 6, for a 500 ms duration (44 kA_{rms}). It was capable of carrying a maximum of 92% of this I^2t value without fusing.

The Encore #4/0 AWG Cu wire did not withstand the EMF current specified in IEEE 837, Table 3 (47 kA_{rms}). It was capable of carrying a maximum of 91% of this current value without failing.

The Copperweld Scorpius CCS 61 x 072 conductor exceeded the 500 ms rms withstand current requirement of IEEE 80, Table 6, and met the EMF current requirements of IEEE 837, Table 3, for a 4/0 conductor.

For the #6 AWG Cu conductor size the Standards did not have current values specified, so these were calculated using Equation (45) from IEEE 80 and Equation (C.1) from IEEE 837. The calculations are presented in Appendix D.

Both the Copperweld Scorpius CCS 7 x 080 conductor and the Encore #6 AWG Cu conductor met the 500 ms rms withstand current requirement of IEEE 80, Table 6 (5.29 kA_{rms}), and the EMF current requirements of IEEE 837, Table 3 (5.81 kA_{rms}), for a #6 AWG Cu conductor.

APPENDIX A – FUSING CURRENT TEST CIRCUIT AND DATA

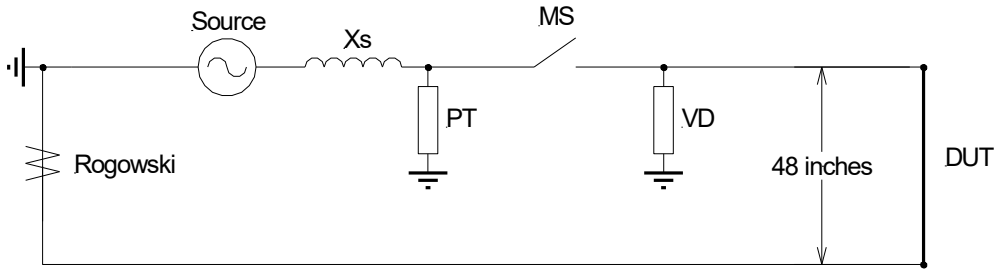


Figure 1: Test circuit schematic for all tests.

Notes:

1. X_S – Source current limiting reactance
2. MS – Making Switch
3. VD – Voltage measurement
4. Rogowski – Current measurement
5. DUT – Device Under Test

Table 1: Strand diameter and dc resistance measurements of sample conductors.

Wire Sample No.	Type	Strand Diameter [1] (in)		Conductor Diameter	Dc Resistance at 20°C
#		1	2	(in)	(μΩ/ft)
1	Encore Wire, 4/0 AWG, 19 strand CU	0.122	0.079	0.492	4.28
2	Encore Wire, 4/0 AWG, 19 strand CU	0.118	0.080	0.501	4.10
3	Encore Wire, 4/0 AWG, 19 strand CU	0.109	0.074	0.495	4.23
4	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.075	0.498	3.98
5	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.079	0.489	4.43
6	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.075	0.490	4.17
7	Encore Wire, 4/0 AWG, 19 strand CU	0.101	0.075	0.489	4.18
8	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.074	0.491	4.15
9	Encore Wire, 4/0 AWG, 19 strand CU	0.106	0.082	0.490	3.97
10	Encore Wire, 4/0 AWG, 19 strand CU	0.105	0.079	0.493	3.73
11	Scorpius 61 x 072 CCS	0.056	---	0.646	6.83
12	Scorpius 61 x 072 CCS	0.058	---	0.649	6.60
13	Scorpius 61 x 072 CCS	0.068	---	0.641	6.60
14	Scorpius 61 x 072 CCS	0.056	---	0.639	6.73
15	Scorpius 61 x 072 CCS	0.067	---	0.646	6.62
16	Scorpius 61 x 072 CCS	0.059	---	0.630	6.53
17	Scorpius 61 x 072 CCS	0.056	---	0.642	6.73
18	Scorpius 61 x 072 CCS	0.067	---	0.637	6.62
19	Scorpius 61 x 072 CCS	0.064	---	0.641	6.85
20	Scorpius 61 x 072 CCS	0.059	---	0.633	6.83
21	Encore Wire, #6 AWG, single strand CU	0.152	---	0.152	33.3
22	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
23	Encore Wire, #6 AWG, single strand CU	0.158	---	0.158	33.2
24	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.4
25	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.3
26	Encore Wire, #6 AWG, single strand CU	0.148	---	0.148	33.6
27	Encore Wire, #6 AWG, single strand CU	0.155	---	0.155	33.3
28	Encore Wire, #6 AWG, single strand CU	0.146	---	0.146	33.1
29	Encore Wire, #6 AWG, single strand CU	0.153	---	0.153	33.2
30	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
31	Scorpius 7 x 080 CCS	0.072	---	0.215	46.3
32	Scorpius 7 x 080 CCS	0.069	---	0.226	45.9
33	Scorpius 7 x 080 CCS	0.065	---	0.220	46.2
34	Scorpius 7 x 080 CCS	0.071	---	0.218	46.4
35	Scorpius 7 x 080 CCS	0.073	---	0.212	46.1
36	Scorpius 7 x 080 CCS	0.065	---	0.216	46.3
37	Scorpius 7 x 080 CCS	0.070	---	0.211	46.1

Note:

[1] Encore 4/0 AWG CU conductor had two sizes of strands, all remaining conductors had one size of strands. Strand and conductor diameters were measured using a digital caliper with a resolution of 0.001 in.

Table 2: Summary of tests on Encore 4/0 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
1	1	Run to fusing	3.85	41.7	60.0	530	923	2	Y
2	2	Withstand	3.85	41.8	62.5	509	889	3	N
3-1	3	EMF (IEEE 837)	4.24	48.0	130	262	826	4	N
3-2	3	EMF (IEEE 837)	4.26	48.0	130	127	503	5	Y
4	4	EMF (IEEE 837)	4.25	48.0	130	260	823	6	Y
5-1	5	EMF (IEEE 837)	4.20	47.4	129	262	808	7	N
5-2	5	EMF (IEEE 837)	4.19	47.4	128	9.9	77	8	Y
6-1	6	EMF (IEEE 837)	3.93	42.6	116	263	662	9	N
6-2	6	EMF (IEEE 837)	3.91	42.6	116	262	654	10	N

Table 3: Summary of tests on Copperweld Scorpius 61 x 072 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
7	11	Run to fusing	3.84	41.7	59.6	673	1173	11	Y
8	12	Run to fusing	4.25	48.1	69.8	500	1157	12	Y
9	13	Run to fusing	4.21	47.5	68.9	508	1150	13	Y
10	14	Withstand	4.09	46.2	66.2	508	1089	14	N
11-1	15	EMF (IEEE 837)	4.21	47.6	129	262	803	15	N
11-2	15	EMF (IEEE 837)	4.20	47.7	129	262	803	16	N
12-1	16	EMF (IEEE 837)	4.21	47.6	129	254	784	17	N
12-2	16	EMF (IEEE 837)	4.19	47.4	128	254	767	18	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

Table 4: Summary of tests on Encore #6 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
13	21	Run to fusing	3.90	5.18	7.36	607	16.3	19	Y
14	23	Run to fusing	3.90	5.18	7.57	600	16.1	20	Y
15	24	Run to fusing	4.27	5.68	8.15	500	16.1	21	Y
16-1	25	EMF (IEEE 837)	3.77	5.86	16.2	262	13.9	22	N
16-2	25	EMF (IEEE 837)	3.77	5.86	16.1	262	13.9	23	N

Table 5: Summary of tests on Copperweld Scorpius 7 x 080 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
17	31	Withstand	3.88	5.16	7.44	858	22.9	24	N
18	32	Run to fusing	3.89	5.16	7.43	908	24.2	25	Y
19	33	Run to fusing	4.48	7.00	10.3	493	24.1	26	Y
20	34	Run to fusing	4.41	6.91	10.2	502	23.9	27	Y
21-1	35	EMF (IEEE 837)	3.81	5.91	16.3	262	14.0	28	N
21-2	35	EMF (IEEE 837)	3.80	5.92	16.2	262	13.8	29	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

APPENDIX B – WAVEFORMS

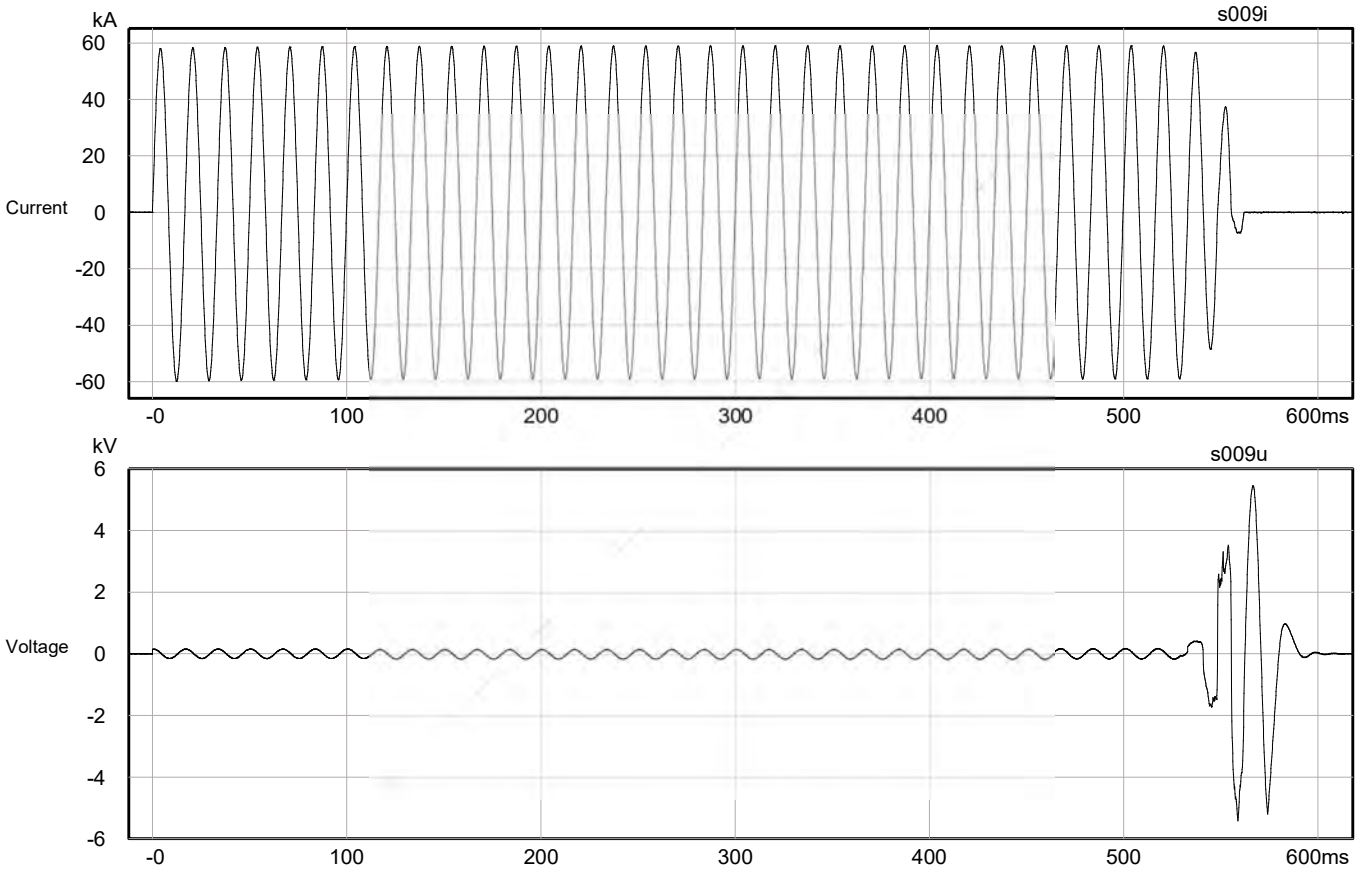


Figure 2: Waveforms for Test #1, Encore 4/0 AWG Sample 1.

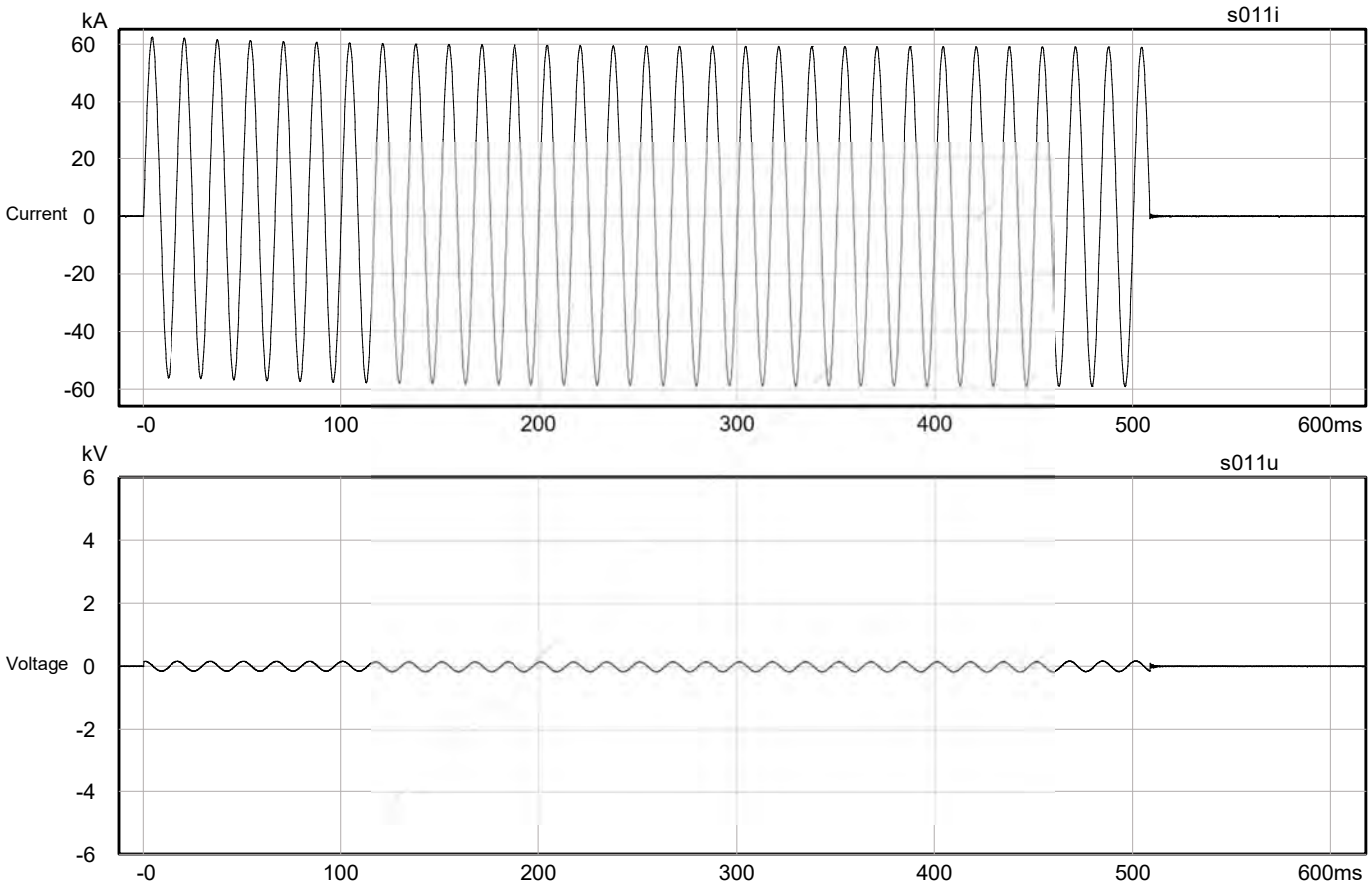


Figure 3: Waveforms for Test #2, Encore 4/0 AWG Sample 2.

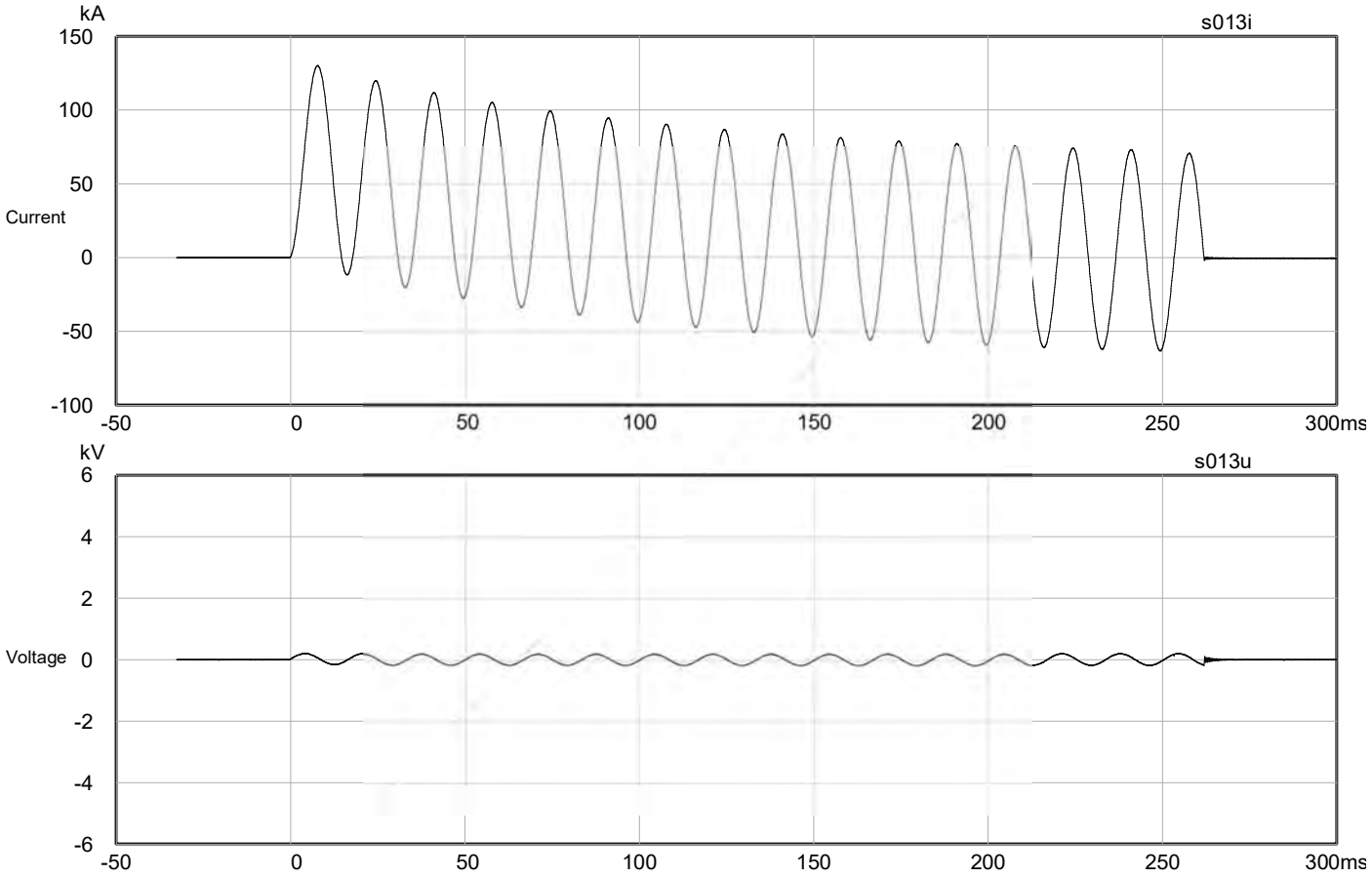


Figure 4: Waveforms for Test #3-1, Encore 4/0 AWG Sample 3.

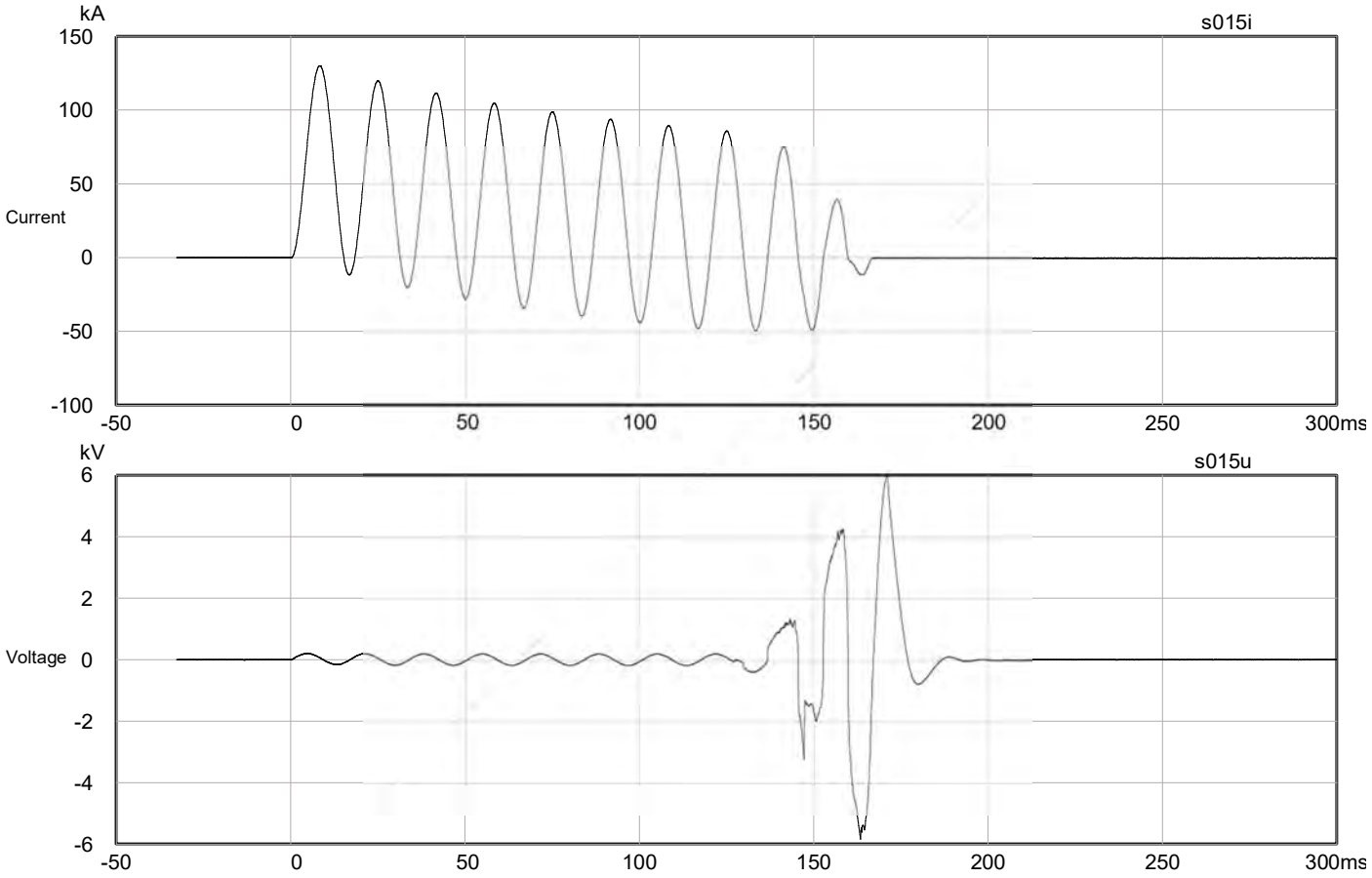


Figure 5: Waveforms for Test #3-2, Encore 4/0 AWG Sample 3.

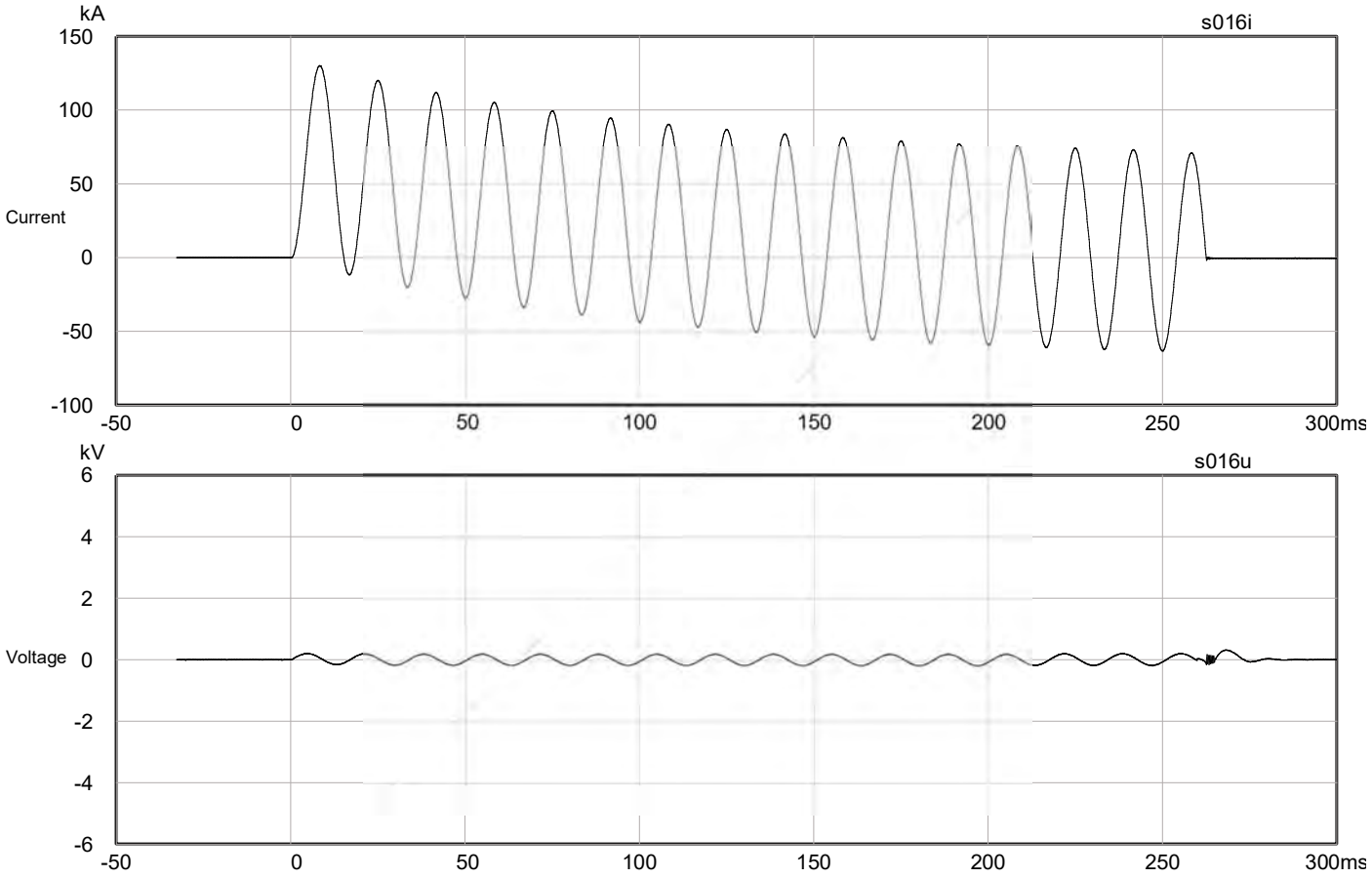


Figure 6: Waveforms for Test #4, Encore 4/0 AWG Sample 4.

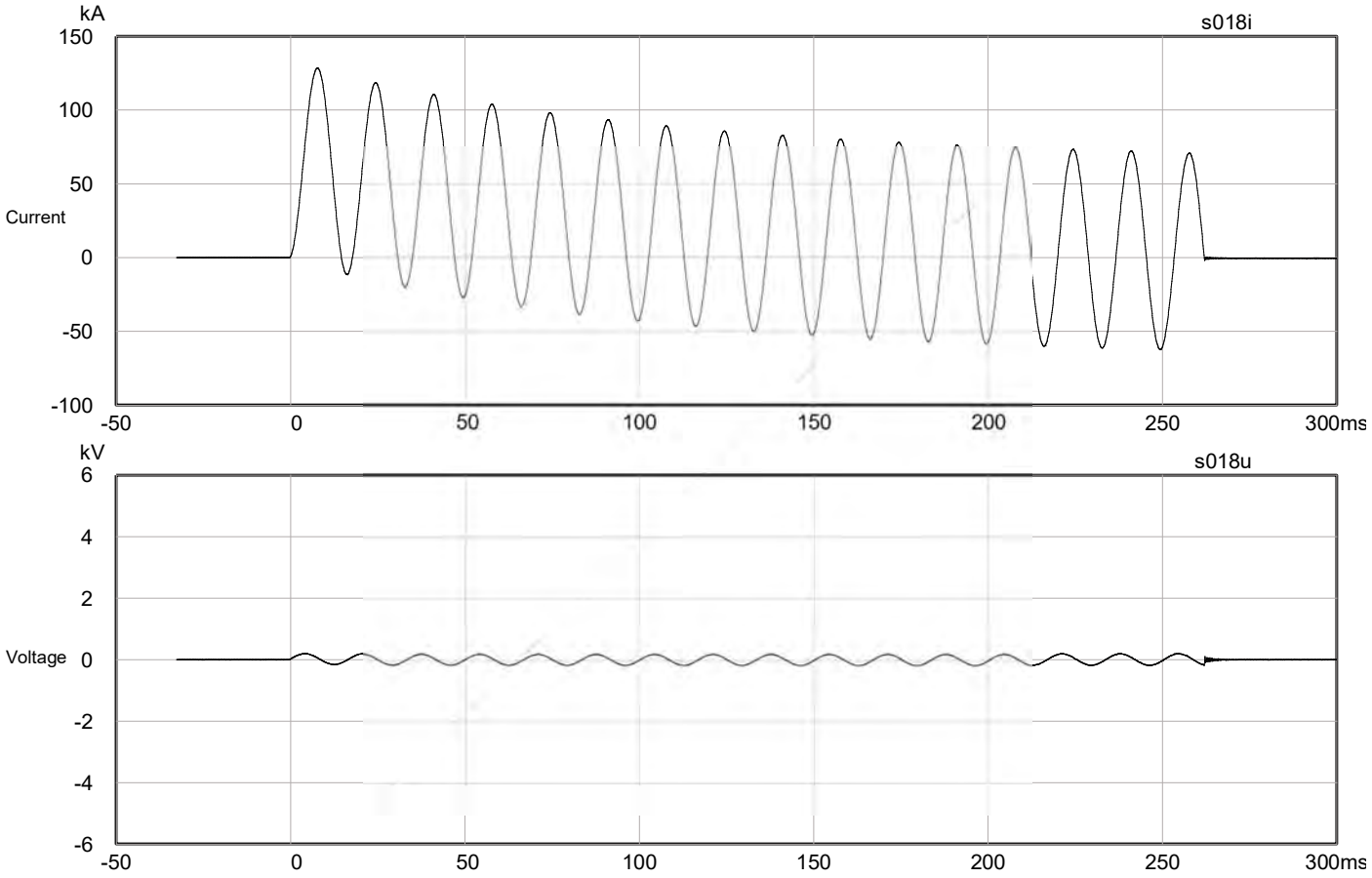


Figure 7: Waveforms for Test #5-1, Encore 4/0 AWG Sample 5.

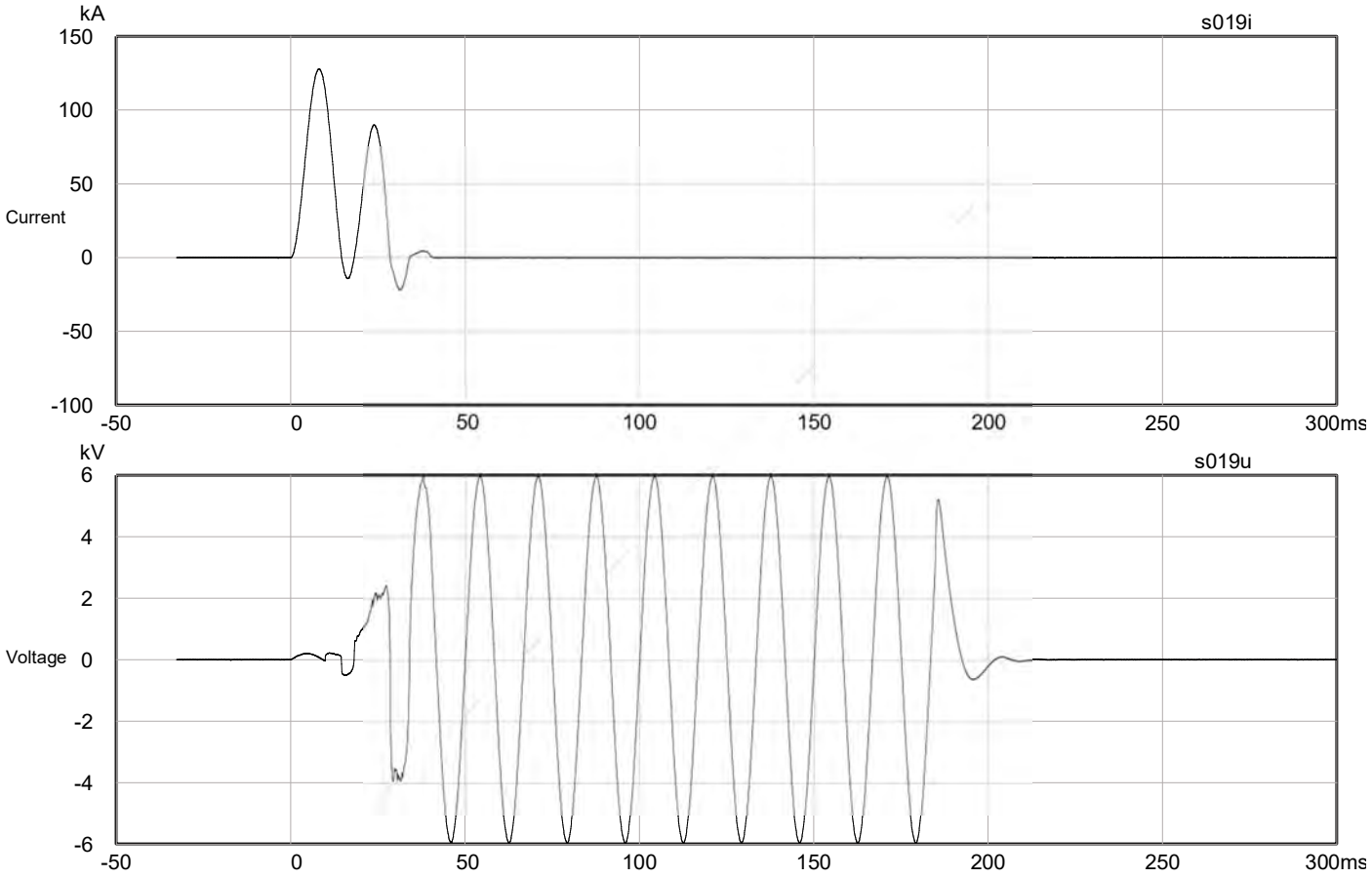


Figure 8: Waveforms for Test #5-2, Encore 4/0 AWG Sample 5.

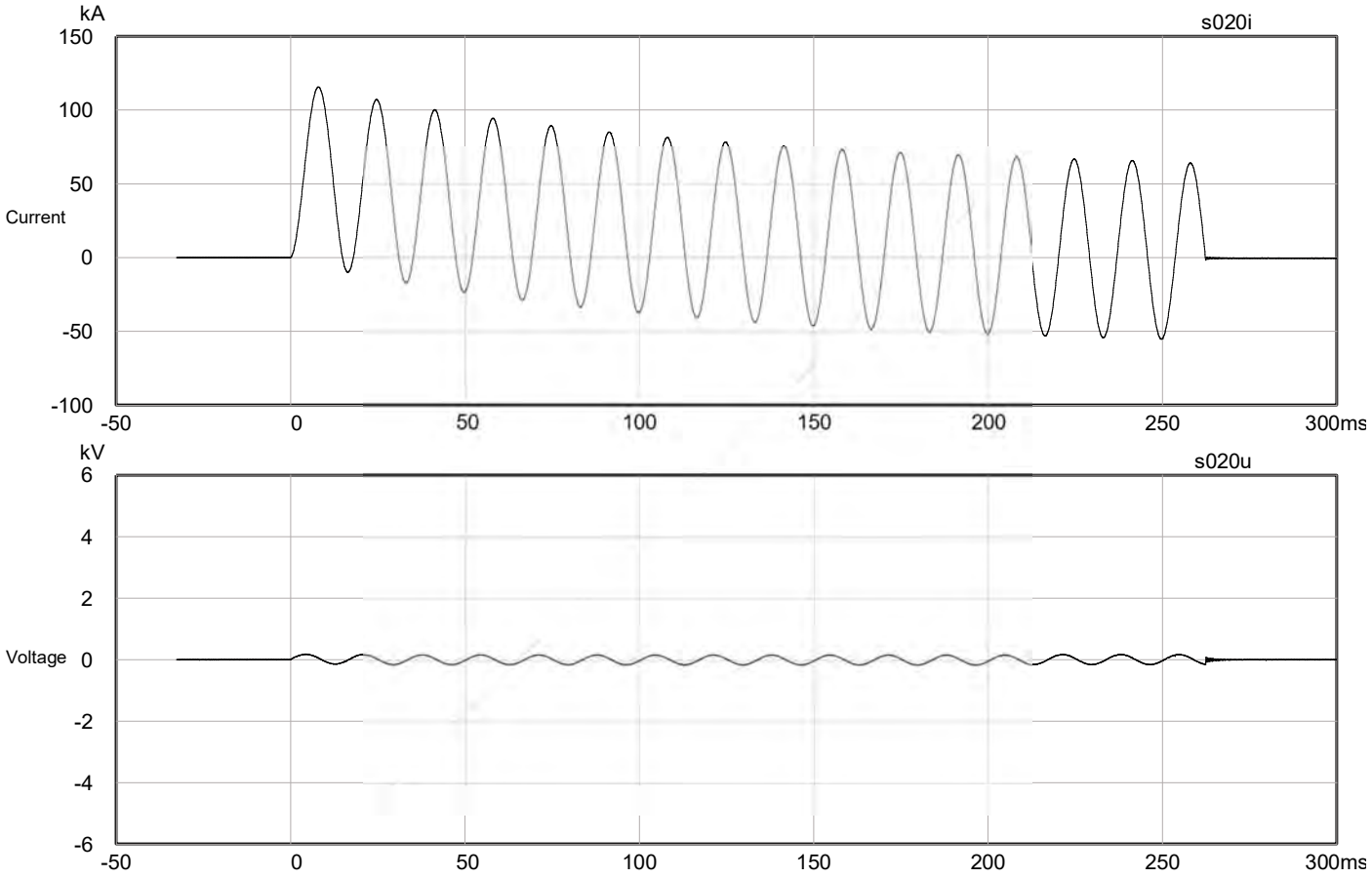


Figure 9: Waveforms for Test #6-1, Encore 4/0 AWG Sample 6.

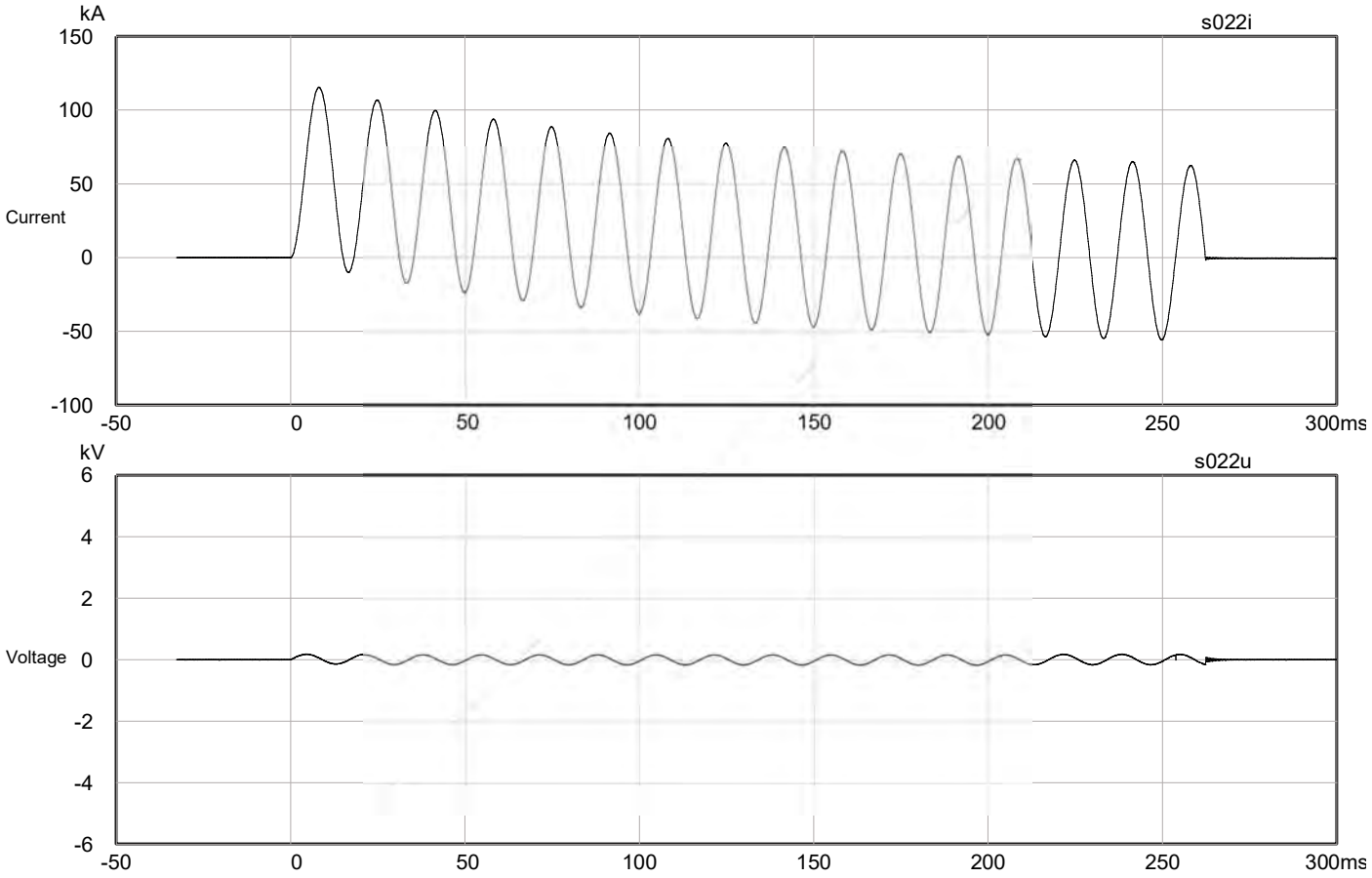


Figure 10: Waveforms for Test #6-2, Encore 4/0 AWG Sample 6.

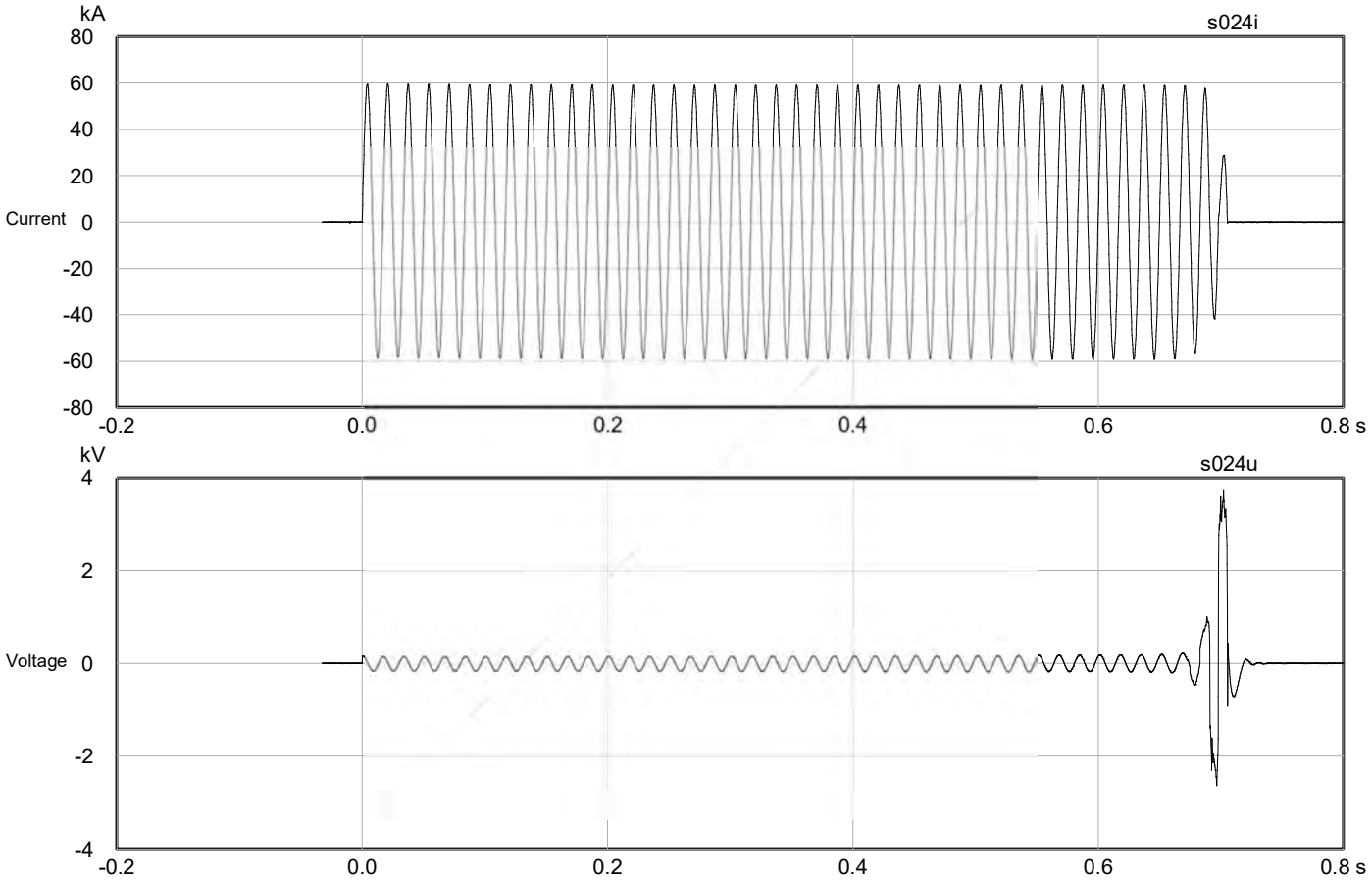


Figure 11: Waveforms for Test #7, Copperweld Scorpius 61 x 072 Sample 11.

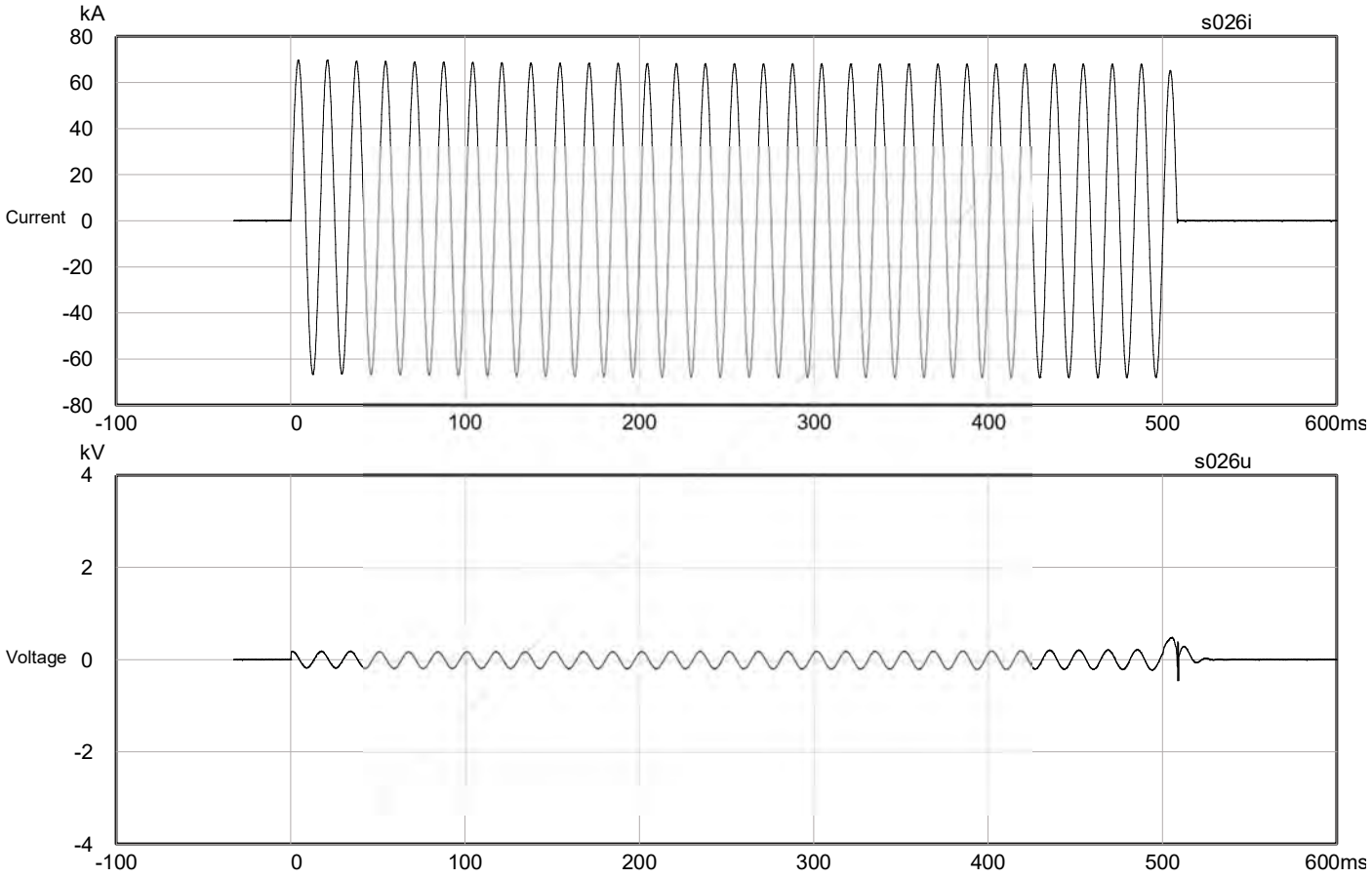


Figure 12: Waveforms for Test #6, Copperweld Scorpius 61 x 072 Sample 12.

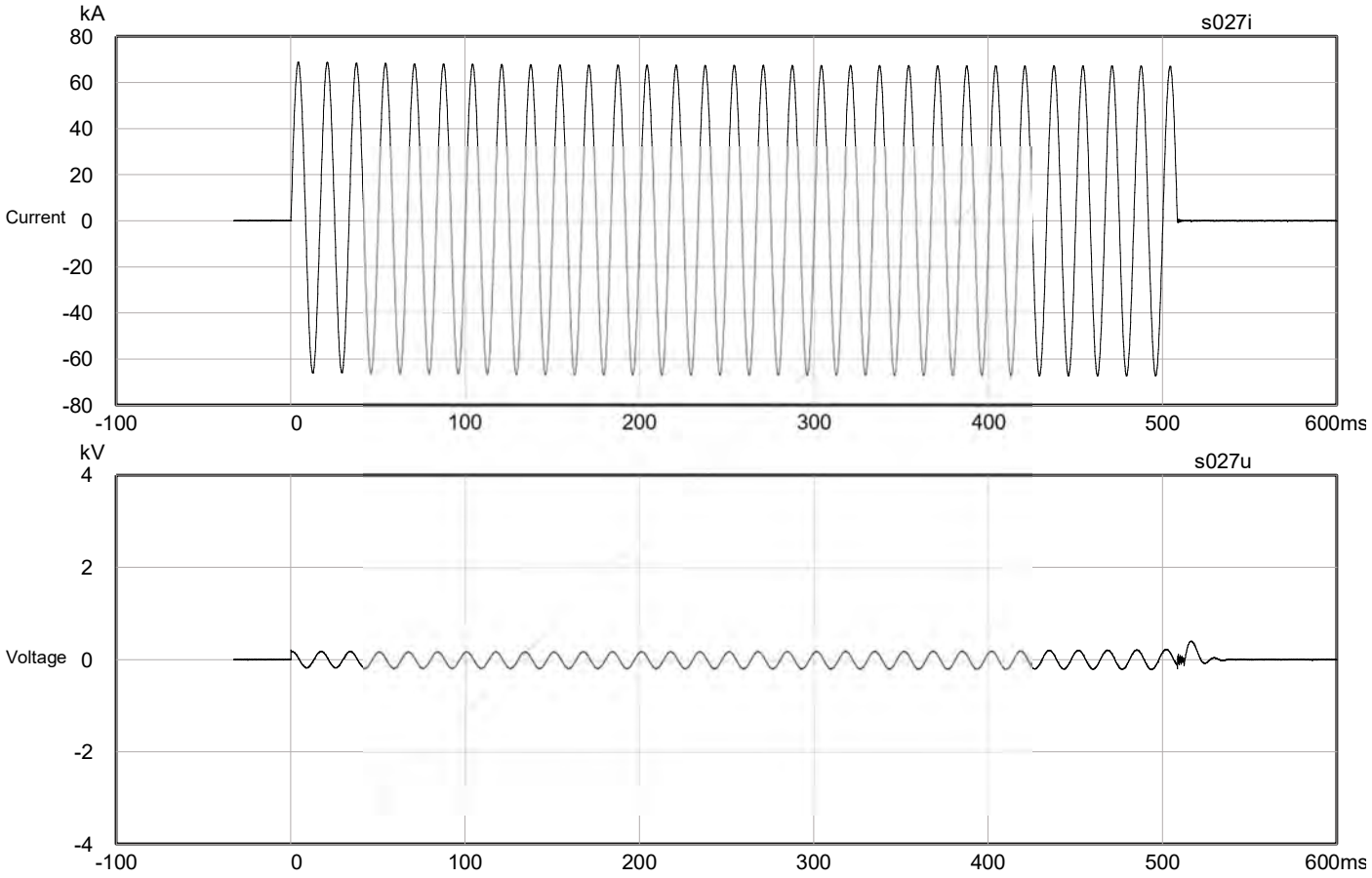


Figure 13: Waveforms for Test #9, Copperweld Scorpius 61 x 072 Sample 13.

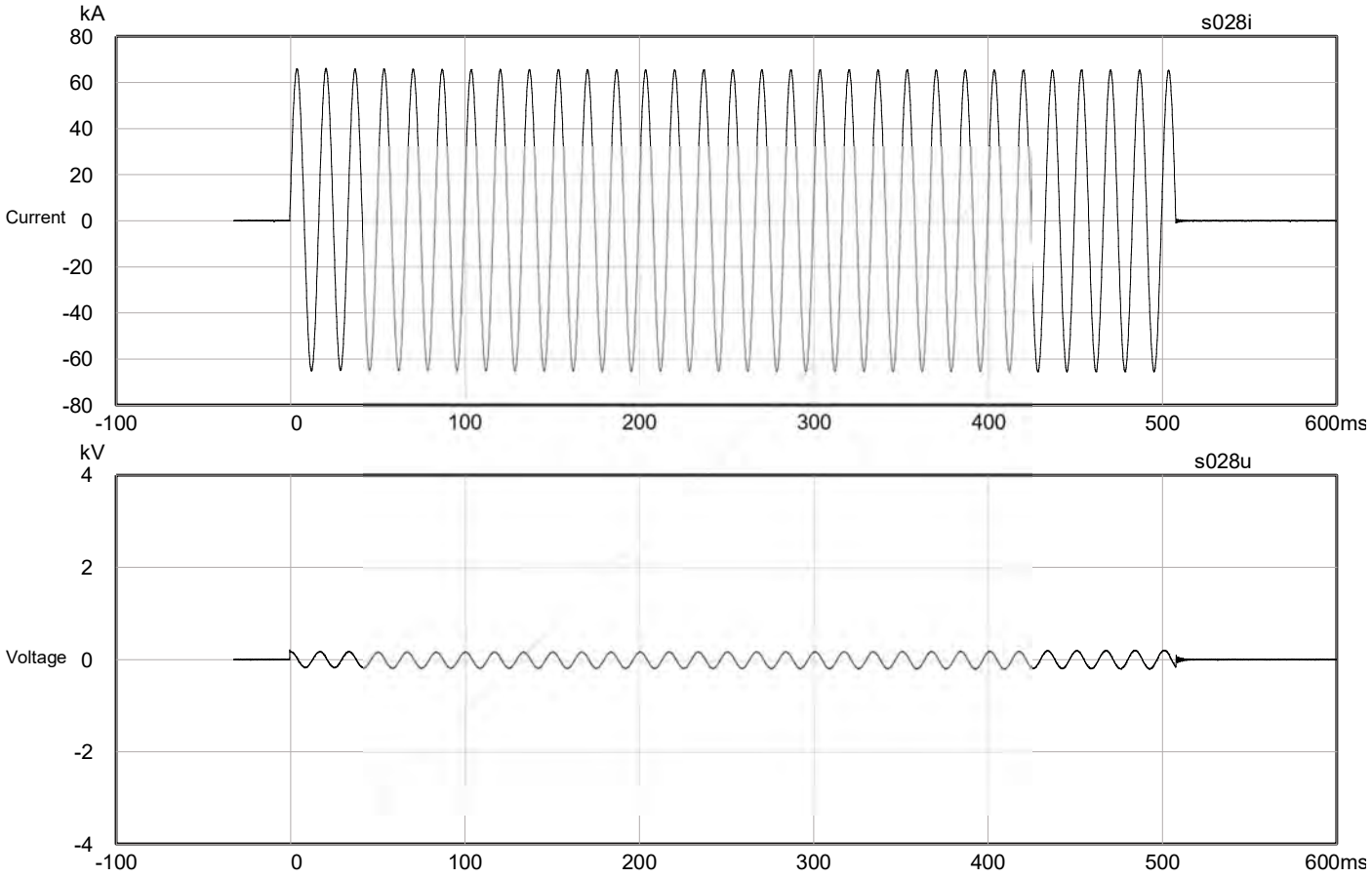


Figure 14: Waveforms for Test #10, Copperweld Scorpius 61 x 072 Sample 14.

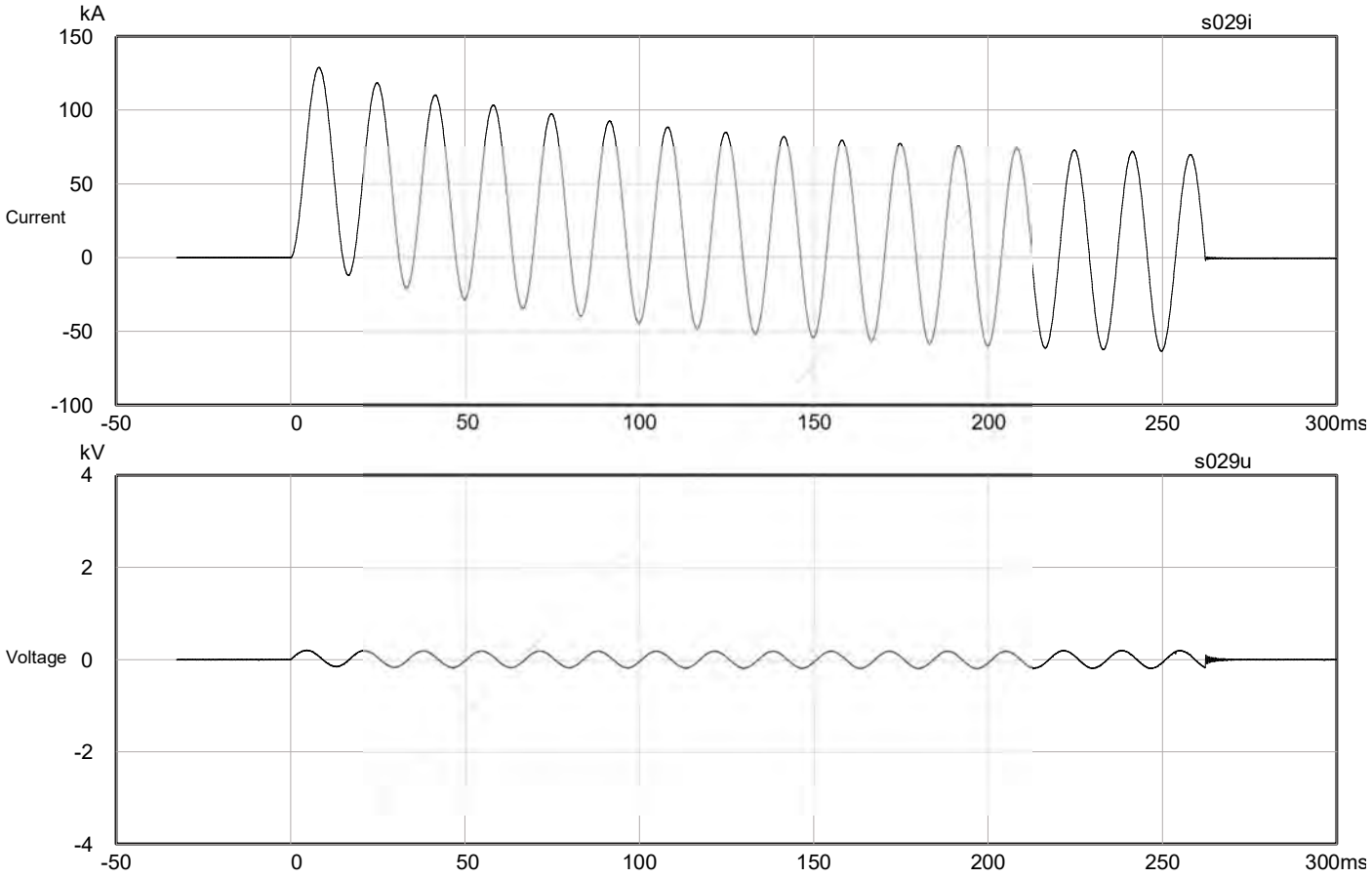


Figure 15: Waveforms for Test #11-1, Copperweld Scorpius 61 x 072 Sample 15.

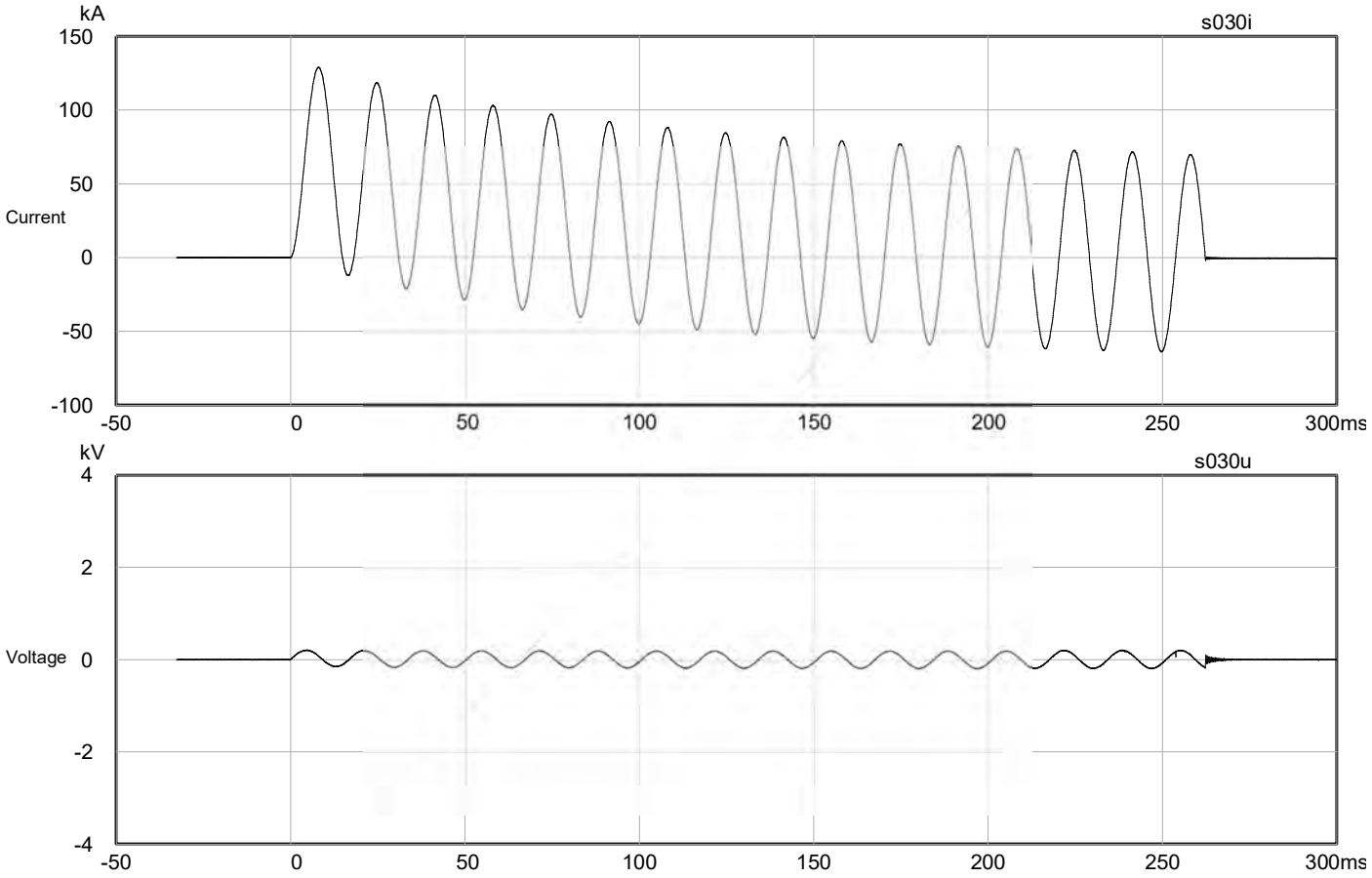


Figure 16: Waveforms for Test #11-2, Copperweld Scorpius 61 x 072 Sample 15.

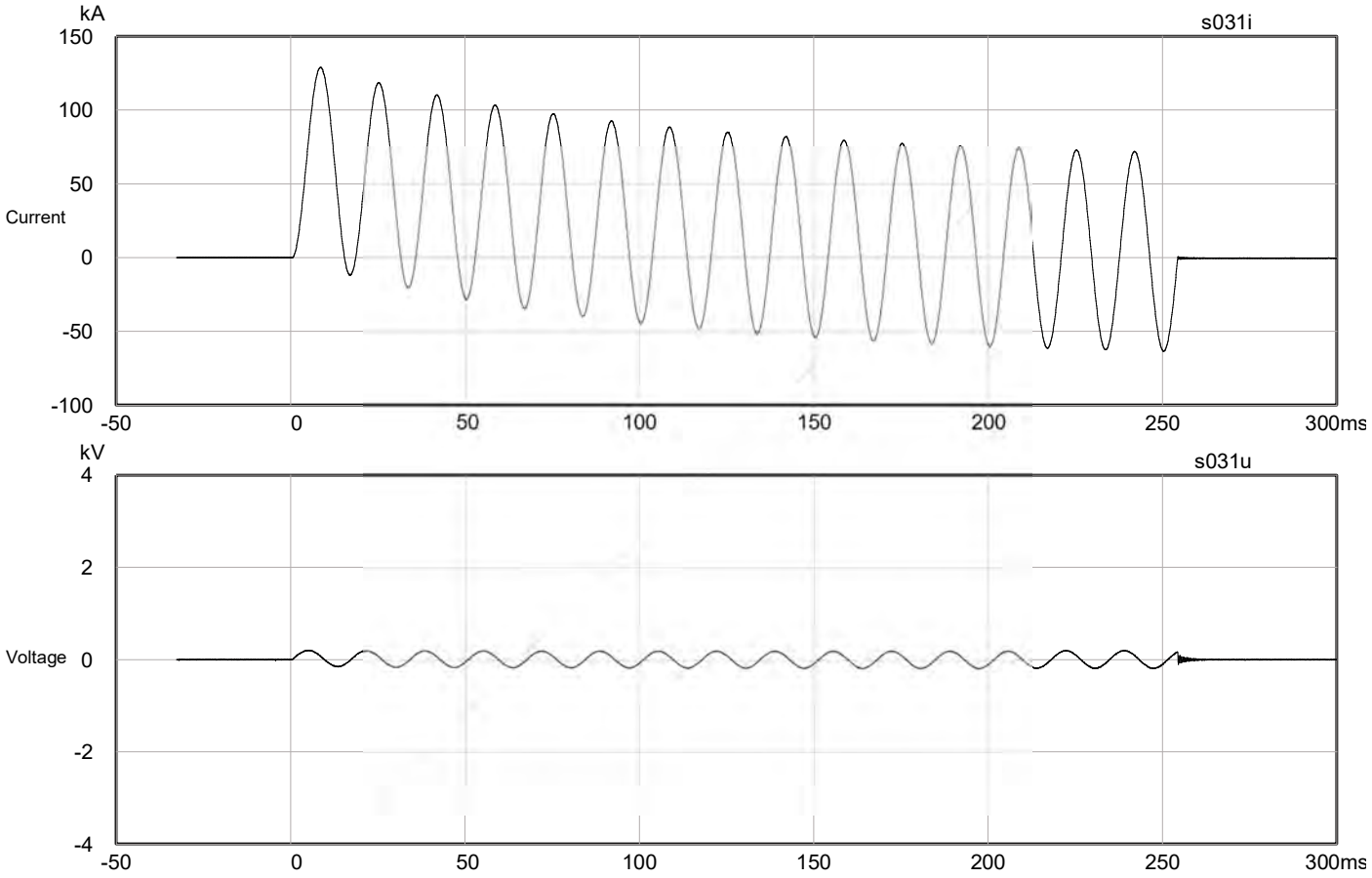


Figure 17: Waveforms for Test #12-1, Copperweld Scorpius 61 x 072 Sample 16.

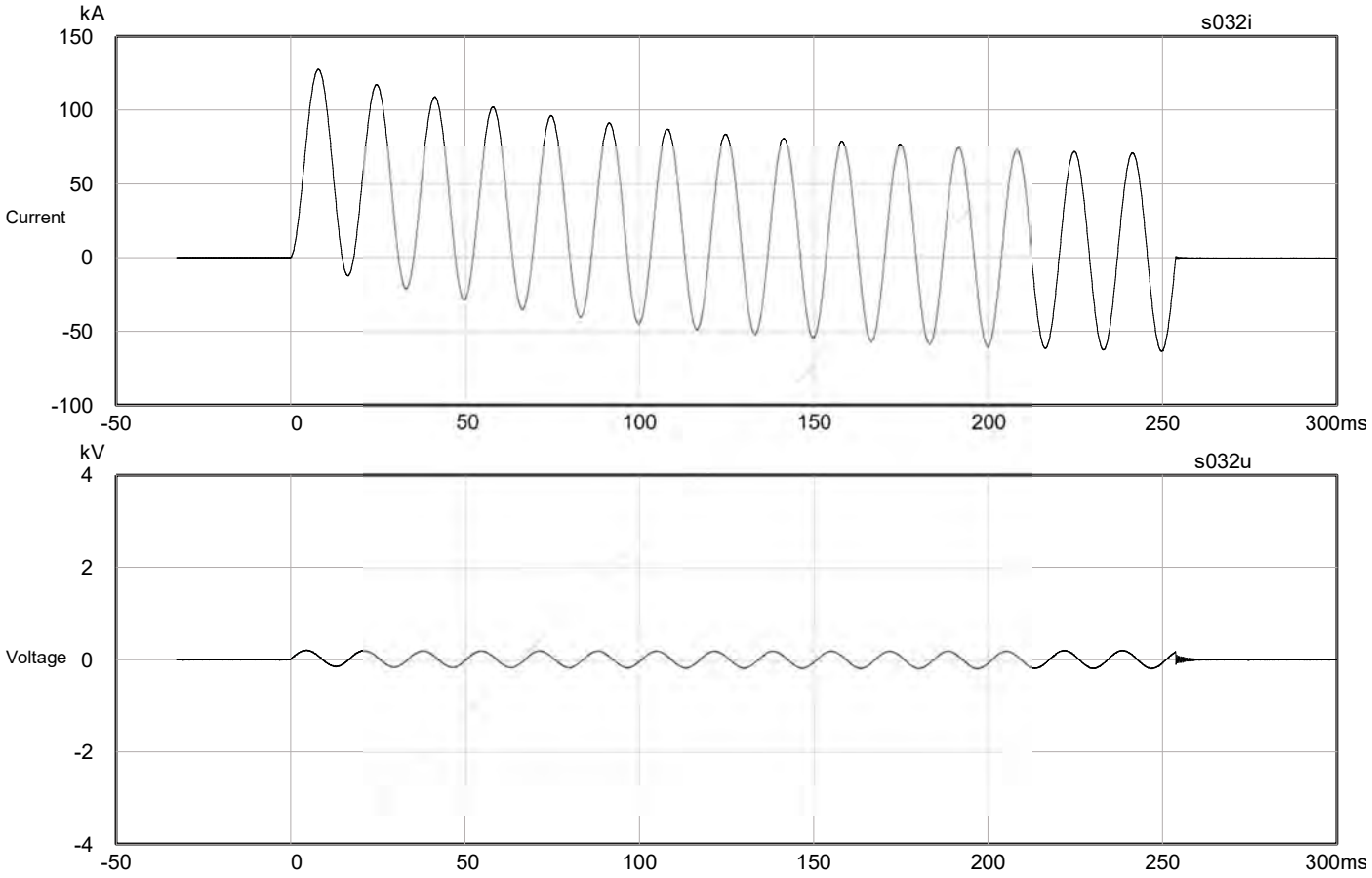


Figure 18: Waveforms for Test #12-2, Copperweld Scorpius 61 x 072 Sample 16.

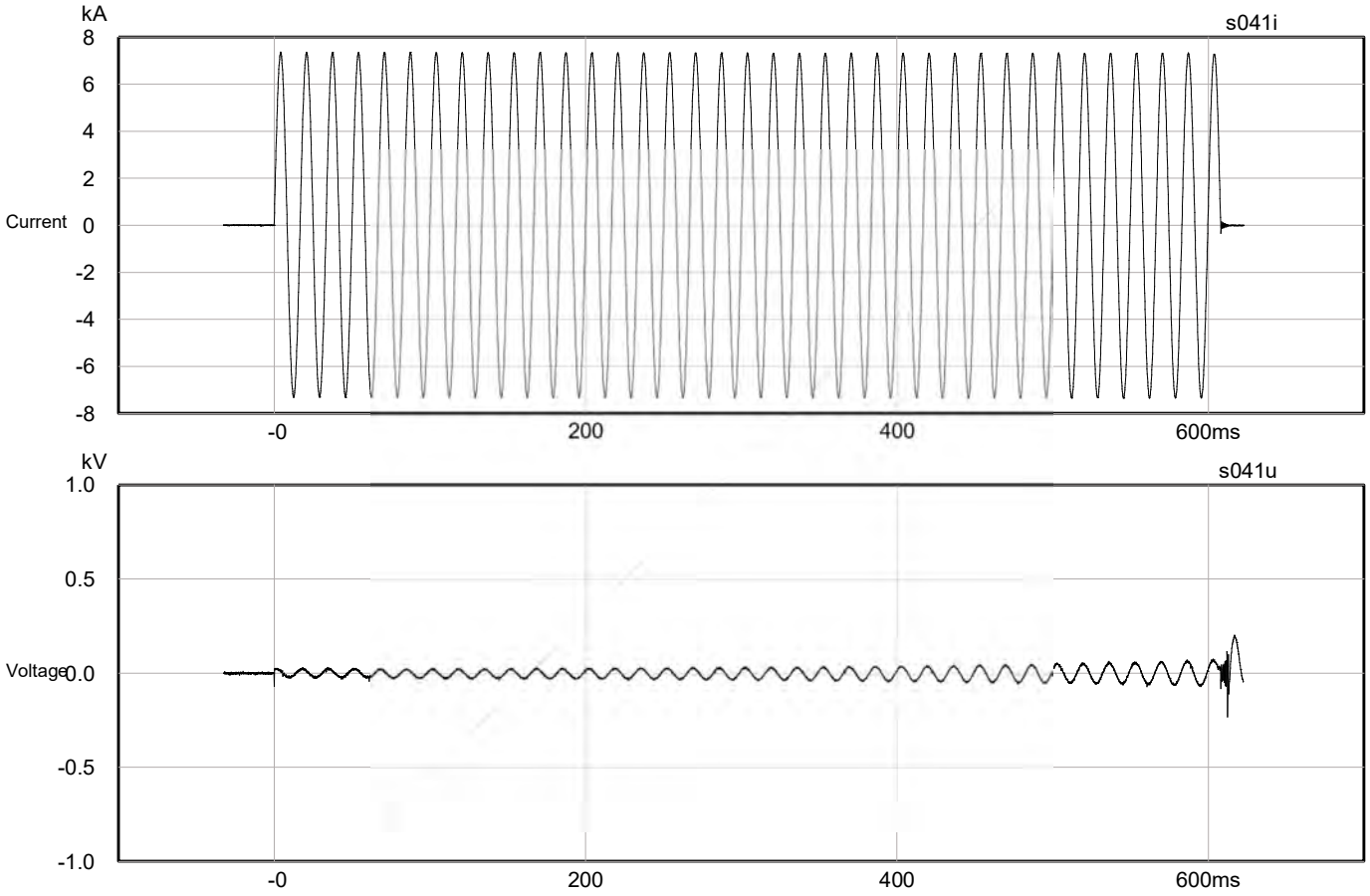


Figure 19: Waveforms for Test #13, Encore #6 AWG Sample 21.

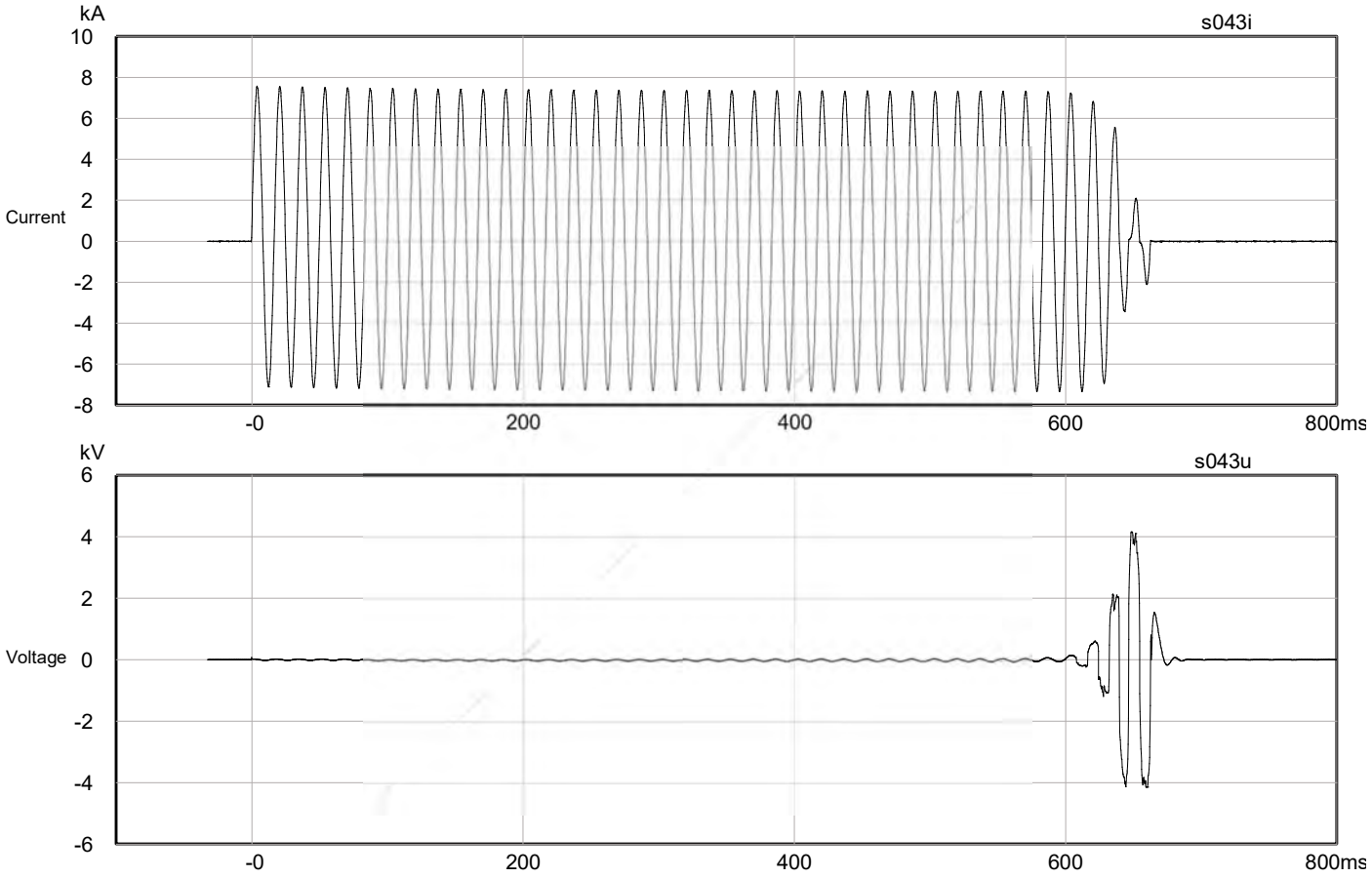


Figure 20: Waveforms for Test #14, Encore #6 AWG Sample 23.

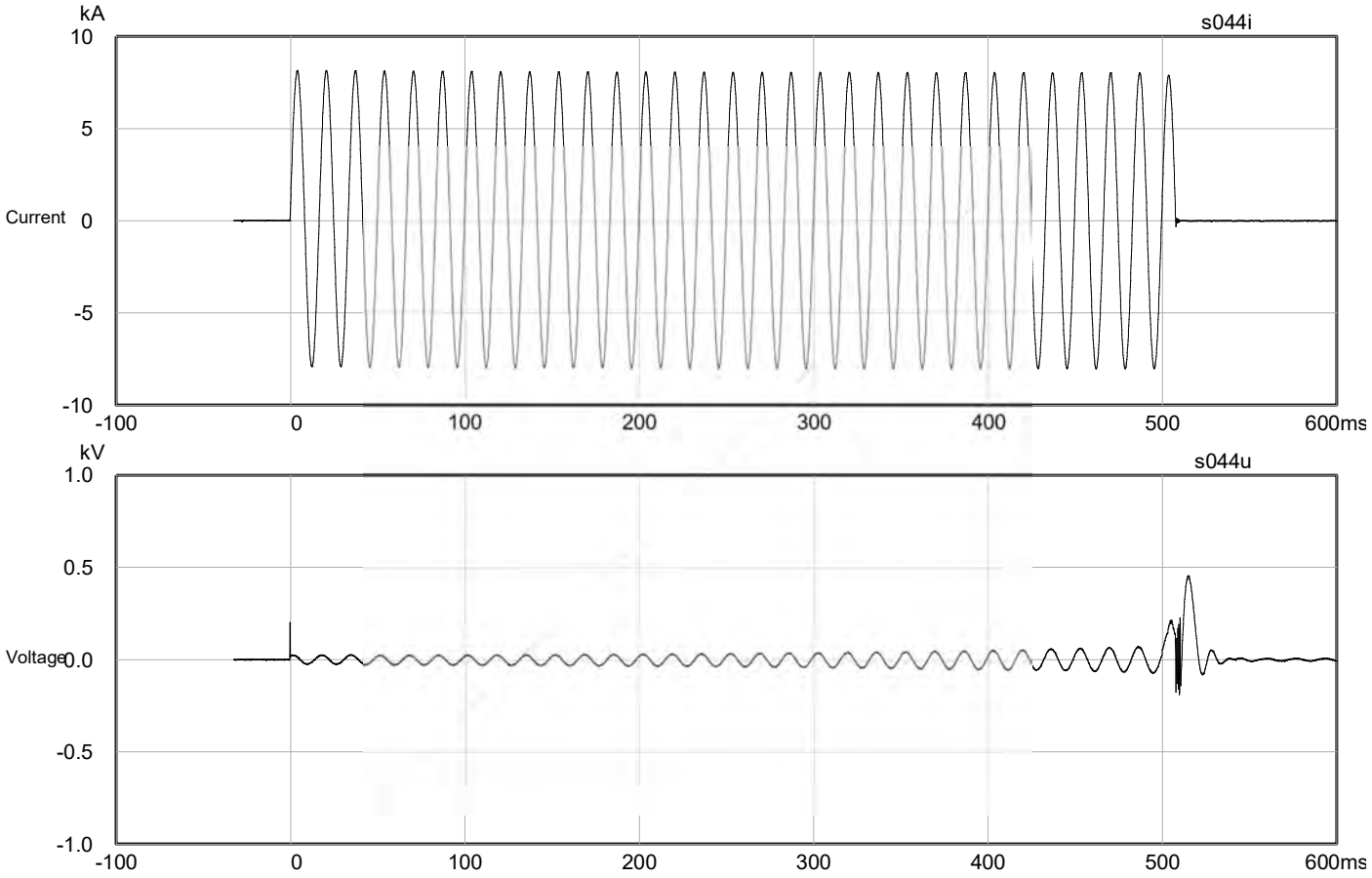


Figure 21: Waveforms for Test #15, Encore #6 AWG Sample 24.

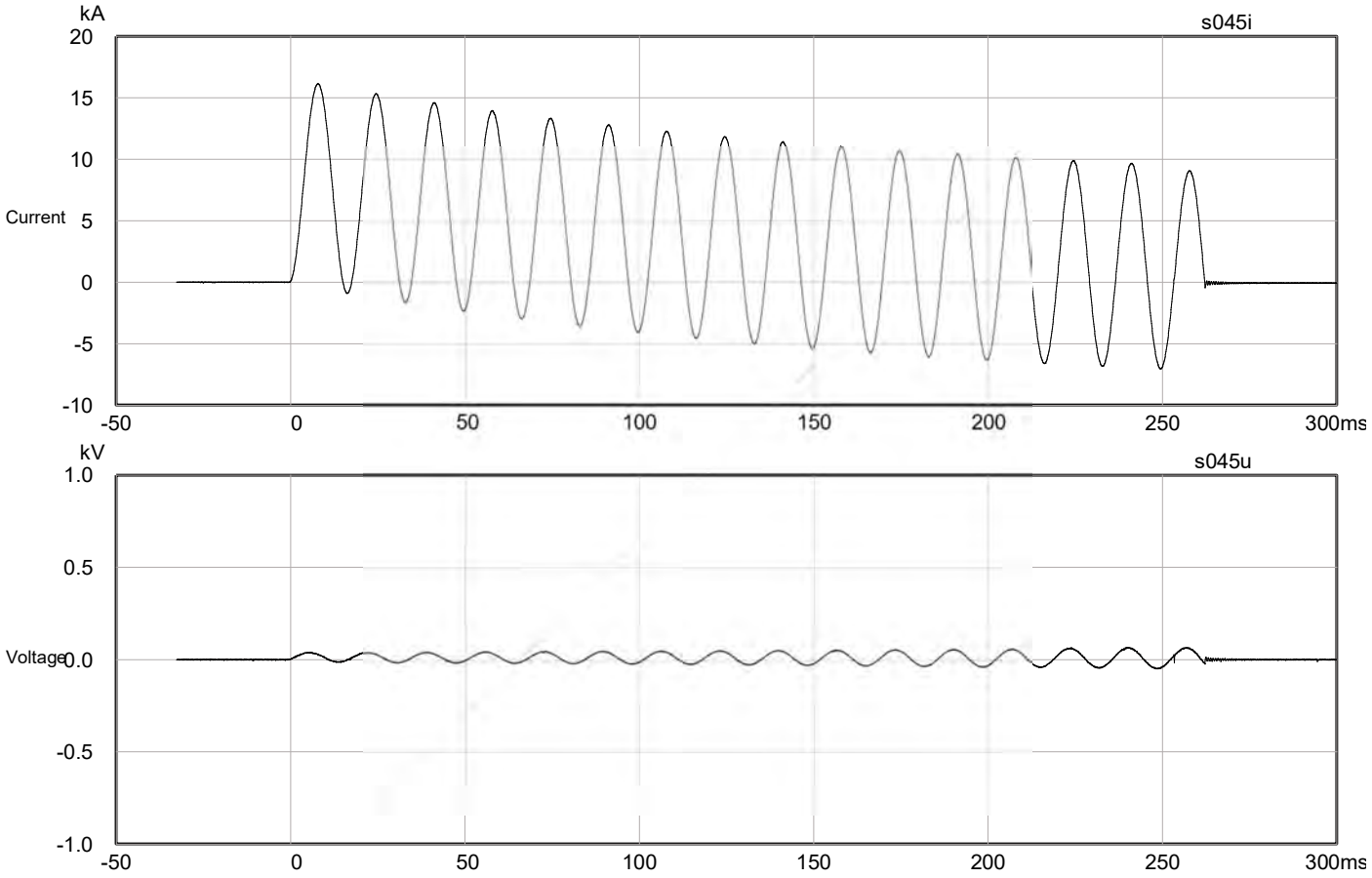


Figure 22: Waveforms for Test #16-1, Encore #6 AWG Sample 25.

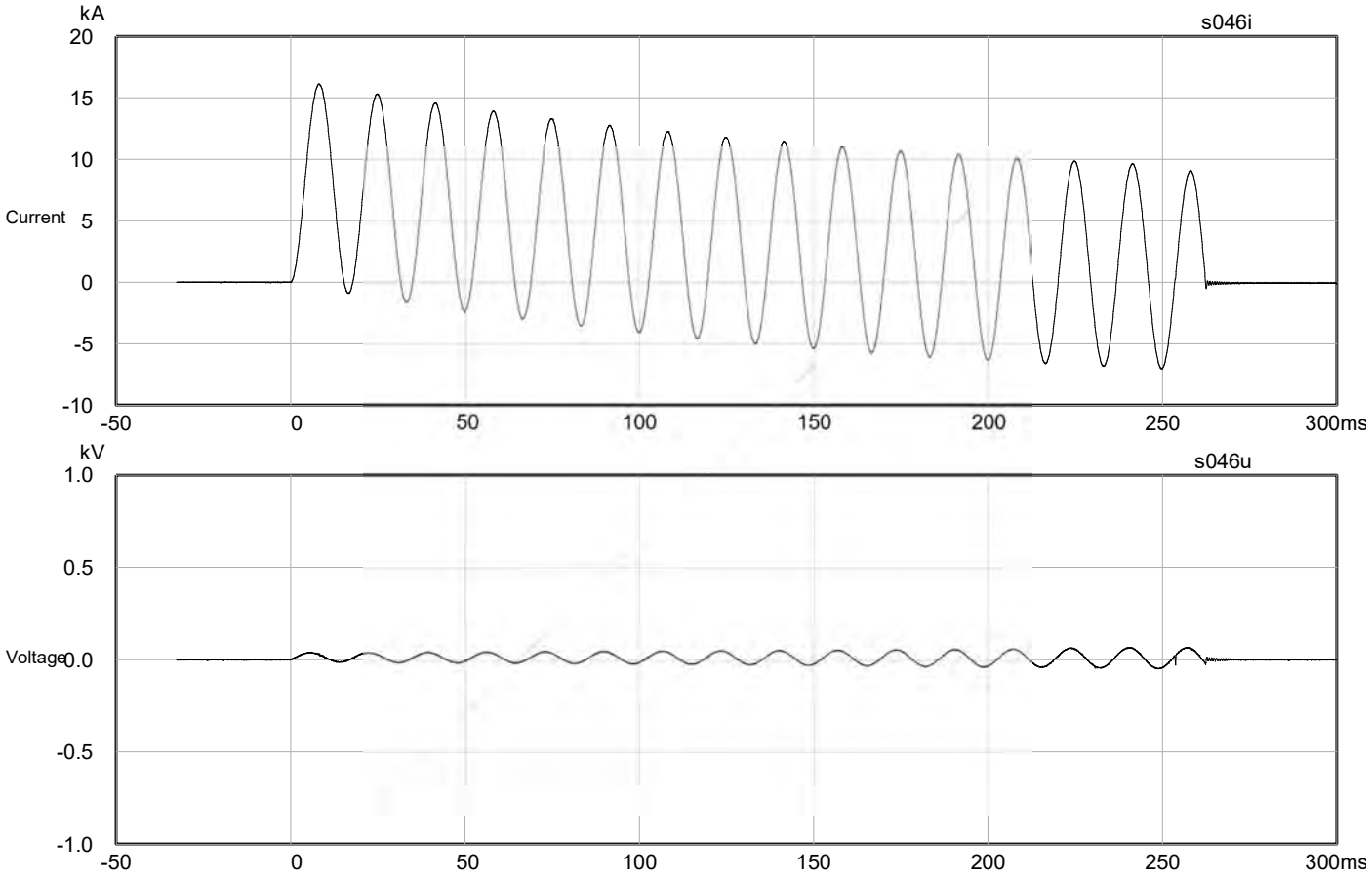


Figure 23: Waveforms for Test #16-2, Encore #6 AWG Sample 25.

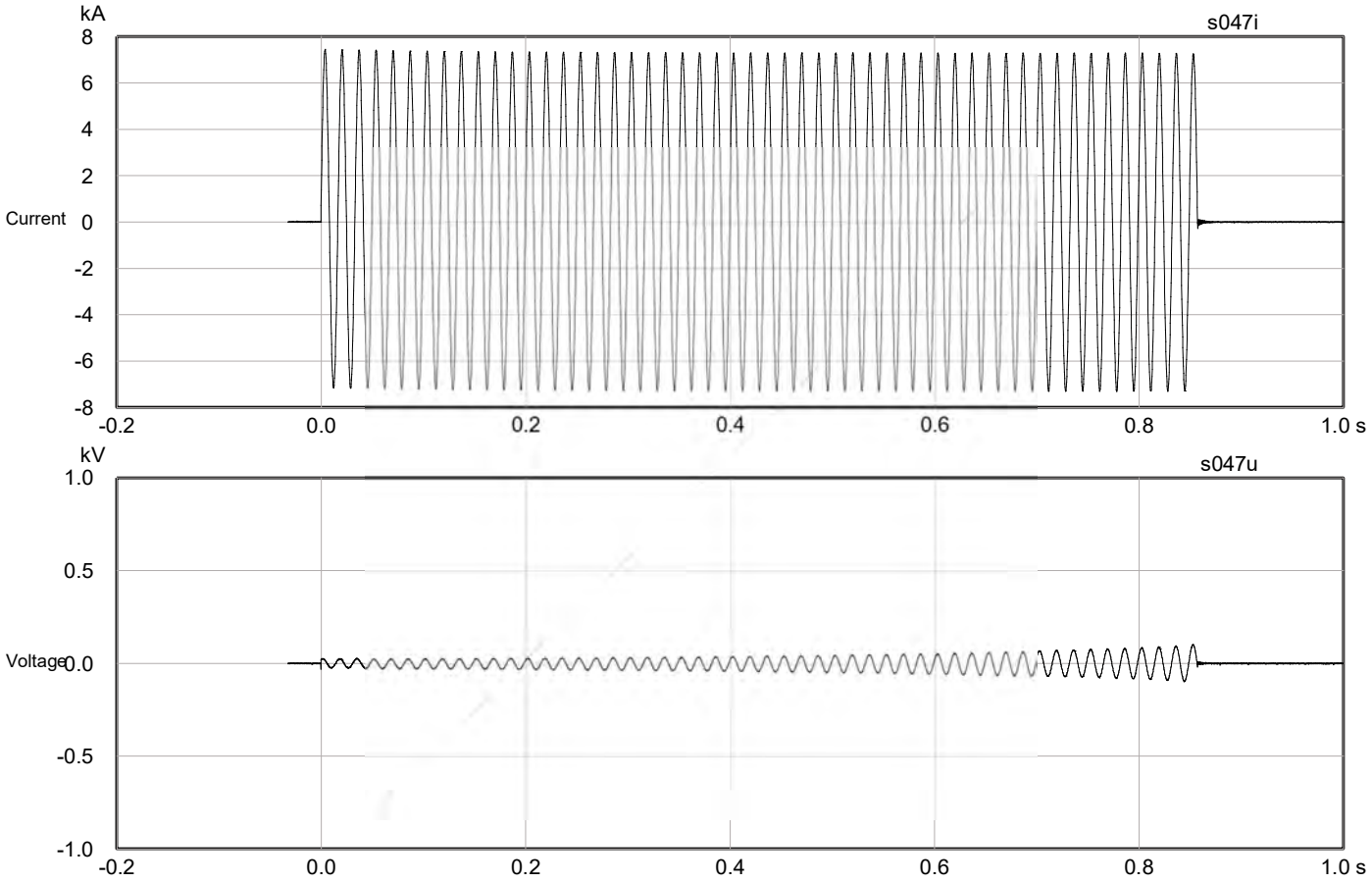


Figure 24: Waveforms for Test #17, Encore #6 AWG Sample 31.

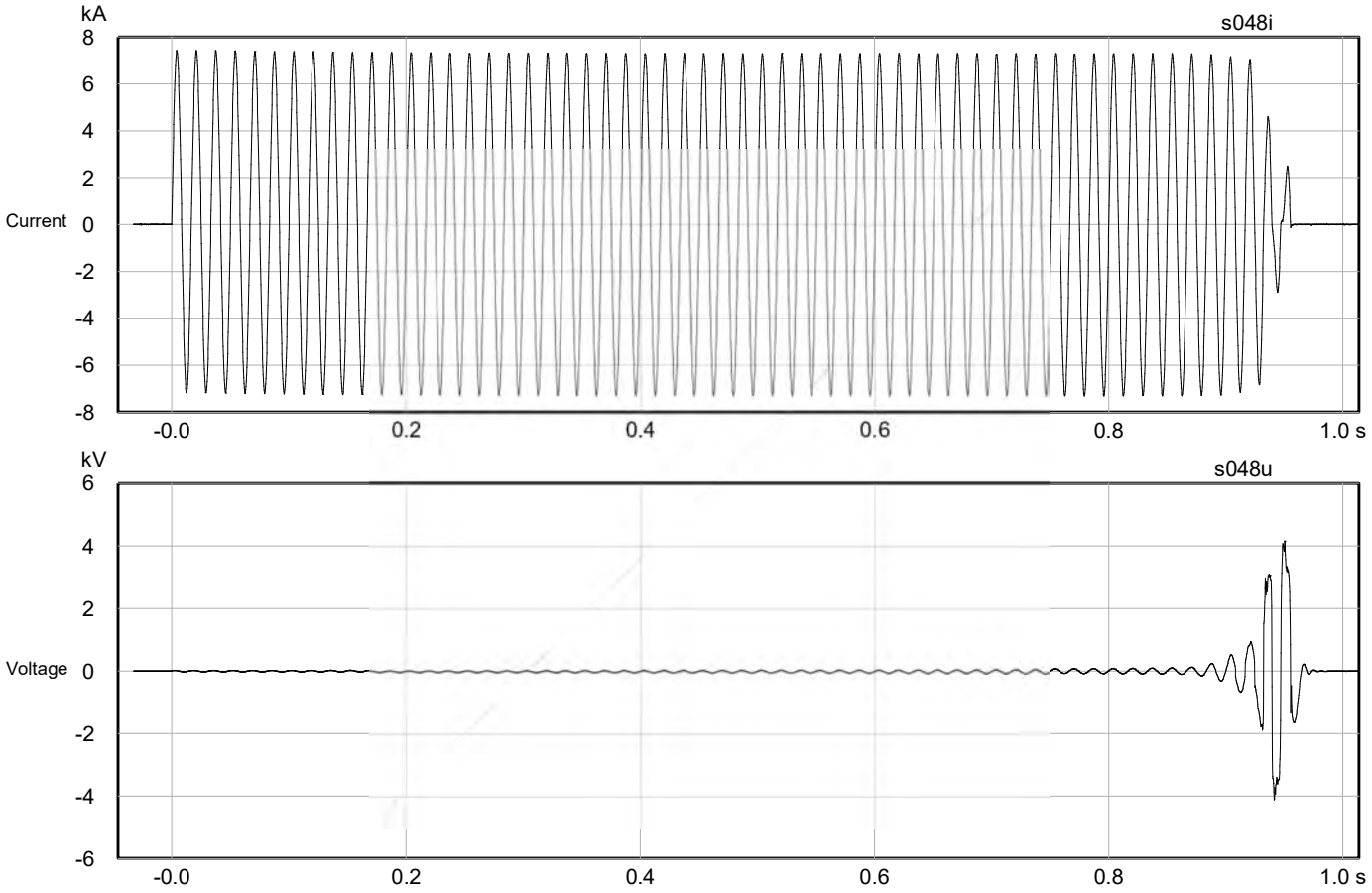


Figure 25: Waveforms for Test #18, Copperweld Scorpius 7 x 080 Sample 32.

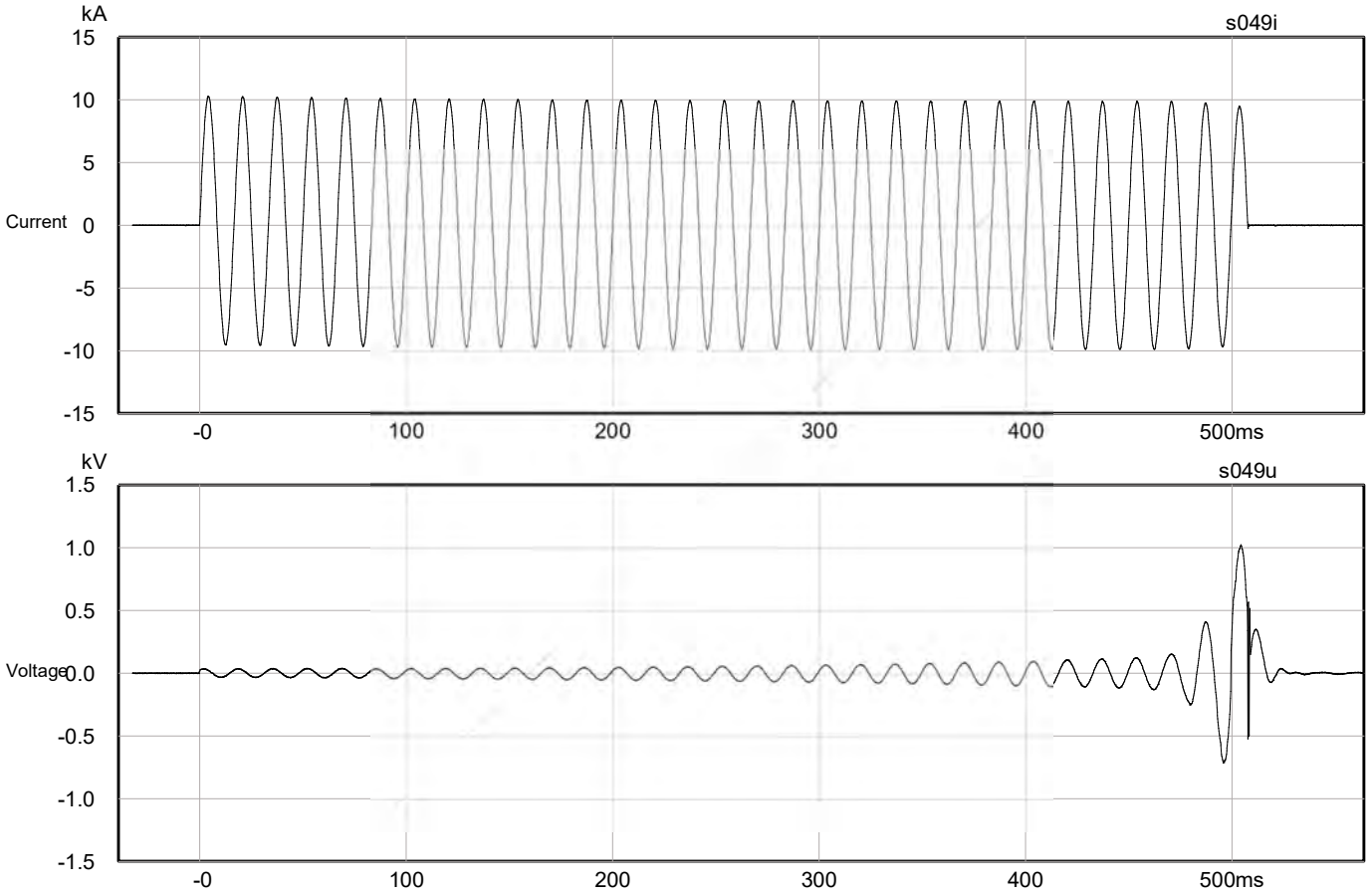


Figure 26: Waveforms for Test #19, Copperweld Scorpius 7 x 080 Sample 33.

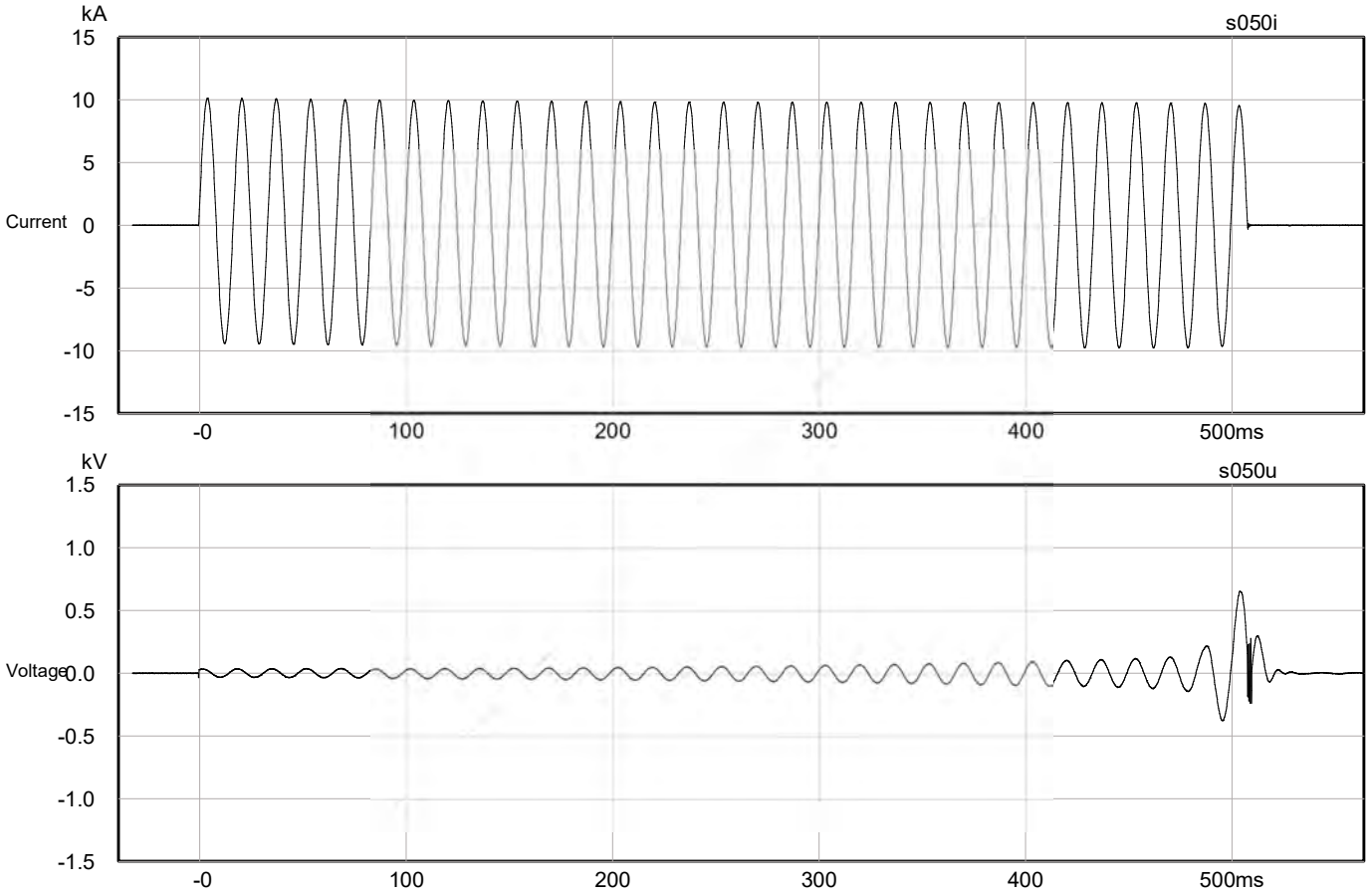


Figure 27: Waveforms for Test #20, Copperweld Scorpius 7 x 080 Sample 34.

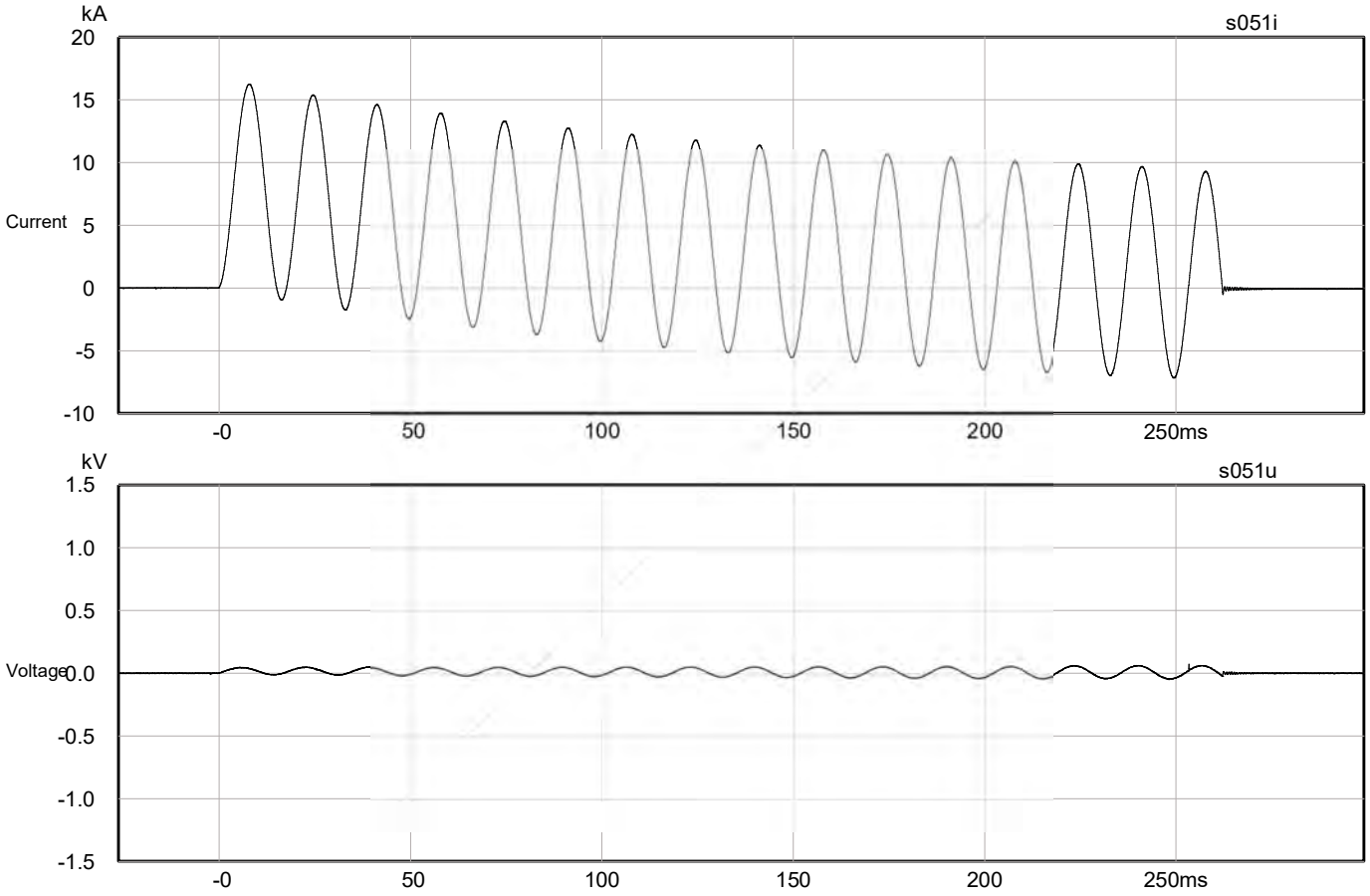


Figure 28: Waveforms for Test #21-1, Copperweld Scorpius 7 x 080 Sample 35.

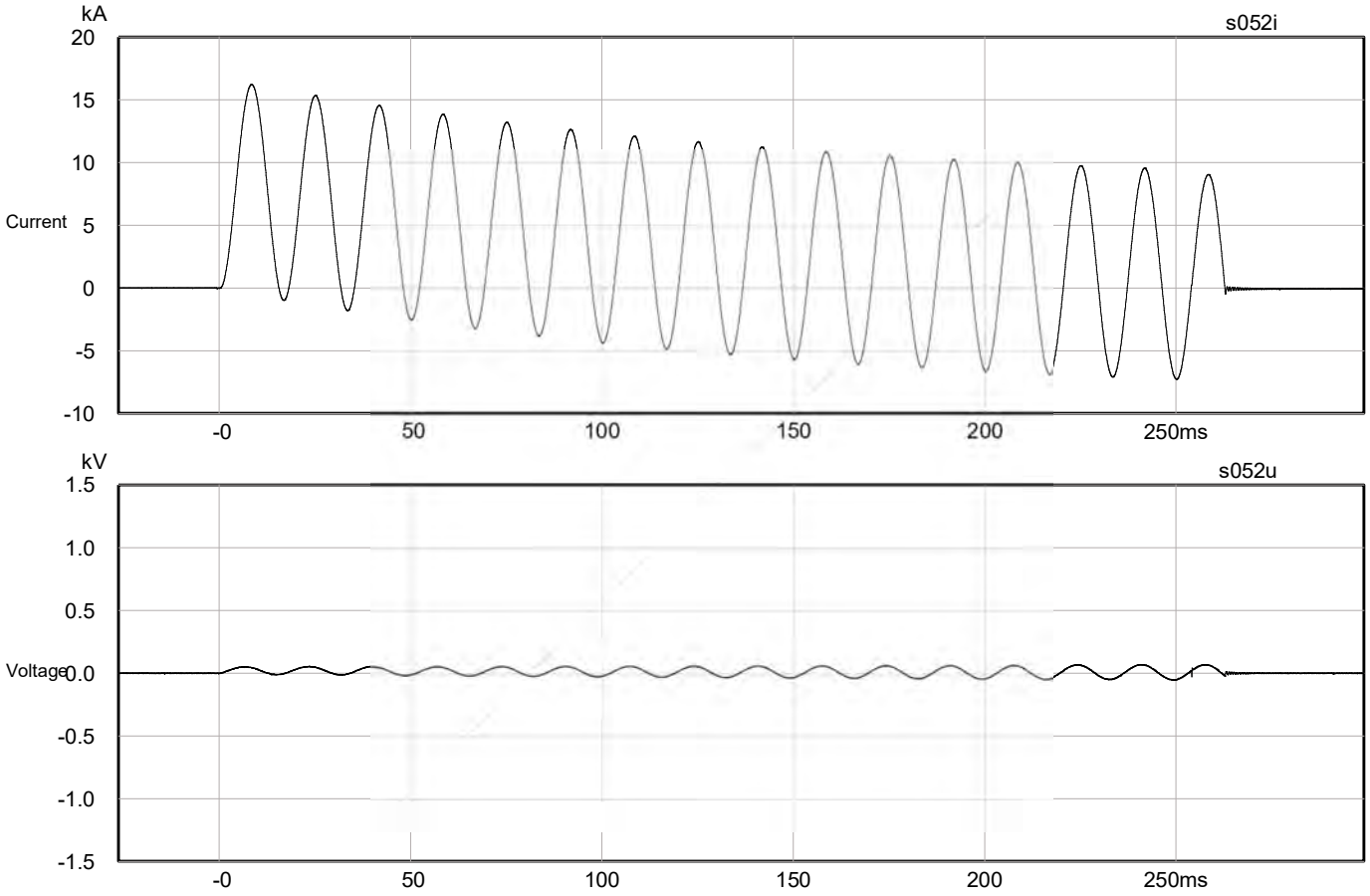


Figure 29: Waveforms for Test #21-2, Copperweld Scorpius 7 x 080 Sample 35.

APPENDIX C – PHOTOGRAPHS OF THE TEST OBJECTS



Figure 30: Test set up for the Encore 4/0 AWG Cu conductor. The power source bus is on the left and the ground bus is on the right.



Figure 31: Test set up for the Copperweld Scorpius 61 x 072 CCS conductor.



Figure 32: Test set up for the Encore #6 AWG Cu conductor.



Figure 33: Test set up for the Copperweld Scorpius 7 x 080 CCS conductor.

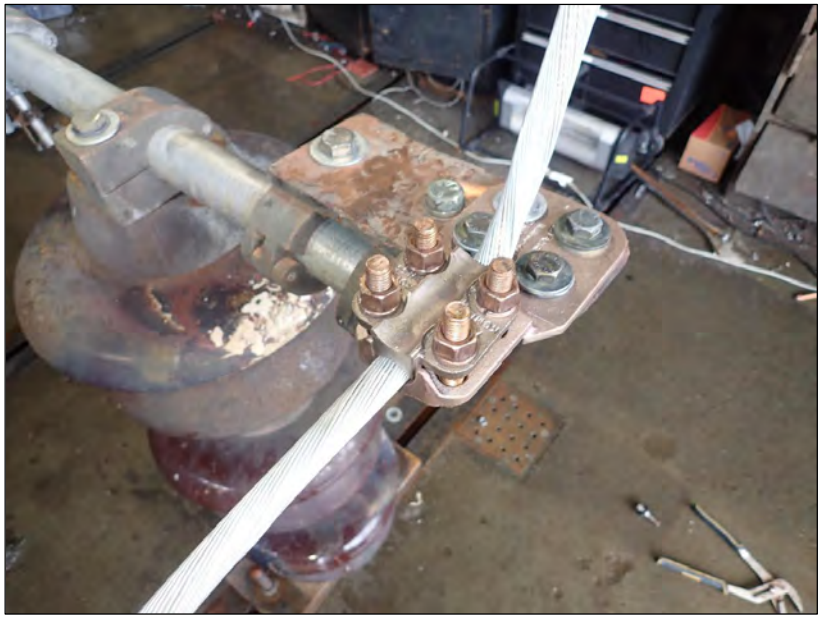


Figure 34: Typical Burndy terminal connector used to connect the Encore 4/0 AWG or Copperweld Scorpius 61 x 072 CCS conductors to the laboratory buses.



Figure 35: Typical Burndy terminal connector used to connect the Encore #6 AWG or Copperweld Scorpius 7 x 080 CCS conductors to the laboratory buses.

APPENDIX D – CALCUATIONS OF TEST CURRENT LEVELS FOR #6 AWG CU CONDUCTOR

Equation (45) in IEEE 80 and Equation (C.1) in IEEE 837 are the same, as follows:

$$I = A\sqrt{\left(\frac{TCAP\times10^{-4}}{t_c\times\alpha_r\times\rho_r}\right)\ln\left(\frac{K_0+T_m}{K_0+T_a}\right)}$$

where

I is root mean square (rms) current in kA
A is conductor cross section in mm^2
T_m is maximum allowable temperature in °C
T_a is initial conductor temperature in °C
T_r is reference temperature for material constants in °C
α_0 is thermal coefficient of resistivity at 0 °C
α_r is thermal coefficient of resistivity at reference temperature T_r
ρ_r is resistivity of the ground conductor at reference temperature T_r in μΩ-cm
K_0 is $1/\alpha_0$, or $(1/\alpha_r)-T_r$ in °C
t_c is time of current flow in seconds (s)
TCAP is thermal capacity factor in joules/cm^3°C

This equation is used to calculate the short-circuit ampacity of a conductor based on it's material constants.

For IEEE 80, Table 6, the symmetrical rms fusing current for #6 AWG soft-drawn Cu conductor at 500 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.5)(0.00393)(1.72)}\cdot\ln\left(\frac{(234+1083)}{(234+40)}\right)} = \boxed{5.29\ kA_{rms}}$$

For IEEE 837, Table 3, the symmetrical rms fusing current for #6 AWG hard-drawn Cu conductor at 250 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.25)(0.00381)(1.78)}\cdot\ln\left(\frac{(242+1084)}{(242+40)}\right)} = 7.41\ kA_{rms}$$

From IEEE 837 Equation (C.4), the asymmetrical rms fusing current is:

$$I_{asym} = \frac{(7.41\ kA)}{(1.148)} = 6.45\ kA_{rms}$$

For the EMF described in IEEE 837, Clause 7.2, a value of 90% of the fusing current is used for conductors up to 4/0 AWG:

$$I_{EMF} = (6.45)(0.9) = \boxed{5.81\ kA_{rms}}$$

Copperweld Bimetallics Data Sheet Packet
Electrical Test Laboratory

Customer:	Copperweld Building Wire	Engineer:	Bill Lewey	Date:	8/25/2020
Sample ID:	EL-13	Tested By:	Bill Lewey, Mike Rozar	Date:	8/25/2020
Product:	Grade 40 Copper Clad Steel Wire Solid Bare #4 and #6 vs Equivalent Solid Copper: Grounding Electrode Conductor Equivalency Test	Sample Condition:	New		
Standard:	ASTM B910/910M Annealed Copper Clad Steel Wire				
Insulation: N/A - Bare		Jacket: N/A - Bare			

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Test Report Summary

Page	Test Performed	Date Completed	Pass/Fail
1	Grounding Electrode Conductor Test for Copper Clad Steel Grade 40	8/25/2020	**Pass**

Requirement:
#4 AWG Grade 40 Copper Clad Steel and #6 AWG Copper Clad Steel when compared to #4 solid copper and #6 solid copper for use as a grounding electrode conductor shall have equal ability to carry amperage during a ground fault condition.

Conclusion:
The ability of bare #4 AWG Copper Clad Steel Grade 40 and bare #6 AWG Copper Clad Steel Grade 40 performed equally to #4 AWG bare solid copper and #6 AWG bare solid copper when used as a grounding electrode conductor under a ground fault condition. The current measured proved equivalency.

Test Equipment Used

Item	Equipment Type	Equipment #	Cal. Due Date
1	Fluke 374FC Clamp Meter	AM-1	Nov 2020
2	Acme Electric 15KVA Transformer	T2535173S	N/A
3	Square D 60A / 600V Safety Interrupter	N/A	N/A
4	Eaton Service Panel	N/A	N/A
5	Eaton Type CH 20 Amp Breaker	N/A	N/A
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

VBU – Verify Before Use

N/A – Not Applicable

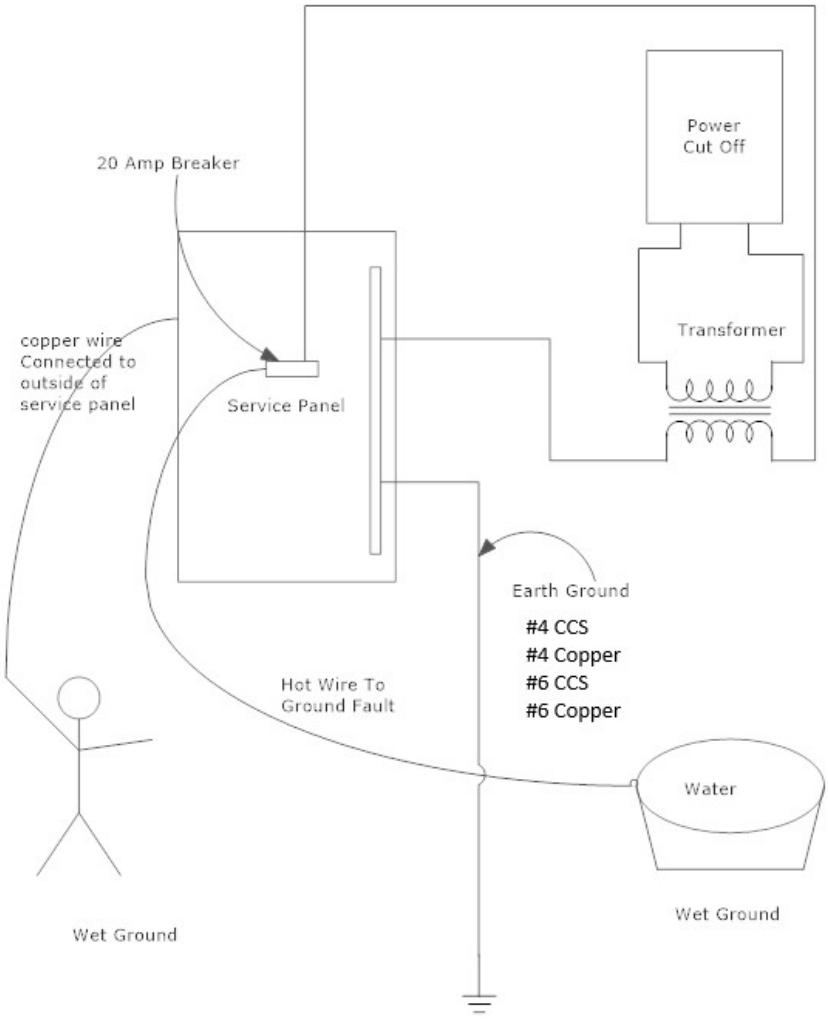
Sample Identification

Item	Description	Length/No. Rec'd
A	#4 AWG 40% Copper Clad Steel Bare	35 Ft
B	#4 AWG Solid Copper Bare	35 Ft
C	#6 AWG 40% Copper Clad Steel Bare	35 Ft
D	#6 AWG Solid Copper Bare	35 Ft
E		
F		

Grounding Electrode Conductor Test

Test Parameters:	
Conditioning:	No preconditioning.
Test Conductors:	1 each of #4 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #6 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #4 AWG Solid Bare copper grounding electrode conductor 1 each of #6 AWG Solid Bare copper grounding electrode conductor
Test Conductor Length:	Each conductor shall be 35 ft.
Test Circuit Configuration:	See schematic shown in Figure 1
Test Current:	Test current from 120 V / 20 A Residential Circuit
Method:	Testing was completed by creating a standard residential test circuit at 120V with 20A breaker wired to an intentional ground fault as shown in figure 1. The ground fault was created by connecting a hot wire from the breaker to a galvanized steel pan full of water and placing the pan on the wet ground. A conductor was also connected to the outside of the electrical panel and a Copper Plated Grounding Electrode (Copperweld Ground Rod) driven 6 inches into the wet ground to determine amount of current going through a grounded person touching the electrical panel during the ground fault condition. The ground fault and the grounded "man" were positioned 20 feet either side of the ground rod. The entire test area was soaked with water overnight using a sprinkler system When the ground fault was electrified, current measurements were taken from the ground fault conductor, the grounding electrode conductor and the grounded "man" conductor. For the four grounding electrode conductors tested, there was one test sequence for each. The current was measured for each. The objective: Compare the amperage measurements of the copper clad steel grounding electrode conductors to those of copper.

Figure 1



Results:			
Ground Conductor	**Fault Conductor Current**	**Current of the Grounding Electrode Conductor**	**Grounded Man Conductor Current**
#4 Copper	2.1 A	1.8 A	0.3 A
#4 40% CCS	2.1 A	1.8A	0.3 A
#6 Copper	1.7 A	1.6 A	0.1 A
#6 40% CCS	1.5 A	1.4 A	0.1 A

Requirement:
For equivalent sizes of Grade 40 Copper Clad steel vs. solid copper grounding conductors, the ability to carry amperage to ground during a ground fault condition is equal.

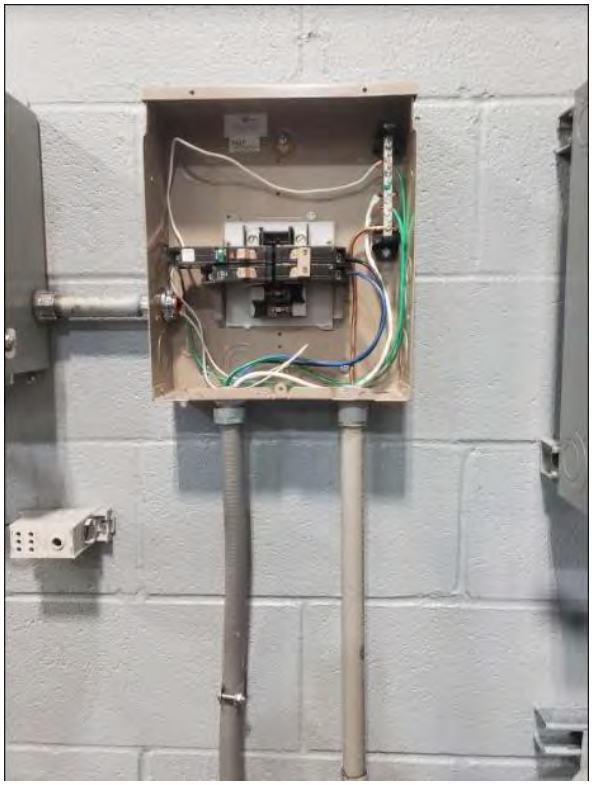
Comments:
____X__ (Pass) The product complies with all applicable requirements of this test. _____ (Fail) The product does not comply with the requirements of this test. **Test Date: 8/25/2020** **Tested By: Bill Lewey**

Environmental Conditions during Testing:

Humidity: % rh __74%_____ Ambient: °C___28_____

Test setup for the electrical service panel







Ground Rod with Grounding Conductor Attached



Ground Fault



Grounded “man”

Public Input No. 3246-NFPA 70-2020 [Section No. 250.170]

250.170 Instrument Transformer Circuits.

Secondary circuits of current and potential instrument transformers shall be grounded where the primary windings are connected to circuits of 300 volts or more to ground and, where installed on or in switchgear and on switchboards, shall be grounded irrespective of voltage.

Exception No. 1: Circuits where the primary windings are connected to circuits of 1000 volts or less with no live parts or wiring exposed or accessible to other than qualified persons.

Exception No. 2: Current transformer secondaries connected in a three-phase delta configuration shall not be required to be grounded.

Informational Note 1: See IEEE 3004.1 Recommended Practice for the Application of Instrument Transformers in Industrial and Commercial Power Systems for more information.

Statement of Problem and Substantiation for Public Input

This is another slice of updated content from the legacy "Red Book" IEEE 141 and "Gray Book: IEEE 241 into the new IEEE 3000 Standards Collection. From the project prospectus:

"The selection and application of instrument transformers used in industrial and commercial power systems are covered in this recommended practice."

https://standards.ieee.org/standard/3004_1-2013.html

Submitter Information Verification

Submitter Full Name: Michael Anthony
Organization: Standards Michigan
Affiliation: IEEE Education & Healthcare Facilities Committee
Street Address:
City:
State:
Zip:
Submittal Date: Mon Sep 07 10:31:46 EDT 2020
Committee: NEC-P05

Public Input No. 2480-NFPA 70-2020 [Section No. 250.178]

250.178 Instrument Equipment Grounding Conductor.

The equipment grounding conductor for secondary circuits of instrument transformers and for instrument cases shall not be smaller than ~~12 AWG copper or 10 AWG aluminum~~ 12 AWG copper or 10 AWG copper-clad aluminum or aluminum . Cases of instrument transformers, instruments, meters, and relays that are mounted directly on grounded metal surfaces of enclosures or grounded metal of switchgear or switchboard panels shall be considered to be grounded, and no additional equipment grounding conductor shall be required.

Statement of Problem and Substantiation for Public Input

COPPER-CLAD ALUMINUM CONDUCTORS:

Please Consult Sections 110.14 Electrical Connections and 110.5 Conductor Materials. Copper-Clad Aluminum as a conductor material should not be excluded for this application. With aluminum and copper, Copper-Clad Aluminum is only one of three conductor materials for general wiring permitted by the NEC. This PI aims to correct an inconsistency in correlation between Articles. It aims to bring safe alternatives to users of this Code. The NFPA Standards Council created in August 2019 a special Bimetals Task Group to in part bring attention to correlation issues effecting Copper-Clad Aluminum, as well as to study expanding its range of applications in 2023. In a coordinated effort, the Bimetals Task Group will submit 19 Public Inputs in this cycle addressing these matters.

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
Affiliation: American Bimetallic Association
Street Address:
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State:
Zip:
Submittal Date: Sun Aug 23 13:21:14 EDT 2020
Committee: NEC-P05

Public Input No. 2153-NFPA 70-2020 [Section No. 250.184(C)]

(C) Multigrounded Neutral Systems.

Where a multigrounded neutral system is used, the following shall apply:

(1) The neutral conductor of a solidly grounded neutral system shall be permitted to be grounded at more than one point. Grounding shall be permitted at one or more of the following locations:

(2) Transformers supplying conductors to a building or other structure

(3) Underground circuits where the neutral conductor is exposed

(4) Overhead circuits installed outdoors

(5) The multigrounded neutral conductor shall be grounded at each transformer and at other additional locations by connection to a grounding electrode.

(6) At least one grounding electrode shall be installed and connected to the multigrounded neutral conductor every 400 m (1300 ft).

(7) The maximum distance between any two adjacent electrodes shall not be more than 400 m (1300 ft).

(8) In a multigrounded shielded cable system, the shielding shall be grounded at each cable joint or termination [ORD1] that is exposed to personnel contact.

(9)

[ORD1] PI should be part of MV "joints and terminations pi". Will remove from here, and include it in the separate PI.

Exception: In a multipoint grounded system, a grounding electrode shall not be required to bond the neutral conductor in an uninterrupted conductor exceeding 400 m (1300 ft) if the only purpose for removing the cable jacket is for bonding the neutral conductor to a grounding electrode.

Statement of Problem and Substantiation for Public Input

This revision modifies the requirement to include the termination.

Submitter Information Verification

Submitter Full Name: David Hittinger
Organization: IEC
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 04 13:51:53 EDT 2020
Committee: NEC-P05

Public Input No. 2654-NFPA 70-2020 [Section No. 250.184(C)]

(C) Multigrounded Neutral Systems.

Where a multigrounded neutral system is used, the following shall apply:

(1) The neutral conductor of a solidly grounded neutral system shall be permitted to be grounded at more than one point. Grounding shall be permitted at one or more of the following locations:

(2) Transformers supplying conductors to a building or other structure

(3) Underground circuits where the neutral conductor is exposed

(4) Overhead circuits installed outdoors

(5) The multigrounded neutral conductor shall be grounded at each transformer and at other additional locations by connection to a grounding electrode.

(6) At least one grounding electrode shall be installed and connected to the multigrounded neutral conductor every 400 m (1300 ft).

(7) The maximum distance between any two adjacent electrodes shall not be more than 400 m (1300 ft).

(8) In a multigrounded shielded cable system, the shielding shall be grounded at each type MV cable joint and type MV cable termination that is exposed to personnel contact.

Exception: In a multipoint grounded system, a grounding electrode shall not be required to bond the neutral conductor in an uninterrupted conductor exceeding 400 m (1300 ft) if the only purpose for removing the cable jacket is for bonding the neutral conductor to a grounding electrode.

Statement of Problem and Substantiation for Public Input

This PI is a companion to PI 2642 related to the addition of type MV cable joints and terminations to article 311.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 2642-NFPA 70-2020 [Article 311]	Companion
Public Input No. 2642-NFPA 70-2020 [Article 311]	

Submitter Information Verification

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Submittal Date: Thu Aug 27 13:07:02 EDT 2020

Committee: NEC-P05

Public Input No. 746-NFPA 70-2020 [Section No. 250.187(A)]

(A) Location.

The grounding impedance shall be ~~inserted in~~ installed between the grounding electrode conductor and the system neutral point. If a neutral point is not available, the grounding impedance shall be installed between the grounding electrode ~~of the supply system~~ conductor and the neutral point ~~of the supply transformer or generator~~ derived from a grounding transformer .

Statement of Problem and Substantiation for Public Input

The next is a copy and paste from 250.36(A). Currently, the impedance device is a part of the Grounding Electrode Conductor. The new text makes it clear that the grounding electrode conductor ends at the resistor. There is a companion PI to name the conductor that is connected from the resistor to the neutral point as the "system impedance conductor."

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 743-NFPA 70-2020 [New Section after 250.1]	redefinition of conductors
Public Input No. 747-NFPA 70-2020 [Section No. 250.187(B)]	
Public Input No. 748-NFPA 70-2020 [Section No. 250.187(C)]	
Public Input No. 749-NFPA 70-2020 [Section No. 250.36(B)]	
Public Input No. 750-NFPA 70-2020 [Section No. 250.36(D)]	
Public Input No. 753-NFPA 70-2020 [Section No. 200.2(A)]	

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Public Input No. 2764-NFPA 70-2020 [Section No. 250.187(B)]

(B) Insulated.

The grounded conductor shall be insulated for the maximum neutral voltage.

Informational Note: The maximum neutral voltage in a 3-phase wye system is 57.7 percent of the phase-to-phase voltage.

Exception: In industrial installations where the transformer and grounding impedance each have exposed neutral bushings and are protected by location, a bare grounded conductor is permitted.

Statement of Problem and Substantiation for Public Input

There are many installations in industrial facilities where a transformer has exposed bushings and the grounding impedance also has an exposed bushing for the neutral connection. The grounding impedance is typically mounted on an elevated platform near the height of the transformer bushings. A short bare grounding conductor is used to connect the transformer neutral bushing to the grounding impedance. This proven design is not permitted per the existing language. The proposed exception allows this proven wiring method.

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Committee: NEC-P05

Public Input No. 747-NFPA 70-2020 [Section No. 250.187(B)]

(B) Insulated.

The ~~grounded conductor~~ system impedance conductor shall be insulated for the maximum neutral voltage.

Informational Note: The maximum neutral voltage in a 3-phase wye system is 57.7 percent of the phase-to-phase voltage.

Statement of Problem and Substantiation for Public Input

This is part of a series of companion public inputs to change the name of the conductor that runs from the neutral point of the system to the high side of the impedance as the "system impedance conductor." It is non intuitive to think of a conductor as grounded when, in a fault condition on a 2400 volt system, the conductor is at 1386 volts potential (for a very brief moment while the protective relaying is operating).

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 743-NFPA 70-2020 [New Section after 250.1]	definition of conductor
Public Input No. 746-NFPA 70-2020 [Section No. 250.187(A)]	clarification of where the grounding electrode conductor ends
Public Input No. 748-NFPA 70-2020 [Section No. 250.187(C)]	
Public Input No. 749-NFPA 70-2020 [Section No. 250.36(B)]	
Public Input No. 750-NFPA 70-2020 [Section No. 250.36(D)]	
Public Input No. 753-NFPA 70-2020 [Section No. 200.2(A)]	

Submitter Information Verification

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Committee: NEC-P05

Public Input No. 1904-NFPA 70-2020 [Section No. 250.187(C)]

(C) Grounded ~~System~~ Circuit Conductor Connection.

~~The system grounded~~ The grounded circuit conductor shall not be connected to ground, except through the grounding impedance.

Statement of Problem and Substantiation for Public Input

The term "System Conductor" is used 12 times in the 2020 NEC and the usage is confined to Articles 100 and 250. In each instance of usage, it is describing a grounded conductor and in 11 of the 12 instances it is part of the term "Grounded System Conductor". The term "Circuit Conductor" is used 81 times throughout the 2020 NEC. The term "Grounded Circuit Conductor" is used 43 times throughout the 2020 NEC and 10 times in Article 250.

In Articles 100 and 250, it is not clear that there is a difference between a "Grounded System Conductor" and a "Grounded Circuit Conductor", these terms appear to be used interchangeably.

If it is not the intent that these terms be used interchangeably:

- Definitions should be provided as proposed in PIs 1881-NFPA 70-2020 and 1882-NFPA 70-2020 to delineate the unique features of a "System Conductor" versus those of a "Circuit Conductor“

- PIs 1883-NFPA 70-2020 , 1906-NFPA 70-2020 , 1892-NFPA 70-2020 , 1893-NFPA 70-2020 , 1904-NFPA 70-2020 , and 1905-NFPA 70-2020 should be disregarded

If it is the intent that the two terms are to be used interchangeably:

- All instances of "System Conductor" should be changed to "Circuit Conductor“

- PIs 1883-NFPA 70-2020 , 1906-NFPA 70-2020 , 1892-NFPA 70-2020 , 1893-NFPA 70-2020 , 1904-NFPA 70-2020 , and 1905-NFPA 70-2020 should be accepted to change instances of “system conductor” to “circuit conductor”

- PI 1881-NFPA 70-2020 may be helpful in this scenario to clarify the meaning of the term ”Circuit Conductor”

- Replacing all instances of "Circuit Conductor“ with "System Conductor" and defining the term "System Conductor" would accomplish the same goal. "Circuit Conductor“ is presently more used throughout the NEC, so the proposal above requires a smaller number of revisions.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 1881-NFPA 70-2020 [New Definition after Definition: Conductor, Bare.]	
Public Input No. 1882-NFPA 70-2020 [New Definition after Definition: Conductor, Insulated.]	
Public Input No. 1883-NFPA 70-2020 [Definition: Grounded Conductor.]	
Public Input No. 1893-NFPA 70-2020 [Section No. 250.84]	
Public Input No. 1905-NFPA 70-2020 [Section No. 250.34(C)]	
Public Input No. 1906-NFPA 70-2020 [Section No. 250.36(B)]	

Public Input No. 1892-NFPA 70-2020 [Section No. 250.80]

Public Input No. 1881-NFPA 70-2020 [New Definition after Definition: Conductor, Bare.]

Public Input No. 1882-NFPA 70-2020 [New Definition after Definition: Conductor, Insulated.]

Public Input No. 1883-NFPA 70-2020 [Definition: Grounded Conductor.]

Public Input No. 1892-NFPA 70-2020 [Section No. 250.80]

Public Input No. 1893-NFPA 70-2020 [Section No. 250.84]

Public Input No. 1905-NFPA 70-2020 [Section No. 250.34(C)]

Public Input No. 1906-NFPA 70-2020 [Section No. 250.36(B)]

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Committee: NEC-P05

Public Input No. 748-NFPA 70-2020 [Section No. 250.187(C)]

(C) ~~Grounded~~ System Impedance Conductor Connection.

The system ~~grounded conductor~~ impedance conductor shall not be connected to ground, except through the grounding impedance.

Statement of Problem and Substantiation for Public Input

This is part of a series of companion public inputs to change the name of the conductor that runs from the neutral point of the system to the high side of the impedance as the "system impedance conductor."

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 743-NFPA 70-2020 [New Section after 250.1]	new definition of conductor
Public Input No. 746-NFPA 70-2020 [Section No. 250.187(A)]	
Public Input No. 747-NFPA 70-2020 [Section No. 250.187(B)]	
Public Input No. 749-NFPA 70-2020 [Section No. 250.36(B)]	
Public Input No. 750-NFPA 70-2020 [Section No. 250.36(D)]	
Public Input No. 753-NFPA 70-2020 [Section No. 200.2(A)]	

Submitter Information Verification

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Committee: NEC-P05

Public Input No. 2481-NFPA 70-2020 [Section No. 250.190(B)]

(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~~ 6 AWG copper-clad steel or copper or ~~4 AWG~~ 4 AWG copper-clad aluminum or aluminum .

Additional Proposed Changes

File Name	Description	Approved
PL-03027_REP1.pdf	Fusing and Withstand Testing	
CEL_-_13_Grounding_Conductor_Current_Test_002_.pdf	Grade 40CCS Conductivity Test Report. Lewey and Rozer	
TD002391.doc	UL 467 Short Circuit and UL 486A-B Mechanical Sequence. Burndy	
CCS_Corrosion_paper_Rev2.pdf	Grade 40CCS 50 Year Corrosion Study Substation Grounding. Seyrif and Hale	

Statement of Problem and Substantiation for Public Input

COPPER-CLAD ALUMINUM CONDUCTORS:

Please Consult Section 110.5 Conductor Materials. Copper-Clad Aluminum as a conductor material should not be excluded for this application. With aluminum and copper, Copper-Clad Aluminum is only one of three conductor materials for general wiring permitted by the NEC®. Copper-Clad Aluminum is referenced as a GEC in Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems, so it should be referenced in this section as well. This Public Input aims to correct inconsistency in correlation between sections and articles. It aims to bring safe alternatives to users of this Code. The NFPA Standards Council created in August 2019 a special Bimetals Task Group to in part bring attention to correlation issues effecting Copper-Clad Aluminum, as well as to study expanding its range of applications in 2023. In a coordinated effort, the Bimetals Task Group will submit 19 Public Inputs in this cycle addressing these matters.

COPPER-CLAD STEEL CONDUCTORS:

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 applicate 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 Inputs for This Document

Related Input	Relationship
Public Input No. 2462-NFPA 70-2020 [Section No. 250.62]	Copper-Clad Steel Grounding Material
Public Input No. 2467-NFPA 70-2020 [Section No. 250.66 [Excluding any Sub-Sections]]	Copper-Clad Steel Grounding Material

Submitter Information Verification

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Submittal Date: Sun Aug 23 13:23:18 EDT 2020
Committee: NEC-P05

Testing done for the safety of our valued customer.

Global Circulation Laboratory Test Report

For Global Distribution

UL467 SHORT CIRCUIT & UL 486A-486B MECHANICAL SEQUENCE TESTS

YGHP29C2, YGHC2C2, YGHC26C26, YGHP34C29, YGHC29C29, YGHP34C34, YGHC34C34 HYTAP™ Connectors
YGL2C2, YGL29C29, YGL34C34 HYGRID™ Connectors
YGA4C2N, YGHA272N, YGA282N, YGHA302N HYLUG™ Connectors

5/8" and 3/4"Copper Clad Steel Ground Rod, #4AWG Solid, 4/0AWG Stranded, 7#7, and 19#8 COPPERWELD® 40% IACS Copper Clad Steel Conductors

PAT750XT-18V PATRIOT® Tool
with
UC, UO, U28RT, U29RT, U32RT, U997, PU998, and U1011 Die Sets

TD002391 REV B

Requested by / Date:	***Authorized by / Date:***	***Completed by / Date:***
C. Gandhi 12-Dec-2014	R Robicheau 12-Dec-2014	R Charpentier 06-Apr-2015
Engineering Approval / Date:	***Marketing Approval / Date:***	***Laboratory Approval / Date:***
R.Roman 20-Aug-2020	J Hogan 20-Aug-2020	R Charpentier 20-Aug-2020

TD002391

Global Circulation Laboratory Test Report

For Global Distribution

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Burndy LLC 47 East Industrial Park Dr.
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TD002391

Global Circulation Laboratory Test Report

For Global Distribution

PURPOSE OF TEST:

To determine if the Burndy HYTAP™, HYGRID™, and HYLUG™ Connectors can meet the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST REQUESTED:

UL486A-486B Mechanical Sequence
UL467 Short Time Current

TEST RESULTS:

Connector	Cable 1	Cable 2	Die	# of crimps	Securness	Pull	Short Time Current		
					Pass / Fail	Average Pull (lb)	Pass / Fail	Current (Amps)	Time (s)
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	U997	1	Pass	1021.3	Pass	1600	6
YGL2C2	#4 Solid CCS	#4 Solid CCS	U-O	1	Pass	1451.8	Pass	1600	6
YGHC2C2	#4 Solid CCS	#4 Solid CCS	U-C	1	Pass	1544.0	Pass	1600	6
YGA4C2N	#4 Solid CCS	n/a	U4CRT	1	Pass	814.0	Pass	1600	6
YGL29C29	7#7 STR CCS	7#7 STR CCS	U997	1	Pass	1643.2	Pass	4600	9
YGHC26C26	7#7 STRCCS	7#7 STR CCS	U-O	1	Pass	1239.4	Pass	4600	9
YGHA272N	7#7 STRCCS	n/a	U29RT	2	Pass	1574.0	Pass	4600	9
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PU998	1	Pass	1789.8	Pass	6100	9
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1849.8	Pass	6100	9
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	U997	1	Pass	1779.1	Pass	6100	9
YGA282N	4/0 AWG CCS	n/a	U28RT	2	Pass	2489.3	Pass	6100	9
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	U1011	3	Pass	2126.8	Pass	9000	9
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	U1011	3	Pass	2380.0	Pass	9000	9
YGL34C34	19#8 STRCCS	19#8 STR CCS	U1011	3	Pass	3158.3	Pass	9000	9
YGHC34C34	19#8 STR CCS	19#8 STR CCS	U1011	3	Pass	3812.1	Pass	9000	9
YGHA302N	19#8 STR CCS	n/a	U32RT	2	Pass	4792.2	Pass	9000	9

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TD002391

Global Circulation Laboratory Test Report

For Global Distribution

CONCLUSIONS:

All samples tested met the UL486A-486B mechanical sequence and UL467 Short time current requirements when installed on COPPERWELD® 40% IACS Copper Clad Steel (CCS) conductors per ASTM B910/B910M-07.

TEST PROCEDURES

The table below shows the connector / conductor combinations tested.

Connector	Cable 1	Cable 2	Tool	Die	# of Crimps
YGHP29C2	5/8in CCS Ground Rod	#4 Solid CCS	PAT750	U997	1
YGL2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-O	1
YGHC2C2	#4 Solid CCS	#4 Solid CCS	PAT750	U-C	1
YGA4C2N	#4 Solid CCS	n/a	PAT750	U4CRT	1
YGL29C29	7#7 STR CCS	7#7 STR CCS	PAT750	U997	1
YGHC26C26	7#7 STR CCS	7#7 STR CCS	PAT750	U-O	1
YGHA272N	7#7 STR CCS	n/a	PAT750	U997	2
YGHP34C29	3/4in CCS Ground Rod	4/0 AWG CCS	PAT750	PU998	1
YGL29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGHC29C29	4/0 AWG CCS	4/0 AWG CCS	PAT750	U997	1
YGA282N	4/0 AWG CCS	n/a	PAT750	U997	2
YGHP34C34	3/4in CCS Ground Rod	19#8 STR CCS	PAT750	U1011	3
YGHP34C34	19#8 STR CCS	3/4in CCS Ground Rod	PAT750	U1011	3
YGL34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHC34C34	19#8 STR CCS	19#8 STR CCS	PAT750	U1011	3
YGHA302N	19#8 STR CCS	n/a	PAT750	U32RT	2

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Global Circulation Laboratory Test Report

For Global Distribution

All conductors were cut to twenty four (24) inch lengths.
All ground rod was pre-crimped with the appropriate pre-crimp die
5/8in Rod UPRECRIMP58
3/4in Rod UPRECRIMP34

Mechanical Sequence
Four samples of each set were secured to the Secureness tester, the height; weight and bushing size were as specified in UL486A-486B Table 26. Samples were rotated for thirty minutes at 9rpm. Samples were then subjected to a 1-minute pull to the value specified in UL486A-486B Table 27 and then to failure.

Short Time Current
Test samples were assembled in a series loop configuration then attached to a current controller as shown below. The test current and duration are listed below. After completion of the test, electrical continuity was checked with a digital multi-meter.

Test current values were derived from the equation Annex C of IEEE Std 837-2002. The diameter of the conductor(s) were measured and the cross-sectional area of the conductors was calculated.

Conductor	***Current Value (A)***	***Duration (sec)***
#4AWG Solid COPPERWELD® 40% IACS CCS	1600	6
4/0AWG 19 strand COPPERWELD® 40% IACS CCS,	6100	9
7#7 stranded COPPERWELD® 40% IACS CCS	4600	9
19#8 stranded COPPERWELD® 40% IACS CCS	9000	9

TEST EQUIPMENT LIST:

MANUFACTURER	MODEL	DESCRIPTION	SERIAL #	RANGE
FLUKE	79 III	DMM	70591301 (Rene)	AUTO
OHIO SEMITRONICS		CURRENT TRANSDUCER	NA	15000:5
SATEC	T5000	TABLE TOP	2038	5000 lbs
VIRTECH	NA	HIGH CURRENT	NA	12V / 12000A
MITUTOYO	505-675	DIAL CALIPER	08914565 (Rene)	6"

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CORROSION ON BURIED COPPER CLAD STEEL



Cece Syarif

Global Application Engineer

&

Anthony Hale

Manager, Utility Products, North America

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For more information, contact sales@copperweld.com.
The results and conclusions obtained from studies done by Copperweld are only applicable to Copper Clad Steel manufactured by Copperweld. Due to proprietary process used to produce the wire, the findings cannot be superimposed on any other copper-clad steel conductor.

254 Cotton Mill Rd, Fayetteville, TN 37334. Tel. (931) 433 – 7177

July 26, 2011

This paper compiles several studies and analysis regarding the corrosion performance of buried Copperweld® Copper-Clad-Steel (CCS) conductors. These range from the early 1900's with the invention of Copperweld® through the present day with studies performed by independent parties as well as Copperweld Company in-house testing. The purpose is to present the available information so that prospective users of Copperweld® CCS wire and strand can evaluate the corrosion resistance and expected performance within their specific application and area. Copperweld uses oxygen free copper in the manufacture of Copperweld® wire and strand. The copper surface of CCS is expected to oxidize and turn color ranging from green (patination) to brown and black the same as any solid copper wire or strand when exposed to environmental stimuli. Corrosion on exposed steel at the cut tip or end of the wire is also expected. The question to be answered is if the corrosion on either material or the interface between the copper and steel (galvanic reaction) will result in degradation of the wire as to make it unsuitable for use as a grounding conductor.

The oldest known underground corrosion study of bimetallic material was performed in the early 1900s[1]. This study focused on the corrosion behavior of Copperweld® CCS underground rod as well as other materials such as Copper and galvanized steel ground rod. The National Bureau of Standards (NBS) conducted an extensive underground corrosion study that involves 36,500 specimens which include 333 varieties of ferrous, nonferrous, and protective coating materials buried in 128 test locations throughout U.S in 1910 - 1955.

The study summarizes the service life of a ground rod as following:

10 mils copper coating – acceptable for service life up to 40 years

13 mils copper coating – acceptable for service life up to 50 years

Similarly, the Naval Civil Engineering Laboratory in collaboration with the National Association of Corrosion Engineers conducted a 7-year program of testing metal rods for electrical grounding to determine the galvanic corrosion effect. The three metals tested were stainless clad steel, copper-bonded steel (CCS), and galvanized steel. The result on the ⅝" CCS ground rod was as expected. The copper surface of the CCS was

virtually free of corrosion and the steel core has corroded at the tip approximately 2 inches down the length of the rod.

Copperweld Corporation is the inventor and sole manufacturer of Copperweld® Copper-bonded ground rods and Copperweld® wire and strand since 1915. The corrosion behavior of a Copperweld® ground rod is similar to the corrosion on Copperweld® wire and strand conductor. Both materials consist of copper permanently bonded to a steel core. All Copperweld® 40% CCS has a copper thickness of 10% of the overall diameter. For example, Copperweld® 4THOUGHT™ has a configuration of 19 strands of 0.1055 inch wires. It means that each strand has a copper thickness of 10.55 mils. Based on the NBS study, 4THOUGHT™ will have at least a minimum service life of 40 years.

Copperweld has also conducted a 5-year study of buried bare 21% conductivity (copper thickness is 3% of the diameter) Copperweld® CCS in 10 different soil conditions in association with Southwest Research Institute[2]. The study reported 100% surface oxidation and various degrees of deterioration of the steel core as expected after 5 years. The exposed steel on the tip of the wire rusted and formed "scab", as shown in Figure 1. The rust appeared to "seal-off" the un-oxidized material from the corrosive medium. The maximum depth of corrosion was 70% of the wire diameter.



Figure 1: Example of Underground Corrosion of Copper Clad Steel

Although the copper surface oxidation was heavy, the samples showed no signs of pits or holes in the copper cladding. The copper thickness of a severely oxidized 5-year sample showed no discernable difference when compared to an un-oxidized control sample that was not subjected to the corrosive environment. The mechanical and resistance testing

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resulted in negligible differences between 5-year samples and the control samples. Thus, the oxidation had no discernable impact on the strength or electrical performance of the wire.

An accelerated corrosion study based on ASTM B117 was conducted on bare CCS and solid Copper wires to evaluate copper surface corrosion. The wires were exposed to salt fog spray for 504 hours. As a result, corrosion on the CCS copper surface showed no significant difference as compared to the corrosion of copper wire.



(a) Copper Clad Steel (b) Copper

Figure 2: Patination of Copper Surface after 504 hours exposure to Salt Fog Spray

In February 2011, three separate sample strands of Copper Clad Steel were un-earthed and cut out from a substation built in Louisville, KY. The conductors were 40% conductivity, Low Carbon Steel, Dead Soft Annealed, 7 No. 5 (231,613 circular mil) and were installed in 1962.

Table 1: Physical properties of the three strands of Copperweld® conductor that had been buried underground for 48 years in a Kentucky substation

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			Strand 1	Strand 2	Strand 3
Conductor Type			40% Low Carbon Annealed		
Conductor Size			7 No. 5		
Cross Section Area		in^2	0.1819	0.1819	0.1819
Diameter of Single end		*inch*	0.1819	0.1819	0.1819
Diameter of Conductor		*inch*	0.5457	0.5457	0.5457
Copper Thickness	Min	*inch*	0.0142	0.0114	0.0134
	Max	*inch*	0.0213	0.0209	0.01975
% Concentricity			83.30%	77.30%	83.90%
Depth of corrosion	Min	*inch*	0.004	0.028	0.111
	Max	*inch*	0.781	0.859	0.484

The 1962 conductors were manufactured by Copperweld with a nominal copper thickness of 10% of its diameter. Figure 3 shows the copper thickness ranges from 11.4 – 21.3 mils and the concentricity of the conductor averaged at 81.5%. Current manufacturing improvements yield concentricity of copper thickness above 85%.

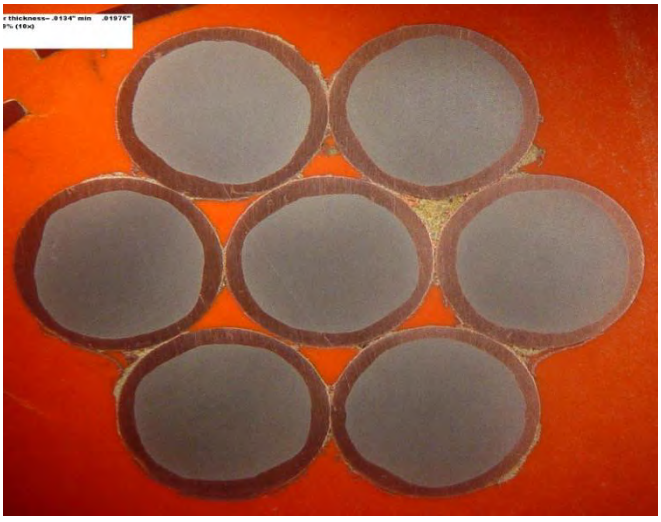


Figure 3: Copperweld® 40% LC DSA 7 No. 5 manufactured in 1962

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Figure 4a shows no visible corrosion observed other than oxidation and patination on the copper surface. At the ends of the wires, the corrosion occurred in the form of steel rust. The maximum depth of the corrosion is 0.859 inch with an average of 0.382 inch, as shown in Figure 4b.



Figure 4a: There is no visible corrosion between the copper and steel on all wires obtained from the substation in Kentucky.



Figure 4b: Corrosion occurred at the ends of the wires. Maximum penetration depth is 0.859 inch.

From all the corrosion studies above, there have not been reported or observed any galvanic corrosion at the interface of copper and steel. The process of cladding for

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Copperweld® ensures a metallurgical bond between the two metals. That metallurgical bond prevents any moisture from penetrating between the two metals precluding the corrosion process. Any propagation of corrosion on an area of exposed steel averages two times the diameter of the wire then stops. The corrosion rate of the copper surface is equivalent to that observed on standard solid copper wire and strand. Based on the results of these studies, it can be summarized that CCS can be expected to have a 50 plus year service life as buried grounding conductors.

REFERENCES:

1. Rempe, Chris. 7 July 2003. "A Technical Report on the Service Life of Ground Rod Electrodes".
2. Fox, Dustin, Belado, Chris, and Brossia, Sean. 23 September 2009. "The Effect of Corrosion on Tracer Wire with a Copper Clad Steel Center Conductor".

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Revision: 0 Issued: 2020-04-15

Copper and CCS Wire Withstand Current and Fusing Current Tests

Copperweld Bimetallics, LLC



The Power of Trust. **The Future of Energy.**

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REPORT OF PERFORMANCE

CLIENT	Copperweld Bimetallics,LLC. 5141 Virginia Way, Suite 410 Brentwood, TN, United States 37027
TEST OBJECTS	Copper Clad Steel (CCS) Wires Manufacturer: Copperweld Bimetallics,LLC. Types: Scorpius Prototypes Part Nos.: 61 x 072 7 x 080 Condition: New Copper Conductor Manufacturer: Encore Wire Types: #4/0 AWG (19 strand) CU #6 AWG (single strand) CU Condition: New
TESTED BY	Powertech Labs Inc. 12388 - 88th Ave, Surrey, BC Canada V3W 7R7 www.powertechlabs.com
TEST DATE	2020-01-24 to 2020-01-25
TEST SPECIFICATION	Client Specified, with reference to IEEE Std 80-2013 and IEEE Std 837-2014

Powertech Labs Inc. does not accept any liability for any damages resulting from the use of this report. The results relate only to the item tested, and it is the responsibility of the manufacturer to maintain conformity of any object having the same designations. Information regarding the estimated measurement uncertainty is available upon request. The test report shall not be reproduced except in full, without written approval of Powertech Labs Inc.

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1 INTRODUCTION

At the request of Copperweld Bimetallics,LLC., withstand current and fusing current tests were performed on standard copper and copper clad steel (CCS) wires in accordance with specifications and procedures provided by the client. Reference was made to IEEE Std 80-2013 and IEEE Std 837-2014 as guides for determining current levels and durations for the tests.

The High Power Lab is accredited by the Standards Council of Canada to ISO 17025 for short-circuit testing.

2 TEST OBJECT INFORMATION

The test objects were identified by the client as follows:

Copper Clad Steel Wires (CCS)

Manufacturer:	Copperweld Bimetallics,LLC.
Types:	Scorpius Prototypes
Part Nos.:	61 x 072
	7 x 080
Condition:	New

Copper Conductor

Manufacturer:	Encore Wire
Types:	4/0 AWG (19 strand) CU
	#6 AWG (single strand) CU
Condition:	New

Conductor sample diameters and dc resistance values were measured by the laboratory before testing, as presented in Table 1.

3 GENERAL INFORMATION

3.1 Purpose

The purpose of the tests is to identify the current limits at short durations for standard copper and Copperweld CCS grounding wire products, and to determine if these products meet the applicable requirements of the referenced Standards.

3.2 Witnesses

Name	Company
Jeff Jordan	Copperweld Bimetallics,LLC.
Lora Aboulmouna	Copperweld Bimetallics,LLC.
Jason Smolko	Copperweld Bimetallics,LLC.
Ryan Hale	Copperweld Bimetallics,LLC.

3.3 Tests Performed

Test Standards/Specifications:

Withstand current tests were performed as requested by the client, with reference to the following Standards to determine the test levels:

IEEE Std 80-2013, Table 6 – Specification for the ultimate current carrying capacity of copper grounding cables using symmetrical current.

IEEE Std 837-2014, Clause 7.2 and Table 3 – Electromagnetic force (EMF) test

4 SHORT-CIRCUIT CURRENT TESTS

General Information:

Standard	Client's Specification, with reference to IEEE Std 80-2013 and IEEE Std 837-2014
Test Dates	2020-01-24 to 2020-01-25
Test Leader	Chris Morton

Environmental Conditions:

Ambient temperature	(7 – 9) °C
Relative Humidity	(95 – 99) %

Test Conditions:

Samples were tested in a covered test cell which was open on one side to the outdoor ambient conditions. During each test, one sample was connected horizontally between the laboratory source bus and ground bus, at a bus spacing of 48 inches, as shown in Figures 30 through 33. The samples were terminated using Burndy mechanical connectors, as shown in Figures 34 and 35. The length of each wire sample was the minimum length required to span the distance between the buses, and each sample was at approximately right angles (90°) to both the source and ground bus. Each sample was suspended in free air approximately 46 inches above the floor of the test cell. The temperature of the sample at the start of each test was the natural outdoor ambient temperature of the laboratory, except for tests performed to IEEE 837, where the sample was allowed to cool to less than 100 °C before the second shot.

All tests were performed at a power frequency of 60 Hz using the test circuit shown in Figure 1. Current was initiated by energizing a current limited source that was calibrated to provide the target current through the circuit. The rms current, current symmetry and duration of each test were specified by the client.

The test current was measured using a 300 kA_{peak} rated Rogowski coil (Powertech ID № 39444). The expanded uncertainty of the current measuring system is estimated as 2% (k=2).

Test Results:

The results of the tests are provided in Tables 2 through 5. Current and voltage waveforms for each test are provided in Figures 2 through 29.

The Encore #4/0 AWG Cu wire did not withstand the I^2t calculated from the current and duration specified in IEEE 80, Table 6, for a 500 ms duration (44 kA_{rms}). It was capable of carrying a maximum of 92% of this I^2t value without fusing.

The Encore #4/0 AWG Cu wire did not withstand the EMF current specified in IEEE 837, Table 3 (47 kA_{rms}). It was capable of carrying a maximum of 91% of this current value without failing.

The Copperweld Scorpius CCS 61 x 072 conductor exceeded the 500 ms rms withstand current requirement of IEEE 80, Table 6, and met the EMF current requirements of IEEE 837, Table 3, for a 4/0 conductor.

For the #6 AWG Cu conductor size the Standards did not have current values specified, so these were calculated using Equation (45) from IEEE 80 and Equation (C.1) from IEEE 837. The calculations are presented in Appendix D.

Both the Copperweld Scorpius CCS 7 x 080 conductor and the Encore #6 AWG Cu conductor met the 500 ms rms withstand current requirement of IEEE 80, Table 6 (5.29 kA_{rms}), and the EMF current requirements of IEEE 837, Table 3 (5.81 kA_{rms}), for a #6 AWG Cu conductor.

APPENDIX A – FUSING CURRENT TEST CIRCUIT AND DATA

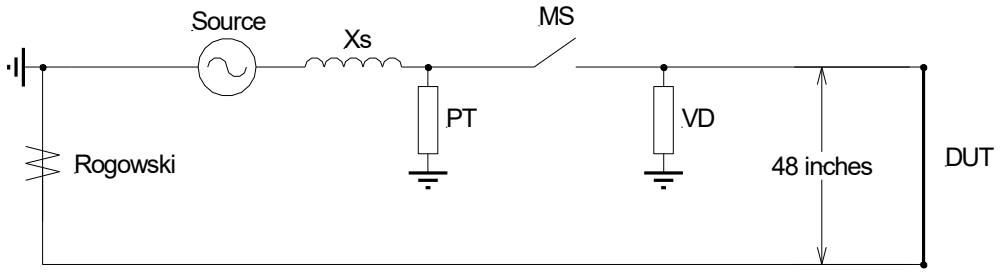


Figure 1: Test circuit schematic for all tests.

Notes:

1. X_S – Source current limiting reactance
2. MS – Making Switch
3. VD – Voltage measurement
4. Rogowski – Current measurement
5. DUT – Device Under Test

Table 1: Strand diameter and dc resistance measurements of sample conductors.

Wire Sample No.	Type	Strand Diameter [1] (in)		Conductor Diameter	Dc Resistance at 20°C
#		1	2	(in)	(μΩ/ft)
1	Encore Wire, 4/0 AWG, 19 strand CU	0.122	0.079	0.492	4.28
2	Encore Wire, 4/0 AWG, 19 strand CU	0.118	0.080	0.501	4.10
3	Encore Wire, 4/0 AWG, 19 strand CU	0.109	0.074	0.495	4.23
4	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.075	0.498	3.98
5	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.079	0.489	4.43
6	Encore Wire, 4/0 AWG, 19 strand CU	0.108	0.075	0.490	4.17
7	Encore Wire, 4/0 AWG, 19 strand CU	0.101	0.075	0.489	4.18
8	Encore Wire, 4/0 AWG, 19 strand CU	0.102	0.074	0.491	4.15
9	Encore Wire, 4/0 AWG, 19 strand CU	0.106	0.082	0.490	3.97
10	Encore Wire, 4/0 AWG, 19 strand CU	0.105	0.079	0.493	3.73
11	Scorpius 61 x 072 CCS	0.056	---	0.646	6.83
12	Scorpius 61 x 072 CCS	0.058	---	0.649	6.60
13	Scorpius 61 x 072 CCS	0.068	---	0.641	6.60
14	Scorpius 61 x 072 CCS	0.056	---	0.639	6.73
15	Scorpius 61 x 072 CCS	0.067	---	0.646	6.62
16	Scorpius 61 x 072 CCS	0.059	---	0.630	6.53
17	Scorpius 61 x 072 CCS	0.056	---	0.642	6.73
18	Scorpius 61 x 072 CCS	0.067	---	0.637	6.62
19	Scorpius 61 x 072 CCS	0.064	---	0.641	6.85
20	Scorpius 61 x 072 CCS	0.059	---	0.633	6.83
21	Encore Wire, #6 AWG, single strand CU	0.152	---	0.152	33.3
22	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
23	Encore Wire, #6 AWG, single strand CU	0.158	---	0.158	33.2
24	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.4
25	Encore Wire, #6 AWG, single strand CU	0.151	---	0.151	33.3
26	Encore Wire, #6 AWG, single strand CU	0.148	---	0.148	33.6
27	Encore Wire, #6 AWG, single strand CU	0.155	---	0.155	33.3
28	Encore Wire, #6 AWG, single strand CU	0.146	---	0.146	33.1
29	Encore Wire, #6 AWG, single strand CU	0.153	---	0.153	33.2
30	Encore Wire, #6 AWG, single strand CU	0.149	---	0.149	33.3
31	Scorpius 7 x 080 CCS	0.072	---	0.215	46.3
32	Scorpius 7 x 080 CCS	0.069	---	0.226	45.9
33	Scorpius 7 x 080 CCS	0.065	---	0.220	46.2
34	Scorpius 7 x 080 CCS	0.071	---	0.218	46.4
35	Scorpius 7 x 080 CCS	0.073	---	0.212	46.1
36	Scorpius 7 x 080 CCS	0.065	---	0.216	46.3
37	Scorpius 7 x 080 CCS	0.070	---	0.211	46.1

Note:

[1] Encore 4/0 AWG CU conductor had two sizes of strands, all remaining conductors had one size of strands. Strand and conductor diameters were measured using a digital caliper with a resolution of 0.001 in.

Table 2: Summary of tests on Encore 4/0 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
1	1	Run to fusing	3.85	41.7	60.0	530	923	2	Y
2	2	Withstand	3.85	41.8	62.5	509	889	3	N
3-1	3	EMF (IEEE 837)	4.24	48.0	130	262	826	4	N
3-2	3	EMF (IEEE 837)	4.26	48.0	130	127	503	5	Y
4	4	EMF (IEEE 837)	4.25	48.0	130	260	823	6	Y
5-1	5	EMF (IEEE 837)	4.20	47.4	129	262	808	7	N
5-2	5	EMF (IEEE 837)	4.19	47.4	128	9.9	77	8	Y
6-1	6	EMF (IEEE 837)	3.93	42.6	116	263	662	9	N
6-2	6	EMF (IEEE 837)	3.91	42.6	116	262	654	10	N

Table 3: Summary of tests on Copperweld Scorpius 61 x 072 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
7	11	Run to fusing	3.84	41.7	59.6	673	1173	11	Y
8	12	Run to fusing	4.25	48.1	69.8	500	1157	12	Y
9	13	Run to fusing	4.21	47.5	68.9	508	1150	13	Y
10	14	Withstand	4.09	46.2	66.2	508	1089	14	N
11-1	15	EMF (IEEE 837)	4.21	47.6	129	262	803	15	N
11-2	15	EMF (IEEE 837)	4.20	47.7	129	262	803	16	N
12-1	16	EMF (IEEE 837)	4.21	47.6	129	254	784	17	N
12-2	16	EMF (IEEE 837)	4.19	47.4	128	254	767	18	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

Table 4: Summary of tests on Encore #6 AWG Copper conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
13	21	Run to fusing	3.90	5.18	7.36	607	16.3	19	Y
14	23	Run to fusing	3.90	5.18	7.57	600	16.1	20	Y
15	24	Run to fusing	4.27	5.68	8.15	500	16.1	21	Y
16-1	25	EMF (IEEE 837)	3.77	5.86	16.2	262	13.9	22	N
16-2	25	EMF (IEEE 837)	3.77	5.86	16.1	262	13.9	23	N

Table 5: Summary of tests on Copperweld Scorpius 7 x 080 CCS conductor.

Test №	Wire Sample No.	Type of Test [1]	Source Voltage [2]	Current		Duration [3]	I^2t [4]	Waveforms	Wire Fused?
				Symm.	Peak				
#	#		(kV_{rms})	(kA_{rms})	(kA_{peak})	(ms)	($A^2s \times 10^6$)	Figure #	Y/N
17	31	Withstand	3.88	5.16	7.44	858	22.9	24	N
18	32	Run to fusing	3.89	5.16	7.43	908	24.2	25	Y
19	33	Run to fusing	4.48	7.00	10.3	493	24.1	26	Y
20	34	Run to fusing	4.41	6.91	10.2	502	23.9	27	Y
21-1	35	EMF (IEEE 837)	3.81	5.91	16.3	262	14.0	28	N
21-2	35	EMF (IEEE 837)	3.80	5.92	16.2	262	13.8	29	N

Notes:

[1] EMF tests were performed with a test circuit with an X/R>30, and the sample wire was cooled to below 100 °C before the second test, as required by IEEE 837.

[2] The source voltage is the open circuit voltage of the test circuit.

[3] For the samples that didn't fuse during the test, the duration is the period of time that test current was applied. For samples that fused during the test, the duration is the time between the initiation of test current and fusing of the sample (as indicated by the occurrence of arc voltage).

[4] I^2t is calculated based on the instantaneous current and duration. For tests where the conductor fused, it is calculated up to the time of fusing.

APPENDIX B – WAVEFORMS

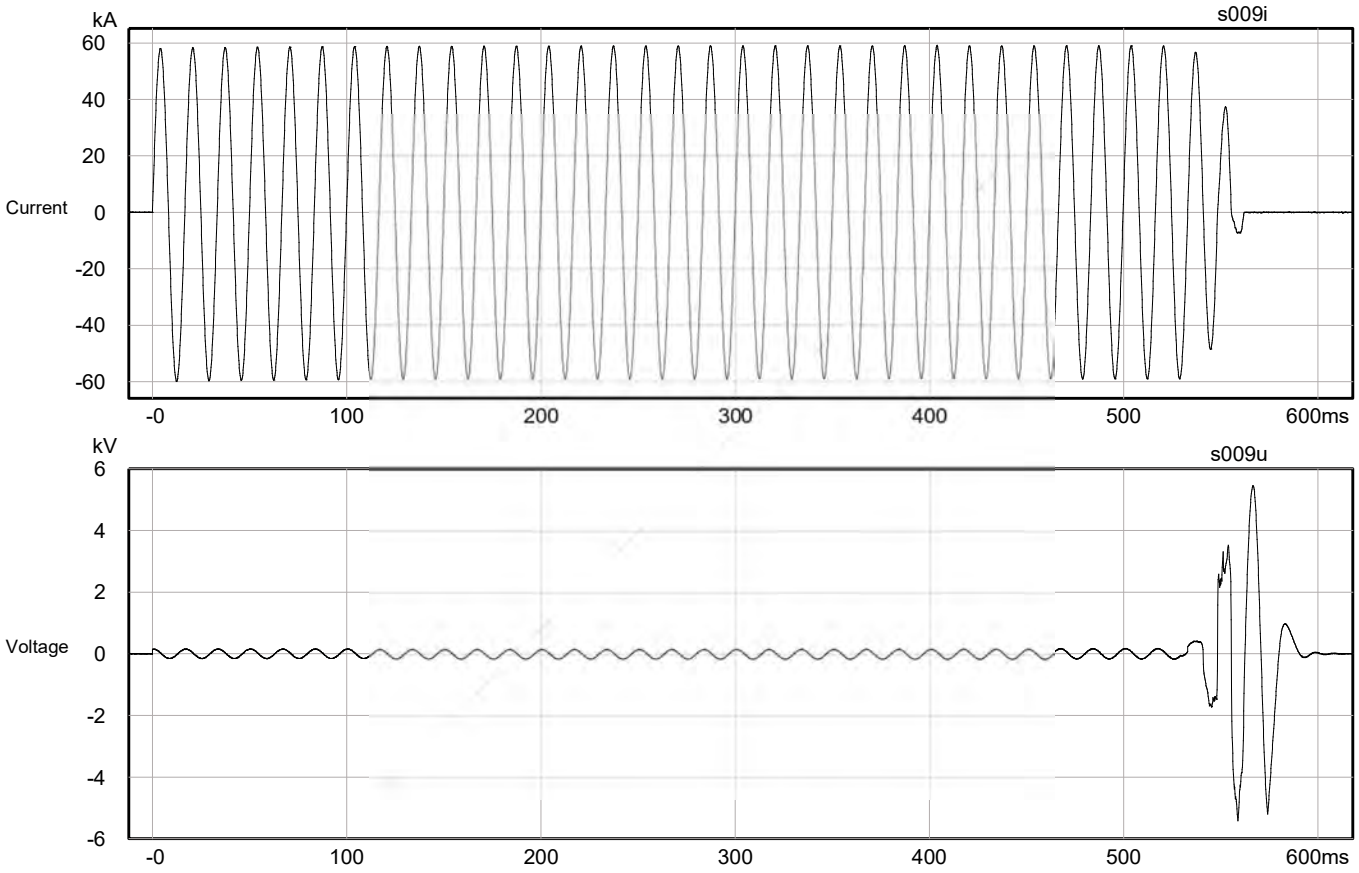


Figure 2: Waveforms for Test #1, Encore 4/0 AWG Sample 1.

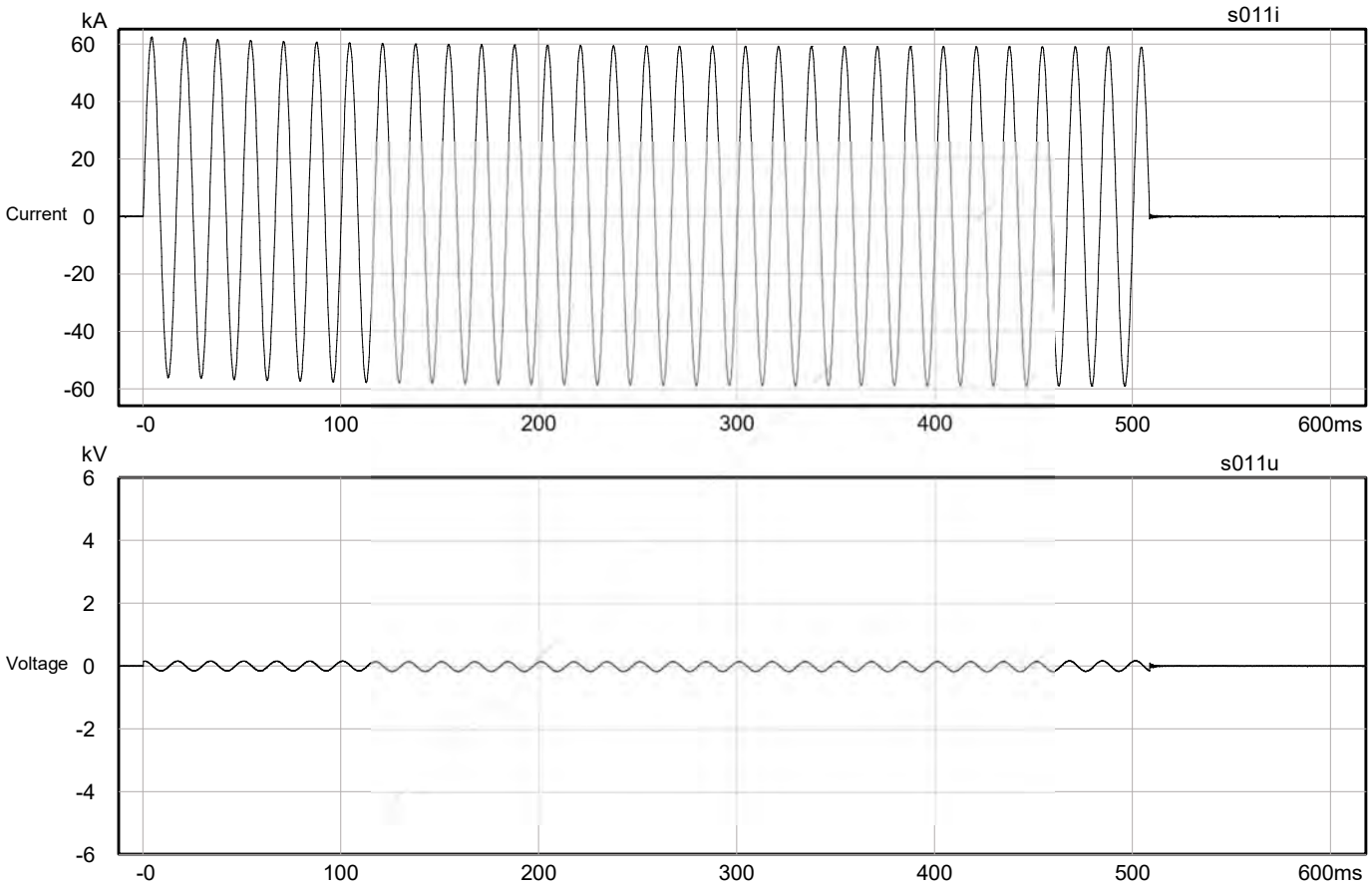


Figure 3: Waveforms for Test #2, Encore 4/0 AWG Sample 2.

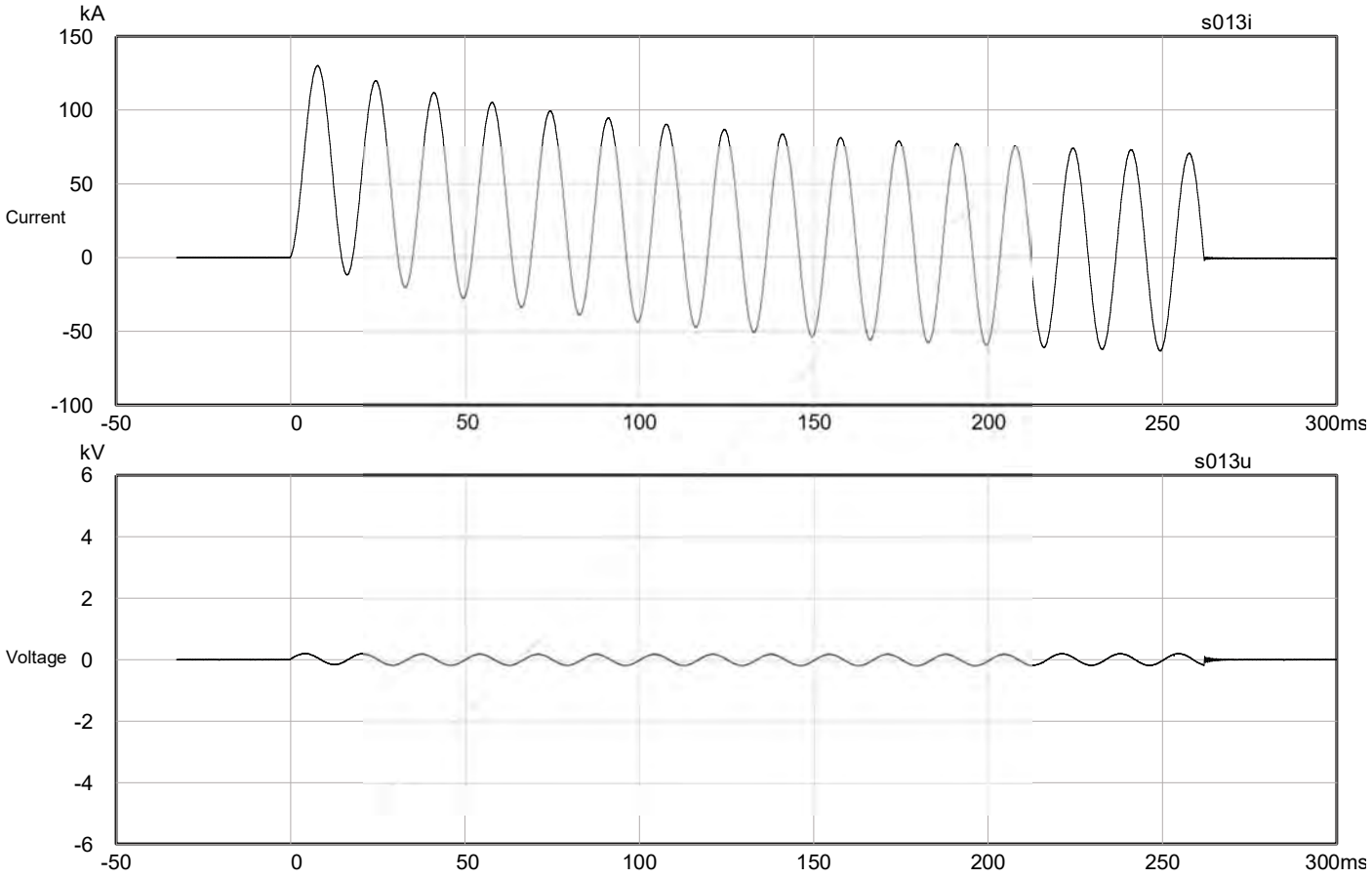


Figure 4: Waveforms for Test #3-1, Encore 4/0 AWG Sample 3.

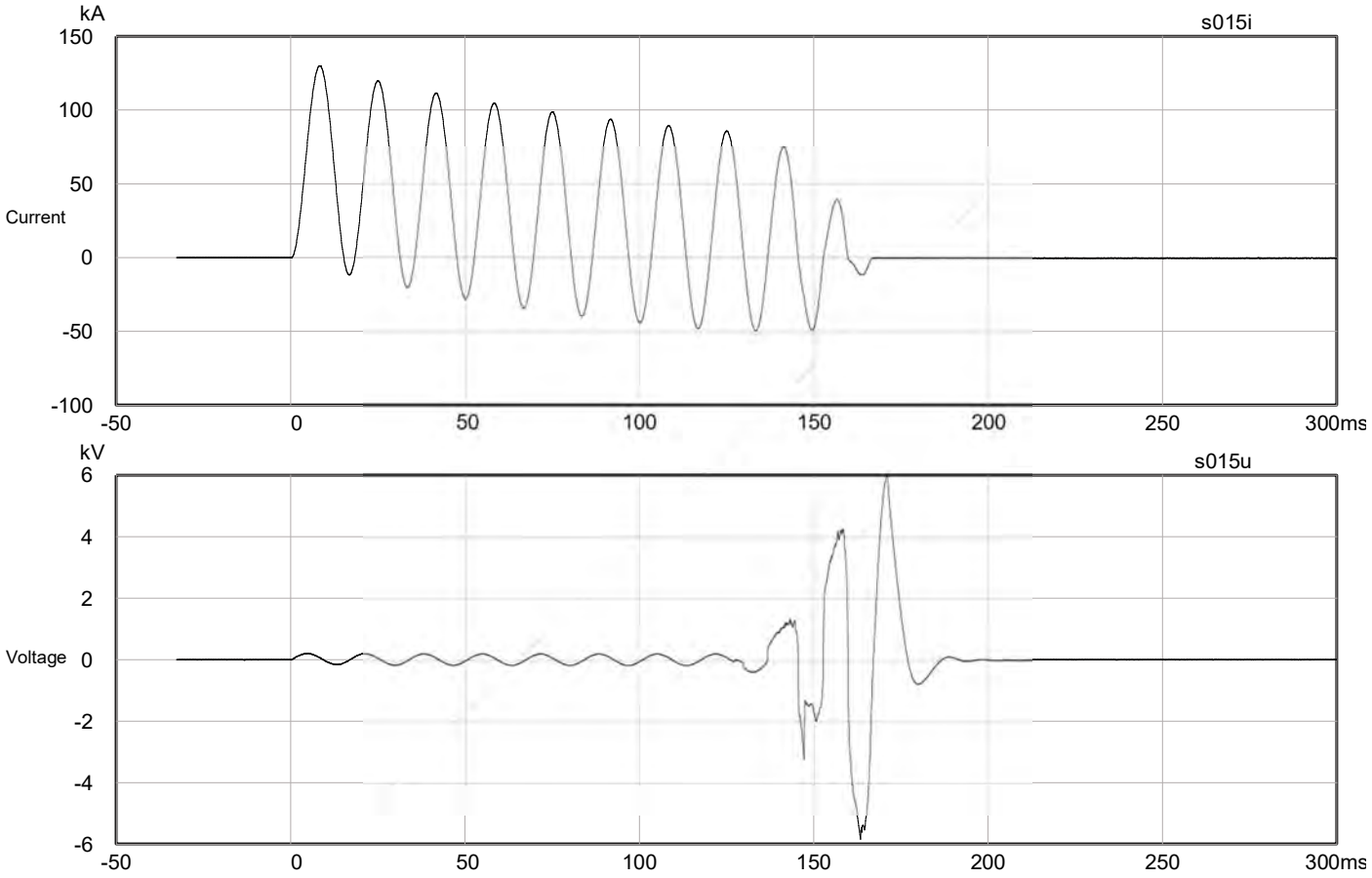


Figure 5: Waveforms for Test #3-2, Encore 4/0 AWG Sample 3.

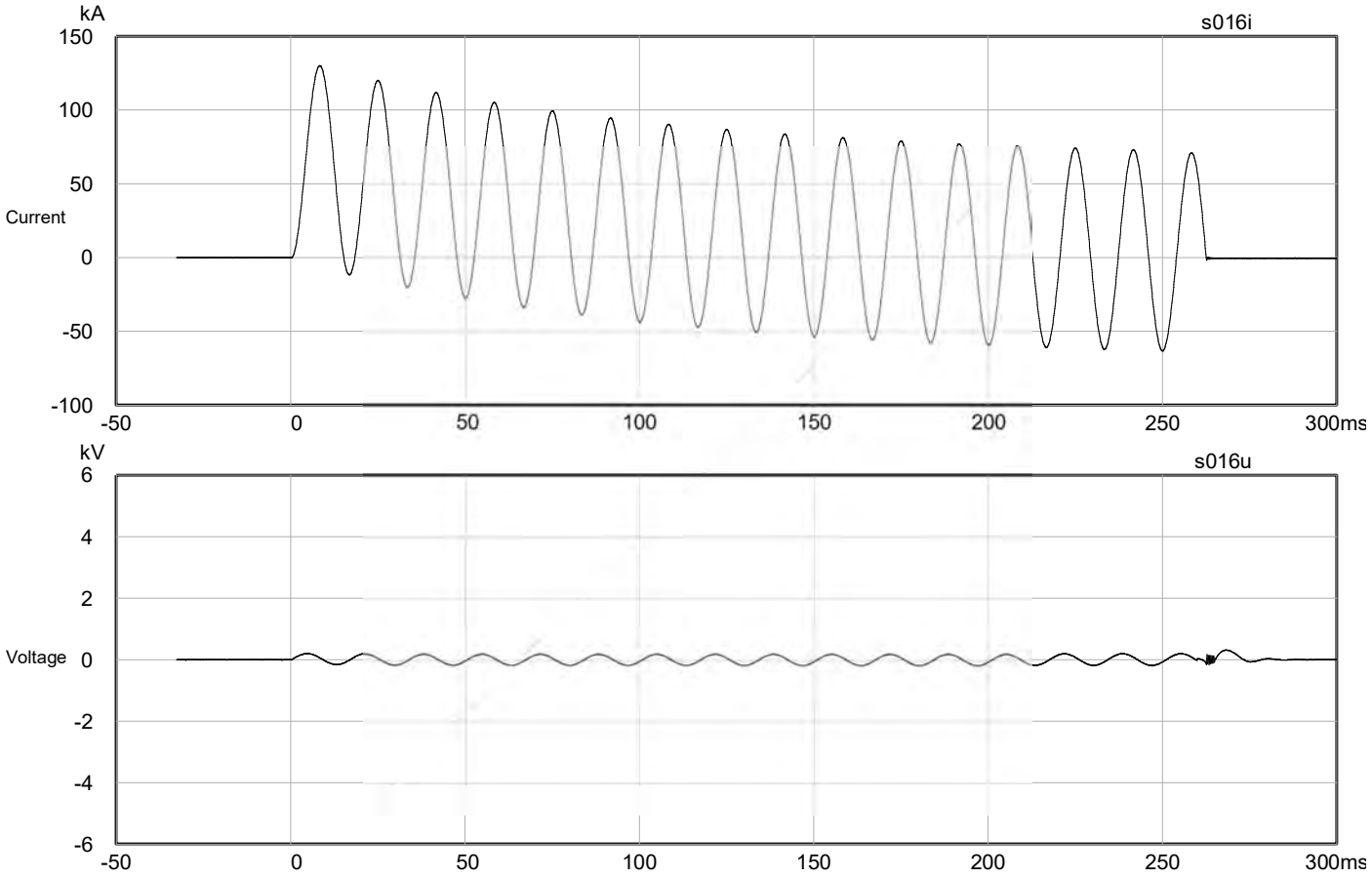


Figure 6: Waveforms for Test #4, Encore 4/0 AWG Sample 4.

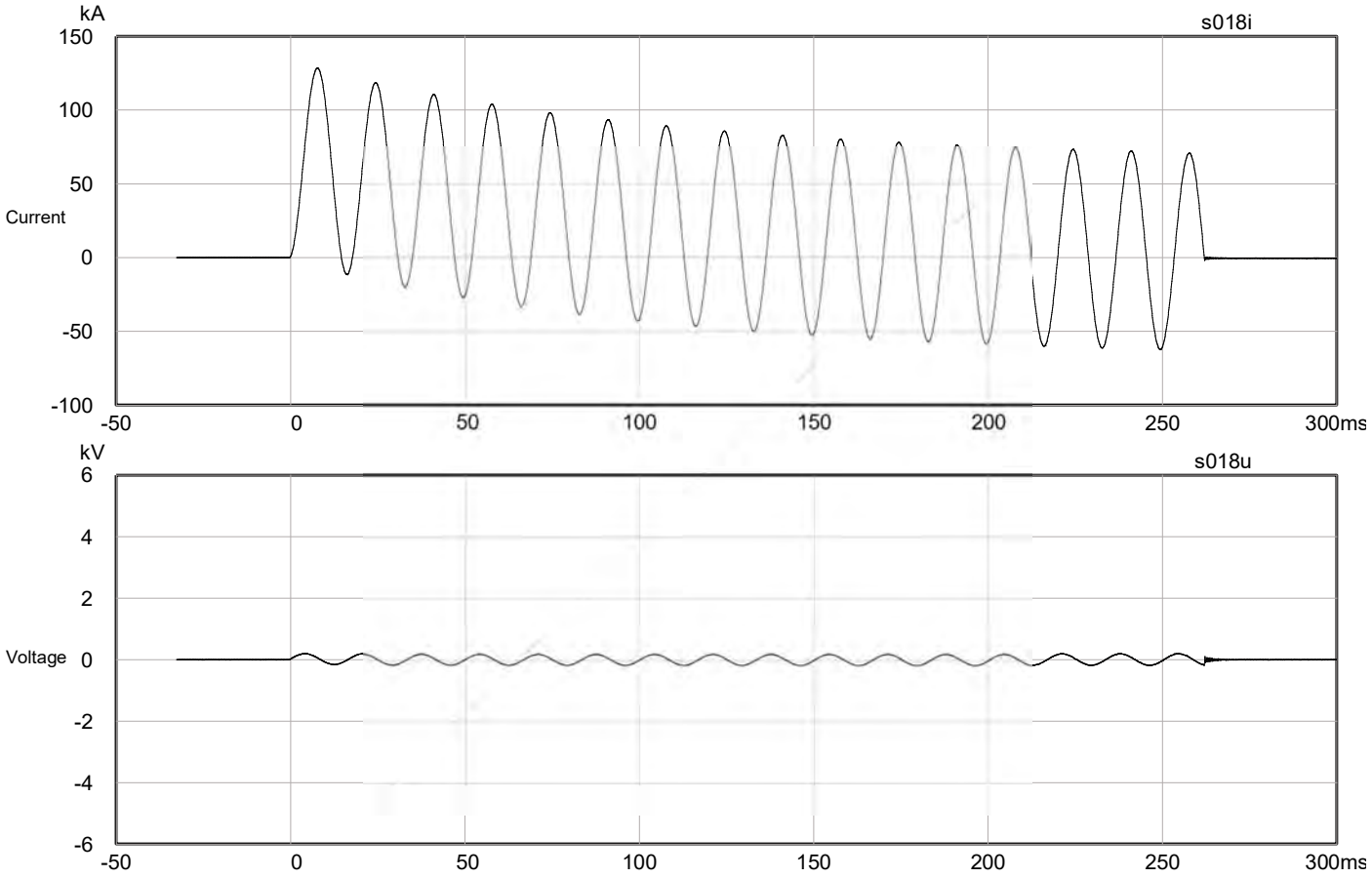


Figure 7: Waveforms for Test #5-1, Encore 4/0 AWG Sample 5.

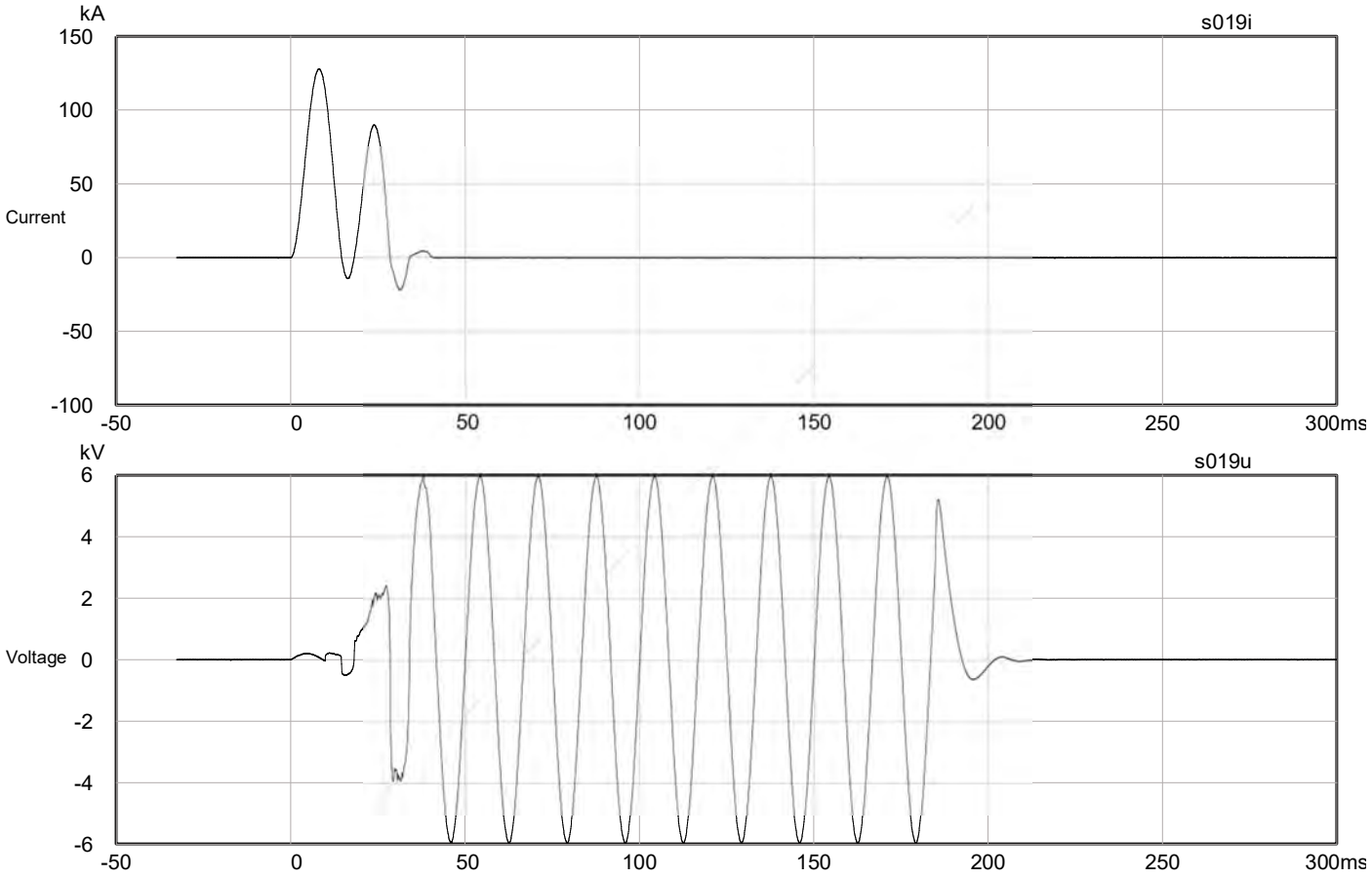


Figure 8: Waveforms for Test #5-2, Encore 4/0 AWG Sample 5.

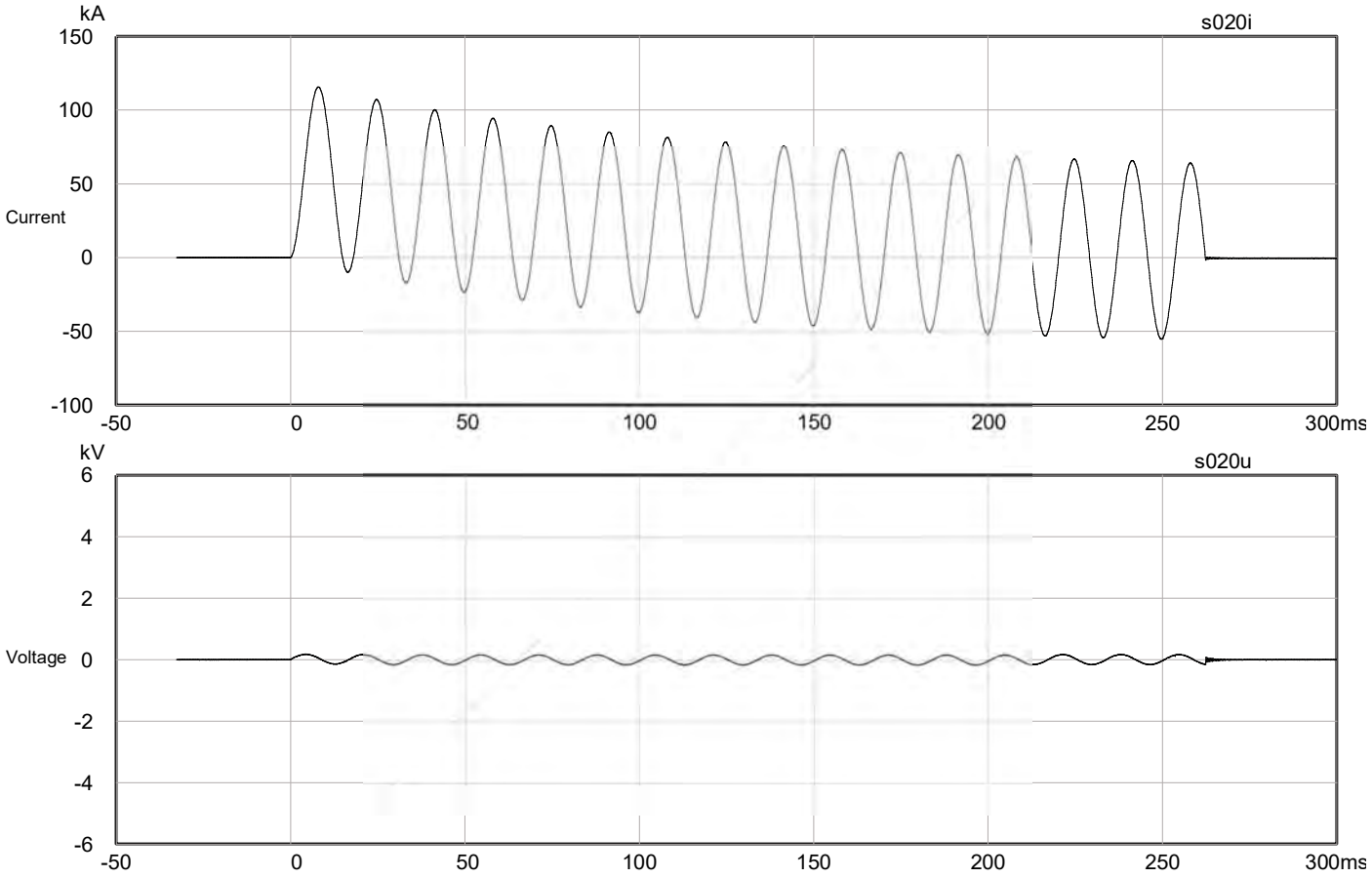


Figure 9: Waveforms for Test #6-1, Encore 4/0 AWG Sample 6.

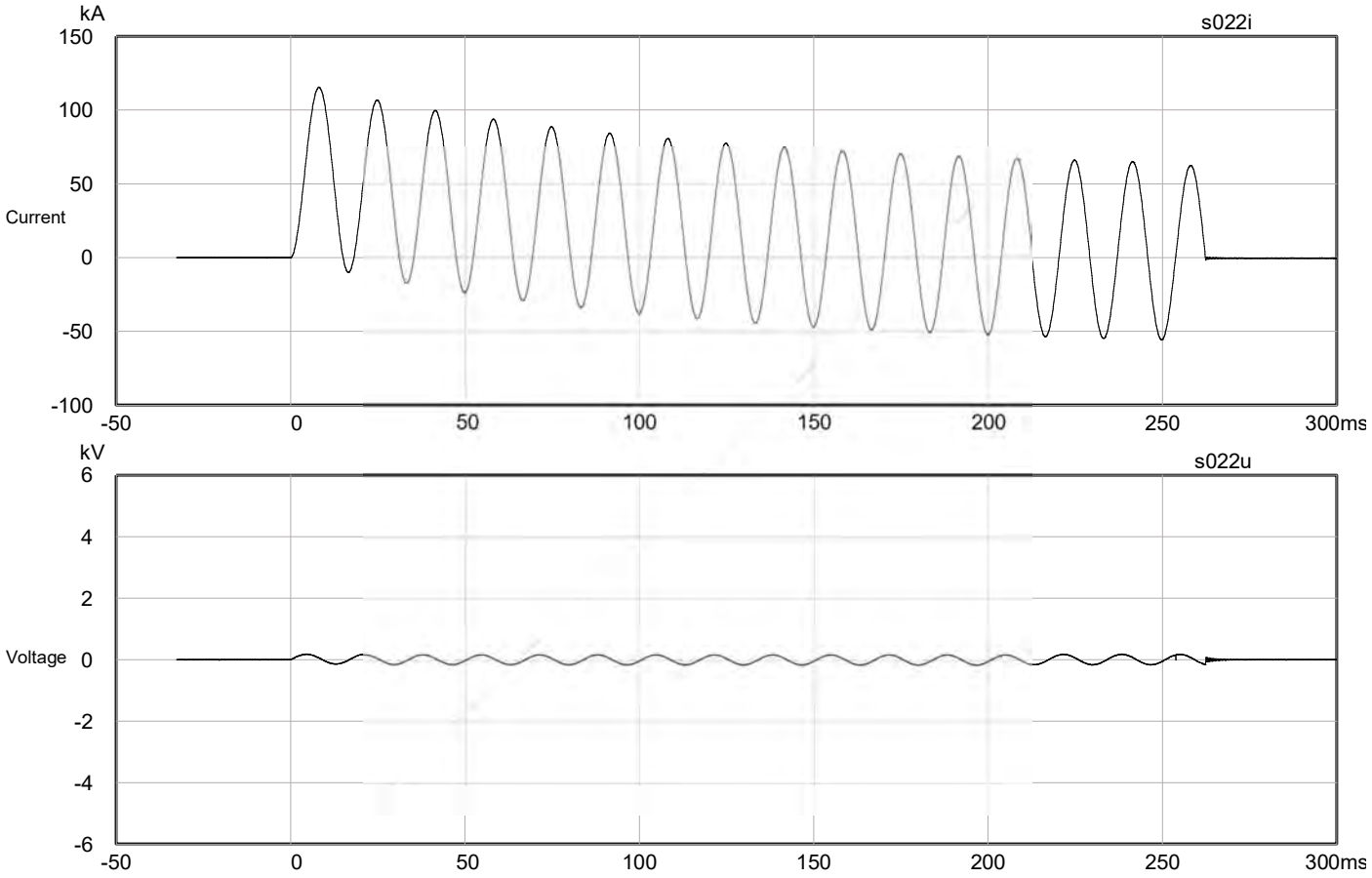


Figure 10: Waveforms for Test #6-2, Encore 4/0 AWG Sample 6.

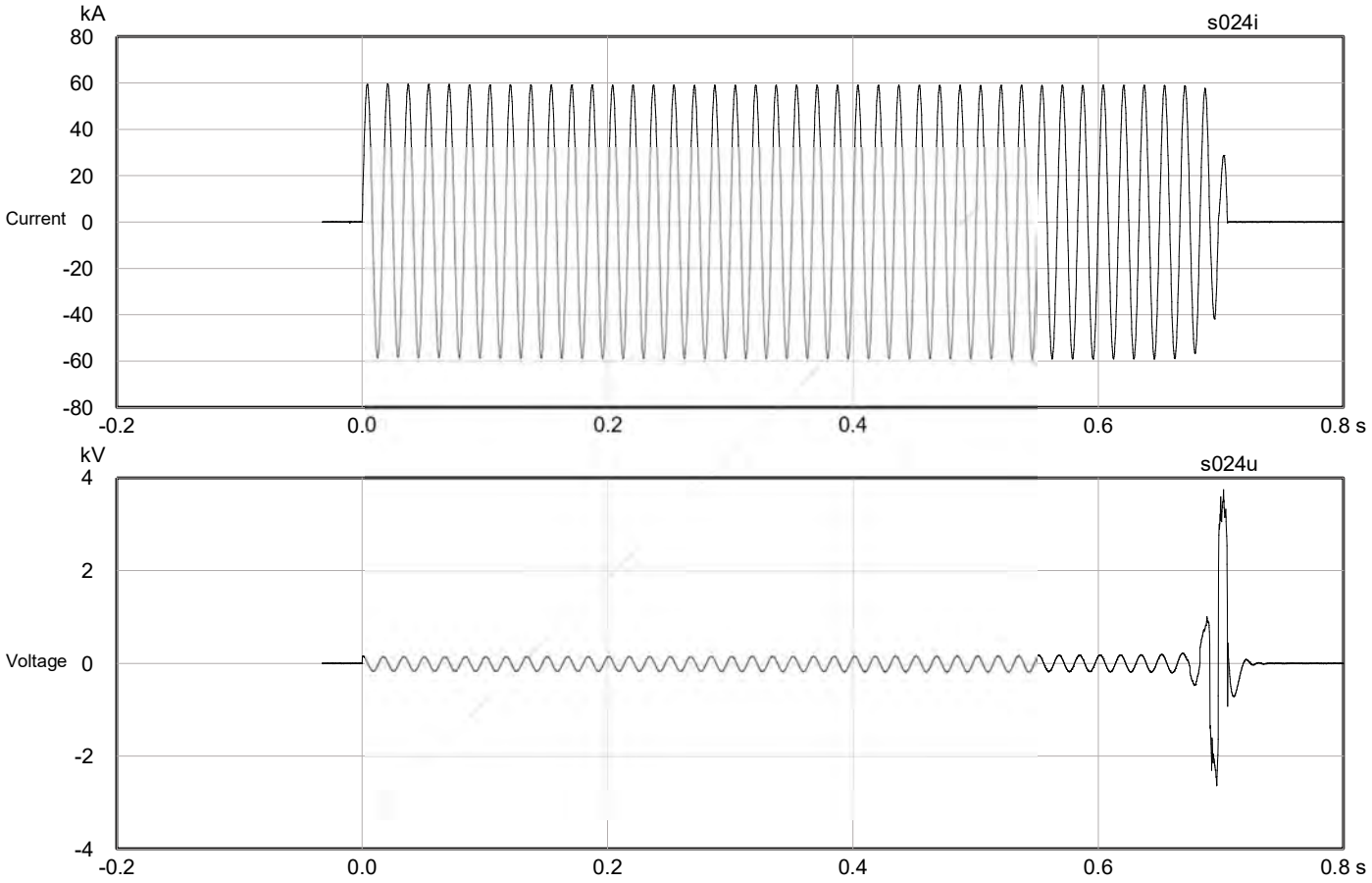


Figure 11: Waveforms for Test #7, Copperweld Scorpius 61 x 072 Sample 11.

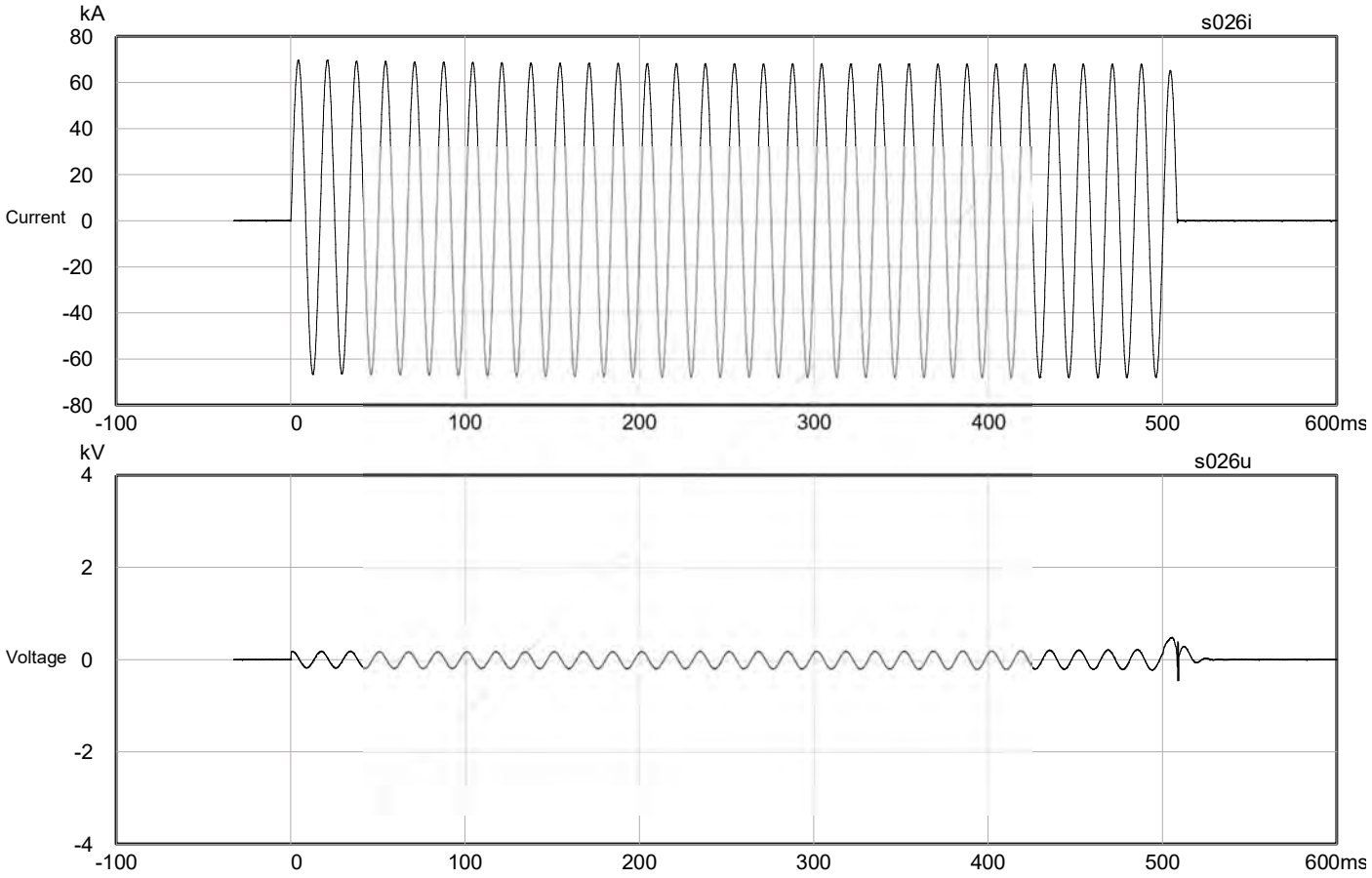


Figure 12: Waveforms for Test #6, Copperweld Scorpius 61 x 072 Sample 12.

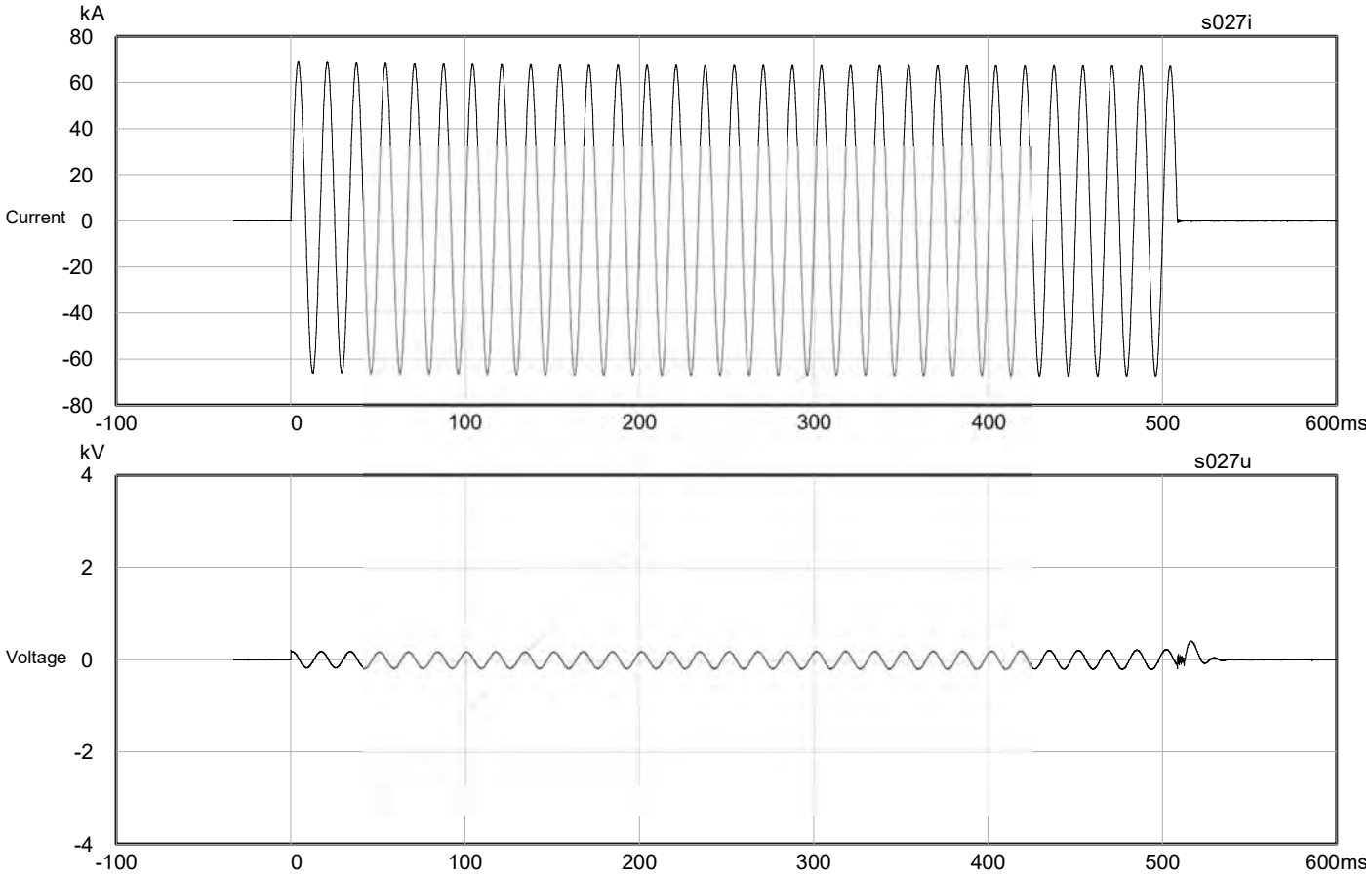


Figure 13: Waveforms for Test #9, Copperweld Scorpius 61 x 072 Sample 13.

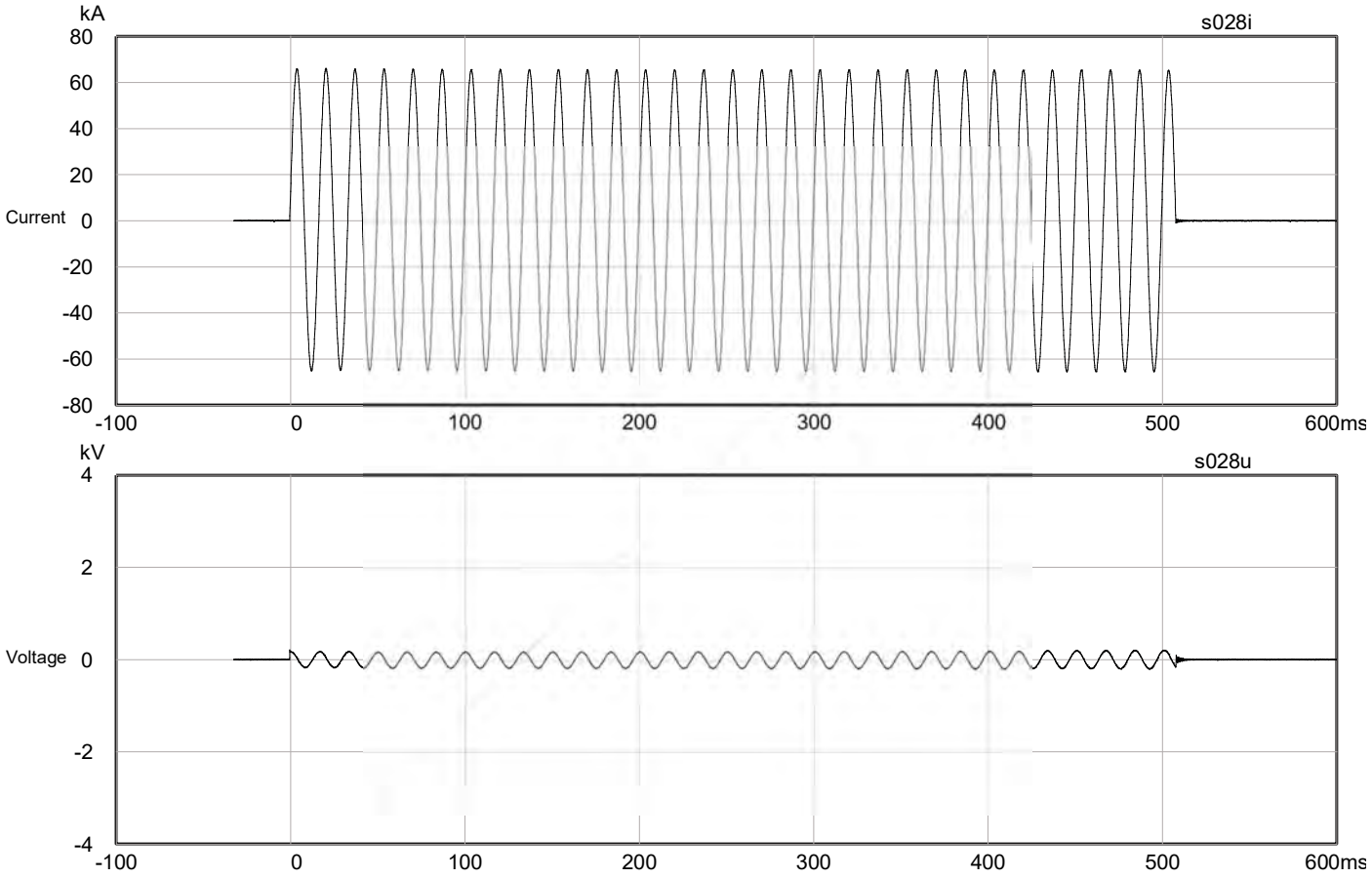


Figure 14: Waveforms for Test #10, Copperweld Scorpius 61 x 072 Sample 14.

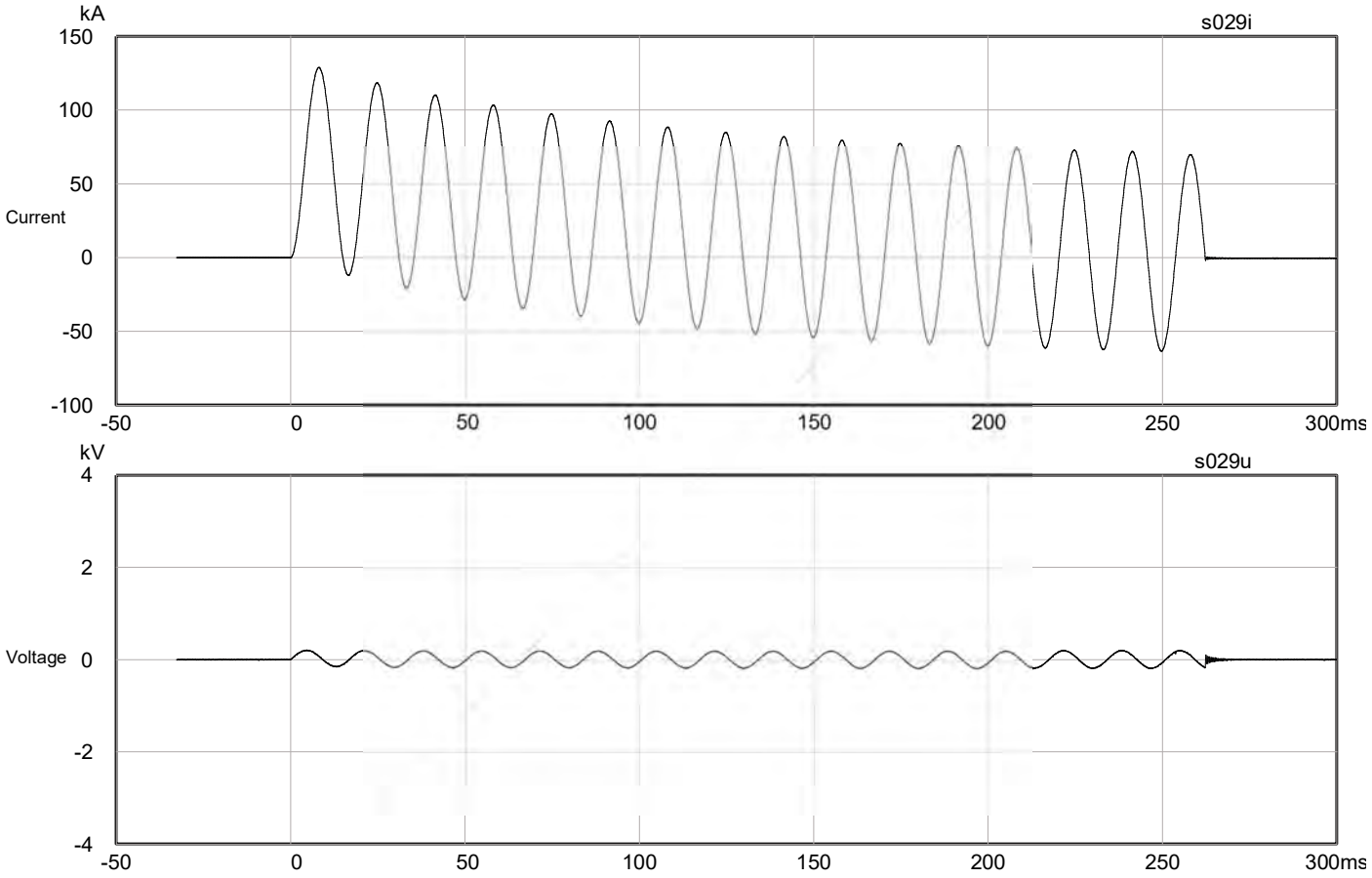


Figure 15: Waveforms for Test #11-1, Copperweld Scorpius 61 x 072 Sample 15.

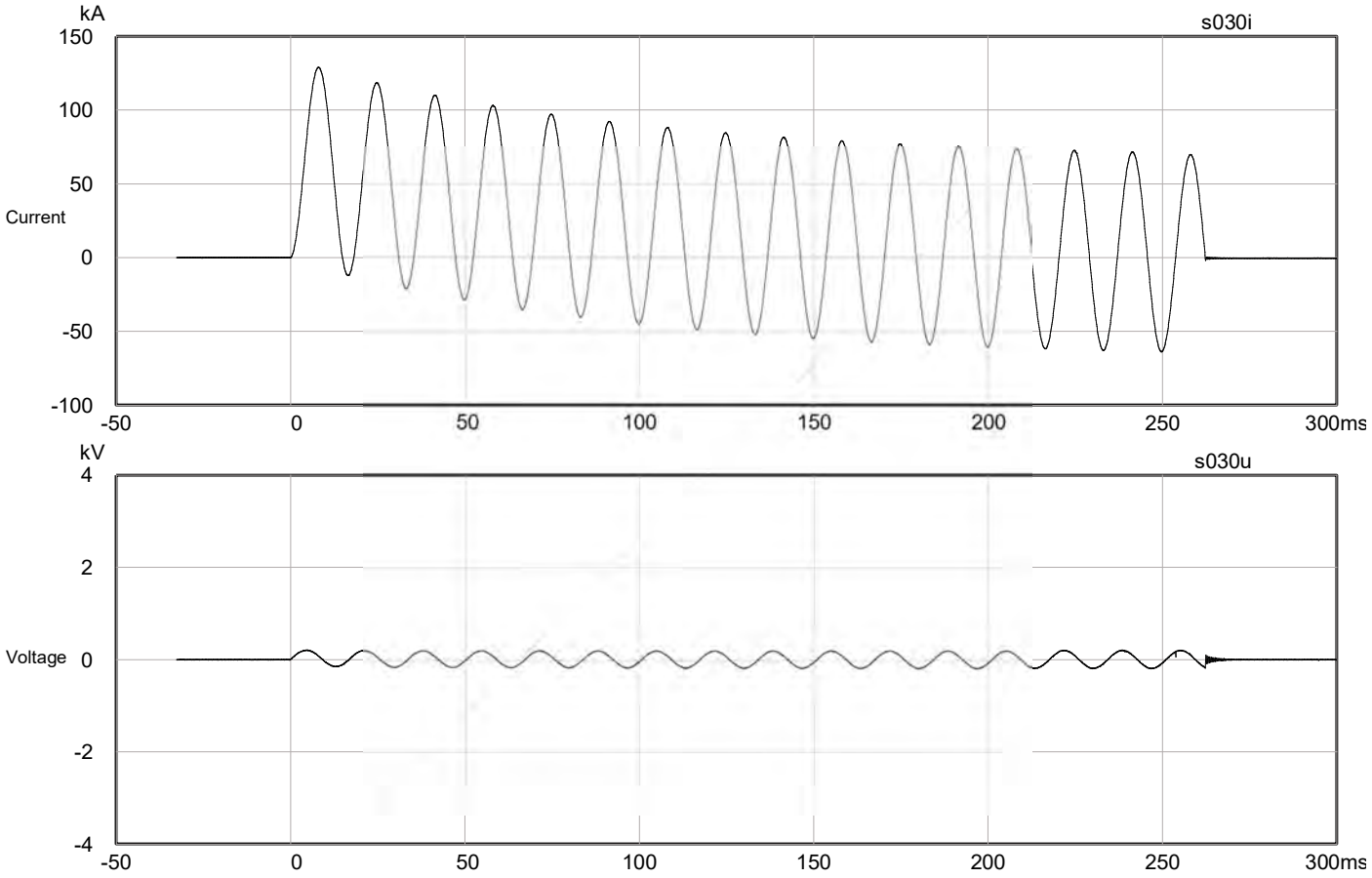


Figure 16: Waveforms for Test #11-2, Copperweld Scorpius 61 x 072 Sample 15.

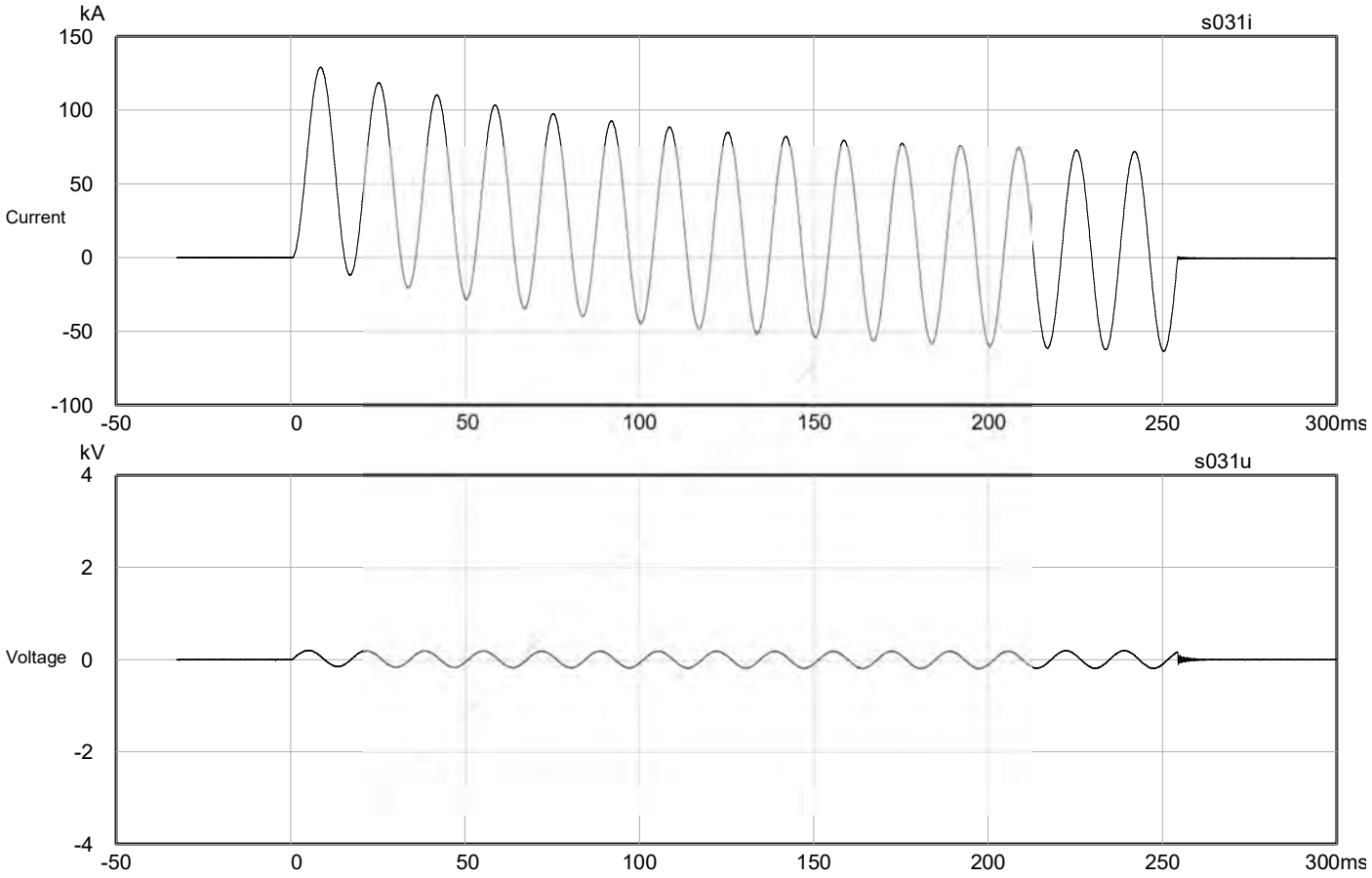


Figure 17: Waveforms for Test #12-1, Copperweld Scorpius 61 x 072 Sample 16.

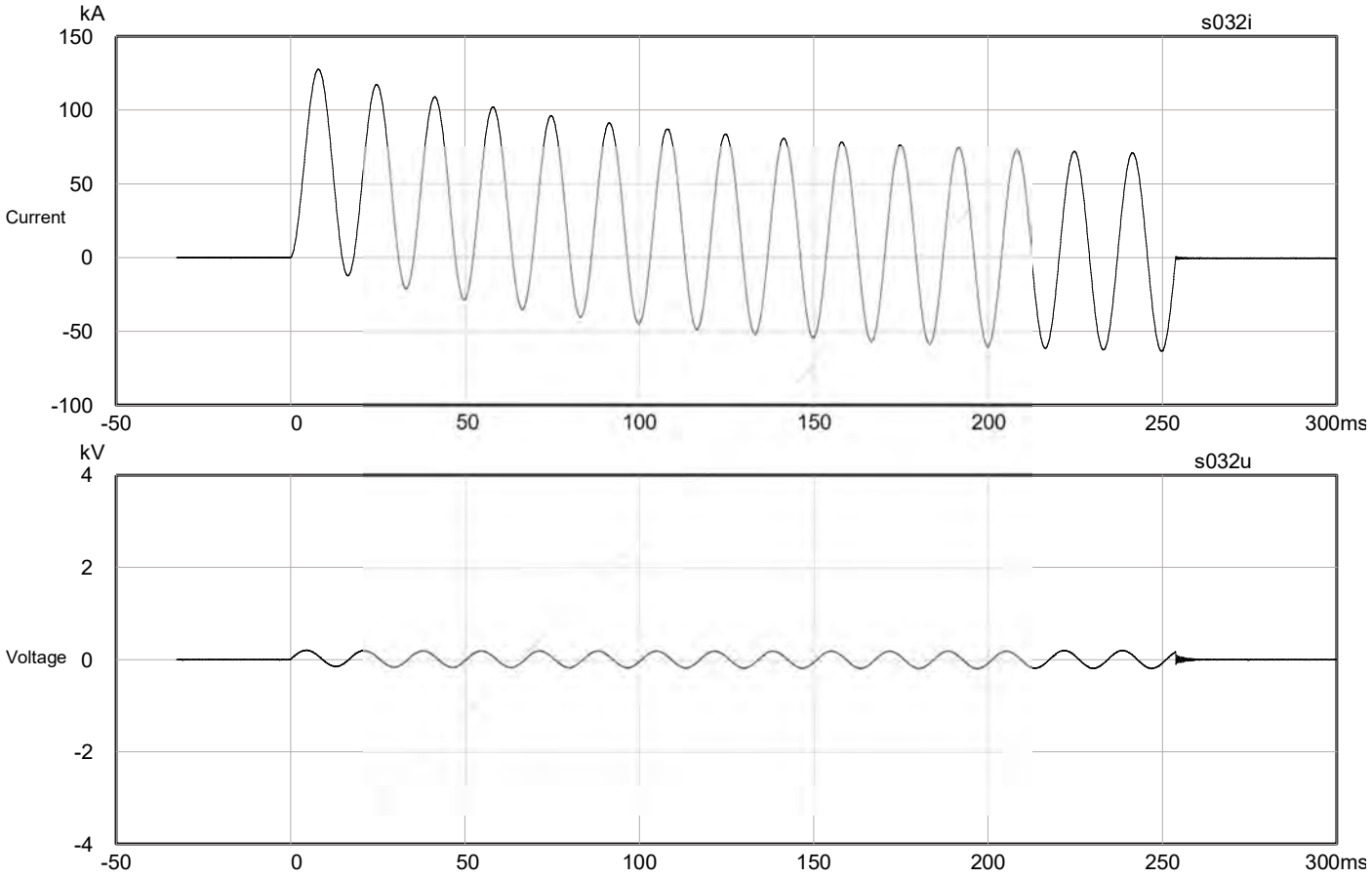


Figure 18: Waveforms for Test #12-2, Copperweld Scorpius 61 x 072 Sample 16.

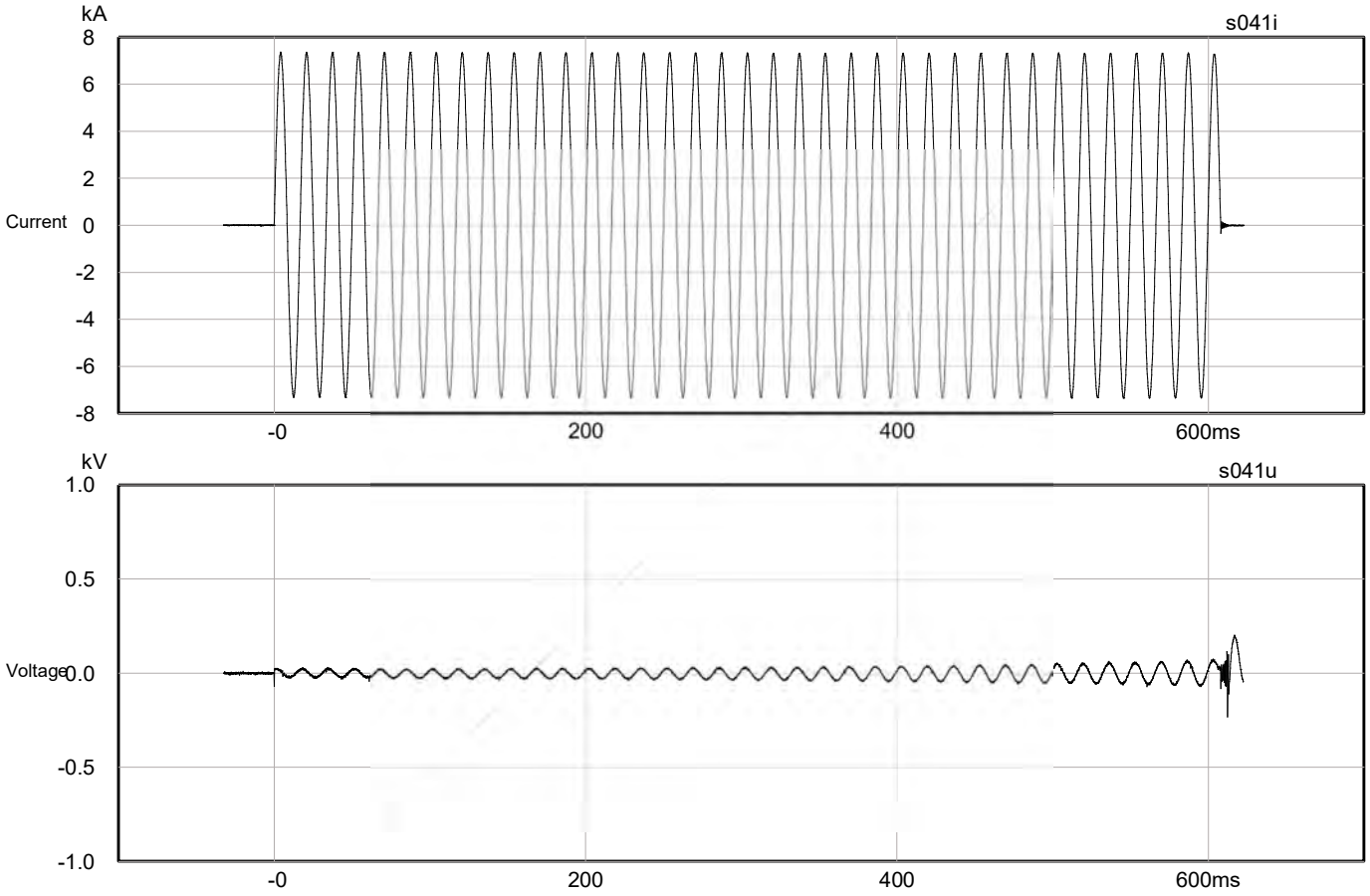


Figure 19: Waveforms for Test #13, Encore #6 AWG Sample 21.

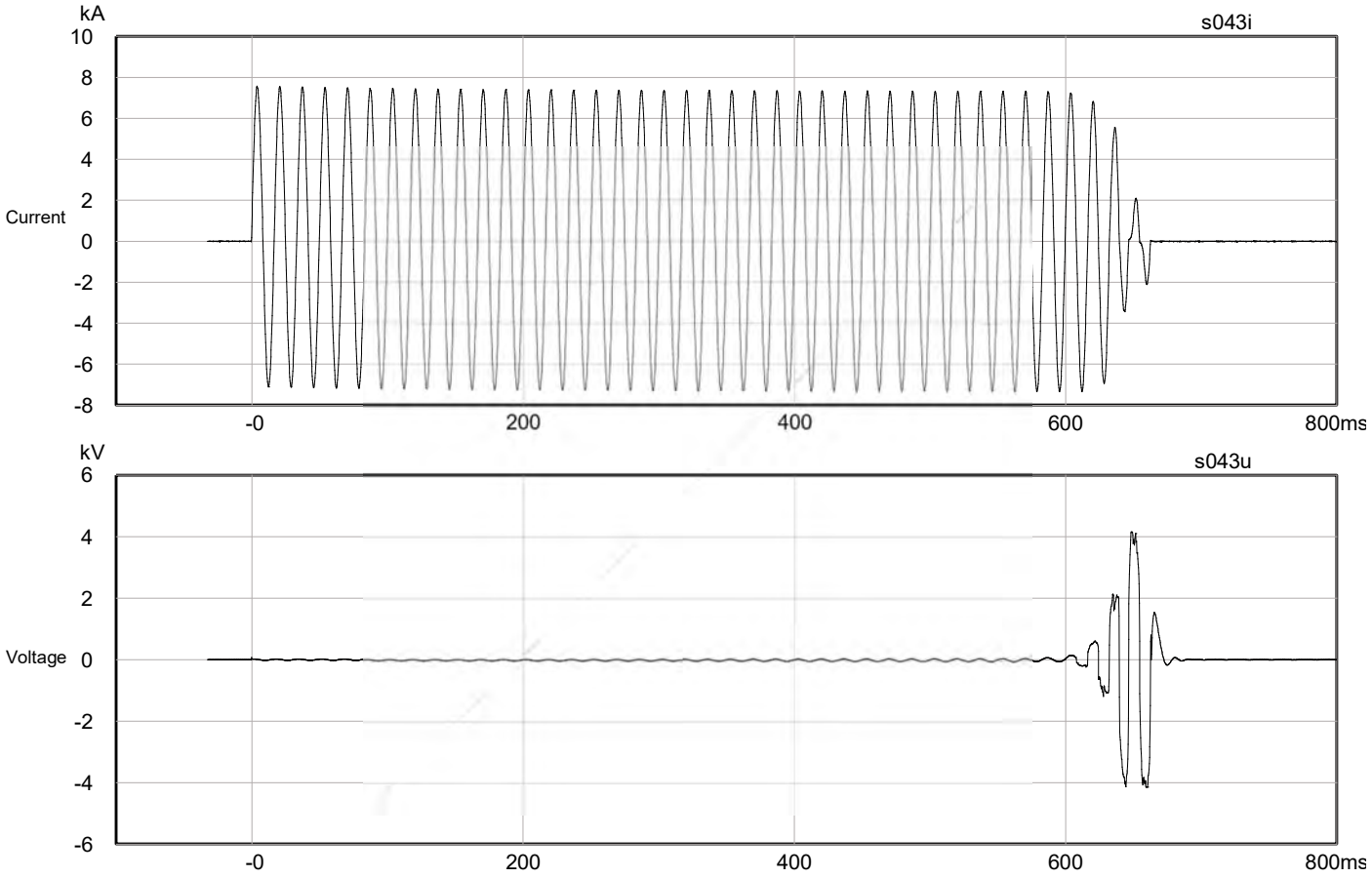


Figure 20: Waveforms for Test #14, Encore #6 AWG Sample 23.

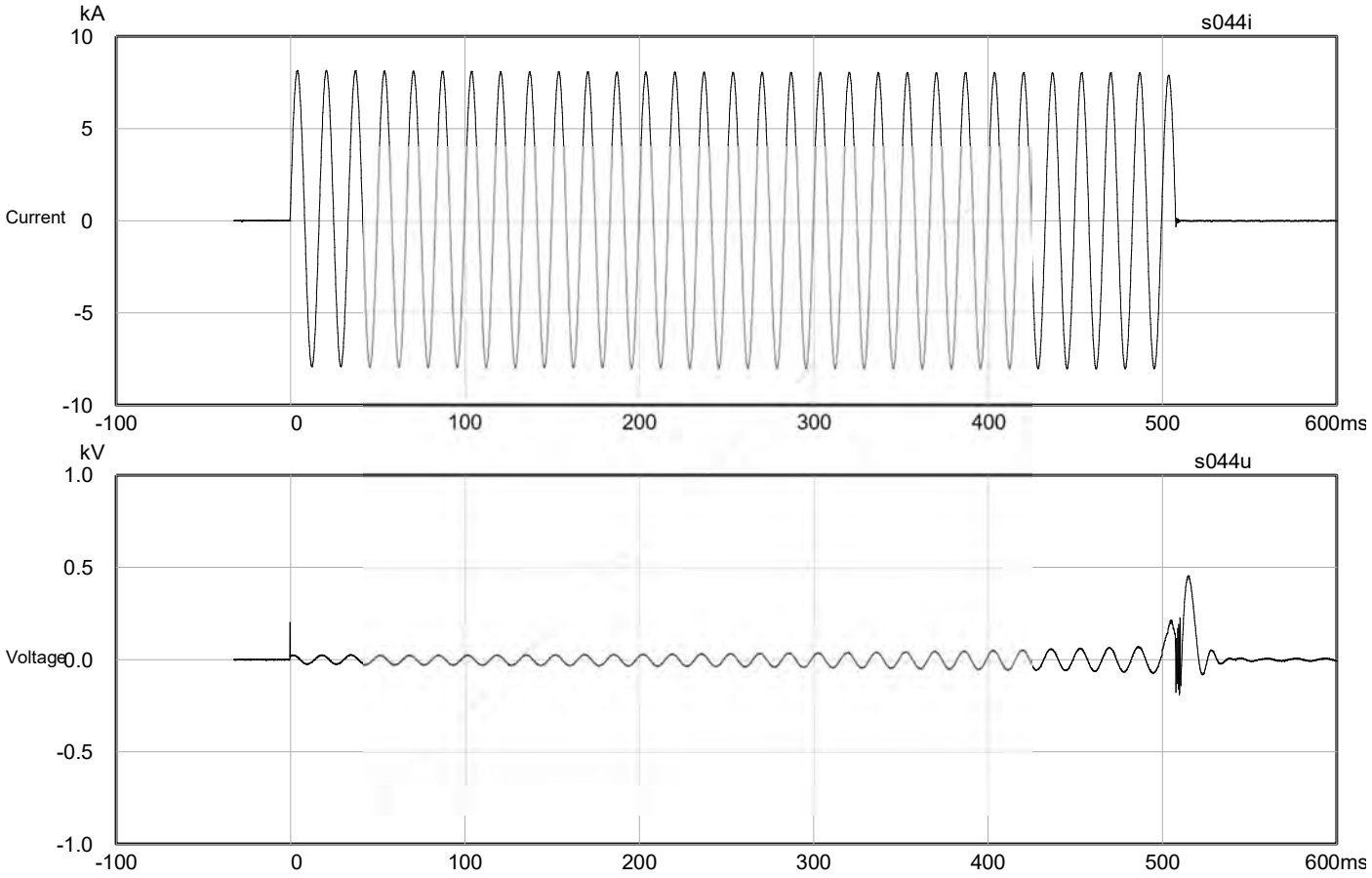


Figure 21: Waveforms for Test #15, Encore #6 AWG Sample 24.

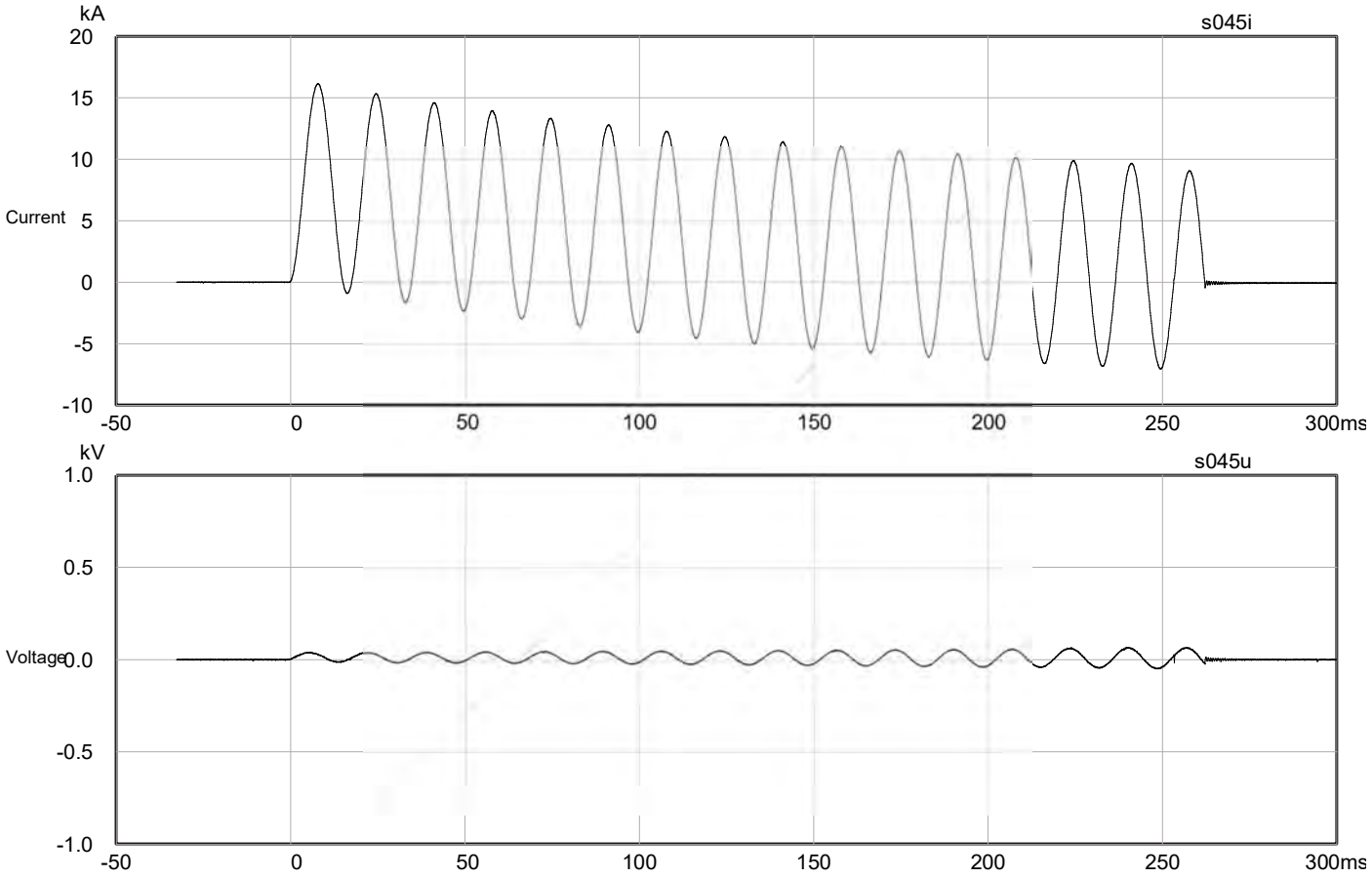


Figure 22: Waveforms for Test #16-1, Encore #6 AWG Sample 25.

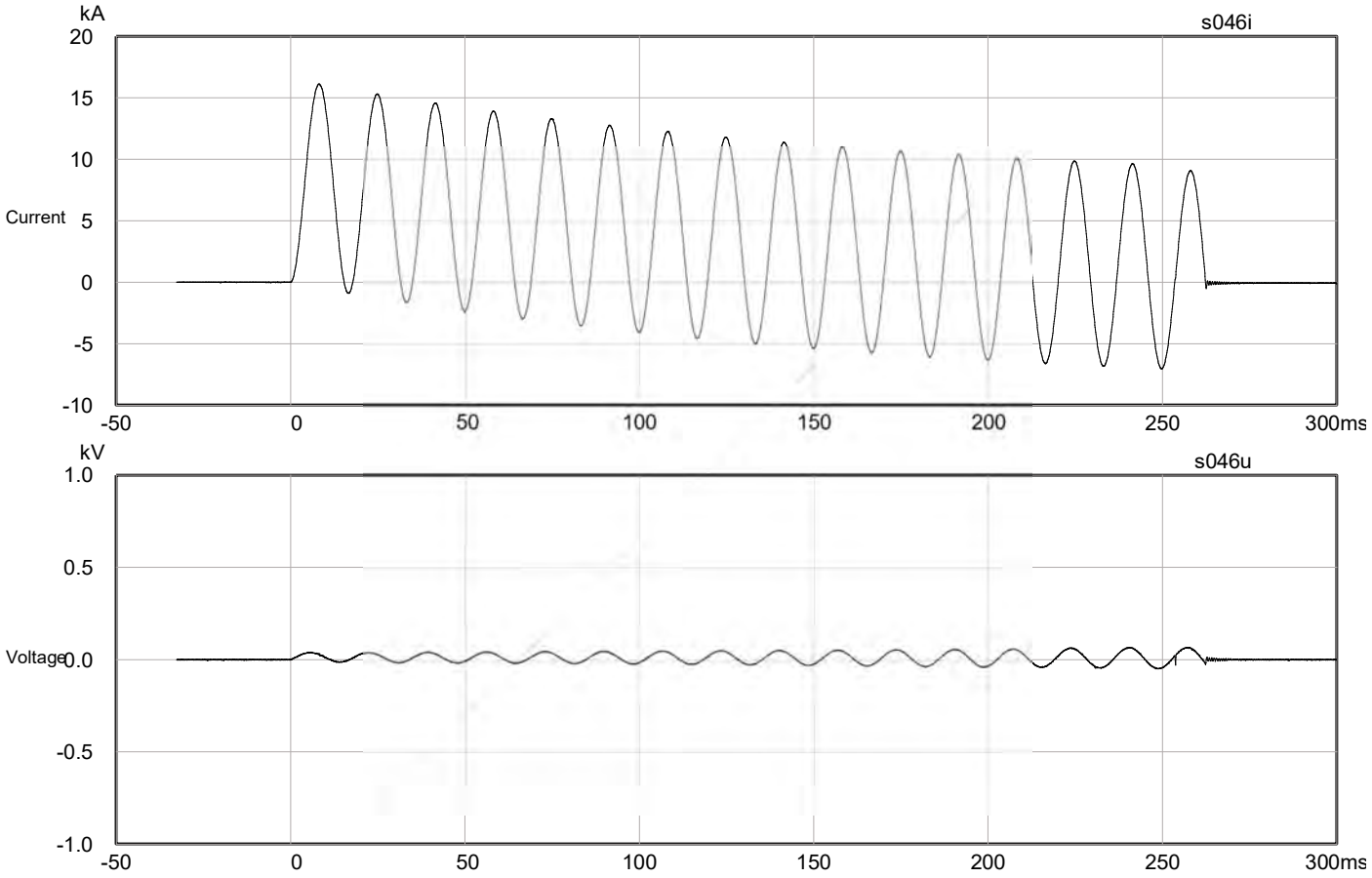


Figure 23: Waveforms for Test #16-2, Encore #6 AWG Sample 25.

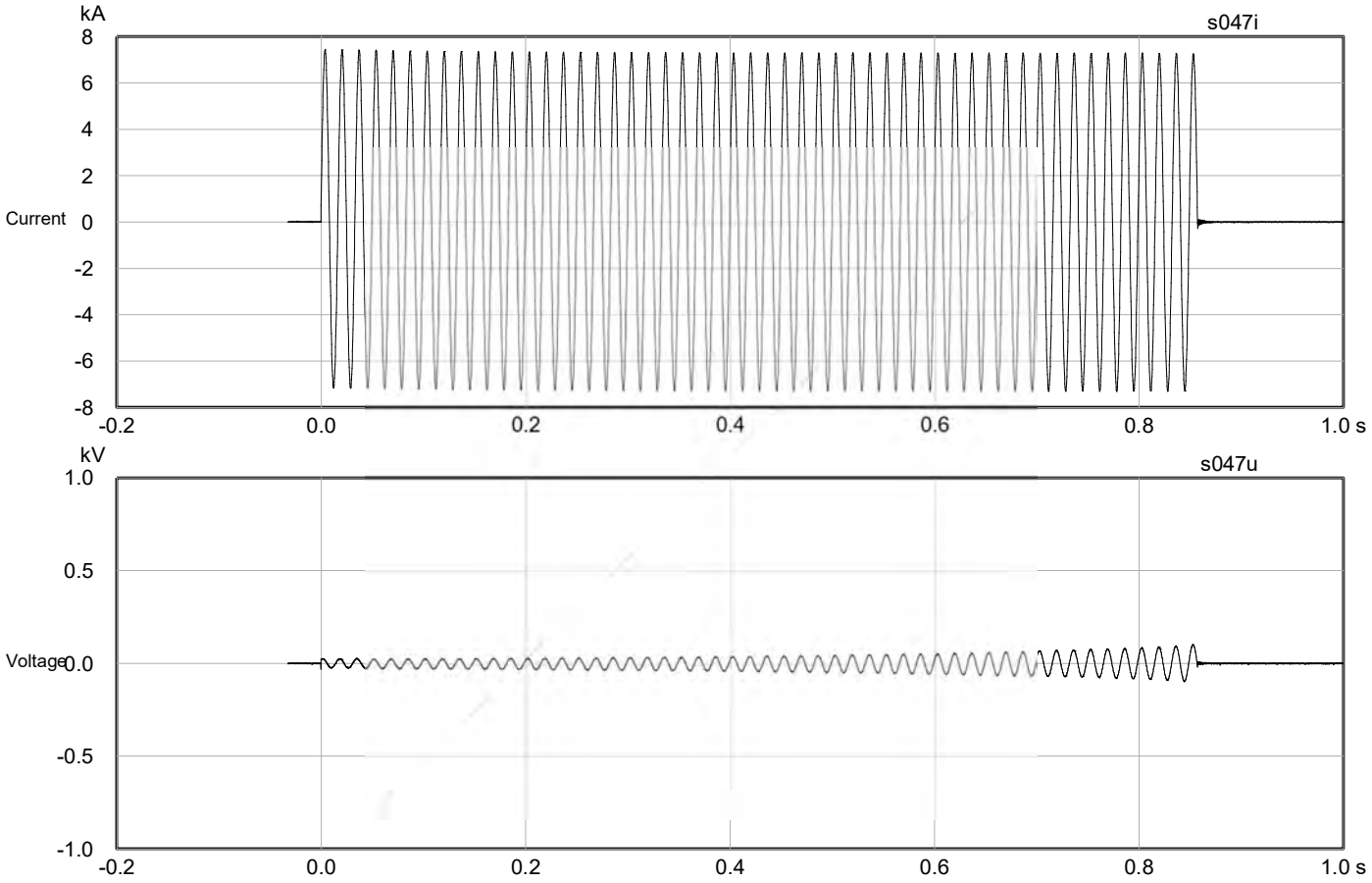


Figure 24: Waveforms for Test #17, Encore #6 AWG Sample 31.

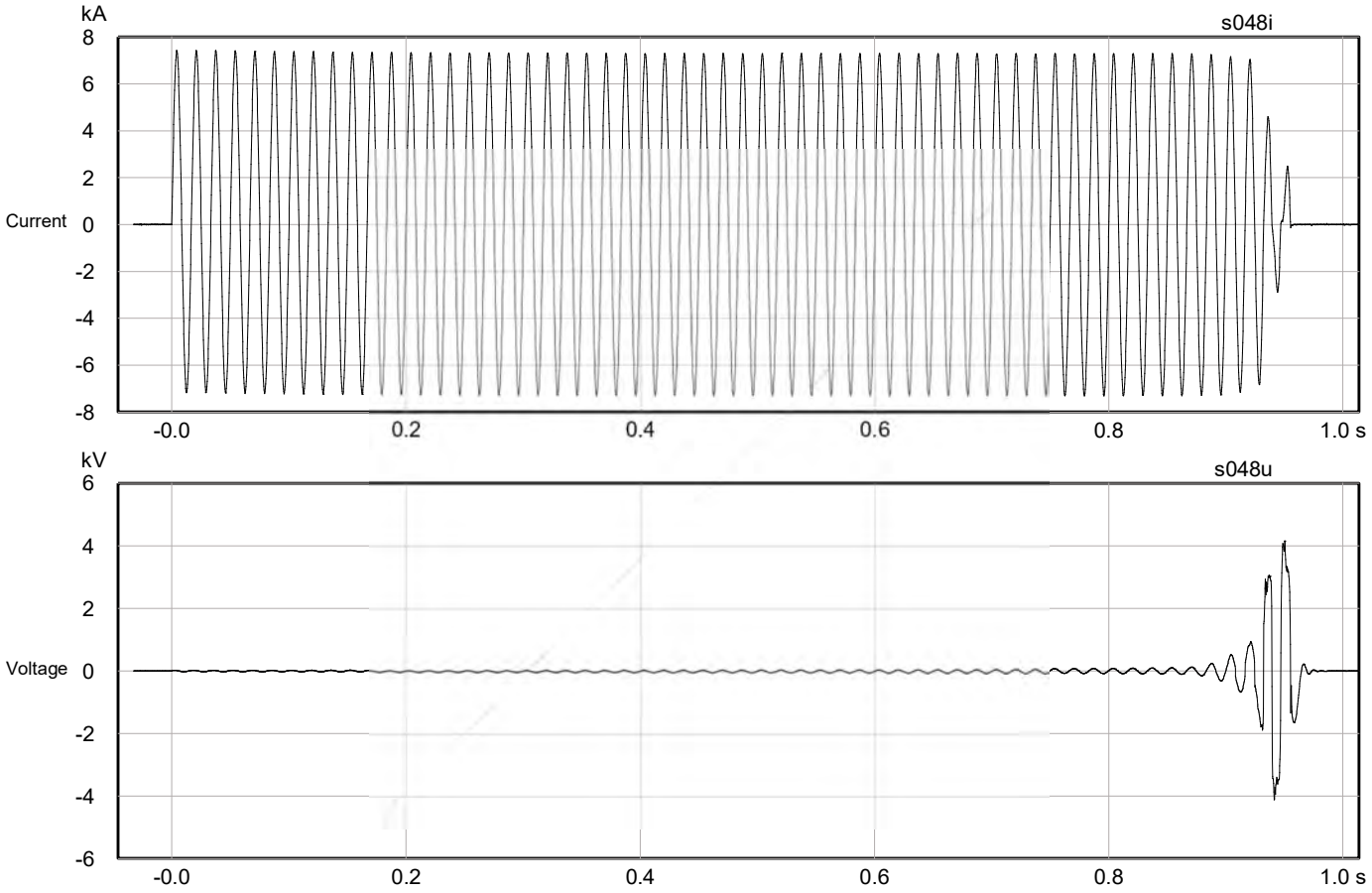


Figure 25: Waveforms for Test #18, Copperweld Scorpius 7 x 080 Sample 32.

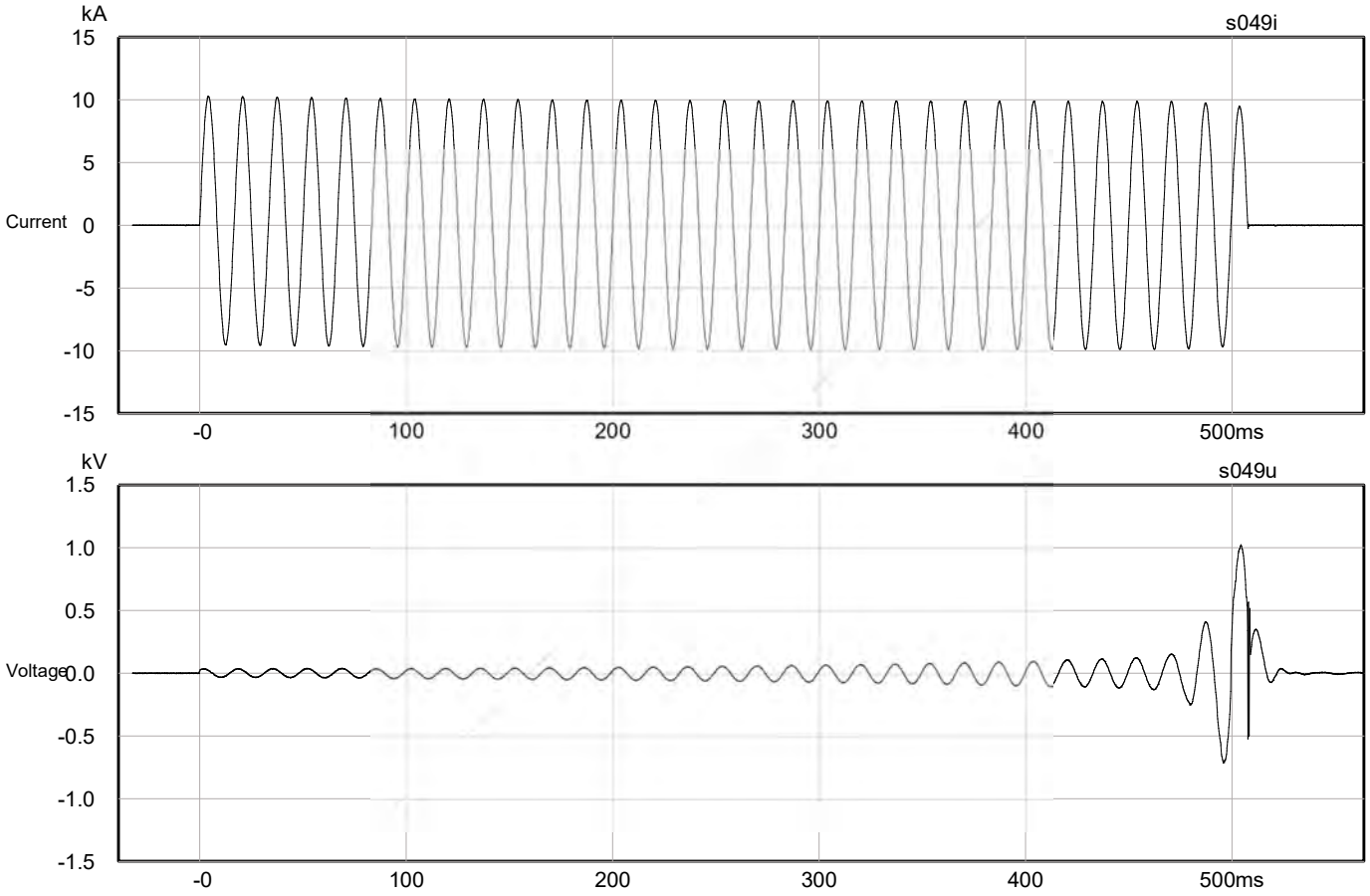


Figure 26: Waveforms for Test #19, Copperweld Scorpius 7 x 080 Sample 33.

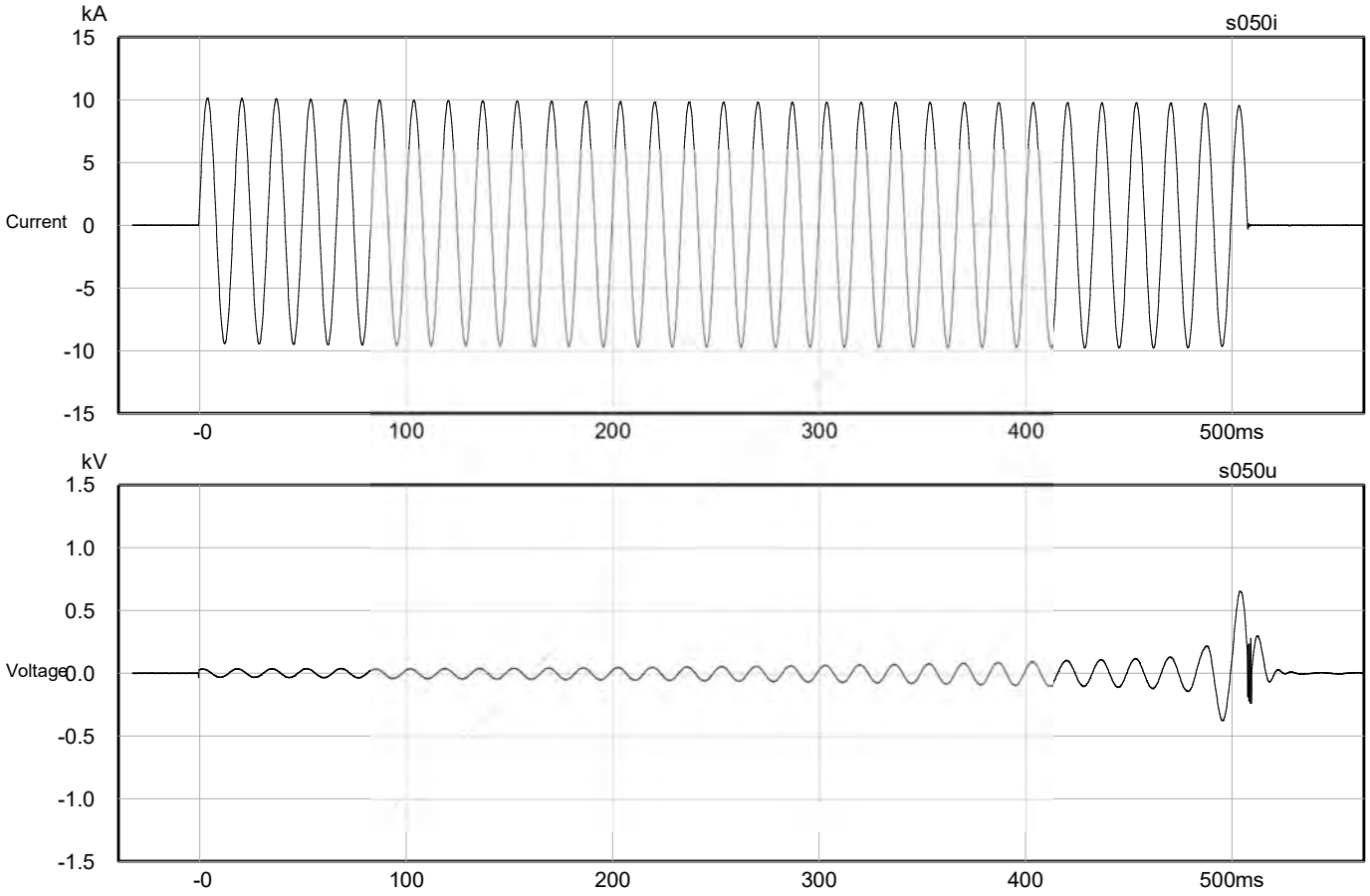


Figure 27: Waveforms for Test #20, Copperweld Scorpius 7 x 080 Sample 34.

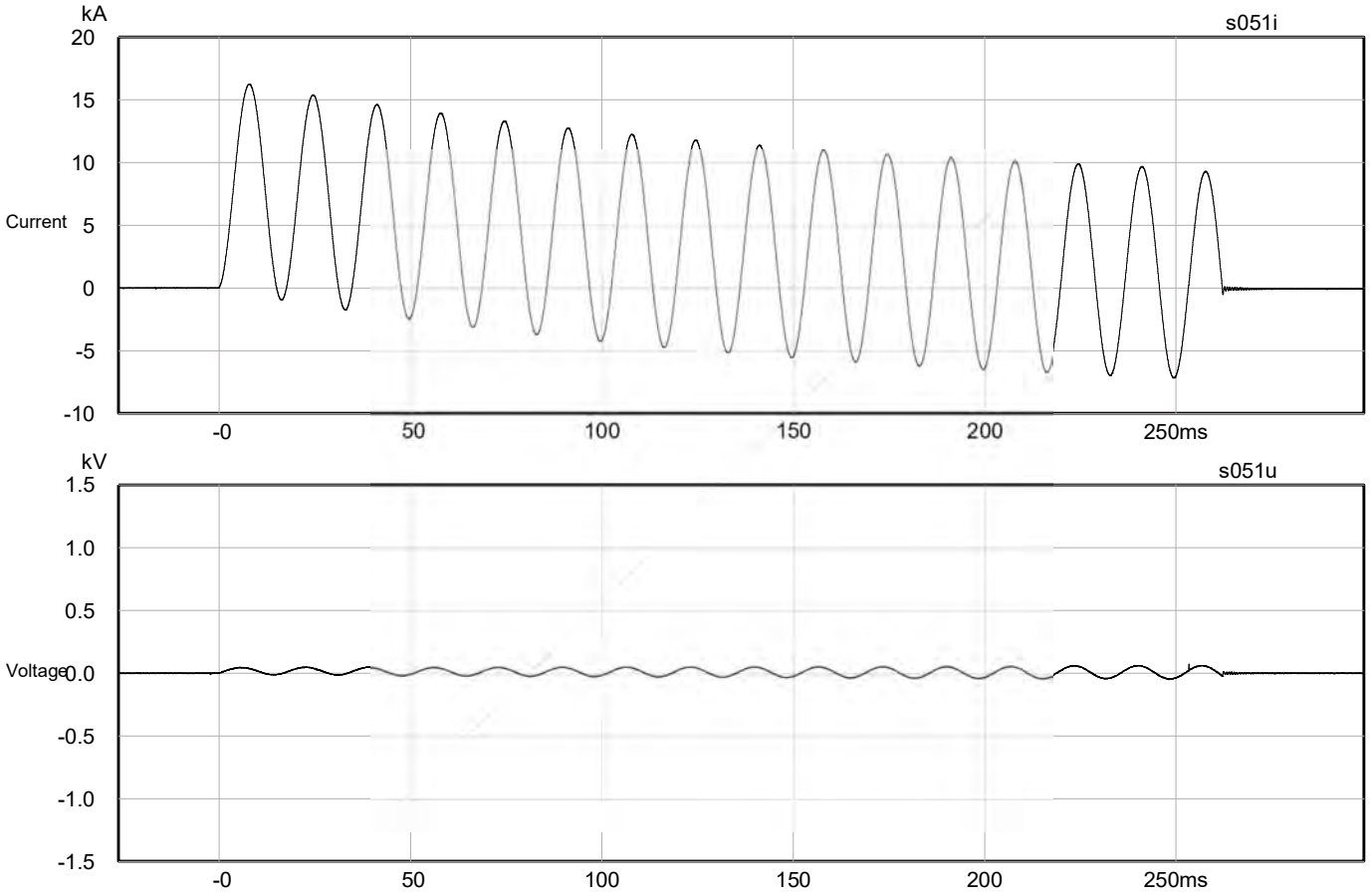


Figure 28: Waveforms for Test #21-1, Copperweld Scorpius 7 x 080 Sample 35.

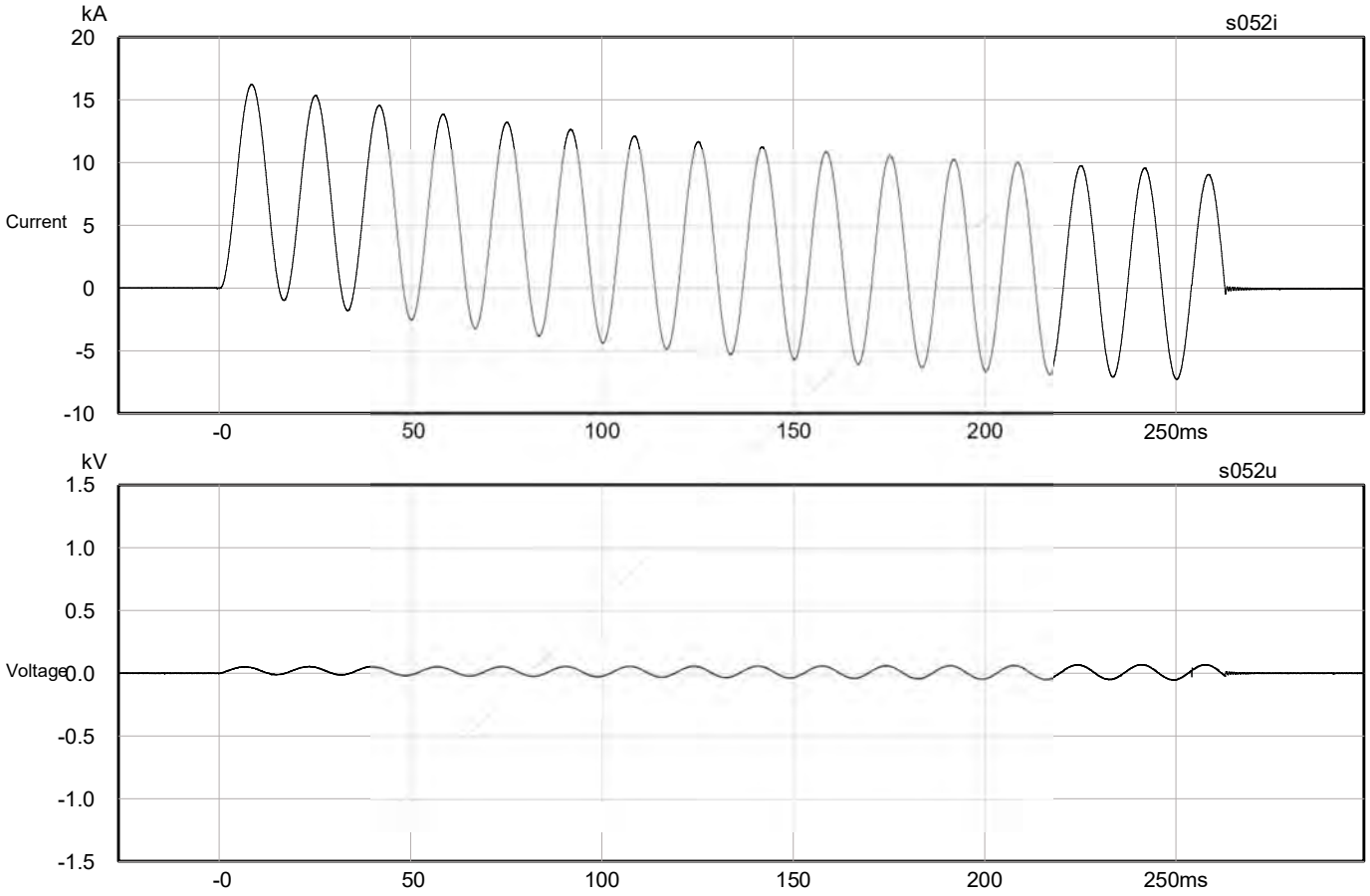


Figure 29: Waveforms for Test #21-2, Copperweld Scorpius 7 x 080 Sample 35.

APPENDIX C – PHOTOGRAPHS OF THE TEST OBJECTS



Figure 30: Test set up for the Encore 4/0 AWG Cu conductor. The power source bus is on the left and the ground bus is on the right.



Figure 31: Test set up for the Copperweld Scorpius 61 x 072 CCS conductor.



Figure 32: Test set up for the Encore #6 AWG Cu conductor.



Figure 33: Test set up for the Copperweld Scorpius 7 x 080 CCS conductor.

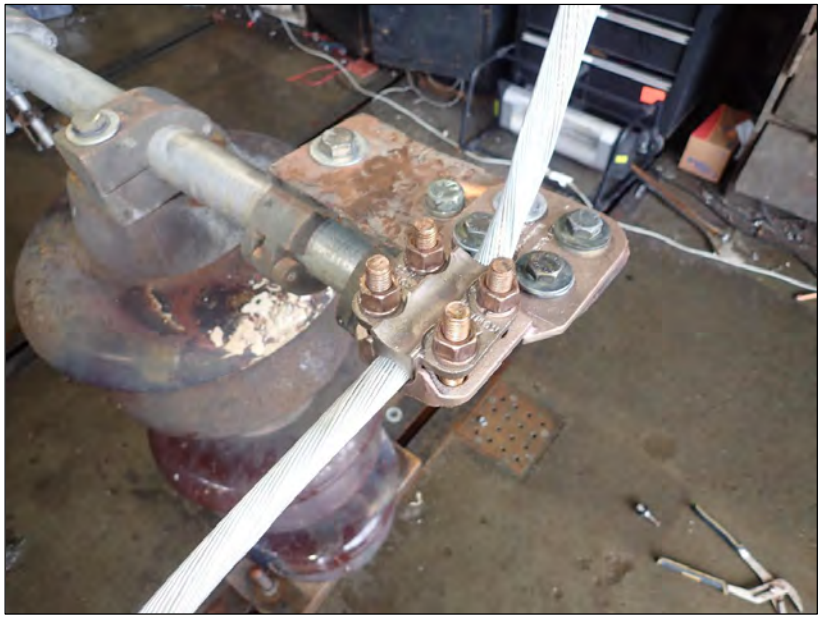


Figure 34: Typical Burndy terminal connector used to connect the Encore 4/0 AWG or Copperweld Scorpius 61 x 072 CCS conductors to the laboratory buses.



Figure 35: Typical Burndy terminal connector used to connect the Encore #6 AWG or Copperweld Scorpius 7 x 080 CCS conductors to the laboratory buses.

APPENDIX D – CALCUATIONS OF TEST CURRENT LEVELS FOR #6 AWG CU CONDUCTOR

Equation (45) in IEEE 80 and Equation (C.1) in IEEE 837 are the same, as follows:

$$I = A\sqrt{\left(\frac{TCAP\times10^{-4}}{t_c\times\alpha_r\times\rho_r}\right)\ln\left(\frac{K_0+T_m}{K_0+T_a}\right)}$$

where

I is root mean square (rms) current in kA
A is conductor cross section in mm^2
T_m is maximum allowable temperature in °C
T_a is initial conductor temperature in °C
T_r is reference temperature for material constants in °C
α_0 is thermal coefficient of resistivity at 0 °C
α_r is thermal coefficient of resistivity at reference temperature T_r
ρ_r is resistivity of the ground conductor at reference temperature T_r in μΩ-cm
K_0 is $1/\alpha_0$, or $(1/\alpha_r)-T_r$ in °C
t_c is time of current flow in seconds (s)
TCAP is thermal capacity factor in joules/cm^3°C

This equation is used to calculate the short-circuit ampacity of a conductor based on it's material constants.

For IEEE 80, Table 6, the symmetrical rms fusing current for #6 AWG soft-drawn Cu conductor at 500 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.5)(0.00393)(1.72)}\cdot\ln\left(\frac{(234+1083)}{(234+40)}\right)} = \boxed{5.29\ kA_{rms}}$$

For IEEE 837, Table 3, the symmetrical rms fusing current for #6 AWG hard-drawn Cu conductor at 250 ms duration is determined to be:

$$I_{sym} = (13.3)\sqrt{\frac{(3.4x10^{-4})}{(0.25)(0.00381)(1.78)}\cdot\ln\left(\frac{(242+1084)}{(242+40)}\right)} = 7.41\ kA_{rms}$$

From IEEE 837 Equation (C.4), the asymmetrical rms fusing current is:

$$I_{asym} = \frac{(7.41\ kA)}{(1.148)} = 6.45\ kA_{rms}$$

For the EMF described in IEEE 837, Clause 7.2, a value of 90% of the fusing current is used for conductors up to 4/0 AWG:

$$I_{EMF} = (6.45)(0.9) = \boxed{5.81\ kA_{rms}}$$

Copperweld Bimetallics Data Sheet Packet
Electrical Test Laboratory

Customer:	Copperweld Building Wire	Engineer:	Bill Lewey	Date:	8/25/2020
Sample ID:	EL-13	Tested By:	Bill Lewey, Mike Rozar	Date:	8/25/2020
Product:	Grade 40 Copper Clad Steel Wire Solid Bare #4 and #6 vs Equivalent Solid Copper: Grounding Electrode Conductor Equivalency Test	Sample Condition:	New		
Standard:	ASTM B910/910M Annealed Copper Clad Steel Wire				
Insulation: N/A - Bare		Jacket: N/A - Bare			

Table of Contents

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Test Setup & Description.....4

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Test Report Summary

Page	Test Performed	Date Completed	Pass/Fail
1	Grounding Electrode Conductor Test for Copper Clad Steel Grade 40	8/25/2020	**Pass**

Requirement:
#4 AWG Grade 40 Copper Clad Steel and #6 AWG Copper Clad Steel when compared to #4 solid copper and #6 solid copper for use as a grounding electrode conductor shall have equal ability to carry amperage during a ground fault condition.

Conclusion:
The ability of bare #4 AWG Copper Clad Steel Grade 40 and bare #6 AWG Copper Clad Steel Grade 40 performed equally to #4 AWG bare solid copper and #6 AWG bare solid copper when used as a grounding electrode conductor under a ground fault condition. The current measured proved equivalency.

Test Equipment Used

Item	Equipment Type	Equipment #	Cal. Due Date
1	Fluke 374FC Clamp Meter	AM-1	Nov 2020
2	Acme Electric 15KVA Transformer	T2535173S	N/A
3	Square D 60A / 600V Safety Interrupter	N/A	N/A
4	Eaton Service Panel	N/A	N/A
5	Eaton Type CH 20 Amp Breaker	N/A	N/A
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

VBU – Verify Before Use

N/A – Not Applicable

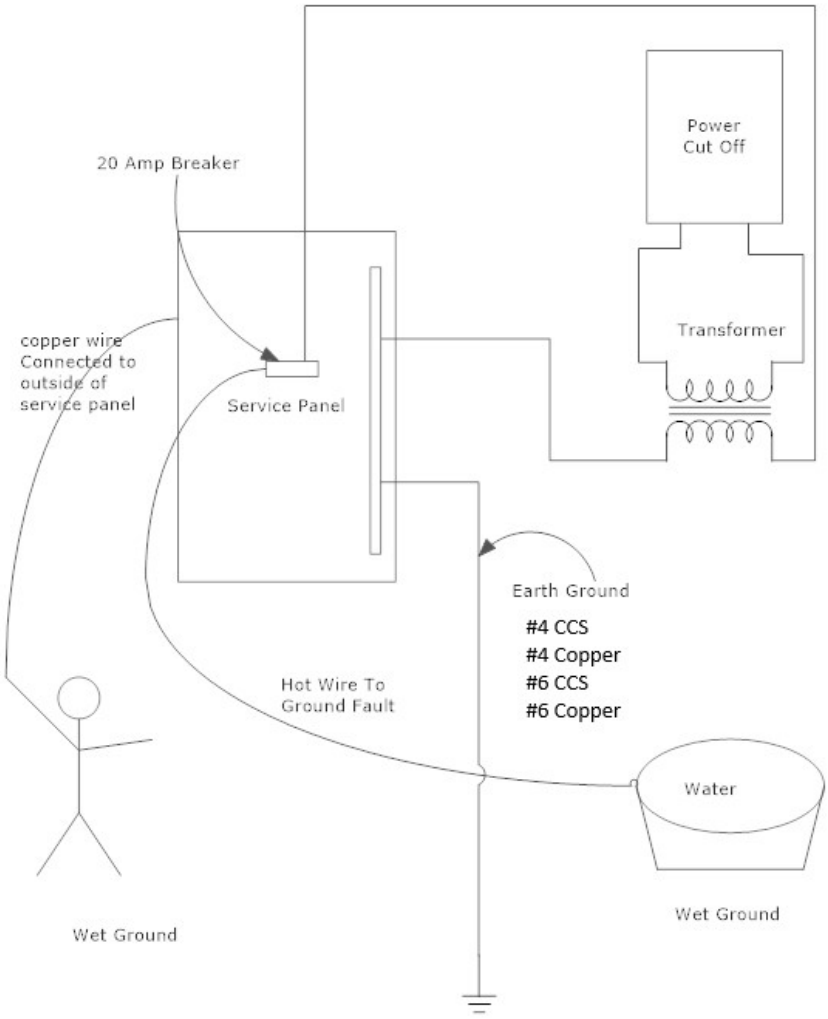
Sample Identification

Item	Description	Length/No. Rec'd
A	#4 AWG 40% Copper Clad Steel Bare	35 Ft
B	#4 AWG Solid Copper Bare	35 Ft
C	#6 AWG 40% Copper Clad Steel Bare	35 Ft
D	#6 AWG Solid Copper Bare	35 Ft
E		
F		

Grounding Electrode Conductor Test

Test Parameters:	
Conditioning:	No preconditioning.
Test Conductors:	1 each of #4 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #6 AWG/Grade 40 CCS Solid Bare grounding electrode conductor 1 each of #4 AWG Solid Bare copper grounding electrode conductor 1 each of #6 AWG Solid Bare copper grounding electrode conductor
Test Conductor Length:	Each conductor shall be 35 ft.
Test Circuit Configuration:	See schematic shown in Figure 1
Test Current:	Test current from 120 V / 20 A Residential Circuit
Method:	Testing was completed by creating a standard residential test circuit at 120V with 20A breaker wired to an intentional ground fault as shown in figure 1. The ground fault was created by connecting a hot wire from the breaker to a galvanized steel pan full of water and placing the pan on the wet ground. A conductor was also connected to the outside of the electrical panel and a Copper Plated Grounding Electrode (Copperweld Ground Rod) driven 6 inches into the wet ground to determine amount of current going through a grounded person touching the electrical panel during the ground fault condition. The ground fault and the grounded "man" were positioned 20 feet either side of the ground rod. The entire test area was soaked with water overnight using a sprinkler system When the ground fault was electrified, current measurements were taken from the ground fault conductor, the grounding electrode conductor and the grounded "man" conductor. For the four grounding electrode conductors tested, there was one test sequence for each. The current was measured for each. The objective: Compare the amperage measurements of the copper clad steel grounding electrode conductors to those of copper.

Figure 1



Results:			
Ground Conductor	**Fault Conductor Current**	**Current of the Grounding Electrode Conductor**	**Grounded Man Conductor Current**
#4 Copper	2.1 A	1.8 A	0.3 A
#4 40% CCS	2.1 A	1.8A	0.3 A
#6 Copper	1.7 A	1.6 A	0.1 A
#6 40% CCS	1.5 A	1.4 A	0.1 A

Requirement:
For equivalent sizes of Grade 40 Copper Clad steel vs. solid copper grounding conductors, the ability to carry amperage to ground during a ground fault condition is equal.

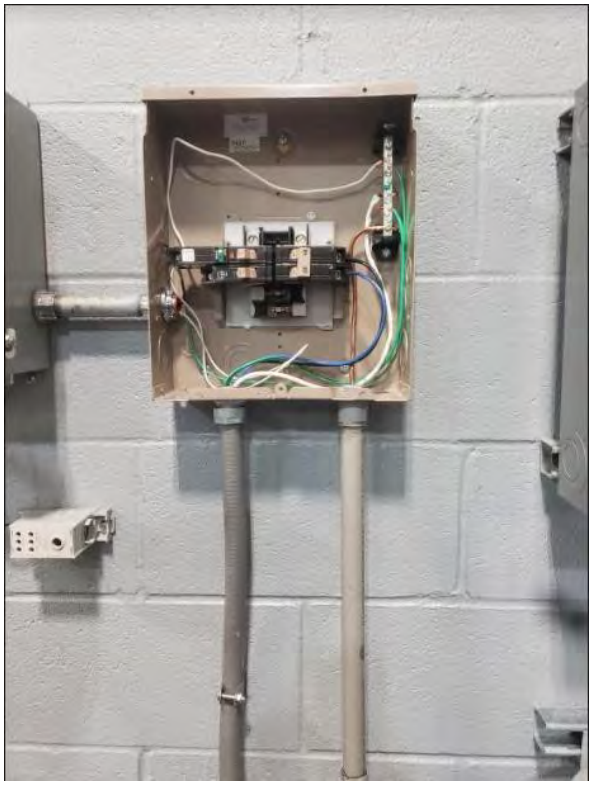
Comments:
____X__ (Pass) The product complies with all applicable requirements of this test. _____ (Fail) The product does not comply with the requirements of this test. **Test Date: 8/25/2020** **Tested By: Bill Lewey**

Environmental Conditions during Testing:

Humidity: % rh __74%_____ Ambient: °C___28_____

Test setup for the electrical service panel







Ground Rod with Grounding Conductor Attached



Ground Fault



Grounded “man”

Public Input No. 2482-NFPA 70-2020 [Section No. 250.190(C)(1)]

(1) General.

Equipment grounding conductors that are not an integral part of a cable assembly shall not be smaller than 6 AWG copper or ~~4 AWG~~ 4 AWG copper-clad aluminum or aluminum .

Statement of Problem and Substantiation for Public Input

Consult Section 110.5 Conductor Materials. Copper-clad aluminum is one of three conductor materials permitted for use in general wiring applications. Copper-Clad Aluminum as a conductor material should not be excluded for this application. Copper-clad Aluminum is currently permitted as a equipment grounding conductor by the NEC. This Public Input aims to correct an inconsistency in correlation between Articles.

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
Affiliation: American Bimetallic Association
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 23 13:29:39 EDT 2020
Committee: NEC-P05

Public Input No. 3765-NFPA 70-2020 [New Section after 250.194(B)]

TITLE OF NEW CONTENT

See Attached Word Document for Changes

Additional Proposed Changes

File Name	Description	Approved
Article_255_FINAL.docx	PI to Revise Article 250 and Add New Article 255	

Statement of Problem and Substantiation for Public Input

This Public Input is submitted on behalf of a Correlating Committee Long-Range Planning Task Group consisting of Robert Osborne (Chair), Paul Barnhart, Lou Grahor, David Temple, Donny Cook, Dean Hunter, Mike Querry, Roger McDaniel, Dave Burns, Rod Belisle, and Kevin Rogers. This Public Input, along with other companion Public Inputs, was developed with the goal of improving usability and providing a platform to increase the focus on requirements associated with Medium or High Voltage.

Installations, including campus-wide distribution systems, microgrids, alternative energy installations, etc., are covered by the Scope of the NEC®; however, requirements for conductors, equipment, and raceways used in applications operating in systems rated over 1000 volts are treated as an “after-thought” in how they are arranged in the document and covered by Technical Committees. In many cases, the “over 1000 volts” requirements exist in a dedicated “Part” within the Article – such is the case with existing Article 300. In other cases, similar products are handled in two separate Articles, such as with “switchgear”, with equipment rated 1000 volts and below addressed in Article 408, and equipment rated over 1000 volts addressed in Article 490. In addition to these two approaches, there are Articles where the “over 1000 volts” is intermingled with the “under 1000 volt” requirements, such as the case with Article 225. In many of these cases, the information for over 1000 volts is very limited (for example, Article 240 has only 3 Sections in the Part dedicated to requirements for over 1000 volts).

This Task Group’s initial task was to establish a demarcation for what can be referred to as Medium or High Voltage. The recommendation has been to establish this threshold as being equipment rated over 1000 Vac, 1500 Vdc. It is believed that levels below these voltages can be addressed with existing requirements for systems rated 1000 V ac max, and 1500 V dc, as this has been established as an upper limit for photovoltaic applications within Article 690, with requirements noting that those systems are not required to comply with Parts II and III of Article 490.

Using these limits, the Task Group then set out to identify a structure to better align requirements, improve consistency in approach, improve usability, and create the opportunity for Code Making Panels to have an increased focus on higher voltage applications.

The new proposed Article 255 would address the grounding and bonding requirements in systems over 1000 volts ac, and 1500 volts dc. The Code text that applied to over 1000 volt systems was extracted from Article 250.

Note: There are other Public Inputs being submitted that address restructuring, and these are identified as “Companion Public Inputs”. Other Article or Section references may be impacted due restructuring activities by those companion Public Inputs; however, changes to references outside of Article 255 are not shown in this Public Input.

Related Public Inputs for This Document

Related Input	Relationship
Public Input No. 3728-NFPA 70-2020 [Global Input]	Companion Public Input (Articles 245 and 495)
Public Input No. 3772-NFPA 70-2020 [New Section after 110.79]	Companion Public Input (Article 115)
Public Input No. 3815-NFPA 70-2020 [New Section after 200.11]	Companion Public Input (Article 205)
Public Input No. 3819-NFPA 70-2020 [Global Input]	Companion Public Input (Article 235)
Public Input No. 3827-NFPA 70-2020 [Global Input]	Companion Public Input (Article 305)
Public Input No. 3838-NFPA 70-2020 [Section No. 690.31(A)]	Companion Public Input (Section 690.31(A))
Public Input No. 3846-NFPA 70-2020 [Section No. 694.30(A)]	Companion Public Input (Section 694.30(A))
Public Input No. 3849-NFPA 70-2020 [New Part after IV.]	Companion Public Input (Section 706.30)
Public Input No. 3728-NFPA 70-2020 [Global Input]	
Public Input No. 3772-NFPA 70-2020 [New Section after 110.79]	
Public Input No. 3815-NFPA 70-2020 [New Section after 200.11]	
Public Input No. 3819-NFPA 70-2020 [Global Input]	
Public Input No. 3827-NFPA 70-2020 [Global Input]	
Public Input No. 3838-NFPA 70-2020 [Section No. 690.31(A)]	
Public Input No. 3846-NFPA 70-2020 [Section No. 694.30(A)]	
Public Input No. 3849-NFPA 70-2020 [New Part after IV.]	

Submitter Information Verification

Submitter Full Name: Robert Osborne
Organization: UL LLC
Street Address:
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State:
Zip:
Submittal Date: Wed Sep 09 12:06:14 EDT 2020
Committee: NEC-P05

Substantiation:

This Public Input is submitted on behalf of a Correlating Committee Long-Range Planning Task Group consisting of Robert Osborne (Chair), Paul Barnhart, Lou Grahor, David Temple, Donny Cook, Dean Hunter, Mike Querry, Roger McDaniel, Dave Burns, Rod Belisle, and Kevin Rogers. This Public Input, along with other companion Public Inputs, was developed with the goal of improving usability and providing a platform to increase the focus on requirements associated with Medium or High Voltage.

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This Task Group's initial task was to establish a demarcation for what can be referred to as Medium or High Voltage. The recommendation has been to establish this threshold as being equipment rated over 1000 Vac, 1500 Vdc. It is believed that levels below these voltages can be addressed with existing requirements for systems rated 1000 V ac max, and 1500 V dc, as this has been established as an upper limit for photovoltaic applications within Article 690, with requirements noting that those systems are not required to comply with Parts II and III of Article 490.

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ARTICLE 250 Grounding and Bonding

Part I. General

250.1 Scope.

This article covers general requirements for grounding and bonding of electrical installations, and the specific requirements in (1) through (6).

(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

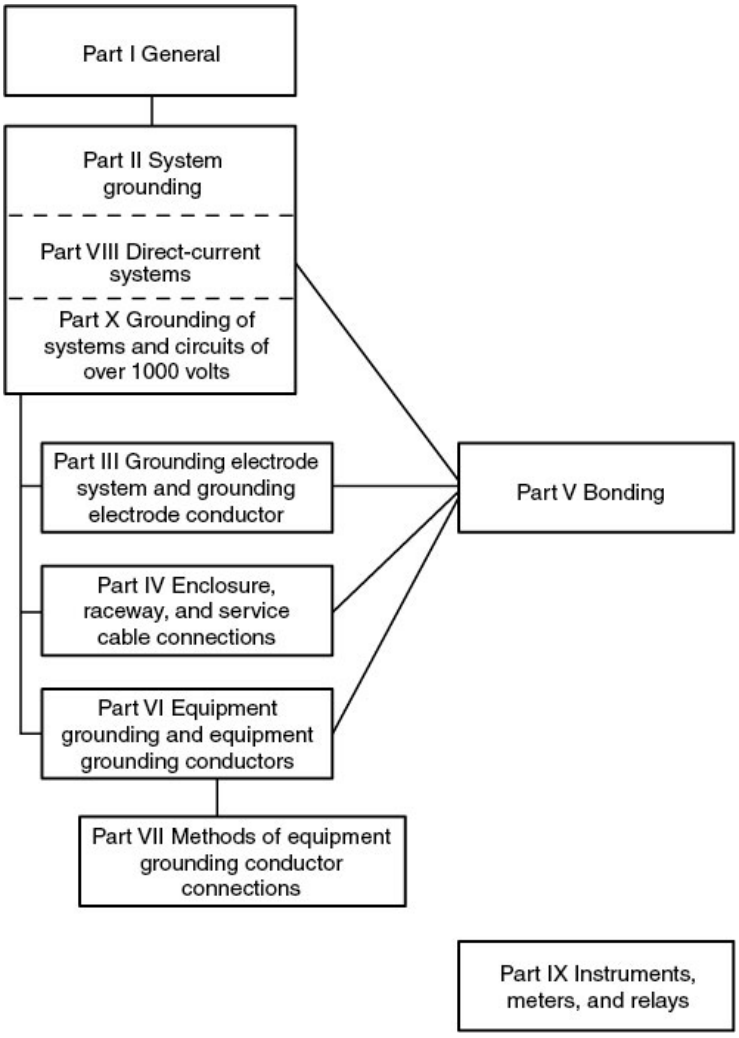
(6) Conditions under which guards, isolation, or insulation may be substituted for grounding

Informational Note No. 1 : See Figure 250.1 for information on the organization of Article 250 covering grounding and bonding requirements.

Informational Note No. 2: For requirements that supplement or modify this Article for Over 1000 Vac, 1500 Vdc installations, see article 255, Grounding of Systems and Circuits of Over 1000 Vac, 1500 Vdc, Nominal.

Figure 250.1 Grounding and Bonding.

(REMOVE “PART X” from Figure)



250.3 Application of Other Articles.

For other articles applying to particular cases of installation of conductors and equipment, grounding and bonding requirements are identified in Table 250.3 that are in addition to, or modifications of, those of this article.

Table 250.3 Additional Grounding and Bonding Requirements

Conductor/Equipment	Article	Section
Agricultural buildings		547.9 and 547.10
Audio signal processing, amplification, and reproduction equipment		640.7
Branch circuits		210.5, 210.6, 406.3

Table 250.3 Additional Grounding and Bonding Requirements

Conductor/Equipment	Article	Section
Cablebus		370.60
Cable trays	392	392.60
Capacitors		460.10, 460.27
Circuits and equipment operating at less than 50 volts	720	
Communications circuits	800	
Community antenna television and radio distribution systems		820.93, 820.100, 820.103, 800.106, 800.100
Conductors for general wiring	310	
Medium voltage conductors and cables	311	
Cranes and hoists	610	
Electrically driven or controlled irrigation machines		675.11(C), 675.12, 675.13, 675.14, 675.15
Electric signs and outline lighting	600	
Electrolytic cells	668	
Elevators, dumbwaiters, escalators, moving walks, wheelchair lifts, and stairway chairlifts	620	
Fixed electric heating equipment for pipelines and vessels		427.29, 427.48
Fixed outdoor electric deicing and snow-melting equipment		426.27
Flexible cords and cables		400.22, 400.23
Floating buildings		555.54, 555.55, 555.56
Grounding-type receptacles, adapters, cord connectors, and attachment plugs		406.10

Table 250.3 Additional Grounding and Bonding Requirements

Conductor/Equipment	Article	Section
Grounding of Systems and Circuits of Over 1000 Vac, 1500 Vdc, Nominal.	255	
Hazardous (classified) locations	500–517	
Health care facilities	517	
Induction and dielectric heating equipment	665	
Industrial machinery	670	
Information technology equipment		645.14, 645.15
Intrinsically safe systems		504.50
Luminaires and lighting equipment		410.40, 410.42, 410.46, 410.155(B)
Luminaires, lampholders, and lamps	410	
Marinas and boatyards		555.37, 555.38
Mobile homes and mobile home park	550	
Motion picture and television studios and similar locations		530.20, 530.64(B)
Motors, motor circuits, and controllers	430	
Natural and artificially made bodies of water	682	682.30, 682.31, 682.32, 682.33
Network powered broadband communications circuits		800.100, 800.106, 830.93
Optical fiber cables		770.100
Outlet, device, pull, and junction boxes; conduit bodies; and fittings		314.4, 314.25
Over 600 volts, nominal, underground wiring methods		300.50(C)

Table 250.3 Additional Grounding and Bonding Requirements

Conductor/Equipment	Article	Section
Panelboards		408.40
Pipe organs	650	
Radio and television equipment	810	
Receptacles and cord connectors		406.3
Recreational vehicles and recreational vehicle parks	551	
Services	230	
Solar photovoltaic systems		690.41, 690.42, 690.43, 690.45, 690.47
Swimming pools, fountains, and similar installations	680	
Switchboards and panelboards		408.18(C)
Switches		404.12
Theaters, audience areas of motion picture and television studios, and similar locations		520.81
Transformers and transformer vaults		450.10
Use and identification of grounded conductors	200	
X-ray equipment	660	517.78

Part X – Delete all of Part X (relocate to New Article 255)

Article 255 Grounding of Systems and Circuits of Over 1000 Vac, 1500 Vdc, Nominal.

(Note: Sections from Article 250 are relocated to New Article 255, Keeping similar Section numbers)

Part I. Scope and General

255.1 Scope. This article covers requirements for grounding and bonding of electrical installations over 1000 Vac, 1500 Vdc, nominal.

~~250.180~~ 255.180 General.

If systems over 1000 volts ac, 1500 volts dc are grounded, they shall comply with all applicable requirements of 250.1 through 250.178 and with ~~250.182~~ 255.182 through ~~250.194~~ 255.194, which supplement and modify ~~the preceding sections~~ Article 250.

~~250.182~~ 255.182Derived Neutral Systems.

A system neutral point derived from a grounding transformer shall be permitted to be used for grounding systems over 1 kV.

~~250.184~~ 255.184 Solidly Grounded Neutral Systems.

Solidly grounded neutral systems shall be permitted to be either single point grounded or multigrounded neutral.

~~250.184(A)~~ 255.184(A) Neutral Conductor.

~~250.184(A)(1)~~ 255.184(A)(1) Insulation Level.

The minimum insulation level for neutral conductors of solidly grounded systems shall be 600 volts.

Exception No. 1: For multigrounded neutral systems as permitted in ~~250.184(C)~~ 255.184(C), bare copper conductors shall be permitted to be used for the neutral conductor of the following:

(1) Service-entrance conductors

(2) Service laterals or underground service conductors

(3) Direct-buried portions of feeders

Exception No. 2: Bare conductors shall be permitted for the neutral conductor of overhead portions installed outdoors.

Exception No. 3: The grounded neutral conductor shall be permitted to be a bare conductor if isolated from phase conductors and protected from physical damage.

Informational Note: See 225.4 for conductor covering where within 3.0 m (10 ft) of any building or other structure.

~~250.184(A)(2)~~ 255.184(A)(2) Ampacity.

The neutral conductor shall be of sufficient ampacity for the load imposed on the conductor but not less than 33 1⁄3 percent of the ampacity of the phase conductors.

Exception: In industrial and commercial premises under engineering supervision, it shall be permissible to size the ampacity of the neutral conductor to not less than 20 percent of the ampacity of the phase conductor.

~~250.184(B)~~ 255.184(B) Single-Point Grounded Neutral System.

Where a single-point grounded neutral system is used, the following shall apply:

(1) A single-point grounded neutral system shall be permitted to be supplied from (a) or (b):

a. A separately derived system

b. A multigrounded neutral system with an equipment grounding conductor connected to the multigrounded neutral conductor at the source of the single-point grounded neutral system

(2) A grounding electrode shall be provided for the system.

(3) A grounding electrode conductor shall connect the grounding electrode to the system neutral conductor.

(4) A bonding jumper shall connect the equipment grounding conductor to the grounding electrode conductor.

(5) An equipment grounding conductor shall be provided to each building, structure, and equipment enclosure.

(6) A neutral conductor shall only be required where phase-to-neutral loads are supplied.

(7) The neutral conductor, where provided, shall be insulated and isolated from earth except at one location.

(8) An equipment grounding conductor shall be run with the phase conductors and shall comply with (a), (b), and (c):

a. Shall not carry continuous load

b. May be bare or insulated

c. Shall have sufficient ampacity for fault current duty

~~250.184(C)~~ 255.184(C)Multigrounded Neutral Systems.

Where a multigrounded neutral system is used, the following shall apply:

(1) The neutral conductor of a solidly grounded neutral system shall be permitted to be grounded at more than one point. Grounding shall be permitted at one or more of the following locations:

a. Transformers supplying conductors to a building or other structure

b. Underground circuits where the neutral conductor is exposed

c. Overhead circuits installed outdoors

(2) The multigrounded neutral conductor shall be grounded at each transformer and at other additional locations by connection to a grounding electrode.

(3) At least one grounding electrode shall be installed and connected to the multigrounded neutral conductor every 400 m (1300 ft).

(4) The maximum distance between any two adjacent electrodes shall not be more than 400 m (1300 ft).

(5) In a multigrounded shielded cable system, the shielding shall be grounded at each cable joint that is exposed to personnel contact.

Exception: In a multipoint grounded system, a grounding electrode shall not be required to bond the neutral conductor in an uninterrupted conductor exceeding 400 m (1300 ft) if the only purpose for removing the cable jacket is for bonding the neutral conductor to a grounding electrode.

~~250.186~~ 255.186 Grounding Service-Supplied Alternating-Current Systems.

~~250.186(A)~~ 255.186(A) Systems with a Grounded Conductor at the Service Point.

Where an ac system is grounded at any point and is provided with a grounded conductor at the service point, a grounded conductor(s) shall be installed and 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's enclosure. The grounded conductor(s) shall be installed in accordance with ~~250.186(A)(1)~~ 255.186(A)(1) through (A)(4). The size of the solidly grounded circuit conductor(s) shall be the larger of that determined by ~~250.184~~ 255.184 or ~~250.186(A)(1)~~ 255.186(A)(1) or (A)(2).

Exception: Where 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.

~~250.186(A)(1)~~ 255.186(A)(1) Sizing for a Single Raceway or Overhead Conductor.

The grounded conductor shall not be smaller than the required grounding electrode conductor specified in Table 250.102(C)(1) but shall not be required to be larger than the largest ungrounded service-entrance conductor(s).

~~250.186(A)(2)~~ 255.186(A)(2) Parallel Conductors in Two or More Raceways or Overhead Conductors.

If the ungrounded service-entrance conductors are installed in parallel in two or more raceways or as overhead parallel conductors, the grounded conductors shall also be installed in parallel. The size of the grounded conductor in each raceway or overhead shall be based on the total circular mil area of the parallel ungrounded conductors in the raceway or overhead, as indicated in ~~250.186(A)(1)~~ 255.186(A)(1), but not smaller than 1/0 AWG.

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

~~250.186(A)(3)~~ 255.186(A)(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.

~~250.186(A)(4)~~ 255.186(A)(4) Impedance Grounded Neutral Systems.

Impedance grounded neutral systems shall be installed in accordance with ~~250.187~~ 255.187.

250.186(B) Systems Without a Grounded Conductor at the Service Point.

Where an ac system is grounded at any point and is not provided with a grounded conductor at the service point, a supply-side bonding jumper shall be installed and routed with the ungrounded conductors to each service disconnecting means and shall be connected to each disconnecting means equipment grounding conductor terminal or bus. The supply-side bonding jumper shall be installed in accordance with ~~250.186(B)(1)~~ 255.186(B)(1) through (B)(3).

Exception: Where 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 supply-side bonding jumper to the assembly common equipment grounding terminal or bus.

~~250.186(B)(1)~~ 255.186(B)(1) Sizing for a Single Raceway or Overhead Conductor.

The supply-side bonding jumper shall not be smaller than the required grounding electrode conductor specified in Table 250.102(C)(1) but shall not be required to be larger than the largest ungrounded service-entrance conductor(s).

~~250.186(B)(2)~~ 255.186(B)(2) Parallel Conductors in Two or More Raceways or Overhead Conductors.

If the ungrounded service-entrance conductors are installed in parallel in two or more raceways or overhead conductors, the supply-side bonding jumper shall also be installed in parallel. The size of the supply-side bonding jumper in each raceway or overhead shall be based on the total circular mil area of the parallel ungrounded conductors in the raceway or overhead, as indicated in ~~250.186(A)(1)~~ 255.186(A)(1), but not smaller than 1/0 AWG.

~~250.186(B)(3)~~ 255.186(B)(3) Impedance Grounded Neutral Systems.

Impedance grounded neutral systems shall be installed in accordance with ~~250.187~~ 255.187.

~~250.187~~ 255.187 Impedance Grounded Systems.

Impedance grounded systems in which a grounding impedance, usually a resistor, limits the ground-fault current shall be permitted where all of 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 ~~250.187(A)~~ 255.187(A) through (D).

~~250.187(A)~~ 255.187(A) Location.

The grounding impedance shall be inserted in the grounding electrode conductor between the grounding electrode of the supply system and the neutral point of the supply transformer or generator.

~~250.187(B)~~ 255.187(B) Insulated.

The grounded conductor shall be insulated for the maximum neutral voltage.

Informational Note: The maximum neutral voltage in a 3-phase wye system is 57.7 percent of the phase-to-phase voltage.

~~250.187(C)~~ 255.187(C) Grounded System Conductor Connection.

The system grounded conductor shall not be connected to ground, except through the grounding impedance.

~~250.187(D)~~ 255.187(D) Equipment Grounding Conductors.

Equipment grounding conductors shall be permitted to be bare and shall be electrically connected to the ground bus and grounding electrode conductor.

~~250.188~~ 255.188 Grounding of Systems Supplying Portable or Mobile Equipment.

Systems supplying portable or mobile equipment over 1000 volts, other than substations installed on a temporary basis, shall comply with ~~250.188(A)~~ 255.188(A) through (F).

~~250.188(A)~~ 255.188(A) Portable or Mobile Equipment.

Portable or mobile equipment over 1000 volts shall be supplied from a system having its neutral conductor grounded through an impedance. Where a delta-connected system over 1000 volts is used to supply portable or mobile equipment, a system neutral point and associated neutral conductor shall be derived.

~~250.188(B)~~ 255.188(B) Exposed Non–Current-Carrying Metal Parts.

Exposed non–current-carrying metal parts of portable or mobile equipment shall be connected by an equipment grounding conductor to the point at which the system neutral impedance is grounded.

~~250.188(C)~~ 255.188(C) Ground-Fault Current.

The voltage developed between the portable or mobile equipment frame and ground by the flow of maximum ground-fault current shall not exceed 100 volts.

~~250.188(D)~~ 255.188(D) Ground-Fault Detection and Relaying.

Ground-fault detection and relaying shall be provided to automatically de-energize any component of a system over 1000 volts that has developed a ground fault. The continuity of the equipment grounding conductor shall be continuously monitored so as to automatically de-energize the circuit of the system over 1000 volts to the portable or mobile equipment upon loss of continuity of the equipment grounding conductor.

~~250.188(E)~~ 255.188(E)Isolation.

The grounding electrode to which the portable or mobile equipment system neutral impedance is connected shall be isolated from and separated in the ground by at least 6.0 m (20 ft) from any other system or equipment grounding electrode, and there shall be no direct connection between the grounding electrodes, such as buried pipe and fence, and so forth.

~~250.188(F)~~ 255.188(F) Trailing Cable and Couplers.

Trailing cable and couplers of systems over 1000 volts for interconnection of portable or mobile equipment shall meet the requirements of Part III of Article 400 for cables and 490.55 for couplers.

~~250.190~~ 255.190 Grounding of Equipment.

~~250.190(A)~~ 255.190(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: Where 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.

~~250.190(B)~~ 255.190(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 or 4 AWG aluminum.

~~250.190(C)~~ 255.190(C) Equipment Grounding Conductor.

Equipment grounding conductors shall comply with ~~250.190(C)(1)~~ 255.190(C)(1) through (C)(3).

~~250.190(C)(1)~~ 255.190(C)(1) General.

Equipment grounding conductors that are not an integral part of a cable assembly shall not be smaller than 6 AWG copper or 4 AWG aluminum.

~~250.190(C)(2)~~ 255.190(C)(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.

~~250.190(C)(3)~~ 255.190(C)(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.

250.191 Grounding System at Alternating-Current Substations.

For ac substations, the grounding system shall be in accordance with Part III of Article 250.

Informational Note: For further information on outdoor ac substation grounding, see IEEE 80-2013, IEEE Guide for Safety in AC Substation Grounding.

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.

~~250.194(A)~~ 250.194(A) Metal Fences.

Where 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) Where 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.

~~250.194(B)~~ 255.194(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.

Public Input No. 2675-NFPA 70-2020 [New Part after VI.]

TITLE OF NEW CONTENT

Informational Note: See IEEE 3003.2 Recommended Practice for Equipment Grounding and Bonding in Industrial and Commercial Power Systems

Statement of Problem and Substantiation for Public Input

Link to the standard that replaces the IEEE Green Book, referenced elsewhere in NFPA electrical safety literature:

https://standards.ieee.org/standard/3003_2-2014.html

It expires at the end of 2024 and will likely be re-affirmed for use in future NEC revision cycles. From the 3003.2 prospectus:

The grounding and bonding of equipment in industrial and commercial power systems is covered in this recommended practice. The interconnection and grounding of the non-electrical metallic elements of a system is covered first. This is followed by a discussion of the objectives of equipment grounding and bonding, including minimizing electric shock hazard to personnel, providing adequate current carrying capability for ground faults, and ensuring the timely operation of overcurrent protection.

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Committee:	NEC-P05

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

TITLE OF NEW CONTENT

Likely to become energized. Normally non-current carrying conductive materials enclosing insulated conductor(s), where the conductor(s) are operating at above ground potential in normal operation, and a failure of insulation, connector or termination may energize the conductive material.

Statement of Problem and Substantiation for Public Input

The term "likely to become energized" is used in at least 26 places in the NEC, yet there is no definition or guidance as to when this should be applied. Numerous safety requirements rely on this condition in order to be implemented. There are widely varying interpretations as to the meaning of the terms; a search of electrical "chat" forums will quickly verify how much discrepancy there is. Something so basic and important should not be left to interpretation and inconsistent application of the requirements. The NEC Style Manual contains a definition, but that is inadequate or incomplete and offers no guidance: likely to become energized -- failure of insulation on

A term that is used so widely and that other requirements depend on needs to be better defined. It is well past time for the NEC to offer guidance on this.

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Public Input No. 4460-NFPA 70-2020 [New Definition after Definition: Lighting Track (Track Ligh...]

Likely to Become Energized

Conductive material that could become energized due to electric insulation failure. (CMP 5)

Statement of Problem and Substantiation for Public Input

Add a definition for Likely to Become Energized to Article 100. That phrase is used 25 times in the NEC, only 7 of which are in Article 250. It is described in Annex B of the NEC Style Manual as "likely to become energized -- failure of insulation on", unfortunately most NEC users do not read the NEC style manual. No offense intended to the NEC Style Manual Authors, but it is not nearly as exciting to read as the NEC. Many other terms in Annex B are defined in Article 100. There is a very important distinction between what can become energized compared to what is likely to become energized. I get many questions about what that phrase means in the NEC such as if it is metal then is it likely to become energized. Yes, if it is in contact with or contains energized conductors. The responsibility for this definition should be given to CMP 5.

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