Dear Ms. Bellis,

Please accept this written submission for the NFPA Standards Council consideration in accordance with 1.6 of the Regulations Governing the Development of NFPA Standards. This statement is in response to the two appeals filed by the American Bimetallic Association (ABA).

The National Electrical Manufacturers Association (NEMA) represents nearly 325 electrical equipment and medical imaging manufacturers that make safe, reliable, and efficient products and systems. In its appeal, the ABA argues that having the same individuals involved in multiple organizations leads to those individuals controlling multiple votes on the panel. In its argument, the ABA implicates NEMA as one of these organizations and specifically mentions the NEMA Codes & Standards Committee.

NEMA would like to correct the record. All NEMA representatives to outside organizations, including NFPA and the NFPA 70 Code Making Panels have directed votes on all official ballots. These votes are directed by the NEMA Codes & Standards Committee, which currently has 17 voting members. The ABA appeals mention a total of 5 voting members of the NEMA Codes & Standards Committee. Even if each of these members voted in a bloc at NEMA, they would not have sufficient votes to reach the majority required to reach a decision. Moreover, the NEMA Standardization Policies and Procedures specify that members are appointed based upon the following criteria “balanced representation of the broadly diversified interests and products within NEMA, technical expertise, and commitment to active participation”. They are “appointed to represent the technical best interests of NEMA as a whole and not of particular Product Groups or members”.

NEMA appreciates the opportunity to participate in the NFPA process and ensures that its representatives carefully follow all NFPA policies and procedures during their participation in NFPA.

Regards,

Peter Tolsdorf
Chief Legal, Membership, and People Officer
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NEMA appreciates the opportunity to participate in the NFPA process and ensures that its representatives carefully follow all NFPA policies and procedures during their participation in NFPA.

Regards,

Peter Tolsdorf
Chief Legal, Membership, and People Officer
August 2, 2022

To: The NFPA Standards Council
Regarding: Appeal Number 22-8-5-j Concerning NFPA 70, Section 250.62

This appeal should be rejected as the issue was given full and complete consideration by the Code Making Panel, and was appropriately rejected for reasons explained in the CMP 5 statement.

Sincerely,

John Hipchen
Director, Energy and Electrical Systems
7918 Jones Branch Drive, Suite 300
McLean, VA  22102
Phone: 212-251-7208
Email: John.Hipchen@CopperAlliance.us
Dear Ms. Bellis,

Please accept this written submission for the NFPA Standards Council consideration in accordance with 1.6 of the Regulations Governing the Development of NFPA Standards. This statement is in response to the appeal filed by the Joe Andre.

The National Electrical Manufacturers Association (NEMA) represents nearly 325 electrical equipment and medical imaging manufacturers that make safe, reliable, and efficient products and systems. NEMA members include those that produce nonmetallic cable. NEMA supports Mr. Andre's appeal to overturn the decision made by Code Making Panel (CMP 6) regarding CAM 70-63. At the NFPA Technical Meeting on June 9, 2022, the NFPA membership overwhelmingly voted to support CAM 70-63 by a vote of 299-92.

Subsequently, during the first CMP 6 ballot, CAM 70-63 received the 2/3 vote necessary to pass and include those changes in the 2023 National Electrical Code ®. During the recirculation ballot, several CMP 6 members changed their votes. Although the CAM did not ultimately receive the required 2/3 majority vote, it did still receive support from a majority of CMP 6 members. In the end, a large majority of NFPA membership indicated their support for the CAM at the Technical Meeting, including experts on CMP 6, expressing their desire to include the changes included in CAM 70-63 into the 2023 code. NEMA supports Mr. Andre's appeal and requests that the NFPA Standards Council overturn the actions of CMP 6.

NEMA appreciates the opportunity to participate in the NFPA process and ensures that its representatives carefully follow all NFPA policies and procedures during their participation in NFPA.

Regards,

Peter Tolsdorf
Chief Legal, Membership, and People Officer
August 2, 2022

Dawn Michele Bellis
Secretary
NFPA Standards Council
1 Batterymarch Park
Quincy, MA 02169

RE: Response to appeal for CAM 70-63

Dear Ms. Bellis,

This is in response to the appeal filed regarding the failure of CAM 70-63. I will be at the Standards Council meeting on August 10, and I am requesting time to speak regarding this appeal.

The submitter of the CAM and this appeal asserts that the NFPA process failed to provide the public review and input that is a basic tenet of the ANSI process. That is untrue, and the number of public inputs and public comments related to this issue show that the information was fully available to the public. The code-making panel discussed it at length in task groups and committee meetings at each stage of the 2023 NEC code development process. No technical or safety reason could be found to limit the use of NM cable in the construction types discussed. The committee members specifically discussed the increased height permitted in Type IV-A, B and C construction types, along with the construction requirements, fire protection requirements, and wiring method installation requirements. Each of the task group meetings and committee meetings were open to the public.

The appellant asserts that the NFPA regulations were violated, and he repeatedly switches between the 2020 NEC code development process and the 2023 NEC code development process in his appeal. The first 9 statements in the appellant's numbered list refer explicitly or implicitly to the 2020 NEC process - not the 2023 NEC process. None of these statements are relevant to the current code development process.

The appellant finally gets to the 2023 NEC process in list item 10. He states that the code-making panel took the position that there was no substantiation to change the code in the first draft. The panel's actual First Draft statement in response to multiple PIs requesting restrictions for NM cable in Type IV buildings was:

The proposed addition of adding the suffix “HT” to the selected cable types is without merit. There was no technical justification submitted to support the addition without consideration of the other types A, B, C for the measures of protection associated with the HT/Mass Timber construction. Additional technical information would be helpful.

In the Second Draft, the code-making panel provided additional information in response to public comments regarding this issue:

CMP6 is aware of the impact to the building height that increased from the existing floor limits by changes made within NFPA 5000 and the International Building Code (IBC). Building height
has no effect on the correct installation of the wiring method nor its safe performance. The requirements of the latest procedurally approved 2021 NFPA 5000 and IBC provided by the changes affect construction and the types of materials used by design for application within these building types. These changes in combination with cable insulation ratings and protective devices required per code in designated occupancies maintain the minimum safe installation requirements of the NEC for the type NM and NMC wiring method to continue per increased floor height. No technical substantiation was provided to change the current physical wiring method or that would show NFPA 70, NFPA 5000 and the IBC were in conflict with the ANSI procedure for code development.

Additionally, code-making panel 6 has been aware of the changes to Type IV construction for over three years. On May 17, 2019, TIA 1458 requesting a change to the 2020 NEC was sent to code-making panel 6 for balloting. NFPA also made the TIA publicly available and requested input from the public in June 2019. That TIA failed ballot on all technical and emergency nature issues. The code-making panel has consistently asked for technical information, fire hazard information, or any credible information that would point to a safety issue – and none has been submitted.

The 3-story limitation for Type NM cable was added to the NEC in 1974 (published in 1975), and the change to building Types was made in the 2002 NEC based on Standards Council Decision D#01-12 (July 13, 2001). I find it particularly illuminating that, along with finding the assertions related to toxicity and physical damage to be unsupported, the Standards Council also stated on page 7 of their decision that:

There has been no evidence, for example, that NM cable presents either a significant ignition source or a flame propagation or smoke generation problem. As proponents have pointed out, the existing fire data have shown no fire problem from the use of NM cable, even in those jurisdictions where it is already permitted above three floors. There is no evidence that NM cable presents any added fire propagation concerns in buildings with combustible type construction. Indeed, it is difficult to argue that the presence of NM cable materially adds to the combustible loading or to the problems of flame propagation and smoke generation already present in such buildings.

Twenty years later, we still have no data showing evidence that NM cable presents any fire problem greater than any other wiring method. As the Standards Council referenced, jurisdictions including Michigan and Massachusetts have amended the NEC to allow NM cable to be used in high rise buildings since the 1970s, and other jurisdictions have allowed NM in high rise buildings by special permission. The appellant’s assertion in list item 10 that NM cable is the “least robust wiring method in the National Electrical Code” may well be his honest opinion, but it is unsupported by evidence. It is far more likely that our existing restrictions for NM cable use are overly restrictive, given the sheer volume of cable installed over the decades and the lack of evidence that it presents any greater fire hazard than any other wiring method.

There were many statements made during the June 9, 2022 Technical Session that I believe are misleading without additional context and discussion. Some were simply factually incorrect based on NFPA records. For example, an incorrect statement was made that in the 2020 NEC process a CAM was submitted to allow the use of NM cable in “high rise building [sic]” (Transcript, pages 227-228). The referenced 2020 CAM proposed to permit Type NM cable in Type I and Type II buildings, with no reference to height. The subject of the appeal today for the
2023 NEC deals with Type IV construction, not Type I or II. Additionally, on page 232 of the transcript, the submitter of CAM 70-63 implied that CMP-6 was keeping information “secret.” That is untrue, as every one of the task group meetings and committee meetings were open to the public in accordance with NFPA procedures.

The results of the Technical Session vote and subsequent CMP vote (that did not support the appellant’s position) both lacked the benefit of the full and open technical discussion that was held during the First and Second Draft meetings. The code-making panel rejected the requests to limit NM cable due to a lack of adequate evidence that would justify the changes they requested.

I am requesting the Standards Council reject this appeal and support the work of the code-making panel.

Sincerely,
Christel Hunter
Vice-President of Standards
Cerro Wire LLC

chunter@cerrowire.com
702-271-7400
TO: NATIONAL FIRE PROTECTION ASSOCIATION STANDARDS COUNCIL

FROM: MIKE WEAVER CMP 17 Chair

DATE: August 1, 2022

SUBJECT: APPEAL BALLOT RESULTS OF TIA No. 1661 (Hartwell)

CMP 17 First voted on TIA No. 1661 on June 22, 2022. The vote was (1) Abstention, (4) agree and (10) disagree with the TIA. After the public comment stage, the panel reaffirmed its vote on July 15, 2022, with (1) Abstention, (4) agree with and (10) disagree with the TIA. CMP 17 does not agree with the language in TIA No. 1661 and therefore does not support this appeal.

The Committee has discussed at great length the options for bonding the pool perimeter surfaces. For the 2023 Code cycle this proposed change, or some form thereof appeared at the first draft in the following PI's 4066, 4011, 4074, 4163, 4315, 4426 and 3288 with 4066 mirroring the TIA language. All the PI's were rejected by the committee. At the second draft stage this change came to the committee as PC 2058. The Committee did a reject but see. The Committee did not accept the language change but needed to address a spelling error to the word “Finished” in the text.

The Committee came to the conclusion that a ground ring is still an acceptable method for perimeter surfaces of in ground pools. A #8 copper conductor properly installed meets the criteria as defined in Article 90.1 (A) and (B) for practical safeguarding and adequacy. The NEC should always allow for alternate methods when possible. If in fact a copper grid is a better installation, nothing prevents an installer from installing it if they wish to. The technical committee was unanimous in the votes regarding this at the Second Draft meeting and the committee ballot.

Respectfully,

Mike Weaver

CMP 17 Chair
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Approved September 1983
Rev. March 16, 2017
Rev. January 2, 2020
Rev. July 9, 2020
Rev. July 7, 2022

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FOREWORD

The rules, policies, and procedures contained herein govern the development of technical publications by the National Electrical Manufacturers Association (NEMA), and the participation by NEMA in the formulation of standards and other technical publications by other organizations, or in the development of joint technical publications.

They do not cover promotional activities related to standards, such as NEMA efforts advocating the adoption and use of the National Electrical Code® and other nationally recognized standards.

NEMA represents electrical equipment and medical imaging manufacturers. It is NEMA’s belief that technical publications play a vital part in the design, production, and distribution of products destined for both national and international commerce. Sound technical publications benefit the user, as well as the manufacturer, by improving safety, bringing about economies in product, eliminating misunderstandings between manufacturer and purchaser, and assisting the purchaser in selecting and obtaining the proper product for their particular need.

NEMA devotes much of its time, effort, and resources to voluntary standardization activities. NEMA standards are offered and recommended to become American National Standards under the procedures of the American National Standards Institute (ANSI). This decision rests with the Product Groups, Councils, or Committees concerned. It is the intent of the Association to continue its support of these activities as the best method to continue providing sound and safe electrical and medical imaging products for the use of all.
In addition, a standard may be reaffirmed by either of the following:

a. In the case of a letter ballot, by an affirmative vote of at least two-thirds of all members of the Product Group, Council, or Committee eligible to vote thereon.

b. At a properly called meeting of the appropriate Product Group, Council, or Committee by the affirmative vote of at least two-thirds of the members of the Product Group, Council, or Committee eligible to vote. Additionally, it is required that all (100 percent) of the members eligible to vote on the subject be present at the meeting.

In either case, reaffirmations are effective upon approval by C&S.

12.1.2 Withdrawal or Extension

If a Product Group, Council, or Committee, following notification by C&S, fails to reaffirm, revise, or withdraw the subject NEMA Standard, Suggested Standard for Future Design, Authorized Engineering Information, or Adoptive Standard within the five-year period, C&S shall take action to withdraw the NEMA Standard, Authorized Engineering Information, Suggested Standard for Future Design, or Adoptive Standard. C&S may, however, for good cause shown, grant annual extensions. No extension of time beyond 10 years from the date of approval shall be granted for action on a standard.

12.1.3 Stabilized Maintenance

The term “Stabilized Maintenance” means a process by which NEMA standards can be placed under a ten-year review cycle under certain conditions.

A Product Group, Council, or Committee may recommend that a standard be maintained under Stabilized Maintenance if it satisfies the following criteria:

a) The standard addresses mature technology or practices, and as a result, is not likely to require revision;
b) The standard is other than safety or health related;
c) The standard has been reaffirmed at least once;
d) At least ten years have passed since approval or revision of the standard;
e) The standard is required for use in connection with existing implementations or for reference purposes.

Approval of Stabilized Maintenance shall follow the same procedures as approval of a new or revised standard. A standard maintained under Stabilized Maintenance is not required to be revised or reaffirmed on a routine cycle. It shall be subject to review of such status on a ten-year cycle. If the Product Group, Council, or Committee agrees that the standard shall continue to be maintained under Stabilized Maintenance and does not require revision or withdrawal, the appropriate NEMA staff shall notify C&S.

If a written recommendation is made at any time that a standard under Stabilized Maintenance requires revision or should be withdrawn, that recommendation shall be considered by the Product Group, Council, or Committee within 60 calendar days of receipt. Recommendations shall include a rationale to withdraw or revise and shall not be dismissed because it does not suggest a specific revision.

13 Standardization Activities with Outside Bodies

13.1 General Rules on Contacts with Outside Bodies

13.1.1 Approval of New Contacts

New contacts or negotiations on technical matters with outside bodies concerning standards or conformity assessment shall be made only with the approval of C&S or IRSC, within their respective scopes, and Counsel or at the direction of the President as provided in the NEMA By-laws. Product Group, Council, or Committee ongoing activity for the development of technical positions for submittal to an ISO or USNC...
TAG need not be approved by the IRSC. Interface with governmental bodies is outside the scope of the SP&P and shall be coordinated by NEMA Government Relations.

13.1.2 Scope of Outside Bodies

When new contacts or negotiations on technical matters with outside bodies are authorized, the scope of the activity of the Association representatives shall be clearly defined. No activities beyond that authorized scope shall be engaged in by the Association representatives.

13.1.3 General Policy

In contacts with outside bodies the policy of the Association shall be, in general, to request the appointment either of Joint Committees composed of representatives of the Association and of the outside body directly concerned, or of accredited representatives of the Association to serve on such outside bodies.

13.1.4 Reports

Copies of the minutes of all meetings, or drafts of all proposed publications, and of all official communications to or from outside representatives, shall be filed with the president, the Product Group NEMA staff, or the Operations Department. For international activities, instructions for participation by individuals sponsored by an Association Committee or Product Group can be obtained from the NEMA IEC-ISO Guidelines for Delegate Funding Activity. Association Committees and Product Groups are encouraged to adopt these guidelines as requirements for delegates they support.

13.2 Instructions to and Reports from NEMA Representatives

13.2.1 Instructions from C&S

NEMA representatives who cooperate with outside bodies in developing standards represent the interests of members who (from the nature of standards) are in any way affected by the standards being contemplated, and who shall vote in accordance with official instructions furnished by C&S whenever formal action is being taken.

13.2.2 Requests for Instructions

Communications from representatives on matters requiring official action shall be addressed to the NEMA Technical Director and shall not be addressed directly to Product Groups. Instructions must not be sent directly to a representative by a Product Group or Committee unless C&S has given specific authorization thereof. (See Appendix D.)

All pertinent supporting information that will be helpful to the Association in formulating voting instructions to Association representatives shall be filed with the NEMA Technical Director.

13.3 Obtaining Product Group Recommendations for Instructions to NEMA Representatives

13.3.1 Determination of Interest in Questions Considered

C&S shall determine which Product Groups are interested in any proposed instructions and shall obtain from those Product Groups or authorized Technical Committees, recommendations for instructions to NEMA representatives.

13.3.2 Recommendations of Product Groups
Recommendations of a Product Group or authorized Technical Committee shall be determined by a majority vote of those present at any meeting at which a quorum is present, or, in the case of a letter ballot, by the vote of a majority of the members of the Product Group or authorized Technical Committee. If the time allotted by the outside body for voting on any technical matter does not permit a 30 calendar day letter ballot, the recommendations of interested Product Groups or authorized Technical Committees may be obtained by a letter ballot upon notice of less than 30 calendar days. If the time allowed is not sufficient to permit a letter ballot, the recommendations of interested Product Groups or authorized Technical Committees shall be obtained by C&S by such means as may be available within the time allowed. The opinions of the interested Product Groups or authorized Technical Committees may be obtained from the records, or may be expressed on behalf of Product Groups by the Product Group’s chair, or by a Product Group Committee designated by the chair for that purpose, subject to confirmation by the Product Group.

13.3.3 Filing Product Group Recommendations

The recommendations of a Product Group shall be filed with C&S by the appropriate NEMA staff. When there is a difference of opinion within any Product Group, NEMA staff shall file a statement of the situation with C&S.

13.4 Basis of C&S Instructions to NEMA Representatives

13.4.1 Basis of Instructions

Except as otherwise directed, C&S, in formulating instructions to NEMA Representatives, shall give due consideration to the recommendations of the interested Product Groups.

13.4.2 Basis of Action in Conflicts

When there is a difference of opinion, in the Product Group or between two or more Product Groups, C&S shall base its instructions to be sent to Association representatives on engineering consideration of the question and of the majority and minority opinions submitted.

13.4.3 Basis of Action Within the Time Limit

When the recommendations of interested Product Groups are not received within the time limit set by the outside organization, C&S shall formulate official instructions based on engineering consideration of the question and shall notify the appropriate NEMA staff of the interested Product Groups of the action taken or not taken.

13.4.4 Appeals Relative to Voting Instructions in Standardization With Outside Bodies

Action of any Product Group or C&S in connection with the formulation of voting instructions to Association representatives cooperating with outside bodies in the development of standards shall be subject to appeal to the SCAPC by any interested member of the Association. Any action of the SCAPC upon any appeal may be further appealed to the Board of Governors by any interested member of the Association. Notice of the time and place at which appeals will be considered by the SCAPC and the Board of Governors, and an opportunity to be heard thereon, shall be given to all members of the Product Group or Committee concerned.

13.5 IRSC Instructions to NEMA Representatives

Interaction concerning management or strategic issues with respect to international or regional standards bodies (not under the scope of C&S) on behalf of NEMA shall be approved by the IRSC.
14 Revisions of Rules, Policies, and Procedures

Revisions of any of the rules, policies, and procedures included in this manual require approval by the Board of Governors. All suggestions for revision to this manual shall be addressed to the Vice President, Operations for consideration by the MC on the SP&P. The MC on the SP&P should review this manual and propose updates as needed, but no less frequently than every five years.

15 Appendices

All appendices included herein are NEMA standards development governance documents and shall be considered part of the Standardization Policies and Procedures of the National Electrical Manufacturers Association.
Exhibit 2
Member Companies

We are nearly 325 Member companies representing a wide range of electrical equipment and medical imaging manufacturers that make safe, reliable, and efficient products and systems. Our combined industries account for more than 370,000 American jobs in more than 6,100 facilities covering every state.

3  A  B  C  D  E  F  G  H  I  J  K  L  M  N  O  P  Q  R  S  T  U  V  W  X  Y  Z

3

> 360 Network Solutions, LLC
> 3M

A

> ABB Inc.
> Accurate Plastics
> Acertara Acoustic Laboratories
> Aclara
> Acuity Brands, Inc.
> Advanced Accelerator Applications a Novartis company
> Advanced Cable Ties, Inc.
> Adventech, LLC
> Agfa HealthCare Inc.
> Agfa US Corp
> AIQ Global, Inc.
> Allied Moulded Products, Inc.
> Amglo Kemlite Laboratories, Inc.
> Anamet Electrical, Inc.
> Apcom, Inc.
Member Companies

- Apollo America Inc.
- Applied Information, Inc.
- Arlington Industries, Inc.
- Arrayus Technologies Inc.
- Ascom Wireless Solutions
- ASK Products, Inc. / Sicame Corp.
- Atkore
- Atkore Talon Products
- Atlas Lighting Products, Inc.
- Austco Healthcare
- Avery Dennison - Fastener Division
- Axis Lighting Inc.

B

- Bayer Radiology and Interventional
- Biogen
- Bison Gear & Engineering Corporation
- Blue Earth Diagnostics
- Boltswitch - Socomec Group
- Bosch Security Systems, LLC
- Bracco Diagnostics Inc.
- Braeburn Systems LLC
- BrainSonix Corporation
- Bridgeport Fittings, LLC
- Brook Crompton North America
- Brooks Utility Products
- Butterfly Network, Inc.

C

- Canon Medical Systems USA, Inc.
- Caption Health, Inc.
Member Companies

- Cardinal Health
- Carlo Gavazzi Automation Components
- CBM Lighting Inc.
- Cerrowire
- Cerveau Technologies Inc.
- Chalfant Manufacturing Company
- Champion Fiberglass, Inc.
- Champlain Cable Corporation
- ChargePoint, Inc.
- CITEL Inc.
- ClipperCreek A division of Enphase Energy, Inc.
- Colonial Wire & Cable Co., Inc.
- Comtran Cable LLC
- CONDUMEX S.A. DE C.V.
- Construction Innovations, LLC
- Continental Control Systems, LLC
- Cooper Lighting Solutions
- Copperweld Bimetallcs, LLC
- Cornell Communications, Inc.
- Cree Lighting
- Crest Healthcare
- Cummins Inc.
- Curbell Medical Products, Inc.
- Curium
- Current

D

- Daktronics, Inc.
- Danfoss Drives
- Delta Electronics (Americas) Ltd.
- DENT Instruments, Inc.
<table>
<thead>
<tr>
<th>Member Companies</th>
</tr>
</thead>
</table>

- Dialight
- Dicom Systems, Inc.
- DuPont
- Duracell, Inc.

**E**
- Eaton
- Eberle Design, Inc.
- EDAP TMS
- EiKO Global, LLC
- ElIZO Corporation
- ELANTAS PDG, INC.
- Electri-Flex Company
- Electro Switch Corp.
- Elektrisola Inc.
- Eli Lilly & Company
- Elliott Control Company, Ltd.
- Emerson Automation Solutions
- Emerson Commercial & Residential Solutions
- Encore Wire Corporation
- Energizer Brands, LLC
- Enerlites Inc.
- Engineered Electronics, Inc.
- ESAB Welding & Cutting Products
- Esaote North America
- Essex Furukawa Magnet Wire LLC
- ExEm Foam, Inc.
- Exro Technologies Inc.
- EYE Lighting International of N.A., Inc.
- EZ Meter Technologies
F

- Fanlight Corp. Inc.
- Federal Pacific
- Feit Electric Company, Inc.
- FFE Ltd.
- Figaro USA, Inc.
- Firetrol, Inc.
- FRE Composites
- Fuji Electric Corporation of America
- FUJIFILM Healthcare Americas, Corp.
- FUJIFILM Sonosite, Inc.
- FUSMobile Inc.

G

- G&W Electric Company
- Galvan Industries, Inc.
- GE Grid Solutions
- GE Healthcare
- GE Healthcare, Life Sciences
- GE Industrial Motors, a Wolong Company
- GE Lighting, a Savant company
- Generac Power Systems, Inc.
- Gentex Corporation
- Gilbert Industries, Inc.
- Google Nest
- GrafTech International Ltd.
- Grand Power Systems
- Graphite Metallizing Corporation

H

- Halco Lighting Technologies
› Hammond Power Solutions Inc.
› Harbour Industries Canada
› HeartFlow, Inc.
› HellermannTyton
› Hendrix Molded Products
› Hillrom
› HistoSonics, Inc.
› Hitachi Energy USA Inc.
› Hologic Inc.
› Honeywell
› Honeywell Building Technologies
› Honeywell Smart Energy
› Horizon Signal Technologies
› HOTWIRE LLC
› HSI Fire & Safety Group LLC
› Hubbell Incorporated
› Hypertherm Incorporated

I

› IDEAL Industries, Inc.
› IER
› ILSCO Corporation
› Infinitum Electric
› INSIGHTEC Ltd.
› Intelight, a Q-Free Company
› International Metal Hose Company
› Interpower Corporation
› Ionetix Corporation
› IPEX USA, LLC
› Iten Industries
› Itron, Inc.
J
> Jeron Electronic Systems, Inc.
> JIE USA, INC.
> John Thomas, Inc.
> Johnson Controls
> Jubilant Radiopharma
> Judd Wire Inc.

K
> Keltron Corporation
> Kheiron Medical Technologies Limited
> K-Line Insulators USA Inc.
> Konica Minolta Healthcare Americas, Inc.
> Kromek

L
> L.H. Dottie
> Laitek Inc.
> Landis+Gyr
> Lantheus Holdings
> Lapp Insulators LLC
> LEDVANCE LLC
> LEESON
> Legrand, North America
> Lenze Americas Corporation
> Leviton Manufacturing Co., Inc.
> Liebel-Flarsheim a wholly owned subsidiary of Guerbet Group
> Life Molecular Imaging
> lifeIMAGE
> Lincoln Electric
> Littelfuse, Inc.
Lutron Electronics Company, Inc.

M

Macurco Gas Detection
Magnekon, S.A. de CV
maiData Corporation
Marathon Motors
Marine Tech Wire and Cable, Inc.
Marmon Aerospace & Defense, LLC
Master Control Systems, Inc.
Maxivolt
MaxLite
MDF Cable Bus Systems
MedTrace Pharma, Inc.
Medtronic
Meltric Corporation
Mersen USA Newburyport-MA, LLC
MGM Transformer Company
Milbank Manufacturing Company
Miller Electric Mfg. LLC An ITW Welding Company
Mitsubishi Electric Automation, Inc.
Mitsubishi Electric Power Products, Inc.
MP Husky LLC
MWS Wire Industries

N

New Cosmos USA, Inc.
New England Wire Technologies Corporation
Newell-PSN, LLC
Nexans
NGK-LOCKE, INC.
> Nidec Motor Corporation
> NORD Gear Corporation
> NSi Industries, LLC
> Nucor
> Numa LLC
> nVent

O
> OrthoScan, Inc.

P
> PACSHealth, LLC
> Panasonic Corporation of North America
> Panduit Corporation
> Panoramic Power Ltd.
> Parsons
> PFISTERER North America Inc.
> PharmaLogic
> Philips
> Phoenix Contact
> Polaris Electrical Connectors
> Post Glover Resistors, Inc.
> Potter Electric Signal Company, LLC
> PPC USA, Inc.
> Preformed Line Products
> Premise Inc.
> ProAqCT
> Producto Electric Corporation
> Profound Medical Inc.
> Progressive Machine Die, Inc.
> Prolec GE
Q
> Quadlogic Controls Corporation
> Qualcomm
> Quirk Wire Company, Inc.

R
> RAB Lighting Inc.
> Radian Research, Inc.
> Radix Wire & Cable, LLC
> RADLogics Inc.
> Rauland, a division of AMETEK, Inc.
> Raycap, Inc.
> Rea Magnet Wire Company, Inc.
> RefleXion Medical, Inc.
> Regal Rexnord Corporation
> Reliance Controls Corporation
> Resideo Technologies, Inc.
> RF Technologies, Inc.
> Rittal North America LLC
> Robroy Industries
> Röchling Industrial Cleveland
> Rockwell Automation
> RSCC Wire & Cable LLC
> RTI Group AB

S
> S&C Electric Company
> Samsung NeuroLogica
> Satco Products, Inc.
> Schneider Electric
> SDi LLC
> SEA Wire and Cable, Inc.
> Sediver USA, Inc.
> Seno Medical Instruments Inc.
> Sensus, A Xylem Brand
> Sentrics
> Service Wire Company
> SEW-Eurodrive, Inc.
> Shimadzu Medical Systems USA
> Siemens Healthineers
> Siemens Industry, Inc.
> Sigma Engineered Solutions
> Signify North America Corporation
> Sky Technologies
> Skyline Products, Inc.
> Snake Tray
> SnapPower
> Sonablate Corp.
> South Atlantic, LLC
> Southern Pipe, Inc.
> Southwire Company
> Space Age Electronics, Inc.
> Specialty Cable Corporation
> Spectrum Dynamics Medical
> Starline Holdings, LLC, a company of Legrand, North America
> Steel Electric Products Co., Inc.
> Sterling Electric, Inc.
> Sunrise SESA Technologies, Inc.
> Systematics

T
> Tatung Electric Company of America
- TE Connectivity
- Techline Mfg.
- Technical Consumer Products, Inc.
- Techtop Industries, Inc.
- TECO-Westinghouse Motor Company
- Tektone Sound & Signal Mfg. Inc.
- Telecor Inc.
- Telix Pharmaceuticals (US) Inc.
- Temple, Inc.
- The Durham Company
- The Gund Company, Inc.
- The Monroe Cable Company, Inc.
- The Okonite Company
- Titan3 Technology LLC
- Tornatech Inc.
- Toshiba International Corporation USA
- Tower Manufacturing Corporation
- Triacta Power Solutions LP a Division of Metergy Solutions Inc
- Turntide Technologies

U
- Underground Devices, Inc.
- United Imaging - North America
- Unitray Systems Inc.

V
- Valcom
- VanTran Industries, Inc.
- Varex Imaging
- Ver-Mac Inc.
- Vertiv Corporation
> Viakable, S.A. de C.V.
> Victor Insulators, Inc.
> Virginia Insulated Products, Inc.
> VISUS Health IT GmbH

> W.L. Gore & Associates, Inc.
> WAGO Corporation
> WEG Electric Corp.
> Weidmüller, Inc.
> West-Com Nurse Call System, Inc.
> Western Automation R & D Corp.
> Western Tube (Division of Zekelman Industries)
> Westinghouse Lighting
> Wheatland Tube Company
> WireMasters, Inc.
> Worldwide Electric Corporation

> Xignux Corporativo

> Yaskawa America, Inc. Drives & Motion Division

> Z Power & Distribution Inc.
> Ziehm Imaging, Inc.
Exhibit 3
CDA Members

Copper Development Association members include the following companies:

CDA Full Members

**AFC Cable Systems, Inc.**
Fabricator  
272 Duchaine Blvd  
New Bedford, MA 02745-1222  
UNITED STATES  
www.afcweb.com  
P: 508-998-1131

**Aurubis Buffalo, Inc.**
Fabricator  
70 Sayre St  
Buffalo, NY 14207-2225  
UNITED STATES  
www.aurubis.com/sites/buffalo  
P: 716-879-6700

**Aviva Metals**
Fabricator  
2929 W 12th St  
Houston TX, 77008-6113  
UNITED STATES  
www.avivametals.com  
P: 800-231-0771

**BHP**
Producer  
1360 Post Oak Blvd, Ste 150  
Houston TX 77056-3030  
UNITED STATES  
www.bhpbilliton.com  
P: 713-961-8500

**BHP (CHILE)**
Producer  
Avda. America Vespucio Sur 100, Piso 9  
Las Condes, Santiago  
CHILE

**BHP Marketing Asia Pte, Ltd**
Producer  
10 Marina Boulevard #50-01  
018983  
SINGAPORE

**Cambridge-Lee Industries LLC**
Cerro Flow Products, LLC
Fabricator
PO Box 6680
Saint Louis, MO 63166-6800
UNITED STATES
www.cerroflow.com
P: 618-337-6000

Cerro Wire, LLC
Fabricator
1099 Thompson Rd SE
Hartselle, AL 35640-8471
UNITED STATES
www.cerrowire.com
P: 256-773-2522

Chicago Extruded Metals Company, LLC
Fabricator
1601 S. 54th Avenue
Cicero, IL 60804-1898
UNITED STATES
www.cxm.com
P: 800-323-8102

CODELCO (USA), Inc. *
Producer
177 Broad ST FL 11th
Stamford, CT 06901-5003
UNITED STATES
www.codelco.com
P: +562 26903000

Concast Metal Products Company
Fabricator
14215 State Route 113
Wakeman, OH 44889
UNITED STATES
www.concast.com
P: 440-965-4455

Drawn Metal Tube Company
Fabricator
218 Elm St
Thomaston, CT 06787-1709
UNITED STATES
www.drawnmetal.com
P: 860-283-4345

Encore Wire Corporation
Freeport-McMoRan Inc.
Producer
333 N Central Ave
Phoenix, AZ 85004
UNITED STATES
www.fcx.com
P: 972-562-9473

Glencore, Ltd. *
Producer
330 Madison Ave
New York, NY 10017-5001
UNITED STATES
www.glencore.com
P: 203-328-4900

Hussey Copper, Ltd. *
Fabricator
100 Washington St
Leetsdale, PA 15056-1000
UNITED STATES
www.husseycopper.com
P: 800-733-8866

Hussey Marine Alloys, Ltd.
Fabricator
100 Washington St
Leetsdale, PA 15056-1000
UNITED STATES

IMC Metals America, LLC
Fabricator
135 Old Boiling Springs Rd.
Shelby, NC 28152
UNITED STATES
www.imc-ma.com
P: 704-482-8200

Kearny Smelting & Refining Corp. *
Fabricator
500 Harrison Ave
Kearny, NJ 07032-5947
UNITED STATES
P: 201-881-7216

Mac Metals, Inc.
500 Harrison Ave
Kearny, NJ 07032-5947
UNITED STATES
www.macmetals.com
P: 201-997-8000

Luvata Appleton, LLC
Fabricator
553 Carter Ct
Kimberly, WI 54136-2201
UNITED STATES
www.luvata.com/Appleton
P: 920-749-3820

Materion Brush Performance Alloys
Fabricator
6075 Parkland Blvd.
Mayfield Heights, OH 44124
UNITED STATES
www.materion.com/brushalloys
P: 216-486-4200

Mueller Industries, Inc. *
Additional Members

Howell Metal
Fabricator
574 New Market Depot Rd
New Market, VA 22844
UNITED STATES

Mueller Brass Company
Fabricator
2199 Upper Ave
New Haven, MI 48803-4155
UNITED STATES

Mueller Copper Tube Company, Inc.
Fabricator
465 Mueller Rd.
Fulton, MS 38843-0849
UNITED STATES

Mueller Copper Tube Products, Inc.
Fabricator
1323 N. Fab Blvd
Wynne, AR 72396-1025
UNITED STATES

Mueller Fittings Company
Fabricator
3400 Mueller Brass Rd
Covington, TN 38019-3750
UNITED STATES

Mueller Refrigeration Products Company
Fabricator
300 Constitution Drive, R51
Menlo Park, CA 94025-1164
UNITED STATES

National Copper & Smelting Company
Fabricator
3122 Lynnwood Blvd NE
Huntsville, Al 35811-8205
www.nationalcopper.com
P: 256-465-2881

Nexans Canada, Inc.
Fabricator
465 Avenue Durocher
Montreal Est., Quebec H1B 5H6
CANADA
www.nexans.ca
P: 514-645-2881

nVEnt Thermal, LLC *
Fabricator
368 Constitution Drive, 851
Menlo Park, CA 94025-1164
UNITED STATES
www.nventthermal.com
P: 650-474-7000

Pyrotenax Cables Ltd.
Fabricator
250 West Street
Trenton, ON K8V 5S2
CANADA

PMX Industries, Inc.
Fabricator
5480 Willow Creek Dr. STH
Cedar Rapids, IA 52404-4330
UNITED STATES
www.pmxind.com
P: 319-368-7780
Revere Copper Products, Inc.
Fabricator
1 Revere Park
Rome, NY 13440-5568
UNITED STATES
www.reverecopper.com
P: 800-448-1776

Rio Tinto/Kennecott Utah Copper Corporation
Producer
4700 Daybreak Pkwy
South Jordan, UT 84009-5120
UNITED STATES
www.kennecott.com
P: 801-204-2000

RLS LLC
Fabricator
101 S Douglas Ave
Shelbina, MO 64666-1050
UNITED STATES
www.rapidlockingsystem.com
P: 813-757-3278

RSCC Wire & Cable, LLC
Fabricator
28 Bradley Park Rd
East Granby, CT 06026-0798
UNITED STATES
www.r-social.com
P: 860-294-2060

SDI LaFarga COPPERWORKS
Fabricator
1640 South Ryan Road
New Haven, IN 46774
UNITED STATES
www.sdilafarga.com
P: 260-748-6565

Small Tube Products, Inc.
Fabricator
200 Oliphant Dr
Duncansville, PA 16635-1017
UNITED STATES
www.smalltubeproducts.com
P: 814-693-6000

Southwire Company
Fabricator
1 Southwire Dr
Carrollton, GA 30119-4400
UNITED STATES
www.southwire.com
P: 770-832-4242

The Okonite Company
* indicates additional members

CDA Associate Members

- **Aereus Technologies, Inc.** - [www.aereustech.com](http://www.aereustech.com)
- **CuGO™** - [www.cu-go.com](http://www.cu-go.com)
- **T-Drill Industries, Inc.** - [www.t-drill.com](http://www.t-drill.com)

If you are interested in becoming a CDA member, please visit our [membership page](http://membership.cda.org).
Exhibit 4
The Aluminum Association is the industry's leading voice, representing companies that make 70% of the aluminum and aluminum products shipped in North America.

Our membership includes several dozen domestic and international companies engaged in the manufacture and sale of aluminum products—or Producer Members.

We also represent Associate Members, which are companies that supply goods or services to the aluminum industry.
Arconic
Aluminum Alloys
Assan Aluminum

Audubon Metals
Brunswick
CASS
JW Aluminum  Kaiser Aluminum  Kobe Steel

Lincoln Electric  Matalco  Minalex

Novelis  Owl's Head  Real Alloy

https://www.aluminum.org/producer-member
Shandong Nanshan Aluminum

Silberline

Skana Aluminum

Smelter Service Corporation

Spectro Alloys

Southwire
Universal Alloy Corporation

Weber Metals, Inc

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Enter Email
Join Us

Join us at the Aluminum Association to stay one step ahead of industry trends and benefit from global best practices.

JOIN TODAY

Aluminum Bookstore

Your one-stop shop for technical articles, publications, standards, data and other information about aluminum.

SHOP NOW

Buyer’s Guide

Providing all necessary information and comparisons in an easily searchable format so you can find a solution to fit your needs.

VIEW NOW

Get To Know Us

About the Association

Get Involved

Join Aluminum Nation

Explore Aluminum

Aluminum 101
<table>
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<th>Link</th>
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Conduit Producers

[logos of Atkore, Nucor Tubular Products, and Western Tube]
Hollow Structural Sections Producers

ArcelorMittal

Atlas Tube

Bull Moose Tube

H.W. Metals

MAC

Maruichi Leavitt

Most

Nucor Tubular Products

Searng Industries

Valmont Tubing

https://steeltubeinstitute.org/about-us/sti-producers/
The Industry is Evolving. Stay Ahead.

Joining our email list ensures you’re up-to-date on important industry news, details on upcoming events and much more.

SIGN-UP NOW
CCA Insulation Strip and Outlet Backstab Testing

Tests Performed: October 19th – October 20th, 2021

Report Date: October 25th 2021

Requested by: Dave Watson

Cofer Center Work Request #: 2021-260

Report by:  

_______________________  
Ryan Landry  
Metallurgy Lab Manager

&

_______________________  
Dave Watson  
Principal Engineer  
Codes & Standards, Applications Engineering
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Introduction
Opened in 1992, Southwire’s D.B. Cofer Technology Center (CTC) is a nearly 60,000 square foot ISO 17025 accredited laboratory. The CTC is also a certified participant in UL’s Client Test Data Program and a certified participant in CSA’s Supervised Manufacturer’s Testing for Certification Program. Both the UL and CSA testing programs are structured so that data for wire and cable certification purposes can be generated at the CTC lab and submitted to UL and CSA. Annual audits are performed by UL and CSA of the CTC’s quality management system and testing practices.

Testing was performed at the CTC in a climate-controlled lab. Data was gathered using equipment and processes that are part of the CTC’s ISO 17025 Quality Management System. The overall procedure and test apparatus were customer defined and not a part of the CTC’s ISO 17015 scope of accreditation.

In addition to the temperature study presented in a separate report, it was deemed important to conduct mechanical misuse testing to evaluate the resiliency of the copper-cladding in the event of improper installation practices – especially since it is difficult to distinguish between solid copper and copper-clad aluminum without very careful inspection. This testing included stripping the wire’s insulation at the 16 AWG size with commercially available wire strippers and outlet backstab testing using commercially available 15A-125V outlets.

Summary
The results of the mechanical misuse testing indicated that the copper-cladding can be compromised with improper installation practices. Removing insulation from 14 AWG CCA with 16 AWG wire strippers completely penetrated through the copper-cladding and inserting CCA into 15A-125V outlet backstab terminations significantly reduced the cladding thickness where the termination’s locking mechanism bit into the wire.

It is the opinion of the authors of this report that these results warrant further action to be taken by stakeholders. Possible actions include, but are not limited to, development of mutually agreed upon test methods to reproduce these results and further investigation into the practicality of copper clad aluminum wire products in residential and commercial applications.

Procedure
Insulation Strip Test
The insulation strip test was performed using a commercially available Southwire SA822 ‘automatic’ wire stripper shown in Figure 1. The test was intended to assess the degree of damage that would occur to the cladding if an installer accidentally used the 16 AWG notch when stripping insulation from the conductor.
Table 1: Equipment Used for Insulation Strip Test

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Cofer Asset #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zeiss Discovery.V20 Stereomicroscope</td>
<td>NA</td>
</tr>
<tr>
<td>Zeiss Observer.Z1m Inverted Microscope</td>
<td>NA</td>
</tr>
<tr>
<td>Electron Microscopy Sciences 68047-PS4R Stage Micrometer</td>
<td>504</td>
</tr>
</tbody>
</table>

Figure 1: Southwire SA822 automatic wire stripper used for Insulation Strip Test

The test was carried out according to the following procedure:

1. Three short lengths of insulated conductor were removed from the NM cable,
2. Approximately 0.75 inch of insulation was stripped from one end of the conductors using a single stroke of the 16 AWG notch on the SA822 stripper,
3. The surfaces of the freshly stripped bare CCA wires were examined and photographed under 8x magnification using a stereomicroscope equipped with a digital camera,
4. Cross-sections through the stripped lengths of the bare wires were metallographically prepared for higher magnification examination,
5. The metallographic cross-sections were examined at magnifications ≥50x with an inverted microscope equipped with a digital camera to locate areas of copper-cladding with the most significant damage,
6. The areas of most significant damage were photographed and the minimum cladding thickness in each of these areas were measured with the inverted microscope’s software (Zeiss AxioVision SE64 Rel 4.9.1). The software scaling was verified for accuracy at each level of magnification used with a calibrated stage micrometer, asset # 504.

Outlet Backstab Test

The outlet backstab test was performed using commercially available Leviton 15A-125V Outlets shown in Figure 2. The test was intended to assess the degree of damage that would occur to the cladding if an installer mistakenly thought the conductors were solid copper and used the backstab termination on an outlet.
Table 2: Equipment Used for Outlet Backstab Test

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<tr>
<th>Equipment</th>
<th>Cofer Asset #</th>
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<td>Zeiss Observer.Z1m Inverted Microscope</td>
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<tr>
<td>Electron Microscopy Sciences 68047-PS4R Stage Micrometer</td>
<td>504</td>
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Figure 2: Leviton 15A-125V outlets used for Outlet Backstab Test

The test was carried out according to the following procedure:

1. 20 short lengths of insulated conductor (10 white and 10 black) were removed from the NM cable,
2. Approximately 0.75 inch of insulation was stripped from one end of the conductors using the 14 AWG notch on a Southwire SA822 stripper,
3. Five new 15A-125V outlets were randomly selected from the 10-pack box pictured in Figure 2 and labeled 1 through 5 indicating the number of times the conductors were to be backstabbed into each outlet,
4. The stripped ends of the wires were inserted straight into the four backstab terminations on each of the five outlets – one wire per termination – according to the number of times labeled on the outlet,
   a. When the wires were to be backstabbed more than once, the outlet’s termination release mechanism was engaged until the wire was completely removed from the termination, the release mechanism disengaged, and the wire re-inserted straight back into the same termination from which it was released,
5. The surfaces of the backstabbed wires were examined and photographed under 8x magnification using a stereomicroscope equipped with a digital camera,
6. Cross-sections through the backstabbed lengths of the bare wires were metallographically prepared for higher magnification examination,
7. The metallographic cross-sections were examined at magnifications ≥50x with an inverted microscope equipped with a digital camera to locate areas of copper-cladding with the most significant damage,

8. The areas of most significant damage were photographed and the minimum cladding thickness in each of these areas were measured with the inverted microscope’s software (Zeiss AxioVision SE64 Rel 4.9.1). The software scaling was verified for accuracy at each level of magnification used with a calibrated stage micrometer, asset # 504.

Results

Insulation Strip Test

Figure 3 shows photos of the bare ends of the three conductors stripped with the 16 AWG notch. Note the transverse cuts where the stripper initially bit into the conductor and the longitudinal scratching damage where the ‘automatic’ action of the stripper dragged down the copper. Figure 4 shows longitudinal metallographic cross-sections through the areas of most significant damage and the minimum measured copper-cladding thicknesses. As can clearly be seen, in two of the three samples tested the 16 AWG notch completely penetrated through the copper exposing the aluminum base metal.

Figure 3: Photo taken at 8x magnification showing the as-stripped ends of the CCA conductors
Figure 4: Photos taken at 100x magnification of longitudinal cross-sections through the areas of most significant conductor damage and the minimum measured copper-cladding thicknesses after the Insulation Strip Test.

**Outlet Backstab Test**

Figure 5 shows photos of the bare backstabbed ends of the wires. Note the transverse cuts where the outlet’s backstab termination locking mechanism bit into the conductors. Figure 6 shows longitudinal metallographic cross-sections through the areas observed to have the deepest cuts into the conductor and the minimum measured copper-cladding thicknesses in these areas. It’s interesting to note that the minimum observed copper thickness of 0.4 mil at the deepest cut was observed on a conductor that had only been backstabbed once - this could be due to variability in the outlet locking mechanisms or not hitting the deepest points of the cuts on all conductors during metallographic preparation. None of the backstab cuts were found to have penetrated to the aluminum base metal although copper thickness was greatly reduced in these areas.

Figure 5: Photos taken at 8x magnification showing the as-backstabbed ends of the CCA conductors

Figure 6: Photos taken at 100x magnification of longitudinal cross-sections through the areas of most significant conductor damage and the minimum measured copper-cladding thicknesses after the Outlet Backstab Test.
Appendix A: Calibration Certificate

Applied Technical Services
Certificate of Calibration
Certificate #3020484

Customer:
Southway Company - D.B. Cofer
D.B. Cofer Technology Center
111 Development Drive
Carrollton, GA 30117

Calibration Location:
Applied Technical Services
1049 Triad Court
Marietta, GA 30062

Instrument Information:
Manufacturer: Electron Microscopy Sciences
Model Number: 68047-PS4R
Description: Stage Micrometer
Asset Number: 504
Serial Number: CS4328
PO Number: 4032014624

Calib. Procedure: ATS-577 Rev 2: Certification of Stage Micrometers and Reticles

This instrument has been calibrated using primary or secondary standards whose calibration is traceable to the International System of Units (SI) through the National Institute of Standards and Technology (NIST) or applicable ASTM specification number for hardness testing equipment. Some measurements are traceable to natural, physical constants, consensus standards, or regulatory measurements. The reported expanded measurement uncertainty is based on a standard uncertainty multiplied by a coverage factor of k=2, providing a confidence level of approximately 95%. This calibration certificate may contain data that is not covered by the Scope of Accreditation. The unmarked last points, where applicable, are indicated by an asterisk (*), or confined to clearly marked sections. Functional tests are not accredited. The expanded measurement uncertainty is not considered when determining in-tolerance or out-of-tolerance conditions. Results are reviewed, if applicable, to establish where any measurement results exceeded the related calibration tolerance and to communicate results by means of this certificate.

All calibrations are performed in accordance with the ATS Quality Manual QM, Rev. 1R, dated 10/16/20. Applied Technical Services, Inc.’s Quality System complies with the applicable requirements of ANSI/ASL Z540-1, ISO 9001:2015, 10CFR50 Appendix B, 10CFR Part 21, and ISO/IEC 17025:2017. The reported data is valid only at the time of the test and related only to the item calibrated. Calibration due dates appearing on this certificate and calibration label are determined by the client and do not imply continued conformance to specifications. This certificate shall not be reproduced except in full, without written permission of Applied Technical Services, Inc.

Technical Remarks:

Calibrated By: Hammond, Christopher
Calibration Tech.

Calibration Equipment Utilized

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End Of Report

Applied Technical Services
1049 Triad Court
Marietta, GA 30062
Phone 770 423-1400  www.atstlab.com

ATS 501, 10/28
Issue date: 16-Jun-2021
Batch Number: 2398705

2021-260 - CCA Insulation Strip and Outlet Backstab Testing
Appendix B: Microscope Software Scaling Verification

Figure B.1: 0.01 in division of stage micrometer (asset #504) reticle scale measured at 100x magnification with microscope’s AxioVision SE64 Rel 4.9.1 software
Exhibit 7
ABOUT

A world-class research and development center

LOCATION
Carrollton, GA

FOUNDED
1992

WHAT WE DO

FUNCTIONS

- Research & Development
- Wire & Cable Specification and Compliance
- Laboratory Services
- Metallurgy

RESEARCH AND DEVELOPMENT SPECIALIZATION

- Focus Areas
  - Compound Technology
  - Advanced Materials
  - Advanced Transmission Technology
  - New Wire & Cable Product Development

ABOUT OUR FACILITY

ACCREDITATIONS

- ISO 17025
- A2LA

4 POLYMER LABS

- Wet Chemistry Lab used for conducting halogen acid gas, hardness, and solvent extraction testing
- Analytical Lab used to identify and characterize insulation, shielding, and jacket materials
- Aging Lab used to test cables for heat, sunlight, weather, oil, and gasoline resistance
- Physical Properties Lab used to determine a wide range of characteristics, including tensile strength, elongation, flammability, and more

COMPOUND EXTRUSION AREA

OVERHEAD CONDUCTOR MECHANICAL TEST LAB

CABLE LIFE TESTING AREA

QUALIFICATION TESTING AREA

HIGH VOLTAGE TEST LAB

- Features a 400kV transformer, torsion tester and an impulse generator capable of generating 1.2 million volts to simulate a lightning strike

METALLURGY LAB

Visit Southwire.com today!
Exhibit 8
Temperature Profile Study of
14 AWG Copper-Clad Aluminum Products

Test Performed:  August 6\textsuperscript{th} – October 22\textsuperscript{nd}, 2021

Report Date:  October 25\textsuperscript{th}, 2021

Requested by:  Dave Watson

Cofer Center Work Order #: 2021-260

Report by:  \underline{Steven Powers, PE}
Lab Manager, Cofer Technology Center

&

\underline{Dave Watson}
Principal Engineer
Codes & Standards, Applications Engineering
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- Figure B.3: Thermocouple Installed in NM-B Sample
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- Figure B.7: Breaker Box
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- Figure B.9: NM-B Sample Installed in Apparatus in Ceiling Configuration

Disclaimer:
The information is accurate to the best of Southwire Company’s knowledge at the time of publication. Southwire Company, LLC and its affiliates disclaim all liability for any errors, omissions, corruption or virus in this message or any attachments. For engineering design information, please contact Southwire Applications Engineering at cabletechsupport@southwire.com.
Introduction

During the First Draft of the 2023 NEC, the smallest size allowed for copper-clad aluminum (CCA) conductors was extended to 14 AWG (from the previous limit of 12 AWG) in several NEC sections, including Table 310.16 and Table 310.17. The proposed Table 310.16 ampacities are 10 Amps at 60°C, 15 Amps at 75°C, and 20 Amps at 90°C. The test data supplied by the American Bimetallic Association in support of this First Draft change addressed performance in open air only. Southwire believes testing in normal residential and commercial installation environments (within insulated walls and ceilings/attics) is also needed to properly assess the safety of 14 AWG copper-clad aluminum conductors at these ampacities.

It was decided to test 14 AWG copper-clad aluminum products using a test fixture intended to simulate real world residential and commercial installation conditions. The temperatures of these 14 AWG copper-clad aluminum product samples were measured when subjected to varying amperages in varying installation conditions.

Opened in 1992, Southwire’s D.B. Cofer Technology Center (CTC) is a nearly 60,000 square foot ISO 17025 accredited laboratory. The CTC is also a certified participant in UL’s Client Test Data Program and a certified participant in CSA’s Supervised Manufacturer’s Testing for Certification program. Both the UL and CSA testing programs are structured so that data for wire and cable certification purposes can be generated at the CTC lab and submitted to UL and CSA. Annual audits are performed by UL and CSA of the CTC’s quality management system and testing practices.

Testing was performed at the CTC in a climate-controlled lab. Data was gathered using equipment and processes that are part of the CTC’s ISO 17025 Quality Management System. The overall procedure and test apparatus were customer defined and not a part of the CTC’s ISO 17015 scope of accreditation.

Test results show that the conductor temperature ratings in NEC Table 310.16 are exceeded when using the ampacities proposed by the American Bimetallic Association (10 Amps at 60°C for 14 AWG CCA NM-B Cable, 15 Amps at 75°C for 14 AWG CCA THWN conductors installed in flexible metallic conduit, and 20 Amps at 90°C for 14 AWG CCA THHN conductors installed in flexible metallic conduit) while the products are installed within insulated walls and ceilings/attics that are typical of residential and commercial installations. These results also indicate the proposed ampacities for 14 AWG CCA conductors in Table 310.17 (Free Air) are likely to lead to conductor temperatures greater than the conductor temperature ratings in Table 310.17.

It is the opinion of the authors of this report that these results warrant further action to be taken by stakeholders. Possible actions include, but are not limited to, development of mutually agreed upon test methods to reproduce these results and further investigation into the practicality of copper-clad aluminum wire products in residential and commercial applications.
Samples

Southwire obtained 14 AWG copper-clad aluminum bare conductor (using 8000 series AL alloy) and used it to manufacture 14/2 NM-B Cable and 14 AWG THHN/THWN dual-rated conductors. (Per NEC Table 310.4, THHN conductors are rated for 90°C in dry and damp locations and THWN conductors are rated for 75°C in dry and wet locations. There are also other conductor types rated for 75°C listed in the NEC.) Since these sizes of copper-clad aluminum are not included within the relevant UL standards at this time (UL 719 and UL 83), we used the same constructions as required for 14 AWG copper products. (While the same constructions were used, process variations (such as line speed) may have been required during the manufacturing process to accommodate the lower tensile strength or other properties of copper-clad aluminum as compared to copper.)

Procedure

Testing was performed on a custom wood and drywall apparatus according to Figure 1. The apparatus was designed to replicate the construction of a traditional wood framed residential wall and ceiling. The apparatus could be flipped 90° from a vertical position (replicating a wall) and a horizontal position (replicating a ceiling). For the data contained in this report, certified electricians were used to install the samples and make electrical connections.

Complete test setup consisted of the following elements:

1. Wooden apparatus either oriented in the vertical plane (wall) or the horizontal plane (ceiling) constructed using 2"x6" wood boards and ½” sheetrock,
2. R13 and R30 fiberglass insulation (for total R value of R26 and R43),
3. Chroma programmable load current supply,
4. Avtron Model K490 load bank,
5. Fluke amp probe,
6. Voltage meters,
7. Graphite temperature datalogger.

Table 1: Equipment Used for Temperature Tests

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Cofer Asset #</th>
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<tr>
<td>Graphtec GL 840 Data Logger</td>
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<tr>
<td>Fluke 336 Clamp Meter</td>
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<td>Chroma Model 63803 Programable Load</td>
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<td>Fluke 289 Multimeter</td>
<td>267</td>
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<tr>
<td>Fluke 789 Multimeter</td>
<td>679</td>
</tr>
<tr>
<td>Avtron Model K490 Load Bank</td>
<td>NA</td>
</tr>
</tbody>
</table>
Figure 1: Test Apparatus

Figure 2: Test Apparatus in Ceiling Configuration
Figure 3: Test Apparatus in Wall Configuration

Figure 4: Test Apparatus with Thermocouple Layout
The following procedure was used for each test.

1. A sufficient length of NM-B cable or THHN/THWN conductors (typically 61 feet) is cut from a coil,
2. While the structure is in the horizontal orientation, one end is terminated in a Siemens EQ 125 Amp 8-Space 16-Circuit Main Lug Flush Mount Indoor Load Center to a Siemens Single-Pole Type QP Circuit Breaker, the amperage based upon the capability of the cable (10, 15, 20 amps typical) or specified by the customer,
3. The sample is secured in the wall at the specified spacing, typically 12” by pulling it through ¾” holes that were drilled through the boards located on either end of the structure,
4. The samples were secured to the apparatus,
   a. The cable samples are secured to the middle board with nailed-on staples listed for NM cable when the test apparatus was oriented in the wall configuration,
   b. The THHN/THWN samples were pulled through the flexible metal conduit (FMC), and the FMC was terminated in the electrical boxes of both end of the circuit,
5. The other end of the cable is terminated to a duplex outlet on the opposite side of the structure,
6. Thermocouples are installed in the apparatus as follows:
   a. One ambient (#8),
   b. One placed inside the cable or conduit where it enters the single gang receptacle box (#1) and another one inside the cable or conduit where it enters the load center panel (#7),
   c. Five others placed inside the sample
      i. Thermocouples #2 through #6 are spaced approximately 10 feet apart throughout the length of the cable or conduit. (Note: The relative order of thermocouples #2 through #6 varied.) The thermocouples were installed in the NM-B Cable by cutting a small slit in the outer jacket and placing the end of the thermocouple next to the conductors under the paper then two (2) wraps of electrical tape are placed over the slit. See Figures B.2 and B.3 for detail. The black mark on the cable jacket shows the final location of the thermocouple under the jacket. The thermocouples were located outside of the area covered by the electrical tape.
      ii. Thermocouples within the flexible metallic conduit were taped to the black conductor using electrical tape every 10 feet,
7. A specified R-value layer of insulation is placed over the sample and is tucked into the structure to minimize air gaps/heat loss,
8. For wall testing, the sheetrock doors are installed while the structure is horizontal, locked and then the structure is stood to the vertical orientation,
9. For ceiling testing, the sheetrock doors are left off, and the apparatus is left in the horizontal position,
10. The incoming power to the panel is turned ON,
11. The initial incoming voltage and outgoing voltage is recorded,
12. The temperature data logger data collection is launched,
13. The power supply is set to the specified current level (10, 15, or 20 amps) and is engaged,
14. The current level is verified with the amp probe,
14.а. It may be necessary to turn the load bank on and off several times for a short duration to
dial in the correct amperage. As such, the starting temperature for each test may not be
the ambient temperature.

15. The loaded voltages as shown in the corresponding voltage meters are recorded.

Each thermocouple was constructed at the CTC from special-limit-of-error thermocouple wire from
Omega (see Appendix A for Certificate of Conformance). UL document 00-OP-C0037-v8.0 is provided
by UL to members of the Client Test Data Program as a guide for accepting and assembling
thermocouples. It was used as a procedure for assembling the thermocouples in this project. After each
thermocouple was welded and connected to the data logger, the thermocouple end was placed in an ice
bath to verify its functionality and accuracy.

After a specified amount of time or at the point where the cable exceeds the temperature limitations
(shown below in the results section) as indicated on the datalogger screen, the power supply is turned off
and the data logger collection is stopped.

Results

Several limits were observed for this study. These limits, coupled with judgement, were considered
when determining when to stop a test. Some of these limits include the following:

- Temperature limit of 60°C for NM-B Cable at 10 Amps,
- Temperature limit of 75°C for THWN conductors installed in conduit at 15 Amps,
- Temperature limit of 90°C for THHN conductors installed in conduit at 20 Amps,
- A temperature rise of 30°C above ambient for NM-B Cable at 10 Amps,
- A temperature rise of 45°C above ambient for THWN conductors installed in conduit at 15
  Amps,
- A temperature rise of 60°C above ambient for THHN conductors installed in conduit at 20
  Amps,
- An elapsed time of 3 hours (“continuous use” classification).

For the ampacities given in NEC Tables 310.16 and 310.17, the ambient temperature is 30°C. The total
temperature achieved by the cable or conductor is composed of the ambient temperature plus the
temperature rise above ambient due to conduction of current. For NM-B Cable (Max Temp = 60°C),
this maximum temperature rise is 30°C above ambient. For THWN conductors installed in conduit
(Max Temp = 75°C), this maximum temperature rise is 45°C above ambient for 15 Amps. For THHN
conductors installed in conduit (Max Temp = 90°C), this maximum temperature rise is 60°C above
ambient for 20 Amps. Normally when installation occurs in an area with a lower ambient temperature,
the allowable conductor ampacity is increased per NEC 310.15. However, this testing had to be
performed with the appropriate over-current protection device (OCPD) sizes (10 Amps for NM-B Cable,
15 Amps for THWN conductors in conduit, or 20 Amps for THHN conductors in conduit) to ensure
accuracy of the results. Since our testing occurred in an environment with an ambient temperature of less than 30°C and we were limited in the current we could use for testing by the OCPD, we are using the maximum temperature rise above ambient as the measure of pass/fail results.

Comparison testing of 14/2 CCA NM-B cable was performed to evaluate the possibility of mutual heating between adjacent runs of cables. Tests were performed at 12” spacing and 18” spacing in the ceiling orientation with R43 insulation at 10 amps. Comparison of the 12” and the 18” spacing temperature data indicated no mutual heating occurred at the 12” spacing.

The temperature on multiple channels on Figure 6 exceeded the limit of the data logger after approximately 26 minutes. The test lasted for 47 minutes before it was decided to stop testing. The maximum temperature recorded was 102°C above ambient.

See Figures 5 through 10 below for the temperature profiles. Temperatures above the maximum temperature rating of the cable/conductors were observed during the 10 Amp, 15 Amp, and 20 Amp testing.
Figure 5: 14/2 CCA NM-B Spaced 12” in R43 Insulation at 10 Amps in Ceiling Configuration
Figure 6: 14 AWG CCA THHN in ½” FMC Spaced 12” in R43 Insulation at 20 Amps in Ceiling Configuration
Figure 7: 14/2 CCA NM-B Spaced 12” in R26 Insulation at 10 Amps in Wall Configuration
WO 2021-260 Copper Clad Aluminum Temperature Profile Study
14 AWG THHN CCA in 1/2" FMC Spaced 12" in R26 Insulation @ 20 Amps
in Wall Configuration

Average Ambient Temperature = 22°C

Time (min)

Temperature Rise Above Ambient (°C)

Thermocouple #1 — Thermocouple #2 — Thermocouple #3 — Thermocouple #4
Thermocouple #5 — Thermocouple #6 — Thermocouple #7

60°C Rise Above Ambient - Fail

Figure 8: AWG 14 THHN CCA in ½” FMC Spaced 12” in R26 Insulation at 20 Amps in Wall Configuration
WO 2021-260 Copper Clad Aluminum Temperature Profile Study
14 AWG CCA THWN in 1/2" Flexible Metal Conduit, 12" Spacing in R43 Insulation @ 15 Amps in Ceiling Orientation

Average Ambient Temperature = 20°C

Figure 9: AWG 14 THWN CCA in ½” FMC Spaced 12” in R43 Insulation at 15 Amps in Ceiling Configuration

Note: The load bank was cycled on/off prior to test start, therefore temperature at the beginning of the test was above ambient.
Figure 10: AWG 14 THWN CCA in ½” FMC Spaced 12” in R26 Insulation at 15 Amps in Wall Configuration
Appendix A: Calibration Certificates
Instrument Information:
Manufacturer: Fluke
Model Number: 336
Description: Clamp Meter, AC / DC
Asset Number: 189
Serial Number: 88307992
PO Number: 4503214824


This instrument has been calibrated using primary or secondary standards whose calibration is traceable to the International System of Units (SI) through the National Institute of Standards and Technology (NIST) or applicable ASTM specification number for hardness testing equipment. Some measurements are traceable to natural, physical constants, consensus standards, or ratio measurement.

The reported expanded measurement uncertainty is based on a standard uncertainty multiplied by a coverage factor of k=2, providing a confidence level of approximately 95%. This calibration certificate may contain data that is not covered by the Scope of Accreditation. The unaccredited test points, where applicable, are indicated by an asterisk (*), or confined to clearly marked sections. Functional tests are not accredited. The expanded measurement uncertainty is not considered when determining in-tolerance or out-of-tolerance conditions. Results are reviewed, if applicable, to establish where any measurement results exceeded the stated calibration tolerance and to communicate results by means of this certificate.

All calibrations are performed in accordance with the ATS Quality Manual QM1, Rev. 18, dated 10/16/20. Applied Technical Services, Inc's Quality System complies with the applicable requirements of ANSI/NCSL Z540-1, ISO 9001:2015, 10CFR50 Appendix B, 10CFR Part 21, and ISO/IEC 17025:2017. The reported data is valid only at the time of the test and related only to the item calibrated. Calibration due dates appearing on this certificate and calibration label are determined by the client and do not imply continued conformance to specifications. This certificate shall not be reproduced except in full, without written permission of Applied Technical Services, Inc.

Technical Remarks:

Calibrated By: Taylor, Collin A

Calibration Equipment Utilized

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<td>5500A/COIL</td>
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<th>Out of Tolerance</th>
<th>As Left</th>
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<td>20.0 V @ 50 Hz</td>
<td>10.0 V ± 0.5 V (EMV 50 mV)</td>
<td>20.0 V ± 0.5 V (EMV 50 mV)</td>
<td>Same</td>
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<tr>
<td>DC Voltage Accuracy</td>
<td>20.0 V</td>
<td>10.0 V ± 0.5 V (EMV 50 mV)</td>
<td>20.0 V ± 0.5 V (EMV 50 mV)</td>
<td>Same</td>
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<tr>
<td>Continuity Test: Audible Tone</td>
<td>25 Ohm</td>
<td>25 Ohm ± 0.5 Ohm (EMV 25 mOhm)</td>
<td>25 Ohm ± 0.5 Ohm (EMV 25 mOhm)</td>
<td>Same</td>
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<tr>
<td>Resistance Accuracy</td>
<td>600.0 Ohm</td>
<td>600.0 Ohm ± 0.5 Ohm (EMV 600 mOhm)</td>
<td>600.0 Ohm ± 0.5 Ohm (EMV 600 mOhm)</td>
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### Calibration Data

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<td>6000 Ohm</td>
<td>6000 to 6006 Ohm [EMU 610 mOhm]</td>
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<td>AC Current Accuracy</td>
<td>20.0 A @ 50 Hz</td>
<td>19.1 to 20.9 A [EMU 0.37 A]</td>
<td>20.1</td>
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<td>200.0 A @ 50 Hz</td>
<td>195.5 to 204.5 A [EMU 2 A]</td>
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<td>500.0 A @ 50 Hz</td>
<td>489.5 to 510.5 A [EMU 3.7 A]</td>
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<td>600.0 A @ 50 Hz</td>
<td>687.5 to 612.5 A [EMU 4.3 A]</td>
<td>601.3</td>
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<td>INRUSH Verification</td>
<td>250.0 A @ 60 Hz</td>
<td>245.6 to 255.6 A [EMU 2.3 A]</td>
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<td>DC Current Accuracy</td>
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<td>-0.5 to 0.5 A [EMU 58 mA]</td>
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<td>20.0 A</td>
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<td>20.0 A</td>
<td>-20.0 to -19.1 A [EMU 0.25 A]</td>
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<td>600.0 A</td>
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<td>-612.5 to -587.5 A [EMU 3.5 A]</td>
<td>-601.0</td>
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End Of Report
Certificate of Calibration

Certificate #3019662

Customer:
Southwire Company - D.B. Cofer
D.B. Cofer Technology Center
111 Development Drive
Carrollton, GA 300119

Calibration Location:
Southwire Company - D.B. Cofer
D.B. Cofer Technology Center
111 Development Drive
Carrollton, GA 300119

Instrument Information:
Manufacturer: Graphitec
Model Number: GL640
Description: Data Acquisition Unit - Temperature
Asset Number: 943
Serial Number: C61215753
PO Number: 4503214824


This instrument has been calibrated using primary or secondary standards whose calibration is traceable to the International System of Units (SI) through the National Institute of Standards and Technology (NIST) or applicable ASTM specification number for hardness testing equipment. Some measurements are traceable to natural, physical constants, consensus standards, or ratio type measurements.

The reported expanded measurement uncertainty is based on a standard uncertainty multiplied by a coverage factor of k=2, providing a confidence level of approximately 95%. This calibration certificate may contain data that is not covered by the Scope of Accreditation. The unaccredited test points, where applicable, are indicated by an asterisk (*), or confined to clearly marked sections. Functional tests are not accredited. The expanded measurement uncertainty is not considered when determining in-tolerance or out-of-tolerance conditions. Results are reviewed, if applicable, to establish where any measurement results exceed the stated calibration tolerance and to communicate results by means of this certificate.

All calibrations are performed in accordance with the ATS Quality Manual, Rev. 18, dated 10/16/20. Applied Technical Services, Inc.'s Quality System complies with the applicable requirements of ANSI/NCSL Z540-1, ISO 9001:2015, 10 CFR 50 Appendix B, 10 CFR Part 21, and ISO/IEC 17025:2017. The reported data is valid only at the time of the test and related only to the item calibrated. Calibration due dates appearing on this certificate and calibration label are determined by the client and do not imply continued conformance to specifications. This certificate shall not be reproduced except in full, without written permission of Applied Technical Services, Inc.

Technical Remarks:

Calibrated By: J. Paget, Aaron J.
Calibration Tech

Calibration Equipment Utilized

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<tr>
<th>Standard I.D.</th>
<th>Mfg.</th>
<th>Model No.</th>
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<th>Serial</th>
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<td>5522A</td>
<td>Calibrator, Multi-Function</td>
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Calibration Data

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<tr>
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<td>50.00 °C</td>
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<td>CH. 5</td>
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### Calibration Data

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<td>CH. 13</td>
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<tr>
<td>CH. 17</td>
<td>50.00 °C</td>
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<td>200.20</td>
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End Of Report

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Test Number: 3012962  Asset Number: 949  Desc: Graphitec / GL640  Data Acquisition Unit - Temperature

Applied Technical Services
1049 Triad Court
Marietta, GA 30060
Phone 770 423-1408  www.atslab.com

ATS 501, 10/20  Issue date: 02-Jun-2021  Batch Number: 2398705

WO 2021-260 Temperature Study of Copper-Clad Aluminum 14/2 NM-B  Page 21 of 37
Applied Technical Services
Certificate of Calibration
Certificate #3019509

Customer:
Southwire Company - D.B.Cofe
D.B. Cofer Technology Center
111 Development Drive
Carrollton, GA 30119

Calibration Location:
Southwire Company - D.B.Cofe
D.B. Cofer Technology Center
111 Development Drive
Carrollton, GA 30119

Instrument Information:
Manufacturer: Fluke
Model Number: 289
Description: Multimeter, Digital - Handheld
Asset Number: 267
Serial Number: 10140030
PO Number: 4503214624


This instrument has been calibrated using primary or secondary standards whose calibration is traceable to the International System of Units (SI) through the National Institute of Standards and Technology (NIST) or applicable ASTM specification number for hardness testing equipment. Some measurements are traceable to natural, physical constants, consensus standards, or ratio type measurements. The reported expanded measurement uncertainty is based on a standard uncertainty multiplied by a coverage factor of k=2, providing a confidence level of approximately 95%. This calibration certificate may contain data that is not covered by the Scope of Accreditation. The unaccredited test points, where applicable, are indicated by an asterisk (*), or confined to clearly marked sections. Functional tests are not accredited. The expanded measurement uncertainty is not considered when determining in-tolerance or out-of-tolerance conditions. Results are reviewed, if applicable, to establish where any measurement results exceeded the stated calibration tolerance and to communicate results by means of this certificate.

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Technical Remarks:

Calibrated By: Taylor, Collin A
Calibration Tech

Calibration Equipment Utilized

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Calibration Data

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<th>CALIBRATION TOLERANCE</th>
<th>As Found</th>
<th>As Left</th>
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</thead>
<tbody>
<tr>
<td>DC mV: 50mV Range: REL Offset On</td>
<td>0.000 mV</td>
<td>-0.020 to 0.020 mV [EMU 1.2 µV]</td>
<td>0.001</td>
<td>Same</td>
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<tr>
<td>DC mV: 50mV Range: REL Offset Off</td>
<td>0.025 mV</td>
<td>0.000 to 0.045 mV [EMU 1.2 µV]</td>
<td>0.027</td>
<td>Same</td>
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<tr>
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<td>-0.025 mV</td>
<td>-0.045 to -0.005 mV [EMU 1.2 µV]</td>
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<td>50.000 mV</td>
<td>49.955 to 50.045 mV [EMU 2.1 µV]</td>
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<tr>
<td>500mV Range: Rel Off</td>
<td>500.00 mV</td>
<td>499.85 to 500.15 mV [EMU 9.5 µV]</td>
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<td>-250.00 mV</td>
<td>-250.08 to -249.92 mV [EMU 8.3 µV]</td>
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<td>mV DC/AC: 500mV Range</td>
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<td>49.97 to 50.03 mV [EMU 6.1 µV]</td>
<td>49.99</td>
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<tr>
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<td>250.00 mV @ 35 kHz</td>
<td>237.10 to 262.90 mV [EMU 96 µV]</td>
<td>248.33</td>
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<td>-0.10 to 0.10 Ohm [EMU 5.9 mOhm]</td>
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<td>0.20 Ohm</td>
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<td>499.65 to 500.35 Ohm [EMU 17 mOhm]</td>
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<td>5.0000 kOhm</td>
<td>4.9973 to 5.0027 kOhm [EMU 170 mOhm]</td>
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<td>49.973 to 50.027 kOhm [EMU 1.7 Ohm]</td>
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<td>500.000 kOhm</td>
<td>499.60 to 500.40 kOhm [EMU 19 Ohm]</td>
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<td>5.0000 MOhm</td>
<td>4.9921 to 5.0079 MOhm [EMU 0.17 Ohm]</td>
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<tr>
<td>30 MOhm Range</td>
<td>30.000 MOhm</td>
<td>29.546 to 30.454 MOhm [EMU 10 kOhm]</td>
<td>29.904</td>
<td>Same</td>
</tr>
<tr>
<td>500 MOhm Range</td>
<td>300.0 MOhm</td>
<td>275.6 to 324.2 MOhm [EMU 1 MOhm]</td>
<td>293.3</td>
<td>Same</td>
</tr>
<tr>
<td>AG mV: 50mV Range</td>
<td>5.000 mV @ 20Hz</td>
<td>4.997 to 5.0035 mV [EMU 10 mV]</td>
<td>4.973</td>
<td>Same</td>
</tr>
<tr>
<td>AC mV: 50mV Range</td>
<td>50.000 mV @ 60Hz</td>
<td>48.210 to 51.790 mV [EMU 72 mV]</td>
<td>49.580</td>
<td>Same</td>
</tr>
<tr>
<td>VAC: 5V Range</td>
<td>0.1000 V @ 60 Hz</td>
<td>0.0952 to 0.1048 V [EMU 62 mV]</td>
<td>0.1023</td>
<td>Same</td>
</tr>
<tr>
<td>VAC: 50V Range</td>
<td>0.5000 V @ 50 Hz</td>
<td>0.4940 to 0.5055 V [EMU 150 mV]</td>
<td>0.4965</td>
<td>Same</td>
</tr>
<tr>
<td>VAC, Hz (% Duty Cycle) 5 Vpp @ 50Hz</td>
<td>15.00 %</td>
<td>4.90 to 25.10 %</td>
<td>23.18</td>
<td>Same</td>
</tr>
<tr>
<td>VAC, 50V Range</td>
<td>14.450 V @ 100 Hz</td>
<td>15.024</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>VAC, Lo Pass 500V Range</td>
<td>50.00 V @ 60 Hz</td>
<td>48.60 to 51.40 V [EMU 13 mV]</td>
<td>50.00</td>
<td>Same</td>
</tr>
<tr>
<td>ACV: 500V Range</td>
<td>50.000 V @ 1k Hz</td>
<td>0.00 V to 8.00 V</td>
<td>0.00</td>
<td>Same</td>
</tr>
<tr>
<td>DCV: 5V Range</td>
<td>0.000 V</td>
<td>0.00 V</td>
<td>0.00</td>
<td>Same</td>
</tr>
<tr>
<td>DCV: 50V Range</td>
<td>0.1940 V @ 5kHz</td>
<td>0.2002</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>DCV: 100V Range</td>
<td>0.5000 V @ 2kHz</td>
<td>1.9994</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>ACV: 4Vpp Sq Wave +1V Offset</td>
<td>2.0000 V @ 2 kHz</td>
<td>2.183 to 2.437 V [EMU 680 μV]</td>
<td>2.183</td>
<td>Same</td>
</tr>
<tr>
<td>Capacitance</td>
<td>5.00 nF</td>
<td>4.90 to 5.10 nF [EMU 23 μF]</td>
<td>4.92</td>
<td>Same</td>
</tr>
<tr>
<td>Diode Test: 3.5kOhm Input</td>
<td>2.0000 V</td>
<td>2.0000 to 3.1000 V [EMU 63 μV]</td>
<td>2.8900</td>
<td>Same</td>
</tr>
<tr>
<td>Diode Test: 0.00mV Input</td>
<td>0.0000 V</td>
<td>Pass/Fail</td>
<td>PASS</td>
<td>Same</td>
</tr>
<tr>
<td>Diode Test: Rel. Offset</td>
<td>0.200 Ohm</td>
<td>0.180 to 0.220 Ohm [EMU 1.2 mOhm]</td>
<td>0.194</td>
<td>Same</td>
</tr>
<tr>
<td>@ 50 Ohm Range</td>
<td>50.00 Ohm</td>
<td>49.905 to 50.095 Ohm [EMU 2.9 mOhm]</td>
<td>50.001</td>
<td>Same</td>
</tr>
<tr>
<td>μA DC: 500μA Range</td>
<td>500.00 μA @ 60 Hz</td>
<td>496.80 to 503.20 μA [EMU 0.65 μA]</td>
<td>499.56</td>
<td>Same</td>
</tr>
<tr>
<td>μA AC: 500μA Range</td>
<td>500.00 μA @ 30 Hz</td>
<td>492.85 to 507.15 μA [EMU 5.6 μA]</td>
<td>498.08</td>
<td>Same</td>
</tr>
<tr>
<td>μA DC: 1kHz Range</td>
<td>5000.0 μA</td>
<td>4996.0 to 5004.0 μA [EMU 0.75 μA]</td>
<td>5000.3</td>
<td>Same</td>
</tr>
<tr>
<td>mA DC: 50mA Range</td>
<td>4.000 mA @ 20Hz</td>
<td>3.940 to 4.060 mA [EMU 5.6 μA]</td>
<td>3.979</td>
<td>Same</td>
</tr>
<tr>
<td>mA AC: 50mA Range</td>
<td>30.000 mA @ 30Hz</td>
<td>29.375 to 30.625 mA [EMU 120 μA]</td>
<td>29.922</td>
<td>Same</td>
</tr>
<tr>
<td>mA DC: 400mA Range</td>
<td>400.00 mA</td>
<td>397.55 to 402.45 mA [EMU 300 μA]</td>
<td>400.05</td>
<td>Same</td>
</tr>
<tr>
<td>mA DC: 50mA Range</td>
<td>0.100 mA</td>
<td>0.100 to 0.110 mA [EMU 0.58 μA]</td>
<td>0.098</td>
<td>Same</td>
</tr>
<tr>
<td>mA DC: 400mA Range</td>
<td>50.000 mA</td>
<td>49.905 to 50.095 mA [EMU 7.5 μA]</td>
<td>50.001</td>
<td>Same</td>
</tr>
<tr>
<td>mA DC: 400mA Range</td>
<td>399.38 to 400.62 mA [EMU 120 μA]</td>
<td>399.97</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Temperature: Type K</td>
<td>0.0 °C</td>
<td>-1.0 to 1.0 °C [EMU 0.17 °C]</td>
<td>1.0</td>
<td>Same</td>
</tr>
<tr>
<td>Temperature: Type K</td>
<td>100.0 °C</td>
<td>0.0 to 102.0 °C [EMU 0.17 °C]</td>
<td>101.5</td>
<td>Same</td>
</tr>
</tbody>
</table>
## Calibration Data

<table>
<thead>
<tr>
<th>FUNCTION TESTED</th>
<th>Nominal Value</th>
<th>CALIBRATION TOLERANCE</th>
<th>As Found</th>
<th>Out of Spec</th>
<th>As Left</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>989.0 to 1011.0 °C [EMU 0.27 °C]</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Audible Tone from Length of Leads</td>
<td>1000.0 °C</td>
<td>1001.7</td>
<td>Same</td>
<td>Same</td>
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<tr>
<td></td>
<td>25.0 Ohm</td>
<td>PASS/FAIL</td>
<td>PASS</td>
<td>Same</td>
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</tr>
</tbody>
</table>

**End Of Report**
**Applied Technical Services**

**Certificate of Calibration**

**Certificate #3019603**

**Customer:**
Southwire Company - D.B.Cofer
D.B.Cofer Technology Center
111 Development Drive
Carrollton, GA 30119

**Calibration Location:**
Southwire Company - D.B.Cofer
D.B.Cofer Technology Center
111 Development Drive
Carrollton, GA 30119

**Instrument Information:**
Manufacturer: Fluke
Model Number: 789
Description: Process Meter
Asset Number: 679
Serial Number: 25200003
PO Number: 4503214624

**Calibration Information/Results:**
- **As Found Condition:** In Tolerance
- **Action Taken / As Left:** In Tolerance - No Adjustment
- **Temperature:** 73°F
- **Humidity:** 53% RH
- **Calibration Date:** 01-Jun-2021
- **Calibration Due Date:** 01-Jun-2022
- **Calibration Interval:** 12 Months

**Calib. Procedure:** ATS-1040 Rev 2: Calibration of Handheld Digital Multimeters

This instrument has been calibrated using primary or secondary standards whose calibration is traceable to the International System of Units (SI) through the National Institute of Standards and Technology (NIST) or applicable ASTM specification number for hardness testing equipment. Some measurements are traceable to natural, physical constants, consensus standards, or ratio type measurements.

The reported expanded measurement uncertainty is based on a standard uncertainty multiplied by a coverage factor of k=2, providing a confidence level of approximately 95%. This calibration certificate may contain data that is not covered by the Scope of Accreditation. The unaccredited test points, where applicable, are indicated by an asterisk (*), or confined to clearly marked sections. Functional tests are not accredited. The expanded measurement uncertainty is not considered when determining in-tolerance or out-of-tolerance conditions. Results are reviewed, if applicable, to establish where any measurement results exceed the stated calibration tolerance and to communicate results by means of this certificate.

All calibrations are performed in accordance with the ATS Quality Manual QM1, Rev. 18, dated 10/16/20. Applied Technical Services, Inc.'s Quality System complies with the applicable requirements of ANSI/NCSL Z540-1, ISO 9001:2015, 10CFR50 Appendix B, 10CFR Part 21, and ISO/IEC 17025:2017. The reported data is valid only at the time of the test and related only to the item calibrated. Calibration due dates appearing on this certificate and calibration label are determined by the client and do not imply continued conformance to specifications. This certificate shall not be reproduced except in full, without written permission of Applied Technical Services, Inc.

**Technical Remarks:**

**Calibrated By:** Taylor, Collin A

**Calibration Equipment Utilized**

<table>
<thead>
<tr>
<th>Standard L.D. Mfg.</th>
<th>Model No.</th>
<th>Description</th>
<th>Serial</th>
<th>Cal. Date</th>
<th>Due Date</th>
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</thead>
<tbody>
<tr>
<td>ATS-04852 Fluke</td>
<td>5522A/1G</td>
<td>Calibrator, Multi-Function</td>
<td>2034901</td>
<td>02/03/2021</td>
<td>02/03/2022</td>
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<tr>
<td>ATS-4124 Agilent Technologies</td>
<td>344O1A Multimeter, Digital - Benchtop</td>
<td>3146A21255</td>
<td>10/07/2020</td>
<td>10/07/2021</td>
<td></td>
</tr>
</tbody>
</table>

**Calibration Data**

<table>
<thead>
<tr>
<th>FUNCTION TESTED</th>
<th>Nominal Value</th>
<th>CALIBRATION TOLERANCE</th>
<th>As Found</th>
<th>Out of Tol</th>
<th>As Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>400mV Range</td>
<td>100.0 mV @60Hz</td>
<td>99.7 to 101.1 mV [EMU 62 µV]</td>
<td>99 mV</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>300.0 mV @60Hz</td>
<td>297.5 to 302.5 mV [EMU 77 µV]</td>
<td>299.9</td>
<td>Same</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4V Range</td>
<td>1.000 V @60Hz</td>
<td>0.991 to 1.009 V [EMU 610 µV]</td>
<td>0.999</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>2.000 V @60Hz</td>
<td>1.984 to 2.018 V [EMU 680 µV]</td>
<td>1.998</td>
<td>Same</td>
<td>Same</td>
<td></td>
</tr>
<tr>
<td>3.000 V @60Hz</td>
<td>2.977 to 3.023 V [EMU 770 µV]</td>
<td>2.999</td>
<td>Same</td>
<td>Same</td>
<td></td>
</tr>
<tr>
<td>40V Range</td>
<td>10.00 V @60Hz</td>
<td>9.91 to 10.09 V [EMU 61 mV]</td>
<td>9.99</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>30.00 V @60Hz</td>
<td>29.77 to 30.23 V [EMU 7.7 mV]</td>
<td>29.99</td>
<td>Same</td>
<td></td>
<td></td>
</tr>
<tr>
<td>400V Range</td>
<td>100.0 V @60Hz</td>
<td>99.1 to 100.9 V [EMU 61 mV]</td>
<td>99.9</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>300.0 V @60Hz</td>
<td>297.7 to 302.3 V [EMU 83 mV]</td>
<td>299.9</td>
<td>Same</td>
<td>Same</td>
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</table>

Applied Technical Services
1049 Triad Court
Marietta, GA 30062
Phone 770 423-1400
www.atslab.com

ATS 501, 10/20
Issue date: 01-Jun-2021
Batch Number: 2398705
## Calibration Data

<table>
<thead>
<tr>
<th>FUNCTION TESTED</th>
<th>Nominal Value</th>
<th>CALIBRATION TOLERANCE</th>
<th>As Found</th>
<th>Out of TOL</th>
<th>As Left</th>
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</thead>
<tbody>
<tr>
<td>1000V Range</td>
<td>100 V @60Hz</td>
<td>97 to 103 V [EMU 580 mV]</td>
<td>100</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>800 V @60Hz</td>
<td>792 to 808 V [EMU 630 mV]</td>
<td>801</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Frequency Accuracy: 199.9 Hz Range</td>
<td>100.00 Hz @ 5 V</td>
<td>99.99 to 100.01 Hz [EMU 5.6 mHz]</td>
<td>100.00</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>1000.0 Hz @ 5 V</td>
<td>999.9 to 1001.0 Hz [EMU 58 mHz]</td>
<td>1000.0</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>19.989 kHz Range</td>
<td>9.999 to 10.011 kHz [EMU 58 mHz]</td>
<td>9.999</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>DC Voltage Accuracy: 4 V Range</td>
<td>1.000 V</td>
<td>0.998 to 1.002 V [EMU 580 μV]</td>
<td>1.000</td>
<td>Same</td>
<td>Same</td>
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<tr>
<td></td>
<td>3.000 V</td>
<td>2.996 to 3.004 V [EMU 580 μV]</td>
<td>3.000</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>40 V Range</td>
<td>10.00 V</td>
<td>9.98 to 10.02 V [EMU 5.8 mV]</td>
<td>10.00</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>30.00 V</td>
<td>29.96 to 30.04 V [EMU 5.8 mV]</td>
<td>30.00</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>400 V Range</td>
<td>100.0 V</td>
<td>96.8 to 100.2 V [EMU 58 mV]</td>
<td>100.0</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>300.0 V</td>
<td>299.9 to 300.4 V [EMU 58 mV]</td>
<td>300.0</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>1000 V Range</td>
<td>100 V</td>
<td>99 to 101 V [EMU 580 mV]</td>
<td>100</td>
<td>Same</td>
<td>Same</td>
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<tr>
<td></td>
<td>800 V</td>
<td>798 to 802 V [EMU 580 mV]</td>
<td>800</td>
<td>Same</td>
<td>Same</td>
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<tr>
<td>400 mV Range</td>
<td>100.0 mV</td>
<td>99.7 to 100.3 mV [EMU 58 μV]</td>
<td>100.1</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>300.0 mV</td>
<td>299.5 to 300.5 mV [EMU 58 μV]</td>
<td>300.0</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Resistance Accuracy: 400 Ohm Range</td>
<td>120.0 Ohm</td>
<td>119.5 to 120.4 Ohm [EMU 58 Ohm]</td>
<td>120.0</td>
<td>Same</td>
<td>Same</td>
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<tr>
<td></td>
<td>300.0 Ohm</td>
<td>299.2 to 300.8 Ohm [EMU 59 mOhm]</td>
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<td>Same</td>
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<tr>
<td>4 kOhm Range</td>
<td>1.200 kOhm</td>
<td>1.197 to 1.203 kOhm [EMU 580 mOhm]</td>
<td>1.200</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>3.000 kOhm</td>
<td>2.993 to 3.007 kOhm [EMU 590 mOhm]</td>
<td>3.000</td>
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<td>Same</td>
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<tr>
<td>40 kOhm Range</td>
<td>12.00 kOhm</td>
<td>11.97 to 12.03 kOhm [EMU 58 Ohm]</td>
<td>12.0</td>
<td>Same</td>
<td>Same</td>
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<tr>
<td></td>
<td>30.00 kOhm</td>
<td>29.93 to 30.07 kOhm [EMU 5.9 Ohm]</td>
<td>29.99</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>400 kOhm Range</td>
<td>120.0 kOhm</td>
<td>119.7 to 120.3 kOhm [EMU 58 Ohm]</td>
<td>120.0</td>
<td>Same</td>
<td>Same</td>
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<tr>
<td></td>
<td>200.0 kOhm</td>
<td>199.5 to 200.5 kOhm [EMU 58 Ohm]</td>
<td>200.0</td>
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<tr>
<td>4 MOhm Range</td>
<td>1.200 MOhm</td>
<td>1.193 to 1.207 MOhm [EMU 0.59 OHm]</td>
<td>1.200</td>
<td>Same</td>
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<tr>
<td></td>
<td>3.000 MOhm</td>
<td>2.987 to 3.013 MOhm [EMU 0.61 OHm]</td>
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<td>Same</td>
<td>Same</td>
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<tr>
<td>40 MOhm Range</td>
<td>12.00 MOhm</td>
<td>11.97 to 12.33 MOhm [EMU 0.8 OHm]</td>
<td>12.00</td>
<td>Same</td>
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<tr>
<td></td>
<td>30.00 MOhm</td>
<td>29.22 to 30.78 MOhm [EMU 12.0 OHm]</td>
<td>30.00</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>DC Current Accuracy: 30 mA Range</td>
<td>4.000 mA</td>
<td>3.996 to 4.004 mA [EMU 0.87 μA]</td>
<td>4.000</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>12.000 mA</td>
<td>11.992 to 12.008 mA [EMU 1.6 μA]</td>
<td>12.000</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>20.000 mA</td>
<td>19.988 to 20.012 mA [EMU 2.3 μA]</td>
<td>19.999</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>1 A Range</td>
<td>0.100 A</td>
<td>0.098 to 0.102 A [EMU 580 μA]</td>
<td>0.100</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>0.400 A</td>
<td>0.396 to 0.402 A [EMU 590 μA]</td>
<td>0.400</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>AC Current Accuracy: 1 A Range</td>
<td>0.100 A @ 60 Hz</td>
<td>0.097 to 0.103 A [EMU 580 μA]</td>
<td>0.100</td>
<td>Same</td>
<td>Same</td>
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<td></td>
<td>0.400 A @ 60 Hz</td>
<td>0.394 to 0.406 A [EMU 650 μA]</td>
<td>0.401</td>
<td>Same</td>
<td>Same</td>
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<tr>
<td>Current Source: DC mA Test</td>
<td>4.000 mA</td>
<td>3.998 to 4.004 mA [EMU 0.59 μA]</td>
<td>3.999</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>12.000 mA</td>
<td>11.992 to 12.008 mA [EMU 1.1 μA]</td>
<td>11.999</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>20.000 mA</td>
<td>19.988 to 20.012 mA [EMU 1.3 μA]</td>
<td>20.000</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Loop Power</td>
<td>&gt;30 V</td>
<td>Pass / Fail</td>
<td>PASS</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>250 Ohm Button</td>
<td>&gt;24 V</td>
<td>Pass / Fail</td>
<td>PASS</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Diode Test</td>
<td>2.000 V</td>
<td>1.959 to 2.041 V [EMU 580 μV]</td>
<td>1.999</td>
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**End Of Report**

---

**Test Number:** 30198503  
**Asset Number:** 679  
**Desc. FluXe / 789 / Process Meter:**  
**Applied Technical Services**  
1049 Triad Court  
MARIETTA, GA 30062  
**Phone:** 770 423-1400  
**www.atslab.com**  
**ATS 501, 10/20**  
**Issue date:** 01-Jun-2021  
**Batch Number:** 2398705
Certificate of Conformance

for

Southwire Company
PO Box 4000
Carrollton GA 30112-5050
United States

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<td>TT-K-24-SLE-1000-CAL-3</td>
<td>SPECIAL LIMITS OF ERROR WIRE</td>
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Omega Engineering, Inc. certifies that the items comprising the above order have been manufactured in accordance with all applicable instructions and specifications as published in the relevant Omega Engineering handbook and encyclopedia, as well as on the Omega's website www.omega.com.

Omega Engineering further certifies that unless otherwise specified, all thermocouple base and noble metal materials conform to ANSI/ASTM E 230 (formerly ANSI/ISA MC 96.1), and most RTD sensor resistance vs. temperature characteristics conform to IEC 60751/ASTM-E-1137.

Certified By:  
David Lucas, Quality Coordinator  

Date: 1/15/2018
Appendix B: Pictures of Wall/Ceiling Apparatus
Figure B.1: Apparatus in Ceiling Configuration with Insulation
Figure B.2: Thermocouple Installed in NM-B Sample
Figure B.3: Thermocouple Installed in NM-B Sample
Figure B.4: Thermocouple Installed in Electrical Box
Figure B.5: Apparatus in Wall Configuration with Sheetrock Doors Closed
Figure B.6: Flexible Metal Conduit Installed in Apparatus
Figure B.7: Breaker Box
Figure B.8: Ampmeter, Data Logger, and Load Bank
Figure B.9: NM-B Sample Installed in Apparatus in Ceiling Configuration
Exhibit 9
Southwire’s Response to Comments submitted by Chuck Mello (Consultant to the BiMetallic Association)

Southwire Temperature Study of 14 AWG Copper-Clad Aluminum Products
Initial Findings

These comments (in black text) are from Chuck Mello - a consultant to the BiMetallic Association who has a vested interest in the rejection of the Southwire test report.

Report Review Comments - Details

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<th>Item</th>
<th>Comment</th>
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<tr>
<td>1</td>
<td>Noted that the report is not actually signed by the identified authors</td>
</tr>
<tr>
<td></td>
<td><strong>Southwire Response:</strong> The final version of the report is signed.</td>
</tr>
<tr>
<td>2</td>
<td>The Southwire testing was unilateral testing by the copper industry stakeholders. The testing facility used was not an independent laboratory but is owned and operated by Southwire. All testing from the Bimetallics Task Group was developed, reviewed and accepted by the Bimetallics Task Group. The Bimetallics Task Group was composed of representatives from a broad spectrum of industry stakeholders including the copper wire industry. Testing was completed in a qualified laboratory independent of any wire or cable manufacturers.</td>
</tr>
<tr>
<td></td>
<td><strong>Southwire Response:</strong> Testing was conducted at Southwire’s D.B. Cofer Technology Center (CTC), which is an ISO 17025 accredited lab by A2LA. Among other things, ISO 17025 ensures that there is a strong focus by the lab on generating accurate and unbiased data/analysis. In addition, the CTC is a certified participant in UL’s Client Test Data Program and CSA’s Supervised Manufacturer’s Testing for Certification program. Both programs require annual audits of the CTC’s labs, including our quality management system and lab practices. Testing has also been performed in two independent laboratories and the test data from these laboratories can be reviewed by the Code Making Panel in parallel with the test data submitted by Southwire.</td>
</tr>
<tr>
<td></td>
<td>In fact, the testing submitted earlier by the BiMetallic Association was performed at a manufacturer’s test facility (Eaton) rather than a separate laboratory whose business...</td>
</tr>
</tbody>
</table>
focus is to provide independent testing to the electrical industry. While Eaton may not be a wire or cable manufacturer, as a manufacturer of products that interface with wire and cable products it cannot be assumed they are a disinterested third party with no interest in the testing outcome.

While the test procedure was approved by the BiMetallics Task Group, the actual testing is not “from the BiMetallics Task Group”. The testing is from the BiMetallic Association which is an organization of copper-clad aluminum industry stakeholders. The BiMetallics Task Group was established via a special action by the NFPA and while the test report was accepted by the task group, that does not establish the test report as being owned and promoted by that task group.

Product standards have testing done in open air within an environmentally controlled laboratory with set ambient conditions, environmental chambers, or where the environment has specific measurements to document the environmental conditions. Wire testing as well as connected device testing is done in open air for the evaluation and listing processes.

Southwire Response: While it is true that existing product standards do not include testing within insulation, that does not invalidate this testing - nor does it mean that such testing should not be undertaken. Real-world performance of these products within common residential and commercial installation environments is vitally important to understand the safety of allowing the use of smaller conductor sizes (regardless of conductor material) in 120V power applications.

“A standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes, and services are fit for their purpose.” - International Standards Organization, ISO

Product standards are designed for the purpose of certifying a product as fit for its purpose and not to fully address the safe installation of that product. The prior testing by the BiMetallic Association assessed compliance with existing product standards in an open-air environment and did not address the performance of 14 AWG CCA products in real-world installation environments. Electrical Codes such as the NEC govern the safe installation of these products and prescribe the parameters of their safe usage. Conductor/cable installation methods and amperages are dictated by the NEC, not the product standards.
| 4 | There are no adopted industry standards for testing in insulation which opens many questions as to how the testing procedure was established, how the testing should be conducted, and under what controls. The summary states “the overall procedure and test apparatus were customer defined and not part of CTC’s ISO 17025 scope of accreditation”

The calibration information indicates the thermocouples were made on site not calibrated to UL requirements or purchased from UL verified vendor with calibration certificate. The thermocouples used for the Bimetallics Task Group testing were obtained from the UL verified source and had certificates of calibration traceable to national standards provided.

**Southwire Response:** Industry experts from Southwire, with inputs from electricians and other companies in the electrical industry, developed the testing procedure to show the performance in a simulated real-world installation. See Comment 6 for additional discussion regarding the testing.

Test reports from independent testing laboratories are also available to the Code Making Panel. Each test lab developed their own test rig so there are variations in product installation – however real-world installations can vary considerably and still be NEC compliant. By reviewing multiple test reports, the Code Making Panel can assess the impact of the differing test installations.

Thermocouples were made from Omega special-limit-of-error thermocouple wire. The certificate of compliance is now included in the report. Thermocouples were made using UL document 00-OP-C0037 v8.0 as a procedure – indicating UL’s acceptance of this method for the use of thermocouples in testing. This method of thermocouple construction and the accompanying verification of performance has been used extensively in the industry.

Link to UL 00-OP-C0037 v8.0:


| 5 | Any testing performed under these customer defined procedures should have been completed and documented with both the copper and verified copper-clad aluminum to show comparison data.

All testing submitted by the Bimetallics Task Group showed direct comparison of copper-clad aluminum with like rated (60ºC ampacities) copper.

**Southwire Response:** The proposed change to the NEC is for the inclusion of 14 AWG CCA conductors at certain ampacities. 14 AWG CU conductors have been in the NEC for many decades and have an established track record in millions of homes across the USA. The question at hand is the safe use of 14 AWG CCA conductors in real-
world residential, commercial, and industrial installations. 14 AWG CCA conductors are a newly proposed product with no installation history – compared to 14 AWG CU conductors which have a very long history of successful use in millions of residential, commercial, and industrial applications. Given this history, there was no need to test 14 AWG CU conductors. The burden of proof is on the BiMetallic Association to show that 14 AWG CCA products can be safely used in actual installations at the proposed ampacities.

And regarding the “verified copper-clad aluminum”, it was only tested in open air in one environmentally controlled laboratory environment at a manufacturer’s testing facility. Has another independent test laboratory “verified” these results?

There are three test reports from three different laboratories submitted for Code Making Panel 6 consideration during the Second Draft stage, not just one as submitted by the BiMetallic Association.
<table>
<thead>
<tr>
<th>Item</th>
<th>Comment</th>
</tr>
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<tbody>
<tr>
<td>6</td>
<td>Statement is made that the test arrangement was “within walls and ceilings/attics that are typical of residential and commercial installations.” The actual test arrangement with NM-B cable and wire in flexible metal conduit was routed back and forth several times over a small area and is not a typical residential or commercial installation. The test set up installation created a “radiator” much like that done for electric ceiling heating or floor radiant heating systems. See the photos provided of the test arrangement. Per the procedure 61 linear feet of NM-B cable was installed into a 58.3 square foot area (wall and ceiling simulation). The 61 feet of cable was routed back and forth at 12” spacing, through ¾ inch holes in end frames, held tight to the end board and then routed parallel to the next cable 12” away. See the figures for the test apparatus setup and photo B9. Procedure for the ceiling configuration indicates the insulation was to be R6.7, R13, and R30. Figures 4 and 5 have results with R43 insulation with back-and-forth wiring at 12” spacing like a radiator – similar to how ceiling heat is installed. See photos B6 and B9. Procedure for the wall configuration indicates the insulation was to be R6.7, R13, and R30. Figures 6 and 7 for results have a R26 insulation with back-and-forth wiring at 12” spacing like a radiator – similar to how ceiling heat is installed. See photos B6 and B9. Southwire Response: The real issue is whether mutual heating of adjacent cables occurred due to the layout of the cables. Did the 12” spacing between adjacent runs impact the test results? We were concerned about that as well and that’s why we conducted testing at multiple spacings to determine whether a 12” spacing was adequate to eliminate the occurrence of mutual heating. From our test report: Comparison testing between adjacent runs of 14/2 CCA NM-B cable were performed to evaluate the possibility of mutual heating between adjacent runs of cables. Tests were performed at 12” spacing and 18” spacing in the ceiling orientation with R43 insulation and 10 Amps. Comparison of the 12” and the 18” spacing data indicated no mutual heating occurred at the 12” spacing.</td>
</tr>
</tbody>
</table>
Testing at 20 amperes (the 90ºC ampacity rating) is 200% of the application rating of 10 amps. No code allowance or practical application allows the current to be applied on a conductor at its 90ºC rating.

The testing completed by the Bimetallics Task Group found at 200% rating the overcurrent device tripped within 2 minutes which is what the UL standard requires. The Bimetallics Task Group testing also showed no adverse temperatures up to the time of the OCPD tripping.

Where does the NEC allow 0 – 2000-volt 90ºC insulated conductors to be applied at the 90ºC (60C rise) rating in conduit. Equipment limits of 60ºC ampacity for 14 AWG – 1 AWG per 110.14(C); 75ºC for 1/0 AWG – 2000 kcmil. A 20-amp OCPD would never be allowed for a 14 AWG conductor, even copper, per 240.4(D)(3).

The procedure indicated test currents of 10, 12, 15 and 20 amps but results shown are only for 10 and 20 amps.

Southwire Response: These amperages were included in the procedure because they were initially considered for testing. The procedure has been revised to reflect the amperages chosen (10, 15, and 20). The test data for 15 Amps has been added to the report.

Since 14 AWG copper-clad aluminum wire is not commercially available, where did the 14 AWG copper-clad aluminum used for this testing come from? No laboratory data was provided to confirm the wire used was 14 AWG, or copper-clad aluminum with an AA8000 aluminum core. All that is provided is the report statement that it was 14 AWG CCA and met ASTM B566.

The Bimetallics Task Group testing had third party witnessed testing documenting the 14 AWG copper-clad aluminum.

Southwire Response: The source of the copper-clad aluminum wire used by Southwire to make 14-2 CCA NM-B Cable and 14 AWG CCA THHN/THWN conductors is considered proprietary information. The wire was specifically procured as ASTM B566 compliant 14 AWG copper-clad aluminum manufactured with 8000 series aluminum alloy core and the manufacturer provided documentation in support of that. Southwire testing confirmed that the conductor material used for testing consisted of an 8000 Series aluminum base metal with an oxygen-free copper cladding that met the UL 1581 direct-current resistance (as required in UL 83 for Thermoplastic Conductors and UL 719 for Nonmetallic-Sheathed Cable) and copper thickness requirements for solid 14 AWG copper-clad aluminum.
<p>| | |</p>
<table>
<thead>
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</tr>
</thead>
</table>
| 9 | ASTM B566, cited in the report, does not specify AA8000 series aluminum for the core so the wire used does not necessarily meet the ASTM B566 standard as stated.  

**Southwire Response:** Correct - ASTM B566 does not restrict the aluminum alloy core to a limited range of the available aluminum alloys. See the response to the comment above.  

ASTM B566 compliant copper-clad aluminum wires made with other aluminum alloys are present in the market and are perhaps more readily available than copper-clad aluminum based upon an 8000 series aluminum alloy. These CCA wire products could be used in the construction of building wire - and there would be no way for an AHJ to know this has happened without laboratory analysis. |
| 10 | The report indicates that in the manufacturing of the wire used for testing there were some manufacturing variations applied. What manufacturer variations were applied?  

**Southwire Response:** As indicated in the test report, the mechanical properties of CCA conductors are different than those of CU conductors (CCA has lower tensile strength for example). This statement was intended to indicate the manufacturing line may have to modify a manufacturing parameter such as line speed to run the CCA conductor without damage (as compared to the manufacture of 14 AWG CU products). Such variations during the manufacturing process are accounted for and do not impact the final construction of the product. I am not aware that any such change in the manufacturing process was actually required – this comment was theoretical in nature. This statement has been revised in the test report to capture the intent more accurately. |
| 11 | The report process indicates the insulation to be used was to be R6.7, R13 and R30. Where is the test data for these insulations? The only data provided was R26 and R43.  

**Southwire Response:** Insulation R-Values of R26 and R43 were used during the testing. These R-Values were obtained by using combinations of R13 and R30 fiberglass insulation. The original listing of elements used in the test procedure includes the individual R13 and R30 insulation products (plus the R6.7 product that was not used). The procedure was changed to reflect this in the test report. |
<p>| 12 | Although provided as a result in the report text, there is no data or figure to show a test that stopped at 47 minutes. There is one test, figure 5 showing a stop at 25 minutes. The report indicated a temperature rise result of 102°C above ambient but this is not shown anywhere in the data provided. |</p>
<table>
<thead>
<tr>
<th></th>
<th>Southwire Response: Continuous data up to approximately 25 minutes was available as shown in the figure. However, the test continued to approximately 47 minutes. The graph has been updated to show the maximum recorded temperature.</th>
</tr>
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</table>
| 13 | Figure 4 [14-2 CCA spaced 12” in R43 insulation at 10 Amps with the ceiling configuration] shows 1 thermocouple (cannot ID which one with black and white photo) above 30ºC, maybe 32ºC rise on ?? ambient, leveling out at 80 minutes. All other thermocouples are showing temperature rise below 30ºC.  

**Southwire Response:** A figure has been added to the report showing the thermocouple layouts. |
| 14 | Test setup information does not show ambient temperature measurement (reference thermocouple -#8 from text) in the area where testing was conducted.  

**Southwire Response:** Testing was conducted in a temperature-controlled lab. The ambient temperature measurement came from a thermocouple exposed to the open air next to the test fixture hooked up to the same data logger as the rest of the thermocouples. |
Exhibit 10
CABLE TECHNOLOGY LABORATORIES

REPORT

EVALUATION OF TEMPERATURE PERFORMANCE
OF 14 AWG COPPER CLAD ALUMINUM CONDUCTOR
IN AN EXPERIMENTAL INSTALLATION

INVESTIGATION PERFORMED FOR

SOUTHWIRE COMPANY LLC

Carrollton, GA

Report No. 21-122
Composed of: Thirty-two (32) pages
Order No. 4503206015 dated 04/30/21
New Brunswick, October 22, 2021

Main Investigators(s)
R. Narayanan
V. Yaroslavskiy

Approved by:
K. Pimlott

This test report shall not be reproduced except in full, without written approval from CTL.
The results reported in this document relate to the tested sample(s) only.
CABLE TECHNOLOGY LABORATORIES

REPORT

EVALUATION OF TEMPERATURE PERFORMANCE
OF 14 AWG COPPER CLAD ALUMINUM CONDUCTOR
IN AN EXPERIMENTAL INSTALLATION

CONTENTS

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<th>Item</th>
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<td>3.0</td>
<td>TEST SETUP, MATERIALS, AND EQUIPMENT USED</td>
<td>3</td>
</tr>
<tr>
<td>4.0</td>
<td>TEST EXECUTION AND RESULTS</td>
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<td>5.0</td>
<td>DISCUSSION AND CONCLUSIONS</td>
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<td>Appendix 1</td>
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625 Jersey Avenue, Unit 14 – P.O. Box 707
New Brunswick, N.J. 08903
Tel: (732) 846-3133
Fax: (732) 846-5531
EVALUATION OF TEMPERATURE PERFORMANCE
OF 14 AWG COPPER CLAD ALUMINUM CONDUCTOR
IN AN EXPERIMENTAL INSTALLATION

1.0 PURPOSE

To report results of laboratory tests evaluating temperature rise of a 14 AWG 8000 Series Copper Clad Aluminum (CCA) cables evaluated in an experimental installation.

2.0 BACKGROUND

This project utilized a non-standardized test program, designed by Southwire request and targeting to evaluate thermal characteristics of a prototype CCA cable in an experimental installation.

The tests were performed on a three-conductor cable (with 2 insulated conductors and 1 bare ground conductor, covered overall with a polymeric jacket, type NM-B), modelling 10 A rated installations, as well as on 2
THHN insulated 14 AWG CCA conductors inserted in a ½ inch Steel Flex Conduit, simulating 15 A and 20 A ratings.

3.0 TEST SETUP, MATERIALS, AND EQUIPMENT USED

The main material used within this project was a prototype of NM-B cable manufactured by Southwire and designated as 14 AWG CCA NM-B. The cable utilized No. 14 AWG CCA conductors and incorporated 2 insulated conductors (rated 90 °C), plus one bare conductor of the same size, all wrapped in paper and covered overall with a polymeric jacket rated 60 °C. Figure 1 illustrates the cable design.

![Cable](image)

*Figure 1: Cable used for testing*

CCA 14 AWG insulated conductors were also used for modelling installations with corrugated metallic conduits. In this case only 2
conductors were pulled into a conduit, Home Depot Catalog #204847339, Model #5502-30-AFC.

A test setup infrastructure, utilized for the project, was built of 4x2 inch wood planks on the side wall and 6x2 inch wood planks on the ceiling, all spaced 16 inches center-to-center. The wall had 0.315 in thick siding sheathing panels attached to the planks; the ceiling was made of a 5/8 in thick 8x4 ft sheetrock board. Owens Corning R13 Kraft Faced Fiberglass Insulation, Home Depot Product Code 314607544 was used on the side wall, while that used in the attic was Owens Corning R38 Kraft Faced Fiberglass Insulation, Home Depot Product Code 315273898.

In addition, Square D panel and circuit breakers rated 10 A, 15 A, or 20 A were employed, as well as Leviton Power Outlets.

Figure 2 illustrates the test setup with the first 50 ft section of 14 AWG CCA NM-B cable installed, prior to application of thermal insulation. The setup with thermal insulation installed is shown in Figure 3.
Figure 2: Test setup; a – overall view; b – attic; c – side wall with breaker panel, power supply, thermocouples, and temperature recorder.
Figure 4 provides a schematic layout of test conductors for the 100 ft test length, which consists of a 50 ft section (on the left), plus two additional 25 ft sections connected in series. The three sections were spliced via power wall outlets. One of the outlets (as appropriate) was also used for connecting the load.

In total, up to 20 T-type thermocouples, Omega model 5TC-GC-T-30-36, were used for temperature measurements at different parts of the
installation. Location of the thermocouples is indicated in Figure 4; their legends are provided in Table 1.

![Diagram of test conductor and location of temperature sensors.]

**Figure 4: Layout of test conductor and location of temperature sensors.**

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<th>Table No. 1 Thermocouple Locations</th>
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</table>

To be noted: ambient temperature was sensed by a thermocouple attached to the side wall, at a remote location, separated at least by 2 ft from the sections heated by the conductors under test.
Special attention was paid to selection and installation of thermocouples, to assure their attachment to the heat dissipating members and reduce heat transfer through their own wires. In particular, thin, No. 30 AWG wire thermocouples were selected\(^1\). In case of the NM-B cable, a short longitudinal slit was made in the jacket and the thermocouple tip was pushed between the insulated conductors for at least 1 inch under the intact jacket. The thermocouple exit from under the jacket was secured with electrical tape wrapping, Figure 5.

\[\text{Figure 5: Thermocouple attached to CCA NM-B cable.}\]

\(^1\) Brand new thermocouples have been used. The following certification from the manufacturer was considered.

Omega Engineering Inc. certifies that the items comprising the above order have been manufactured in accordance with all applicable instructions and specifications as published in the relevant Omega Engineering handbook and encyclopedia, as well as on Omega/s website www.omega.com. Omega Engineering further certifies that unless otherwise specified, all thermocouple base and noble metal materials conform to ANSI/ASTM E 230 (formerly ANSI/ISA MC 96.1), and most RTD sensor resistance vs. temperature characteristics conform to IEC 60751/ASTM-E 1137.
In case of the THHN conductors installed in the metallic conduit, the latter was cut, the ends separated, the thermocouple tip attached to the conductors, wrapped around several times (to reduce heat transfer), the conduit ends brought together and secured, Figure 6.

![Thermocouple attached to CCA conductors in metallic conduit.](image)

A special load approximately 1.6 Ω, capable of dissipating 650 W, was designed, comprising six 10 Ω resistors connected in parallel and mount on copper busbars acting as heat sinks, Figure 7. The load was freely suspended in air, at least 10 ft away from the active test sections and was provided with forced air cooling.
Measurement equipment employed within the project is listed in Table 2.

Table No. 2
Measurement Equipment

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<th>Serial No.</th>
<th>Calibration Valid Through</th>
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<td>08/31/22</td>
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<tr>
<td>Digital multimeter</td>
<td>Klein Tools</td>
<td>MM 2000</td>
<td>0514X-C1</td>
<td>08/31/22</td>
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<td>Graphtec</td>
<td>GL240</td>
<td>C61239231</td>
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<td>C51232900</td>
<td>06/24/22</td>
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<td>Chroma</td>
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<td>616040002852</td>
<td>NA</td>
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</table>

4.0 TEST EXECUTION AND RESULTS

The tests on each cable design (type NM-B or THHN conductors in the metallic conduit) were performed in the following sequence:

- 50 ft section without thermal insulation;
- 50 ft section with insulation, plus 25 ft non-insulated;
- 75 ft insulated, plus 25 ft non-insulated following;
- 100 ft insulated.
Figure 8 illustrates a combination of thermally insulated and bare sections of cable. The example is provided for the CCA NM-B jacketed cable.

Testing on CCA NM-B cable was performed at 10 A. Chroma power supply was employed, providing current stability within ±0.2 A.

Figure 8: Setup with 50 ft of thermally insulated and 25 ft of non-insulated cable.
Testing on CCA insulated conductors inside the metallic conduit was repeated twice: at 15 A and at 20 A. An autotransformer was employed, with the load current regulated and maintained within ±1 A throughout the tests.

Each test was discontinued after temperature stabilization at all locations or after 3 hours of heating (the maximum specified non-continuous use duration), or when the following temperature limits were exceeded:

- 10 A test mode: 60°C absolute temperature or 30°C Rise Over Ambient (ROA);
- 15 A test mode: 75°C absolute temperature or 45°C ROA;
- 20 A test mode: 90°C absolute temperature or 60°C ROA.

Temperatures at all locations involved in a particular test were continuously recorded. Upon completion of the test session, temperature difference between the test object and ambient was calculated and plotted. These temperature profiles are provided in Appendices 1 through 3 for 10 A, 15 A, and 20 A test configurations, respectively.

Table 3 summarizes overall test results indicating that jacketed cable tested at 10 A practically satisfied all test criteria, except for one case where ROA was marginal. In contrast, testing conductors in the metallic conduit, with
thermal insulation applied, rendered negative results after approximately one hour of heating under 15 A load current and ½ hour at 20 A.

Table No. 3
Overall Test Results

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<th>Duration (min)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
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<td>10</td>
<td>120</td>
<td>Temperature stabilized</td>
</tr>
<tr>
<td>14 AWG CCA NM-B, 50 ft with Insulation, 25 ft without Insulation</td>
<td>10</td>
<td>180</td>
<td>Temperature stabilized</td>
</tr>
<tr>
<td>14 AWG CCA NM-B, 25 ft without Insulation</td>
<td>10</td>
<td>180</td>
<td>Temperature stabilized</td>
</tr>
<tr>
<td>14 AWG CCA NM-B, 100 ft with Insulation</td>
<td>10</td>
<td>180</td>
<td>Temperature exceed 30°C ROA by 1 °C</td>
</tr>
<tr>
<td>14 AWG THHN 50 ft Conduit, No Insulation</td>
<td>15</td>
<td>105</td>
<td>Temperature stabilized</td>
</tr>
<tr>
<td>14 AWG THHN 50 ft Conduit with Insulation, 25 ft without Insulation</td>
<td>15</td>
<td>43</td>
<td>Temperature exceeded 45°C ROA</td>
</tr>
<tr>
<td>14 AWG THHN 75 ft Conduit with Insulation, 25 ft without Insulation</td>
<td>15</td>
<td>54</td>
<td>Temperature exceeded 45°C ROA</td>
</tr>
<tr>
<td>14 AWG THHN 100 ft Conduit with Insulation</td>
<td>15</td>
<td>73</td>
<td>Temperature exceeded 45°C ROA</td>
</tr>
<tr>
<td>14 AWG THHN 50 ft Conduit, No Insulation</td>
<td>20</td>
<td>66</td>
<td>Temperature stabilized. 60°C ROA exceeded in some cases</td>
</tr>
<tr>
<td>14 AWG THHN 50 ft Conduit with Insulation, 25 ft without Insulation</td>
<td>20</td>
<td>30</td>
<td>Temperature exceeded 60°C ROA</td>
</tr>
<tr>
<td>14 AWG THHN 75 ft Conduit with Insulation, 25 ft without Insulation</td>
<td>20</td>
<td>21</td>
<td>Temperature exceeded 60°C ROA</td>
</tr>
<tr>
<td>14 AWG THHN 100 ft Conduit with Insulation</td>
<td>20</td>
<td>27</td>
<td>Temperature exceeded 60°C ROA</td>
</tr>
</tbody>
</table>
As an additional check for the test samples integrity, as well as for proper operation of the entire test loop, voltage drop across different parts of the circuit were measured. Table 4 provides data for 10 A and 20 A test modes together with calculated specific resistance of the test cable conductors. Some variation in this characteristic can be noted caused by a number of reasons, like effect of splices and accessories in the loop, temperature variations, deviation from exact section lengths, etc. Nonetheless, no issues with the test loop integrity surfaced.

### Table No. 4

**Voltage Drop and Resistance of Test Loop Sections**

<table>
<thead>
<tr>
<th>Test Configuration</th>
<th>Current A</th>
<th>1st 50 ft section</th>
<th>2nd 25 ft section</th>
<th>3rd 25 ft section</th>
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<tr>
<td></td>
<td></td>
<td>Voltage Drop, V</td>
<td>Resistance mΩ per ft</td>
<td>Voltage Drop, V</td>
</tr>
<tr>
<td>14 AWG CCA NM-B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 ft no insulation</td>
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<tr>
<td>50 ft insulated plus 25 ft without insulation</td>
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<td>3.5</td>
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<td>1.8</td>
</tr>
<tr>
<td>75 ft insulated plus 25 ft without insulation</td>
<td></td>
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<td>3.6</td>
<td>1.7</td>
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<td></td>
<td>3.4</td>
<td>3.4</td>
<td>1.7</td>
</tr>
<tr>
<td>14 AWG CCA In Conduit</td>
<td>20</td>
<td>9.7</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>50 ft no insulation</td>
<td></td>
<td>9.2</td>
<td>4.6</td>
<td>4.8</td>
</tr>
<tr>
<td>50 ft insulated plus 25 ft without insulation</td>
<td></td>
<td>9.1</td>
<td>4.6</td>
<td>4.6</td>
</tr>
<tr>
<td>75 ft insulated plus 25 ft without insulation</td>
<td></td>
<td>9.4</td>
<td>4.7</td>
<td>4.6</td>
</tr>
</tbody>
</table>

Repeated test sessions providing several data entries for the same location (for instance locations in the first 50 ft section, tested insulated in
a 75 ft circuit, as well as in a 100 ft loop), as well as multiple thermocouples installed at similar locations (for instance, in the middle of the side wall), allowed for accumulation of a significant amount of data and some statistical evaluation. Tables 5, 6, and 7 (for 10 A, 15 A, and 20 A test modes) summarize temperature readings at the end of heating periods. The data is grouped based on the thermocouple location in the test loop. Figures 9 through 11 illustrate this data in a graphical format. Horizontal red lines in these figures indicate maximum ROA limit pertinent to each case.

### Table No. 5
Temperature Rise Over Ambient (°C)

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<th>Sidewall Middle 2</th>
<th>Sidewall Middle 3</th>
<th>Sidewall Middle 4</th>
<th>Sidewall Middle 5</th>
<th>Sidewall Middle 6</th>
</tr>
</thead>
<tbody>
<tr>
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<td>6</td>
<td>8.7</td>
<td>9.2</td>
<td>5.9</td>
<td>6.2</td>
<td>8.4</td>
<td>8.4</td>
</tr>
<tr>
<td>51 through 75 ft bare</td>
<td>25.6</td>
<td>7.1</td>
<td>14.7</td>
<td>17.1</td>
<td>13.3</td>
<td>16.6</td>
<td>14.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>76 through 100 ft bare</td>
<td>26.1</td>
<td>8.1</td>
<td>14.3</td>
<td>17.3</td>
<td>13.6</td>
<td>15.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 ft insulated</td>
<td>25.6</td>
<td>7.1</td>
<td>14.7</td>
<td>17.1</td>
<td>13.3</td>
<td>16.6</td>
<td>14.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>75 ft insulated</td>
<td>26.1</td>
<td>8.1</td>
<td>14.3</td>
<td>17.3</td>
<td>13.6</td>
<td>15.1</td>
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<tr>
<td>100 ft insulated</td>
<td>19.4</td>
<td>9.1</td>
<td>13.4</td>
<td>17.2</td>
<td>13.8</td>
<td>15.1</td>
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<th>Ceiling 2</th>
<th>Ceiling 3</th>
<th>Outlet 1</th>
<th>Outlet 2</th>
<th>Outlet 3</th>
</tr>
</thead>
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<tr>
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<td>9.6</td>
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<td></td>
<td>6.9</td>
<td>8.9</td>
<td></td>
</tr>
<tr>
<td>51 through 75 ft bare</td>
<td>7.3</td>
<td>7.2</td>
<td>21.2</td>
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<td></td>
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<td>15.3</td>
<td>12.5</td>
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<tr>
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<td>16.8</td>
<td>24.2</td>
<td>28</td>
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<td>30.4</td>
<td>32.4</td>
<td>15.2</td>
<td>12.4</td>
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Table No. 6
Temperature Rise Over Ambient (°C)
14 AWG CCA in conduit  15 A

<table>
<thead>
<tr>
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<th>Ambient</th>
<th>Circuit Breaker</th>
<th>Sidewall Bottom</th>
<th>Sidewall Middle 1</th>
<th>Sidewall Middle 2</th>
<th>Sidewall Middle 3</th>
<th>Sidewall Middle 4</th>
<th>Sidewall Middle 5</th>
<th>Sidewall Middle 6</th>
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<tbody>
<tr>
<td>50 ft bare</td>
<td>12</td>
<td>28.6</td>
<td>36</td>
<td>36.6</td>
<td>39.2</td>
<td>47</td>
<td>42.7</td>
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<td>33.4</td>
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<td>17.6</td>
<td>30.2</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>76 through 100 ft bare</td>
<td>30.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 ft insulated</td>
<td>17.6</td>
<td>31.2</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>75 ft insulated</td>
<td>30.2</td>
<td>24.2</td>
<td>46.5</td>
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<td>43.9</td>
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<tr>
<td>100 ft insulated</td>
<td>22.5</td>
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Table No. 7
Temperature Rise Over Ambient (°C)
14 AWG CCA in conduit  20 A

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<tr>
<td>50 ft bare</td>
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<td>42.4</td>
<td>58.9</td>
<td>59.1</td>
<td>64.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51 through 75 ft bare</td>
<td>21.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td>27</td>
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<td></td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>50 ft insulated</td>
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<table>
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<tr>
<th></th>
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<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>76 through 100 ft bare</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>50 ft insulated</td>
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<td>60.9</td>
<td>63.5</td>
<td>51.6</td>
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</tr>
<tr>
<td>75 ft insulated</td>
<td>76.1</td>
<td></td>
<td></td>
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<td>52.7</td>
<td>57</td>
<td>46.3</td>
<td>48.8</td>
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<td>58.5</td>
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<td>71.2</td>
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Figure 9: Histogram of minimum, average, and maximum readings for different thermocouple groups in 14 AWG CCA NM-B setup.
Figure 10: Histogram of minimum, average, and maximum readings for different thermocouple groups in 14 AWG CCA in conduit, at 15 A.
Figure 11: Histogram of minimum, average, and maximum readings for different thermocouple groups in 14 AWG CCA in conduit, at 20 A.

It should be considered that these tests were not designed to qualify CCA conductors, but rather to assess their performance in an experimental structure constructed as required by the customer. From this standpoint, it is interesting to note that thermal insulation played a critical role in the case of 14 AWG CCA NM-B cable tested at 10 A load current. This
statement is evidenced, for instance by temperature plots of Appendix 1 and by the histogram of Figure 9.

In contrast, in both test modes executed on THHN conductors installed in the metallic conduit (at 15 A and 20 A), the effect of the outer thermal insulation is not that obvious. For instance, cable sections on the ceiling were affected by the external insulation only a little (Figure 11), while in the case of the jacketed cable this section of the cable loop reacted the most on the insulation application (Figure 9).

It appears, therefore, that the effect of the air entrapped in the metallic conduits (acting as good thermal insulation, especially in narrow gaps where turbulent flows are impeded) dominated in the overall structure of heat transfer. Evaluation of smaller diameter conduits might be worth consideration.

5.0 DISCUSSION AND CONCLUSIONS

A relatively high scatter in the test results can be noted on Figures 9 through 11. This scatter is due to several reasons, including ill conditioned heat transfer by free convection in air, variation in ambient conditions, inconsistent layout of thermal insulation when applied over test cable at different locations, lack of temperature stabilization in some of the
test runs, etc. Nevertheless, it appears that the integrity of the test results provides a good insight into the problem.

It can be concluded that the 14 AWG CCA NM-B cable exhibited acceptable results practically meeting the test requirements (with one marginal outlier). In contrast, 14 AWG CCA THHN conductors tested in the metallic conduit failed test requirements in all trials when thermal insulation was applied and in some test sessions with no insulation. It took $\frac{1}{2}$ to 1 hour for temperatures to exceed the ROA requirement, when insulated.
APPENDIX 1

TEMPERATURE RECORDS ON 14 AWG CCA NM-B CABLE

AT 10 A LOAD
APPENDIX 2

TEMPERATURE RECORDS ON 14 AWG CCA THHN CONDUCTORS IN CONDUIT AT 15 A LOAD
14 AWG CCA IN CONDUIT - 75 ft With Insulation Plus 25 ft Without Insulation 15 A
APPENDIX 3

TEMPERATURE RECORDS ON 14 AWG CCA THHN CONDUCTORS IN CONDUIT AT 20 A LOAD
Exhibit 11
Second Revision No. 8347-NFPA 70-2021 [ Global Comment ]

Please see attached Word file for CMP-6 changes to Definitions in Article 100 for style manual compliance and correlation issues.

Supplemental Information

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Submitter Information Verification

Committee: NEC-P06  
Submittal Date: Mon Oct 25 18:03:12 EDT 2021

Committee Statement

Committee Statement: Modifications were made on multiple definitions at the request of the Correlating Committee and to comply with the NEC Style Manual.  
Response: SR-8347-NFPA 70-2021  
Message: Public Comment No. 793-NFPA 70-2021 [Global Input]
Conductor, Bare. **(Bare Conductor)**. A conductor having no covering or electrical insulation whatsoever. (CMP-6)

Conductor, Covered. **(Covered Conductor)**. A conductor encased within material of composition or thickness that is not recognized by this Code as electrical insulation. (CMP-6)

Conductor, Insulated. **(Insulated Conductor)**. A conductor encased within material of composition and thickness that is recognized by this Code as electrical insulation. (CMP-6)

Conductor, Copper-Clad Aluminum. **(Copper-Clad Aluminum Conductor)**. Conductors drawn from a copper-clad aluminum rod, with the copper metallurgically bonded to an aluminum core. (CMP-6)

**Messenger or Messenger Wire** **(Messenger)**. A wire that is run along with or integral with a cable or conductor to provide mechanical support for the cable or conductor. (CMP-6)

Cable, Power and Control Tray, Type TC. **(Power and Control Tray Cable)**. A factory assembly of two or more insulated conductors, with or without associated bare or covered equipment grounding conductors, under a nonmetallic jacket. (CMP-6)
310.10(G)(4) Ampacity Correction or Adjustment. Conductors installed in parallel shall comply with the 310.15(B) and or 310.15(C).

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Tue Oct 26 14:56:24 EDT 2021

Committee Statement

Committee Statement: An editorial change has been made to ensure that when installing conductors in parallel that both adjustment factors and temperature corrections are applied and not one or the other.
Response Message: SR-8426-NFPA 70-2021

Public Comment No. 1323-NFPA 70-2021 [Section No. 310.10(G)(4)]
See attached Word file for revisions to Table 310.16 and Table 310.17.

Supplemental Information

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Submitter Information Verification

Committee: NEC-P06
Submittal Date: Tue Oct 26 15:15:35 EDT 2021

Committee Statement

The panel acted to revert to 2020 code language for the minimum size of conductors for 310.3(A), Tables 310.16 and 310.17, and wiring methods in multiple articles, including Articles 320, 330, 334, 336, and 340. To ensure public safety, further time is needed to study 14 AWG copper-clad aluminum and 16 AWG copper as minimum conductor sizes.

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

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

1) the Bimetallics Task Group (conducted at an Eaton facility)
2) the Copper Development Association (conducted at a Hampton Tedder facility)
3) the Southwire company (conducted at the DB Cofer laboratory)
4) the Cable Technologies Laboratory (conducted at their facility)
5) the Cerrowire company (conducted at the Marmon Innovation and Technology Center)

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

After considering all the information and results presented in the reports, public inputs, and public comments, concerns were recognized about conductor overheating in common, everyday installations that need to be addressed prior to reducing the allowable branch circuit conductor size. Primarily, the evidence of excessive heat rise that occurs when wiring methods are installed in thermal insulation needs to be addressed. Voltage drop was also identified as a concern and needs to be addressed.
To determine the appropriate code requirements to ensure the installation of reduced branch circuit conductor sizes is both practical and safe, additional information is required. The panel requests public input that includes the following information obtained from credible sources and qualified testing laboratories:

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

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

3) At a minimum, testing of 16 AWG copper and 14 AWG copper-clad aluminum in thermal insulation is required. To address questions that were raised about existing branch circuit conductor sizes and heat rise in thermal insulation, the panel is also requesting testing of:
   a. 14 AWG copper and 12 AWG copper-clad aluminum
   b. 12 AWG copper and 10 AWG copper-clad aluminum

4) Equivalent testing of aluminum conductors is also welcomed.

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

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

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

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

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

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

11) All conductors shall be tested under equivalent conditions.

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

Response Message: SR-8432-NFPA 70-2021
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<td>Public Comment No. 1447-NFPA 70-2021 [Section No. 310.21]</td>
</tr>
</tbody>
</table>
### 310.21 Ampacities of Bare or Covered Conductors in Free Air.

The ampacities shall be as specified in Table 310.21 where all of the following conditions apply:

1. Wind velocity is 610 mm/sec (2 ft/sec).
2. Conductors are 80°C (176°F) total conductor temperature.
3. Wiring is installed in a 40°C (104°F) ambient temperature.

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

<table>
<thead>
<tr>
<th>Size</th>
<th>Copper</th>
<th>Aluminum or Copper-Clad Aluminum</th>
</tr>
</thead>
<tbody>
<tr>
<td>18*</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>16*</td>
<td>—</td>
<td>10†</td>
</tr>
<tr>
<td>14*</td>
<td>15</td>
<td>15†</td>
</tr>
<tr>
<td>12*</td>
<td>20</td>
<td>—</td>
</tr>
<tr>
<td>10*</td>
<td>30</td>
<td>40†</td>
</tr>
<tr>
<td>8</td>
<td>40</td>
<td>40†</td>
</tr>
<tr>
<td>6</td>
<td>55</td>
<td>75†</td>
</tr>
<tr>
<td>4</td>
<td>70</td>
<td>95†</td>
</tr>
<tr>
<td>3</td>
<td>85</td>
<td>115†</td>
</tr>
<tr>
<td>2</td>
<td>95</td>
<td>130†</td>
</tr>
<tr>
<td>1</td>
<td>110</td>
<td>145†</td>
</tr>
<tr>
<td>1/0</td>
<td>125</td>
<td>170†</td>
</tr>
<tr>
<td>2/0</td>
<td>145</td>
<td>195†</td>
</tr>
<tr>
<td>3/0</td>
<td>165</td>
<td>225†</td>
</tr>
<tr>
<td>4/0</td>
<td>195</td>
<td>260†</td>
</tr>
<tr>
<td>250</td>
<td>215</td>
<td>290†</td>
</tr>
<tr>
<td>300</td>
<td>240</td>
<td>320†</td>
</tr>
<tr>
<td>350</td>
<td>260</td>
<td>350†</td>
</tr>
<tr>
<td>400</td>
<td>280</td>
<td>380†</td>
</tr>
<tr>
<td>500</td>
<td>320</td>
<td>430†</td>
</tr>
</tbody>
</table>

*Note: The values above are in amperes.*
## Table 310.4(1) Temperature Rating of Conductor

<table>
<thead>
<tr>
<th>Size AWG or kcmil</th>
<th>Types TW, UF</th>
<th>Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHHW-2, XHWN, USE, ZW-2</th>
<th>Types THHN, THHW, THW, THWN, XHHW, XHHW, USE</th>
<th>Types TW, UF</th>
<th>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHHW-2, XHWN, USE, ZW-2</th>
<th>Types THHN, THHW, THW, THWN, XHHW, XHHW, USE</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>350</td>
<td>420</td>
<td>475</td>
<td>285</td>
<td>340</td>
<td>385</td>
</tr>
<tr>
<td>700</td>
<td>385</td>
<td>460</td>
<td>520</td>
<td>315</td>
<td>375</td>
<td>425</td>
</tr>
<tr>
<td>750</td>
<td>400</td>
<td>475</td>
<td>535</td>
<td>320</td>
<td>385</td>
<td>435</td>
</tr>
<tr>
<td>800</td>
<td>410</td>
<td>490</td>
<td>555</td>
<td>330</td>
<td>395</td>
<td>445</td>
</tr>
<tr>
<td>900</td>
<td>435</td>
<td>520</td>
<td>585</td>
<td>355</td>
<td>425</td>
<td>480</td>
</tr>
<tr>
<td>1000</td>
<td>455</td>
<td>545</td>
<td>615</td>
<td>375</td>
<td>445</td>
<td>500</td>
</tr>
<tr>
<td>1250</td>
<td>495</td>
<td>590</td>
<td>665</td>
<td>405</td>
<td>485</td>
<td>545</td>
</tr>
<tr>
<td>1500</td>
<td>525</td>
<td>625</td>
<td>705</td>
<td>435</td>
<td>520</td>
<td>585</td>
</tr>
<tr>
<td>1750</td>
<td>545</td>
<td>650</td>
<td>735</td>
<td>455</td>
<td>545</td>
<td>615</td>
</tr>
<tr>
<td>2000</td>
<td>555</td>
<td>665</td>
<td>750</td>
<td>470</td>
<td>560</td>
<td>630</td>
</tr>
</tbody>
</table>

Notes:

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

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

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

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

†Applicable only to copper-clad aluminum conductors.

### Table 310.17 Ampacities of Single-Insulated Conductors in Free Air
<table>
<thead>
<tr>
<th>Size AWG or kcmil</th>
<th>Copper Types</th>
<th>Temperature Rating of Conductor [See Table 310.4(1)]</th>
<th>Aluminum or Copper-Clad Aluminum Types</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TW, UF</td>
<td>60°C (140°F)</td>
<td>75°C (167°F)</td>
</tr>
<tr>
<td>18</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>16</td>
<td>20</td>
<td>20</td>
<td>—</td>
</tr>
<tr>
<td>14*</td>
<td>25</td>
<td>25</td>
<td>—</td>
</tr>
<tr>
<td>12*</td>
<td>30</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>10*</td>
<td>40</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>8</td>
<td>60</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>6</td>
<td>80</td>
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<td>95</td>
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<td>105</td>
<td>105</td>
<td>125</td>
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<tr>
<td>3</td>
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<td>120</td>
<td>145</td>
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<tr>
<td>2</td>
<td>140</td>
<td>140</td>
<td>170</td>
</tr>
<tr>
<td>1</td>
<td>165</td>
<td>165</td>
<td>195</td>
</tr>
<tr>
<td>1/0</td>
<td>195</td>
<td>195</td>
<td>230</td>
</tr>
<tr>
<td>2/0</td>
<td>225</td>
<td>225</td>
<td>265</td>
</tr>
<tr>
<td>3/0</td>
<td>260</td>
<td>260</td>
<td>300</td>
</tr>
<tr>
<td>4/0</td>
<td>300</td>
<td>300</td>
<td>340</td>
</tr>
<tr>
<td>250</td>
<td>340</td>
<td>340</td>
<td>405</td>
</tr>
<tr>
<td>300</td>
<td>375</td>
<td>375</td>
<td>445</td>
</tr>
<tr>
<td>350</td>
<td>420</td>
<td>420</td>
<td>505</td>
</tr>
<tr>
<td>400</td>
<td>455</td>
<td>455</td>
<td>545</td>
</tr>
<tr>
<td>500</td>
<td>515</td>
<td>515</td>
<td>620</td>
</tr>
<tr>
<td>600</td>
<td>575</td>
<td>575</td>
<td>690</td>
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<tr>
<td>700</td>
<td>630</td>
<td>630</td>
<td>755</td>
</tr>
<tr>
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<td>655</td>
<td>655</td>
<td>755</td>
</tr>
<tr>
<td>800</td>
<td>680</td>
<td>680</td>
<td>815</td>
</tr>
<tr>
<td>900</td>
<td>730</td>
<td>730</td>
<td>870</td>
</tr>
<tr>
<td>1000</td>
<td>780</td>
<td>780</td>
<td>935</td>
</tr>
<tr>
<td>1250</td>
<td>890</td>
<td>890</td>
<td>1065</td>
</tr>
<tr>
<td>1500</td>
<td>980</td>
<td>980</td>
<td>1175</td>
</tr>
<tr>
<td>1750</td>
<td>1070</td>
<td>1070</td>
<td>1280</td>
</tr>
<tr>
<td>2000</td>
<td>1155</td>
<td>1155</td>
<td>1385</td>
</tr>
</tbody>
</table>

COPPER

ALUMINUM OR COPPER-CLAD ALUMINUM
Important Notice: This document is the copyright property of the National Fire Protection Association (NFPA), Copyright © 2021 NFPA, and may not be used for any other purpose or distributed to any other persons or parties.

Notes:

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

2. Section 310.17 shall be referenced for conditions of use.

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

†Applicable only to copper-clad aluminum.
Second Revision No. 8224-NFPA 70-2021 [Definition: Bottom Shield, Type FCC.]

Bottom Shield, Type FCC.
A protective layer that is installed between the floor and Type FCC flat conductor cable (Type FCC) to protect the cable from physical damage and may or may not be incorporated as an integral part of the cable. (324) (CMP-6)

Submitter Information Verification

Committee: NEC-P06
Submit Date: Mon Oct 25 11:17:21 EDT 2021

Committee Statement

Committee Statement: “Type FCC” removed from the title and relocated into the definition body for ease of searchability by the code user. Definition body reworded for clarity.
Response Message: SR-8224-NFPA 70-2021

Public Comment No. 151-NFPA 70-2021 [Definition: Bottom Shield, Type FCC.]
Cable Connector, Type FCC.

A connector designed to join flat conductor cables (Type FCC cables) without using a junction box. (324) (CMP-6)

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 11:19:58 EDT 2021

Committee Statement

Committee Statement: “Type FCC” removed from the title and relocated into the definition body for ease of searchability by the code user. Definition body reworded for clarity.
Response Message: SR-8226-NFPA 70-2021

Public Comment No. 153-NFPA 70-2021 [Definition: Cable Connector, Type FCC.]
Second Revision No. 8234-NFPA 70-2021 [Definition: Cable Joint, Type MV.]

Cable Joint, Type MV.
A connection consisting of an insulation system and a connector where two (or more) medium voltage (Type MV) cables are joined together in a way that is to be chemically, mechanically, and electrically stable. (CMP-6)

Submitter Information Verification

Committee: NEC-P06
Submit Date: Mon Oct 25 11:39:02 EDT 2021

Committee Statement

Committee Statement: Removed "in a way that is to be chemically, mechanically, and electrically stable" as definitions cannot contain requirements. "Type MV" removed from the title and relocated into the definition body for ease of searchability by the code user. The use of "Type MV" clarifies the product application. Definition body reworded for clarity.

Response Message: SR-8234-NFPA 70-2021

Public Comment No. 154-NFPA 70-2021 [Definition: Cable Joint, Type MV]
Public Comment No. 1705-NFPA 70-2021 [Definition: Cable Joint, Type MV]
Public Comment No. 1223-NFPA 70-2021 [Definition: Cable Joint, Type MV]
Cable Termination, Type MV.
A connection consisting of an insulation system and a connector and installed on a medium voltage (Type MV) cable to connect from a cable to a device, such as equipment, in a way that is to be chemically, mechanically, and electrically stable. (CMP-6)

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 11:54:28 EDT 2021

Committee Statement

Committee Statement: Removed "in a way that is to be chemically, mechanically, and electrically stable" as definitions cannot contain requirements. “Type MV” removed from the title and relocated into the definition body for ease of searchability by the code user. The use of "Type MV" clarifies the product application. Definition body reworded for clarity.

Response Message: SR-8239-NFPA 70-2021

Public Comment No. 1707-NFPA 70-2021 [Definition: Cable Termination, Type MV]
Public Comment No. 1224-NFPA 70-2021 [Definition: Cable Termination, Type MV]
**Second Revision No. 8716-NFPA 70-2021 [ Definition: Cable, Medium Voltage, Type MV. ]**

<table>
<thead>
<tr>
<th><strong>Cable, Medium Voltage, Type MV. (Medium Voltage Cable)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>A single or multiconductor solid dielectric insulated cable rated 2001 volts up to and including 35,000 volts, nominal. (CMP-6)</td>
</tr>
</tbody>
</table>

### Submitter Information Verification

<table>
<thead>
<tr>
<th><strong>Committee:</strong></th>
<th>NEC-P06</th>
</tr>
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<tbody>
<tr>
<td><strong>Submittal Date:</strong></td>
<td>Wed Nov 10 10:15:31 EST 2021</td>
</tr>
</tbody>
</table>

### Committee Statement

<table>
<thead>
<tr>
<th><strong>Committee Statement:</strong></th>
<th>This editorial second revision is created by NFPA staff for compliance with 2.2.2.3.1 of the NEC Style Manual regarding inclusion of searchable terms.</th>
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</thead>
<tbody>
<tr>
<td><strong>Response:</strong></td>
<td>SR-8716-NFPA 70-2021</td>
</tr>
<tr>
<td><strong>Message:</strong></td>
<td></td>
</tr>
</tbody>
</table>

---

10 of 76 12/7/2021, 12:11 PM
Second Revision No. 8251-NFPA 70-2021 [Definition: Cable, Portable Power Feeder. (Portable Power Feeder Cable)]

Cable, Portable Power Feeder. (Portable Power Feeder Cable)

One or more flexible shielded insulated power conductors enclosed in a flexible covering that provides mechanical protection with voltage rating from 2000 to 25,000 volts.

(CMP-6)

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 12:21:25 EDT 2021

Committee Statement

Committee Statement: Removed "that provides mechanical protection" as definitions cannot contain requirements. Voltage range modified to "2001 to 25,000 volts" to match the voltage range of medium voltage products covered in Article 315. Definition body reworded for clarity.

Response Message: SR-8251-NFPA 70-2021

Public Comment No. 1704-NFPA 70-2021 [New Definition after Definition: Cable, Portable Power Feed...]
Second Revision No. 8254-NFPA 70-2021 [ Definition: Compact (as applied to conductor stranding). ]

**Stranding, Compact, (as applied to conductor stranding Compact Stranding).**

A conductor *where* stranding method in which each layer of strands is pressed together to minimize the extent that almost all the gaps between the strands are eliminated so that the overall diameter of the finished conductor is less than a concentric stranded conductor and less than a compressed stranded conductor. (CMP-6)

### Submitter Information Verification

**Committee:** NEC-P06  
**Submittal Date:** Mon Oct 25 12:24:35 EDT 2021

### Committee Statement

**Committee Statement:** Modified title with "Stranding, Compact" as requested by the Correlating Committee and added "(Compact Stranding)" for ease of searchability by the code user. Replaced "where" with "in which" as requested by the Correlating Committee. Definition body reworded for clarity.

**Response Message:** SR-8254-NFPA 70-2021

[Public Comment No. 1709-NFPA 70-2021] [Definition: Compact (as applied to conductor stranding).]
Second Revision No. 8255-NFPA 70-2021 [Definition: Compressed (as applied to conductor stranding).]

Stranding, Compressed. (as applied to conductor stranding Compressed Stranding).
A conductor where stranding method in which the outer layer of strands is pressed together so that the overall diameter of the finished conductor is less than a concentric stranded conductor but greater than a compact stranded conductor. (CMP-6)

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 12:29:19 EDT 2021

Committee Statement

Committee Statement: Modified title with "Stranding, Compressed" as requested by the Correlating Committee and added "(Compressed Stranding)" for ease of searchability by the code user. Replaced "where" with "in which" as requested by the Correlating Committee. Definition body reworded for clarity.

Response Message: SR-8255-NFPA 70-2021

Public Comment No. 1711-NFPA 70-2021 [Definition: Compressed (as applied to conductor stranding),]
Conductor, Insulated (as applied to messenger-supported wiring).
Overhead service conductor encased in a polymeric material that has been evaluated adequate for the applied nominal voltage and any conductor types described in 310.4. (396) (CMP-6)

Informational Note: See ICEA S-76-474-2011, Standard for Neutral Supported Power Cable Assemblies with Weather-Resistant Extruded Insulation Rated 600 Volts, for evidence of evaluation of information about overhead service conductors.

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 16:55:26 EDT 2021

Committee Statement

Committee Statement: Change language in definition from “that has been evaluated” to “adequate for”. to avoid having requirements in definitions and informational notes.
Response Message: SR-8321-NFPA 70-2021

Public Comment No. 810-NFPA 70-2021 [Global Input]
Second Revision No. 8456-NFPA 70-2021 [Definition: Cord Connector.]

Cord Connector.
A female contact device that mates with terminated to a flexible cord that accepts an attachment plug or other male insertion device. (CMP-6)

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Tue Oct 26 16:39:52 EDT 2021

Committee Statement

Committee Statement: The definition was revised for clarity and to reflect the use of this device in general installations. (See Correlating Committee Global PC 1828).
Response Message: SR-8456-NFPA 70-2021

Public Comment No. 1658-NFPA 70-2021 [Definition: Cord Connector.]
Second Revision No. 8242-NFPA 70-2021 [Definition: Cord, Flexible. (Flexible Cord)]

Cord, Flexible. (Flexible Cord)
Two or more flexible insulated conductors enclosed in a flexible covering that provides mechanical protection. [NFPA 79: 3.3.29] (CMP-6)

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 12:01:42 EDT 2021

Committee Statement

Committee Statement: Removed "that provides mechanical protection" as definitions cannot contain requirements. Removed NFPA 79 reference as the revised definition no longer matches the definition in NFPA 79.

Response Message: SR-8242-NFPA 70-2021

Public Comment No. 1714-NFPA 70-2021 [Definition: Cord, Flexible. (Flexible Cord)]
Second Revision No. 8340-NFPA 70-2021 [Definition: Drilling Rig Cable, Type P.]

**Drilling Rig Cable, Type P. Industrial Mobile, Type IM. (Industrial Mobile Cable)**

A factory assembly of one or more insulated flexible tinned copper conductors, with associated equipment grounding conductor(s), with or without a braided metallic armor and with an overall nonmetallic jacket. (CMP-6)

### Submitter Information Verification

**Committee:** NEC-P06  
**Submittal Date:** Mon Oct 25 17:40:18 EDT 2021

### Committee Statement

**Committee Statement:** The title for Type P cable was changed to Type IM in correlation with the changes made in Article 337.  
**Response:** SR-8340-NFPA 70-2021
Second Revision No. 8221-NFPA 70-2021 [Definition: Flat Conductor Cable, Type FCC Cable.]

Flat Conductor Cable, Type FCC Cable.
Three or more separate flat copper conductors placed horizontally edge-to-edge and separated and enclosed within an insulating assembly. (324) (CMP-6)

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 11:11:08 EDT 2021

Committee Statement

Committee Statement: The use of the word "Type" helps differentiate the specific cable constructions referred to in the definition versus a more general use of terminology such as "service entrance cables" or "nonmetallic-sheathed cables" that might refer to a group of cable types. For wire and cable products, the use of "Type" reinforces the relationship between the NEC and product safety standards. "Cable" is redundant and removed from the end of the title. Definition body reworded for clarity by adding "separate" and "horizontally". "(324) (CMP-6)" is added at the end of the definition body to match the structure of related definitions.

Response Message: SR-8221-NFPA 70-2021

Public Comment No. 383-NFPA 70-2021 [Definition: Flat Conductor Cable, Type FCC Cable.]
Second Revision No. 8228-NFPA 70-2021 [ Definition: Insulating End, Type FCC. ]

**Insulating End, Type FCC.**

An insulator designed to electrically insulate the end of a flat conductor cable (Type FCC cable). (324) (CMP-6)

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 11:22:33 EDT 2021

Committee Statement

Committee Statement: “Type FCC” removed from the title and relocated into the definition body for ease of searchability by the code user. Definition body reworded for clarity.
Response Message: SR-8228-NFPA 70-2021

Public Comment No. 384-NFPA 70-2021 [Definition: Insulating End, Type FCC.]

https://submittals.nfpa.org/TerraViewWeb/ContentFetcher?commentPar...
Metal Shield Connections, Type FCC.

Means of connection for flat conductor cables (Type FCC), designed to electrically and mechanically connect a metal shield to another metal shield, to a receptacle housing or self-contained device, or to a transition assembly. (324) (CMP-6)

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 11:26:14 EDT 2021

Committee Statement

"Type FCC" removed from the title and relocated into the definition body for ease of searchability by the code user.

Response Message: SR-8229-NFPA 70-2021

Public Comment No. 387-NFPA 70-2021 [Definition: Metal Shield Connections, Type FCC.]
Power-Supply Cord.

A length of flexible cord with an assembly consisting of an attachment plug at one end and individual cord conductors not terminated in a cord connector at the opposite end a length of flexible cord connected to utilization equipment. (CMP-6)

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 12:17:46 EDT 2021

Committee Statement

Committee Statement: This revised definition more adequately applies to installations under the purview of both CMP 6 and CMP 12 and is intended to replace the two existing definitions.
Response Message: SR-8250-NFPA 70-2021

Public Comment No. 1663-NFPA 70-2021 [Definition: Power-Supply Cord.]
Second Revision No. 8230-NFPA 70-2021 [Definition: Top Shield, Type FCC.]

**Top Shield, Type FCC.**
A grounded metal shield covering under-carpet components of the flat conductor cable (Type FCC) system for the purposes of providing protection against physical damage. (324)

(CMP-6)

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 11:28:26 EDT 2021

Committee Statement

Committee Statement: "Type FCC" removed from the title and relocated into the definition body for ease of searchability by the code user. Definition body reworded for clarity.

Response Message: SR-8230-NFPA 70-2021

Public Comment No. 391-NFPA 70-2021 [Definition: Top Shield, Type FCC.]
Second Revision No. 8232-NFPA 70-2021 [Definition: Transition Assembly, Type FCC.]

Transition Assembly, Type FCC.
An assembly to facilitate connection of the flat conductor cable (Type FCC) system to other wiring systems, incorporating (1) a means of electrical interconnection and (2) a suitable box or covering for providing electrical safety and protection against physical damage. (CMP-6)

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 11:31:30 EDT 2021

Committee Statement

Committee Statement: “Type FCC” removed from the title and relocated into the definition body for ease of searchability by the code user. Definition body reworded for clarity.
Response Message: SR-8232-NFPA 70-2021

Public Comment No. 392-NFPA 70-2021 [Definition: Transition Assembly, Type FCC.]
310.1 Scope.

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

Informational Note: See Article Chapter 400 for flexible cords, and flexible cables, and See Article 402 for fixture wires.

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 13:58:43 EDT 2021

Committee Statement

Committee Statement: It is most helpful for the Code user to have references to the Articles that cover flexible cords, flexible cables, and fixture wires. This would make it clear that those items have separate requirements and that Section 310 provisions do not apply. In this case, the NEC Style Manual prohibits the most useful references for the Code user, so the FR was an attempt to help the Code user as much as possible and still comply with the NEC Style Manual. The suggested return to referring to Articles would be very helpful for the Code user, so we are requesting that the Correlating Committee use their discretion in permitting this deviation from the NEC Style Manual.

Response Message: SR-8276-NFPA 70-2021

Public Comment No. 778-NFPA 70-2021 [Section No. 310.1]
Minimum Size of Conductors.
The minimum size of conductors for voltage ratings up to and including 2000 volts shall be
16 AWG copper, 14 or 12 AWG aluminum or copper-clad aluminum, or 12 AWG aluminum, except as permitted elsewhere in this Code.
1) Testing of representative wiring methods with 14 AWG copper-clad aluminum and 16 AWG copper shall be performed. Representative wiring methods could include those with non-metallic jackets, metallic sheaths, and those in metallic and non-metallic raceway systems.

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

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

   a. 14 AWG copper and 12 AWG copper-clad aluminum
   b. 12 AWG copper and 10 AWG copper-clad aluminum

4) Equivalent testing of aluminum conductors is also welcomed.

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

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

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

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

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

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

11) All conductors shall be tested under equivalent conditions.

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

Response Message: SR-8404-NFPA 70-2021
Public Comment No. 2008-NFPA 70-2021 [Section No. 310.3(A)]
Public Comment No. 1937-NFPA 70-2021 [Section No. 310.3(A)]
Public Comment No. 2171-NFPA 70-2021 [Section No. 310.3(A)]
(G) Conductors in Parallel.

(1) General.

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

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

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

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

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

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

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

(2) Conductor and Installation Characteristics.

The paralleled conductors that comprise each phase ungrounded conductor, polarity grounded conductor, neutral, grounded circuit conductor, equipmentgrounding conductor, equipment bonding jumper, or supply-side bonding jumper shall comply with all of the following:

(1) Be the same length

(2) Consist of the same conductor material

(3) Be the same size in circular mil area

(4) Have the same insulation type

(5) Be terminated in the same manner

(3) Separate Cables or Raceways.

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

(4) Ampacity Correction or Adjustment.

Conductors installed in parallel shall comply with the 310.15(B) or and 310.15(C).
(5) Equipment Grounding Conductors.
Where parallel equipment grounding conductors are used, they shall be sized in accordance with 250.122. Sectioned equipment grounding conductors smaller than 1/0 AWG shall be permitted in multiconductor cables, if the combined circular mil area of the sectioned equipment grounding conductors in each cable complies with 250.122.

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

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Tue Oct 26 14:45:52 EDT 2021

Committee Statement

Committee Statement: The language in these sections have been revised to provide clarity and usability when referencing conductors in parallel installations.
Response Message: SR-8420-NFPA 70-2021
Public Comment No. 1814-NFPA 70-2021 [Section No. 310.10(G)(1)]
Public Comment No. 775-NFPA 70-2021 [Section No. 310.10(G)]
Second Revision No. 8429-NFPA 70-2021 [Section No. 310.14(A)(1)]

(1) Tables or Engineering Supervision.

Ampacities for conductors shall be permitted to be determined by tables as provided in 310.15 or under engineering supervision, as provided in 310.14(B).

Informational Note No. 1: See 210.19(A), Informational Note No. 4, for voltage drop on branch circuits that this section does not take into consideration. See 215.2(A), Informational Note No. 2, for voltage drop on feeders that this section does not take into consideration.

Informational Note No. 2: See Table 12.5.1 in NFPA 79-2021, Electrical Standard for Industrial Machinery, for the allowable ampacities of Type MTW wire.

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Tue Oct 26 14:58:39 EDT 2021

Committee Statement

Committee Statement: A correction was made to the reference for voltage drop in Informational Note No. 1. The reference was to 210.19(A) Informational Note No. 4 and should be Informational Note No. 3.
Response Message: SR-8429-NFPA 70-2021

Public Comment No. 1325-NFPA 70-2021 [Section No. 310.14(A)(1)]
310.21 Ampacities of Bare or Covered Conductors in Free Air.
The ampacities shall be as specified in Table 310.21 where all of the following conditions apply:

1. Wind velocity is 610 mm/sec (2 ft/sec).
2. Conductors are 80°C (176°F) total conductor temperature.
3. Wiring is installed in a 40°C (104°F) ambient temperature.

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

<table>
<thead>
<tr>
<th>Diameter</th>
<th>AWG or kcmil</th>
<th>Temperature Rating of Conductor [See Table 310.4(1)]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60°C (140°F)</td>
<td>75°C (167°F)</td>
</tr>
<tr>
<td></td>
<td>60°C (140°F)</td>
<td>75°C (167°F)</td>
</tr>
<tr>
<td>Copper</td>
<td>Types TW, UF</td>
<td>Types THW, THHW, THWN, THW-2, THHN-2, USE-2, XHHW, XHWN-2, XHHN-2, XHV, XHWN, XHWN-2, XHHN</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHWW, XHWN, XHWN-2, XHHN, Z, ZW-2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Size</th>
<th>Types TW, UF</th>
<th>Types THW, THHW, THWN, THW-2, THHN-2, USE-2, XHHW, XHWN-2, XHHN-2, XHV, XHWN, XHWN-2, XHHN</th>
<th>Types TW, UF</th>
<th>Types THW, THHW, THWN, THW-2, THHN-2, USE-2, XHHW, XHWN, USE</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWG or kcmil</td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18&quot;</td>
<td>14</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
<tr>
<td>16&quot;</td>
<td>14</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
<tr>
<td>14&quot;</td>
<td>20</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
<tr>
<td>12&quot;</td>
<td>20</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
<tr>
<td>10&quot;</td>
<td>20</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
<tr>
<td>8</td>
<td>30</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
<tr>
<td>6</td>
<td>30</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
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<td></td>
<td></td>
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<td>3</td>
<td>30</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
<tr>
<td>1</td>
<td>30</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
<tr>
<td>1/0</td>
<td>30</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
<tr>
<td>2/0</td>
<td>30</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
<tr>
<td>3/0</td>
<td>30</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
<tr>
<td>4/0</td>
<td>30</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
<tr>
<td>250</td>
<td>250</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
<tr>
<td>300</td>
<td>285</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
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<tr>
<td>350</td>
<td>310</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
<tr>
<td>400</td>
<td>335</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
<tr>
<td>500</td>
<td>380</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
<tr>
<td>600</td>
<td>420</td>
<td></td>
<td></td>
<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
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<tr>
<td>700</td>
<td>460</td>
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<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
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<td>750</td>
<td>500</td>
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<td>Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHWN, XHWN-2, XHHN</td>
</tr>
</tbody>
</table>
Notes:
1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 30°C (86°F).
2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.
3. Section 310.16 shall be referenced for conditions of use.
*Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the Code.
† Applicable only to copper-clad aluminum conductors.

Table 310.17 Ampacities of Single-Insulated Conductors in Free Air

<table>
<thead>
<tr>
<th>Size AWG or kcmil</th>
<th>Types TW, UF</th>
<th>Temperature Rating of Conductor [See Table 310.4(1)]</th>
<th>Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHHN, Z, ZW-2</th>
<th>Types TW, UF</th>
<th>Types TBS, SA, SIS, THHN, THHW, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHHN</th>
</tr>
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<tbody>
<tr>
<td>18</td>
<td></td>
<td>60°C (140°F)</td>
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<td></td>
</tr>
<tr>
<td>16*</td>
<td>20</td>
<td>75°C (167°F)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14*</td>
<td>25 30 35 40</td>
<td>90°C (194°F)</td>
<td></td>
<td>20 25 30 35 40</td>
<td></td>
</tr>
<tr>
<td>12*</td>
<td>30 35 40 50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10*</td>
<td>40 50 55 60</td>
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<td></td>
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<td>80 95 105</td>
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<td>105 125 140</td>
<td></td>
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<tr>
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<td>260 310 350</td>
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<td>300 360 405</td>
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</tbody>
</table>
Notes:
1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 30°C (86°F).
2. Section 310.17 shall be referenced for conditions of use.
*Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the Code.
† Applicable only to copper-clad aluminum.

Table 310.18 Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway or Cable

<table>
<thead>
<tr>
<th>Size AWG or kcmil</th>
<th>Temperature Rating of Conductor [See Table 310.4(1)]</th>
<th>150°C (302°F)</th>
<th>200°C (392°F)</th>
<th>250°C (482°F)</th>
<th>150°C (302°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COPPER</td>
<td>Types Z</td>
<td>Types FEP, FEPB, PFA, SA</td>
<td>Types PFAH, TFE</td>
<td>Type Z</td>
</tr>
<tr>
<td>14</td>
<td>34</td>
<td>36</td>
<td>39</td>
<td>—</td>
<td>14</td>
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<td>288</td>
<td>297</td>
<td>308</td>
<td>227</td>
<td>3/0</td>
</tr>
</tbody>
</table>
### Table 310.19 Ampacities of Single-Insulated Conductors in Free Air

<table>
<thead>
<tr>
<th>Size (AWG or kcmil)</th>
<th>Temperature Rating of Conductor [See Table 310.4(1)]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>150°C (302°F)</td>
</tr>
<tr>
<td>Type Z</td>
<td>Types FEP, FEPB, PFA, SA</td>
</tr>
<tr>
<td>4/0</td>
<td>332</td>
</tr>
</tbody>
</table>

**Notes:**
1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 40°C (104°F).
2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.
3. Section 310.18 shall be referenced for conditions of use.

### Table 310.20 Ampacities of Conductors on a Messenger

<table>
<thead>
<tr>
<th>Size (AWG or kcmil)</th>
<th>Temperature Rating of Conductor [See Table 310.4(1)]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>150°C (302°F)</td>
</tr>
<tr>
<td>Type Z</td>
<td>Types FEP, FEPB, PFA, SA</td>
</tr>
<tr>
<td>14</td>
<td>46</td>
</tr>
<tr>
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<td>190</td>
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<td>293</td>
</tr>
<tr>
<td>1/0</td>
<td>339</td>
</tr>
<tr>
<td>2/0</td>
<td>390</td>
</tr>
<tr>
<td>3/0</td>
<td>451</td>
</tr>
<tr>
<td>4/0</td>
<td>529</td>
</tr>
</tbody>
</table>

**Notes:**
1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 40°C (104°F).
2. Section 310.19 shall be referenced for conditions of use.

Table 310.19 Ampacities of Single-Insulated Conductors in Free Air

Table 310.20 Ampacities of Conductors on a Messenger
## Table 310.21 Ampacities of Bare or Covered Conductors in Free Air

<table>
<thead>
<tr>
<th>AWG or kcmil</th>
<th>Copper Conductors</th>
<th>Aluminum Conductor</th>
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<tr>
<td></td>
<td>75°C (167°F)</td>
<td>90°C (194°F)</td>
</tr>
<tr>
<td><strong>Copper</strong></td>
<td><strong>ALUMINUM OR COPPER-CLAD</strong></td>
<td><strong>ALUMINUM</strong></td>
</tr>
<tr>
<td>8</td>
<td>57</td>
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<td>6</td>
<td>76</td>
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<td>78</td>
</tr>
<tr>
<td>3</td>
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<td>92</td>
</tr>
<tr>
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<td>106</td>
</tr>
<tr>
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<td>158</td>
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<td>339</td>
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<tr>
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<td>532</td>
</tr>
<tr>
<td>900</td>
<td>704</td>
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<tr>
<td>1000</td>
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<td>612</td>
</tr>
</tbody>
</table>

**Notes:**

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 40°C (104°F).
2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.
3. Section 310.20 shall be referenced for conditions of use.
<table>
<thead>
<tr>
<th>AWG or kcmil</th>
<th>Copper Conductors Bare</th>
<th>AWG or kcmil</th>
<th>Copper Conductors Covered</th>
<th>AWG or kcmil</th>
<th>AAC Aluminum Conductors Bare</th>
<th>AWG or kcmil</th>
<th>AAC Aluminum Conductors Covered</th>
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Note: Section 310.21 shall be referenced for conditions of use.

Supplemental Information

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<th>File Name</th>
<th>Description</th>
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<td>For staff use</td>
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</table>

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 14:39:23 EDT 2021

Committee Statement

Committee Statement: XHWN was deleted in the 90C columns in Tables 310.16, 310.17 and 310.20 because this insulation type is not rated for use at 90C.
Response Message: SR-8287-NFPA 70-2021
Public Comment No. 767-NFPA 70-2021 [Section No. 310.21]
315.1 Scope.

This article covers the use, installation, construction specifications, and ampacities for Type MV medium voltage conductors, cable, cable joints, and cable terminations. This article includes voltages from 2001 volts to 35,000 volts. This article does not cover cables used include voltages above 2500 volts for dc circuits.
320.23 In Accessible Attics.
Type AC cables in accessible attics or roof spaces shall be installed as specified in 320.23(A) and (B).

(A) Cables Run Across the Top of Joists Framing Members.
Where run across the top of joists framing members, or across the face of rafters or studding within 2.1 m (7 ft) of the floor or joists equivalent horizontal surface, the cable shall be protected by guard strips that are at least as high as the cable. Where this space is not accessible by permanently installed stairs or ladders, protection shall only be required within 1.8 m (6 ft) of the nearest edge of the scuttle hole or attic entrance.

(B) Cable Installed Parallel to Framing Members.
Where the cable is installed parallel to the sides of rafters, studs, or ceiling or floor joists, neither guard strips nor running boards shall be required, and the installation shall also comply with 300.4(D).
Second Revision No. 8296-NFPA 70-2021 [Section No. 322.56(B)]

(B) Taps.

Taps shall be made between any phase conductor and the grounded conductor or any other phase conductor by means of devices and fittings identified for the use. Tap devices shall be rated at not less than 15 amperes, or more than 300 volts to ground, and shall be color-coded marked in accordance with 322.120(C).

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 15:14:41 EDT 2021

Committee Statement

Committee Statement: The term “color-coded” was changed to “marked” to correlate with the terminology in 322.120.
Response Message: SR-8296-NFPA 70-2021

Public Comment No. 773-NFPA 70-2021 [Section No. 322.56(B)]
330.104 Conductors.
For ungrounded, grounded, and equipment grounding conductors, the minimum conductor sizes shall be 16 AWG copper, 14 AWG nickel, or nickel-coated copper, and 12 AWG aluminum or copper-clad aluminum, and 12 AWG aluminum.

For control and signal conductors, minimum conductor sizes shall be 18 AWG copper, nickel, or nickel-coated copper, 14 AWG copper-clad aluminum, and 12 AWG aluminum.

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Tue Oct 26 15:46:36 EDT 2021

Committee Statement
The panel acted to revert to 2020 code language for the minimum size of conductors for 310.3(A), Tables 310.16 and 310.17, and wiring methods in multiple articles, including Articles 320, 330, 334, 336, and 340. To ensure public safety, further time is needed to study 14 AWG copper-clad aluminum and 16 AWG copper as minimum conductor sizes.

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

During the 2023 NEC revision cycle, the panel received reports and presentations from:
1) the Bimetallics Task Group (conducted at an Eaton facility)
2) the Copper Development Association (conducted at a Hampton Tedder facility)
3) the Southwire company (conducted at the DB Cofer laboratory)
4) the Cable Technologies Laboratory (conducted at their facility)
5) the Cerrowire company (conducted at the Marmon Innovation and Technology Center)

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

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

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

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

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

3) At a minimum, testing of 16 AWG copper and 14 AWG copper-clad aluminum in thermal insulation is required. To address questions that were raised about existing branch circuit conductor sizes and heat rise in thermal insulation, the panel is also requesting testing of:
   a. 14 AWG copper and 12 AWG copper-clad aluminum
   b. 12 AWG copper and 10 AWG copper-clad aluminum

4) Equivalent testing of aluminum conductors is also welcomed.

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

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

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

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

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

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

11) All conductors shall be tested under equivalent conditions.

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

Response Message: SR-8436-NFPA 70-2021

Public Comment No. 2068-NFPA 70-2021 [Section No. 330.104]
Public Comment No. 2173-NFPA 70-2021 [Section No. 330.104]
Second Revision No. 8309-NFPA 70-2021 [Section No. 330.112(A)]

(A) 1000 Volts or Less.
Insulated control and signal conductors in sizes 18 AWG and 16 AWG shall be of a type listed in Table 402.3, with a maximum operating temperature not less than 90°C (194°F) and as permitted by 725.49. Conductors larger than 16 AWG Ungrounded, grounded, and equipment grounding conductors 16 AWG and larger shall be of a type listed in Table 310.4(1) or of a type identified for use in Type MC cable.

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 16:04:30 EDT 2021

Committee Statement

Committee Statement: Editorial changes were made to this section to correlate with the addition of 16awg copper as a conductor for general use wiring.
The reference to 725.49 is changed to 724.49 based on first draft changes to Article 725.

Response Message: SR-8309-NFPA 70-2021

Public Comment No. 306-NFPA 70-2021 [Section No. 330.112(A)]
Second Revision No. 8337-NFPA 70-2021 [ Section No. 334.40(B) ]

(B) Devices of Insulating Material.

Self-contained switches, self-contained receptacles, and listed nonmetallic-sheathed cable interconnector devices of insulating material that are listed for the purpose use without a box shall be permitted to be used without boxes in exposed cable wiring and for wiring in existing and new buildings where the cable is concealed or concealed installations. Openings in such devices shall form a close fit around the outer covering of the cable, and the device shall fully enclose the part of the cable from which any part of the covering has been removed. Where connections to conductors are by binding-screw terminals, there shall be available as many terminals as conductors.

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 17:33:45 EDT 2021

Committee Statement

Committee Statement: An editorial change was made to 334.40(B). This change provided clarity and distinction by removing unnecessary words and changing the term “listed for the purpose” to “listed for use without a box”.

Response Message:

Public Comment No. 1329-NFPA 70-2021 [Section No. 334.40(B)]
Public Comment No. 787-NFPA 70-2021 [Section No. 334.40(B)]
Conductors.

For ungrounded, grounded, and equipment grounding conductors, the conductor sizes shall be 16 to 14 AWG through 2 AWG copper, and 14 to 12 AWG through 2 AWG copper-clad aluminum, or 12 AWG through 2 AWG aluminum.

For control and signaling conductors, the minimum conductor sizes shall be 18 AWG copper, and 14 to 12 AWG copper-clad aluminum, and 12 AWG aluminum.

Committee Information Verification

Committee: NEC-P06
Submital Date: Tue Oct 26 15:53:37 EDT 2021

Committee Statement:

The panel acted to revert to 2020 code language for the minimum size of conductors for 310.3(A), Tables 310.16 and 310.17, and wiring methods in multiple articles, including Articles 320, 330, 334, 336, and 340. To ensure public safety, further time is needed to study 14 AWG copper-clad aluminum and 16 AWG copper as minimum conductor sizes.

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

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

1) the Bimetallics Task Group (conducted at an Eaton facility)
2) the Copper Development Association (conducted at a Hampton Tedder facility)
3) the Southwire company (conducted at the DB Cofer laboratory)
4) the Cable Technologies Laboratory (conducted at their facility)
5) the Cerrowire company (conducted at the Marmon Innovation and Technology Center)

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

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

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

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

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

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

   a. 14 AWG copper and 12 AWG copper-clad aluminum
   b. 12 AWG copper and 10 AWG copper-clad aluminum

4) Equivalent testing of aluminum conductors is also welcomed.

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

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

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

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

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

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

11) All conductors shall be tested under equivalent conditions.

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

Response Message: SR-8437-NFPA 70-2021

Public Comment No. 2176-NFPA 70-2021 [Section No. 334.104]
Public Comment No. 1939-NFPA 70-2021 [Section No. 334.104]
336.104 Conductors.

For ungrounded, grounded, and equipment grounding conductors, the conductor sizes shall be 16 AWG through 1000 kcmil copper, 14 AWG through 1000 kcmil copper-clad aluminum, nickel, or nickel-coated copper, or and 12 AWG through 1000 kcmil aluminum or copper-clad aluminum. Insulation types shall be one of the types listed in Table 310.4(1) or Table 310.4(2) that is suitable for branch circuit and feeder circuits or one that is identified for such use.

For control and signal conductors, the minimum conductor sizes shall be 18 AWG copper, nickel, or nickel-coated copper, 14 AWG copper-clad aluminum, and 12 AWG aluminum.

(A) Fire Alarm Systems.

Where used for fire alarm systems, conductors shall also be in accordance with 760.49.

(B) Thermocouple Circuits.

Conductors in Type TC cable used for thermocouple circuits in accordance with Part III of Article 724 shall also be permitted to be any of the materials used for thermocouple extension wire.

(C) Class 1 Circuit Conductors.

Insulated conductors of 18 AWG and 16 AWG copper shall also be in accordance with 725.49.

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Tue Oct 26 16:02:09 EDT 2021

Committee Statement

The panel acted to revert to 2020 code language for the minimum size of conductors for 310.3(A), Tables 310.16 and 310.17, and wiring methods in multiple articles, including Articles 320, 330, 334, 336, and 340. To ensure public safety, further time is needed to study 14 AWG copper-clad aluminum and 16 AWG copper as minimum conductor sizes.

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

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

1) the Bimetallics Task Group (conducted at an Eaton facility)
2) the Copper Development Association (conducted at a Hampton Tedder facility)
3) the Southwire company (conducted at the DB Cofer laboratory)
4) the Cable Technologies Laboratory (conducted at their facility)
5) the Cerrowire company (conducted at the Marmon Innovation and Technology Center)

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

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

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

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

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

3) At a minimum, testing of 16 AWG copper and 14 AWG copper-clad aluminum in thermal insulation is required. To address questions that were raised about existing branch circuit conductor sizes and heat rise in thermal insulation, the panel is also requesting testing of:
   a. 14 AWG copper and 12 AWG copper-clad aluminum
   b. 12 AWG copper and 10 AWG copper-clad aluminum

4) Equivalent testing of aluminum conductors is also welcomed.

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

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

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

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

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

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

11) All conductors shall be tested under equivalent conditions.

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

The references in parts B and C have been updated in correlation with CMP 3 action to create a new Article 724 on Class 1 circuits.

Response Message: SR-8443-NFPA 70-2021

Public Comment No. 2186-NFPA 70-2021 [Section No. 336.104 [Excluding any Sub-Sections]]
Public Comment No. 2073-NFPA 70-2021 [Section No. 336.104 [Excluding any Sub-Sections]]
Article 337  Drilling Rig Industrial Mobile Cable: Type P IM

Part I. General

337.1 Scope.
This article covers the use, installation, and construction specifications for up through 2000 volt drilling rig industrial mobile cable, Type P IM (armored and unarmored).

337.6 Listing Requirements.
Type P IM cables and associated fittings shall be listed.

Part II. Installation

337.10 Uses Permitted.
Type P IM cable shall be permitted to be used as follows:

(1) Under engineering supervision in industrial installations where conditions of maintenance and supervision ensure that only qualified persons monitor and service the system.

(2) In hazardous (classified) locations where specifically permitted by other articles in this Code.

337.12 Uses Not Permitted.
Type P IM cable shall not be installed or used for the following:

(1) Where it will be exposed to physical damage

(2) Where not specifically permitted by other articles in the Code

337.24 Bending Radius.
The minimum bending radii during installations and handling in service shall be adequate to prevent damage to the cable.

337.30 Securing and Supporting.
Type P IM cable shall be supported and secured by cable ties listed and identified for securement and support; straps, hangers, or similar fittings; or other approved means designed and installed so as not to damage the cable.

337.31 Single Conductors.
Where single-conductor cables are used, the installation shall comply with 300.20.

337.80 Ampacity.
The ampacity of Type P IM cable shall be determined in accordance with 310.14(A) or (B) for 14 AWG and larger conductors. For 18 AWG and 16 AWG conductors, the ampacities shall be determined in accordance with Table 402.5 or 310.14(B). When installed in cable tray, the ampacities shall be permitted to be determined in accordance with 392.80. The installation shall not exceed the temperature ratings of terminations and equipment.

Part III. Construction Specifications

337.104 Conductors.
Conductors shall be of tinned copper. Conductors shall employ flexible stranding. The minimum conductor size shall be 18 AWG.
337.108 Equipment Grounding Conductor.
An equipment grounding conductor complying with 250.122 shall be provided within
multiconductor Type P IM cable.

337.112 Insulation.
Insulated conductors shall be a thermoset type identified for use in Type P IM cable. All
conductors shall be suitable for wet locations. The minimum wall thickness shall be 0.76 mm
(30 mils).

337.114 Shield.
Metallic shield(s) shall be permitted over a single conductor or groups of conductors.

337.115 Jacket.
Multiconductor cables shall have an overall nonmetallic jacket that is impervious to moisture,
corrosion resistant, and sunlight resistant. When installed external to an enclosure or industrial
machinery, single conductor cables shall have an overall nonmetallic jacket that is impervious
to moisture, corrosion resistant, and sunlight resistant. Single conductor cables rated 2000
volts with conductor sizes equal to or larger than 4/0 AWG shall be permitted to use an
increased insulation thickness in lieu of using a separate cable jacket. When the increased
insulation thickness is used, the insulation material shall be sunlight resistant.

337.116 Armor.
Armor shall be permitted over the jacket. If provided, the armor or metallic covering shall be a
braided basket weave type consisting of wire laid closely together, flat and parallel, and
forming a basket weave that shall firmly grip the cable. The wire shall be commercial bronze,
tinned copper, stainless steel, or aluminum. The armor shall not be used as a current-carrying
conductor or as an equipment grounding conductor. A nonmetallic jacket that conforms to
337.115 shall be provided over the armor.

337.120 Marking.
Type P IM cable shall be marked in accordance with 310.8. When an armor is provided, the
cable shall be marked accordingly.

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 15:17:02 EDT 2021

Committee Statement

Committee Statement: The Article title and cable type designation were changed to Industrial Mobile Cable and
Type IM. The references within the article were changed to reflect the new designations.

This article is not focused on Marine applications, most of which are not under the Scope
of the NEC. Although similar Type P cables are used for offshore drilling rigs, those
applications are not under the Scope of the NEC. There are already cable designations
for instrumentation, control, and power cable in other parts of the NEC, and none of
these terms would provide clarity for the Code user. VFD cable is not defined in the NEC,
and this is not a cable specifically designed for VFD applications. Robust Industrial cable
could easily be confused with other existing types of cable like Tray Cable or Metal-Clad
Cable.

The primary use for this cable and the purpose for its inclusion in the NEC was to
recognize a suitable wiring method for Land Based Drilling Rigs, but the cable would not
be limited to that application by the Uses Permitted and Uses Not Permitted.

Like many cable wiring methods, there are other locations where the cable will likely be
useful, but the title chosen is the most descriptive and useful for the Code user. Just like with Service-Entrance Cable, the title does not limit the use of the wiring method. Uses Permitted and Uses Not Permitted are the determining sections for permissible uses of any particular wiring method.

Response Message:

SR-8298-NFPA 70-2021

Public Comment No. 784-NFPA 70-2021 [Article 337]
Public Comment No. 2136-NFPA 70-2021 [Article 337]
340.10 Uses Permitted.

Type UF cable shall be permitted as follows:

1. For use underground, including direct burial in the earth.
2. As single-conductor cables. Where installed as single-conductor cables, all conductors of the feeder or branch circuit, including the grounded conductor and equipment grounding conductor, if any, shall be installed in accordance with 300.3.
3. For wiring in wet, dry, or corrosive locations.
4. Installed as nonmetallic-sheathed cable. Where so installed, the installation and conductor requirements shall comply with Parts II and III of Article 334, except for 334.12(B), and shall be of the multiconductor type.
5. As single-conductor cables as the nonheating leads for heating cables as provided in 424.43.
6. Supported by cable trays. Type UF cable supported by cable trays shall be of the multiconductor type.

Informational Note: See 310.14(A)(3) for temperature limitation of conductors.

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 16:11:18 EDT 2021

Committee Statement

Committee Statement: Language was added to provide clarity that when UF cable is installed as NM cable it does not have to meet the requirements of 334.12(B).
Response Message: SR-8310-NFPA 70-2021

Public Comment No. 937-NFPA 70-2021 [Section No. 340.10]
340.104 Conductors.

For ungrounded, grounded, and equipment grounding conductors, the conductor sizes shall be 16 AWG through 4/0 AWG copper, or 14 AWG through 4/0 AWG copper-clad aluminum, or 12 AWG through 4/0 AWG aluminum or copper-clad aluminum.

Supplemental Information

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Submitter Information Verification

Committee: NEC-P06
Submittal Date: Tue Oct 26 16:08:13 EDT 2021

Committee Statement

The panel acted to revert to 2020 code language for the minimum size of conductors for 310.3(A), Tables 310.16 and 310.17, and wiring methods in multiple articles, including Articles 320, 330, 334, 336, and 340. To ensure public safety, further time is needed to study 14 AWG copper-clad aluminum and 16 AWG copper as minimum conductor sizes.

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

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

1) the Bimetallics Task Group (conducted at an Eaton facility)
2) the Copper Development Association (conducted at a Hampton Tedder facility)
3) the Southwire company (conducted at the DB Cofer laboratory)
4) the Cable Technologies Laboratory (conducted at their facility)
5) the Cerrowire company (conducted at the Marmon Innovation and Technology Center)

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

After considering all the information and results presented in the reports, public inputs, and public comments, concerns were recognized about conductor overheating in common, everyday installations that need to be addressed prior to reducing the allowable branch circuit conductor size. Primarily, the evidence of excessive heat rise that occurs when wiring methods are installed in thermal insulation needs to be addressed. Voltage drop was also identified as a concern and needs to be addressed.
To determine the appropriate code requirements to ensure the installation of reduced branch circuit conductor sizes is both practical and safe, additional information is required. The panel requests public input that includes the following information obtained from credible sources and qualified testing laboratories:

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

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

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

   a. 14 AWG copper and 12 AWG copper-clad aluminum
   b. 12 AWG copper and 10 AWG copper-clad aluminum

4) Equivalent testing of aluminum conductors is also welcomed.

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

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

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

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

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

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

11) All conductors shall be tested under equivalent conditions.

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

Public Comment No. 1940-NFPA 70-2021 [Section No. 340.104]
Public Comment No. 2191-NFPA 70-2021 [Section No. 340.104]
Exposed to Physical Damage.

Conductors within 2.1 m (7 ft) from the floor shall be considered exposed to physical damage. Where open conductors cross ceiling joists and wall studs and are exposed to physical damage, they shall be protected by one of the following methods:

(1) Guard strips shall not be less than 25 mm (1 in.) nominal in thickness and at least as high as the insulating supports, placed on each side of and close to the wiring.

(2) A substantial running board at least 13 mm (1/2 in.) thick in back of the conductors with side protections. Running boards shall extend at least 25 mm (1 in.) outside the conductors, but not more than 50 mm (2 in.), and the protecting sides shall be at least 50 mm (2 in.) high and at least 25 mm (1 in.), nominal, in thickness.

(3) Boxing made in accordance with 398.15(C)(1) or (C)(2) and furnished with a cover kept at least 25 mm (1 in.) away from the conductors within. Where protecting vertical conductors on side walls, the boxing shall be closed at the top and the holes through which the conductors pass shall be bushed.

(4) Rigid metal conduit (RMC), intermediate metal conduit (IMC), rigid polyvinyl chloride conduit (PVC), reinforced thermosetting resin conduit (RTRC), high density polyethylene conduit (HDPE), or electrical metallic tubing (EMT). When installed in metal piping, the conductors shall be encased in continuous lengths of approved flexible tubing.

Committee Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 16:02:41 EDT 2021

Committee Statement

Committee Statement: HDPE was removed from line item (4) as a permitted means to provide physical protection for open wiring on insulators. This was done because 353.12 prohibits its use for exposed installations.
Response Message: SR-8308-NFPA 70-2021

Public Comment No. 5-NFPA 70-2021 [Section No. 398.15(C)]
| Second Revision No. 8274-NFPA 70-2021 [ Section No. 400.4 ] |
400.4 Types.
Flexible cords and flexible cables shall conform to the description in Table 400.4. The use of flexible cords and flexible cables other than those in Table 400.4 shall require permission by the authority having jurisdiction.

**Table 400.4 Flexible Cords and Flexible Cables**

<table>
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<tr>
<th>Trade Name</th>
<th>Type Letter</th>
<th>Voltage</th>
<th>AWG or kcmil</th>
<th>Number of Conductors</th>
<th>Insulation</th>
<th>AWG or kcmil</th>
<th>Nominal Insulation Thickness</th>
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<td>C</td>
<td>300 600</td>
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<td>15–10</td>
<td>2 or more</td>
<td>18–16</td>
<td>15–10</td>
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<td>E 1,2,3,4</td>
<td>300 or 600</td>
<td>20–2</td>
<td>2 or more</td>
<td>Thermoset</td>
<td>20–16</td>
<td>15–12 12–10 8–2</td>
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<td>Elevator cable EO</td>
<td>EO 1,2,4</td>
<td>300 or 600</td>
<td>20–2</td>
<td>2 or more</td>
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<td>20–16</td>
<td>15–12 12–10 8–2</td>
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<td>Electric vehicle</td>
<td>EV 5,6</td>
<td>1000</td>
<td>18–500</td>
<td>2 or more plus</td>
<td>Thermoset with</td>
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Notes:
All types listed in Table 400.4 shall have individual conductors twisted together, except for Types HPN, SP-1, SP-2, SP-3, SPE-1, SPE-2, SPE-3, SPT-1, SPT-2, SPT-3, SPT-1W, SPT-2W, TPT, NISP-1, NISP-2, NISPT-1, NISPT-2, NISPE-1, NISPE-2, and three-conductor parallel versions of SRD, SRDE, and SRDT.
The individual conductors of all cords, except those of heat-resistant cords, shall have a thermoset or thermoplastic insulation, except that the equipment grounding conductor, where used, shall be in accordance with 400.23(B).

1Rubber-filled or varnished cambric tapes shall be permitted as a substitute for the inner braids.

2Elevator traveling cables for operating control and signal circuits shall contain nonmetallic fillers as necessary to maintain concentricity. Cables shall have steel supporting members as required for suspension by 620.41. In locations subject to excessive moisture or corrosive vapors or gases, supporting members of other materials shall be permitted. Where steel supporting members are used, they shall run straight through the center of the cable assembly and shall not be cabled with the copper strands of any conductor.

In addition to conductors used for control and signaling circuits, Types E, EO, ETP, and ETT elevator cables shall be permitted to incorporate in the construction one or more 20 AWG telephone conductor pairs, one or more coaxial cables, one or more optical fibers, or one or more communications cables. The 20 AWG or larger conductor pairs shall be permitted to be covered with suitable shielding for telephone, audio, data transfer, or higher frequency communications circuits; the coaxial cables shall consist of a center conductor, insulation, and a shield for use in video or other radio frequency communications circuits. The optical fiber shall be suitably covered with flame-retardant thermoplastic. The insulation of the conductors shall be rubber or thermoplastic of a thickness not less than specified for the other conductors of the particular type of cable. Metallic shields shall have their own protective covering. Where used, these components shall be permitted to be incorporated in any layer of the cable assembly but shall not run straight through the center.

3Insulations and outer coverings that meet the requirements as flame retardant, limited smoke, and are so listed, shall be permitted to be marked for limited smoke after the Code type designation.

4Elevator cables in sizes 20 AWG through 14 AWG are rated 300 volts, and sizes 10 AWG through 2 AWG are rated 600 volts. 12 AWG is rated 300 volts with a 0.76 mm (30 mil) insulation thickness and 600 volts with a 1.14 mm (45 mil) insulation thickness.

5Conductor size for Types EV, EVJ, EVE, EVJE, EVT, and EVJT cables apply to nonpower-limited circuits only. Conductors of power-limited (data, signal, or communications) circuits may extend beyond the stated AWG size range. All conductors shall be insulated for the same cable voltage rating.

6Insulation thickness for Types EV, EVJ, EVEJE, EVT, and EVJT cables of nylon construction is indicated in parentheses.

7Types G, G-GC, S, SC, SCE, SCT, SE, SEO, SEOO, SEOW, SEOOW, SO, SOO, SOW, SOOW, ST, STO, STOO, STW, STOW, STOOW, PPE, and W shall be permitted for use on theater stages, in garages, and elsewhere where flexible cords are permitted by this Code.

8The third conductor in Type HPN shall be used as an equipment grounding conductor only. The insulation of the equipment grounding conductor for Types SPE-1, SPE-2, SPE-3, SPT-1, SPT-2, SPT-3, NISPT-1, NISPT-2, NISPE-1, and NISPE-2 shall be permitted to be thermoset polymer.

9Cords that comply with the requirements for outdoor cords and are so listed shall be permitted to be designated as weather and water resistant with the suffix “W” after the Code type designation. Cords with the “W” suffix are suitable for use in wet locations and are sunlight resistant.

10The required outer covering on some single-conductor cables may be integral with the insulation.

11Types TPT and TST shall be permitted in lengths not exceeding 2.5 m (8 ft) where attached directly, or by means of a special type of plug, to a portable appliance rated at 50 watts or less.
and of such nature that extreme flexibility of the cord is essential.

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Mon Oct 25 13:37:28 EDT 2021

Committee Statement

Committee Statement: This change correlates with the second revision changes made in 620.12 by CMP-12. The smaller gauge wires are necessary to accommodate the additional communication requirements added to industry standards and some building codes for use with enhanced emergency communication systems for people with hearing loss. The AWG sizes were not changed in the table in order to avoid allowing smaller circuit conductors in applications other than communications.

Response Message: SR-8274-NFPA 70-2021

Public Comment No. 1838-NFPA 70-2021 [Section No. 400.4]
Public Comment No. 2110-NFPA 70-2021 [Section No. 400.4]
Public Comment No. 2167-NFPA 70-2021 [Section No. 400.4]
### Informative Annex E Types of Construction

*This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.*

#### E.1

**Table E.1 Fire Resistance Ratings for Type I Through Type V Construction (hr)**

<table>
<thead>
<tr>
<th></th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type IV</th>
<th>Type V</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exterior Bearing Walls</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supporting more than one floor, columns, or other bearing walls</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Supporting one floor only</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
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<td>3</td>
<td>1</td>
<td>1</td>
<td>0&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td><strong>Interior Bearing Walls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supporting more than one floor, columns, or other bearing walls</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Supporting one floor only</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Supporting roofs only</td>
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<td>2</td>
<td>1</td>
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<td>0</td>
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<tr>
<td><strong>Columns</strong></td>
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<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Supporting one floor only</td>
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<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Supporting roofs only</td>
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<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
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<tr>
<td><strong>Beams, Girders, Trusses, and Arches</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Supporting more than one floor, columns, or other bearing walls</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Supporting one floor only</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Supporting roofs only</td>
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<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>Floor/Ceiling Assemblies</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Roof/Ceiling Assemblies</strong></td>
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<td></td>
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<td>2</td>
<td>1&lt;sup&gt;½&lt;/sup&gt;</td>
<td>1</td>
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<td>0</td>
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<tr>
<td><strong>Interior Nonbearing Walls</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Exterior Nonbearing Walls</strong>&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>


H: Heavy timber members.

<sup>a</sup>See 7.3.2.1 in *NFPA 5000.*

<sup>b</sup>See Section 7.3 in *NFPA 5000.*

<sup>c</sup>See 7.2.3.2.12, 7.2.4.2.3, and 7.2.5.6.8 in *NFPA 5000.*
Table E.1 contains the fire resistance rating, in hours, for Types I through V construction. The five different types of construction can be summarized briefly as follows (see also Table E.2):

E.2.1

Type I is a fire-resistive construction type. All structural elements and most interior elements are required to be noncombustible. Interior, nonbearing partitions are permitted to be 1- or 2-hour rated. For nearly all occupancy types, Type I construction can be of unlimited height.

Type II construction has three categories: fire-resistive, one-hour rated, and nonrated. The number of stories permitted for multifamily dwellings varies from two for nonrated and four for one-hour rated to 12 for fire-resistive construction.

Type III construction has two categories: one-hour rated and nonrated. Both categories require the structural framework and exterior walls to be of noncombustible material. One-hour rated construction requires all interior partitions to be one-hour rated. Nonrated construction allows nonbearing interior partitions to be of nonrated construction. The maximum permitted number of stories for multifamily dwellings and other structures is two for nonrated and four for one-hour rated.

Type IV is a single construction category that provides for heavy timber construction. Both the structural framework and the exterior walls are required to be noncombustible except that wood members of certain minimum sizes are allowed. This construction type is seldom used for multifamily dwellings but, if used, would be permitted to be four stories high. It includes traditional heavy timber construction and mass timber construction. In heavy timber construction, the structural framework and the exterior walls are required to be noncombustible except that wood members of certain minimum sizes are allowed. In mass timber construction, structural elements of cross-laminated timber (CLT) are permitted. Allowable building height for mass timber is much higher than for heavy timber.

Type V construction has two categories: one-hour rated and nonrated. One-hour rated construction requires a minimum of one-hour rated construction throughout the building. Nonrated construction allows nonrated interior partitions with certain restrictions. The maximum permitted number of stories for multifamily dwellings and other structures is two for nonrated and three for one-hour rated.

Table E.2 Maximum Number of Stories for Types V, IV, and III Construction

<table>
<thead>
<tr>
<th>Construction Type</th>
<th>Maximum Number of Stories Permitted</th>
</tr>
</thead>
<tbody>
<tr>
<td>V Nonrated</td>
<td>2</td>
</tr>
<tr>
<td>V Nonrated, Sprinklered</td>
<td>3</td>
</tr>
<tr>
<td>V One-Hour Rated</td>
<td>3</td>
</tr>
<tr>
<td>V One-Hour Rated, Sprinklered</td>
<td>4</td>
</tr>
<tr>
<td>IV Heavy Timber</td>
<td>4</td>
</tr>
<tr>
<td>IV Heavy Timber, Sprinklered</td>
<td>5</td>
</tr>
<tr>
<td>IV Mass Timber</td>
<td>12</td>
</tr>
<tr>
<td>III Nonrated</td>
<td>2</td>
</tr>
<tr>
<td>III Nonrated, Sprinklered</td>
<td>3</td>
</tr>
<tr>
<td>III One-Hour Rated</td>
<td>4</td>
</tr>
<tr>
<td>III One-Hour Rated, Sprinklered</td>
<td>5</td>
</tr>
</tbody>
</table>

E.3
In Table E.1 the system of designating types of construction also includes a specific breakdown of the types of construction through the use of arabic numbers. These arabic numbers follow the roman numeral notation where identifying a type of construction [for example, Type I(442), Type II(111), Type III(200)] and indicate the fire resistance rating requirements for certain structural elements as follows:

1. First arabic number — exterior bearing walls
2. Second arabic number — columns, beams, girders, trusses and arches, supporting bearing walls, columns, or loads from more than one floor
3. Third arabic number — floor construction

E.3.1
Table E.3 provides a comparison of the types of construction for various model building codes. [5000: A.7.2.1.1]

Table E.3 Cross-Reference of Building Construction Types

<table>
<thead>
<tr>
<th>NFPA 5000</th>
<th>I (442)</th>
<th>II (332)</th>
<th>II (222)</th>
<th>II (111)</th>
<th>II (000)</th>
<th>III (211)</th>
<th>III (200)</th>
<th>IV (2HH)</th>
<th>V (111)</th>
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<tr>
<td>UBC</td>
<td>—</td>
<td>I FR</td>
<td>II FR</td>
<td>II 1 hr</td>
<td>II N</td>
<td>III 1 hr</td>
<td>III N</td>
<td>IV HT</td>
<td>V 1 hr</td>
<td>V N</td>
</tr>
<tr>
<td>B/NBC</td>
<td>1A</td>
<td>1B</td>
<td>2A</td>
<td>2B</td>
<td>2C</td>
<td>3A</td>
<td>3B</td>
<td>4</td>
<td>5A</td>
<td>5B</td>
</tr>
<tr>
<td>SBC</td>
<td>I</td>
<td>II</td>
<td>—</td>
<td>IV 1 hr</td>
<td>IV UNP</td>
<td>V 1 hr</td>
<td>V UNP</td>
<td>III</td>
<td>VI 1 hr</td>
<td>VI UNP</td>
</tr>
<tr>
<td>IBC</td>
<td>—</td>
<td>IA</td>
<td>IB</td>
<td>II A</td>
<td>II B</td>
<td>III A</td>
<td>III B</td>
<td>IV*</td>
<td>VA</td>
<td>VB</td>
</tr>
</tbody>
</table>

*Mass timber in the IBC is Type IV A, IV B, and IV C


FR: Fire rated.
N: Nonsprinklered.
HT: Heavy timber.
UNP: Unprotected.

Supplemental Information

<table>
<thead>
<tr>
<th>File Name</th>
<th>Description</th>
<th>Approved</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEC_CMP_6_SR8483_Annex_E.docx</td>
<td>For staff use</td>
<td></td>
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</table>

Submitter Information Verification

Committee: NEC-P06
Submittal Date: Wed Oct 27 14:59:58 EDT 2021

Committee Statement

Committee Statement: Changes were required to address the addition of mass timber buildings to Type IV construction in the model building codes.
<table>
<thead>
<tr>
<th>Response Message:</th>
<th>SR-8483-NFPA 70-2021</th>
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</thead>
<tbody>
<tr>
<td>Public Comment No. 924-NFPA 70-2021 [Annex E]</td>
<td></td>
</tr>
</tbody>
</table>
Exhibit 12
PERRY JOHNSON LABORATORY ACCREDITATION, INC.

Certificate of Accreditation

Perry Johnson Laboratory Accreditation, Inc. has assessed the Laboratory of:

Cable Technology Laboratories
625 Jersey Avenue, Unit-14, New Brunswick, NJ 08901

(Hereinafter called the Organization) and hereby declares that Organization is accredited in accordance with the recognized International Standard:

ISO/IEC 17025:2017

This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (as outlined by the joint ISO-ILAC-IAF Communiqué dated April 2017):

Electrical, Mechanical, Dimensional, and Thermodynamic Testing
(As detailed in the supplement)

Accreditation claims for such testing and/or calibration services shall only be made from addresses referenced within this certificate. This Accreditation is granted subject to the system rules governing the Accreditation referred to above, and the Organization hereby covenants with the Accreditation body’s duty to observe and comply with the said rules.

For PJLA:

Tracy Szerszen
President

Perry Johnson Laboratory Accreditation, Inc. (PJLA)
755 W. Big Beaver, Suite 1325
Troy, Michigan 48084

Initial Accreditation Date: January 12, 2018
Issue Date: January 17, 2022
Expiration Date: April 30, 2024

Accreditation No.: 97636
Certificate No.: L22-57

The validity of this certificate is maintained through ongoing assessments based on a continuous accreditation cycle. The validity of this certificate should be confirmed through the PJLA website: www.pjlabs.com
August 1, 2022

To: The NFPA Standards Council
Regarding: Appeal Number 22-8-5-Y Submitted July 18, 2022 by Peter Graser of Copperweld Bimetallics, current President of the American Bimetallic Association.

The Copper Development Association (CDA) is concerned by accusations made in this appeal and hereby submits comments to address and rebut these statements. As a long-time member of NFPA, CDA fully supports the NFPA process and the integrity of the National Electrical Code. The proposed changes referred to in this appeal did not receive the required ballot results due to significant technical concerns that can lead to hazardous overheating or even fire in real-world installation conditions. CDA holds safety as our highest priority when considering changes to the NEC. The NFPA process was followed, technical concerns have not yet been addressed, and therefore, this appeal should be rejected.

The public comments submitted by CDA on CMP-6 and subsequent action on the proposed code changes were based on well-documented, independent testing by an accredited third-party laboratory using certified equipment, the report and details of which were included in the public comment and are part of the public record. The proponent's continued characterization of the results as “sham testing”, “dubious”, and “unreliable” is a thinly-disguised attempt to discredit these credible, independent technical results by either ignoring the submission of this testing, or characterizing this testing as one and the same with the “garage test” to which they take exception.

The proponent also characterizes this independent testing as intentionally misleading, since the testing did not include or report results on 14 AWG copper conductors. This testing was conducted at great effort and expense by CDA and 14 AWG copper conductors were not included in the testing for three reasons: 1) 14 AWG copper conductors have been used in these applications safely for many years so performance had already been established and was not the subject of question; 2) the subject code change only addressed addition of 14 AWG CCA to the code, and did not include any changes to the use of copper conductors that required investigation; and 3) the testing was conducted to address the specific concern that testing performed by the Bimetallics Task Group where conductors were tested only in open air, and not under or within building thermal insulation as would be expected in service would not be representative of actual technical performance and safety. We would like to make it completely clear the test report included with the CDA public comment includes all the data resulting from the independent research into 14 AWG CCA. Here again, the proponent mischaracterizes the body of technical data by lumping this
test report with the “garage test” or other information shared by Bimetallics Task Group members either in their meetings or at a NEMA meeting at which CDA was not present or party to.

Lastly, we strongly object to accusation by inference that CDA, through its actions or representation colluded with NEMA or the Aluminum Association or acted to restrain trade in performing and submitting valid, independent technical research to uphold the safety of electrical installations covered by the code, and in directing the votes of our CMP-6 panel representative(s) to oppose the subject code change on the basis of the results of such testing.

CDA firmly believes in the integrity of the NFPA process and has made every effort to follow process rules and regulations. CDA’s primary interest is safety, as public incidents can cause irreparable damage industry-wide. If 14 AWG CCA is proven to operate safely in real world conditions, CDA will have no objections to this product being in the code along with 16 AWG copper.

Sincerely yours,

John Hipchen
Director, Energy and Electrical Systems
7918 Jones Branch Drive, Suite 300
McLean, VA 22102
Phone: 212-251-7208
Email: John.Hipchen@CopperAlliance.us
August 2, 2022

Dawn Michele Bellis  
Secretary  
NFPA Standards Council  
1 Batterymarch Park  
Quincy, MA 02169

RE: Response to copper-clad aluminum appeal/2023 NEC

Dear Ms. Bellis,

This is in response to the appeal regarding 14 AWG copper-clad aluminum conductors in the 2023 NEC. I will be at the Standards Council meeting on August 10, and I would like the opportunity to speak to this issue.

1) **Is declining to include 14 AWG copper-clad aluminum as a branch circuit conductor size a “restraint of trade”? No.** Following the NFPA/ANSI process and declining to include a never-before permitted conductor size for branch circuits is not restraint of trade. The appellant is requesting that one metal (14 AWG copper-clad aluminum) be included as a smaller branch circuit size while other alternatives (like 16 AWG copper) be excluded. He has made it clear in his appeal that he is attempting to create a code-endorsed commercial advantage for his product while excluding metals of substantially equal conductivity and mechanical performance, with no regard for the installation safety concerns that have been identified. CAM 70-128 and this appeal both seek to add only 14 AWG copper-clad aluminum to Tables 310.16 and 310.17. That conflicts with the action taken by the code-making panel in the first draft process. In the first draft, both 14 AWG copper-clad aluminum and 16 AWG copper were added at equal ampacities in each temperature column. Although only evidence of 14 AWG copper-clad aluminum overheating in thermal insulation was submitted in the second draft, the panel agreed to remove both conductors for branch circuit wiring until the field installation overheating issue could be fully investigated.

2) **Was the NFPA process followed? Yes.** The code-making panel 6 activities were carried out in accordance with NFPA regulations. The proponents for including 14 AWG copper-clad aluminum in the NEC were given great deference in the code-making process. The code-making panel devoted more time to this subject than any other issue on our agenda. The Standards Council not only gave the bimetallic association a voting position on the panel, but they also directed the formation of a Correlating Committee task group to consider the addition of 14 AWG copper-clad aluminum to the 2023 NEC, an addition that will have a small economic impact for Code users and will only benefit one or two companies that manufacture copper-clad aluminum insulated conductors. The bimetallic association was given two voting positions on both the Bi-metals Task Group and the CMP-6 task group that was formed to consider the public comments.
concerning this subject in the second draft process, whereas every other interest was only given one vote on each task group. Despite all the advantages they were given and their steady pressure on the code-making panel members outside the committee meetings, they were still unable to convince the required 2/3 of the committee that the addition of 14 AWG copper-clad aluminum as a branch circuit was necessary and safe.

3) **Are the requirements for providing overcurrent protection for Class 1 control circuits found in the 2023 NEC?** Yes. The concern that was raised by the appellant in the 2020 NEC (the use of 14 AWG copper-clad aluminum conductors as control conductors) has been successfully addressed in the 2023 NEC, and it does not require ampacities be added to Tables 310.16 and 310.17. The complaint was that the allowance of 14 AWG copper-clad aluminum conductors as Class 1 control circuits in Type MC and Type TC cable would result in installations without adequate overcurrent protection. In the 2023 NEC, code-making panel 10 added 240.4(D)(3) that permits a 10-ampere overcurrent protective device for 14 AWG copper-clad aluminum conductors, as long as the continuous load is no greater than 8 amperes. This is similar to the allowances for 18 AWG and 16 AWG copper in 240.4(D)(1) and (2), both of which are used for control circuits. The inclusion of overcurrent protection sized for 14 AWG copper-clad aluminum control makes it clear how the Code user can protect the circuit from overcurrent and removes any concerns regarding correlation.

Additionally, in 2023 NEC Section 724.43, overcurrent protection for Class 1 control conductors is specified to be provided without applying ampacity adjustment and correction factors in 310.15, therefore no Table 310.16 or Table 310.17 ampacity is needed for correction or adjustment factors. Section 724.43 goes on to say that overcurrent protection shall not exceed 10 amperes for 16 AWG (copper) conductors. Section 110.5 states that “If the conductor material is not specified, the sizes given in this Code shall apply to copper conductors. If other materials are used, the size shall be changed accordingly.” Therefore, if copper-clad aluminum is used for Class 1 control conductors, the size would be changed to 14 AWG copper-clad aluminum, which is of approximately equal conductivity to 16 AWG copper.

<table>
<thead>
<tr>
<th>AWG size of conductor</th>
<th>Copper Resistance (ohms per thousand feet) at 20°C</th>
<th>Copper-clad aluminum Resistance (ohms per thousand feet) at 20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>4.10</td>
<td>-</td>
</tr>
<tr>
<td>14</td>
<td>-</td>
<td>4.21</td>
</tr>
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**Table 1: Comparative Resistance Values from UL 1581 Table 30.1**

Section 724.49 in the 2023 NEC addresses Class 1 circuit conductor size and ampacity. It states that 16 AWG copper is permitted if the supply loads do not exceed the ampacities in 402.5. The equivalent copper-clad aluminum would be 14 AWG. In Table 402.5, the ampacity of 16 AWG copper is limited to 8 amperes, as would be the similar 14 AWG copper-clad aluminum. There is only one column in Table 402.5, and it applies...
to the allowable insulation types in Table 402.3 and the associated maximum operating temperatures.

Section 724.51(A)(1) requires the use of adjustment factors (for number of current-carrying conductors) as specified in 310.15(C)(1) if a raceway contains only Class 1 conductors, and the conductors carry continuous loads of more than 10% of the ampacity of the conductors. Again, there is clear direction on what ampacity to use, and additional direction on how to compensate for more than three current carrying conductors in a raceway.

4) **Are the ampacities in Table 310.16 for 18 AWG and 16 AWG copper intended to be used for all of the insulated conductor types in the NEC?** No. In the 1974 National Electrical Code Preprint, Part II, Proposal No. 84, CMP6 added ampacities for 18 AWG and 16 AWG copper to Tables 310-16 and 310-17 to provide ampacities for Type MTW, Type MI cable, and Type AVB (Asbestos and Varnished Cambric). Type AVB is no longer included in the NEC. In the 2023 NEC Table 310.4(1), the smallest Type MI cable conductor permitted is 18 AWG copper, and the smallest Type MTW conductor permitted is 22 AWG. The note included with Type MTW directs the Code user to see NFPA 79, which is where Type MTW material, size, and ampacity details are located. NFPA 79 permits only copper conductor material. The applicable product standards for Type MTW and Type MI cable permit only copper conductors. No other insulated conductor types in Table 310.4(1) permit conductors smaller than 14 AWG copper (which corresponds to 12 AWG copper-clad aluminum), so there is no need to include ampacities for 14 AWG copper-clad aluminum in these tables. If a valid need for parity in Table 310.16 and Table 310.17 is identified in the future, 18 amps could be added to the 90°C column in Table 310.16 and 24 amps could be added to the 90°C column in Table 310.17 for 14 AWG copper-clad aluminum. Based on the resistance values published in UL 1581 for 16 AWG copper and 14 AWG copper-clad aluminum, this would be an equivalent use (shown in Table 1 above).

5) **Was the Correlating Committee Bi-Metals Task Group informed of the concern regarding smaller branch circuit conductors installed in thermal insulation?** Yes. The correlating committee task group considering the bimetallic conductor issue for the 2023 NEC was informed of preliminary testing indicating that 14 AWG copper-clad aluminum overheated when installed in typical lengths in typical thicknesses of thermal insulation. They declined to investigate the issue during the testing conducted prior to the submission of public inputs. The argument was made during the task group meetings by the two members representing the bimetallic interests that there was no UL established test for installations in thermal insulation, and that therefore it would be an invalid test. However, there are many test procedures created to support code proposals that are not based on UL test standards. UL test standards are intended for certification of electrical products for use in accordance with the NEC, they are not comprehensive testing procedures for every consideration needed for code changes. Even a cursory review of previous code-making cycles will reveal many tests that were performed to
gather information for proposed code changes, including a number of test reports provided to and accepted by CMP-6.

6) **Is there clear direction for next steps in the code development process for the subject of this appeal? Yes.** Code-making panel 6 spent many hours developing a lengthy statement regarding testing to be performed for the potential inclusion of 14 AWG copper-clad aluminum conductors for use as branch circuits. The statement also included direction on what type of testing would be needed for other conductor metal and size combinations that could be proposed to reduce the size of branch circuit conductors. The statement includes specific information about what type of testing is needed to verify the suitability and safety of smaller branch circuit conductors installed in typical construction. Several code-making panel members requested that the Chair of the CMP indicate in her report that the code-making panel would prefer to see the testing done under the direction of the Fire Protection Research Foundation.

Regarding the appellant’s allegations of misconduct by code-making panel members, the accusations are baseless. It is clear from the information submitted in his appeal and statements made during many NFPA meetings that the appellant is trying to silence the voice of anyone who disagrees with his position. His actions are very clearly in opposition to the NFPA Conduct Guide:

- In the NFPA Conduct Guide 3.1(c), it states that “Participants should encourage full participation in the standards development process by all interested persons, and they should encourage and facilitate the full and open dissemination of all information necessary to enable full and fair consideration of all points of view."
- In 3.1(d), it states that: "No participant should ever attempt to withhold or prohibit information or points of view from being disseminated, particularly on the grounds that the participant is in disagreement with the information or points of view. Disagreements should be addressed and resolved through full presentation and discussion of all information and points of view, not through withholding information or preventing points of view from being expressed."
- In 3.1(f), it states that "In all discussion, debate, and deliberation within the standards development process, participants should confine their comments to the merits of the scientific, technical, and procedural issues under review. Although participants may forcefully advocate their views or positions, they should be candid and forthcoming about any weaknesses in their position, and they should refrain from debate and discussion which is disrespectful or unprofessional in tone or which is unduly personalized or damaging to the overall process of achieving consensus."

During committee meetings, the appellant repeatedly accused other committee members of being dishonest, of attempting to mislead other committee members, of conducting and submitting false testing, and other, similar unprofessional and inaccurate claims. These accusations have been delivered both verbally and in written submissions to NFPA. I have not witnessed any chair of any of the task groups or the code-making panel ask the appellant to
refrain from these statements that are in conflict with the NFPA Conduct Guide, which only seems to embolden his attacks.

I am requesting that the Standards Council deny this appeal. The code-making process was followed, the appellant was given tremendous deference during the process, and there is no restraint of trade issue with the 2023 NEC as currently accepted.

Sincerely,
Christel Hunter
Vice-President of Standards
Cerro Wire LLC

chunter@cerrowire.com
702-271-7400
August 2, 2022

Dawn Bellis
Council Secretary
NFPA Standards Council
1 Batterymarch Park
Quincy, MA 02169

RE: Appeal For CAMs Dealing with 14 AWG Copper-Clad Aluminum from The American Bimetallic Association

Dear Ms. Bellis,

It is our understanding that the American Bimetallic Association (ABA) submitted an appeal (Ref: Appeal Materials for Council Consideration for Copper-Clad Aluminum, dated July 18, 2022) to the NFPA Standards Council to request a hearing regarding the inclusion of 14 AWG copper-clad aluminum (CCA) into the National Electric Code (NEC) through the NFPA’s code making panel 6 (CMP 6). The Aluminum Association (henceforth, “The Association”) requests that the Council entirely reject the allegations contained therein against the Association, its membership, and its representatives on NFPA technical committees.

The Association’s Electrical Division, which consists of its members from the wire and cable industry, employs mandatory consensus-based balloting requiring unanimous approval as the sole method of developing directions on all standards-related issues that are passed on to the Association’s representatives on the NEC code making panels. Any votes cast on the various NFPA technical committees by the representatives of the Association are “directed” votes, and not “individual” votes. The Association and its representatives on NFPA technical committees operate in complete accordance with the procedures laid out in Section 3.2 Membership of Technical Committees and Correlating Committees of the Regulations Governing the Development of NFPA Standards. The ABA appeal fails to identify any respect in which the Association or its members have violated the procedural requirements for NFPA balloting.

The Association and its Electrical Division neither collaborate nor consult with any external individual or organization in making the decisions that are relayed to its representatives on NFPA technical committees. Those decisions are entirely free of influences from any external individual or organization. Those decisions are made on the merits of the issues that come before the Electrical Division.

Furthermore, strict antitrust guidelines are followed before, during, and after all work carried out by the Electrical Division, and all ballots incurred during such work are completely restricted to technical matters and/or safety concerns only. Electrical Division meetings are monitored by external antitrust counsel. The ABA’s inability to persuade the members of the panel to agree with its technical positions does not constitute nor imply improper conduct by the panel members.
Therefore, the Association unequivocally rejects any claims by the ABA that the Association or its representatives on the NFPA technical committees violate any governing rules and operating procedures required to be followed for participation in NFPA activities.

The Association and its Electrical Division reserve the right to supplement this response in any proceedings that may come before the Council.

Charles Johnson
President & CEO
The Aluminum Association
1400 Crystal Drive, Suite 430
Arlington, VA 22202
Dear Ms. Bellis,

Please accept this written submission for the NFPA Standards Council consideration in accordance with 1.6 of the Regulations Governing the Development of NFPA Standards. This statement is in response to the two appeals filed by the American Bimetallic Association (ABA).

The National Electrical Manufacturers Association (NEMA) represents nearly 325 electrical equipment and medical imaging manufacturers that make safe, reliable, and efficient products and systems. In its appeal, the ABA argues that having the same individuals involved in multiple organizations leads to those individuals controlling multiple votes on the panel. In its argument, the ABA implicates NEMA as one of these organizations and specifically mentions the NEMA Codes & Standards Committee.

NEMA would like to correct the record. All NEMA representatives to outside organizations, including NFPA and the NFPA 70 Code Making Panels have directed votes on all official ballots. These votes are directed by the NEMA Codes & Standards Committee, which currently has 17 voting members. The ABA appeals mention a total of 5 voting members of the NEMA Codes & Standards Committee. Even if each of these members voted in a bloc at NEMA, they would not have sufficient votes to reach the majority required to reach a decision. Moreover, the NEMA Standardization Policies and Procedures specify that members are appointed based upon the following criteria “balanced representation of the broadly diversified interests and products within NEMA, technical expertise, and commitment to active participation”. They are “appointed to represent the technical best interests of NEMA as a whole and not of particular Product Groups or members”.

NEMA appreciates the opportunity to participate in the NFPA process and ensures that its representatives carefully follow all NFPA policies and procedures during their participation in NFPA.

Regards,

Peter Tolsdorf
Chief Legal, Membership, and People Officer
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Dear Ms. Bellis,

Please accept this written submission for the NFPA Standards Council consideration in accordance with 1.6 of the Regulations Governing the Development of NFPA Standards. This statement is in response to the appeal filed by the Leading Builders of America (LBA).

The National Electrical Manufacturers Association (NEMA) represents nearly 325 electrical equipment and medical imaging manufacturers that make safe, reliable, and efficient products and systems. In its appeal, the LBA alleges that the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) extended an invitation to NEMA to participate in a research project, and that NEMA has not accepted that invitation. NEMA would like to correct the record and emphatically denies the LBA statement. NEMA has not been invited to participate in this research project, although NEMA has discussed the project with AHRI and NEMA members are aware of the project.

NEMA continues to support the expansion of Ground Fault Circuit Interruption (GFCI) technology to protect lives. NEMA supports the process going forward for TIAs 1656 and 1657 (related to 210.8(F)). NEMA agrees that the process for 210.8(F) has been followed and is satisfied with the outcome. NEMA has no reason to believe that any policy or procedure has been violated throughout the process that would warrant upholding this appeal. NEMA appreciates the opportunity to participate in the NFPA process and ensures that its representatives carefully follow all NFPA policies and procedures during their participation in NFPA.

Regards,

Peter Tolsdorf
Chief Legal, Membership, and People Officer
August 1, 2022

To: National Fire Protection Association Standards Council
(Submitted via email to stds_admin@nfpa.org)

Re: Standards Council Meeting Agenda Item No. 22-8-16

Dear Members of the NFPA Standards Council,

NAHB is a federation of more than 700 state and local home builder associations nationwide that work to ensure that housing remains a national priority and that all Americans have access to safe, decent and affordable homes. The organization's membership includes over 140,000 firms engaged in land development, single and multifamily residential construction, design, remodeling, multifamily ownership and management, building material trades, building products manufacturing and supply, and commercial and light industrial construction projects. Over 95 percent of NAHB’s members are classified as “small businesses” as defined by the U.S. Small Business Administration (SBA). NAHB members collectively employ over 3.4 million people nationwide. Four out of every five new homes are built by NAHB members.

NAHB fully supports the appeals that seek the issuance of TIA No. 1653 and TIA No. 1654. We request the NFPA Standards Council to exempt listed HVAC equipment from GFCI requirements for outdoor outlets in accordance with TIA No. 1653 and TIA No. 1654 for the following reasons:

1. The language of both TIAs was developed through a Task Group whose creation was directed by the Standards Council. The Task Group consisted of a broad set of affected stakeholders, including electrical contractors, HVAC manufacturers, GFCI manufacturers, CMP-2 members, electrical inspectors, the U.S. Consumer Product Safety Commission, testing laboratories, and the home building industry. We believe the Task Group fulfilled the Council’s mandate and reached an informed, technically-substantiated resolution to the issues raised.

2. There is a known incompatibility between GFCI devices and a broad range of HVAC equipment. Field data shows that unnecessary GFCI tripping does occur on air conditioner and heat pump units that do not have power conversion equipment. However, the competing TIAs do not exempt all equipment affected by nuisance tripping. The technical reasoning for the incompatibility problem has been adequately described in previous documentation for TIA No. 1653 and TIA No. 1654 developed through the work of the Task Group.
3. The risk that people will be exposed to extreme temperatures is much higher than the risk that somebody may become exposed to an electrical current leak from HVAC equipment that could cause injury or harm. This is especially true as various parts of the country deal with record summer heat. “At risk” populations, such as young children, the elderly, and individuals with underlying medical conditions, are especially at risk due to loss of essential cooling during a tripping event.

Air conditioning outages due to the incompatibility of GFCI devices and HVAC equipment can cause harm to the occupants of buildings. NAHB requests that TIA No. 1653 and TIA No. 1654 be approved in accordance with task group recommendation to provide a relief until the issue of equipment incompatibility is resolved.

Sincerely,

Daniel Buuck, Sr. Program Manager, Codes & Standards
National Association of Home Builders
1201 15th Street NW | Washington, DC 20005
D 202 266 8366 | dbuuck@nahb.org
July 31, 2022

Report on TIA 1653 & 1654 Appeal

The appeal to Standards Council of TIA No. 1653 & 1654 has been received and reviewed by the Chair of CMP 2 David G. Humphrey. The Chair supports the panel’s action based on the vote of the technical committee and the issues to be detailed below.

The technical committee vote was 11 -5 in favor of support on the merits and 12-4 in support of the concept of the TIA being of an emergency nature for both TIA 1653 and TIA 1654. Accordingly, the voting resulted in the tally being one vote short on the merits and meeting the necessary approval votes on emergency nature.

CMP 2 has worked diligently on the issue of GFCI protection of outdoor HVAC equipment at dwellings for some time. The panel widely concurs that GFCI protection is an important component of overall electrical safety and GFCI protection would enhance the safe use of HVAC equipment. To these ends NEC section 210.8(F) has been established to assure the safety that GFCI protection affords is provided for HVAC equipment at dwellings.

Reports have surfaced in various municipal and state jurisdictions of unwanted tripping events associated with HVAC equipment during normal use. This unwanted tripping has been shown to occur in products with variable speed drives and some brands of single stage type HVAC equipment. It should at this juncture be noted that this unwanted tripping has not been shown to be a deficiency associated with the GFCI protective device rather the tripping has been shown to be a result of current leakage of the HVAC equipment at or in excess of the amount necessary to trip the GFCI device. It has been the consensus of CMP 2 that current leakage at these levels may pose a hazard to those that come in contact with the HVAC equipment.

The task group created at the direction of Standards Council to address this issue concluded that additional time is needed to address the issue of excessive current leakage at dwelling unit HVAC equipment and has asserted that work is ongoing to resolve this issue.

It should be noted that CMP 2 has at all times during this process acted prudently, professionally and within the scope of the Regulations Governing the Development of NFPA Standards.

Respectfully Submitted

David G. Humphrey
Chair CMP 2
Dear Ms. Bellis,

Please accept this written submission for the NFPA Standards Council consideration in accordance with 1.6 of the Regulations Governing the Development of NFPA Standards. This statement is in response to the appeal filed by the Leading Builders of America (LBA).

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Regards,

Peter Tolsdorf
Chief Legal, Membership, and People Officer
August 1, 2022

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(Submitted via email to stds_admin@nfpa.org)

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Dear Members of the NFPA Standards Council,

NAHB is a federation of more than 700 state and local home builder associations nationwide that work to ensure that housing remains a national priority and that all Americans have access to safe, decent and affordable homes. The organization’s membership includes over 140,000 firms engaged in land development, single and multifamily residential construction, design, remodeling, multifamily ownership and management, building material trades, building products manufacturing and supply, and commercial and light industrial construction projects. Over 95 percent of NAHB’s members are classified as “small businesses” as defined by the U.S. Small Business Administration (SBA). NAHB members collectively employ over 3.4 million people nationwide. Four out of every five new homes are built by NAHB members.

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1. The language of both TIAs was developed through a Task Group whose creation was directed by the Standards Council. The Task Group consisted of a broad set of affected stakeholders, including electrical contractors, HVAC manufacturers, GFCI manufacturers, CMP-2 members, electrical inspectors, the U.S. Consumer Product Safety Commission, testing laboratories, and the home building industry. We believe the Task Group fulfilled the Council’s mandate and reached an informed, technically-substantiated resolution to the issues raised.

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Sincerely,

Daniel Buuck, Sr. Program Manager, Codes & Standards
National Association of Home Builders
1201 15th Street NW | Washington, DC 20005
D 202 266 8366 | dbuuck@nahb.org
July 31, 2022

Report on TIA 1653 & 1654 Appeal

The appeal to Standards Council of TIA No. 1653 & 1654 has been received and reviewed by the Chair of CMP 2 David G. Humphrey. The Chair supports the panel’s action based on the vote of the technical committee and the issues to be detailed below.

The technical committee vote was 11-5 in favor of support on the merits and 12-4 in support of the concept of the TIA being of an emergency nature for both TIA 1653 and TIA 1654. Accordingly, the voting resulted in the tally being one vote short on the merits and meeting the necessary approval votes on emergency nature.

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Reports have surfaced in various municipal and state jurisdictions of unwanted tripping events associated with HVAC equipment during normal use. This unwanted tripping has been shown to occur in products with variable speed drives and some brands of single stage type HVAC equipment. It should at this juncture be noted that this unwanted tripping has not been shown to be a deficiency associated with the GFCI protective device rather the tripping has been shown to be a result of current leakage of the HVAC equipment at or in excess of the amount necessary to trip the GFCI device. It has been the consensus of CMP 2 that current leakage at these levels may pose a hazard to those that come in contact with the HVAC equipment.

The task group created at the direction of Standards Council to address this issue concluded that additional time is needed to address the issue of excessive current leakage at dwelling unit HVAC equipment and has asserted that work is ongoing to resolve this issue.

It should be noted that CMP 2 has at all times during this process acted prudently, professionally and within the scope of the Regulations Governing the Development of NFPA Standards.

Respectfully Submitted

David G. Humphrey
Chair CMP 2
Statement of E. P. Hamilton III, Ph.D., P.E.
Regarding TIA 1661
July 29, 2022

To the NFPA Standards Council:

I have submitted comments regarding this TIA during earlier portions of this process. I am a licensed professional electrical engineer with a Ph.D. in Electrical Engineering. I am codeveloper of grounding/bonding test equipment and protocols for pools utilized throughout the industry and have worked in this specific technical area for over 25 years. I currently serve in a volunteer capacity as a Principal on CMP-17, representing PHTA and its predecessor APSP, standards-making organizations with stewardship of multiple ANSI standards related to various aspects of pool and spa design and safety. I have served on CMP-17 since 2008. During this period, the issue of equipotential bonding of perimeter surfaces as addressed in 680.26(B)(2) has occupied a disproportionate amount of the Panel’s time. Contrary to several incorrect and inflammatory statements being made (primarily by some of the submitters associated with the grid proposal) regarding this TIA and the associated PIs, PCs and NITMAM, it has been my observation that CMP-17 is neither irresponsible, dominated by any one faction, ignoring “facts,” or waiting on someone to die before we do anything. In fact, the very opposite is true. Even a cursory review of panel statements and actions over this period make it abundantly clear that CMP-17 has spent considerable time reviewing the studies submitted, along with CPSC data, and are quite familiar with claims made by the copper mesh manufacturer and the electric utility industry regarding this issue. The Panel commissioned a study, which was inconclusive regarding this issue (I was on the advisory group for that study and have considerable firsthand knowledge), and has also convened various task groups to address this specific issue (about which I also have firsthand knowledge) during my tenure on CMP-17. The position of the panel, at least during my tenure on it, as identified in Chairman Weaver’s comment, is that “The Committee came to the conclusion that a ground ring is still an acceptable method for perimeter surfaces of in ground pools. A #8 copper conductor properly installed meets the criteria as defined in Article 90.1 (A) and (B) for practical safeguarding and adequacy. The NEC should always allow for alternate methods when possible. If in fact a copper grid is a better installation, nothing prevents an installer from installing it if they wish to.” I agree. The current Code language should stand as written.

Regarding technical merit of this TIA, I submitted the following comment, “Proposers have not provided any new data justifying their proposal. The maximum 10Vac claimed in the submitters’ statement is well below the Low Voltage Contact Limit, which is considered
throughout the NEC to be a safe voltage. There has been no information provided to the Panel that the use of the #8 copper ring (which is a minimum standard; the copper mesh has always been allowed and the Panel made that fact clear in the 2020 Edition) is insufficient. Ground currents and step potentials resulting from utility ground faults do not just involve the 3’ area around swimming pools; the shock hazard exists regardless of whether or not a pool or spa is even present.” This comment still stands. Several questions have been raised in the public comments:

First, “How can CMP17 (negative voters) suggest in their comments that the single bare wire is adequate?” First, despite this claim by the submitters proposing the copper grid (regardless of association with this TIA, which has been made both within and outside the bounds of NFPA, the current and past Code language does not prescribe a single bare #8 wire to the exclusion of all other methods (as the TIA proposes to do with the copper grid), but instead offers the installer considerable latitude to provide perimeter bonding which has been determined to be adequate in the specific area where the pool is installed, including the proposed copper grid or even other grids of different size and geometries. The incident accounts provided to the panel by submitters, none of which resulted in serious injury or death, are generally concentrated in a few local geographical areas on a vary small number of pools. The fact of the matter is that the single wire has been used nationwide by default or prescription (even prior to inclusion in the NEC) on millions of permanently installed pools and spas for over 50 years across the USA without any documented incident. Further, the Panel has reviewed the studies as identified by the submitters and, as CMP-17 Principal Mr. Sandberg pointed out in his comments regarding the CAM, he identified numerous technical deficiencies in the study materials (as have other various members of the Panel). The materials submitted to the panel associated with the testing by various parties (all prepared in support of the copper wire grid) over the history of this issue have been determined by the panel after close and involved scrutiny as being insufficient to support elimination of all other perimeter bonding alternatives except a copper wire grid on a nationwide basis.

Second, “Why does the Pool and Hot Tub Association boast on their website that they influence CMP17 to the peril of pool owners?” This is a very serious and unfounded allegation. The statement then quotes a small portion of a PHTA Advocacy webpage entry, the quotation consisting of one complete sentence and only a portion of the second sentence. It then states, “Based on this excerpt, it does not appear that all of the members of CMP17 can view the deficiency of the single
bare wire with objectivity.” Note that the unquoted portion of the second sentence states, “which addresses Article 680 that includes pool and spa requirements, to ensure technically accurate and rationale [sic] requirements exist and keep out onerous provisions that are not necessary.” The PHTA statement deals with practical safeguarding. There is no bias as alleged. In fact, unlike some CMP-17 members, PHTA does not utilize instructed votes; PHTA representatives are and have been free to vote in whatever manner they choose, based on the technical merits of the specific proposal. Regarding the alleged “peril of pool owners,” see the first comment above.

Third, “If you measured 10Vac between a metal service panel and nearby steel conduit would you dismiss this as OK because the voltage is below 15Vac? Or would you suspect you have inadequate bonding?” This statement is a red herring. The fact is that 10V is below the Low Voltage Contact Limit (LVCL) which is recognized in the NEC as safe. As former CMP-17 Mr. Cook states in his response to the TIA regarding the LVCL, “Review of the NEC definition for low voltage contact limit indicate 15 volt (RMS) sinusoidal ac is a safe voltage level. That value correlates with values in Chapter 9, Table 11. Both voltage requirements have been considered safe for many years.” The existence of 10 volts or less indicates that the bonding system was holding the voltage at safe levels as accepted by the NEC. There is no requirement for 0 Vac in terms of safety.

Fourth, “How can qualified Panel 17 members mistakenly suggest that the shock hazards at these pools may have something to do with soil resistivity?” This is a straw man argument with no basis in fact. No responses to this TIA by any panel member even mention soil resistivity. The closest comment is one by CMP-17 Principal Mr. Sandberg, who stated, “At the CMP17 meeting it was discussed that areas with ‘stray currents’ and ‘marsh like’ soils could have a local requirement to specify a complete copper grid.” I remember these discussions (they have occurred more than once), and they had to do with what was presented as complaint data submitted by utilities and the copper wire grid manufacturer, that indicated that these two areas were of concern and may require a different bonding technique than the remainder of the nation. The comment regarding soil resistivity is contained in the Public Comment Circulation on this TIA and is from an individual who identifies himself as a P.E. specialist in “LV Installation, Grounding, & Haz. Areas,” and who is not a member of CMP-17.

Regarding emergency nature of this TIA, I submitted the following comment, “There is no
emergency here. This same proposal, in various forms, has been brought before CMP-17 for over 15 years, was brought up as a NITMAM in 2014, and has been introduced as a NITMAM this cycle as well. During this period various studies (or portions thereof) have been referred to the Panel, all claiming that an imminent hazard exists. Yet there has been no incident of injury or death reported during this period.” This comment still stands, and I anticipate that the Panel will have ample opportunity to address it again during the next Code cycle.

This TIA should be rejected and the matter addressed by the Panel in the next Code cycle.

Thank you for your attention to this matter.