Public Comment No. 683-NFPA 70-2018 [Global Input]

Type your content here ...{strikethrough}physical{/strikethrough} damage

Statement of Problem and Substantiation for Public Comment

I have to respectfully disagree with the concept that the term, "Physical damage" is well understood. My basis for this is the fact that there have been many, many attempts to define the term based on the various understandings that experienced electricians and inspectors have. Based on the committee's response to PI 1781, it appears that removing the adjective will increase the consistency of interpretation of the rules that pertain to damage, while entailing no loss.

Related Item

- Based to committee statement in reponse to PI 1781

Submitter Information Verification

Submitter Full Name: David Shapiro
Organization: Safety First Electrical
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 15 12:34:48 EDT 2018
Committee: NEC-AAC

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Public Comment No. 979-NFPA 70-2018 [Global Input]

This Global Public Comment requests that each CMP review all products under their purview and determine whether reconditioning should be permitted. This public comment is submitted by a task group assigned by the NEC Correlating Committee. This task group was charged with reviewing Public Input 2935 which was resolved by CMP-1 during the first draft stage. This PI would have required that "Reconditioned Equipment" be "listed as "reconditioned" and the "original listing marks removed". This PI has ramifications that are global in nature and impacts all products referenced in the NEC under the purview of every CMP.

Additional Proposed Changes

File Name	Description	Approved
NEMA-Position_Refubishing_on_ElecEquip.pdf		

Statement of Problem and Substantiation for Public Comment

This Public Comment is submitted on behalf of a task group appointed by the NEC® Correlating Committee. This Task Group was appointed to review the use of refurbished equipment throughout the NEC®. Task Group members are Jim Dollard, Robert Osborne, Jim Pierce, and David Williams. This task group has been charged with reviewing Public Input (PI) 2935 which was resolved by CMP-1 during the first draft stage. This PI would have required that "Reconditioned Equipment" be "listed as "reconditioned" and the "original listing marks removed". This PI has ramifications that are global in nature and impacts all products referenced in the NEC under the purview of every CMP.

Task group members noted that some types of equipment are capable of being reconditioned, then re-evaluated to ensure compliance with the applicable product standards. Other types of equipment do not lend themselves to reconditioning due to the complexity of the product, the manufacturing process, or the level of knowledge the company performing the reconditioning may need, etc.

The "NEMA Policy on Reconditioned Electrical Equipment" details the following aspects of Reconditioning of Electrical Equipment:

- Fundamental Tenets for Reconditioning Electrical Equipment
- Electrical Infrastructure and Worker Safety
- Integrity of Reconditioned Equipment
- Listing or Certification Marks
- UL Guidance on the UL Mark
- Components or Assemblies Not Suitable For Reconditioning (Appendix A)
- Components or Assemblies Which May Be Reconditioned (Appendix B)

A PDF copy of this NEMA policy is attached and may also be found on the internet at the following URL:

https://www.nema.org/Policy/Documents/NEMA-Position_Refubishing%20on%20ElecEquip.pdf

NEC® section 110.21(A)(2), which was new for the 2017 Edition of the NEC®, included marking requirements for "Reconditioned Equipment". PI 2935 would have required that "Reconditioned Equipment" be "listed as "reconditioned" and the "original listing marks removed". CMP 1 resolved this PI. Due to the global nature of PI 2935 this Task Group, appointed by the NEC® Correlating Committee, has developed a number of Public Comments, based on the products identified in the referenced NEMA document, to determine whether or not equipment can be reconditioned, and if reconditioned, what additional requirements apply.

While several Public Comments were developed for specific equipment by this task group, not all equipment was addressed (neither was all the equipment noted in the NEMA Policy document addressed). This Global Public

Comment requests each CMP to review the products required to be listed under their purview and determine whether reconditioning should be permitted. It is recommended that the NEMA Policy document be used as one of the guidelines in making this determination. It is also recommended that one of the following options/examples be chosen for listed equipment:

Option 1 - Equipment NOT suitable for Reconditioning (EXAMPLE):

695.10 Listed Equipment. Diesel engine fire pump controllers, electric fire pump controllers, electric motors, fire pump power transfer switches, foam pump controllers, and limited service controllers shall be listed for fire pump service. [20:9.5.1.1, 10.1.2.1, 12.1.3.1]

Fire pump controllers and transfer switches shall not be permitted to be reconditioned.

Option 2 - Equipment which MAY BE suitable for Reconditioning (EXAMPLE):

408.8 Reconditioned Equipment.

(A) Panelboards. The use of reconditioned panelboards shall comply with (1) and (2):

(1) Industrial and commercial panelboards shall be permitted to be reconditioned. Reconditioned equipment shall be listed as “reconditioned” and the original listing mark removed.

(2) Panelboards installed in dwelling units shall not be permitted to be reconditioned.

(B) Switchboards and Switchgear. Low voltage switchgear, medium voltage switchgear and switchboards shall be permitted to be reconditioned. Reconditioned equipment shall be listed as “reconditioned” and the original listing mark removed.

Note that equipment where no specific guidance is provided would be permitted to be reconditioned and would only be required to meet the marking requirements in 110.21(A)(2).

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 980-NFPA 70-2018 [New Section after 240.87(B)]	
Public Comment No. 981-NFPA 70-2018 [New Section after 240.61]	
Public Comment No. 982-NFPA 70-2018 [New Section after 240.101(B)]	
Public Comment No. 983-NFPA 70-2018 [Section No. 695.10]	
Public Comment No. 984-NFPA 70-2018 [Section No. 700.5(C)]	
Public Comment No. 985-NFPA 70-2018 [Section No. 701.5(C)]	
Public Comment No. 986-NFPA 70-2018 [Section No. 702.5]	
Public Comment No. 987-NFPA 70-2018 [New Section after 408.7]	

Related Item

- PI 2935

Submitter Information Verification

Submitter Full Name: James Dollard
Organization: IBEW Local Union 98
Street Address:
City:
State:

Zip:

Submittal Date: Tue Aug 21 08:08:39 EDT 2018

Committee: NEC-AAC

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NEMA Policy on Reconditioned Electrical Equipment

Executive Summary:

The option of reconditioning existing equipment (instead of purchasing new equipment) exists today. Proper electrical equipment reconditioning provides a means to extend the life of electrical products as well as an opportunity in some cases to update installed equipment with the latest performance and safety features. However, not all components of the electrical infrastructure are candidates for reconditioning.

There are a number of precautions that must be adhered to when reconditioning electrical equipment if that equipment is to operate safely and with acceptable performance. Those precautions are discussed below and include the use of design qualified parts, testing to industry-recognized safety standards, original manufacturer specification and/or recommendations, when possible, and reconditioning performed by qualified personnel. The integrity of reconditioned electrical equipment must be established by documenting and demonstrating that component replacement has not compromised the manufacturer's original specifications and accepted industry standards.

The third party certification mark must be removed or obliterated from reconditioned electrical products to indicate that an evaluation of the reconditioning process or reconditioned product has not been conducted by the original third party.

As guidance, Appendix B provides a list of electrical products and components that are considered by NEMA suitable for reconditioning and Appendix A provides a list of electrical products considered not suitable for reconditioning. Medical Imaging Equipment is specifically not addressed by this policy (reference MITA 1, Good Refurbishment Practices for Medical Imaging Equipment).

Introduction:

The U.S. electrical industry includes discussions on implementing new technologies to enhance existing electrical infrastructure. Further, sustainability and safeguarding the environment are growing in importance. In the midst of this is the option for reconditioning existing equipment. Paramount in all this is the fundamental priority that all electrical systems operate while safe-guarding personnel and infrastructure from potential hazards (electrical, mechanical, fire, etc.). This forms the basis for the NEMA position on reconditioning electrical products.

Given that electrical systems are diverse in design, function, and application, not all components of the electrical infrastructure are candidates for reconditioning.

Definition:

Reconditioning: the process of restoring electromechanical systems, equipment, apparatus or components to operating conditions as recommended by the

manufacturer's instructions, using only design qualified parts. Reverse engineered parts (designs copied from existing parts by other manufacturers) are not considered to be "design qualified parts" unless specifically design verified under applicable Standards. Electrical industry practitioners and other organizations may also use the following terms/words to describe the process of reconditioning: remanufacturing, refurbishing, recycling, repairing, restoring, rebuilding, reengineering, and reusing.

In addition to design considerations, it is often impossible to obtain the service records, application environment, and operation parameters of all electrical components. Not having access to such information could have an adverse impact on the final safety and reliability of refurbished or reconditioned equipment. While NEMA supports the reconditioning of some electrical equipment, the components listed in Appendix A are not recommended for reconditioning, unless otherwise indicated by the original manufacturer. Normal servicing of equipment that remains within a facility should not be considered reconditioning or refurbishing. For electrical components suitable for reconditioning listed in Appendix B, the following fundamental tenets have been established.

Fundamental Tenets for Reconditioning Electrical Equipment

- Reconditioning electrical equipment may be a viable option for extending operational lifetime of equipment and enhancing equipment with additional features.
- Electrical equipment reconditioning activity must be based on available guidance documentation from the Original Equipment Manufacturer, or industry-developed standards. Where any conflict in guidance is noted between the OEM and industry standards, the OEM guidance should take precedence.
- Electrical equipment must be reconditioned and qualified to an industry-developed standard that ensures equipment is in a usable and safe operating condition. An industry-developed standard is a widely agreed upon rule, set of rules, procedures or requirements for a product, assembly or process which are developed by members or organizations of an aggregate of manufacturing and technically productive enterprises in a particular field. Products deemed to be candidates for reconditioning must be reconditioned and qualified to industry standards containing the most relevant and critical design aspects, testing criteria and manufacturing specifications when the item was built.
- Reconditioning work must be performed by qualified personnel.
- Electrical equipment that has been exposed to adverse conditions, such as fire, water damage, etc., may not be suitable for reconditioning.
- A comprehensive assessment of the electrical equipment being considered for reconditioning with service records, application, environment, service life, and operating parameters is critical before deciding to pursue reconditioning of the electrical equipment and system. Trained, skilled technicians should be able to assess whether a device or system is suitable for reconditioning through physical inspection and test.
- Appendix A provides guidance on which components or assemblies of the electrical system are not suitable for reconditioning because they may pose a

hazard. Appendix B provides guidance on the components or assemblies are suitable for reconditioning.

- Reconditioning electrical equipment must utilize electrical product safety standards as they contain design aspects, testing criteria and manufacturing specifications to ensure a given product will function as intended. These requirements are established to deliver a usable and safe operating condition as a key component of intended product functionality.

Electrical Infrastructure and Worker Safety

Electrical equipment that is properly installed, tested, maintained, and operated will provide reliable power as well as protect the electrical infrastructure. The reconditioning of electrical equipment requires the electrical industry, in collaboration with manufacturers, to establish performance specifications and accepted industry standards to help ensure safe and reliable equipment that help protect our electrical infrastructure so workers and users can continue to benefit from a safe and effective electrical system. Reconditioning standards must include prescriptive actions and performance requirements that result in equipment that complies with standards that include but are not limited to CSA, IEC, IEEE, NEC, OSHA, NFPA 70E, NFPA 70B, NETA ATS, NETA MTS, and EASA AR100 for example. Qualified personnel must possess the knowledge of how to assess equipment condition, potential hazards, and specifications to accurately determine the suitability for reconditioning. A safe and reliable electrical infrastructure that can be safely maintained is dependent on compliance with manufacturers' instructions, qualified workers, proper maintenance, and accepted industry standards for reconditioning activities.

Electrical Equipment Reliability, Performance and Safety

Proper electrical equipment reconditioning provides a means to extend the life of electrical products as well as an opportunity to update installed equipment with the latest performance and safety features. Establishing well defined guidelines for those performing the reconditioning activity, based on original manufacturer's requirements, creates a solid foundation for the electrical industry and users. It is paramount that reconditioned electrical equipment be reliable in not only providing power, but also in safely performing its intended function as part of a safe operating electrical system. Understanding the environment, electrical load characteristics and historical maintenance performed on equipment being considered for reconditioning are all important parts of an assessment for reconditioning that can have a significant bearing on reliability, performance and safety. The electrical equipment manufacturer is the foremost authority on the design, performance and intended safe application of their product. Reconditioned electrical equipment must not compromise the reliability, performance, safe operation, or maintenance of the electrical system.

Integrity of Reconditioned Equipment

Reconditioned electrical equipment must comply with all applicable standards at the time the equipment was initially built as a minimum as well as the original manufacturer's performance requirements in accordance with the nameplate markings and ratings. Replacement parts shall meet the design criteria (form, fit, and function) for the device to perform its intended function and provide safe operation. Replacement parts shall not include counterfeit parts (i.e., parts that have been misrepresented to be an authorized item of the legally authorized source.) Equipment shall operate safely in its intended application after reconditioning occurs. Care must be taken to ensure specific operations such as timing, sequencing, control, transfer, etc. continue to function in the manner originally intended, unless changes are specified during the reconditioning process. The integrity of reconditioned electrical equipment must be established by documenting and demonstrating that component replacement and performance changes have not compromised the manufacturer's specifications and accepted industry standards.

Listing or Certification Marks

NEMA members manufacture products that are more than likely to be evaluated as part of a third party certification program to nationally recognized safety standards. These products can be marked with a listing or certification mark when the products are manufactured and shipped from the factory. The organization that reconditions the product is responsible for adhering to the guidelines from the issuing agency authorizing the mark to determine if the mark can remain on the product after reconditioning. The organization that reconditions is responsible for any actions necessary for the mark to remain on the product (analysis, testing, etc.). Otherwise, reconditioned electrical products must have their mark removed or obliterated to indicate that an evaluation of the reconditioning process has not been conducted by the original third party.

The organization that reconditions the product is additionally responsible for applying a mark or seal that indicates that the equipment has been reconditioned. This mark must provide traceability to the reconditioning organization in the event that it is necessary to determine the details of who reconditioned the equipment and the report on what was completed during this process.

There are a number of NEMA products that are not allowed to be reconditioned due to the inherent safety characteristics and requirements for those products to be evaluated according to a regular follow up program to evaluate the safety performance requirements as a condition of maintaining the listing or certification mark. This process cannot be applied to reconditioned electrical products since these are normally destructive tests and sample sets of reconditioned products are not possible due to limited quantities or ratings of specific devices.

UL Guidance on the UL Mark

When the manufacturer places the UL Mark on the product at the factory, it is their attestation that the product complies with the applicable requirements. Unless there is further oversight or review/inspection (field inspection) UL cannot ascertain that the

product continues to comply with all requirements should field repairs, modifications or component replacements be made to the product.

Obviously there is little control over what manufacturers will or can do to equipment which left the factory with a certification mark. UL has created rebuilt categories where the reconditioning of product is done in an organized consistent manner under the supervision of UL's FUS (Follow-Up Services) field representatives. In these cases the first action conducted with equipment being rebuilt is the removal of the initial certification mark (if provided). Upon completion of the reconditioning, in accordance with the surveillance document, the manufacturer is permitted to affix a mark which clearly identifies the product as reconditioned.

Cases where a reconditioner is instructed to NOT remove any certification mark will result in confusion. Clearly such equipment in the field, which has undergone modification or reconditioning, is ineligible to bear a mark which designates a compliance with a certification standard.

APPENDIX A

COMPONENTS OR ASSEMBLIES NOT SUITABLE FOR RECONDITIONING*

Adjustable speed drives
Arc fault circuit breakers
Ballasts
Busway (mylar wrapped)
Busway (powder coated)
Cable tray
Cast resin transformers
Components containing semiconductors and transistors
Control transformers
Dry type transformers
Electrical Connectors
Electrical submetering equipment
Electrical vehicle supply equipment
Enclosed switches
Fire detectors, smoke alarms, co detectors
Fire pump controllers
Flexible and extension cords
Flexible conduit
Ground fault circuit breakers
High performance wire and cable
Lighting controls
Liquid filled transformers
Low and medium voltage fuse holders
Low and medium voltage non-renewable fuses
Low voltage power circuit breaker electronic trip units
Luminaires
Meters (electromechanical, electronic or digital)
Meter sockets
Molded case circuit breakers
Non-Metallic conduit, tubing, raceways and fittings
Non-metallic surface raceways and fittings
Outlet and junction boxes
Overload relays
Pin and sleeve plugs receptacles and connectors
Power and control cable
Protective relays (electronic or digital)
Residential panel boards
Solid state contactors and starters
Solid state drives
Strut type channel raceway
Surface metal raceways and fittings
Surge protective devices
Transfer switches
Wire or cable
Wireway
Wiring devices

*The components or products listed above are not recommended for reconditioning, unless otherwise indicated by the original manufacturer.

APPENDIX B

COMPONENTS OR ASSEMBLIES WHICH MAY BE RECONDITIONED

Electromechanical protective relays, and current transformers
High voltage circuit breakers
Industrial and commercial panel boards
Low and medium voltage power circuit breakers
Low and medium voltage replaceable link fuses
Low voltage switchgear
Manual and magnetic controllers
Medium voltage switchgear
Metallic conduit, tubing, raceways and fittings
Motor control centers
Motors
Switchboards
Uninterruptible Power Supply Equipment

Public Comment No. 2211-NFPA 70-2018 [Global Input]

The Correlating Committee directs Panel 6 to review all references to Article 310 under their purview. Article 310 has been divided into Article 310,

Conductors for General Wiring, and Article 311, Medium Voltage Conductors and Cables for usability and clarity. Panel 6 shall appoint a task group

to review all necessary references to verify their accuracy and submit Public Comments where necessary. This action instructs Panel 6 to

submit a Public Comment(s) within the time frame required in the NEC schedule.

This action shall be considered as a public comment.

Additional Proposed Changes

File Name	Description	Approved
CN_270.pdf	CN_270	

Statement of Problem and Substantiation for Public Comment

NOTE: This Public Comment appeared as CC Note No. 270 in the First Draft Report.

The Correlating Committee directs Panel 6 to review all references to Article 310 under their purview. Article 310 has been divided into Article 310,

Conductors for General Wiring, and Article 311, Medium Voltage Conductors and Cables for usability and clarity. Panel 6 shall appoint a task group

to review all necessary references to verify their accuracy and submit Public Comments where necessary. This action instructs Panel 6 to

submit a Public Comment(s) within the time frame required in the NEC schedule.

This action shall be considered as a public comment.

Related Item

• Correlating Committee Note No. 270

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC
Organization: NEC Correlating Committee
Street Address:
City:
State:
Zip:
Submittal Date: Fri Sep 07 13:53:41 EDT 2018
Committee: NEC-P06

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Correlating Committee Note No. 270-NFPA 70-2018 [Global Input]

Submitter Information Verification

Submitter Full Name: Sarah Caldwell
Committee:
Submittal Date: Fri May 11 17:54:55 EDT 2018

Committee Statement and Meeting Notes

Committee Statement: The Correlating Committee directs all panels to review all references to Article 310 under their purview. Article 310 has been divided into Article 310, Conductors for General Wiring, and Article 311, Medium Voltage Conductors and Cables for usability and clarity. Each panel shall appoint a task group to review all necessary references to verify their accuracy and submit Public Comments where necessary. This action instructs the referenced panels to submit a Public Comment(s) within the time frame required in the NEC schedule.

This action shall be considered as a public comment.

Ballot Results

This item has passed ballot

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

Affirmative All

Brunssen, James E.
Dressman, Kevin L.
Hickman, Palmer L.
Hittinger, David L.
Holub, Richard A.
Johnston, Michael J.
Kovacik, John R.
Manche, Alan
McDaniel, Roger D.
Pierce, James F.
Saporita, Vincent J.
Williams, David A.

Public Comment No. 2228-NFPA 70-2018 [Global Input]

The Correlating Committee directs Panel 6 to review all Articles, within their purview, that supplement or modify (90.3) GFCI requirements in 210.8 for correlation, clarity, usability and standardized format. A Correlating Committee Task Group will be appointed and will submit comments where necessary.

This action shall be considered as a public comment.

Additional Proposed Changes

File Name	Description	Approved
CN_152.pdf	CN_152	

Statement of Problem and Substantiation for Public Comment

NOTE: This Public Comment appeared as CC Note No. 152 in the First Draft Report

The Correlating Committee directs Panel 6 to review all Articles, within their purview, that supplement or modify (90.3) GFCI requirements in 210.8 for correlation, clarity, usability and standardized format. A Correlating Committee Task Group will be appointed and will submit comments where necessary.

This action shall be considered as a public comment.

Related Item

• Correlating Committee Note No. 152

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC
Organization: NEC Correlating Committee
Street Address:
City:
State:
Zip:
Submittal Date: Fri Sep 07 14:45:04 EDT 2018
Committee: NEC-P06

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Correlating Committee Note No. 152-NFPA 70-2018 [Global Input]

Submitter Information Verification

Submitter Full Name: Erik Hohengasser

Committee:

Submittal Date: Thu May 10 18:00:52 EDT 2018

Committee Statement

Committee Statement: The Correlating Committee directs each panel to review all Articles, within their purview, that supplement or modify (90.3) GFCI requirements in 210.8 for correlation, clarity, usability and standardized format. A Correlating Committee Task Group will be appointed and will submit comments where necessary.

This action shall be considered as a public comment.

Ballot Results

✔ **This item has passed ballot**

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

Affirmative All

Brunssen, James E.
Dressman, Kevin L.
Hickman, Palmer L.
Hittinger, David L.
Holub, Richard A.
Johnston, Michael J.
Kovacik, John R.
Manche, Alan
McDaniel, Roger D.
Pierce, James F.
Saporita, Vincent J.
Williams, David A.

Public Comment No. 792-NFPA 70-2018 [Global Input]

The Correlating Committee advises that article scope statements and article titles are the responsibility of the correlating committee. The correlating committee accepts the scope statement and directs that the Article title be changed to "Type P Cable".

This action will be considered as a Public Comment.

Additional Proposed Changes

File Name	Description	Approved
CCN_1_-_Global.pdf	70_ CN 1	

Statement of Problem and Substantiation for Public Comment

NOTE: This Public Comment appeared as CC Note No. 1 in the First Draft Report on First Revision No. 8036, and is also related to Public Input No. 4309.

The Correlating Committee advises that article scope statements and article titles are the responsibility of the correlating committee. The correlating committee accepts the scope statement and directs that the Article title be changed to "Type P Cable".

This action will be considered as a Public Comment.

Related Item

- FR 8036

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC
Organization: NEC Correlating Committee
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 17 15:28:51 EDT 2018
Committee: NEC-P06

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Correlating Committee Note No. 1-NFPA 70-2018 [Global Input]

Submitter Information Verification

Submitter Full Name: Sarah Caldwell

Committee:

Submittal Date: Wed May 09 11:01:37 EDT 2018

Committee Statement and Meeting Notes

Committee Statement: The Correlating Committee advises that article scope statements and article titles are the responsibility of the correlating committee. The correlating committee accepts the scope statement and directs that the Article title be changed to “Type P Cable”.

This action will be considered as a Public Comment.

The Correlating Committee directs the panel to reconsider the use of first level subdivisions in 337.24 this section. Consider using two list item type format to meet the requirements of the NEC® Style Manual 2.1.5.1.

This action will be considered as a Public Comment.

The Correlating Committee notes that the hazardous (classified) location uses or permissions to use Type P cable are under the purview of CMP14 and are better located in Chapter 5 for usability. The Correlating Committee directs CMP 6 to correlate uses permitted, as done in other cable assembly articles, for Type P Cable in Chapter 5 locations.

This action will be considered as a Public Comment.

It was the action of the Correlating Committee that this first revision be referred to Code-Making Panel 10 for correlation of permitted wiring methods in Article 230.

This action will be considered as a public comment.

First Revision No. 8036-NFPA 70-2018 [Global Input]

Ballot Results

✔ **This item has passed ballot**

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

Affirmative All

Brunssen, James E.

Dressman, Kevin L.

Hickman, Palmer L.

Hittinger, David L.

Holub, Richard A.

Johnston, Michael J.

Kovacik, John R.

Manche, Alan

McDaniel, Roger D.

Pierce, James F.

Saporita, Vincent J.

Williams, David A.

Public Comment No. 794-NFPA 70-2018 [Global Input]

The Correlating Committee directs the panel to reconsider the use of first level subdivisions in 337.24 this section. Consider using two list item type format to meet the requirements of the NEC® Style Manual 2.1.5.1.

This action will be considered as a Public Comment.

Additional Proposed Changes

File Name	Description	Approved
CCN_1_-_Global.pdf	70_CN 1	

Statement of Problem and Substantiation for Public Comment

NOTE: This Public Comment appeared as CC Note No. 1 in the First Draft Report on First Revision No. 8036, and is also related to Public Input No. 4309.

The Correlating Committee directs the panel to reconsider the use of first level subdivisions in 337.24 this section. Consider using two list item type format to meet the requirements of the NEC® Style Manual 2.1.5.1.

This action will be considered as a Public Comment.

Related Item

- FR 8036

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC
Organization: NEC Correlating Committee
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 17 15:36:32 EDT 2018
Committee: NEC-P06

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Correlating Committee Note No. 1-NFPA 70-2018 [Global Input]

Submitter Information Verification

Submitter Full Name: Sarah Caldwell

Committee:

Submittal Date: Wed May 09 11:01:37 EDT 2018

Committee Statement and Meeting Notes

Committee Statement: The Correlating Committee advises that article scope statements and article titles are the responsibility of the correlating committee. The correlating committee accepts the scope statement and directs that the Article title be changed to “Type P Cable”.

This action will be considered as a Public Comment.

The Correlating Committee directs the panel to reconsider the use of first level subdivisions in 337.24 this section. Consider using two list item type format to meet the requirements of the NEC® Style Manual 2.1.5.1.

This action will be considered as a Public Comment.

The Correlating Committee notes that the hazardous (classified) location uses or permissions to use Type P cable are under the purview of CMP14 and are better located in Chapter 5 for usability. The Correlating Committee directs CMP 6 to correlate uses permitted, as done in other cable assembly articles, for Type P Cable in Chapter 5 locations.

This action will be considered as a Public Comment.

It was the action of the Correlating Committee that this first revision be referred to Code-Making Panel 10 for correlation of permitted wiring methods in Article 230.

This action will be considered as a public comment.

First Revision No. 8036-NFPA 70-2018 [Global Input]

Ballot Results

✔ **This item has passed ballot**

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

Affirmative All

Brunssen, James E.

Dressman, Kevin L.

Hickman, Palmer L.

Hittinger, David L.

Holub, Richard A.

Johnston, Michael J.

Kovacik, John R.

Manche, Alan

McDaniel, Roger D.

Pierce, James F.

Saporita, Vincent J.

Williams, David A.

Public Comment No. 795-NFPA 70-2018 [Global Input]

The Correlating Committee notes that the hazardous (classified) location uses or permissions to use Type P cable are under the purview of CMP14 and are better located in Chapter 5 for usability. The Correlating Committee directs CMP 6 to correlate uses permitted, as done in other cable assembly articles, for Type P Cable in Chapter 5 locations.

This action will be considered as a Public Comment.

Additional Proposed Changes

File Name	Description	Approved
CCN_1_-_Global.pdf	70_CN 1	

Statement of Problem and Substantiation for Public Comment

NOTE: This Public Comment appeared as CC Note No. 1 in the First Draft Report on First Revision No. 8036, and is also related to Public Input No. 4309.

The Correlating Committee notes that the hazardous (classified) location uses or permissions to use Type P cable are under the purview of CMP14 and are better located in Chapter 5 for usability. The Correlating Committee directs CMP 6 to correlate uses permitted, as done in other cable assembly articles, for Type P Cable in Chapter 5 locations.

This action will be considered as a Public Comment.

Related Item

- FR 8036

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC
Organization: NEC Correlating Committee
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 17 15:38:35 EDT 2018
Committee: NEC-P06

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Correlating Committee Note No. 1-NFPA 70-2018 [Global Input]

Submitter Information Verification

Submitter Full Name: Sarah Caldwell

Committee:

Submittal Date: Wed May 09 11:01:37 EDT 2018

Committee Statement and Meeting Notes

Committee Statement: The Correlating Committee advises that article scope statements and article titles are the responsibility of the correlating committee. The correlating committee accepts the scope statement and directs that the Article title be changed to “Type P Cable”.

This action will be considered as a Public Comment.

The Correlating Committee directs the panel to reconsider the use of first level subdivisions in 337.24 this section. Consider using two list item type format to meet the requirements of the NEC® Style Manual 2.1.5.1.

This action will be considered as a Public Comment.

The Correlating Committee notes that the hazardous (classified) location uses or permissions to use Type P cable are under the purview of CMP14 and are better located in Chapter 5 for usability. The Correlating Committee directs CMP 6 to correlate uses permitted, as done in other cable assembly articles, for Type P Cable in Chapter 5 locations.

This action will be considered as a Public Comment.

It was the action of the Correlating Committee that this first revision be referred to Code-Making Panel 10 for correlation of permitted wiring methods in Article 230.

This action will be considered as a public comment.

First Revision No. 8036-NFPA 70-2018 [Global Input]

Ballot Results

✔ **This item has passed ballot**

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

Affirmative All

Brunssen, James E.

Dressman, Kevin L.

Hickman, Palmer L.

Hittinger, David L.

Holub, Richard A.

Johnston, Michael J.

Kovacik, John R.

Manche, Alan

McDaniel, Roger D.

Pierce, James F.

Saporita, Vincent J.

Williams, David A.

Public Comment No. 830-NFPA 70-2018 [Global Input]

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

The Correlating Committee directs the panel to reconsider the parent text in 311.10 for correlation with other requirements that provide requirements to comply with multiple first level subdivisions.

The Correlating Committee directs the panel to reconsider the text in 311.10(C)(1) for compliance with NEC style. The second sentence does not comply with NEC style, is confusing and infers that the first sentence somehow limits application to grounded systems.

The Correlating Committee directs the panel to reconsider the text in 311.10(C)(2) for compliance with NEC style and the use of unenforceable and vague terms.

The Correlating Committee directs the panel to reconsider the text in 311.10(C)(3) for compliance with NEC style and the use of unenforceable and vague terms.

The Correlating Committee directs the panel to reconsider the text in 311.16(C) for compliance with NEC style. Clarify the intent of the first sentence with respect to the scope of Article 311.

The Correlating Committee directs the panel to reconsider the text in the IN following 311.32 for compliance with the NEC style manual.

The Correlating Committee directs the panel to reconsider the second sentence in 311.36 for clarity and compliance with the NEC style manual.

This action will be considered as a Public Comment.

Additional Proposed Changes

File Name	Description	Approved
CN_2_-_Global.pdf	70_CN 2	

Statement of Problem and Substantiation for Public Comment

NOTE: This Public Comment appeared as CC Note No. 2 in the First Draft Report on First Revision No. 8030.

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

The Correlating Committee directs the panel to reconsider the parent text in 311.10 for correlation with other requirements that provide requirements to comply with multiple first level subdivisions.

The Correlating Committee directs the panel to reconsider the text in 311.10(C)(1) for compliance with NEC style. The second sentence does not comply with NEC style, is confusing and infers that the first sentence somehow limits application to grounded systems.

The Correlating Committee directs the panel to reconsider the text in 311.10(C)(2) for compliance with NEC style and the use of unenforceable and vague terms.

The Correlating Committee directs the panel to reconsider the text in 311.10(C)(3) for compliance with NEC style and the use of unenforceable and vague terms.

The Correlating Committee directs the panel to reconsider the text in 311.16(C) for compliance with NEC style.

Clarify the intent of the first sentence with respect to the scope of Article 311.

The Correlating Committee directs the panel to reconsider the text in the IN following 311.32 for compliance with the NEC style manual.

The Correlating Committee directs the panel to reconsider the second sentence in 311.36 for clarity and compliance with the NEC style manual.

This action will be considered as a Public Comment.

Related Item

• FR 8030

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC
Organization: NEC Correlating Committee
Street Address:
City:
State:
Zip:
Submittal Date: Mon Aug 20 10:19:28 EDT 2018
Committee: NEC-P06

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Correlating Committee Note No. 2-NFPA 70-2018 [Global Input]

Submitter Information Verification

Submitter Full Name: Sarah Caldwell

Committee:

Submittal Date: Wed May 09 11:15:33 EDT 2018

Committee Statement

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

The Correlating Committee directs the panel to reconsider the parent text in 311.10 for correlation with other requirements that provide requirements to comply with multiple first level subdivisions.

The Correlating Committee directs the panel to reconsider the text in 311.10(C)(1) for compliance with NEC style. The second sentence does not comply with NEC style, is confusing and infers that the first sentence somehow limits application to grounded systems.

The Correlating Committee directs the panel to reconsider the text in 311.10(C)(2) for compliance with NEC style and the use of unenforceable and vague terms.

The Correlating Committee directs the panel to reconsider the text in 311.10(C)(3) for compliance with NEC style and the use of unenforceable and vague terms.

The Correlating Committee directs the panel to reconsider the text in 311.16(C) for compliance with NEC style. Clarify the intent of the first sentence with respect to the scope of Article 311.

The Correlating Committee directs the panel to reconsider the text in the IN following 311.32 for compliance with the NEC style manual.

The Correlating Committee directs the panel to reconsider the second sentence in 311.36 for clarity and compliance with the NEC style manual.

This action will be considered as a Public Comment.

First Revision No. 8030-NFPA 70-2018 [Global Input]

Ballot Results

✔ **This item has passed ballot**

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

Affirmative All

Brunssen, James E.

Dressman, Kevin L.

Hickman, Palmer L.

Hittinger, David L.

Holub, Richard A.

Johnston, Michael J.

Kovacik, John R.

Manche, Alan

McDaniel, Roger D.

Pierce, James F.

Saporita, Vincent J.

Williams, David A.

Public Comment No. 1217-NFPA 70-2018 [Definition: Free Air (as applied to conductors).]

Free Air (as applied to conductors).

Open or ventilated environment that allows for air flow around an installed conductor with no other conductors closer than one cable diameter and no insulation or building materials in contact with the conductor insulation for more than 75 mm (3 in.) for every 3 m (10 ft) of conductor.

Additional Proposed Changes

File Name	Description	Approved
CN_6.pdf	70_CN 6	

Statement of Problem and Substantiation for Public Comment

NOTE: This Public Comment appeared as CC Note No. 6 in the First Draft Report on First Revision No. 7861

The Correlating Committee directs that this first revision be rewritten to comply with the NEC Style Manual, Section 2.2.2, regarding requirements within a definition. This action will be considered as a Public Comment.

The Correlating Committee directs that this First Revision be reviewed for correlation with the use of this term in other sections of the NEC. The term may be used differently in Articles 300, 332, 392, 399 and 725.

This action will be considered as a public comment.

It was the action of the Correlating Committee that this first revision be referred to Code-Making Panel 3 and 8 for comment.

Related Item

• FR 7861

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC
Organization: NEC Correlating Committee
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 24 13:21:02 EDT 2018
Committee: NEC-P06

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Correlating Committee Note No. 6-NFPA 70-2018 [New Part after I.]

Submitter Information Verification

Submitter Full Name: Sarah Caldwell
Committee:
Submittal Date: Wed May 09 11:41:36 EDT 2018

Committee Statement and Meeting Notes

Committee Statement: The Correlating Committee directs that this first revision be rewritten to comply with the NEC Style Manual, Section 2.2.2, regarding requirements within a definition. This action will be considered as a Public Comment.

The Correlating Committee directs that this First Revision be reviewed for correlation with the use of this term in other sections of the NEC. The term may be used differently in Articles 300, 332, 392, 399 and 725.

This action will be considered as a public comment.

It was the action of the Correlating Committee that this first revision be referred to Code-Making Panel 3 and 8 for comment.

First Revision No. 7861-NFPA 70-2018 New Part after I.

Ballot Results

This item has passed ballot

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

Affirmative All

Brunssen, James E.
Dressman, Kevin L.
Hickman, Palmer L.
Hittinger, David L.
Holub, Richard A.
Johnston, Michael J.
Kovacik, John R.
Manche, Alan
McDaniel, Roger D.
Pierce, James F.
Saporita, Vincent J.
Williams, David A.

Public Comment No. 1315-NFPA 70-2018 [Definition: Free Air (as applied to conductors).]

~~**Free Air (as applied to conductors).**~~

~~Open or ventilated environment that allows for air flow around an installed conductor with no other conductors closer than one cable diameter and no insulation or building materials in contact with the conductor insulation for more than 75 mm (3 in.) for every 3 m (10 ft) of conductor.~~

Statement of Problem and Substantiation for Public Comment

While I appreciate the willingness of Code Making Panel 6 to provide a definition for free air, this one is better left out of the code unless the Panel can satisfy all types of wiring methods. And in my opinion this cannot be accomplished. The new definition should be deleted.

In addition the definition conflicts with other parts of the code.

Type MI cable wiring methods allow for free air to be considered as conductors to be installed in a triangular fashion with not less than 2.15 times one conductor diameter of the largest conductor between bundles.

Metal Cable tray and single conductor MC cable allows for free air in the same manner as MI cable.

Table 310.15(B)(17) is used for conductors in free air. This table has been used for Quadruplex without cause for concern for many years. Quadruplex or Triplex wiring methods do not have conductor separation and rely heavily on the use of wind and lack of wiring method surrounding the conductors to allow heat to be removed.

Related Item

• Definition of Free Air

Submitter Information Verification

Submitter Full Name: David Hittinger
Organization: IEC
Affiliation: Independent Electrical Contractors
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 26 21:03:15 EDT 2018
Committee: NEC-P06

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Public Comment No. 1742-NFPA 70-2018 [Definition: Free Air (as applied to conductors).]

Free Air (as applied to conductors).

Open or ventilated environment that allows for heat dissipation and air flow around an installed conductor ~~with no other conductors closer than one cable diameter and no insulation or building materials in contact with the conductor insulation for more than 75 mm (3 in .) for every 3 m (10 ft) of conductor.~~

Statement of Problem and Substantiation for Public Comment

There was some concern that the definition contained requirements, so the revision is intended to address that concern.

Related Item

- PI 3621

Submitter Information Verification

Submitter Full Name: Christel Hunter
Organization: Cerro Wire
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 29 19:35:45 EDT 2018
Committee: NEC-P06

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Public Comment No. 735-NFPA 70-2018 [Definition: Free Air (as applied to conductors).]

~~**Free Air (as applied to conductors).**~~

~~Open or ventilated environment that allows for air flow around an installed conductor with no other conductors closer than one cable diameter and no insulation or building materials in contact with the conductor insulation for more than 75 mm (3 in.) for every 3 m (10 ft) of conductor.~~

Statement of Problem and Substantiation for Public Comment

CMP-8 recommends the deletion of FR-7861 for the definition for “Free Air (as applied to conductors)” until a Correlating Committee Task Group can be assigned. The use of the term “Free Air” is used throughout the Code and is a needed definition. The goal of “free air” is the ability to have convective cooling of the conductor’s heat without having any heat trapped and the need to derate the cable ampacity.

The First Revision 7861 definition for Free Air is in violation of the NEC Style Manual. Definitions shall not contain requirements per the NEC Style Manual Section 2.2.2.

In addition, technical substantiation for the spacing requirement was not supplied within Public Input No. 3621 or the First Revision No. 7861. Cable bus (Article 370) and Cable Tray (Article 392) refer to the practice of maintaining spacing between cables so the free air ampacity tables can be used. The revised definition could add confusion to the cable tray and cable bus industry.

CMP-8 request that the Correlating Committee assigns a Task Group consisting members of from CMP-6 and CMP-8 for the 2023 NEC to address the definition and physical requirements pertaining to “Free Air” and the placement within the Code.

This Comment was submitted by CMP-8 Correlating Committee Task Group consisting of David Kendall, Pete Jackson, Ken Hengst, Doug Adams, Rhett Roe, and Gary Johnson.

Related Item

• FR 7861 • CC Note No. 6

Submitter Information Verification

Submitter Full Name: David Kendall
Organization: Thomas & Betts Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 16 15:56:53 EDT 2018
Committee: NEC-P06

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Public Comment No. 2002-NFPA 70-2018 [Definition: Messenger or Messenger Wire.]

Messenger or Messenger Wire.

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

Statement of Problem and Substantiation for Public Comment

Using the word "parallel" could cause confusion with hot that term is presently used in the NEC regarding parallel conductors that are required to be "electrically joined at both ends". A messenger wire is not necessarily electrically joined to any other conductor.

Possibly revising to " A wire run with a cable or conductor to provide mechanical support for the cable or conductor. (CMP-6)"
would be simpler.

Related Item

- FR 7864

Submitter Information Verification

Submitter Full Name: Paul Dobrowsky
Organization: Innovative Technology Services
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 30 14:25:43 EDT 2018
Committee: NEC-P06

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Public Comment No. 1402-NFPA 70-2018 [Section No. 310.3(A)]

310.3 (A)

Minimum Size

~~of~~

Conductors.

The minimum size of conductors for voltage ratings up to and including 2000

~~volts~~

Volts shall be 14 AWG copper and copper-clad aluminum , or 12 AWG aluminum ~~or copper-clad aluminum~~ , except as permitted elsewhere in this Code .

Additional Proposed Changes

File Name	Description	Approved
14_AWG_Thermal_Expansion_Summary.docx	CCA 14 AWG More Thermally Stable at 90C than Cu 14 AWG	
ETL.14awgCCA.Thermalstablei6049.04-106-31-r0.pdf	Intertek Thermal Stability of 14 AWG CCA	
ETL.14awgCu.Thermalstablei6049.03-106-31-r0.pdf	Intertek Thermal Stability of 14 AWG Cu	
J-00265162_FINAL_Copperweld_FFR-_CCA-Cu_Final_Report_Revised_10-27-17.pdf	NSF NRTL Test Report Fact Finding Heat Rise 14, 12 and 10 AWG	
Prop_Table_310.16_310.15_B_16_.pdf	New Table 310.16 Including 14 AWG CCA plus CCA Temperature Columns	
Proposed_Table_310.17_310.15_B_17_.pdf	New Table 310.17 Including 14 AWG CCA plus CCA Temperature Columns	
CONCLUSIONS_FROM_UL_486C_SPRING.pdf	Summary and Conclusions for UL 486C Spring Action Sequence Test Repot	
Intetek.UL486C.SAS.103589128CRT-001A_003_.pdf	Test Report: UL486C ETL. Spring Action Sequence. CCA with "Copper Only" Push-In Connectors	
14_AWG_CCA_Summary.NSFvETL.pdf	Summary Report: 14 AWG CCA at 20 Amps: Heat Data from NSF and ETL Statistically Identical	

Statement of Problem and Substantiation for Public Comment

Public Comment Response:

• Introduction: Public Comment 1401 asks CMP6 to consider multiple Test Reports from reputable NRTL's in respect to heat data and ampacity as they apply to 14 AWG ASTM B-566 Copper-Clad Aluminum wire. In response to PI 2123, CMP6 did not give a technical reason that 14 AWG copper-clad aluminum should not be part of Code, evidencing the bias towards classifying copper-clad aluminum and single-metal aluminum as the same "stuff." CMP6 offered general direction to PI 2123's author to "undertake a thorough Fact Finding of 14 AWG CCA" to demonstrate its safety at the proposed amperage. Amperage rating is more a function of insulation limits (considering ambient) than conductor size. As defined by Article 100, Ampacity is “The maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating.” In simple terms, ampacity is “the level of heat that a conductor achieves when a level of current is imposed under standard test conditions,” (test conditions, generally, being conditions of ambient temperature). The amperage suggested for 14 AWG copper-clad aluminum are clearly in line with the amperages for CCA that already exist in this Code, and the NRTL testing clearly shows that 14 AWG CCA poses no safety concerns. Perhaps there is indeed a technical reason for "single-metal aluminum wire" to be limited in size by Code, but that

reason should not be arbitrarily applied to copper-clad aluminum, a metal whose mechanical and electrical performance are unique, and differ from single-metal aluminum.

ANY TEST REPORT FROM AN NRTL WITH A CERTIFIED ELECTRICAL LAB IS CREDIBLE:

- The NFPA Only Requires that Data Presented to CMP's be "Credible": There are only 19 NRTL's in the United States, and less than 1/4 of these have electrical labs. Being an NRTL means that a lab upholds the most rigorous standards. NSF is an NRTL that maintains a fully functional electrical division (NSF Electrical) with the following certifications: SCC, File Number 10025, ISO/IEC 17065-2012; OSHA NRTL Program. NSF as an NRTL has the ability to issue formal listings for dozens of electrical products under various product safety standards. There is no technical reason that CMP6 should discount the heat rise data found in the submitted NSF report. In conducting the many research and/or testing projects for listing certification, NSF routinely completes temperature testing on conductors, terminals and equipment under specified testing conditions, the same way that ampacity is determined. Therefore, the research report which details a valid test procedure, proper laboratory test conditions and calibrated test and measurement equipment is valid in accordance with NFPA requirements.
- Research and Timeliness Made the NRTL "NSF" the Best Option for Fact Finding of Heat Rise. Copper-Clad Aluminum Conductors Were Already UL listed at the time of the Fact Finding, So No Listing Was Sought at NSF: There is no technical reason that CMP6 should discount the heat rise data found in the NSF report. Because copper-clad aluminum conductors had Listings from UL already in place at the time of the testing, research and timeliness were the driving factors in working with NSF. UL 1581 (Reference Standard for Electrical Wires, Cables and Flexible Cords) is not part of NSF's Scope of Recognition, meaning simply that NSF cannot offer "Listings" under OSHA's overview for wire and cable products like they would for those many other electrical products within their Scope of Recognition. The lack of a listing for 14 AWG copper-clad aluminum conductor is due to the NEC not recognizing it.

This does not mean, however, that NSF Electrical is incapable of conducting credible research with electrical products where NSF listings are not offered. Such research is routine. Further, heat rise testing is elemental to any electrical lab, even more so with an electrical lab working under the credentials of an NRTL.

After communicating with NRTL's with Wire & Cable in their Scopes of Recognition, it was realized that NSF was the only NRTL with a certified electrical lab able to agree to prioritize the work in accordance to the proposed time-line. In that a Listing was not sought, but rather conducting RESEARCH was sought, NSF's certified electrical lab was a legitimate option.

- Standards or Test Procedures to Determine Ampacity: When two of the NRTLs were approached to complete the fact-finding study as requested through the panel statement, it became obvious very quickly that neither NRTL had a standard, a test procedure or clear understanding of how to accomplish the necessary testing.

For any testing of terminations, devices and equipment, the applicable standards for those items require finding the proper conductor based on the allowed ampacity from wire size, AWG, and insulation provided, and accounting for what are specified temperature limitations for the terminal, equipment or device. Not having 14 AWG copper-clad aluminum in these tables creates a chicken and egg problem for anyone that wanted to do testing for suitability of copper-clad aluminum with their terminal, device or equipment.

THREE NRTL'S INVOLVED IN FACT FINDING OF 14 AWG Copper-Clad Aluminum: UL, Intertek and NSF. 14 AWG Copper-Clad Aluminum Poses No Safety Hazard, and Is Notably More Thermally Stable than 14 AWG ETP Copper at 90°C.

- 14 AWG Copper-Clad Aluminum Was Used in Testing to Acquire UL Listing for NMB: Having a UL Listing means that a wire & cable product was tested and met the applicable requirements of UL 1581 under the present Listings. While in the employ of a copper-clad aluminum manufacturer, UL tested 14/2 NMB copper-clad aluminum NMB cable, which lead to a listing for NMB cables in sizes 12 AWG and larger. Not having a listing for a 14 AWG copper-clad aluminum conductor is only due to the NEC not recognizing it. It is also noted that UL has had listings for copper-clad aluminum conductors for over 50 years.

- Intertek Continues Copper-Clad Aluminum "Fact Finding" Research: At CMP6's request, a "Fact Finding" study was conducted by an NRTL with UL 1581 and UL 486C within their Scope of Recognition, Intertek Laboratories. This includes thermal stability testing to ASTM E228 and UL 817 and, even though beyond the needs for conductor ampacity determination, connector testing to UL 486C. The terminal testing was undertaken to determine that in a normal or overcurrent condition, the heat generated by the conductor did not compromise the circuit by destroying the connector.

Temperatures measured on the 14 AWG copper-clad aluminum reference conductors in the Spring Sequence UL 486C test (conducted by Intertek) are equivalent to those found in the NSF Heat Rise Report. Data clearly indicates that 14 AWG copper-clad aluminum poses no safety hazard when used correctly and within the guidelines of the proposed Code changes. There is no technical reason that 14 AWG copper-clad aluminum should not be part of this Code.

- Intertek and NSF Heat Data is Equivalent, Making NSF Data Even More Credible:

Kindly Review the attached NSF and Intertek data for particular diameters at particular ampacities. These independent finds are having the same temperatures recorded under the test conditions.

- Wire Termination and Connectors Are Under the Purview of Other Code Panels; Conductor Insulation Key to Conductor Ampacity Rating in Article 310: For any testing of terminations, devices and equipment, the applicable standards for those items require finding the proper conductor based on the allowed ampacity from wire size,

AWG, and insulation provided, and accounting for what are specified temperature limitations for the terminal, equipment or device. Not having 14 AWG copper-clad aluminum in this table creates a chicken and egg problem for anyone that desires to do testing for suitability of 14 AWG copper-clad aluminum with their terminal, device or equipment.

• Allowing 14 AWG Copper-Clad Aluminum is Warranted: The 10-amp rating at 60C for 14 AWG copper-clad aluminum to be included in 310.3 of the first draft as proposed is valid, since there are branch circuit overcurrent devices and associated branch circuit panelboards available that would provide overcurrent protection at 60C when the 75C terminal ratings are not present. It is also noted that the standard OCPD sizes found in section 240.6 do not limit manufacturers to make branch circuit rated overcurrent devices with other ratings.
ASTM B566 Copper-Clad Aluminum IS A UNIQUE METAL THAT REQUIRES SEPARATION IN ARTICLE 310 FROM SINGLE-METAL ALUMIMUM:
• The Current Table Formats Found in 310.15 Mislead the User, which Puts Copper-Clad Aluminum at a Commercial Disadvantage and Denies the Industry a Valid Alternative: Users of tables 310.15(B)(16) and (17) mistake copper-clad aluminum and single-metal Aluminum as being the same with all the same limits on use. Due to copper-clad aluminum's copper content (27% by mass), copper-clad aluminum maintains inherent differences and advantages to single-metal aluminum wire. Due to single-metal aluminum's tarnished reputation in certain conductor categories, the table formats in 310.15 make copper-clad aluminum guilty by association of single-metal aluminum's unique and singular history. In addition, users of Code consistently wrongly apply the same limitations on copper-clad aluminum for installation, corrosion inhibitors and other requirements for single metal aluminum conductors -- again guilt by misrepresentation due to the current format of 310.15 tables. The proposed action would allow CMP6 to fix a decades-long problem that the modern economy has made relevant.
• Adding 14 AWG Copper-Clad Aluminum to Article 310 Would Further Differentiate Copper-Clad Aluminum from Single-Metal Aluminum: Establishing 14 AWG copper-clad aluminum will help to correct this perception error, bring clarity to the users, and guide users to a truer understanding of copper-clad aluminum as both a suitable conductor and as a feasible alternative. Adding 14 AWG copper-clad aluminum to 310.3 of the first draft will further differentiate copper-clad aluminum and single-metal aluminum in the mind of the user.
• When shown to numerous Authorities Having Jurisdiction, as well as to others. at a number of inspector meetings, the comments on the revised tables and the allowance for 14 AWG copper-clad aluminum as proposed was clearly favorable showing clarity for use of copper-clad aluminum that is not present today.

Related Item

• 2123

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 28 06:48:47 EDT 2018
Committee: NEC-P06

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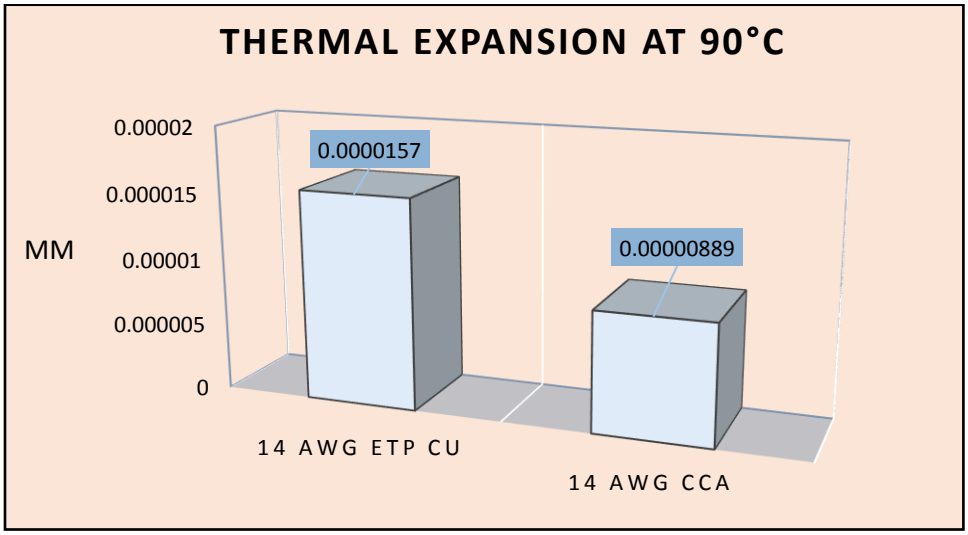
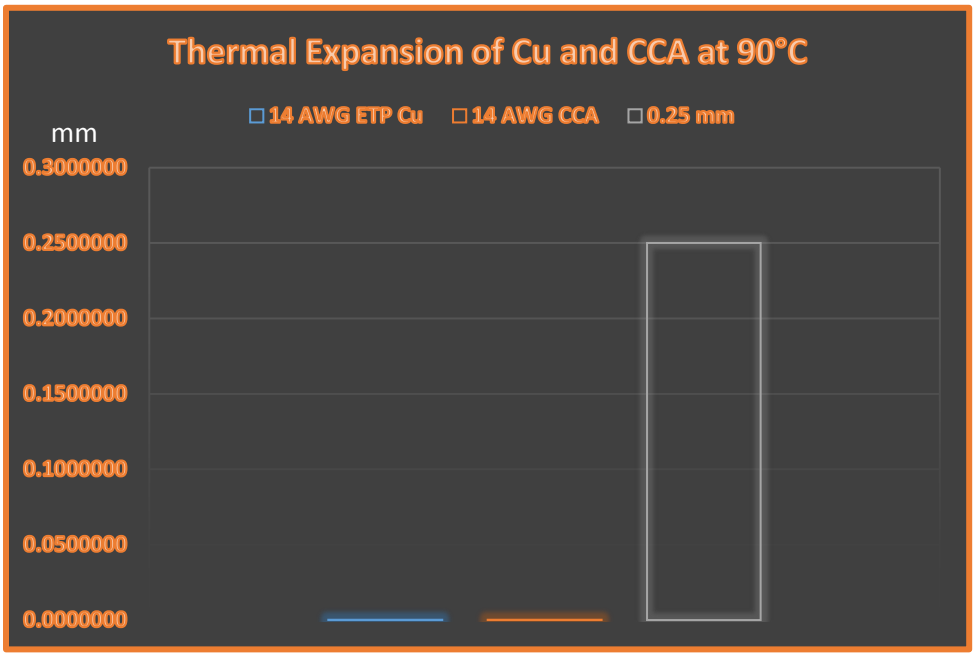
At 90°C, 14 AWG Copper-Clad Aluminum is nearly Twice as Thermally Stable as 14 AWG ETP Copper

Testing By Intertek B&C Labs per ASTM 228 Linear Thermal Expansion



At 90C, ETP 14 AWG Cu expands nearly twice that of Copper Clad Aluminum 14 AWG



At 90°C, Both Copper Clad Aluminum and Copper are Extremely Thermally Stable

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COPPERWELD BIMETALLICS
TEST REPORT

SCOPE OF WORK
ASTM E228 LINEAR THERMAL EXPANSION EVALUATION OF 14 AWG GAGE COPPER CLAD ALUMINUM (CCA) WIRE

REPORT NUMBER
I6049.04-106-31 R0

TEST DATES
07/12/18 - 07/19/18

ISSUE DATE
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RECORD RETENTION END DATE
07/26/22

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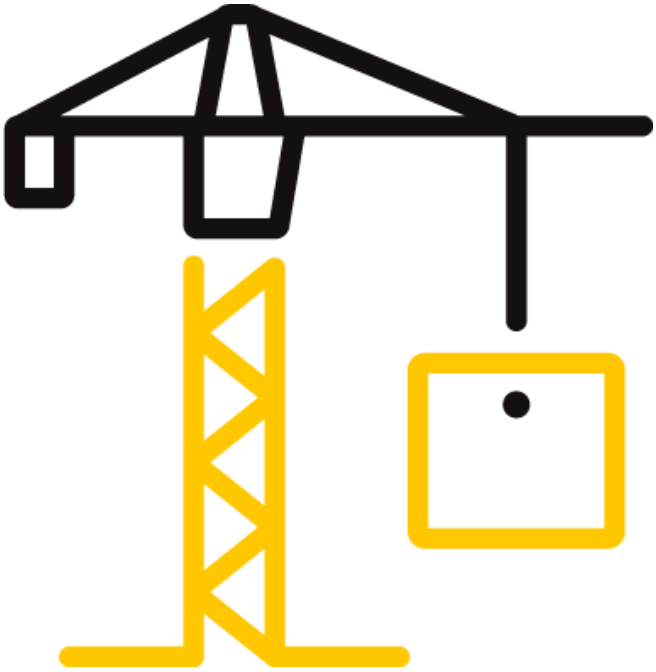

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TEST REPORT FOR COPPERWELD BIMETALLICS

Report No.: I6049.04-106-31 R0
Date: 08/15/18

REPORT ISSUED TO

COPPERWELD BIMETALLICS
254 Cotton Mill Road
Fayetteville, Tennessee 37334

SECTION 1

SCOPE

Products: 14 AWG gage Copper Clad Aluminum (CCA) Wire

Intertek Building & Construction (B&C) was contracted by Copperweld Bimetallics to evaluate 14 AWG gage Copper Clad Aluminum (CCA) Wire in accordance with ASTM E228 for Linear Thermal Expansion properties. Results obtained are tested values and were secured by using the designated test methods. Testing was conducted at the Intertek B&C test facility in York, Pennsylvania.

This report does not constitute certification of this product nor an opinion or endorsement by this laboratory.

SECTION 2

SUMMARY OF TEST RESULTS

COPPER CLAD ALUMINUM (CCA) WIRE AWG GAGE	CLTE (mm/mm/°C) 25°C to 90°C TEMPERATURE RANGE
14	8.89E-06

For INTERTEK B&C:

COMPLETED BY:	Joseph M. Brickner	**REVIEWED BY:**	Dawn M. Chaney
TITLE:	Laboratory Supervisor Materials Laboratory	**TITLE:**	Technician Team Lead Materials laboratory
SIGNATURE:		**SIGNATURE:**	
DATE:	08/15/18	**DATE:**	08/15/18

JMB:dmc/jp

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SECTION 3
TEST METHOD

The specimens were evaluated in accordance with the following:

> **ASTM E228-17**, *Standard Test Method for Linear Thermal Expansion of Solid Materials with a Push-Rod Dilatometer*

SECTION 4
MATERIAL SOURCE

The test materials were provided by Copperweld Bimetallics. The following was received: One (1), nominally 76 mm copper clad aluminum wire specimens in 14 AWG gage. Refer to the product description photo in Section 10. The material was tested as received except for smoothing the cut ends of each specimen. Representative test specimens will be retained by Intertek B&C for a minimum of four years from the test completion date.

SECTION 5
LIST OF OFFICIAL OBSERVERS

NAME	COMPANY
Joseph M. Brickner	Intertek B&C
Dawn M. Chaney	Intertek B&C

SECTION 6
TEST PROCEDURE

All conditioning of test specimens and test conditions were at standard laboratory conditions unless otherwise reported. Refer to the test related photos in Section 10.

ASTM E228 - Linear Thermal Expansion
One specimen for each wire gage was measured for initial length using a 6" digital caliper (ICN: 65688) and placed in the bottom of an outer glass dilatometer tube with an inner glass tube resting on it. An aluminum support cylinder was utilized to keep the wire oriented in a vertical position. The dilatometer tube was suspended in a heated environment utilizing a muffle furnace (ICN: Y002864) and subjected to exposure conditions of nominally 25°C and 90°C. At the equilibrium of each temperature condition, specimen temperature was measured using a thermocouple reader (ICN: 62101) and a measurement was recorded from a digital indicator (ICN: INT00193) resting on top of the inner tube. The Linear Thermal Expansion between the temperature range was calculated.

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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.04-106-31 R0
Date: 08/15/18

SECTION 7
TEST SPECIMEN DESCRIPTIONS

TEST PROCEDURE	NUMBER OF SPECIMENS	NOMINAL SPECIMEN DIMENSIONS	VISUAL CHARACTERISTICS
ASTM E228 Linear Thermal Expansion	1	75 mm x 14 gage wire thickness	Copper Clad Aluminum wire

SECTION 8
TEST RESULTS

ASTM E228 - Linear Thermal Expansion

Copper Clad Aluminum (CCA) Wire - 14 Gage

All Temperatures

LENGTH (mm)	75.56	
TARGET TEMPERATURE (°C)	25	90
ACTUAL TEMPERATURE (°C)	25.4	90.9
GAGE READING (mm)	6.6070	6.6510
ΔT (°C)		65.5
ΔL (mm)		0.0440
ΔL/ΔT (mm/°C)		6.72E-04
CLTE (mm/mm/°C)		**8.89E-06**

SECTION 9
CONCLUSION

The requested test method did not contain specific performance requirements.

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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.04-106-31 R0
Date: 08/15/18

SECTION 10
PHOTOGRAPHS

Photo No. 1
Copper Clad Aluminum - Specimen Detail

Photo No. 2
ASTM E228 - Equipment Detail

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Report No.: I6049.04-106-31 R0
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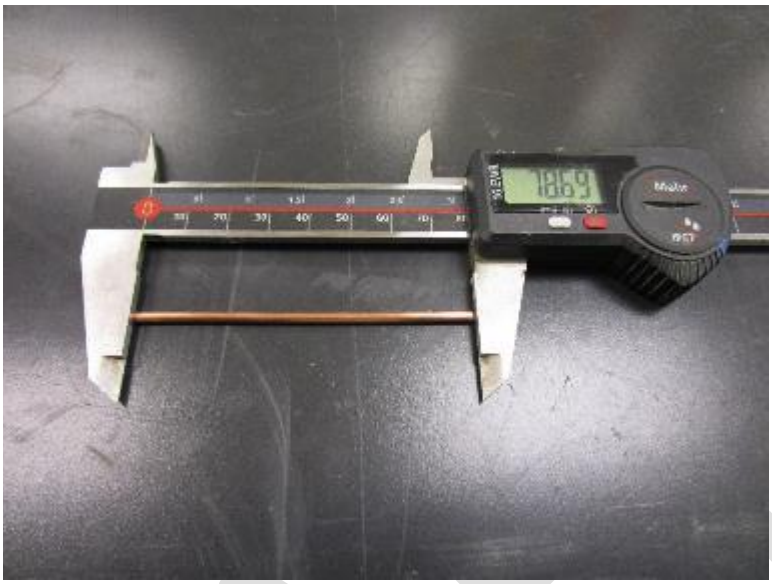

Photo No. 3
ASTM E228 - Length Measurement Equipment Detail

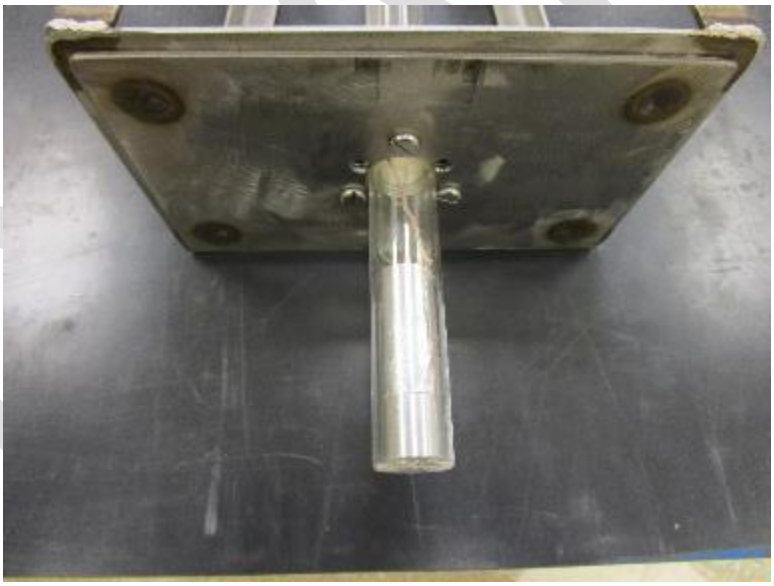

Photo No. 4
ASTM E228 - Specimen Support Detail

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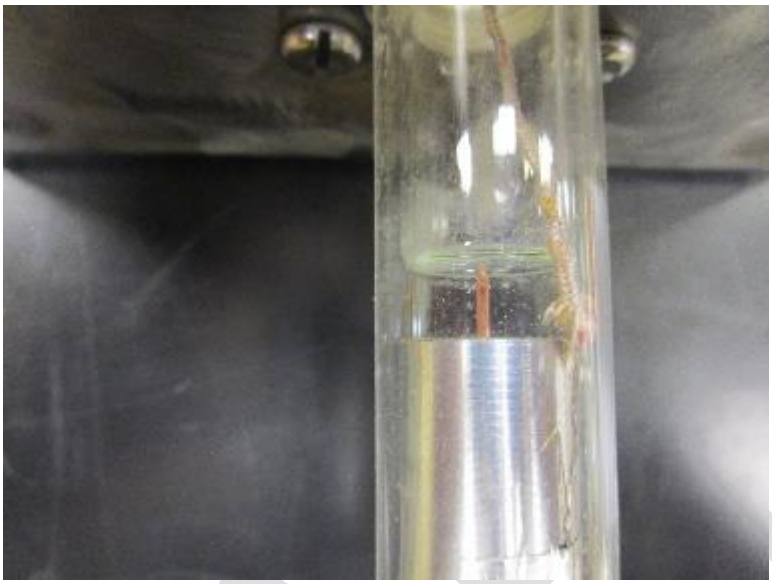

Photo No. 5
ASTM E228 - Specimen Temperature Measurement Detail

Photo No. 6
ASTM E228 - Linear Expansion Measurement Equipment Detail

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TEST REPORT FOR COPPERWELD BIMETALLICS
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SECTION 11
REVISION LOG

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COPPERWELD BIMETALLICS
TEST REPORT

SCOPE OF WORK
ASTM E228 LINEAR THERMAL EXPANSION EVALUATION OF 14 AWG GAGE ELECTROLYTIC TOUGH PITCH (ETP) COPPER WIRE

REPORT NUMBER
I6049.03-106-31 R0

TEST DATES
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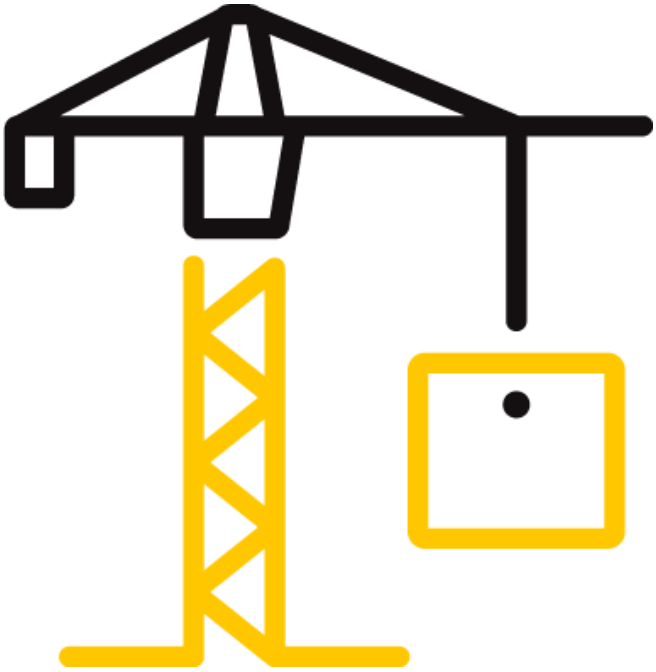

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TEST REPORT FOR COPPERWELD BIMETALLICS

Report No.: I6049.03-106-31 R0
Date: 08/15/18

REPORT ISSUED TO

COPPERWELD BIMETALLICS
254 Cotton Mill Road
Fayetteville, Tennessee 37334

SECTION 1

SCOPE

Products: 14 AWG gage Electrolytic Tough Pitch (ETP) Wire

Intertek Building & Construction (B&C) was contracted by Copperweld Bimetallics to evaluate 14 AWG gage Electrolytic Tough Pitch (ETP) Wire in accordance with ASTM E228 for Linear Thermal Expansion properties. Results obtained are tested values and were secured by using the designated test methods. Testing was conducted at the Intertek B&C test facility in York, Pennsylvania.

This report does not constitute certification of this product nor an opinion or endorsement by this laboratory.

SECTION 2

SUMMARY OF TEST RESULTS

ELECTROLYTIC TOUGH PITCH (ETP) COPPER WIRE AWG GAGE	CLTE (mm/mm/°C) 25°C to 90°C TEMPERATURE RANGE
14	1.57E-05

For INTERTEK B&C:

COMPLETED BY:	Joseph M. Brickner	**REVIEWED BY:**	Dawn M. Chaney
TITLE:	Laboratory Supervisor Materials Laboratory	**TITLE:**	Technician Team Lead Materials laboratory
SIGNATURE:		**SIGNATURE:**	
DATE:	08/15/18	**DATE:**	08/15/18

JMB:dmc/jlp

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SECTION 3
TEST METHOD

The specimens were evaluated in accordance with the following:

> **ASTM E228-17**, *Standard Test Method for Linear Thermal Expansion of Solid Materials with a Push-Rod Dilatometer*

SECTION 4
MATERIAL SOURCE

The test materials were provided by Copperweld Bimetallics. The following were received: One (1), nominally 76 mm electrolytic tough pitch copper wire specimen in 14 AWG gage. Refer to the product description photo in Section 10. The material was tested as received except for smoothing the cut ends of each specimen. Representative test specimens will be retained by Intertek B&C for a minimum of four years from the test completion date.

SECTION 5
LIST OF OFFICIAL OBSERVERS

NAME	COMPANY
Joseph M. Brickner	Intertek B&C
Dawn M. Chaney	Intertek B&C

SECTION 6
TEST PROCEDURE

All conditioning of test specimens and test conditions were at standard laboratory conditions unless otherwise reported. Refer to the test related photos in Section 10.

ASTM E228 - Linear Thermal Expansion
One specimen for each wire gage was measured for initial length using a 6" digital caliper (ICN: 65688) and placed in the bottom of an outer glass dilatometer tube with an inner glass tube resting on it. An aluminum support cylinder was utilized to keep the wire oriented in a vertical position. The dilatometer tube was suspended in a heated environment utilizing a muffle furnace (ICN: Y002864) and subjected to exposure conditions of nominally 25°C and 90°C. At the equilibrium of each temperature condition, specimen temperature was measured using a thermocouple reader (ICN: 62101) and a measurement was recorded from a digital indicator (ICN: INT00193) resting on top of the inner tube. The Linear Thermal Expansion between the temperature range was calculated.

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SECTION 7
TEST SPECIMEN DESCRIPTIONS

TEST PROCEDURE	NUMBER OF SPECIMENS	NOMINAL SPECIMEN DIMENSIONS	VISUAL CHARACTERISTICS
ASTM E228 Linear Thermal Expansion	1 each	75 mm x 14 gage wire thickness	Electrolytic Tough Pitch Copper wire

SECTION 8
TEST RESULTS

ASTM E228 - Linear Thermal Expansion

Electrolytic Tough Pitch (ETP) Copper Wire - 14 Gage

All Temperatures

LENGTH (mm)	75.60	
TARGET TEMPERATURE (°C)	25	90
ACTUAL TEMPERATURE (°C)	28.7	91.3
GAGE READING (mm)	5.6440	5.7220
ΔT (°C)		62.6
ΔL (mm)		0.0780
ΔL/ΔT (mm/°C)		1.25E-03
CLTE (mm/mm/°C)		**1.57E-05**

SECTION 9
CONCLUSION

The requested test method did not contain specific performance requirements.

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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.03-106-31 R0
Date: 08/15/18

SECTION 10
PHOTOGRAPHS

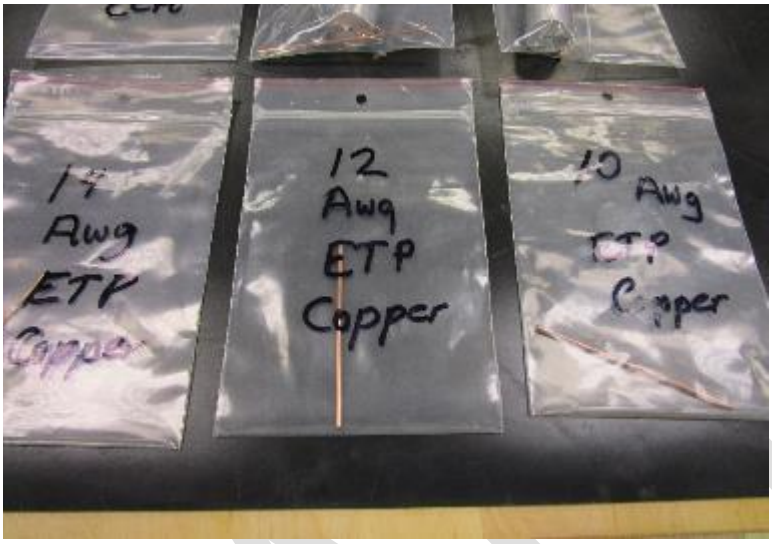

Photo No. 1
Electrolytic Tough Pitch - Specimen Detail

Photo No. 2
ASTM E228 - Equipment Detail

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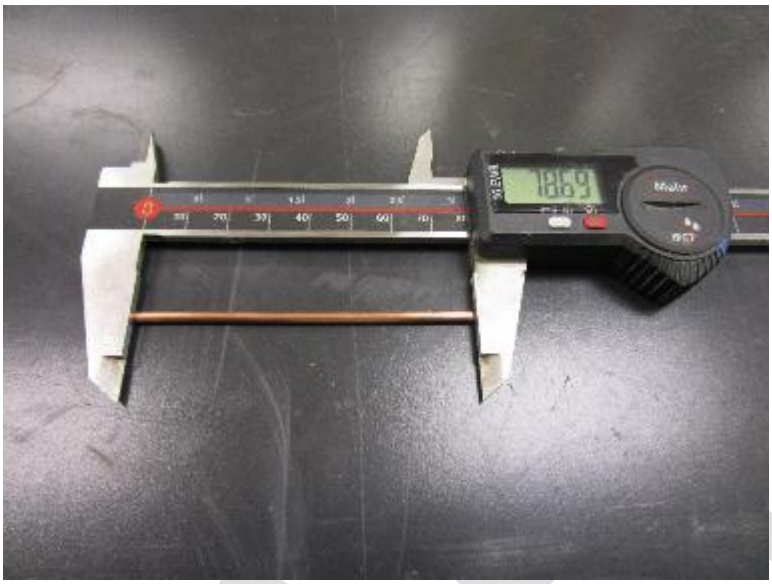

Photo No. 3
ASTM E228 - Length Measurement Equipment Detail

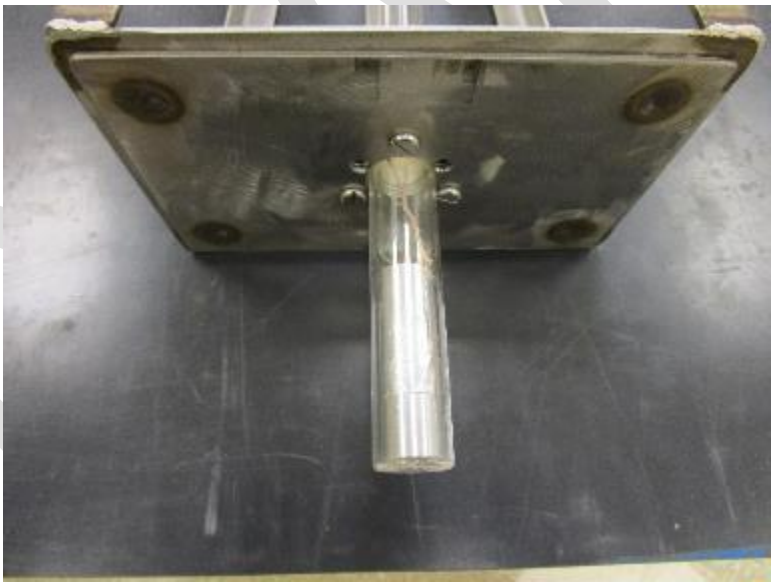

Photo No. 4
ASTM E228 - Specimen Support Detail

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Report No.: I6049.03-106-31 R0
Date: 08/15/18

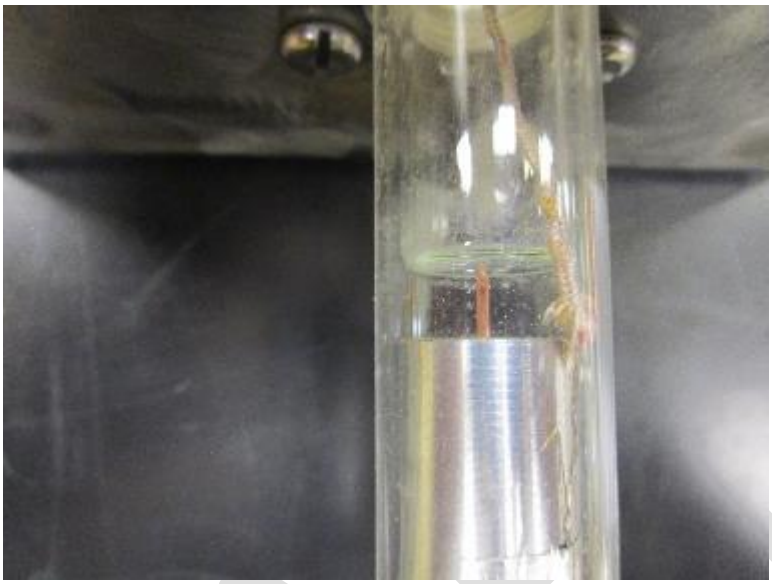

Photo No. 5
ASTM E228 - Specimen Temperature Measurement Detail

Photo No. 6
ASTM E228 - Linear Expansion Measurement Equipment Detail

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TEST REPORT FOR COPPERWELD BIMETALLICS
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TEST REPORT

Send To: C0352008
Peter Graser
Copperweld Bimetallic
215 Centerview Dr
Brentwood TN 37027

Facility: C0352008
Copperweld Bimetallic
215 Centerview Dr
Brentwood TN 37027

Report Date: October 27, 2017

Description:	CCA –Cu Ampacity Comparison
Type of Evaluation	Fact Finding Investigation
Job Number	J-00265162
Project Number	0225-104
Project Manager	Don Tottingham
Location	789 Dixboro Road, Ann Arbor
Inspection Dates	August 7- August 18, 2017
Total # of Pages	125 Pages

Evaluated By: _____

Anas Alaghazali- Engineer

Reviewed By: Steve Fabian

Steve Fabian- Senior Technical Manager

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12 Awg non-metallic cable (2 conductor) in open air	51-61
12 Awg two conductors in conduit	62-71
10 Awg single Conductor in open air	72-87
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Purpose: The purpose of this testing was to evaluate copper clad aluminum wire (CCA) and copper wire (Cu) as a single conductor, non- -metallic 2 hot conductors, and two conductor in conduit, under the same current condition, and to determine their equivalence in performance

Credentials: NSF International, an accredited Nationally Recognized Testing Laboratory (NRTL), an Accredited Standards Council of Canada (SCC) laboratory, and accredited by the International Standards Organization (ISO) to ISO 14001.

Executive Summary: This Fact-Finding Investigation was conducted to develop a comparative temperature – heat rise database for Copper and Copper-Clad Aluminum Conductors in Sizes No. 14 -10 AWG.

The details of the test procedure for each conductor size, 14-10 AWG, is outlined in the report.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 14 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 18, 29, and 38.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 12 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 50, 61, and 71.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 10 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 87, 100, and 113.

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Test Set- Up/ Layout
14 AWG single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 14AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 14AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 14 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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FIGURE 1
Circuit Layout

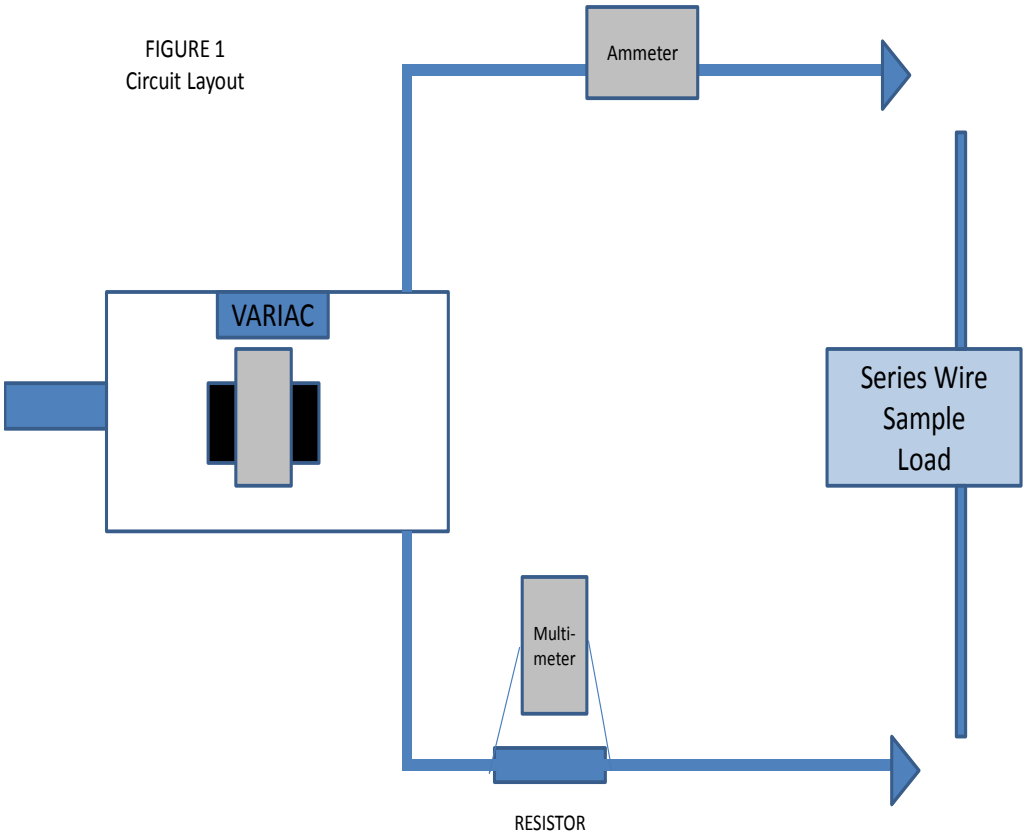

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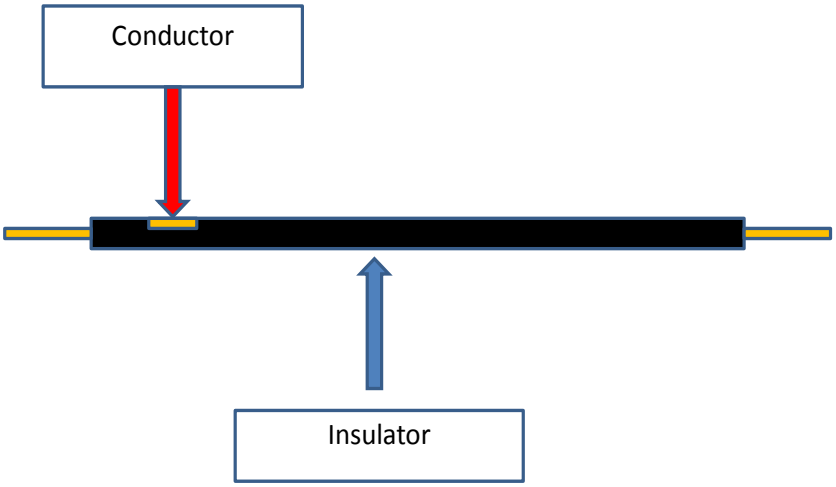
FIGURE 2
Single conductor



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Test Procedure
14 AWG Single Conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	Open air	5	30
14	Open air	10	30
14	Open air	15	30
14	Open air	20	30
14	Open air	25	30
14	Open air	30	30
14	Open air	35	30
14	Open air	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA Single Conductor open Air (Page 1/3))

Scan	Time	Elapsed	212 CU-AL #1 Core	213 CU-AL #1 Insu	203 CU-AL#2 Core	204 CU-AL#2 Insu	205 CU-AL#3 Insu
	5 AMPS						
32.00	42956.43	00:00:30:59	23.66	23.26	23.60	23.45	23.89
		Corrected Ambient	32.38	31.98	32.32	32.17	32.61
		Average	32.31				
		Average Core	32.40				
		Average Insulation	32.20				
	10 AMPS						
62.00	42956.45	00:01:00:59	28.37	28.10	27.74	28.35	28.81
		Corrected Ambient	36.96	36.69	36.33	36.94	37.40
		Average	36.38				
		Average Core	36.52				
		Average Insulation	36.22				
	15 AMPS						
92.00	42956.47	00:01:30:59	33.80	33.78	32.88	33.88	34.50
		Corrected Ambient	42.42	42.40	41.50	42.50	43.12
		Average	41.70				
		Average Core	42.16				
		Average Insulation	41.20				
	20 AMPS						
122.00	42956.49	00:02:00:59	43.82	43.54	42.12	43.28	44.61
		Corrected Ambient	52.04	51.76	50.34	51.50	52.83

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		Average	50.79				
		Average Core	51.77				
		Average Insulation	49.71				
	25 AMPS						
154.00	42956.52	00:02:32:59	53.50	53.49	51.23	52.53	54.61
		Corrected Ambient	61.81	61.80	59.54	60.84	62.92
		Average	60.07				
		Average Core	61.51				
		Average Insulation	58.50				
	30 AMPS						
183.00	42956.54	00:03:01:59	69.00	67.27	65.45	65.49	69.18
		Corrected Ambient	77.08	75.35	73.53	73.57	77.26
		Average	73.57				
		Average Core	75.91				
		Average Insulation	71.02				
	35 AMPS						
216.00	42956.56	00:03:34:59	85.83	83.73	80.52	81.75	86.71
		Corrected Ambient	93.96	91.86	88.65	89.88	94.84
		Average	89.81				
		Average Core	92.67				
		Average Insulation	86.68				

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14 AWG CCA Single Conductor open Air (Page 2/3))

208 CU-AL#3 Core	120 CU-AL #4 Core	211 CU-AL#4 Insu	102 CU-AL#5 Core	110 CU-AL#5 Insu	117 CU-AL#6 Core	116 CU-AL#7 Insul	320 CU-AL#7 Core	113 CU-AL#8 Core
23.51	23.63	23.37	23.62	23.47	23.86	23.44	23.36	23.79
32.23	32.35	32.09	32.34	32.19	32.58	32.16	32.08	32.51
27.61	27.35	26.86	27.79	27.18	27.93	27.43	27.16	27.92
36.20	35.94	35.45	36.38	35.77	36.52	36.02	35.75	36.51
32.59	32.02	31.20	33.01	31.82	33.24	31.93	32.18	33.99
41.21	40.64	39.82	41.63	40.44	41.86	40.55	40.80	42.61
41.25	41.32	38.66	42.34	39.53	43.15	40.71	41.44	44.59
49.47	49.54	46.88	50.56	47.75	51.37	48.93	49.66	52.81

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49.39	49.93	45.71	51.18	46.84	52.51	48.79	50.05	53.67
57.70	58.24	54.02	59.49	55.15	60.82	57.10	58.36	61.98
62.25	62.46	56.14	64.18	58.21	68.21	60.49	63.39	67.06
70.33	70.54	64.22	72.26	66.29	76.29	68.57	71.47	75.14
76.43	76.02	68.71	79.20	71.51	84.64	74.08	77.84	82.07
84.56	84.15	76.84	87.33	79.64	92.77	82.21	85.97	90.20

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14 AWG CCA Single Conductor open Air (Page 3/3))

114 CU-AL#8 Insul	109 CU-AL#9 Core	112 CU-AL#9 Insul	106 CU-AL#10 Core	107 CU-AL#10 Insul	101 CU-AL#11 Core	103 CU-AL#11 Insul	104 CU-AL#12 Core	105 CU-AL#12 Insul
23.65	23.82	23.63	23.82	23.54	23.54	23.19	23.97	23.43
32.37	32.54	32.35	32.54	32.26	32.26	31.91	32.69	32.15
27.87	27.44	27.22	27.77	27.44	28.29	26.84	29.82	27.86
36.46	36.03	35.81	36.36	36.03	36.88	35.43	38.41	36.45
32.54	33.29	31.49	33.60	32.07	34.85	31.62	37.00	33.55
41.16	41.91	40.11	42.22	40.69	43.47	40.24	45.62	42.17
42.59	42.44	39.88	44.38	40.51	46.65	40.27	49.14	42.83

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50.81	50.66	48.10	52.60	48.73	54.87	48.49	57.36	51.05
51.66	51.50	47.77	54.91	48.80	58.73	49.17	61.74	52.68
59.97	59.81	56.08	63.22	57.11	67.04	57.48	70.05	60.99
64.87	64.44	60.00	70.51	61.42	75.50	62.17	81.54	67.10
72.95	72.52	68.08	78.59	69.50	83.58	70.25	89.62	75.18
81.21	80.84	74.81	88.65	76.44	96.72	79.11	105.73	86.00
89.34	88.97	82.94	96.78	84.57	104.85	87.24	113.86	94.13

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14 AWG Cu Single conductor open air (Page 1/2))

Scan	Time	Elapsed	313 CU#1 Insul	312 CU#1 Core	309 CU#2 Core	310 CU#2 Insul	304 CU#3 Core	305 CU#3 Insul
	5 AMPS							
32.00	42956.43	00:00:30:59	22.94	22.76	23.27	22.75	23.19	22.87
		Corrected Ambient	31.66	31.48	31.99	31.47	31.91	31.59
		Average	31.76					
		Average Core	31.82					
		Average Insulation	31.70					
	10 AMPS							
62.00	42956.45	00:01:00:59	26.12	25.30	26.88	25.64	25.98	25.79
		Corrected Ambient	34.71	33.89	35.47	34.23	34.57	34.38
		Average	34.71					
		Average Core	34.68					
		Average Insulation	34.75					
	15 AMPS							
92.00	42956.47	00:01:30:59	29.59	28.15	30.84	28.94	29.08	29.21
		Corrected Ambient	38.21	36.77	39.46	37.56	37.70	37.83
		Average	38.20					
		Average Core	38.06					
		Average Insulation	38.34					

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	20 AMPS							
122.00	42956.49	00:02:00:59	35.06	33.50	38.22	34.03	34.76	34.30
		Corrected Ambient	43.28	41.72	46.44	42.25	42.98	42.52
		Average	43.85					
		Average Core	44.07					
		Average Insulation	43.64					
	25 AMPS							
154.00	42956.52	00:02:32:59	41.11	39.21	44.97	39.53	39.76	39.48
		Corrected Ambient	49.42	47.52	53.28	47.84	48.07	47.79
		Average	49.79					
		Average Core	49.98					
		Average Insulation	49.60					
	30 AMPS							
183.00	42956.54	00:03:01:59	50.05	48.57	55.19	47.04	46.81	46.68
		Corrected Ambient	58.13	56.65	63.27	55.12	54.89	54.76
		Average	58.05					
		Average Core	58.69					
		Average Insulation	57.42					
	35 AMPS							
216.00	42956.56	00:03:34:59	58.77	56.46	67.22	55.89	54.87	54.95
		Corrected Ambient	66.90	64.59	75.35	64.02	63.00	63.08
		Average	67.08					
		Average Core	67.91					
		Average Insulation	66.25					

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14 AWG Cu Single Conductor open Air (Page 2/2))

206 CU#4 Core	302 CU#4 Insul	218 CU#5 Core	220 CU#5 Insul	209 CU#6 Core	214 CU#6 Insul
23.07	23.20	23.11	22.85	23.21	23.30
31.79	31.92	31.83	31.57	31.93	32.02
26.07	26.44	26.00	26.11	26.30	26.84
34.66	35.03	34.59	34.70	34.89	35.43
29.44	30.07	29.34	29.78	29.81	30.74
38.06	38.69	37.96	38.40	38.43	39.36
35.82	35.84	35.94	35.90	36.83	37.36

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44.04	44.06	44.16	44.12	45.05	45.58
41.32	41.65	41.70	41.84	43.06	44.11
49.63	49.96	50.01	50.15	51.37	52.42
50.11	49.91	50.16	49.62	52.82	52.73
58.19	57.99	58.24	57.70	60.90	60.81
59.11	58.81	59.35	57.77	61.68	62.52
67.24	66.94	67.48	65.90	69.81	70.65

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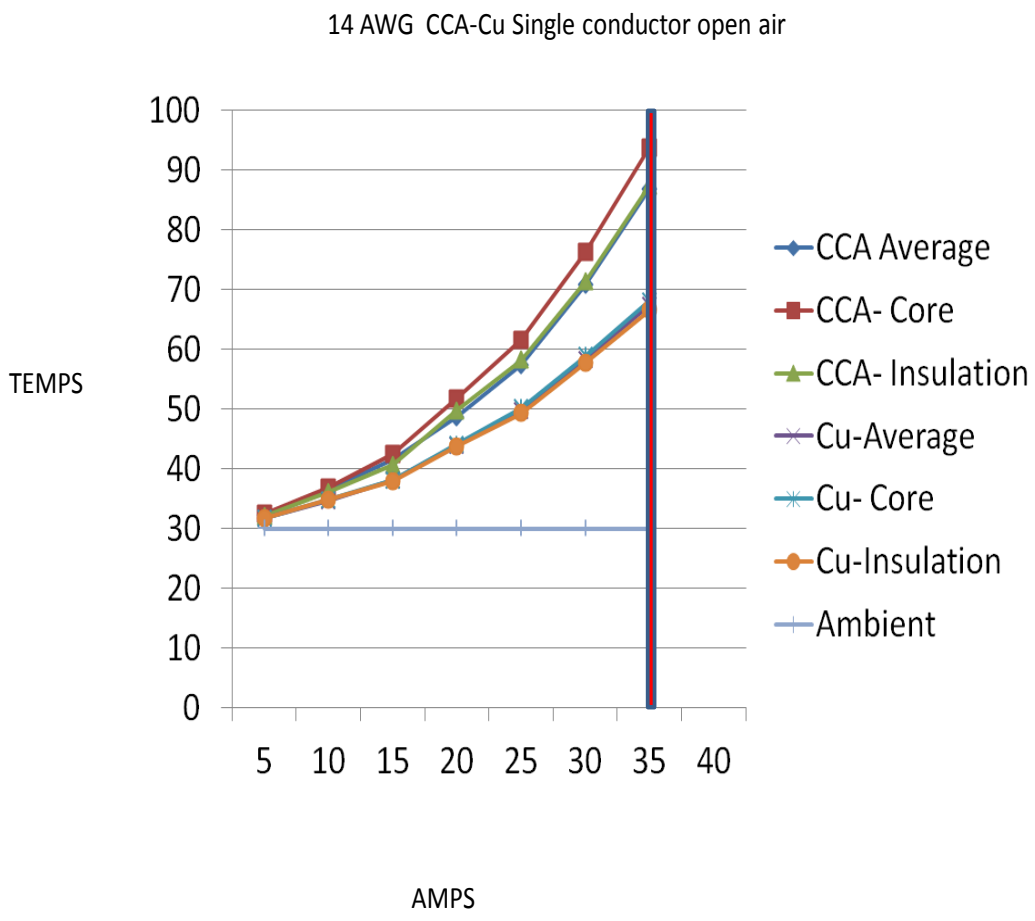

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Test Set- Up/ Layout
14 AWG in non-metallic cable in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 14 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 14 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 14 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used is calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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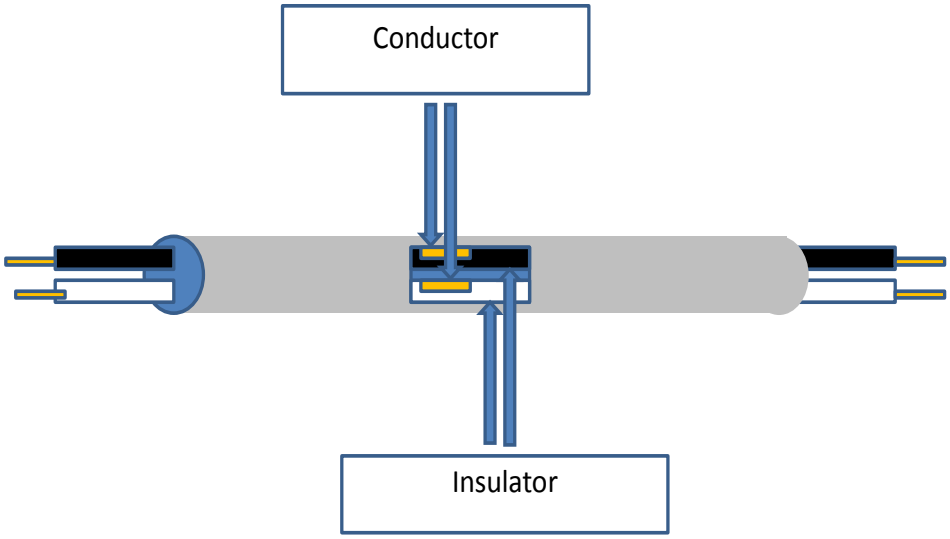
FIGURE 3
Two Line Conductor/ Ground(not connected) Non- metallic Cable



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Test Procedure
14 AWG in Non-metallic cable

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.
.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	NM Cable	5	30
14	NM Cable	10	30
14	NM Cable	15	30
14	NM Cable	20	30
14	NM Cable	25	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA Non Metallic (2 Conductor) open air (Page 1/3)

Scan	Time	Elapsed	101-CU-AL White Cable-Core	103 CU-AL White Cable Insulation	104 CU-AL Black Cable Core	105 CU-AL Black Cable Insulation	106 CU-AL Black Cable Core
29	5 AMPS	00:00:27:59					
30	8/15/2017 12:13	00:00:28:59	24.592	24.57	24.179	24.336	24.308
		Corrected Ambient	32.96	32.94	32.55	32.71	32.68
		Average	32.80				
		Average Core	32.92				
		Average Insulation	32.86				
60	10 AMPS	00:00:58:59	29.924	30.049	28.525	28.47	28.704
61	8/15/2017 12:44	00:00:59:59	29.497	30.014	28.308	28.427	28.595
		Corrected Ambient	37.95	38.46	36.76	36.88	37.04
		Average	37.53				
		Average Core	38.05				
		Average Insulation	38.13				
88	15 AMPS	00:01:26:59					
89	8/15/2017 13:12	00:01:27:59	37.658	38.549	35.166	34.525	34.751
		Corrected Ambient	45.92	46.81	43.43	42.79	43.02
		Average	44.46				
		Average Core	45.13				
		Average Insulation	45.22				
120	20 AMPS	00:01:58:59					
121	8/15/2017 13:44	00:01:59:59	48.404	50.441	43.994	43.521	43.462
		Corrected Ambient	56.61	58.65	52.20	51.73	51.67

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		Average	54.26				
		Average Core	54.78				
		Average Insulation	55.89				
151	25 AMPS	00:02:29:59					
152	8/15/2017 14:15	00:02:30:59	64.72	68.548	57.572	55.957	56.371
		Corrected Ambient	73.02	76.85	65.87	64.26	64.67
		Average	68.95				
		Average Core	69.61				
		Average Insulation	71.60				

14 AWG CCA Non Metallic (2 Conductor) open air (Page 2/3)

107 CU-AL Black Cable Insulation	109 CU-AL White Cable Core	112 CU-AL White Cable# 2 Insulation	113 CU-AL Black Cable#3 Core	114 CU-AL Black Cable #3 Insulation	116 CU-AL White Cable #3 Insulation	320 CU-AL White Cable#3 Core	315 CU-AL Black Cable#4 Core	118 CU-AL Black Cable#4 Insulation	102 CU-AL White Cable #4 Core
24.3	24.745	24.436	24.638	24.609	24.972	25.105	24.416	23.739	24.551
32.67	33.12	32.81	33.01	32.98	33.34	33.48	32.79	32.11	32.92
28.89	29.97	29.341	29.59	29.289	30.546	31.225	29.545	29.786	29.823
28.741	29.96	29.233	29.734	29.38	30.642	31.368	29.462	29.627	29.73
37.19	38.41	37.68	38.18	37.83	39.09	39.82	37.91	38.08	38.18

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35.244	37.473	35.97	36.069	36.113	38.561	39.712	36.608	35.975	37.473
43.51	45.74	44.23	44.33	44.38	46.83	47.98	44.87	44.24	45.74
44.923	47.618	47.015	45.275	46.599	50.61	51.411	46.52	44.202	47.657
53.13	55.83	55.22	53.48	54.81	58.82	59.62	54.73	52.41	55.86
58.491	62.893	62.242	58.51	61.014	67.133	69.89	61.364	57.959	63.192
66.79	71.19	70.54	66.81	69.32	75.43	78.19	69.67	66.26	71.49

14 AWG CCA Non Metallic (2 Conductor) open air (Page 3/3)

110 CU-AL White Cable#4 Insulation	120 CU-AL Black Cable#5 Core	211 CU-AL Black Cable#5 Insulation	205CU-AL White Cable#5 Insulation	208 CU-AL White Cable#5 Core	203 CU-AL Black Cable#6 Core	204 CU-AL Black Cbale#6 Insulation	212 CU-AL White Cable#6 Core	213 CU-AL White Cable#6 Insulation
25.194	24.66	25.029	24.923	24.407	24.321	24.045	24.677	23.717
33.56	33.03	33.40	33.29	32.78	32.69	32.42	33.05	32.09

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31.019	29.933	30.894	30.803	29.33	29.022	29.051	30.233	28.558
31.019	29.959	30.909	30.863	29.348	29.055	28.806	30.238	28.543
39.47	38.41	39.36	39.31	37.80	37.50	37.26	38.69	36.99
39.162	37.293	38.859	38.947	35.984	35.982	36.311	38.22	35.275
47.43	45.56	47.12	47.21	44.25	44.25	44.58	46.48	43.54
51.486	47.619	50.771	50.602	44.739	43.968	46.287	48.202	45.682
59.69	55.83	58.98	58.81	52.95	52.18	54.49	56.41	53.89
69.419	62.641	68.43	68.105	58.395	56.519	61.868	63.671	60.471
77.72	70.94	76.73	76.41	66.70	64.82	70.17	71.97	68.77

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14 AWG Cu Non Metallic (2 Conductor) open air
Page (1/2)

Scan	Time	Elapsed	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core
29	5 AMPS	00:00:27:59					
30	8/15/2017 12:13	00:00:28:59	23.451	23.326	22.977	23.042	22.899
		Corrected Ambient	31.82	31.70	31.35	31.41	31.27
		Average	31.63				
		Average Core	31.61				
		Average Insulation	31.66				
60	10 AMPS	00:00:58:59					
61	8/15/2017 12:44	00:00:59:59	27.177	26.623	25.544	25.678	25.495
		Corrected Ambient	35.63	35.07	33.99	34.13	33.94
		Average	34.60				
		Average Core	34.58				
		Average Insulation	34.62				
88	15 AMPS	00:01:26:59					
89	8/15/2017 13:12	00:01:27:59	32.586	31.152	29.253	29.605	29.106
		Corrected Ambient	40.85	39.42	37.52	37.87	37.37
		Average	38.69				
		Average Core	38.68				
		Average Insulation	38.70				
120	20 AMPS	00:01:58:59					
121	8/15/2017 13:44	00:01:59:59	40.601	37.689	35.231	35.538	35.083
		Corrected Ambient	48.81	45.90	43.44	43.75	43.29

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		Average	44.60				
		Average Core	44.79				
		Average Insulation	44.41				
151	25 AMPS	00:02:29:59					
152	8/15/2017 14:15	00:02:30:59	51.287	47.245	42.544	43.699	41.81
		Corrected Ambient	59.59	55.55	50.85	52.00	50.11
		Average	53.14				
		Average Core	53.05				
		Average Insulation	53.23				

14 AWG Cu Non Metallic (2 Conductor) open air Page (2/2)

302 CU Black Cable#3 Insulation	304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
23.44	23.503	23.264	23.458	23.245	23.126	23.416
31.81	31.87	31.63	31.83	31.62	31.50	31.79
26.374	26.371	26.051	26.426	25.928	25.744	26.369
34.82	34.82	34.50	34.88	34.38	34.19	34.82

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31.135	30.734	30.046	30.955	29.706	29.884	30.947
39.40	39.00	38.31	39.22	37.97	38.15	39.21
37.502	36.586	35.021	37.138	34.631	34.872	36.818
45.71	44.79	43.23	45.35	42.84	43.08	45.03
47.427	44.327	43.744	45.605	42.023	42.908	45.452
55.73	52.63	52.05	53.91	50.32	51.21	53.75

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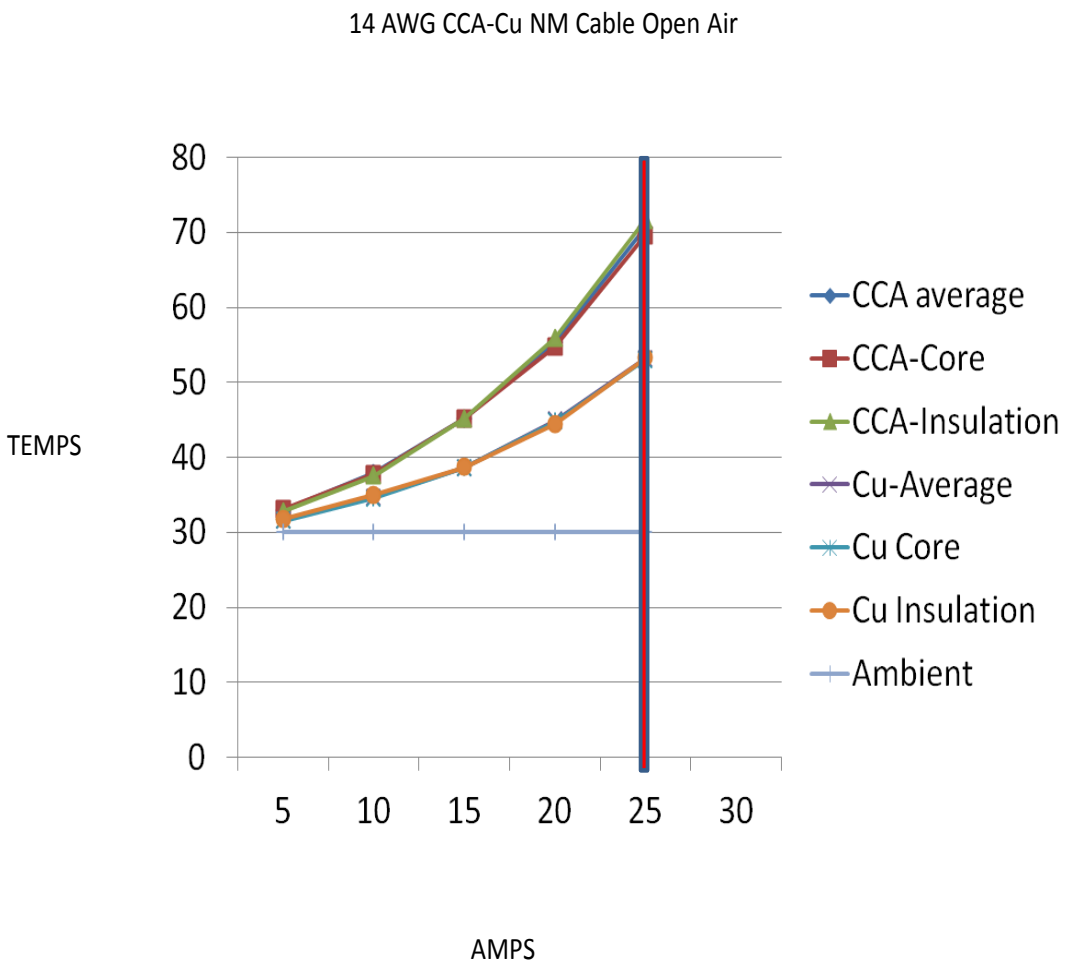

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Test Set- Up/ Layout
14 AWG (2 conductors) in Conduit

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 14 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 14 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 14 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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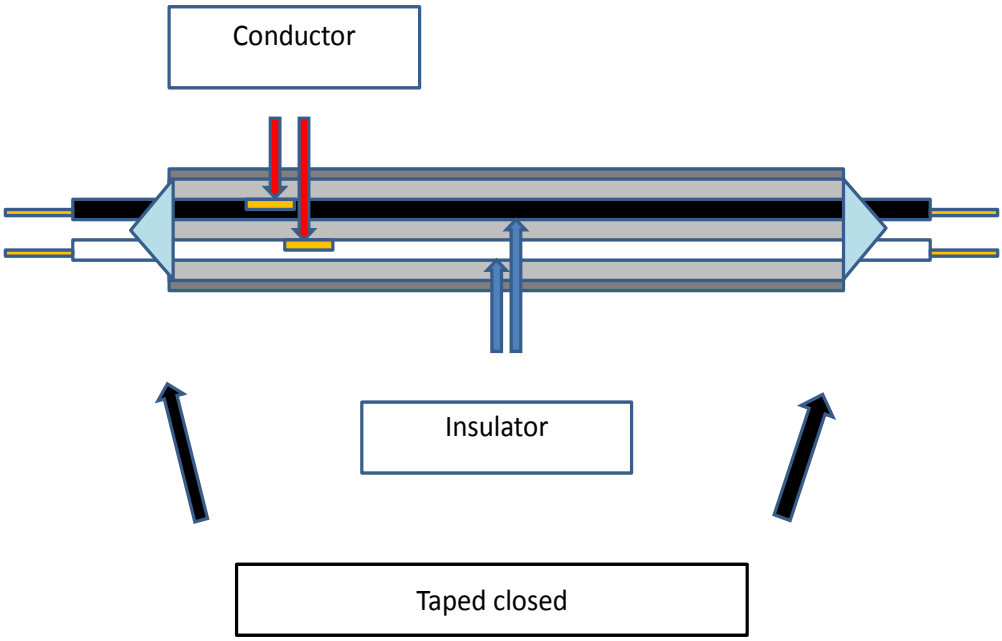
FIGURE 4
Two Conductors in ½ Inch Conduit



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Test Procedure
14 AWG(2 conductors) in Conduit

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 Amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	Conduit	5	30
14	Conduit	10	30
14	Conduit	15	30
14	Conduit	20	30
14	Conduit	25	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA (2 Conductor) in Conduit
Page(1/3)

	101-CCA#1 Core	106 CCA#1 Insulation	107 CCA#2 Core	105 CCA#2 Insulation	112 CCA#3 Core	109 CCA#3 Insulation	113 CCA#4 Core	104 CCA#4 Insulaiton
5 AMPS								
00:00:51:59	24.79	24.61	24.66	24.03	24.04	23.58	23.96	23.72
Corrected Ambient	34.83	34.65	34.70	34.07	34.08	33.62	34.00	33.76
Average	34.19							
Core Average	34.55							
Insulation Average	33.86							
10 AMPS								
00:02:01:59	34.64	34.94	34.84	32.81	32.64	31.25	32.51	31.30
Corrected Ambient	44.83	45.13	45.03	42.99	42.83	41.44	42.70	41.49
Average	43.35							
Core Average	44.12							
Insulation Average	42.64							
15 AMPS								
00:02:52:59	51.48	52.20	52.36	47.74	46.95	43.79	46.60	43.97
Corrected Ambient	61.07	61.78	61.94	57.32	56.53	53.37	56.18	53.55
Average	58.13							
Core Average	59.84							
Insulation Average	56.57							
20 AMPS								
00:03:43:59	72.68	74.44	73.96	66.89	66.02	59.92	64.39	60.07
Corrected Ambient	82.07	83.84	83.35	76.28	75.41	69.31	73.78	69.47
Average	77.26							
Core Average	80.16							
Insulation Average	74.60							
25 AMPS								
00:04:33:59	117.65	117.35	119.71	105.33	107.61	92.87	101.25	92.53
Corrected Ambient	127.06	126.76	129.12	114.74	117.02	102.28	110.66	101.94
Average	117.69							
Core Average	124.41							

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Insulation Average	111.52							

14 AWG CCA (2 Conductor) in Conduit Page(2/3)

120 CCA#5 Core	116 CCA#5 Insulation	110 CCA#6 Core	102 CCA#6 Insulation	118 CCA#7 Insulation	117 CCA#8 Core	103 CCA#8 Insulation	114 CCA#9 Core
24.64	23.92	25.11	24.39	23.42	24.81	23.37	24.43
34.69	33.97	35.15	34.43	33.47	34.85	33.42	34.48
34.64	32.33	35.84	34.63	30.90	33.95	31.16	32.84
44.82	42.52	46.03	44.82	41.09	44.13	41.35	43.03
51.59	46.53	54.59	52.00	43.29	50.64	44.39	47.81
61.17	56.11	64.17	61.58	52.88	60.22	53.97	57.39
73.42	64.63	78.42	73.82	58.67	71.14	60.84	67.02
82.81	74.02	87.81	83.21	68.06	80.53	70.23	76.41
119.35	101.08	128.37	117.64	88.72	117.29	94.74	110.37
128.76	110.49	137.78	127.05	98.13	126.70	104.15	119.78

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14 AWG CCA (2 Conductor) in Conduit Page(3/3)

211 CCA#9 Insulation	212 CCA#10 Core	204 CCA#10 Insulation	220 CCA#11 Core	203 CCA#11 Insulaiton	218 CCA#12 Core	214 CCA#12 Insulation
23.42	24.44	23.75	24.58	24.03	24.15	23.59
33.46	34.48	33.80	34.62	34.07	34.20	33.63
31.17	34.07	33.65	34.69	33.24	32.61	32.04
41.36	44.26	43.84	44.88	43.43	42.80	42.22
45.01	50.94	50.44	52.39	48.40	47.47	46.07
54.59	60.52	60.02	61.97	57.98	57.05	55.65
61.56	71.91	71.23	73.72	67.11	65.73	63.36
70.95	81.30	80.62	83.11	76.50	75.12	72.75
97.96	118.18	113.21	118.54	104.99	106.66	98.95
107.37	127.59	122.62	127.95	114.40	116.07	108.36

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14 AWG Cu (2 Conductor) in Conduit Page 1/2)

	206 CU#1 Core	209 CU#1 Insulation	213 CU#3 Core	208 CU#3 Insualtion	205 CU#5 Core	305 CU#5 Insulation
5 AMPS						
00:00:51:59	22.48	21.97	22.25	22.56	22.77	22.70
Corrected Ambient	32.52	32.02	32.30	32.60	32.81	32.74
Average	32.67					
Core Average	32.81					
Insulation Average	32.53					
10 AMPS						
00:02:01:59	27.37	26.44	27.92	28.45	28.47	28.16
Corrected Ambient	37.56	36.63	38.11	38.63	38.65	38.35
Average	38.29					
Core Average	38.65					
Insulation Average	37.92					
15 AMPS						
00:02:52:59	36.14	34.08	37.61	38.51	38.48	37.28
Corrected Ambient	45.72	43.67	47.19	48.09	48.07	46.86
Average	47.09					
Core Average	47.98					
Insulation Average	46.20					
20 AMPS						
00:03:43:59	45.98	42.87	49.09	50.19	50.16	47.55
Corrected Ambient	55.37	52.26	58.48	59.58	59.56	56.94
Average	57.97					
Core Average	59.56					
Insulation Average	56.39					
25 AMPS						
00:04:33:59	65.98	59.49	71.81	72.52	73.11	68.34
Corrected Ambient	75.39	68.90	81.22	81.93	82.52	77.75
Average	79.54					
Core Average	82.77					
Insulation Average	76.31					

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14 AWG Cu (2 Conductor) in Conduit
Page (2/2)

318 CU#7 Core	315 CU#7 Insulation	310 CU#9 Core	313 CU#9 Insulaiton	304 CU#11 Core	312 CU#11 Insulation
23.00	22.44	23.28	22.62	22.81	22.62
33.04	32.48	33.33	32.66	32.85	32.66
29.12	27.38	29.95	27.92	27.95	28.05
39.31	37.57	40.14	38.11	38.14	38.24
39.72	36.00	41.63	36.70	36.82	37.14
49.30	45.58	51.21	46.28	46.40	46.73
52.56	46.16	55.35	47.13	47.86	48.12
61.95	55.55	64.74	56.52	57.25	57.51
78.19	65.80	82.60	66.20	68.46	69.08
87.60	75.21	92.01	75.61	77.87	78.49

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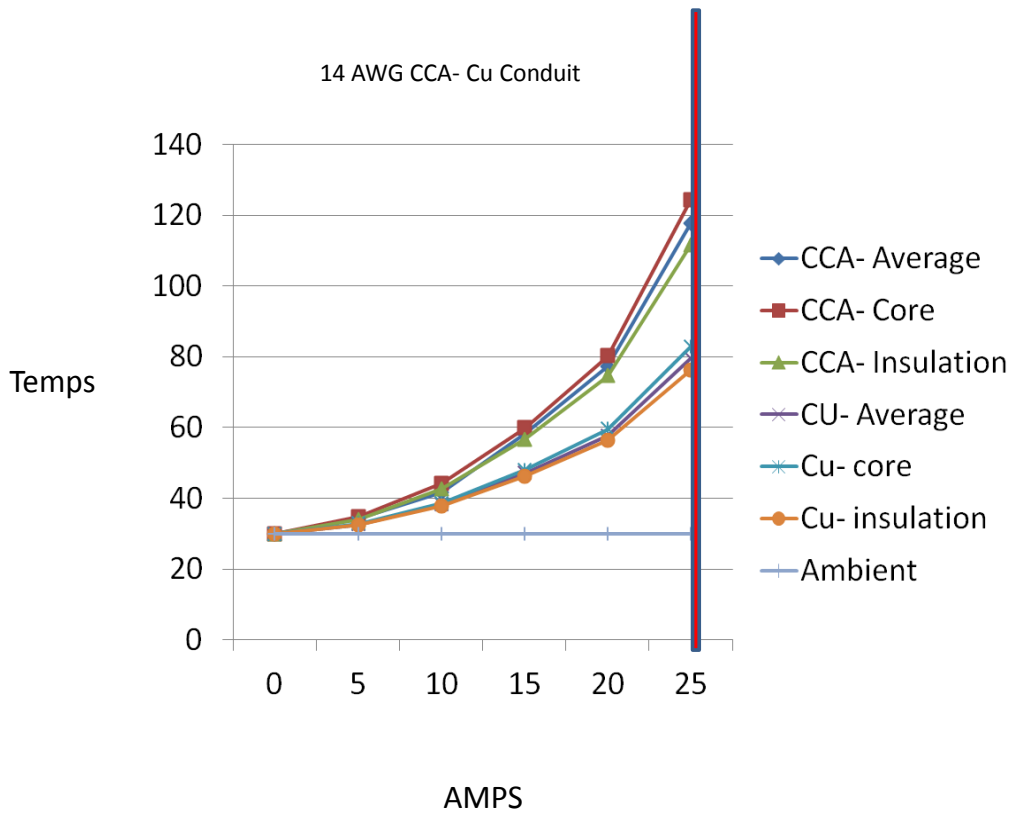

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Test Set- Up/ Layout
12 AWG Single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 12 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 12 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 12 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG single conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	Open air	5	30
12	Open air	10	30
12	Open air	15	30
12	Open air	20	30
12	Open air	25	30
12	Open air	30	30
12	Open air	35	30
12	Open air	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG single conductors
(Page 1 of 3)

Scan	Time	101- CU-AL White Cable#1- Insulation	104 CU-AL Black Cable#1 Core	105 CU-AL Black Cable#1 Insulation	106 CU-AL Black Cable#2 Core	107 CU-AL Black Cable#2 Insulation	109 CU-AL White Cable#2 Core
	5 AMPS						
30	8/16/2017 14:54	23.5	23.719	23.597	24.101	23.626	23.882
	Corrected Ambient	31.925	32.144	32.022	32.526	32.051	32.307
	Average	31.86845					
	Average Core	32.1068					
	Average Insulation	31.66983					
	10 AMPS						
60	8/16/2017 15:24	26.487	26.702	26.788	27.393	26.714	26.989
	Corrected Ambient	35	35.215	35.301	35.906	35.227	35.502
	Average	34.92791					
	Average Core	35.3563					
	Average Insulation	34.57092					
	15 AMPS						
91	8/16/2017 15:55	30.559	30.658	30.656	32.374	30.779	31.249
	Corrected Ambient	38.79	38.889	38.887	40.605	39.01	39.48
	Average	38.64927					
	Average Core	39.4042					
	Average Insulation	38.02017					
	20 AMPS						
121	8/16/2017 16:25	35.826	35.837	35.678	38.337	35.742	36.622
	Corrected Ambient	44.421	44.432	44.273	46.932	44.337	45.217
	Average	43.80986					
	Average Core	45.065					
	Average Insulation	42.76392					

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	25 AMPS						
152	8/16/2017 16:56	42.958	43.207	43.137	48.117	43.123	44.441
	Corrected Ambient	51.22	51.469	51.399	56.379	51.385	52.703
	Average	50.82832					
	Average Core	52.8027					
	Average Insulation	49.183					
	30 AMPS						
182	8/16/2017 17:26	50.663	51.573	51.558	58.75	51.353	52.748
	Corrected Ambient	59.164	60.074	60.059	67.251	59.854	61.249
	Average	58.849					
	Average Core	61.1368					
	Average Insulation	56.9425					
	35 AMPS						
213	8/16/2017 17:57	59.241	60.489	60.736	70.389	59.671	62.631
	Corrected Ambient	67.397	68.645	68.892	78.545	67.827	70.787
	Average	67.43436					
	Average Core	70.5558					
	Average Insulation	64.83317					
	40 AMPS						
244	8/16/2017 18:28	67.579	70.938	69.371	84.754	68.417	73.658
	Corrected Ambient	75.86	79.219	77.652	93.035	76.698	81.939
	Average	76.85605					
	Average Core	80.71511					
	Average Insulation	72.72958					

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12 AWG Single conductor
(Page 2 of 3)

112 CU-AL White Cable# 2 Insulation	113 CU-AL Black Cable#3 Core	114 CU-AL Black Cable #3 Insulation	116 CU-AL White Cable #3 Insulation	320 CU-AL White Cable#4 Core	118 CU-AL Black Cable#4 Insulation
23.57	23.62	23.4	23.285	23.776	23.093
31.995	32.045	31.825	31.71	32.201	31.518
26.464	26.507	26.264	25.822	26.845	25.692
34.977	35.02	34.777	34.335	35.358	34.205
30.073	30.291	29.915	29.382	31.533	29.206
38.304	38.522	38.146	37.613	39.764	37.437
34.775	34.982	34.305	33.662	37.097	32.398
43.37	43.577	42.9	42.257	45.692	40.993
41.606	42.027	41.564	40.681	46.895	35.318

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49.868	50.289	49.826	48.943	55.157	43.58
49.167	49.465	49.303	47.244	55.947	45.015
57.668	57.966	57.804	55.745	64.448	53.516
57.152	57.789	57.623	54.861	67.265	52.7
65.308	65.945	65.779	63.017	75.421	60.856
66.056	67.263	67.276	63.756	81.93	48.048
74.337	75.544	75.557	72.037	90.211	56.329

12 AWG Single conductor
(Page 3 of 3)

110 CU-AL White Cable#4 Core	120 CU-AL Black Cable#5 Core	211 CU-AL Black Cable#5 Insulation	205CU-AL White Cable#5 Insulation	208 CU-AL White Cable#6 Core	203 CU-AL Black Cable#6 Core	204 CU-AL Black Cbale#6 Insulation
23.509	23.482	23.149	23.038	23.485	23.786	22.755
31.934	31.907	31.574	31.463	31.91	32.211	31.18

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26.402	26.539	25.762	25.861	26.673	27.668	25.409
34.915	35.052	34.275	34.374	35.186	36.181	33.922
30.025	30.717	29.685	29.704	31.023	32.791	28.963
38.256	38.948	37.916	37.935	39.254	41.022	37.194
34.209	35.835	33.848	34.108	36.344	39.108	32.692
42.804	44.43	42.443	42.703	44.939	47.703	41.287
40.855	43.7	41.307	41.654	44.03	48.851	39.803
49.117	51.962	49.569	49.916	52.292	57.113	48.065
47.49	51.417	48.521	49.376	51.659	58.336	46.401
55.991	59.918	57.022	57.877	60.16	66.837	54.902

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55.696	61.164	57.106	58.492	61.252	69.982	53.979
63.852	69.32	65.262	66.648	69.408	78.138	62.135
63.039	72.843	66.826	67.72	70.828	83.361	63.75
71.32	81.124	75.107	76.001	79.109	91.642	72.031

12 AWG Cu Single conductors
(Page 1 of 2)

Scan	Time	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core
	5 AMPS					
30	8/16/2017 14:54	22.678	22.601	23.084	22.862	23.1
	Corrected Ambient	31.103	31.026	31.509	31.287	31.525
	Average	31.28				
	Average Core	31.346				
	Average Insulation	31.214				
	10 AMPS					
60	8/16/2017 15:24	24.574	24.195	25.492	24.984	25.629
	Corrected Ambient	33.087	32.708	34.005	33.497	34.142
	Average	33.44408				
	Average Core	33.63167				
	Average Insulation	33.2565				
	15 AMPS					

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91	8/16/2017 15:55	27.938	27.51	29.234	28.369	29.346
	Corrected Ambient	36.169	35.741	37.465	36.6	37.577
	Average	36.27708				
	Average Core	36.65483				
	Average Insulation	35.89933				
	20 AMPS					
121	8/16/2017 16:25	31.89	31.073	33.381	32.19	33.634
	Corrected Ambient	40.485	39.668	41.976	40.785	42.229
	Average	40.2505				
	Average Core	40.86083				
	Average Insulation	39.64017				
	25 AMPS					
152	8/16/2017 16:56	37.908	36.251	39.895	37.963	40.79
	Corrected Ambient	46.17	44.513	48.157	46.225	49.052
	Average	45.57908				
	Average Core	46.602				
	Average Insulation	44.55617				
	30 AMPS					
182	8/16/2017 17:26	45.629	44.793	46.939	43.77	47.443
	Corrected Ambient	54.13	53.294	55.44	52.271	55.944
	Average	51.87658				
	Average Core	53.18617				
	Average Insulation	50.567				
	35 AMPS					
213	8/16/2017 17:57	53.356	52.266	54.603	50.492	54.888
	Corrected Ambient	61.512	60.422	62.759	58.648	63.044
	Average	58.39692				
	Average Core	60.13967				
	Average Insulation	56.65417				
	40 AMPS					
244	8/16/2017 18:28	62.217	61.357	63.891	59.265	64.258
	Corrected Ambient	70.498	69.638	72.172	67.546	72.539

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	Average	66.52817				
	Average Core	69.18933				
	Average Insulation	63.867				

12 AWG Cu Single conductors
(Page 1 of 2)

	Time	304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
	5 AMPS						
30	8/16/2017 14:54	22.672	22.586	23.069	22.909	22.923	22.74
	Corrected Ambient	31.097	31.011	31.494	31.334	31.348	31.165
	10 AMPS						
60	8/16/2017 15:24	24.713	24.647	25.355	24.993	24.949	24.515
	Corrected Ambient	33.226	33.16	33.868	33.506	33.462	33.028
	15 AMPS						
91	8/16/2017 15:55	27.693	27.514	28.674	27.745	27.658	26.826
	Corrected Ambient	35.924	35.745	36.905	35.976	35.889	35.057
	20 AMPS						
121	8/16/2017 16:25	31.304	30.91	32.491	31.202	30.895	29.56
	Corrected Ambient	39.899	39.505	41.086	39.797	39.49	38.155

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	25 AMPS						
152	8/16/2017 16:56	36.656	36.446	39.125	36.545	35.666	33.819
	Corrected Ambient	44.918	44.708	47.387	44.807	43.928	42.081
	30 AMPS						
182	8/16/2017 17:26	42.269	41.429	45.709	41.914	40.122	38.201
	Corrected Ambient	50.77	49.93	54.21	50.415	48.623	46.702
	35 AMPS						
213	8/16/2017 17:57	50.113	48.676	53.39	48.317	45.552	43.055
	Corrected Ambient	58.269	56.832	61.546	56.473	53.708	51.211
	40 AMPS						
244	8/16/2017 18:28	55.495	53.591	66.664	55.887	52.925	47.744
	Corrected Ambient	63.776	61.872	74.945	64.168	61.206	56.025

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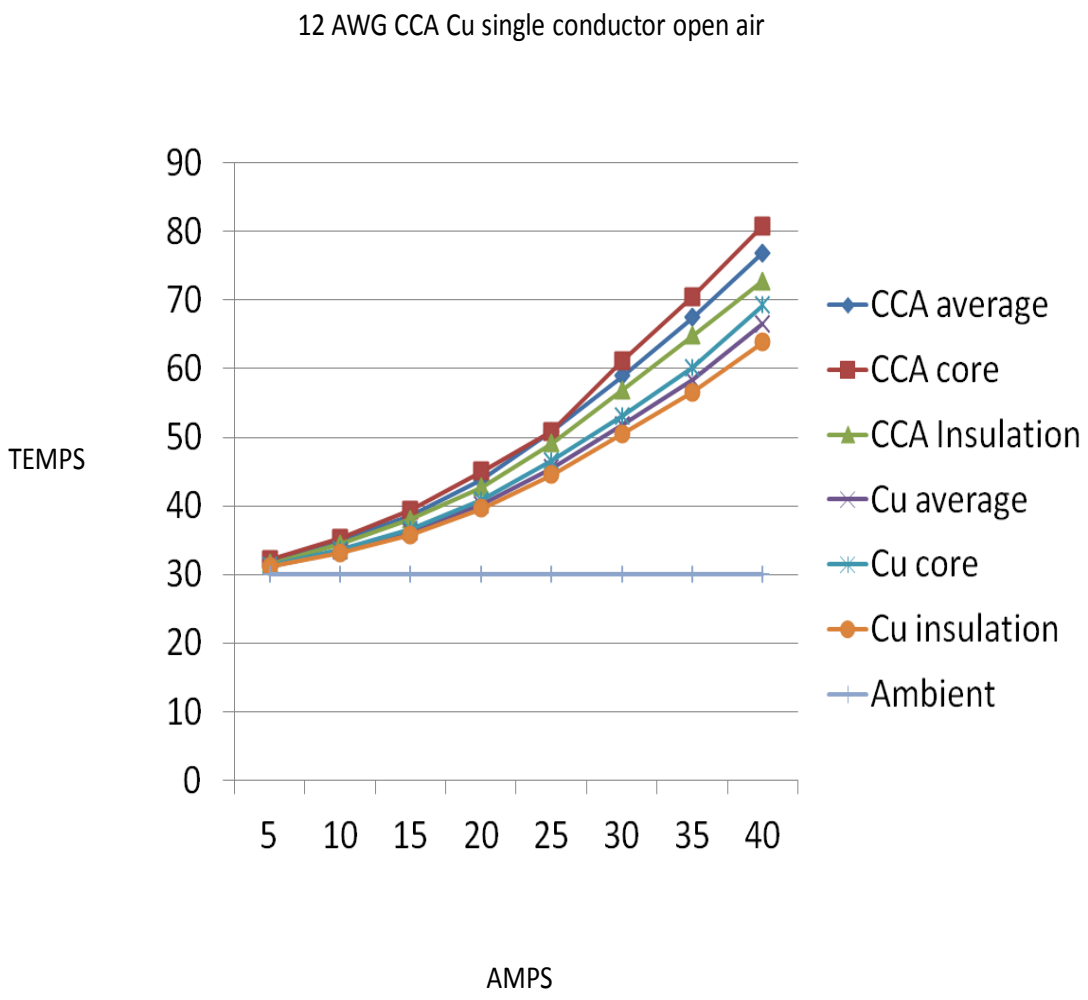

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Test Set- Up/ Layout
12 AWG in non-metallic cable (2 Conductor) in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 12 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 12 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 12 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG In (2 conductor) non-metallic cable

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	NM Cable	5	30
12	NM Cable	10	30
12	NM Cable	15	30
12	NM Cable	20	30
12	NM Cable	25	30
12	NM Cable	30	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 1 of 3)

Scan	Time	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	208 CU-AL Black Cable#2 Core	205 CU-AL Black Cable#2 Insulation
	5 AMPS					
30	**8/17/2017 10:29**	**22.67**	**22.926**	**23.13**	**23.256**	**23.015**
	Corrected Ambient	31.08	31.335	31.539	31.665	31.424
	Average	31.68				
	Average Core	31.73				
	Average Insulation	31.63				
	10 AMPS					
61	8/17/2017 11:00	25.93	26.059	26.92	26.863	26.217
	Corrected Ambient	34.32	34.443	35.304	35.247	34.601
	Average	34.88				
	Average Core	35.09				
	Average Insulation	34.68				
	15 AMPS					
91	8/17/2017 11:30	30.31	30.408	32.809	32.228	31.062
	Corrected Ambient	38.40	38.497	40.898	40.317	39.151
	Average	39.36				
	Average Core	39.90				
	Average Insulation	38.87				
	20 AMPS					
121	8/17/2017 12:00	35.95	36.03	40.071	39.839	36.86
	Corrected Ambient	44.35	44.426	48.467	48.235	45.256

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	Average	45.56				
	Average core	46.67				
	Average Insulation	44.54				
	25 AMPS					
152	8/17/2017 12:31	41.34	41.083	45.352	45.612	42.454
	Corrected Ambient	49.85	49.598	53.867	54.127	50.969
	Average	51.67				
	Average Core	53.50				
	Average Insulation	50.00				
	30 AMPS					
182	8/17/2017 13:01	47.44	47.015	53.341	52.596	50.518
	Corrected Ambient	55.74	55.316	61.642	60.897	58.819
	Average	59.54				
	Average Core	62.19				
	Average Insulation	57.11				

12 AWG CCA In non-metallic cable(2 conductor)
(Page 2 of 3)

211 CU-AL White Cable# 2 Insulation	102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #3 Insulation
23.196	**23.139**	**23.493**	**23.536**
31.605	31.548	31.902	31.945
26.208	26.16	26.433	26.599
34.592	34.544	34.817	34.983

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30.375	30.414	30.425	31.929
38.464	38.503	38.514	40.018
35.556	35.329	35.55	36.683
43.952	43.725	43.946	45.079
41.089	40.342	41.332	41.256
49.604	48.857	49.847	49.771
48.436	46.618	48.28	47.403
56.737	54.919	56.581	55.704

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 3of 3)

116 CU-AL Black Cable#4 Insulation	113 CU-AL White Cable #4 Core	114 CU-AL White Cable#4 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#5 Insulation
23.222	**23.2**	**23.399**	**23.443**	**23.14**
31.631	31.609	31.808	31.852	31.549
25.734	26.056	26.523	26.702	25.713
34.118	34.44	34.907	35.086	34.097
28.997	31.638	30.56	30.878	29.977
37.086	39.727	38.649	38.967	38.066
33.062	37.403	35.681	36.471	35.027
41.458	45.799	44.077	44.867	43.423

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37.425	44.796	40.903	42.529	40.103
45.94	53.311	49.418	51.044	48.618
43.655	55.384	48.43	51.204	48.229
51.956	63.685	56.731	59.505	56.53

12 AWG Cu In non-metallic cable(2 Conductor)
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30	**8/17/2017 10:29**	**22.614**	**22.554**	**22.891**	**22.59**	**22.796**	**22.882**
	Corrected Ambient	31.023	30.963	31.3	30.999	31.205	31.291
	Average	31.22208					
	Average Core	31.295					
	Average Insulation	31.14917					
	10 AMPS						
61	8/17/2017 11:00	25.114	24.271	25.231	24.387	24.977	24.9
	Corrected Ambient	33.498	32.655	33.615	32.771	33.361	33.284
	Average	33.271					

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	Average Core	33.58917					
	Average Insulation	32.95283					
	15 AMPS						
91	8/17/2017 11:30	28.333	27.255	28.517	27.065	28.032	28.006
	Corrected Ambient	36.422	35.344	36.606	35.154	36.121	36.095
	Average	36.00508					
	Average Core	36.45233					
	Average Insulation	35.55783					
	20 AMPS						
121	8/17/2017 12:00	32.461	30.737	32.806	30.378	32.047	31.754
	Corrected Ambient	40.857	39.133	41.202	38.774	40.443	40.15
	Average	40.02075					
	Average core	40.70133					
	Average Insulation	39.34017					
	25 AMPS						
152	8/17/2017 12:31	37.317	35.362	38.138	34.253	36.101	35.718
	Corrected Ambient	45.832	43.877	46.653	42.768	44.616	44.233
	Average	44.385					
	Average Core	45.3695					
	Average Insulation	43.4005					
	30 AMPS						
182	8/17/2017 13:01	43.719	41.111	44.969	39.04	42.173	41.491
	Corrected Ambient	52.02	49.412	53.27	47.341	50.474	49.792
	Average	49.96617					
	Average Core	51.36633					
	Average Insulation	48.566					

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 2 of 2)

305 CU White Cable#3 Insulation	309 CU Black Cable#2 Core	310 CU Black Cable#2 Insulation	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.726	**23.1**	**22.833**	**22.872**	**22.856**
31.135	31.509	31.242	31.281	31.265
24.487	25.693	24.642	24.877	24.726
32.871	34.077	33.026	33.261	33.11
27.237	29.01	27.541	27.932	27.709
35.326	37.099	35.63	36.021	35.798
30.746	33.217	31.041	31.343	31.009
39.142	41.613	39.437	39.739	39.405

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34.482	37.831	34.853	35.499	34.645
42.997	46.346	43.368	44.014	43.16
39.792	44.397	39.901	41.125	40.255
48.093	52.698	48.202	49.426	48.556

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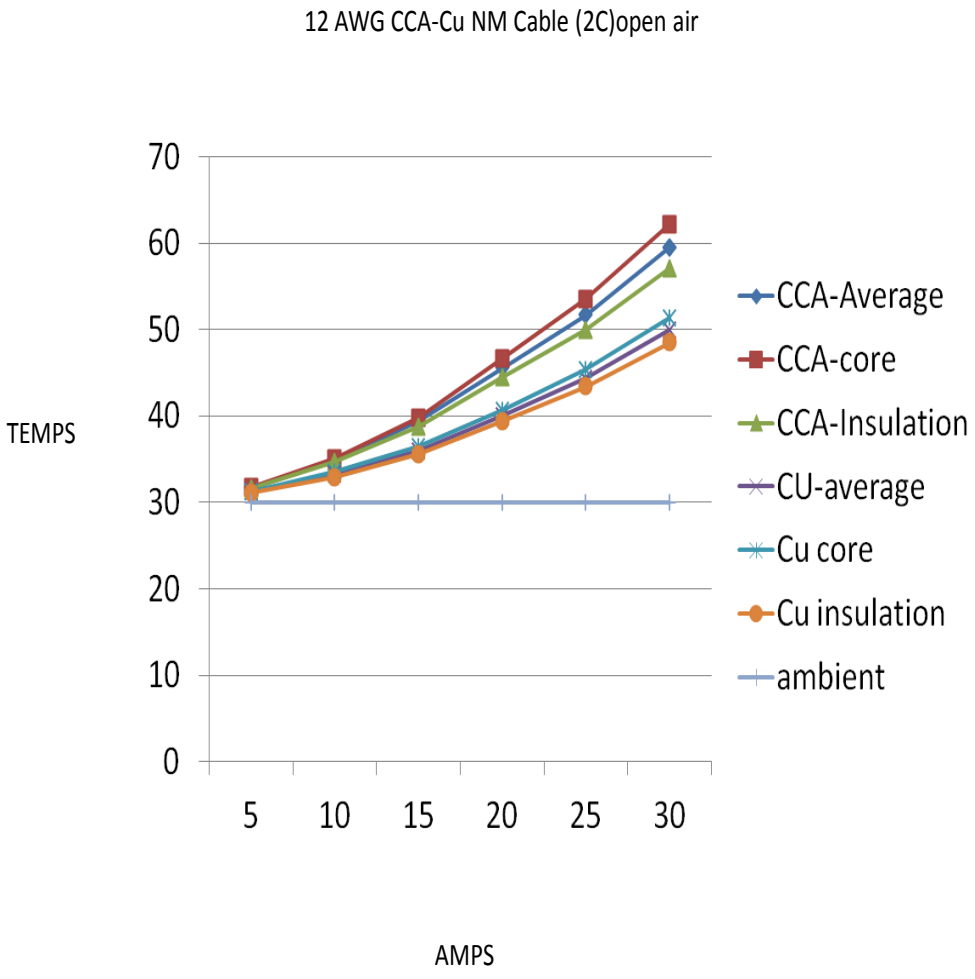

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Test Set- Up/ Layout
12 AWG in Conduit (2 conductors)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 12 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 12 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 12 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG In conduit (2 conductors)

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	Conduit	5	30
12	Conduit	10	30
12	Conduit	15	30
12	Conduit	20	30
12	Conduit	25	30
12	Conduit	30	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG CCA In conduit (2 conductors)
(Page 1 of 3)

Scan	Time	101- CU-AL White Cable-Core	103 CU-AL White Cable Insulation	104 CU-AL Black Cable Core	105 CU-AL Black Cable Insulation	106 CU-AL Black Cable Core	107 CU-AL Black Cable Insulation
	5 AMPS						
34.00	42,963.45	24.80	24.55	24.92	24.52	25.20	24.98
	Corrected Ambient	33.20	32.95	33.32	32.92	33.60	33.38
	Average	32.92					
	Average core	33.12					
	Average Insulation	32.75					
	10 Amps						
66.00	42,963.47	30.79	29.98	30.50	29.05	31.64	30.86
	Corrected Ambient	39.24	38.43	38.95	37.50	40.09	39.30
	Average	38.30					
	Average core	38.54					
	Average Insulation	38.71					
	15 Amps						
98.00	42,963.49	39.83	38.14	39.13	35.99	41.35	39.89
	Corrected Ambient	48.24	46.54	47.54	44.40	49.75	48.30
	Average	46.26					
	Average core	47.36					
	Average Insulation	45.34					
	20 AMPS						
130.00	42,963.51	53.93	51.10	52.57	46.42	56.43	53.62
	Corrected Ambient	62.34	59.51	60.98	54.83	64.84	62.03
	Average	58.48					

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	Average core	60.33					
	Average Insulation	56.95					
	25 AMPS						
162.00	42,963.54	71.01	66.92	68.93	58.87	75.38	70.30
	Corrected Ambient	79.37	75.29	77.29	67.23	83.74	78.66
	Average	73.37					
	Average core	76.31					
	Average Insulation	70.92					
	30 AMPS						
208.00	42,963.57	95.27	88.98	92.19	76.76	102.19	93.33
	Corrected Ambient	103.67	97.37	100.58	85.15	110.58	101.72
	Average	94.77					
	Average core	99.22					
	Average Insulation	91.05					

12 AWG CCA in Conduit (2 Conductors)
Page (2 of 3)

109 CU-AL White Cable Core	112 CU-AL White Cable Insulation	113 CU-AL Black Cable Core	114 CU-AL Black Cable Insulation	116 CU-AL White Cable Insulation	320 CU-AL White Cable Core
25.06	24.79	24.97	24.89	24.38	24.57
33.46	33.19	33.36	33.29	32.78	32.97
30.95	29.96	30.85	30.45	28.75	29.93
39.40	38.41	39.30	38.89	37.19	38.38

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39.93	38.02	39.99	39.25	35.66	38.12
48.34	46.43	48.40	47.65	44.07	46.53
53.56	50.15	53.76	52.46	45.78	50.35
61.97	58.57	62.17	60.87	54.19	58.76
70.65	65.52	71.23	69.04	58.58	65.18
79.02	73.88	79.59	77.40	66.95	73.54
94.77	86.67	95.96	92.55	76.17	86.50
103.16	95.06	104.35	100.95	84.56	94.89

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12 AWG CCA in Conduit (2 Conductors)
(Page 3 of 3)

315 CU-AL Black Cable Core	118 CU-AL Black Cable Insulation	102 CU-AL White Cable Insulation	110 CU-AL White Cable Core	211 CU-AL Black Cable Insulation	205CU-AL White Cable Insulation
24.41	24.04	24.69	25.09	24.46	24.15
32.81	32.44	33.08	33.49	32.86	32.55
29.90	27.86	30.58	31.01	30.08	29.09
38.35	36.31	39.03	39.46	38.52	37.54
38.26	34.03	39.40	40.19	38.41	36.46
46.67	42.44	47.80	48.60	46.82	44.87
50.81	45.67	52.82	53.77	51.24	47.67
59.23	54.08	61.23	62.19	59.65	56.08

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66.35	55.12	68.87	70.60	68.22	62.30
74.72	63.48	77.23	78.97	76.58	70.66
88.26	70.54	92.61	94.54	93.37	83.09
96.65	78.93	101.00	102.93	101.76	91.48

12 AWG Cu In conduit (2 Conductors)
(Page 1 of 2)

Scan	Time	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core	302 CU Black Cable#3 Insulation
	5 AMPS						
34.00	42,963.45	23.58	23.40	23.92	23.37	23.59	23.54
	Corrected Ambient	31.98	31.79	32.32	31.77	31.99	31.93
	Average	32.04					
	Average core	32.16					
	Average Insulation	31.92					
	10 Amps						
66.00	42,963.47	27.28	26.39	28.16	26.32	27.09	25.98
	Corrected Ambient	35.73	34.84	36.61	34.77	35.54	34.43
	Average	35.49					
	Average core	35.99					
	Average Insulation	34.99					
	15 Amps						

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98.00	42,963.49	32.59	30.64	34.57	30.92	32.40	30.16
	Corrected Ambient	40.99	39.05	42.98	39.32	40.81	38.57
	Average	40.68					
	Average core	41.67					
	Average Insulation	39.68					
	20 AMPS						
130.00	42,963.51	41.24	37.72	44.71	38.16	40.68	36.33
	Corrected Ambient	49.66	46.14	53.12	46.58	49.10	44.74
	Average	48.81					
	Average core	50.65					
	Average Insulation	46.96					
	25 AMPS						
162.00	42,963.54	52.09	46.85	57.21	46.77	50.75	44.10
	Corrected Ambient	60.45	55.21	65.57	55.14	59.11	52.46
	Average	58.67					
	Average core	61.52					
	Average Insulation	55.81					
	30 AMPS						
208.00	42,963.57	67.48	59.62	74.44	58.61	64.15	54.26
	Corrected Ambient	75.87	68.01	82.83	67.01	72.54	62.65
	Average	72.19					
	Average core	76.53					
	Average Insulation	67.86					

12 AWG Cu In conduit (2 Conductors)
(Page 2 of 2)

304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
23.91	23.65	23.81	23.67	23.76	23.55

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32.30	32.04	32.20	32.07	32.15	31.94
27.70	26.94	27.55	27.04	27.49	26.59
36.15	35.39	36.00	35.48	35.94	35.04
33.58	32.18	33.20	32.27	33.25	31.45
41.99	40.59	41.60	40.68	41.66	39.85
42.62	40.10	42.09	40.23	42.11	38.73
51.03	48.52	50.50	48.65	50.53	47.14
53.25	49.79	52.80	49.90	52.88	47.31
61.61	58.15	61.16	58.26	61.24	55.67
67.84	62.54	67.31	62.93	67.59	58.86
76.24	70.93	75.70	71.33	75.98	67.25

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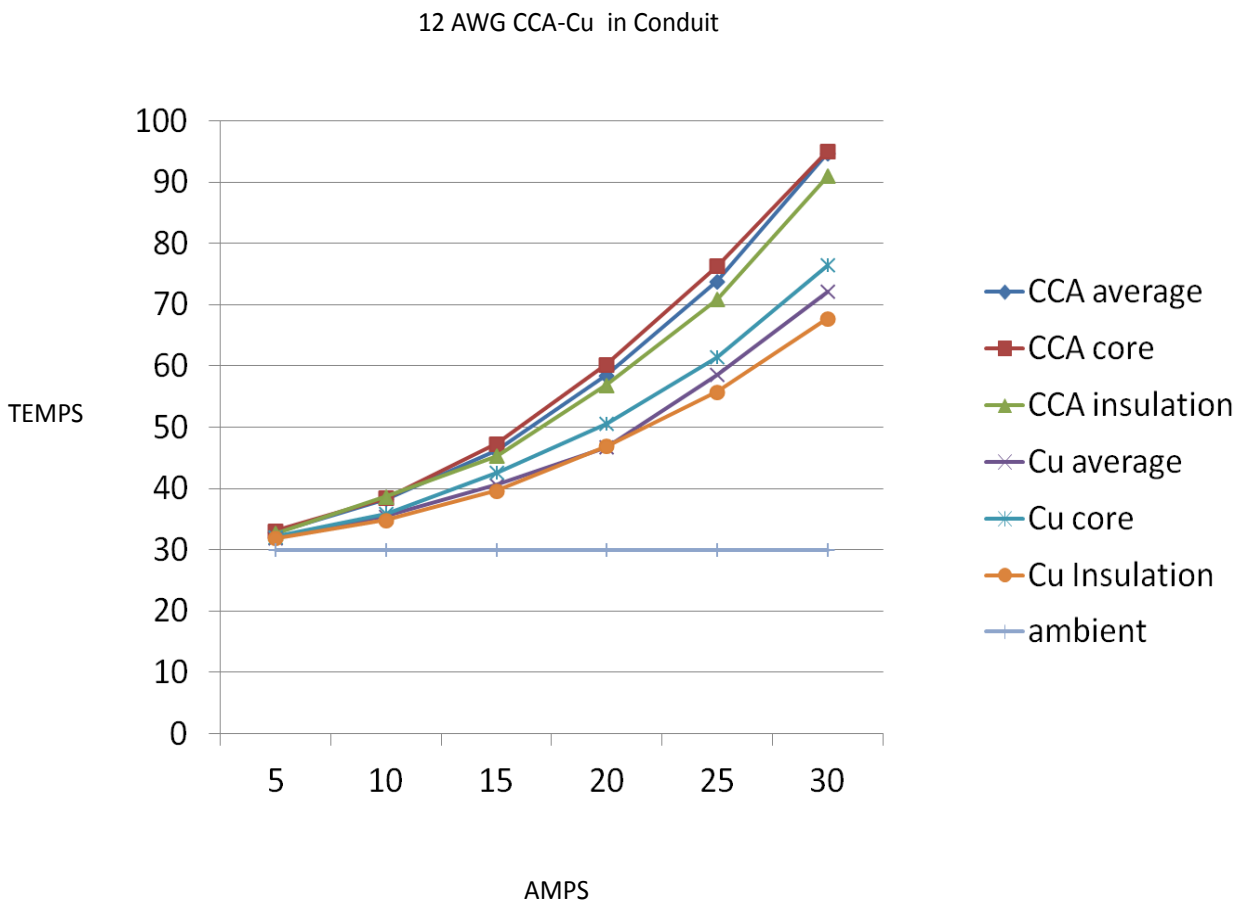

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Test Set- Up/ Layout
10 AWG single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 10 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 10 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 10 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG Single conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	Open air	5	30
10	Open air	10	30
10	Open air	15	30
10	Open air	20	30
10	Open air	25	30
10	Open air	30	30
10	Open air	35	30
10	Open air	40	30
10	Open air	45	30
10	Open air	50	30
10	Open air	55	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA Single conductor Open Air
(Page 1 of 3)

Scan	Time	Elapsed	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	208 CU-AL Black Cable#1 Core	205 CU-AL Black Cable#2 Insulation	120 CU-AL White Cable#2 Core	211 CU-AL White Cable#2 Insulation
	5 AMPS							
30.00	42965.59	00:00:28:59	22.27	22.95	22.82	22.50	23.18	22.75
	Corrected Ambient		30.81	31.49	31.36	31.04	31.72	31.28
	Average		31.47					
	Average core		31.47					
	Average Insulation		31.47					
	10 AMPS							
60.00	42965.62	00:00:58:59	24.20	25.01	24.70	24.41	25.11	24.60
	Corrected Ambient		32.71	33.52	33.20	32.91	33.61	33.10
	Average		33.30					
	Average core		33.34					
	Average Insulation		33.25					
	15 AMPS							
94.00	42965.64	00:01:32:59	27.20	28.61	27.87	27.26	28.29	27.43
94.00	Corrected Ambient		35.60	37.01	36.27	35.66	36.69	35.83
	Average		36.09					
	Average core		36.22					
	Average Insulation		35.94					
	20 AMPS							
121.00	42965.66	00:01:59:59	30.94	33.08	31.72	30.92	32.64	31.08
	Corrected Ambient		39.39	41.52	40.17	39.36	41.08	39.52
	Average		39.81					
	Average core		40.07					
	Average Insulation		39.52					

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	25 AMPS							
152.00	42965.68	00:02:30:59	35.76	39.24	36.76	34.98	37.75	35.59
	Corrected Ambient		44.20	47.67	45.20	43.41	46.19	44.03
	Average		44.24					
	Average core		44.68					
	Average Insulation		43.78					
	30 AMPS							
182.00	42965.70	00:03:00:59	39.98	43.90	41.39	39.49	42.72	39.71
	Corrected Ambient		48.45	52.37	49.85	47.96	51.19	48.18
	Average		48.75					
	Average core		49.39					
	Average Insulation		48.05					
	36 AMPS							
214.00	42965.72	00:03:32:59	47.04	48.39	48.73	46.42	50.45	46.40
	Corrected Ambient		55.61	56.97	57.30	54.99	59.03	54.97
	Average		55.57					
	Average core		56.61					
	Average Insulation		54.48					
	40 AMPS							
243.00	42965.74	00:04:01:59	52.41	53.30	54.36	51.59	56.81	51.39
	Corrected Ambient		60.70	61.59	62.65	59.88	65.10	59.68
	Average		60.64					
	Average core		62.02					
	Average Insulation		59.17					
	45 AMPS							
273.00	42965.76	00:04:31:59	59.93	60.57	61.45	59.16	64.82	58.73
	Corrected Ambient		68.43	69.07	69.94	67.66	73.32	67.23
	Average		68.02					
	Average core		69.86					

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	Average Insulation		66.10					
	50 AMPS							
304.00	42965.78	00:05:02:59	68.58	66.89	70.98	67.58	75.68	67.24
	Corrected Ambient		76.79	75.10	79.19	75.80	83.89	75.45
	Average		76.51					
	Average core		78.99					
	Average Insulation		73.93					
	55 AMPS							
334.00	42965.81	00:05:32:59	77.66	75.32	80.26	77.00	85.13	75.41
	Corrected Ambient		86.08	83.74	88.68	85.42	93.54	83.83
	Average		85.54					
	Average core		88.62					
	Average Insulation		82.30					

10 AWG CCA Single conductor Open Air
(Page 2 of 3)

102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #3 Insulation	315 CU-AL White Cable#4 Core	320 CU-AL Black Cable#4 Core	116 CU-AL Black Cable#4 Insulation
22.98	23.06	23.06	22.84	23.14	23.11
31.51	31.60	31.60	31.37	31.67	31.64
24.95	24.87	24.76	24.78	25.11	24.95

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33.46	33.37	33.27	33.29	33.61	33.46
27.94	27.66	27.49	28.04	28.49	27.92
36.34	36.06	35.89	36.45	36.89	36.32
31.97	31.21	31.04	32.09	32.60	31.53
40.41	39.65	39.48	40.54	41.04	39.98
36.86	35.52	34.62	36.88	37.56	35.94
45.30	43.96	43.05	45.32	46.00	44.38
41.65	40.19	38.87	41.54	42.71	40.19
50.12	48.66	47.34	50.00	51.18	48.66
49.26	47.09	45.20	48.99	50.60	47.06
57.83	55.66	53.78	57.57	59.17	55.63

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55.51	52.71	50.13	54.95	56.69	52.01
63.79	60.99	58.42	63.24	64.98	60.29
63.32	59.97	55.29	63.12	65.06	58.74
71.81	68.47	63.79	71.61	73.55	67.23
74.74	68.93	64.75	72.42	74.12	66.84
82.95	77.14	72.96	80.63	82.34	75.05
84.59	77.87	73.40	82.41	84.78	75.05
93.00	86.29	81.82	90.83	93.19	83.47

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10 AWG CCA Single conductor Open Air
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113 CU-AL White Cable #5 Core	114 CU-AL White Cable#5 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#6 Insulation	107 CU-AL White Cable#6 Insulation	106 CU-AL White Cable#6 Core
23.07	22.99	23.03	23.10	22.96	23.24
31.60	31.52	31.57	31.64	31.49	31.78
24.79	24.58	24.88	24.94	24.88	25.30
33.30	33.08	33.38	33.45	33.38	33.80
27.39	27.03	27.64	27.62	27.50	28.42
35.79	35.43	36.04	36.03	35.90	36.82
30.90	30.18	31.18	31.06	30.77	32.25
39.34	38.62	39.62	39.51	39.22	40.70

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34.92	33.57	35.29	35.22	34.83	37.20
43.36	42.01	43.73	43.65	43.27	45.64
39.04	37.63	40.14	39.22	39.04	42.06
47.51	46.10	48.60	47.69	47.50	50.53
45.69	43.45	46.83	45.74	45.25	49.22
54.26	52.02	55.40	54.32	53.83	57.79
50.91	48.17	52.61	50.82	50.25	55.22
59.19	56.46	60.90	59.10	58.54	63.51
58.10	54.41	60.26	57.35	56.69	63.45
66.59	62.90	68.75	65.85	65.18	71.95

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66.27	61.46	69.66	65.42	64.96	73.26
74.48	69.67	77.87	73.64	73.17	81.47
74.81	69.25	79.65	72.63	73.00	82.89
83.23	77.67	88.07	81.04	81.42	91.30

10 AWG Cu Single conductor Open Air
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30.00	42965.59	22.07	22.56	22.62	22.55	22.48	22.67
	Corrected Ambient	30.60	31.10	31.16	31.09	31.01	31.20
	Average	31.02					
	Average core	30.96					
	Average Insulation	31.08					
	10 AMPS						
60.00	42965.62	23.25	23.92	23.69	23.51	23.81	23.90
	Corrected Ambient	31.76	32.42	32.19	32.01	32.31	32.41
	Average	32.23					
	Average core	32.20					

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	Average Insulation	32.27					
	15 AMPS						
94.00	42965.64	25.17	26.29	25.70	25.23	26.09	25.97
94.00	Corrected Ambient	33.57	34.69	34.11	33.63	34.49	34.38
	Average	34.26					
	Average core	34.25					
	Average Insulation	34.28					
	20 AMPS						
121.00	42965.66	27.66	29.10	28.12	27.45	28.84	28.45
	Corrected Ambient	36.11	37.54	36.57	35.90	37.28	36.90
	Average	36.90					
	Average core	36.93					
	Average Insulation	36.86					
	25 AMPS						
152.00	42965.68	30.70	32.92	31.23	30.03	32.55	31.95
	Corrected Ambient	39.14	41.36	39.67	38.47	40.99	40.39
	Average	40.29					
	Average core	40.41					
	Average Insulation	40.18					
	30 AMPS						
182.00	42965.70	33.65	36.60	34.35	32.85	36.08	35.22
	Corrected Ambient	42.12	45.07	42.82	41.32	44.55	43.69
	Average	43.76					
	Average core	43.89					
	Average Insulation	43.63					
	36 AMPS						
214.00	42965.72	38.55	42.08	39.00	36.69	41.07	39.69
	Corrected Ambient	47.12	50.65	47.57	45.26	49.64	48.26
	Average	48.80					
	Average core	49.09					
	Average Insulation	48.51					

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	40 AMPS						
243.00	42965.74	41.71	46.30	42.78	40.04	45.42	43.45
	Corrected Ambient	50.00	54.59	51.07	48.33	53.71	51.74
	Average	52.54					
	Average core	52.83					
	Average Insulation	52.24					
	45 AMPS						
273.00	42965.76	47.71	51.95	47.60	43.96	50.47	48.26
	Corrected Ambient	56.20	60.44	56.09	52.45	58.97	56.75
	Average	58.05					
	Average core	58.61					
	Average Insulation	57.49					
	50 AMPS						
304.00	42965.78	53.84	59.41	54.11	49.30	57.74	54.24
	Corrected Ambient	62.05	67.62	62.32	57.52	65.96	62.45
	Average	64.37					
	Average core	65.11					
	Average Insulation	63.63					
	55 AMPS						
334.00	42965.81	60.19	63.55	59.83	53.97	58.77	58.08
	Corrected Ambient	68.60	71.96	68.24	62.39	67.18	66.50
	Average	69.97					
	Average core	70.96					
	Average Insulation	68.98					

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10 AWG Cu Single conductor Open Air
(Page 2 of 2)

304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Insulation	310 CU Black Cable#2 Core	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.23	22.47	22.49	22.70	22.46	22.50
30.77	31.01	31.03	31.24	30.99	31.04
23.53	23.74	23.77	24.13	23.77	23.74
32.03	32.25	32.28	32.64	32.28	32.24
25.65	25.95	26.07	26.49	25.96	25.75
34.05	34.35	34.47	34.89	34.37	34.16
28.23	28.61	28.70	29.55	28.52	28.20
36.68	37.05	37.14	38.00	36.97	36.64

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31.72	32.05	32.16	33.52	32.13	31.34
40.15	40.49	40.59	41.96	40.57	39.78
35.53	35.86	35.80	37.45	35.48	34.67
44.00	44.33	44.27	45.91	43.95	43.14
40.84	41.40	40.65	43.30	40.35	39.11
49.41	49.97	49.23	51.87	48.92	47.68
44.87	45.96	44.94	48.11	44.39	43.05
53.16	54.25	53.23	56.40	52.68	51.33
51.56	51.64	50.42	53.97	49.37	47.77
60.06	60.14	58.92	62.46	57.87	56.26

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57.88	58.65	56.87	61.91	55.93	54.05
66.10	66.86	65.08	70.12	64.14	62.26
64.75	65.59	62.39	70.14	61.61	59.85
73.17	74.00	70.80	78.55	70.03	68.26

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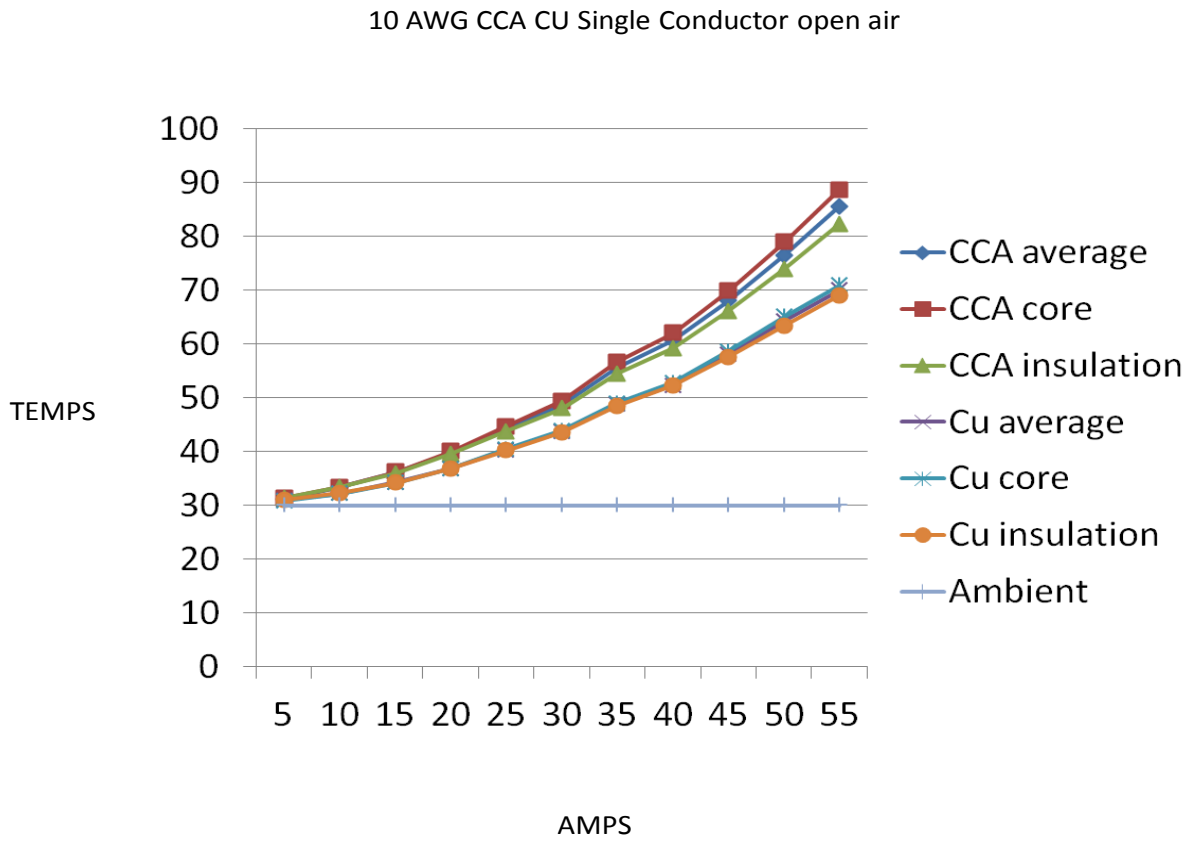

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Test Set- Up/ Layout
10 AWG in non-metallic cable in open air (2 Conductor)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 10 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 10 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 10 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG in Non-Metallic Cable (2 Conductors)

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	NM Cable	5	30
10	NM Cable	10	30
10	NM Cable	15	30
10	NM Cable	20	30
10	NM Cable	25	30
10	NM Cable	30	30
10	NM Cable	35	30
10	NM Cable	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA Non-Metallic Open Air (2 Conductor)

Page 1 of 3

Scan	Time	203 CU-AL White Cable#1-Core	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	208 CU-AL Black Cable#2 Core	120 CU-AL White Cable#2 Core	211 CU-AL White Cable# 2 Insulation
	5 AMPS						
29.00	42965.31	22.56	22.00	22.22	22.70	22.86	22.80
	Corrected Ambient	31.01	30.45	30.67	31.15	31.31	31.25
	Average	31.22					
	Average Core	31.25					
	Average Insulation	31.18					
	10 AMPS						
59.00	42965.34	24.64	24.13	24.46	24.90	25.31	25.33
	Corrected Ambient	33.21	32.70	33.02	33.47	33.88	33.90
	Average	33.48					
	Average Core	33.59					
	Average Insulation	33.34					
	15 AMPS						
90.00	42965.36	27.20	26.74	27.08	27.30	28.47	28.45
	Corrected Ambient	35.98	35.52	35.86	36.09	37.25	37.24
	Average	36.34					
	Average Core	36.53					
	Average Insulation	36.10					
	20 AMPS						
120.00	42965.38	30.31	29.56	30.82	31.04	32.46	31.76
120.00	Corrected Ambient	38.92	38.18	39.43	39.65	41.08	40.38
	Average	39.47					
	Average Core	39.91					
	Average Insulation	38.94					

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	25 AMPS						
151.00	42965.40	34.17	34.26	34.09	33.82	36.82	36.81
	Corrected Ambient	42.70	42.79	42.62	42.35	45.35	45.34
	Average	43.20					
	Average Core	43.67					
	Average Insulation	42.63					
	30 AMPS						
181.00	8/18/2017	40.14	40.25	39.61	39.67	44.07	43.95
	Corrected Ambient	48.87	48.97	48.34	48.40	52.80	52.68
	Average	49.73					
	Average Core	50.27					
	Average Insulation	49.07					
	35 AMPS						
211.00	8/18/2017	45.43	45.21	44.93	45.04	50.87	50.51
	Corrected Ambient	53.94	53.71	53.44	53.55	59.38	59.01
	Average	55.39					
	Average Core	56.18					
	Average Insulation	54.43					
	40 AMPS						
242.00	8/18/2017	50.84	50.96	50.37	51.04	58.24	57.38
	Corrected Ambient	59.52	59.63	59.04	59.71	66.92	66.05
	Average	61.97					
	Average Core	62.84					
	Average Insulation	60.91					

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10 AWG CCA Non-Metallic Open Air (2 Conductor)
(Page 2 of 3)

102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #4 Insulation	315 CU-AL White Cable#3 Core	320 CU-AL Black Cable#4 Core	116 CU-AL Black Cable#4 Insulation
22.96	22.92	22.95	22.83	22.89	22.68
31.41	31.37	31.40	31.29	31.35	31.13
25.39	24.90	25.21	25.08	25.02	24.41
33.96	33.47	33.77	33.65	33.59	32.98
28.53	27.32	28.01	27.79	27.59	26.58
37.31	36.10	36.79	36.58	36.37	35.36
32.18	30.26	31.60	31.28	30.79	29.22
40.80	38.87	40.21	39.89	39.40	37.83

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36.38	33.53	35.13	35.47	34.88	32.40
44.91	42.06	43.65	43.99	43.41	40.93
43.55	39.91	41.12	41.92	41.13	37.92
52.27	48.64	49.85	50.64	49.85	46.65
50.62	45.49	46.83	48.46	47.36	42.93
59.13	53.99	55.34	56.97	55.87	51.43
56.97	51.48	52.58	55.03	54.43	49.04
65.65	60.15	61.26	63.70	63.10	57.71

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10 AWG CCA Non-Metallic Open Air (2 Conductor)
(Page 3 of 3)

114 CU-AL White Cable#6 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#5 Insulation	107 CU-AL White Cable#6 Insulation	106 CU-AL White Cable#5 Core	103 CU-AL Black Cable#6 Core
22.86	23.16	22.83	22.75	23.01	22.61
31.31	31.62	31.28	31.21	31.46	31.06
24.90	25.52	24.59	24.68	25.19	24.49
33.46	34.08	33.16	33.25	33.76	33.06
27.45	28.59	26.81	26.95	27.86	26.80
36.23	37.37	35.59	35.73	36.64	35.58
30.62	32.31	29.51	29.96	31.51	29.93
39.23	40.93	38.12	38.57	40.12	38.54

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34.23	36.96	32.84	33.64	35.02	33.09
42.76	45.49	41.37	42.17	43.55	41.62
40.58	44.15	38.29	40.01	41.40	38.66
49.31	52.87	47.02	48.74	50.13	47.39
46.42	51.15	43.40	45.61	47.21	43.99
54.93	59.66	51.91	54.12	55.71	52.50
53.18	58.34	49.24	52.19	53.82	49.96
61.86	67.01	57.92	60.86	62.49	58.63

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10 AWG Cu in non-metallic cable (2 Conductor) in open air
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
29.00	42965.31	22.35	22.15	22.22	22.08	22.35	22.41
	Corrected Ambient	30.80	30.60	30.67	30.53	30.80	30.86
	Average	30.77					
	Average Core	30.79					
	Average Insulation	30.75					
	10 AMPS						
59.00	42965.34	23.86	23.34	23.35	23.28	23.64	23.74
	Corrected Ambient	32.42	31.91	31.92	31.85	32.21	32.31
	Average	32.18					
	Average Core	32.25					
	Average Insulation	32.12					
	15 AMPS						
90.00	42965.36	25.78	24.85	24.84	24.85	25.28	25.45
	Corrected Ambient	34.56	33.63	33.62	33.64	34.06	34.23
	Average	34.05					
	Average Core	34.14					
	Average Insulation	33.97					
	20 AMPS						
120.00	42965.38	28.46	26.70	26.84	26.63	27.38	27.39
120.00	Corrected Ambient	37.07	35.32	35.45	35.24	35.99	36.01
	Average	35.93					
	Average Core	36.20					
	Average Insulation	35.65					

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	25 AMPS						
151.00	42965.40	31.70	29.22	29.24	29.04	30.00	29.99
	Corrected Ambient	40.23	37.75	37.77	37.57	38.53	38.52
	Average	38.40					
	Average Core	38.78					
	Average Insulation	38.03					
	30 AMPS						
181.00	8/18/2017	36.74	33.05	33.55	33.39	33.88	34.40
	Corrected Ambient	45.47	41.78	42.28	42.12	42.61	43.13
	Average	42.80					
	Average Core	43.21					
	Average Insulation	42.39					
	35 AMPS						
211.00	8/18/2017	41.63	36.87	37.11	36.85	37.80	38.22
	Corrected Ambient	50.14	45.37	45.61	45.36	46.30	46.73
	Average	46.58					
	Average Core	47.13					
	Average Insulation	46.03					
	40 AMPS						
242.00	8/18/2017	47.11	41.04	41.32	40.92	42.28	42.42
	Corrected Ambient	55.78	49.71	50.00	49.59	50.96	51.10
	Average	51.05					
	Average Core	51.88					
	Average Insulation	50.21					

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10 AWG Cu in non-metallic cable (2 Conductor) in open air

Page 2 of 2

304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Core	310 CU Black Cable#2 Insulation	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.46	22.17	22.34	22.44	22.34	22.52
30.91	30.62	30.79	30.89	30.80	30.97
23.89	23.29	23.74	23.72	23.64	23.93
32.46	31.86	32.31	32.28	32.20	32.50
25.78	24.68	25.27	25.47	25.21	25.82
34.56	33.46	34.05	34.25	33.99	34.60
27.95	26.31	27.57	27.28	27.34	27.92
36.56	34.92	36.18	35.89	35.95	36.54

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30.76	28.50	30.31	29.75	29.47	30.49
39.29	37.03	38.84	38.28	38.00	39.02
35.55	32.13	34.15	34.05	33.00	34.97
44.28	40.86	42.88	42.77	41.73	43.70
40.14	35.60	38.38	38.05	36.70	39.58
48.65	44.11	46.89	46.56	45.21	48.08
44.88	38.92	43.18	42.00	40.48	43.95
53.55	47.60	51.85	50.67	49.16	52.62

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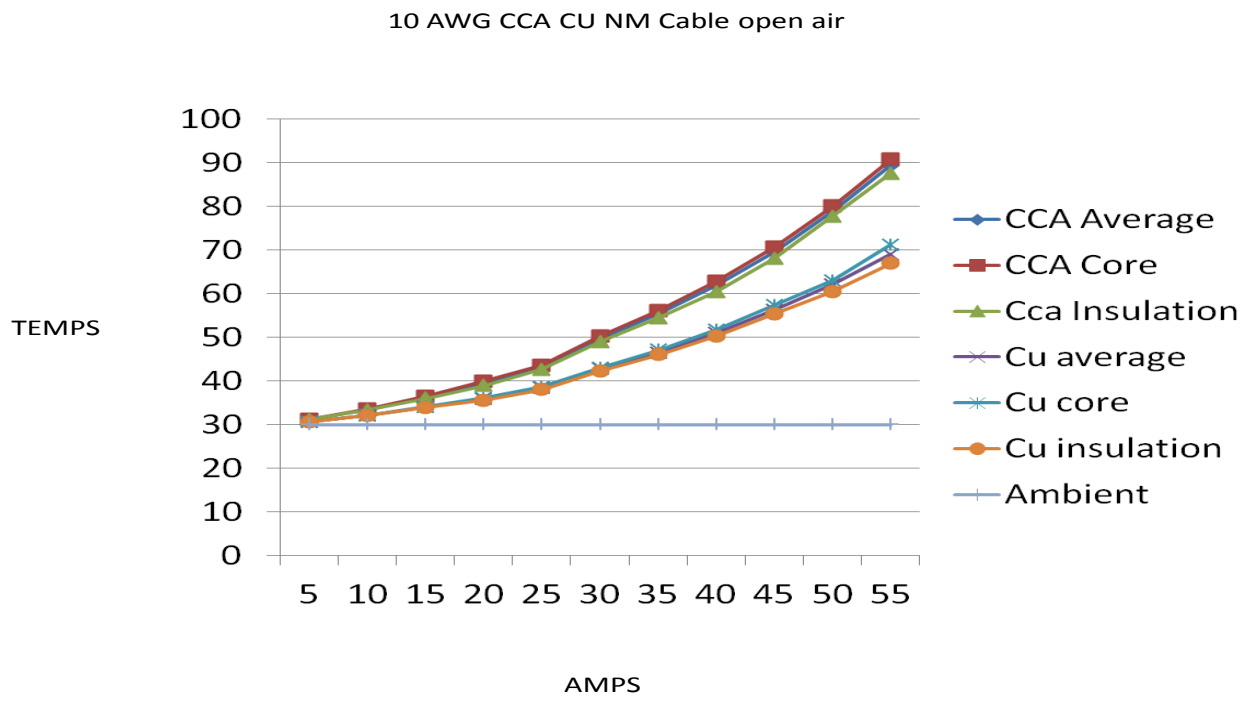

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Test Set- Up/ Layout
10 AWG in Conduit (2 Conductor)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 10 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 10 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 10 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG Conduit

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	Conduit	5	30
10	Conduit	10	30
10	Conduit	15	30
10	Conduit	20	30
10	Conduit	25	30
10	Conduit	30	30
10	Conduit	35	30
10	Conduit	40	30

Equilibrium: With reference to the test, test was continued until constant temperatures were attained. Thermal equilibrium is considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicate no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA in Conduit (2 Conductor)

(Page 1 of 3)

Scan	Time	203 CU-AL White Cable#1-Core	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	205 CU-AL Black Cable#2 Insulation	120 CU-AL White Cable#2 Core
	5 AMPS						
30.00	42966.40	23.32	22.63	22.90	23.15	23.26	23.40
	Corrected Ambient	31.77	31.08	31.35	31.59	31.70	31.85
	Average	31.85					
	Average core	31.89					
	Average insulation	31.80					
	10 AMPS						
64.00	42966.42	26.59	25.43	26.27	25.92	26.52	26.56
	Corrected Ambient	34.93	33.76	34.60	34.25	34.85	34.90
	Average	34.75					
	Average core	34.84					
	Average insulation	34.66					
	15 AMPS						
95.00	42966.44	31.92	29.65	31.74	30.41	31.65	31.89
	Corrected Ambient	40.23	37.96	40.05	38.72	39.97	40.21
	Average	39.72					
	Average core	39.93					
	Average insulation	39.49					
	20 AMPS						
132.00	42966.47	38.70	35.07	38.69	36.15	38.16	38.61
	Corrected Ambient	46.73	43.10	46.72	44.18	46.19	46.64
	Average	45.82					
	Average core	46.15					

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	Average insulation	45.45					
	26 AMPS						
162.00	42966.49	47.38	42.40	47.49	43.29	46.07	46.97
	Corrected Ambient	55.50	50.51	55.61	51.40	54.18	55.09
	Average	53.85					
	Average core	54.35					
	Average insulation	53.30					
	30 AMPS						
192.00	42966.51	57.44	50.50	57.79	51.44	55.09	56.93
	Corrected Ambient	65.41	58.46	65.75	59.40	63.05	64.90
	Average	62.99					
	Average core	63.71					
	Average insulation	62.17					
	35 AMPS						
222.00	42966.53	70.55	60.57	71.31	61.86	66.91	69.78
	Corrected Ambient	78.66	68.68	79.42	69.97	75.02	77.89
	Average	75.21					
	Average core	76.27					
	Average insulation	74.01					
	40 AMPS						
260.00	42966.56	86.35	74.81	87.61	74.53	81.18	86.55
	Corrected Ambient	94.33	82.80	95.59	82.51	89.16	94.53
	Average	89.94					
	Average core	91.36					
	Average insulation	88.34					

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10 AWG CCA in Conduit (2 Conductor)
(Page 2 of 3)

211 CU-AL White Cable# 3 Insulation	102 CU-AL Black Cable#3 Core	320 CU-AL Black Cable#4 Core	113 CU-AL White Cable #4 Core	114 CU-AL White Cable#4 Insulation	109 CU-AL Black Cable#5 Core
23.26	23.49	23.53	23.64	23.57	23.74
31.70	31.94	31.98	32.08	32.01	32.18
26.21	26.62	26.66	26.73	26.46	26.83
34.54	34.96	35.00	35.07	34.80	35.17
30.86	31.75	31.93	32.02	31.42	32.03
39.17	40.06	40.24	40.33	39.73	40.34
36.72	38.39	38.61	38.74	37.61	38.57
44.75	46.42	46.64	46.77	45.64	46.60

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43.72	46.74	46.85	47.03	45.17	46.62
51.83	54.86	54.96	55.14	53.28	54.74
51.86	56.42	56.62	56.89	54.04	56.27
59.83	64.38	64.58	64.86	62.00	64.23
62.45	69.09	69.33	69.71	65.42	68.98
70.56	77.20	77.43	77.81	73.53	77.09
74.86	84.65	84.99	85.42	79.26	84.28
82.84	92.63	92.97	93.40	87.25	92.26

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10 AWG CCA in Conduit (2 Conductor)
(Page 3 of 3)

107 CU-AL White Cable#5 Insulation	103 CU-AL Black Cable#5 Core	101 CU-AL Black Cbale#6 Insulation	104 CU-AL White Cable#6 Core	105 CU-AL White Cable#6 Insulation
23.63	23.30	23.62	23.65	23.71
32.08	31.75	32.07	32.09	32.16
26.63	25.87	26.80	26.40	26.61
8.34	8.34	8.34	8.34	8.34
34.97	34.21	35.14	34.73	34.94
31.70	30.22	32.18	31.08	31.53
8.31	8.31	8.31	8.31	8.31
40.01	38.53	40.49	39.39	39.85
38.35	35.78	39.22	37.02	38.08
8.03	8.03	8.03	8.03	8.03
46.38	43.81	47.25	45.05	46.11

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46.57	42.58	48.00	44.44	46.26
54.68	50.69	56.12	52.55	54.38
56.53	50.33	58.28	53.07	55.91
64.50	58.29	66.24	61.04	63.87
69.86	60.42	71.69	64.34	68.46
77.97	68.52	79.80	72.44	76.57
86.55	72.57	88.22	77.95	83.47
94.53	80.55	96.20	85.93	91.45

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10 AWG Cu in Conduit (2 Conductor)

(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30.00	42966.40	22.82	22.91	22.98	22.94	22.84	23.12
	Corrected Ambient	31.26	31.36	31.43	31.39	31.28	31.57
	Average	31.43					
	Average core	31.41					
	Average insulation	31.46					
	10 AMPS						
64.00	42966.42	24.81	24.98	24.84	24.87	24.60	24.72
	Corrected Ambient	33.14	33.32	33.18	33.21	32.94	33.06
	Average	33.21					
	Average core	33.19					
	Average insulation	33.23					
	15 AMPS						
95.00	42966.44	28.18	28.33	28.05	28.18	27.66	27.71
	Corrected Ambient	36.49	36.64	36.36	36.49	35.97	36.02
	Average	36.47					
	Average core	36.46					
	Average insulation	36.49					
	20 AMPS						
132.00	42966.47	32.50	32.63	32.33	32.54	31.64	31.58
	Corrected Ambient	40.53	40.66	40.36	40.57	39.67	39.61
	Average	40.49					
	Average core	40.48					
	Average insulation	40.50					
	26 AMPS						

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162.00	42966.49	37.65	37.76	37.74	37.82	36.46	36.24
	Corrected Ambient	45.76	45.87	45.85	45.93	44.58	44.35
	Average	45.73					
	Average core	45.75					
	Average insulation	45.72					
	30 AMPS						
192.00	42966.51	43.85	43.86	43.85	44.09	42.10	41.80
	Corrected Ambient	51.81	51.83	51.82	52.05	50.06	49.76
	Average	51.69					
	Average core	51.72					
	Average insulation	51.67					
	35 AMPS						
222.00	42966.53	51.88	51.82	51.54	52.18	49.45	48.85
	Corrected Ambient	59.99	59.93	59.65	60.29	57.56	56.95
	Average	59.66					
	Average core	59.67					
	Average insulation	59.65					
	40 AMPS						
260.00	42966.56	61.89	61.68	59.87	62.27	58.36	57.45
	Corrected Ambient	69.87	69.66	67.86	70.25	66.34	65.43
	Average	69.09					
	Average core	68.99					
	Average insulation	69.19					

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10 AWG Cu in Conduit (2 Conductor)

(Page 2 of 2)

304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Insulation	310 CU Black Cable#2 Core	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
23.07	22.92	23.07	23.03	23.07	23.10
31.52	31.37	31.51	31.48	31.51	31.54
24.81	24.45	25.07	24.82	25.23	25.25
33.15	32.79	33.41	33.16	33.56	33.58
27.97	27.26	28.60	28.02	29.02	28.99
36.28	35.57	36.91	36.33	37.33	37.30
32.12	30.89	33.22	32.16	33.93	33.93
40.15	38.92	41.25	40.19	41.96	41.96

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37.07	35.14	38.79	37.10	39.78	39.86
45.19	43.26	46.90	45.22	47.90	47.98
43.01	40.14	45.40	42.95	46.77	46.95
50.97	48.10	53.36	50.92	54.73	54.92
50.52	46.53	53.82	50.33	55.67	56.04
58.62	54.64	61.93	58.43	63.78	64.14
60.04	54.32	64.29	59.29	66.58	67.26
68.02	62.30	72.28	67.27	74.57	75.24

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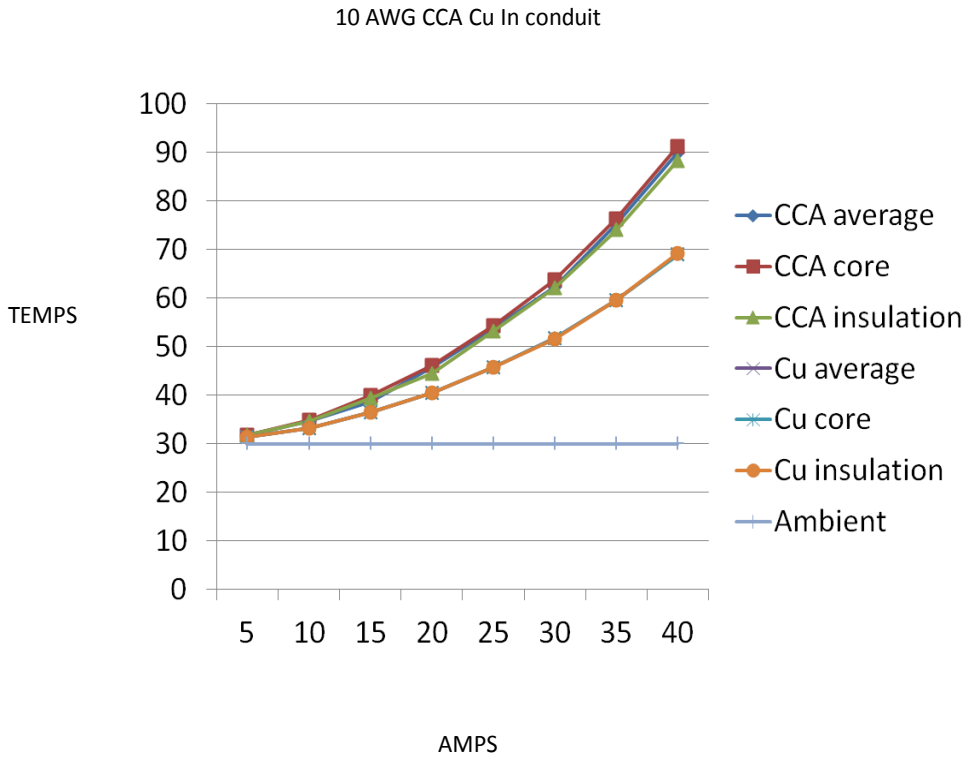

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Summary

14 AWG						
Max Temps	Single conductor@35A		NM cable@25A		Conduit@25A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	89.81	67.08	68.95	53.14	117.69	79.54
Average Core	92.67	67.91	69.61	53.05	124.41	82.77
Average Insulation	86.68	66.25	71.60	53.23	111.52	76.31

12 AWG						
Max Temps	Single conductor@40A		NM cable@30A		Conduit@30A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	76.85605	66.52817	59.54	49.96617	94.77	72.19
Average Core	80.71511	69.18933	62.19	51.36633	99.22	76.53
Average Insulation	72.72958	63.867	57.11	48.566	91.05	67.86

10 AWG						
Max Temps	Single conductor@55		NM cable@40A		Conduit@40 A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	85.54	69.97	61.97	51.05	89.94	69.09
Average Core	88.62	70.96	62.84	51.88	91.36	68.99
Average Insulation	82.30	68.98	60.91	50.21	88.34	69.19

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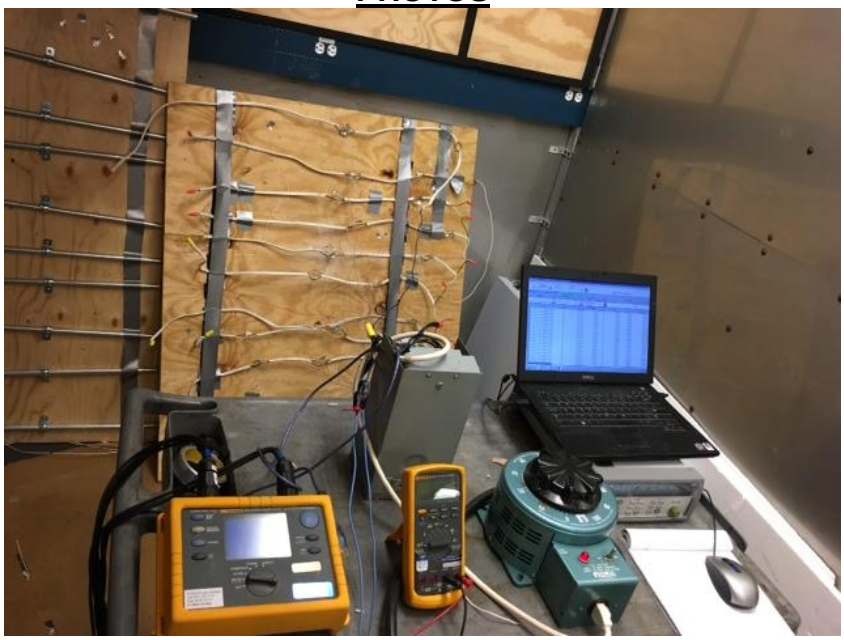
APPENDIX A
PHOTOS



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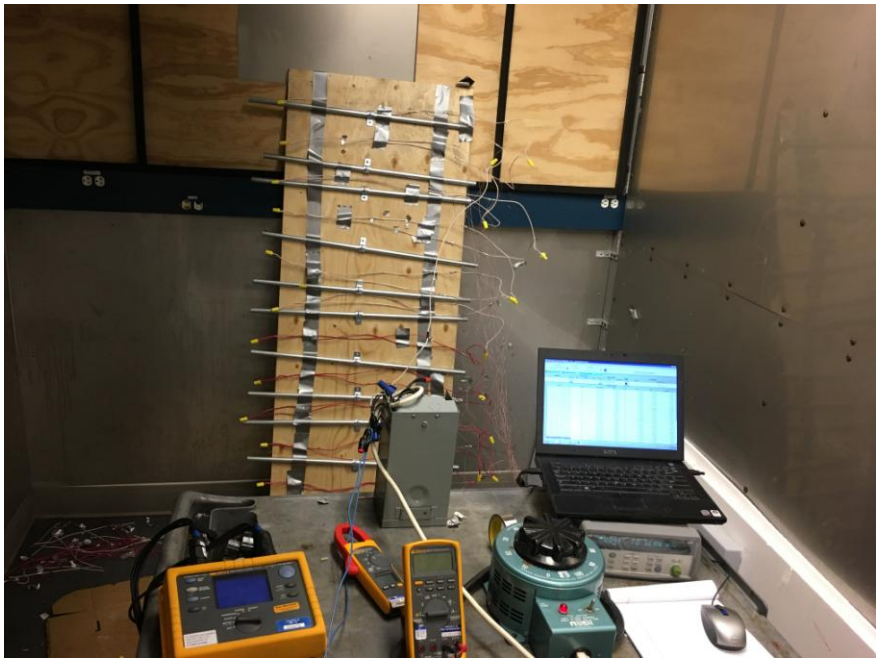

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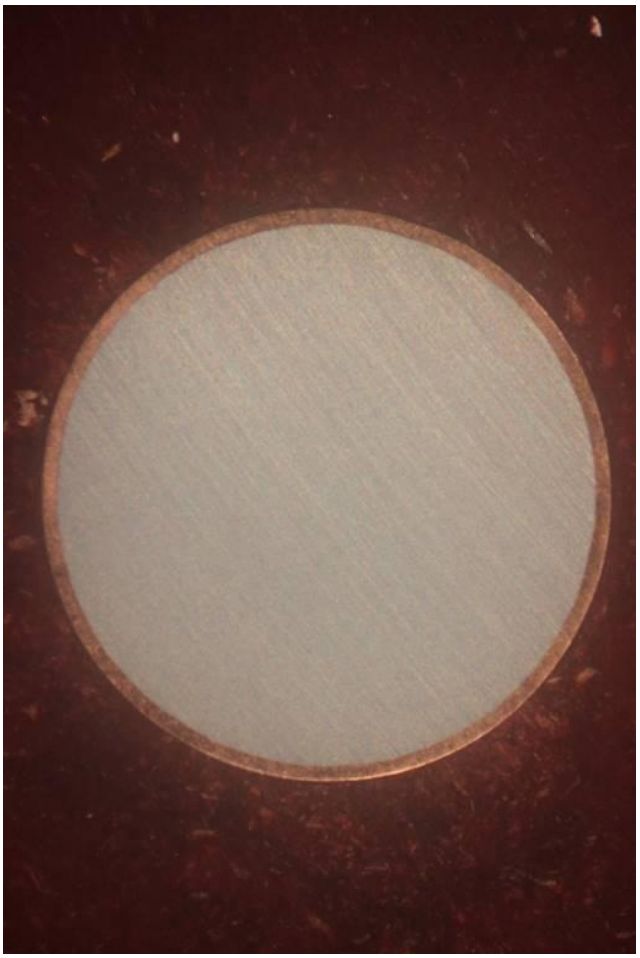

Cross Sectional view of the CCA

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APPENDIX B
EQUIPMENT LIST

Equipment	PL Code	Calibration
Transformer	PL004985	N/A
Agilent Temperature Data Acquisition system	PL005628	N/A
Thermocouples Cartridge, Type J	PL004988 PL003269 PL003268	Calibrated Daily or before each usage.
Simpson Model 06713100 Current shunt	PL002161	See Certificate Below Appendix C
Fluke multi meter, model 87V	PL004935	See Certificate Below Appendix C
Fluke Digital Clamp Meter, model 374FC	PL005812	See Certificate Below Appendix C
Thermocouples	Same as above	Conducted Daily
Power Logger	PL003379	See Certificate Below Appendix C

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APPENDIX C
CALIBRATION

Trescal

Certificate #: *3869120002 e* *W*

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	374FC
Description:	Clamp Meter
Serial Number:	37421743WS
Asset Number:	PL005812
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	05/01/2017
Due Date:	05/01/2018
Temperature:	73.00 **deg. F**
Humidity:	40.00 **%**
Baro. Press.:	
Procedure:	DCN 50442
Reference:	TO 33K1-4-853-1 Rev. 30 Jun 2008
Dept:	

Incoming Remarks:
w/case

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390482	Fluke	5522A	Multifunction Calibrator	11/22/2016	11/22/2017

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Trescal

Certificate #: *3765740001 e* *W*

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	87V
Description:	DMM
Serial Number:	26270081
Asset Number:	PL004935
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	01/31/2017
Due Date:	01/31/2018
Temperature:	74.00 **deg. F**
Humidity:	20.00 **%**
Baro. Press.:	
Procedure:	DCN 07074
Reference:	manufacturer's manual
Dept:	

Incoming Remarks:
w/case/leads/holster

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390169	Fluke	5500A	Multifunction Calibrator	04/26/2016	04/26/2017

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Trescal

Certificate #: *3869120002 e* *W*

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	374FC
Description:	Clamp Meter
Serial Number:	37421743WS
Asset Number:	PL005812
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	05/01/2017
Due Date:	05/01/2018
Temperature:	73.00 deg. F
Humidity:	40.00 %
Baro. Press.:	
Procedure:	DCN 50442
Reference:	TO 33K1-4-853-1 Rev. 30 Jun 2008
Dept:	

Incoming Remarks:
w/case

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390482	Fluke	5522A	Multifunction Calibrator	11/22/2016	11/22/2017

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ACCREDITED
Calibration Cert# 2165.01

FLUKE

Certificate of Calibration

Everett Service Center

Certificate Number:	322693		
Data Type:	As-Left	**Calibration Date:**	27-Feb-2017
Result Summary:	Measurement Results < Limits		
Manufacturer:	Fluke	**Certificate Date:**	28-Feb-2017
Model:	1735	**Temperature:**	23.6 °C
Serial Number:	S090503258B6	**Humidity:**	28.1 %
Description:	Power Quality Logger		
Procedure:	Fluke 1735:(2 year) ACAL VER RS-232/5520	**Revision:**	2.1
Customer:	NSF INTERNATIONAL		
City:	ANN ARBOR	**Country:**	US
State:	MI		
Purchase Order:	CCS CALIBRATION LAB - NSF INTERNATIONAL	**RMA:**	31194022
Asset ID:	PL003379		

This calibration is traceable to the International System of Units (SI), through National Metrology Institutes (NIST, PTB, NRC, NPL, etc.), ratiometric techniques, or natural physical constants. This certificate applies only to the item identified and shall not be reproduced either than in full, without the specific written approval by Fluke Corporation. Calibration certificates without signature are not valid. The calibration has been completed in accordance with Fluke Electronics Corporation Quality System Document 111.0 Revision 11B 8/2014 and/or Fluke 17025 Quality Manual QSD 111.41 Revision 005 8/2014.

The Data Type found in this certificate must be interpreted as:

- As - Found Calibration data collected before the unit is adjusted and / or repaired.
- As - Left Calibration data collected after the unit has been adjusted and / or repaired.
- Found-Left Calibration data collected without any adjustment and / or repair performed.

This calibration conforms to the requirements of ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994 (R2002).

In the attached measurement results, deviation may be expressed with units, Measured Value (MV) - Nominal Value (NV) or as a proportion of the nominal value ((MV-NV)/NV), expressed without units with a scalar multiplier such as % (0.01), or as a ratio of the units (mA/A, µ/V, etc.) Descriptions such as µA/A, µV/V, and others, where used to annotate results or column headings are the preferred replacements for what was historically labeled as "ppm" or parts-per-million and described the results in that column, unless otherwise noted by units symbols.

Where applicable, the expanded uncertainty of measurement at the time of test is given in the following pages. They are calculated in accordance with the method described in the ISO Guide to the Expression of Uncertainty in Measurement (GUM). The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k, such that the confidence level approximates 95%.

This calibration certificate may contain data that is not covered by the A2LA Scope of Accreditation. Unaccredited material, where applicable is indicated by an asterisk (*), or confined to clearly marked sections. Functional (Pass / Fail) tests are not accredited.

No statement of compliance with specifications is made or implied on this certificate. However, measurement results are reviewed, where applicable, to establish where any measurement result exceeded the manufacturer's specifications.

Measurement results greater than limits of error are indicated by '!'.

Accredited FLUKE

Cert # 322693
Cal Date 27-Feb-2017
S/N S090503258B6
www.fluke.com

Cert # 322693
Date 27/2/2017
www.fluke.com

Rolly Sherwood
Calibration Technician

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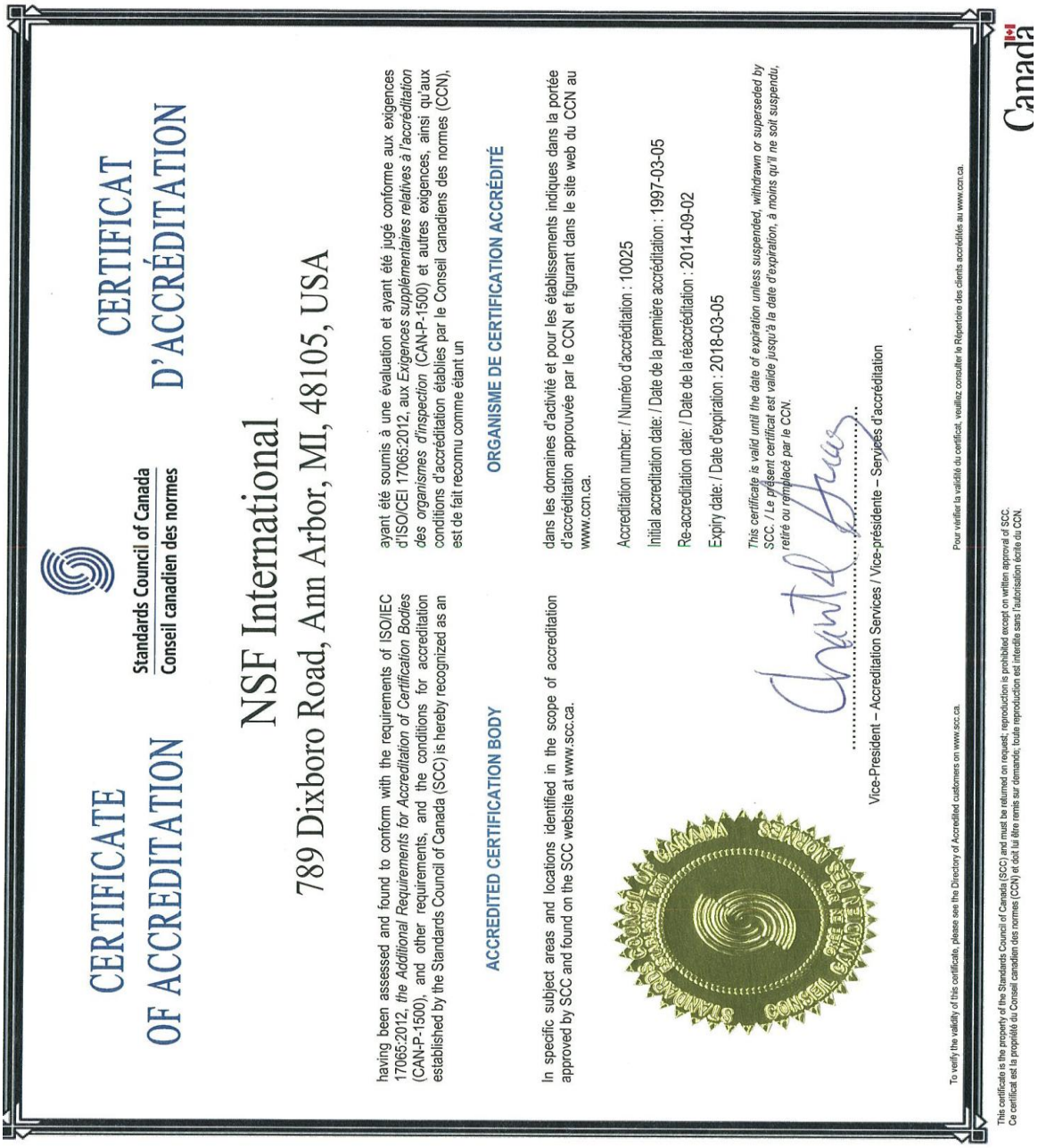
APPENDIX D
LABORATORY CERTIFICATIONS



CERTIFICATE OF ACCREDITATION

Standards Council of Canada
Conseil canadien des normes

CERTIFICAT D'ACCRÉDITATION

NSF International
789 Dixboro Road, Ann Arbor, MI, 48105, USA

having been assessed and found to conform with the requirements of ISO/IEC 17065:2012, *the Additional Requirements for Accreditation of Certification Bodies* (CAN-P-1500), and other requirements, and the conditions for accreditation established by the Standards Council of Canada (SCC) is hereby recognized as an

ayant été soumis à une évaluation et ayant été jugé conforme aux exigences d'ISO/CEI 17065:2012, aux *Exigences supplémentaires relatives à l'accréditation des organismes d'inspection* (CAN-P-1500) et autres exigences, ainsi qu'aux conditions d'accréditation établies par le Conseil canadiens des normes (CCN), est de fait reconnu comme étant un

ACCREDITED CERTIFICATION BODY

ORGANISME DE CERTIFICATION ACCRÉDITÉ

In specific subject areas and locations identified in the scope of accreditation approved by SCC and found on the SCC website at www.scc.ca.

dans les domaines d'activité et pour les établissements indiques dans la portée d'accréditation approuvée par le CCN et figurant dans le site web du CCN au www.ccn.ca.

Accreditation number: / Numéro d'accréditation : 10025

Initial accreditation date: / Date de la première accréditation : 1997-03-05

Re-accreditation date: / Date de la réaccréditation : 2014-09-02

Expiry date: / Date d'expiration : 2018-03-05

This certificate is valid until the date of expiration unless suspended, withdrawn or superseded by SCC. / Le présent certificat est valide jusqu'à la date d'expiration, à moins qu'il ne soit suspendu, retiré ou remplacé par le CCN.

STANDARDS COUNCIL OF CANADA
CONSEIL CANADIEN DES NORMES

Vice-President – Accreditation Services / Vice-présidente – Services d'accréditation

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CERTIFICATE

Certificate Number: 140920.00

The Environmental Management System and implementation of:

NSF International
789 N. Dixboro Road
Ann Arbor, MI 48105
United States

meets the requirements of the standard:

ISO 14001:2015

Scope:
Laboratory testing, product certification, and domestic (U.S.) auditing associated with the facility located at 789 N. Dixboro Road, Ann Arbor, Michigan. NSF-ISR operations are excluded from the scope of registration.

Certificate Expires:	July 04, 2018
Re-issued:	August 08, 2017
Certificate Issued:	July 05, 2015
Certified Since:	July 05, 2006

Dr. Cem O. Onus
Managing Director, Business Assurance
DEKRA Certification, Inc.
1120 Welsh Road, Suite 210
North Wales, PA 19454 USA
(215) 997-4519
dekra-certification.us

ANAB ACCREDITED ISO/IEC 17021 MANAGEMENT SYSTEMS CERTIFICATION BODY

MEMBER OF MULTILATERAL RECOGNITION ARRANGEMENT IAF

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Occupational Safety and Health Administration

Nationally Recognized Testing Laboratory Program

NRTLP

Certificate of Recognition

NSF International

with headquarters at:

789 Dixboro Road
Ann Arbor, Michigan 48105
United States

is recognized by the Occupational Safety and Health Administration (OSHA) as meeting the requirements for a Nationally Recognized Testing Laboratory (NRTL) established under Section 1910.7 of *Title 29, Code of Federal Regulations.* This recognition is limited to testing and certification only within the current scope of recognition and is subject to all other terms set forth in the letter of recognition and in applicable *Federal Register* notices and as summarized on OSHA's website. This recognition continues in force beyond the "*Effective through*" date below provided the NRTL has filed a timely request for renewal with OSHA. For current recognition status and other recognition information, contact the OSHA NRTL Program or visit *https://www.osha.gov/dts/otpca/nrtl/*

July 14, 2019
Effective Through

David Michaels, PhD, MPH
Assistant Secretary of Labor for
Occupational Safety and Health Administration

UNITED STATES OF AMERICA · DEPARTMENT OF LABOR

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Table 310.15(B)(16) (formerly Table 310.16) Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)*

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.104(A).]									Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	COPPER			COPPER-CLAD ALUMINUM			ALUMINUM ~~OR COPPERCLAD ALUMINUM~~			
18**	-	-	14	-	-	-	-	-	-	-
16**	-	-	18	-	-	-	-	-	-	-
14**	15	20	25	10	15	20	-	-	-	-
12**	20	25	30	15	20	25	15	20	25	12**
10**	30	35	40	25	30	35	25	30	35	10**
8	40	50	55	35	40	45	35	40	45	8
6	55	65	75	40	50	55	40	50	55	6
4	70	85	95	55	65	75	55	65	75	4
3	85	100	115	65	75	85	65	75	85	3
2	95	115	130	75	90	100	75	90	100	2
1	110	130	145	85	100	115	85	100	115	1
1/0	125	150	170	100	120	135	100	120	135	1/0
2/0	145	175	195	115	135	150	115	135	150	2/0
3/0	165	200	225	130	155	175	130	155	175	3/0
4/0	195	230	260	150	180	205	150	180	205	4/0
250	215	255	290	170	205	230	170	205	230	250
300	240	285	320	195	230	260	195	230	260	300
350	260	310	350	210	250	280	210	250	280	350
400	280	335	380	225	270	305	225	270	305	400
500	320	380	430	260	310	350	260	310	350	500
600	350	420	475	285	340	385	285	340	385	600
700	385	460	520	315	375	425	315	375	425	700
750	400	475	535	320	385	435	320	385	435	750
800	410	490	555	330	395	445	330	395	445	800
900	435	520	585	355	425	480	355	425	480	900
1000	455	545	615	375	445	500	375	445	500	1000
1250	495	590	665	405	485	545	405	485	545	1250
1500	525	625	705	435	520	585	435	520	585	1500
1750	545	650	735	455	545	615	455	545	615	1750
2000	555	665	750	470	560	630	470	560	630	2000

*Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F). Refer to 310.15(B)(3)(a) for more than three current-carrying conductors.

**Refer to 240.4(D) for conductor overcurrent protection limitations.

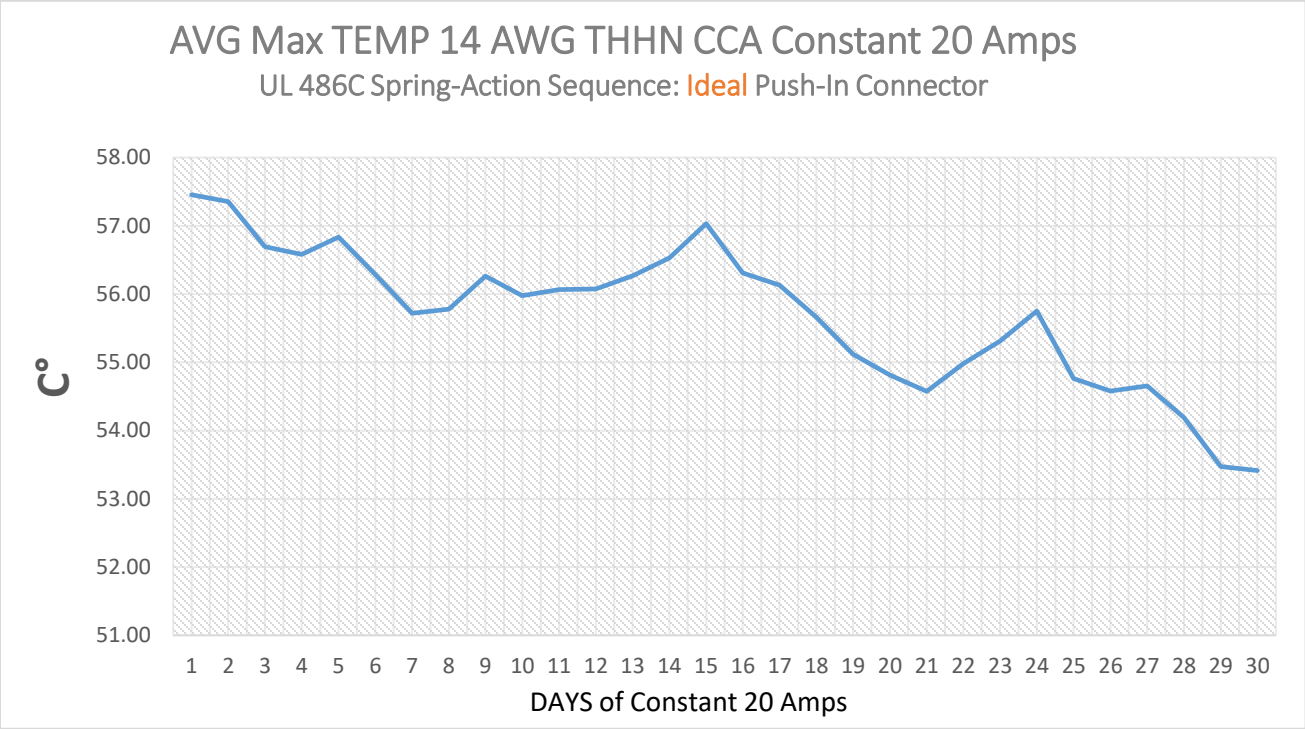
Table 310.15(B)(17) (formerly Table 310.17) Allowable Ampacities of Single-Insulated Conductors Rated Up to and Including2000 Volts in Free Air, Based on Ambient Temperature of 30°C (86°F)*

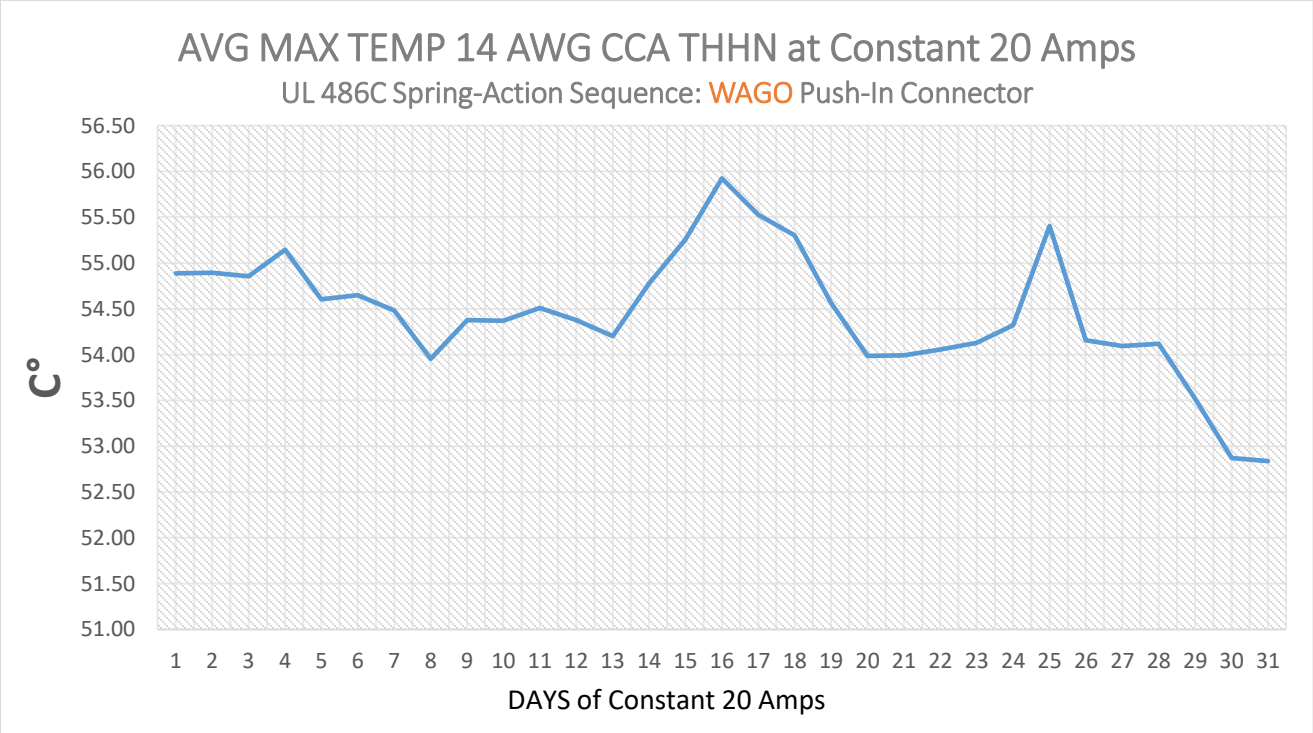
Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.104(A).]									Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW,	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	COPPER			COPPER-CLAD ALUMINUM			ALUMINUM ~~OR COPPERCLAD ALUMINUM~~			
18**	-	-	18	-	-	-	-	-	-	-
16**	-	-	24	-	-	-	-	-	-	-
14**	25	30	35	20	25	30	-	-	-	-
12**	30	35	40	25	35	40	25	30	35	12**
10**	40	50	55	35	40	50	35	40	45	10**
8	60	70	80	45	55	60	45	55	60	8
6	80	95	105	60	75	85	60	75	85	6
4	105	125	140	80	100	115	80	100	115	4
3	120	145	165	95	115	130	95	115	130	3
2	140	170	190	110	135	150	110	135	150	2
1	165	195	220	130	155	175	130	155	175	1
1/0	195	230	260	150	180	205	150	180	205	1/0
2/0	225	265	300	175	210	235	175	210	235	2/0
3/0	260	310	350	200	240	270	200	240	270	3/0
4/0	300	360	405	235	280	315	235	280	315	4/0
250	340	405	455	265	315	355	265	315	355	250
300	375	445	500	290	350	395	290	350	395	300
350	420	505	570	330	395	445	330	395	445	350
400	455	545	615	355	425	480	355	425	480	400
500	515	620	700	405	485	545	405	485	545	500
600	575	690	780	455	545	615	455	545	615	600
700	630	755	850	500	595	670	500	595	670	700
750	655	785	885	515	620	700	515	620	700	750
800	680	815	920	535	645	725	535	645	725	800
900	730	870	980	580	700	790	580	700	790	900
1000	780	935	1055	625	750	845	625	750	845	1000
1250	890	1065	1200	710	855	965	710	855	965	1250
1500	980	1175	1325	795	950	1070	795	950	1070	1500
1750	1070	1280	1445	875	1050	1185	875	1050	1185	1750
2000	1155	1385	1560	960	1150	1295	960	1150	1295	2000

*Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F).
**Refer to 240.4(D) for conductor overcurrent protection limitations.

Performance of
14 AWG CCA THHN Under EXTREME OVERCURRENT CONDITION

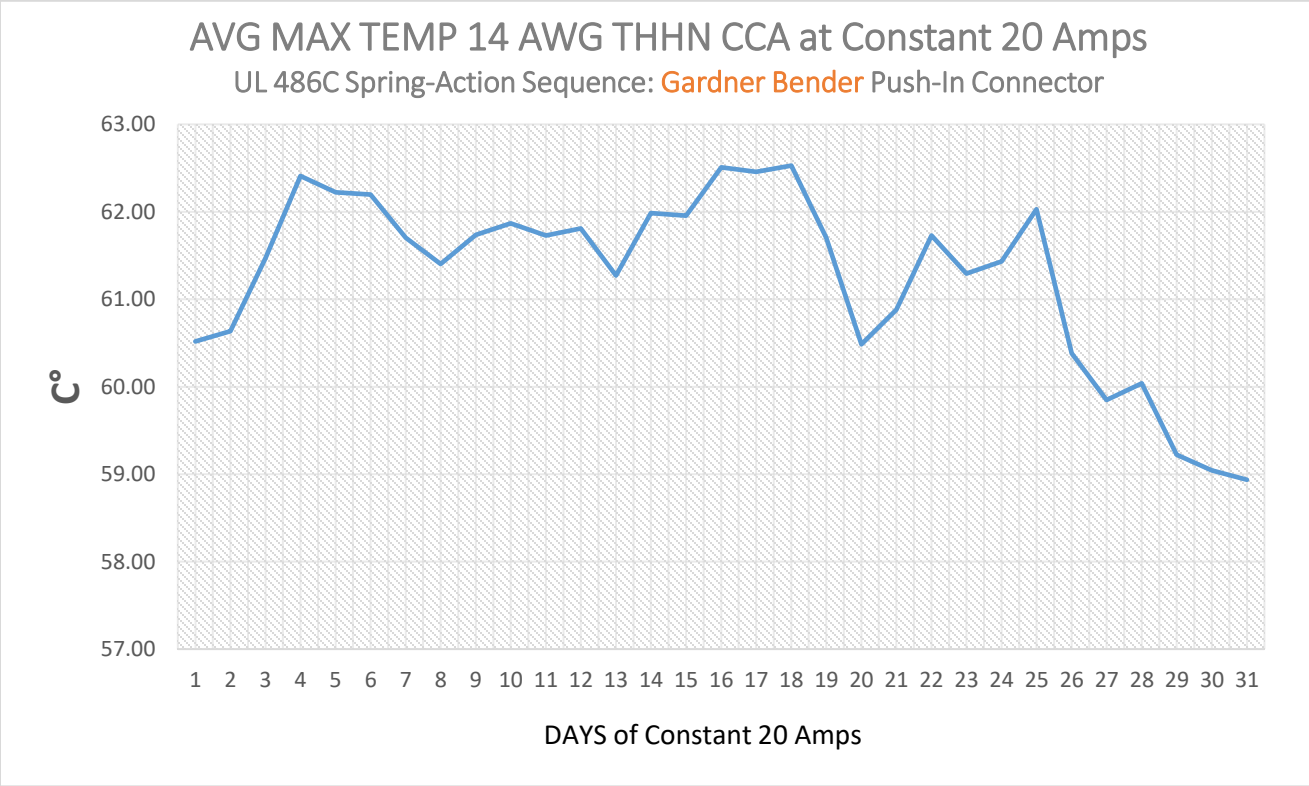
Three Push-In Connectors Tested By Intertek (NRTL with Wire & Cable in Scope of Recognition) to UL 486C Spring-Action Sequence





Performance of
14 AWG CCA THHN Under EXTREME OVERCURRENT CONDITION

Three Push-In Connectors Tested By Intertek (NRTL with Wire & Cable in Scope of Recognition) to UL 486C Spring-Action Sequence



CONCLUSIONS FROM UL 486C SPRING-Action SEQUENCE TESTING REG 14 AWG THHN MADE WITH ASTM B566 COPPER-CLAD ALUMINUM WIRE:

- The THHN Insulation (Rated at 90°C) Remained in Good Condition Throughout the Test
- Over 30 Days at Constant 20 Amps (twice the amperage of the proposed amperage at 60°C column requested by Public Comment 1402), the highest temperature registered by 14 AWG CCA was under 63°C. Over Current Protection Devices (OCPD's) are in place in a circuit to keep wire from over-heating. OCPD's will open the circuit when the amperage limit (10 amps in case of 14 AWG CCA) is reached.
- Ambient Temperature of 23°C Over 30 Days, Standard Deviation of ½ °C
- Average Max Temperatures decreased by 3°C over the month when connected to the three brands of push-in connectors
- The Gardner Bender Connector created more heat (+/- 6°C) within the wire than the other two test subjects
- Of the nine push-in connectors tested (three different brands), not one saw degradation or damage due to excessive heat, despite the constant over-current condition applied to the wire
- The wire remained thermally stable at the points of termination over all nine push-in connectors, and no arc-faulting was observed due to thermal expansion of the wire

3933 Route 11
Cortland, NY 13045
Telephone: 1-607-753-6711
Facsimile: 1-607-758-6595
www.intertek.com

TEST LETTER REPORT

Copperweld Bimetallics, LLC
Test Report

SCOPE OF WORK
PERFORMANCE TESTING – PRODUCT TYPE PER STANDARD

REPORT NUMBER
103589128CRT-001A

ISSUE DATE	**[REVISED DATE]**
27-Aug-2018	28-Aug-2018

PAGES
14

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TEST LETTER REPORT

27-Aug-2018

Intertek Report No.: 103589128CRT-001A
Intertek Project No.: G103589128

Mr. Peter Graser
Copperweld Bimetallics, LLC
215 Centerview Drive
Suite 360
Brentwood, TN 37027

Ph: (770) 952-6445
email: pgraser@copperweld.com

Subject: Static Heating test of Push-in Wire Connectors on CCA Conductors in accordance with Claus 9.12 Spring-action sequence per UL 486C.

Dear Mr. Peter Graser,

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

> **UL 486C / CSA C22.2 No. 188-18 –** Splicing Wire Connectors, Seventh Edition, Dated January 26, 2018

SECTION 1
SUMMARY

This investigation was authorized by signed proposal number Qu-00894894, dated 29-June-2018. A production sample was received on 26-June-2018 and tested from 23-Jul-2018 to 27-Aug-2018 at the Intertek Cortland facility.

TEST LETTER REPORT

SECTION 2
TESTING

Below is a summary of the tests and results for the entire test period. The test data appears at the end of this report in the Appendix.

Performance testing was carried out in accordance with UL486C, Clause 9.12 Spring-action sequence.

Three test circuits were built in the sizes 14AWG, 12AWG, and 10AWG, each circuit containing Copperweld CCA THHN wire and 3 three specimens each of push-in
wire connectors manufactured by Ideal, Wago, and Gardner and Bender, as available. This setup is a deviation from the standard which requires connectors to be tested separately on individual circuits.

Test currents (20A for 14AWG, 30A for 12AWG and 50A for 10AWG) were selected in accordance with client request rather than per Table 6 static heating columns in UL486C, and additional setup criteria indicated in Clause 9.1 of UL486C will not be used. Test currents were monitored periodically with a clamp style meter.

Ambient thermocouples were placed at least two feet out from the connectors under test, and approximately 3 feet apart, the number of ambient thermocouples is reduced due to the size of the apparatus.

Connector thermocouples are placed on the input and output side of each connector with a reference conductor between each set of three connectors.

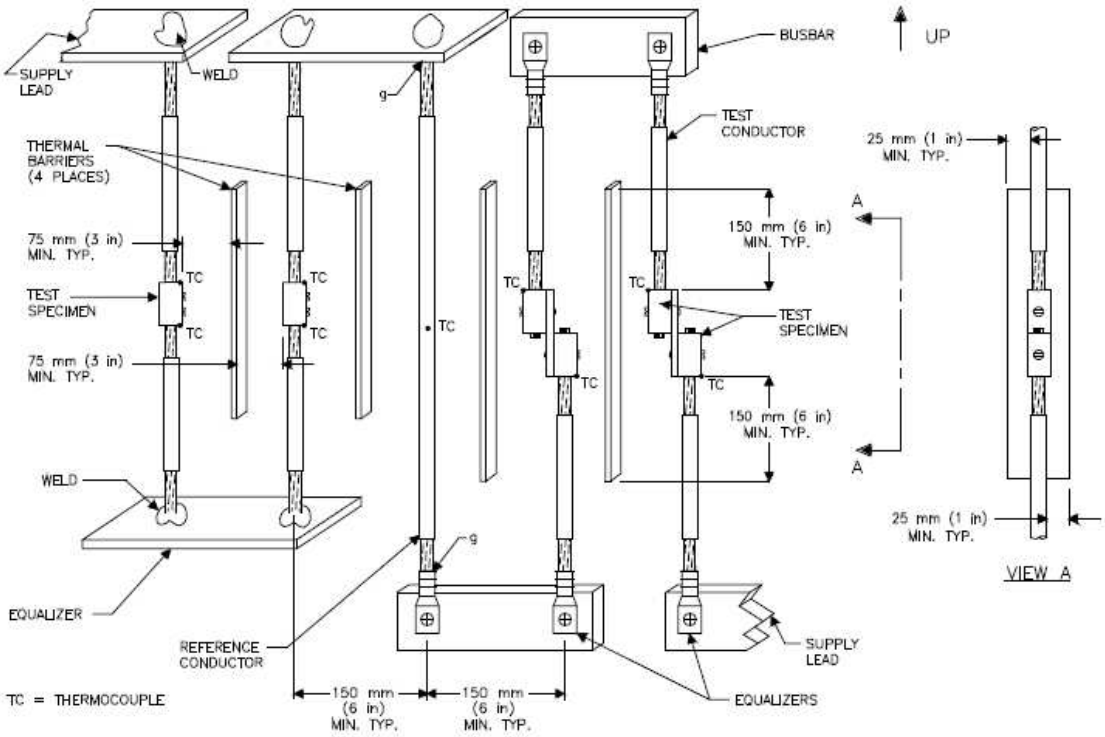
The apparatus is set up in complete compliance with Figure 2 on the next page, no other deviations from the standard were made.

Calibration Information:

Item #	Equipment Type	Asset #	Calibration Due
1	Fluke 365 True RMS Clamp Meter	M262	04/06/2019
2	Fluke Hydra Temperature Recorder	T1152	04/20/2019
3	Fluke Hydra Temperature Recorder	U080	07/16/2019
4	Fluke Hydra Temperature Recorder	T834S	02/13/2019
5	Fluke Hydra Temperature Recorder	T1565	09/27/2018

TEST LETTER REPORT

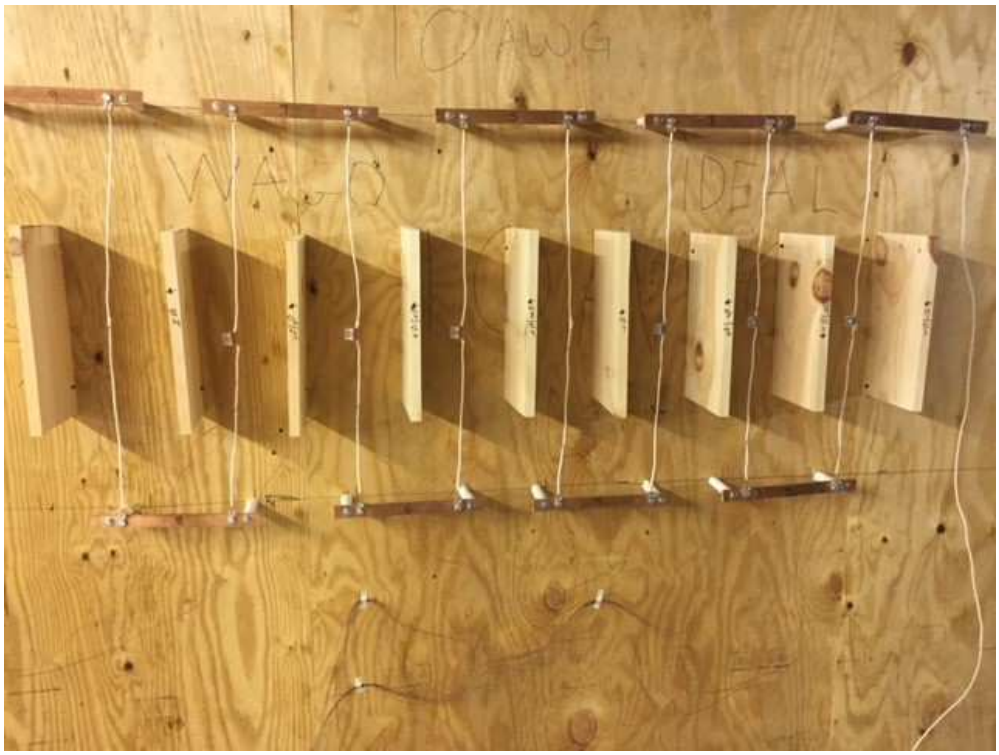
Figure 2
Vertical arrangement of specimen for current-cycling test
(Clause 9.1.10.7)



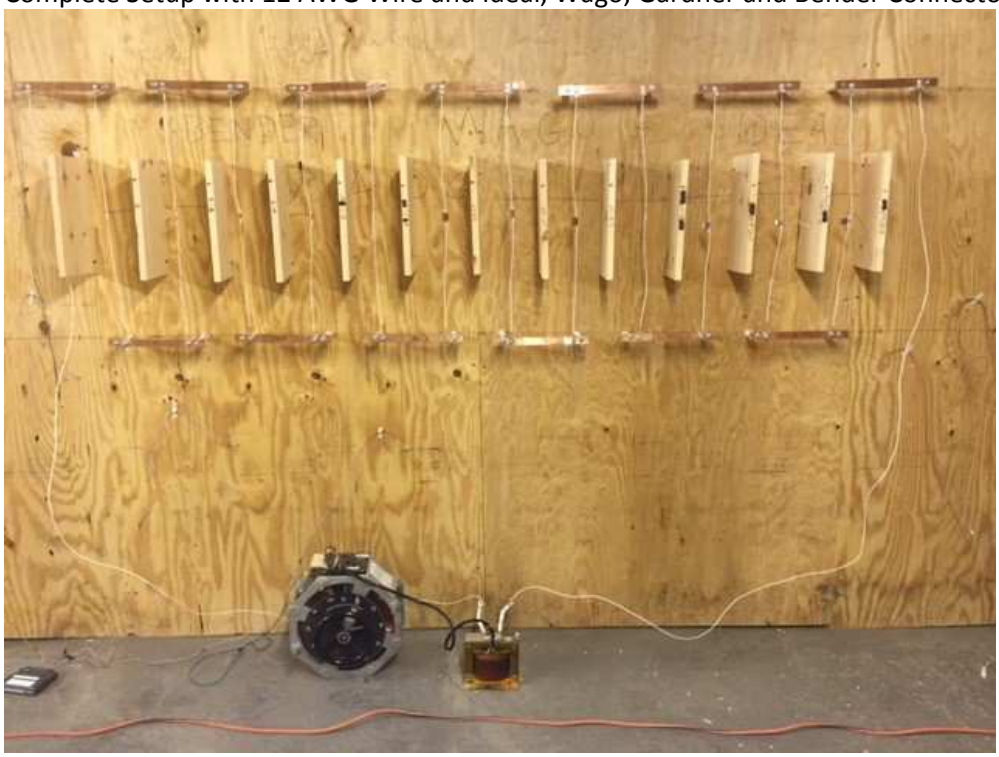
TEST LETTER REPORT

SECTION 3
PHOTOGRAPHS

10AWG Wire with IDEAL and WAGO connectors

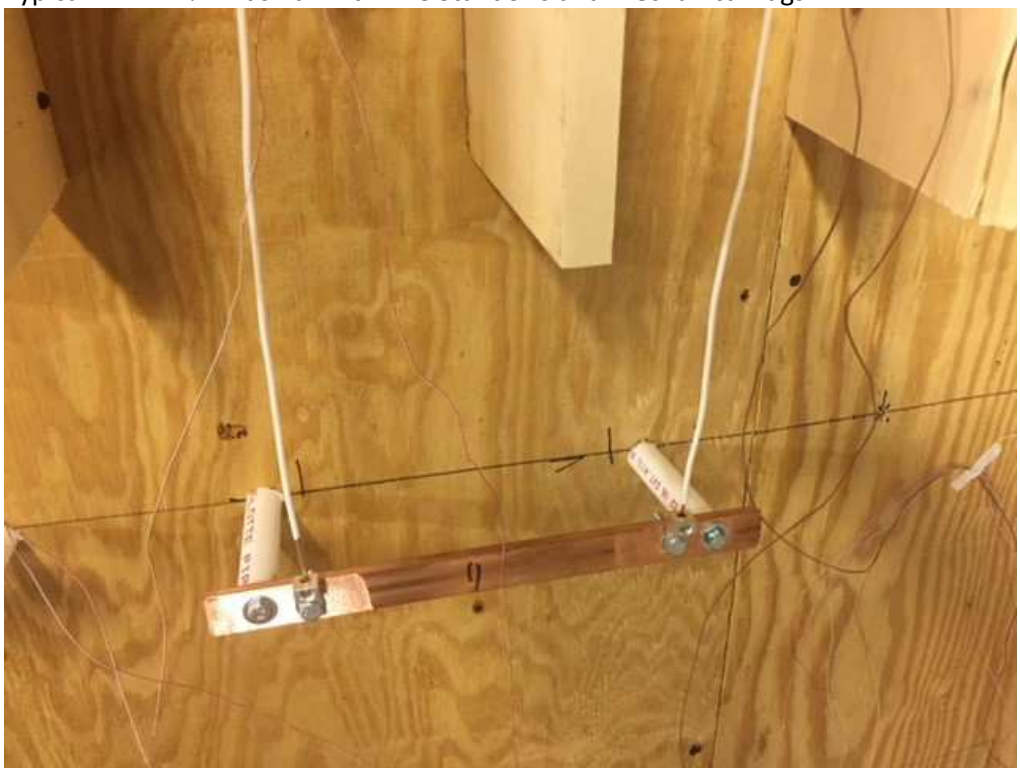


Complete Setup with 12 AWG Wire and Ideal, Wago, Gardner and Bender Connectors

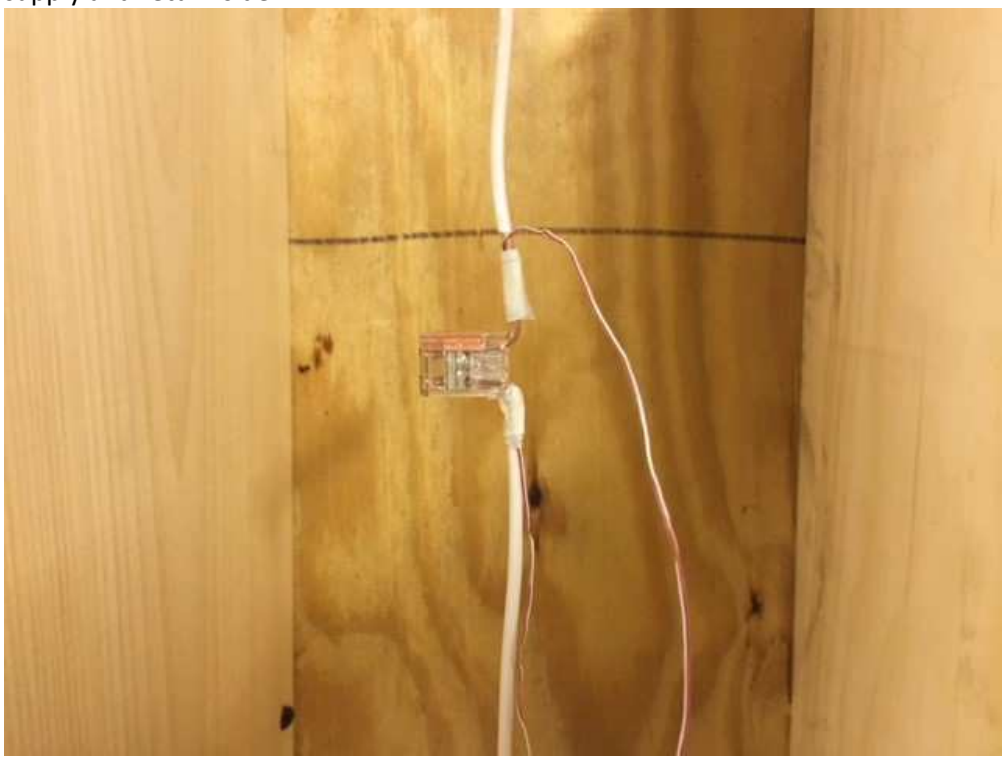


TEST LETTER REPORT

Typical 12 x 1 x ¼" Bus Bar with PVC Standoffs and Mechanical Lugs



Typical Connector, Gardner and Bender Shown, TC attached within 1/2" of the connector on supply and return side



TEST LETTER REPORT

SECTION 4
PROJECT STATUS & ACTION

One set of thermocouples did not record results on the first day of testing on one of the data recorders in use. Intertek performed a full 31 days of testing to capture a minimum of 30 days these thermocouples in question, at the request of the client.

One ambient thermocouple stopped recording at the end of the last day of testing, on the Ideal connectors for the 20A test setup. Data is recorded as “No Data” due to this malfunction. The seven remaining thermocouples reading ambient temperature show normal results.

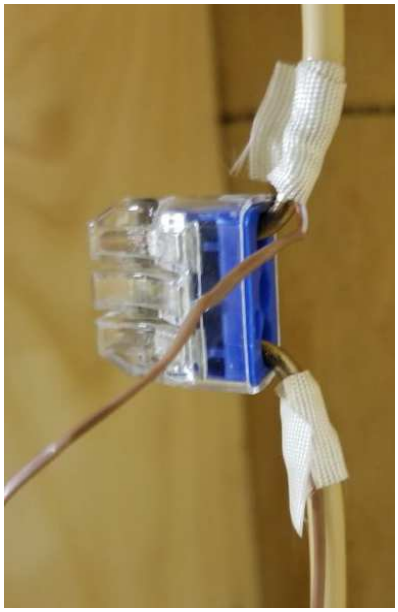
All testing is now complete.

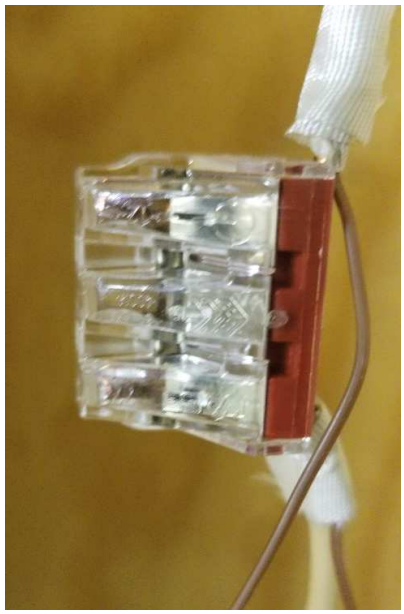
SECTION 5
CONCLUSION

The results contained in this report are to be evaluated by the client. This data is not to be used for certification of these products.

Upon completion of the test, there was no visible damage to any of the connectors contained within this report. There was however a visible change to the coloration of the insulation on the conductors involved in the 50A test on the 10 AWG conductors; no other conductors involved in the test exhibited this discoloration. The consistent temperatures recorded during the test, indicate that there is no evidence of arcing at the connectors.

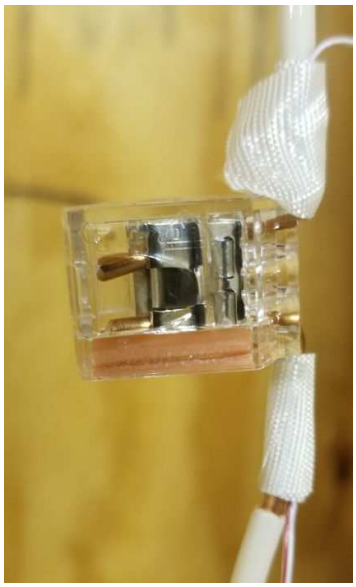
10 AWG Connectors (Left to Right: Ideal, Wago):



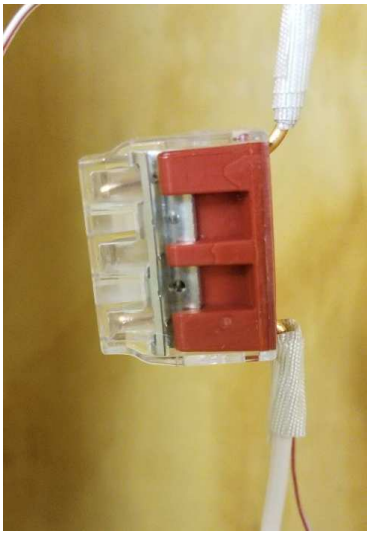
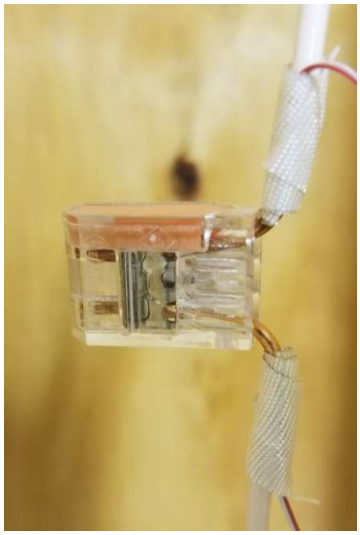


TEST LETTER REPORT

12 AWG Connectors (Left to right: Ideal, Wago, Gardner and Bender):



14 AWG Connectors (Left to right: Ideal, Wago, Gardner and Bender):

TEST LETTER REPORT

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

Completed by:	Joshua O'Connor	Reviewed by:	James Diescher
Title:	Engineering Team Lead	Title:	Technical Lead
Signature:		Signature	
Date	08/28/2018	Date:	08/28/2018

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

Revision History

08/28/2018: Added information in the conclusions about the condition of the connectors and conductors at the end of the test. Added example pictures of each connector for each test setup at the completion of the test.

TEST LETTER REPORT

APPENDIX

MAX TEMP (50A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		1	104.82	101.00	100.66	99.70	98.60	98.79	98.82	98.52	97.64	98.16	97.79	97.82	97.16	97.85	97.85	98.06	97.49	97.63	97.64	97.06	96.68	97.02	96.45	96.65	97.49	Power Outage			98.90	96.25	97.02	96.45	96.40	96.40
	1	2	83.92	81.32	81.26	80.73	80.09	80.76	80.48	80.18	79.64	80.31	79.79	79.55	79.49	80.47	79.93	80.34	80.07	79.59	79.50	79.27	79.02	78.94	78.79	78.94	79.93				80.77	78.35	78.70	78.40	78.30	78.26
		3	90.28	90.79	91.78	90.78	90.16	91.16	91.82	90.89	91.38	91.08	91.32	91.26	90.70	90.75	92.09	92.63	92.46	92.58	91.78	91.17	91.46	91.99	91.87	91.58	92.43				92.03	91.35	91.57	91.57	91.17	91.48
	2	4	77.14	77.62	78.16	77.92	77.83	78.34	77.99	77.93	78.12	78.28	78.10	78.06	77.93	77.76	79.17	79.25	79.16	79.14	78.74	78.29	78.55	78.53	78.67	78.38	79.24				78.86	78.68	78.79	78.53	78.25	78.37
		5	89.40	88.00	88.06	87.39	87.14	87.66	87.95	87.41	87.60	87.22	87.75	87.22	86.90	86.69	87.59	88.87	88.31	88.06	87.62	87.42	87.39	87.85	87.47	87.94	88.26				87.35	87.09	86.96	87.18	86.77	86.46
	3	6	92.73	91.58	92.06	91.46	91.54	91.75	92.33	92.00	92.01	91.28	91.62	91.88	90.90	90.83	92.07	93.37	92.96	92.68	92.04	91.75	92.20	92.29	92.00	92.57	92.69				92.26	91.65	91.54	92.05	91.31	91.72
	Ref	7	86.70	86.98	87.33	87.63	87.71	87.57	88.23	88.32	88.19	87.94	88.14	88.45	88.04	88.34	88.47	90.28	89.05	89.39	89.32	88.39	89.12	89.10	88.61	88.89	88.95				88.30	88.79	88.18	88.82	87.86	87.96
WAGO		8	81.37	80.88	80.74	80.56	80.08	79.93	79.18	79.02	78.45	79.39	79.33	79.00	79.07	79.55	79.65	79.63	79.81	79.52	78.93	77.99	78.56	78.44	78.10	78.43	78.26				79.39	77.75	77.91	77.48	76.92	77.02
	4	9	87.95	87.91	88.06	88.05	87.56	87.44	87.70	87.40	86.31	87.10	87.04	86.49	86.47	86.60	87.34	86.86	87.23	87.05	86.03	84.97	85.43	85.51	84.84	84.26	83.99				87.60	82.66	82.59	83.04	82.02	81.62
		10	87.19	87.84	87.90	88.43	87.66	87.34	86.86	86.11	86.57	87.48	87.70	87.54	87.20	87.45	87.88	87.92	88.00	86.61	86.52	85.52	85.46	85.47	85.73	86.22	86.18				87.75	85.60	85.48	85.31	85.87	85.36
	5	11	82.99	83.08	82.87	82.89	82.67	82.08	81.59	80.97	81.03	81.96	82.48	81.96	81.56	81.82	82.39	82.34	82.33	81.56	80.99	80.17	80.20	80.27	80.35	80.94	80.77				81.80	79.82	79.83	79.33	79.68	79.62
		12	85.43	85.05	85.09	85.12	84.61	84.80	84.10	83.59	83.47	84.12	84.26	84.58	84.16	84.36	84.31	84.97	84.57	84.23	83.86	83.73	83.34	83.49	83.12	84.01	83.75				84.34	83.84	83.04	83.06	83.41	83.41
	6	13	89.14	88.21	88.76	88.48	88.17	88.23	87.82	87.01	87.15	87.56	87.82	88.05	88.09	87.89	88.53	88.38	88.30	88.18	87.92	88.06	87.42	87.56	87.31	87.99	87.42				88.68	87.93	86.71	86.83	88.01	87.86
	Ref	14	88.72	89.64	91.45	90.71	91.45	91.75	91.57	91.95	91.31	90.84	92.18	92.33	92.35	91.99	92.78	92.10	93.57	93.63	92.06	91.81	92.52	93.07	92.84	94.56	92.34				91.83	91.48	91.76	90.88	91.75	92.01

MIN TEMP (50A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		1	22.29	95.90	95.73	93.01	91.23	93.56	92.72	93.94	92.48	90.88	92.40	92.03	91.11	91.39	90.62	91.45	91.51	91.06	89.73	93.36	91.73	91.20	89.59	91.80	90.50	Power Outage			88.57	89.43	88.66	87.20	89.04	88.91
	1	2	22.78	75.58	76.48	74.61	74.09	74.86	73.01	75.43	74.83	73.38	74.29	74.35	73.76	73.98	73.51	74.34	73.20	72.76	72.79	75.75	73.99	71.52	71.85	73.85	73.60				70.57	71.15	71.60	70.77	72.03	72.00
		3	22.32	86.68	86.59	86.16	86.30	86.08	83.75	86.01	85.92	86.01	86.10	86.12	86.44	86.39	86.00	87.18	85.73	86.73	84.95	86.06	85.97	85.69	84.59	86.34	86.40				86.41	84.28	82.96	83.55	86.01	86.60
	2	4	23.01	73.41	74.53	73.82	73.74	73.90	71.63	74.62	74.23	73.44	74.07	74.11	74.11	74.10	73.74	74.07	73.55	74.16	73.04	75.59	74.45	72.99	72.67	75.16	74.60				73.70	71.28	72.09	72.66	74.55	74.63
		5	22.81	82.43	83.23	81.87	81.43	81.93	82.40	83.10	83.04	81.18	81.53	82.37	82.07	81.62	80.99	81.31	82.41	83.19	83.08	83.34	83.08	83.36	82.56	82.89	81.89				83.00	80.76	80.45	78.26	82.23	82.20
	3	6	22.78	88.40	88.90	87.84	87.42	88.03	87.74	88.31	88.04	87.25	87.44	88.02	87.65	87.71	87.08	87.91	88.31	88.13	88.39	87.65	87.47	88.14	87.58	88.05	88.04				87.82	87.69	86.02	85.31	86.77	86.95
	Ref	7	22.80	81.99	82.99	82.63	83.18	82.18	83.80	84.81	83.61	82.84	83.48	83.28	83.82	83.52	82.89	82.37	84.23	85.36	85.18	85.16	84.67	85.61	84.25	85.09	83.40				85.03	84.55	82.60	82.30	84.22	84.61
WAGO		8	22.80	76.69	76.90	75.55	75.53	75.70	76.45	76.09	75.90	74.84	75.21	75.08	75.48	74.30	73.94	74.72	75.67	75.74	76.09	75.53	75.31	75.63	75.48	75.29	73.59				75.39	75.23	74.02	73.67	74.40	74.30
	4	9	22.75	83.28	83.55	82.80	83.07	82.84	83.59	82.50	82.47	81.84	82.09	81.47	81.66	81.43	80.58	81.16	81.56	81.90	81.02	81.21	80.95	80.60	80.67	79.89	78.46				78.59	78.57	76.50	76.81	77.42	78.12
		10	22.75	82.20	82.69	81.78	82.24	82.32	82.49	81.70	82.03	81.84	81.99	81.63	81.98	81.22	81.81	81.26	82.31	82.46	82.27	82.11	82.40	82.79	82.36	81.77	81.11				81.76	81.86	80.13	80.89	82.58	82.28
	5	11	22.70	78.01	77.83	76.59	77.48	77.09	77.56	77.03	77.05	76.60	76.94	76.43	76.92	75.85	76.32	75.92	77.07	77.78	77.22	77.46	77.68	77.94	77.27	76.76	75.78				76.67	77.06	75.06	74.97	77.20	77.02
		12	22.73	79.80	79.49	79.39	79.38	79.26	79.13	78.50	78.95	78.66	78.39	78.53	78.81	77.70	78.11	78.08	78.59	79.55	79.11	79.58	80.09	80.23	79.47	79.04	78.20				80.03	80.00	77.96	78.62	80.09	80.09
	6	13	22.70	83.65	83.07	83.06	82.47	82.70	81.87	82.49	82.24	82.41	82.51	82.69	82.38	82.30	82.45	82.67	82.99	83.63	82.82	83.27	83.53	82.79	82.66	83.04	82.52				83.28	82.88	81.04	81.24	83.12	83.10
	Ref	14	22.75	83.42	83.49	83.33	83.15	83.16	84.08	83.31	83.25	83.72	83.44	84.10	83.54	83.30	83.76	83.49	84.07	85.48	84.55	84.60	84.76	86.01	86.22	84.12	83.95				85.18	86.83	84.58	85.39	86.90	86.05

AVE TEMP (50A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		1	99.09	97.98	98.38	96.49	96.29	96.22	96.29	96.62	95.90	94.68	94.80	95.19	94.67	94.22	93.82	94.56	95.24	94.85	95.27	95.51	94.83	95.38	94.79	94.84	93.99	Power Outage			94.89	94.26	94.24	94.20	94.00	93.87
	1	2	78.62	77.88	78.84	77.46	77.72	77.86	77.92	78.29	77.87	76.79	76.90	77.39	76.91	76.46	76.14	76.80	77.45	77.10	77.47	77.66	76.99	77.46	76.86	77.13	76.46				77.03	76.21	76.26	76.30	76.08	75.89
		3	87.84	88.16	88.53	88.23	88.08	88.11	88.28	89.15	88.37	87.83	87.96	88.17	88.13	88.01	88.27	88.92	88.91	88.76	89.17	89.46	89.14	89.83	89.40	88.87	88.33				89.35	89.23	89.23	89.66	89.13	89.13
	2	4	74.75	75.56	76.47	75.77	76.01	76.19	76.27	76.75	76.46	75.81	76.07	76.44	76.22	76.03	75.91	76.52	77.05	76.92	77.14	77.29	76.93	77.37	76.97	76.95	76.55				77.40	77.13	77.02	77.23	76.91	76.87
		5	85.18	85.31	86.02	84.86	84.92	85.09	85.23	85.58	85.08	84.29	84.65	84.97	84.72	84.37	84.00	84.77	85.68	85.51	85.55	85.51	85.35	85.90	85.44	85.27	84.63				85.15	85.01	84.98	85.35	84.70	84.57
	3	6	89.99	89.95	90.10	89.68	89.52	89.54	89.60	89.92	89.43	89.14	89.38	89.37	89.34	89.25	89.24	89.79	90.18	90.00	90.00	89.89	89.87	90.32	89.99	89.55	89.44				89.70	89.75	89.67	90.16	89.29	89.23
	Ref	7	83.50	85.01	86.15	85.57	85.88	86.06	86.26	86.37	86.24	85.89	86.32	86.57	86.42	86.21	85.84	86.43	87.54	87.24	87.07	86.83	86.84	87.13	86.83	86.82	86.54				86.65	86.66	86.39	86.75	86.16	86.09
WAGO		8	78.35	79.13	79.27	78.39	78.35	78.06	77.90	77.38	77.23	77.29	77.47	77.56	77.44	77.45	77.14	77.46	78.23	77.77	77.39	76.77	76.84	76.80	76.83	76.98	76.73				76.63	76.32	76.04	75.97	75.51	75.42
	4	9	84.58	85.48	86.36	85.50	85.75	85.54	85.61	85.08	84.72	84.50	84.67	84.86	84.45	84.21	83.69	84.00	84.92	84.05	83.52	82.87	82.82	82.80	82.74	82.61	81.91				80.89	80.74	80.41	80.61	79.86	79.65
		10	83.91	85.12	86.05	85.11	85.40	85.17	85.01	84.69	84.79	84.74	85.01	85.30	85.06	84.91	84.51	84.81	85.78	84.94	84.53	84.03	84.08	84.17	84.11	84.43	84.03				84.44	84.26	83.59	83.64	83.85	83.81
	5	11	80.26	80.70	81.22	80.18	80.42	80.17	79.78	79.44	79.60	79.51	79.76	80.01	79.81	79.68	79.25	79.58	80.47	79.72	79.44	79.06	78.99	79.14	78.99	79.44	78.90				78.97	78.61	77.87	77.75	78.20	78.18
		12	82.32	82.81	83.38	82.23	82.52	82.39	81.93	81.68	81.73	81.45	81.71	82.35	82.02	81.68	81.38	81.71	82.58	82.39	81.91	81.77	81.72	81.78	81.45	81.81	80.94				82.08	81.76	80.74	80.37	81.44	81.64
	6	13	85.70	86.01	86.62	85.59	85.98	85.86	85.30	84.99	85.27	85.14	85.34	85.96	85.64	85.40	85.22	85.48	86.23	86.10	85.59	85.45	85.37	85.27	85.02	85.68	85.04				85.73	85.16	83.85	83.47	84.99	85.23
	Ref	14	84.72	85.98	87.39	86.49	86.92	87.91	88.34	89.19	88.00	86.86	87.38	88.68	88.21	87.26	87.03	87.49	88.69	89.53	89.36	89.39	89.47	90.37	89.71	89.12	87.38				88.84	89.23	88.46	87.94	88.82	89.13

MAX TEMP (30A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		15	68.57	62.14	61.07	60.48	60.15	59.65	59.37	58.88	59.40	59.21	59.03	59.59	59.52	59.65	59.99	60.38	60.45	59.45	59.20	58.92	58.77	58.79	58.81	58.92	59.54	Power Outage			59.22	59.20	59.03	57.81	58.09	58.50
	7	16	70.43	68.41	67.93	68.09	68.43	67.89	67.69	67.60	68.16	68.53	68.28	68.40	68.92	69.05	69.48	69.99	69.51	68.90	68.62	68.40	68.22	68.39	68.44	68.78	69.62				69.42	69.18	69.09	67.95	68.09	68.48
		17	80.39	65.87	64.23	64.36	64.12	64.12	63.84	63.72	63.63	63.62	63.27	63.19	63.31	63.70	64.09	64.17	63.63	62.92	62.82	62.44	62.19	62.22	61.94	62.91	62.70				61.81	61.15	61.09	59.86	59.84	60.07
	8	18	85.75	73.23	72.38	72.61	72.10	71.52	71.15	70.74	71.21	71.51	70.95	71.21	71.18	71.59	71.92	71.56	71.49	70.52	70.30	69.77	69.93	70.05	70.06	70.05	70.87				69.84	69.72	69.64	68.99	68.71	68.62
		19	65.78	64.66	64.04	64.77	64.75	63.82	63.62	63.56	63.54	63.56	63.63	63.38	63.44	63.94	64.33	64.51	64.62	63.36	63.50	63.00	63.26	63.48	63.70	63.34	63.57				63.36	63.25	62.99	62.38	62.04	61.95
	9	20	66.27	65.63	64.73	65.12	65.13	64.40	63.75	63.91	63.97	64.18	64.01	63.92	63.94	64.15	64.53	64.88	64.45	63.56	63.36	63.26	63.32	63.22	63.41	63.25	63.63				63.27	63.16	63.19	62.11	61.91	62.00
	Ref	21	67.20	67.35	66.97	67.88	67.89	67.24	67.55	67.53	67.24	66.93	67.88	67.56	67.55	67.87	68.14	68.77	68.16	68.30	68.23	67.37	68.14	67.45	68.48	67.70	67.67				68.10	68.36	67.75	67.62	67.07	67.07
WAGO		22	65.17	64.36	64.07	64.63	64.25	63.61	63.37	63.14	62.95	62.40	63.08	63.02	63.03	63.12	63.70	63.99	63.60	63.24	63.14	62.71	62.44	62.43	62.68	62.38	62.81				62.04	61.98	61.88	61.51	61.12	61.12
	10	23	68.15	67.25	66.94	67.10	66.98	66.28	65.89	65.83	65.73	65.47	65.73	65.81	65.53	65.73	66.41	66.67	66.20	65.39	65.46	64.95	64.75	64.86	64.97	64.77	65.26				64.25	64.38	64.25	63.67	63.45	63.45
		24	65.42	64.44	64.92	64.86	64.90	64.75	64.43	64.46	64.20	64.16	64.51	64.42	64.44	64.71	65.24	65.05	64.99	64.41	64.53	64.13	63.94	63.86	63.69	63.81	64.36				63.36	63.76	63.50	63.13	63.11	63.11
	11	25	64.28	61.42	61.21	61.24	61.13	60.69	60.29	60.28	60.01	60.01	60.27	60.29	60.44	59.64	59.79	59.84	59.96	59.49	59.24	58.74	58.55	58.60	58.17	58.42	58.97				57.57	57.58	57.45	57.45	56.89	56.89
		26	64.38	63.89	64.46	64.34	64.05	63.46	63.45	63.50	63.01	62.61	63.23	63.18	63.08	63.01	63.75	63.17	63.81	62.80	63.06	62.42	61.96	62.39	61.92	62.32	62.88				61.77	61.14	60.99	60.83	60.72	60.72
	12	27	67.34	67.23	67.54	67.26	67.17	67.19	66.53	66.41	65.93	65.99	66.46	66.16	66.28	66.03	66.53	66.53	66.88	66.02	65.95	65.53	65.04	65.08	65.23	65.31	66.17				64.83	64.29	64.23	64.03	63.79	63.79
	Ref	28	60.36	60.63	61.31	61.58	61.70	61.36	60.77	60.95	60.41	60.41	61.25	61.03	61.14	60.78	61.20	61.14	61.63	60.92	61.26	60.79	60.38	60.18	60.48	60.56	60.90				60.27	60.70	60.18	59.65	59.69	59.69
Gardner Bender		29	62.68	62.96	63.23	62.97	63.25	62.90	62.67	62.94	62.30	62.38	62.95	62.66	63.07	62.67	63.11	62.55	63.57	63.03	62.65	62.57	62.16	62.00	62.31	62.55	62.56				61.79	61.47	61.62	61.09	60.97	60.97
	13	30	64.06	64.02	64.43	64.32	64.44	64.32	64.04	64.15	63.91	63.98	64.28	64.22	64.51	64.26	64.75	64.44	65.41	64.22	64.25	64.16	63.74	63.55	64.06	64.11	64.33				63.81	63.81	63.91	63.13	63.08	63.08
		31	67.09	66.75	67.66	67.43	67.57	67.25	67.46	67.18	66.81	66.98	67.50	67.36	67.36	67.46	67.60	67.32	68.12	67.12	67.60	67.16	66.68	66.65	67.04	67.10	67.15				67.34	66.88	67.05	66.51	66.23	66.23
	14	32	No Data	67.16	67.72	67.56	67.82	67.27	67.57	67.43	66.98	67.55	67.95	67.50	67.50	67.33	67.63	67.41	68.28	67.21	67.96	67.42	66.89	66.79	67.33	67.49	67.43				67.86	66.79	66.94	66.31	66.25	66.25
		33	No Data	68.57	68.92	68.71	68.94	68.61	68.47	68.64	68.06	68.67	68.83	68.89	68.52	68.42	68.78	68.61	68.92	67.98	68.57	68.39	67.78	67.47	68.01	68.15	67.96				68.29	67.33	67.37	66.91	66.81	66.81
	15	34	No Data	65.91	65.94	65.52	65.62	65.33	65.00	64.92	64.42	64.83	65.17	65.19	64.34	64.53	64.76	64.51	64.68	63.67	64.28	64.26	63.49	63.09	63.76	63.87	63.44				63.23	62.80	62.35	61.87	61.92	61.92
	Ref	35	No Data	65.03	65.01	64.45	64.81	64.77	64.45	64.50	64.22	64.68	64.79	64.49	64.74	64.36	64.70	64.42	65.08	64.28	64.36	64.39	64.27	63.92	63.98	64.55	64.63				64.18	64.33	64.26	63.69	63.50	63.50

MIN TEMP (30A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		15	22.77	57.58	56.18	55.47	56.17	56.05	54.30	56.03	54.67	55.31	54.34	54.49	56.15	55.24	55.12	54.89	55.83	55.52	53.60	56.59	55.37	54.74	56.06	54.83	54.52	Power Outage			56.05	55.18	53.01	53.28	55.20	55.76
	7	16	22.75	64.48	64.38	63.99	64.72	64.79	63.90	65.26	64.38	65.44	64.65	64.53	66.23	65.24	65.00	64.95	65.76	66.08	64.69	65.90	66.02	65.34	65.89	65.79	65.72				66.20	66.45	63.80	64.49	66.06	66.17
		17	22.72	60.87	60.38	60.22	60.35	60.73	60.20	60.58	59.82	60.60	59.59	60.37	60.44	59.53	59.53	59.51	59.88	59.76	59.66	59.65	59.09	59.07	59.20	59.21	58.97				58.75	58.51	56.75	56.91	57.43	57.44
	8	18	22.73	69.00	69.03	68.30	68.23	68.70	68.06	68.73	67.88	68.03	67.70	67.69	68.59	67.68	67.31	66.96	67.95	67.89	67.32	68.39	68.31	67.35	68.10	67.69	66.99				67.27	67.55	64.94	65.56	67.07	67.37
		19	22.73	59.98	60.15	59.82	59.93	60.23	60.98	60.99	59.94	59.98	59.26	60.02	59.92	59.93	60.20	59.29	60.47	59.96	60.62	61.18	60.87	60.36	60.73	60.00	59.11				60.39	60.55	58.06	58.78	60.52	60.37
	9	20	22.70	61.16	61.38	61.20	61.55	61.51	61.68	61.04	60.78	60.90	60.68	61.06	60.54	61.25	60.92	60.34	61.25	61.27	61.53	61.29	61.40	60.79	61.06	60.77	60.38				60.64	60.93	59.00	59.81	60.22	60.27
	Ref	21	23.00	62.21	62.84	62.36	63.25	63.69	64.05	64.89	63.00	62.62	63.53	62.58	64.50	63.99	63.41	63.48	63.79	64.67	64.44	65.95	65.58	64.06	64.49	63.65	62.50				64.62	64.74	61.88	62.35	63.63	63.63
WAGO		22	23.02	59.21	59.42	58.74	58.99	59.38	59.33	60.21	58.13	57.78	58.80	57.64	59.60	58.67	57.99	58.01	58.48	58.96	58.93	60.69	60.04	57.83	58.84	58.02	56.75				58.68	58.52	56.02	56.86	57.95	57.95
	10	23	23.00	62.52	62.21	61.72	61.82	61.94	62.50	63.04	60.80	60.67	61.60	60.52	62.47	61.55	60.96	60.80	61.47	61.81	61.33	63.19	62.51	60.66	61.53	60.82	59.77				61.51	61.43	59.00	59.92	60.68	60.68
		24	23.02	60.65	60.80	60.62	60.81	61.46	60.99	61.87	60.15	60.26	60.59	59.96	61.62	60.89	60.49	60.46	60.95	61.58	61.47	62.36	61.67	60.51	60.98	60.13	59.75				60.48	60.99	58.22	59.69	59.84	59.84
	11	25	23.07	57.07	56.58	56.68	56.69	56.88	56.66	57.07	56.35	55.85	56.35	55.84	56.70	55.53	54.59	54.30	55.11	55.45	55.37	56.38	55.05	54.50	53.48	53.09	52.24				52.13	53.09	50.44	50.89	51.40	51.40
		26	23.05	58.73	58.77	58.40	59.00	58.48	58.52	59.16	57.75	57.96	57.86	57.39	58.41	58.42	57.88	57.79	58.09	58.42	58.22	60.13	58.57	57.41	57.14	57.18	57.05				57.66	57.98	55.59	56.70	56.63	56.63
	12	27	23.02	62.05	62.29	61.74	62.48	62.06	62.35	62.57	61.59	61.31	61.82	61.22	61.92	61.95	61.74	61.41	61.80	62.12	61.41	63.02	62.21	61.25	61.29	60.89	60.91				61.45	61.74	59.33	60.39	60.26	60.26
	Ref	28	23.05	55.09	54.46	54.76	56.16	55.22	55.92	56.42	55.98	55.79	56.10	55.70	56.37	55.77	56.14	56.02	55.91	56.25	56.33	57.81	56.53	55.96	55.80	55.62	55.48				56.30	57.54	55.38	55.88	56.27	56.27
Gardner Bender		29	23.03	56.09	55.54	55.72	56.34	55.68	56.74	56.71	56.14	55.32	56.25	56.46	57.26	57.41	56.92	56.71	56.27	56.76	55.89	59.38	58.23	56.04	55.97	55.91	56.04				56.30	57.15	55.72	56.01	56.10	56.10
	13	30	23.00	58.88	58.14	58.57	58.60	58.83	59.15	59.75	58.92	57.87	59.21	59.46	60.23	60.13	59.37	59.43	58.80	59.60	59.40	61.86	60.54	59.05	59.15	58.59	58.51				59.47	60.48	58.94	59.36	59.27	59.27
		31	22.91	60.43	59.64	59.94	60.71	60.63	61.05	62.26	59.81	59.70	60.51	60.80	62.60	60.70	61.36	60.98	59.79	61.30	60.67	63.95	62.40	60.33	60.62	60.06	60.39				61.77	62.93	61.23	62.62	62.11	62.11
	14	32	No Data	59.91	59.38	59.83	60.02	59.62	60.37	61.40	59.30	59.39	60.35	60.12	61.55	60.39	60.74	60.75	59.19	60.49	59.97	63.98	61.42	59.87	59.67	59.61	60.27				60.89	62.15	60.49	61.70	61.62	61.62
		33	No Data	63.35	62.04	61.80	61.88	61.90	61.99	62.92	61.26	61.57	61.88	62.11	62.91	61.98	62.67	62.15	60.99	61.71	61.53	64.55	62.26	61.06	60.82	60.58	61.22				61.39	62.68	61.00	62.39	61.60	61.60
	15	34	No Data	60.13	58.82	58.25	58.86	58.51	58.42	59.14	57.44	57.34	57.62	58.39	59.05	57.74	57.98	58.19	56.76	57.66	56.81	60.03	58.20	56.55	56.50	55.56	55.44				56.14	57.06	55.99	56.96	55.70	55.70
	Ref	35	No Data	60.01	59.16	59.60	59.57	59.61	59.71	60.18	58.88	59.50	59.28	59.95	59.52	59.73	59.97	60.38	59.10	58.74	59.26	60.50	60.06	58.98	58.66	58.36	58.92				59.41	60.12	59.63	59.35	58.66	58.66

AVE TEMP (30A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		15	62.96	60.51	59.09	58.64	58.55	58.25	57.68	57.73	57.72	57.76	57.63	57.85	57.93	58.04	58.29	58.21	58.34	58.07	57.93	57.80	57.58	57.76	57.69	57.76	57.73	Power Outage			59.22	57.62	56.55	56.00	56.89	57.06
	7	16	67.80	67.05	66.52	66.72	67.00	66.93	66.45	66.53	66.95	67.25	67.21	67.42	67.59	67.88	68.24	68.24	68.21	67.75	67.55	67.36	67.19	67.48	67.42	67.79	67.99				69.42	67.95	66.93	66.42	66.93	67.03
		17	65.55	63.34	62.66	62.44	62.62	62.72	62.34	62.15	62.25	62.03	62.00	62.05	61.92	62.11	62.30	62.10	62.14	61.56	61.34	61.00	60.65	60.79	60.65	60.82	61.01				61.81	59.87	59.11	58.38	58.57	58.64
	8	18	72.98	71.28	70.57	70.55	70.48	70.28	70.02	69.91	70.01	69.88	69.74	69.80	69.82	69.95	70.20	70.00	69.97	69.67	69.44	69.16	69.10	69.11	69.09	69.06	69.14				69.84	69.06	68.06	67.76	68.03	67.95
		19	63.36	62.65	62.53	62.52	62.73	62.50	62.45	62.39	62.30	61.91	61.96	62.23	62.15	62.32	62.58	62.54	62.77	62.48	62.45	62.21	62.22	62.17	62.22	61.94	61.95				63.36	62.22	61.24	61.17	61.36	61.25
	9	20	64.35	63.60	63.29	63.26	63.34	63.07	62.88	62.78	62.81	62.52	62.54	62.70	62.65	62.83	63.13	63.09	63.19	62.76	62.60	62.31	62.28	62.29	62.31	62.13	62.27				63.27	62.29	61.49	61.17	61.22	61.14
	Ref	21	65.33	65.41	65.85	65.71	66.26	66.08	66.19	66.19	66.07	65.58	65.93	66.17	66.12	66.26	66.37	66.42	66.89	66.77	66.78	66.63	66.65	66.55	66.71	66.31	66.16				66.59	66.86	65.65	65.71	65.95	65.95
WAGO		22	62.58	62.44	62.80	61.98	62.48	62.15	62.07	62.04	61.67	61.03	61.45	61.71	61.48	61.61	61.48	61.32	62.01	61.72	61.86	61.82	61.52	61.28	61.37	60.96	60.86				60.90	60.92	59.73	59.76	60.04	60.04
	10	23	65.64	65.47	65.60	64.63	65.20	64.92	64.80	64.78	64.42	63.80	64.13	64.42	64.17	64.35	64.27	64.02	64.64	64.24	64.35	64.21	63.92	63.69	63.75	63.36	63.34				63.25	63.32	62.29	62.28	62.38	62.38
		24	62.85	62.98	63.65	62.98	63.64	63.54	63.40	63.47	63.15	62.78	63.10	63.34	63.28	63.35	63.31	63.07	63.61	63.34	63.55	63.38	63.05	62.88	62.86	62.53	62.58				62.49	62.61	61.70	61.80	62.13	62.13
	11	25	60.31	59.35	59.79	58.99	59.56	59.36	59.24	59.28	58.79	58.22	58.79	59.04	58.79	58.17	57.52	57.30	58.21	57.78	57.87	57.78	57.34	57.14	56.83	56.32	56.22				55.87	55.74	54.77	54.79	55.06	55.06
		26	61.30	61.24	62.45	61.23	62.06	61.91	61.71	61.85	61.09	60.53	61.16	61.49	61.14	61.05	60.66	60.49	61.54	60.94	61.26	61.34	60.62	60.45	60.37	60.09	60.02				59.91	59.63	58.84	58.80	59.08	59.08
	12	27	64.19	64.20	65.46	64.30	65.14	65.04	64.94	65.02	64.40	63.79	64.39	64.74	64.38	64.37	64.07	63.95	64.87	64.32	64.61	64.56	63.94	63.78	63.81	63.45	63.48				63.25	63.17	62.48	62.41	62.46	62.46
	Ref	28	57.47	57.72	59.09	58.44	59.26	59.15	59.27	59.36	58.80	58.33	58.93	59.20	58.99	58.84	58.73	58.77	59.52	59.09	59.48	59.57	59.11	58.86	59.06	58.71	58.72				58.86	59.03	58.42	58.40	58.24	58.24
Gardner Bender		29	59.04	59.48	60.89	59.71	60.70	60.60	60.86	61.05	60.32	59.90	60.47	60.80	60.67	60.35	59.91	59.73	60.83	60.31	60.81	61.18	60.45	60.09	60.32	59.77	59.83				60.09	60.18	59.40	59.29	59.51	59.51
	13	30	61.18	61.58	62.66	61.75	62.61	62.55	62.75	62.87	62.33	62.03	62.47	62.80	62.70	62.55	62.34	62.20	63.04	62.60	62.93	63.07	62.49	62.26	62.41	61.99	62.09				62.39	62.52	62.00	61.85	61.81	61.81
		31	63.63	63.96	65.26	64.15	65.12	65.04	65.34	65.44	64.75	64.54	65.02	65.35	65.21	65.00	64.67	64.27	65.35	64.76	65.45	65.88	65.13	64.65	64.98	64.41	64.43				65.27	65.47	64.84	64.91	64.89	64.89
	14	32	No Data	63.57	65.09	63.76	64.90	64.80	65.09	65.19	64.44	64.24	64.79	65.13	64.99	64.75	64.32	63.82	65.05	64.37	65.16	65.82	64.91	64.39	64.71	64.11	64.22				64.99	65.13	64.34	64.41	64.70	64.70
		33	No Data	65.59	66.72	65.43	66.31	66.22	66.48	66.49	65.93	65.90	66.23	66.44	66.42	66.17	65.90	65.39	66.31	65.78	66.30	66.80	65.80	65.37	65.62	65.14	65.21				65.49	65.58	64.95	64.84	65.21	65.21
	15	34	No Data	62.85	63.73	62.23	62.91	62.69	62.89	62.83	62.23	62.07	62.30	62.46	62.31	61.95	61.63	61.10	62.03	61.39	61.86	62.18	61.33	60.82	61.15	60.53	60.50				60.27	60.41	59.78	59.66	59.80	59.80
	Ref	35	No Data	62.16	63.09	62.21	62.62	62.54	62.89	62.73	62.44	62.48	62.65	62.65	62.71	62.43	62.40	62.23	62.79	62.57	62.68	62.86	62.34	61.95	62.30	61.97	62.19				62.37	62.49	62.19	61.90	61.74	61.74

MAX TEMP (20A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		36	No Data	62.13	61.46	60.56	60.29	60.59	59.48	59.07	58.70	58.95	58.83	58.72	58.61	58.78	58.97	59.81	58.95	58.60	57.88	57.27	57.12	57.72	57.02	57.49	58.02	Power Outage			55.94	56.39	55.77	54.77	54.71	54.52
	16	37	No Data	61.55	61.48	60.69	60.29	60.42	59.33	58.77	58.49	59.20	58.83	58.91	58.80	58.85	59.36	60.28	58.72	58.39	57.21	57.18	56.89	56.21	56.79	57.72	57.67				56.06	55.89	55.26	55.12	54.70	54.71
		38	No Data	53.15	53.64	52.80	52.67	53.02	52.45	52.11	52.09	52.60	52.50	52.54	52.74	52.96	53.10	53.16	52.74	53.18	52.53	51.91	51.67	51.18	51.62	52.10	52.53				52.03	51.42	52.15	51.49	50.43	50.66
	17	39	No Data	53.55	53.88	53.02	53.33	53.47	52.88	52.47	52.77	53.33	53.18	53.27	53.13	53.11	53.64	53.92	53.68	53.27	53.14	52.67	52.14	51.76	52.10	52.54	53.11				52.15	51.65	52.10	51.53	50.89	51.19
		40	No Data	58.52	58.37	57.97	57.89	58.17	58.29	57.23	57.63	57.96	57.56	57.85	57.78	58.40	58.14	58.80	58.13	58.01	57.80	57.28	56.80	56.33	57.45	57.09	57.96				57.14	56.87	57.52	57.04	56.10	55.62
	18	41	56.13	55.83	55.29	55.13	55.00	55.35	55.29	54.68	54.99	55.53	54.95	55.10	55.40	55.49	55.95	56.23	55.65	55.32	55.43	54.40	54.26	54.25	54.91	54.95	55.22				55.24	55.27	55.11	55.20	54.01	53.78
	Ref	42	56.42	56.74	56.50	56.62	56.33	56.28	56.37	56.22	55.96	56.23	56.48	56.54	56.60	56.96	57.50	58.27	57.01	56.53	56.28	55.38	55.46	55.50	55.62	56.07	57.18				56.25	56.25	55.48	55.38	54.02	53.94
WAGO		43	53.75	53.87	53.82	54.10	53.50	53.57	53.50	52.85	53.41	53.48	53.44	53.31	53.17	53.72	54.38	54.62	54.30	54.03	53.64	53.09	52.91	52.87	53.25	53.21	54.05				53.32	53.22	53.29	52.33	51.90	51.89
	19	44	55.89	55.65	55.78	55.82	55.25	55.40	55.26	54.84	55.04	55.27	55.32	54.92	54.82	55.36	56.26	56.63	56.03	55.85	54.97	54.46	54.50	54.34	54.62	54.71	56.00				54.68	54.77	54.47	53.68	53.04	53.04
		45	52.99	52.56	52.37	52.78	52.28	52.39	51.91	51.41	52.14	51.95	52.12	51.92	51.77	52.32	52.70	53.38	53.05	52.99	52.06	51.45	51.56	51.28	51.61	52.00	52.99				51.71	51.64	51.68	51.02	50.29	50.59
	20	46	57.96	57.96	58.00	58.20	57.49	57.50	57.34	56.82	56.96	56.99	57.24	57.16	56.95	57.64	57.95	58.84	58.49	58.11	57.46	56.50	56.58	56.79	56.97	56.85	58.01				56.80	56.91	56.95	56.39	55.60	55.52
		47	53.18	53.28	53.38	53.69	53.55	53.35	53.31	52.74	53.21	53.00	53.30	53.27	52.91	53.47	53.94	54.55	54.36	54.40	53.55	53.10	53.19	53.37	53.15	53.33	54.35				53.02	52.94	52.99	52.49	52.10	51.88
	21	48	55.56	56.03	55.79	56.28	55.54	55.68	55.56	55.06	55.50	55.52	55.63	55.69	55.57	56.12	56.31	57.52	56.93	56.43	55.72	55.31	55.22	55.68	55.18	55.82	57.01				55.40	55.08	55.32	55.19	54.29	54.10
	Ref	49	59.88	59.48	59.52	59.78	59.74	59.54	59.32	58.76	59.02	59.55	59.43	59.60	59.70	60.14	60.29	61.11	60.15	60.55	59.73	58.64	59.01	59.14	58.71	59.67	60.63				59.49	57.94	57.98	57.35	57.49	57.67
Gardner Bender		50	59.35	59.42	59.95	60.32	60.10	59.65	59.22	59.17	59.70	59.58	59.53	59.91	59.58	60.30	60.72	61.01	61.32	61.23	60.14	59.45	59.70	60.72	60.05	60.38	61.19				59.47	59.21	59.74	58.66	58.40	58.24
	22	51	61.96	61.58	61.77	62.22	61.85	61.58	60.92	60.99	61.25	61.51	61.27	61.81	61.27	62.80	62.52	63.28	62.56	62.82	61.88	61.01	60.90	62.66	62.00	62.71	63.59				61.36	60.54	61.33	59.95	59.91	59.67
		52	66.06	66.79	68.72	70.24	70.50	70.99	70.27	69.62	69.82	69.78	69.56	69.39	68.80	69.02	68.78	69.45	69.11	69.08	68.03	66.70	66.93	68.02	67.48	67.56	67.48				65.92	65.69	65.37	64.75	64.53	64.40
	23	53	64.35	65.25	66.55	68.23	68.67	68.51	67.96	67.56	67.49	67.69	67.29	67.03	66.68	66.49	66.51	66.98	66.88	66.84	65.76	64.83	64.73	65.30	65.00	65.00	65.02				63.50	63.06	63.04	62.42	62.02	61.88
		54	55.36	54.87	55.50	56.30	55.60	55.79	55.48	55.15	55.71	55.81	55.94	55.96	55.13	56.22	56.19	56.60	57.05	57.12	56.81	54.97	56.06	56.35	56.19	56.09	56.92				55.52	54.86	54.79	54.18	54.23	54.17
	24	55	56.03	55.91	56.35	57.15	56.61	56.65	56.36	55.93	56.44	56.83	56.78	56.76	56.16	57.08	57.02	57.72	57.82	58.08	57.58	55.95	56.97	57.32	57.03	56.86	57.98				56.51	55.73	55.96	55.38	55.18	55.26
	Ref	56	57.85	57.34	58.14	58.45	58.11	58.29	57.80	57.79	58.00	58.26	58.49	58.19	57.91	58.52	58.96	59.31	59.46	59.75	58.73	58.07	58.74	58.89	58.86	58.61	59.32				58.52	58.03	57.79	57.42	57.41	57.28

MIN TEMP (20A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		36	No Data	59.35	58.63	57.86	57.56	57.20	56.72	56.52	55.94	56.36	56.49	56.26	56.20	56.30	56.63	56.66	56.30	55.87	55.43	54.74	54.82	54.93	54.79	55.20	55.26	Power Outage			54.14	53.70	52.99	52.13	52.45	52.29
	16	37	No Data	57.79	57.06	56.48	56.14	55.91	55.38	55.24	55.21	55.24	55.15	55.20	55.05	55.24	55.58	55.58	55.34	54.86	54.43	53.72	53.84	53.79	53.38	54.02	54.44				53.12	52.87	52.22	51.82	51.65	51.61
		38	No Data	49.75	49.98	49.67	49.75	49.31	49.02	48.63	49.23	49.38	49.51	49.41	49.51	50.28	50.34	50.40	50.06	49.63	49.53	49.25	48.51	48.91	48.37	49.05	49.95				48.12	48.34	48.27	47.40	47.43	47.71
	17	39	No Data	50.82	50.92	50.31	49.90	49.96	49.24	49.84	50.10	50.56	49.98	50.29	50.27	50.79	51.28	50.99	50.57	49.91	49.81	49.54	48.94	49.36	48.70	49.30	50.66				48.65	48.64	48.11	47.65	47.82	48.16
		40	No Data	55.18	55.29	54.75	54.41	54.78	53.98	54.16	53.99	54.52	54.21	54.25	54.66	54.96	55.24	55.12	53.62	54.03	53.64	53.63	52.40	53.14	52.87	52.99	54.58				53.13	52.93	53.08	52.44	52.17	52.41
	18	41	22.86	52.29	52.65	52.48	52.14	52.15	51.89	51.58	52.03	51.88	52.19	52.23	52.31	52.52	53.15	53.36	52.73	51.94	52.08	51.26	51.32	51.46	50.98	51.87	52.47				51.54	51.62	50.85	51.01	50.33	50.86
	Ref	42	22.88	52.07	53.43	52.73	52.59	52.26	52.30	52.58	52.32	52.32	53.09	53.11	52.81	51.80	52.71	51.32	53.41	52.17	52.87	51.55	52.17	51.97	52.11	52.48	52.22				52.56	51.63	51.30	51.25	50.30	50.80
WAGO		43	22.90	50.19	51.07	49.83	50.72	51.22	50.90	51.03	51.03	51.32	50.99	51.53	51.32	50.32	50.18	49.22	50.40	51.92	51.73	51.02	51.08	51.13	51.25	51.43	50.34				51.31	50.96	50.69	50.04	49.93	50.16
	19	44	22.88	51.23	52.25	50.87	51.42	52.09	52.41	52.35	51.81	52.44	51.92	52.60	52.11	51.11	50.86	49.83	50.85	53.18	52.77	51.85	52.01	51.90	52.07	52.15	51.13				52.07	51.60	51.56	50.79	50.53	50.61
		45	22.88	48.73	49.44	48.31	48.85	49.19	48.74	49.27	49.56	49.69	49.07	49.80	49.36	47.50	47.44	47.56	48.58	50.38	49.96	49.51	49.51	49.52	49.61	49.98	48.48				49.70	49.40	49.33	48.42	48.46	48.58
	20	46	22.90	53.18	54.28	53.41	54.27	54.09	53.31	54.01	54.41	54.55	53.91	54.38	54.23	52.66	52.79	52.77	53.34	55.14	54.94	54.69	54.80	54.11	54.50	54.71	53.17				54.70	54.38	54.57	53.62	53.36	53.76
		47	22.86	48.90	49.92	49.34	49.38	49.73	49.55	49.88	50.21	50.20	48.87	50.15	50.08	48.36	48.97	48.64	49.93	51.04	50.75	50.99	50.82	51.28	51.08	51.13	49.94				50.66	51.01	51.08	50.49	49.96	50.68
	21	48	22.85	50.05	50.83	50.24	50.67	50.80	50.55	51.55	52.03	51.66	49.48	51.39	51.07	49.69	50.11	49.68	50.86	52.18	51.95	52.44	52.70	52.49	52.07	52.61	51.19				52.51	52.75	52.82	52.29	51.15	51.94
	Ref	49	22.85	52.31	53.12	52.11	52.79	53.02	53.25	53.67	54.19	53.43	51.96	53.91	53.11	51.78	51.67	52.72	53.34	54.64	53.62	54.57	54.76	54.82	55.01	54.57	53.48				54.76	54.54	54.22	53.79	53.82	54.81
Gardner Bender		50	22.82	53.04	53.91	53.59	54.27	54.49	54.33	54.51	54.63	54.22	54.16	54.86	54.70	53.55	53.28	53.89	54.27	55.96	55.18	55.14	55.77	55.23	56.24	55.22	55.05				56.33	55.73	55.79	56.51	55.47	56.24
	22	51	22.69	53.66	54.11	53.97	54.71	55.02	54.91	55.14	55.52	54.80	54.58	55.20	55.27	53.57	52.89	54.15	54.33	56.56	55.70	55.37	56.50	56.21	56.91	55.79	55.09				56.40	56.89	56.66	57.25	56.09	56.53
		52	22.70	59.15	60.30	61.39	63.00	63.46	63.42	63.63	63.43	62.55	62.30	62.46	62.06	60.52	60.60	60.90	60.69	62.22	61.00	61.81	61.94	61.57	61.16	60.35	59.99				61.06	60.99	60.05	61.57	60.52	61.33
	23	53	22.70	57.96	59.48	60.06	61.63	61.74	60.48	61.87	61.59	61.08	60.51	60.61	59.86	59.36	59.35	59.25	59.30	59.88	59.48	59.78	59.81	59.47	59.70	58.40	58.65				58.92	58.37	58.28	59.16	58.30	59.14
		54	22.69	48.53	48.73	48.85	49.31	49.08	49.33	49.87	49.51	49.40	49.07	49.17	49.49	48.35	48.21	49.38	49.25	50.09	49.37	50.31	50.26	50.98	50.13	50.68	49.76				50.34	50.89	50.78	50.81	50.87	50.56
	24	55	22.67	48.93	49.19	49.36	49.47	49.69	49.29	50.17	49.76	49.93	49.61	49.42	50.01	48.98	48.83	49.55	49.62	51.01	50.24	50.57	50.60	51.09	50.52	50.91	50.31				50.62	51.03	51.01	52.23	51.43	51.51
	Ref	56	22.67	50.30	50.45	50.53	50.97	50.51	50.98	51.60	50.90	51.36	51.00	51.29	51.42	50.75	51.16	51.15	51.30	52.26	51.60	51.74	51.74	52.88	52.04	52.03	51.84				52.01	53.03	53.29	52.89	52.51	53.01

AVE TEMP (20A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		36	No Data	60.77	59.99	59.24	58.80	58.40	58.00	57.49	57.52	57.76	57.57	57.30	57.23	57.33	57.76	57.80	57.64	57.23	56.62	55.92	55.94	55.93	55.88	56.18	56.41	Power Outage			55.04	54.76	54.33	53.61	53.61	53.38
	16	37	No Data	59.73	59.15	58.20	57.97	57.61	57.21	56.61	56.80	57.16	56.97	56.73	56.67	56.83	57.26	57.16	56.99	56.29	55.69	55.13	54.96	54.78	54.74	55.25	55.77				54.45	53.99	53.52	52.73	52.79	52.83
		38	No Data	51.64	51.53	51.16	51.23	51.05	50.88	50.46	50.78	51.23	51.13	51.05	51.16	51.32	51.72	51.89	51.78	51.21	50.92	50.47	50.25	50.03	50.05	50.54	51.13				50.27	50.05	50.06	49.36	48.98	49.14
	17	39	No Data	52.36	52.28	51.85	51.98	51.84	51.62	51.21	51.53	51.98	51.88	51.79	51.87	52.06	52.56	52.70	52.44	51.80	51.50	51.02	50.73	50.55	50.45	51.19	51.86				50.82	50.31	50.14	49.41	49.31	49.63
		40	No Data	57.10	56.83	56.46	56.37	56.22	56.18	55.59	55.98	56.44	56.20	56.06	56.21	56.40	56.80	56.96	56.68	56.18	55.89	55.15	55.04	54.84	54.94	55.52	56.13				55.55	55.12	55.25	54.72	53.96	54.04
	18	41	54.35	54.35	54.11	53.73	53.66	53.51	53.53	53.04	53.48	53.89	53.63	53.60	53.69	53.85	54.28	54.42	54.35	53.89	53.64	52.95	52.89	52.64	52.80	53.23	53.72				53.56	53.41	53.53	53.05	52.25	52.22
	Ref	42	54.46	54.97	54.95	54.71	54.71	54.56	54.52	53.98	54.20	54.69	54.53	54.54	54.65	54.74	55.27	55.60	55.45	55.02	54.56	53.63	53.65	53.55	53.64	54.24	54.82				54.09	53.61	53.64	53.01	52.33	52.35
WAGO		43	52.34	52.86	52.83	52.65	52.62	52.60	52.50	52.13	52.17	52.55	52.49	52.40	52.46	52.56	52.85	53.12	53.35	53.18	52.71	52.00	51.96	51.99	52.03	52.35	52.75				52.16	51.89	51.76	51.15	50.90	50.94
	19	44	53.85	54.41	54.30	54.00	53.94	53.89	53.83	53.35	53.46	53.91	53.75	53.66	53.72	53.80	54.13	54.38	54.58	54.37	53.78	53.02	52.99	52.96	52.95	53.43	53.89				53.19	52.78	52.71	52.01	51.65	51.73
		45	50.72	51.29	51.32	51.11	51.09	51.09	50.95	50.66	50.76	51.10	51.02	50.93	50.92	51.04	51.30	51.57	51.85	51.73	51.16	50.53	50.46	50.43	50.40	50.82	51.21				50.58	50.27	50.16	49.44	49.33	49.44
	20	46	55.98	56.52	56.48	56.35	56.23	56.22	56.14	55.79	55.84	56.15	56.05	55.95	55.94	56.04	56.30	56.56	56.87	56.79	56.22	55.57	55.55	55.52	55.52	55.84	56.16				55.66	55.47	55.45	54.85	54.58	54.61
		47	51.11	51.74	51.95	51.89	51.88	52.04	51.95	51.98	52.00	52.08	52.09	52.14	52.02	52.10	52.29	52.67	52.98	53.07	52.61	52.25	52.21	52.28	52.28	52.43	52.63				52.20	52.09	52.00	51.41	51.24	51.27
	21	48	52.89	53.69	53.92	53.82	53.79	54.02	53.95	53.96	54.15	54.19	54.09	54.18	54.06	54.11	54.26	54.64	54.97	55.03	54.55	54.19	54.18	54.16	54.18	54.41	54.71				54.26	54.06	54.03	53.42	53.12	53.16
	Ref	49	55.39	56.19	56.54	56.47	56.49	56.91	56.47	56.79	56.93	57.03	56.85	56.95	56.66	56.83	57.08	57.66	57.59	57.74	57.32	56.91	56.86	57.09	56.76	57.41	57.60				57.35	56.52	56.08	55.30	55.86	56.14
Gardner Bender		50	55.71	56.39	56.97	57.15	57.15	57.46	57.23	57.60	57.66	57.54	57.44	57.62	57.34	57.48	57.84	58.33	58.40	58.63	58.28	58.15	58.10	58.30	58.26	58.34	58.49				58.28	58.09	58.02	57.49	57.48	57.52
	22	51	57.01	57.72	58.08	58.21	58.23	58.63	58.29	58.74	58.92	58.77	58.59	58.80	58.43	58.63	59.01	59.53	59.52	59.77	59.39	59.19	59.16	59.37	59.28	59.54	59.74				59.43	59.11	58.93	58.28	58.38	58.45
		52	61.13	62.84	64.45	65.90	67.06	67.63	66.98	67.63	67.46	66.66	66.23	66.31	65.41	65.37	65.53	65.90	65.57	65.67	65.29	65.24	64.97	65.14	64.86	64.73	64.52				64.38	64.15	63.84	63.18	63.10	63.09
	23	53	60.07	61.53	62.97	64.21	65.24	65.72	65.02	65.67	65.39	64.69	64.29	64.34	63.48	63.40	63.57	63.87	63.60	63.66	63.37	63.36	63.05	63.27	62.97	62.78	62.55				62.09	61.88	61.63	61.02	60.93	60.90
		54	51.35	51.69	51.99	52.22	52.26	52.59	52.15	53.04	52.90	52.57	52.45	52.70	52.18	52.40	52.98	53.66	53.45	53.67	53.44	53.40	53.28	53.83	53.66	53.82	53.81				53.51	53.33	52.99	52.50	52.79	52.86
	24	55	51.67	52.13	52.52	52.75	52.78	53.22	52.76	53.77	53.72	53.26	53.14	53.43	52.83	53.04	53.59	54.30	54.07	54.37	54.23	54.30	54.19	54.70	54.52	54.63	54.56				54.52	54.43	54.18	53.65	53.87	53.96
	Ref	56	52.96	53.47	54.00	54.16	54.27	54.76	54.18	55.51	55.43	54.79	54.68	55.02	54.35	54.51	55.12	55.81	55.56	55.92	55.88	56.09	55.95	56.60	56.32	56.32	56.07				56.26	56.30	56.11	55.67	56.01	56.06

MAX TEMP (Ambient, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
50A																																				
IDEAL	1-3	1	23.37	23.48	23.45	23.95	23.75	23.61	23.47	23.24	23.33	23.51	23.61	23.55	23.58	23.74	24.22	24.47	24.45	24.44	24.16	23.67	23.68	23.65	23.62	23.84	24.15	24.10	23.45	23.10	23.61	23.43	23.42	22.93	22.84	22.87
WAGO	4-6	2	23.80	23.31	23.32	23.82	23.57	23.47	23.33	23.14	23.19	23.30	23.42	23.41	23.42	23.61	24.07	24.32	24.36	24.36	24.03	23.64	23.56	23.52	23.50	23.66	23.99	24.00	23.43	23.05	23.52	23.34	23.39	22.80	22.77	22.74
30A																																				
IDEAL	7-9	3	23.43	23.19	23.10	23.47	23.40	23.23	23.13	22.93	22.95	23.15	23.23	23.24	23.21	23.43	23.92	24.16	24.20	24.11	23.85	23.38	23.36	23.37	23.31	23.44	23.79	23.77	23.39	22.97	23.29	23.26	23.31	22.77	22.49	22.50
WAGO	10-12	4	23.59	23.19	23.13	23.49	23.41	23.26	23.11	22.92	22.96	23.18	23.27	23.24	23.25	23.51	23.98	24.25	24.16	24.08	23.84	23.38	23.33	23.33	23.28	23.40	23.85	23.80	23.38	22.97	23.23	23.22	23.28	22.75	22.51	22.49
Gardner Bender	13-15	5	23.66	23.21	23.15	23.67	23.49	23.31	23.12	22.92	23.06	23.21	23.30	23.28	23.25	23.56	24.04	24.38	24.19	24.08	23.84	23.37	23.28	23.35	23.27	23.44	24.01	23.82	23.43	23.12	23.21	23.18	23.24	22.73	22.47	22.46
20A																																				
IDEAL	16-18	6	23.58	23.28	23.22	23.76	23.53	23.36	23.16	23.03	23.10	23.31	23.37	23.38	23.38	23.65	24.11	24.30	24.28	24.21	23.93	23.48	23.35	23.44	23.36	23.54	23.97	23.92	23.43	23.10	23.28	23.17	23.23	22.72	22.55	No Data
WAGO	19-21	7	23.66	23.28	23.24	23.61	23.50	23.35	23.17	22.99	23.05	23.27	23.35	23.36	23.37	23.62	24.10	24.25	24.24	24.13	23.89	23.46	23.37	23.44	23.33	23.49	23.83	23.94	23.42	23.02	23.27	23.18	23.22	22.68	22.60	22.59
Gardner Bender	22-24	8	23.70	23.23	23.22	23.55	23.46	23.32	23.15	22.95	23.02	23.26	23.34	23.33	23.36	23.59	24.06	24.22	24.22	24.12	23.85	23.43	23.33	23.41	23.30	23.43	23.83	23.91	23.41	22.98	23.26	23.15	23.17	22.64	22.55	22.54

MIN TEMP (Ambient, °C)

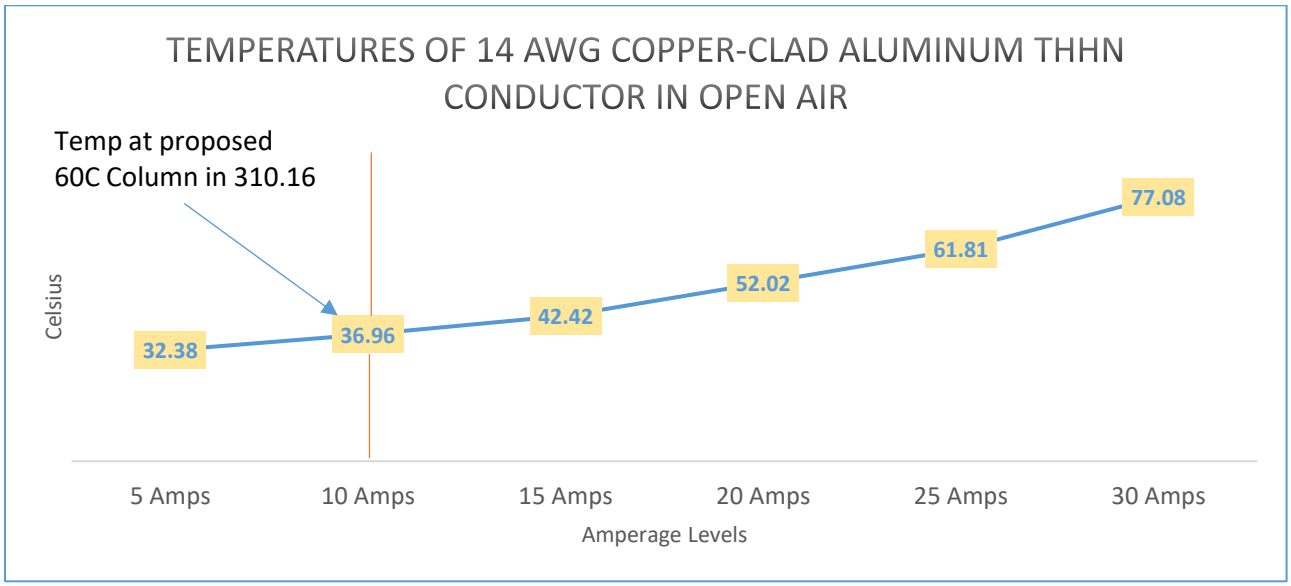
Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
50A																																				
IDEAL	1-3	1	22.86	23.21	23.18	23.24	23.38	23.21	23.09	23.04	22.91	23.06	23.28	23.23	23.27	23.39	23.69	24.13	24.13	23.99	23.67	23.31	23.28	23.39	23.31	23.36	23.63	23.42	22.87	22.71	22.65	23.16	22.61	22.37	22.37	22.49
WAGO	4-6	2	23.07	23.11	23.07	23.12	23.27	23.11	22.98	22.90	22.81	22.96	23.17	23.13	23.14	23.30	23.58	23.99	24.05	23.89	23.62	23.26	23.19	23.31	23.18	23.21	23.47	23.40	22.81	22.66	22.60	23.09	22.58	22.32	22.29	22.40
30A																																				
IDEAL	7-9	3	22.96	22.95	22.88	22.94	23.12	22.92	22.78	22.74	22.64	22.77	23.00	22.95	22.96	23.12	23.43	23.87	23.89	23.66	23.35	23.07	23.06	23.05	23.00	23.06	23.27	23.34	22.77	22.60	22.55	22.90	22.58	22.28	22.18	22.28
WAGO	10-12	4	22.96	22.99	22.92	22.97	23.15	22.94	22.78	22.71	22.66	22.82	23.03	22.98	22.99	23.13	23.47	23.91	23.92	23.68	23.32	23.06	23.07	23.05	23.01	23.03	23.27	23.35	22.79	22.63	22.55	22.89	22.61	22.26	22.21	22.28
Gardner Bender	13-15	5	22.98	22.99	22.91	22.99	23.15	22.94	22.78	22.71	22.64	22.84	23.01	22.98	22.99	23.13	23.50	23.95	23.90	23.66	23.34	23.06	23.06	23.03	22.98	23.03	23.30	23.37	22.82	22.70	22.57	22.87	22.58	22.21	22.19	22.27
20A																																				
IDEAL	16-18	6	23.06	23.04	23.00	23.05	23.24	23.03	22.82	22.79	22.71	22.95	23.11	23.05	23.07	23.21	23.61	24.07	24.02	23.74	23.44	23.15	23.10	23.16	23.05	23.09	23.37	23.39	22.83	22.70	22.54	22.95	22.55	22.20	22.22	No Data
WAGO	19-21	7	23.07	23.04	22.96	23.03	23.23	23.00	22.81	22.75	22.66	22.92	23.08	23.02	23.04	23.18	23.59	24.04	24.00	23.72	23.42	23.06	23.03	23.16	23.04	23.07	23.35	23.39	22.82	22.67	22.52	22.91	22.54	22.20	22.16	22.26
Gardner Bender	22-24	8	23.06	23.04	22.93	22.98	23.21	22.96	22.79	22.73	22.64	22.89	23.04	23.01	23.01	23.16	23.56	24.00	24.00	23.72	23.36	23.03	23.01	23.11	23.00	23.03	23.30	23.36	22.79	22.65	22.51	22.89	22.50	22.15	22.11	22.22

AVE TEMP (Ambient, °C)

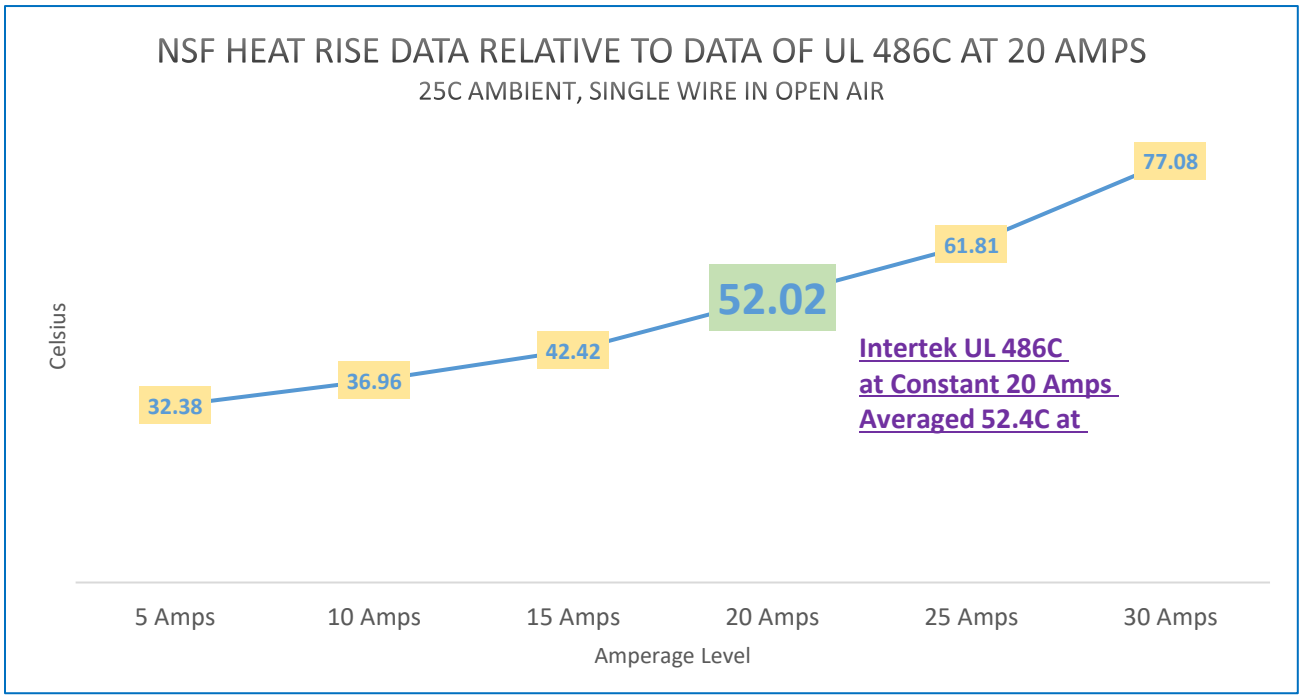
Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
50A																																				
IDEAL	1-3	1	23.23	23.31	23.29	23.44	23.51	23.41	23.26	23.16	23.07	23.28	23.41	23.40	23.42	23.58	23.99	24.28	24.29	24.18	23.92	23.57	23.47	23.51	23.43	23.58	23.86	23.69	23.24	22.92	23.29	23.28	23.14	22.73	22.68	22.69
WAGO	4-6	2	23.19	23.22	23.17	23.33	23.39	23.29	23.17	23.04	22.95	23.16	23.28	23.27	23.30	23.48	23.90	24.17	24.19	24.09	23.84	23.51	23.39	23.40	23.34	23.45	23.73	23.64	23.22	22.89	23.20	23.20	23.06	22.64	22.59	22.60
30A																																				
IDEAL	7-9	3	23.04	23.05	22.99	23.15	23.23	23.09	22.95	22.82	22.76	22.99	23.10	23.09	23.11	23.30	23.75	24.00	23.99	23.84	23.60	23.26	23.17	23.16	23.10	23.22	23.53	23.55	23.16	22.83	22.99	23.03	22.89	22.51	22.41	22.40
WAGO	10-12	4	23.06	23.07	23.02	23.18	23.26	23.11	22.96	22.83	22.78	23.02	23.13	23.11	23.13	23.33	23.78	24.04	24.01	23.83	23.60	23.27	23.18	23.17	23.10	23.24	23.56	23.56	23.16	22.84	23.00	23.01	22.88	22.50	22.40	22.40
Gardner Bender	13-15	5	23.07	23.08	23.02	23.20	23.26	23.12	22.96	22.82	22.78	23.03	23.14	23.11	23.13	23.34	23.80	24.07	24.02	23.84	23.59	23.24	23.16	23.15	23.08	23.25	23.59	23.59	23.22	22.91	23.00	22.98	22.85	22.46	22.37	22.37
20A																																				
IDEAL	16-18	6	23.18	23.17	23.09	23.26	23.35	23.23	23.04	22.92	22.86	23.13	23.23	23.22	23.24	23.46	23.94	24.20	24.17	23.95	23.71	23.34	23.23	23.25	23.16	23.36	23.68	23.65	23.20	22.90	23.06	23.04	22.89	22.47	22.43	No Data
WAGO	19-21	7	23.20	23.18	23.09	23.26	23.35	23.21	23.03	22.90	22.83	23.11	23.22	23.19	23.22	23.44	23.92	24.18	24.14	23.93	23.68	23.33	23.21	23.25	23.17	23.32	23.65	23.64	23.20	22.88	23.03	23.03	22.91	22.49	22.45	22.45
Gardner Bender	22-24	8	23.18	23.17	23.08	23.25	23.33	23.18	23.01	22.86	22.81	23.10	23.20	23.17	23.20	23.42	23.89	24.14	24.11	23.90	23.64	23.29	23.18	23.21	23.13	23.29	23.61	23.62	23.19	22.87	23.00	23.00	22.88	22.46	22.41	22.40

14 AWG CCA SAFE AT PROPOSED AMPERAGE OF TABLE 310.16:

UL 486C Testing Confirms NSF Data



Data Results of Fact Finding from NRTL Certified Electrical Lab, NSF. Orange Line Indicates Proposed Amperage of 14 AWG Copper-Clad Aluminum (ASTM B566) at 60C in Table 310.16



Average Heat Generated at 20 Amps by 14 AWG Copper-Clad Aluminum (ASTM B-566) is practically the same when comparing the testing done by NSF Electrical and that done by Intertek. Both labs are NRTL's with OSHA certified electrical labs. For 14 AWG CCA, NSF averaged 52.02C at 20 Amps, whereas Intertek Averaged 52.4C at 20 Amps.

14 AWG CCA SAFE AT PROPOSED AMPERAGE OF TABLE 310.16:

UL 486C Testing Confirms NSF Data

CONCLUSION:

At a temperature of 36.96 C° at Full Circuit of 10 Amps in the 60C column of proposed table 310.16, 14 AWG Copper-Clad Aluminum (ASTM B-566) is SAFE even considering elevated ambient temperatures. 75°C is the minimum temperature rating of insulation for the vast majority of general wiring applications, with the most utilized insulation types (THHN, XHHW, for example) rated at 90°C. All modern branch circuit components (switches, connectors, equipment and receptacles) are rated at a minimum of 75°C, most at 90°C. Even in severe overcurrent conditions, heat rise temperatures of 14 AWG Copper-Clad Aluminum (ASTM B-566) are well below the rating of the wire insulation and circuit components. OCPD's exist today for 10 Amp circuits, thus making 14 AWG Copper-Clad Aluminum wire a viable option. LED and Energy Star Equipment are driving the trend for more efficient circuits.

NRTL Credentials for NSF

Occupational Safety and Health Administration

Nationally Recognized Testing Laboratory Program

NRTLP

Certificate of Recognition

NSF International

with headquarters at:

789 Dixboro Road
Ann Arbor, Michigan 48105
United States

is recognized by the Occupational Safety and Health Administration (OSHA) as meeting the requirements for a Nationally Recognized Testing Laboratory (NRTL) established under Section 1910.7 of *Title 29, Code of Federal Regulations.* This recognition is limited to testing and certification only within the current scope of recognition and is subject to all other terms set forth in the letter of recognition and in applicable *Federal Register* notices and as summarized on OSHA's website. This recognition continues in force beyond the "*Effective through*" date below provided the NRTL has filed a timely request for renewal with OSHA. For current recognition status and other recognition information, contact the OSHA NRTL Program or visit *https://www.osha.gov/dts/otpca/nrtl/*

July 14, 2019
Effective Through

David Michaels, PhD, MPH
Assistant Secretary of Labor for
Occupational Safety and Health Administration

OSHA Scope of Recognition for NSF Electrical: https://www.osha.gov/dts/otpca/nrtl/nsf.html

Among other electrical equipment and circuit components, the NSF Scope of Recognition Includes Small Electrical Appliances, Wired Cabinets, Luminaires, Washers, Driers, Residential Water Heaters, Electric Ranges and Temperature Measuring Equipment. Heat Rise Testing is Routine at NSF.

Public Comment No. 1406-NFPA 70-2018 [Section No. 310.3(B)]

(B)

Conductor Material.

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

(1) Solid aluminum conductors 8, 10, and

~~12 AWG~~

12 AWG shall be made of an AA-8000 series electrical grade aluminum alloy conductor material.

(2) Stranded aluminum conductors

~~8 AWG through~~

8 AWG though 1000 kcmil marked as Type RHH, RHW, XHHW, XHHN, XHWN, THW, THHW, THWN, THHN, service-entrance Type SE

~~Style U~~

Style U , and SE Style R shall be made of an AA-8000 series electrical grade aluminum

~~alloy~~

allow conductor material.

(3) For

~~a~~

copper-clad aluminum conductor s , the copper shall form a minimum

~~of~~

10 percent of the cross-sectional area of a solid conductor or each strand of a stranded conductor. The aluminum core of a copper-clad aluminum conductor shall be made of an AA-8000 series ~~electric~~ electrical grade aluminum alloy conductor material. Copper-clad aluminum conductors shall be listed and labeled .

Additional Proposed Changes

File Name	Description	Approved
Prop_Revised_Text.pdf	Proposed Text 310.3(B) Conductor Material	
WC_CopperAluminum_LTR-1117_DIGITAL.pdf	UL DVVU2 Listing Program to Ensure CCA is ASTM B566	

Statement of Problem and Substantiation for Public Comment

Substantiation

- Correct Text as Intended for List. Please see the attachment to show how the intended text is to appear in the Code as Terra does not convert text to list very well and show the actual changes.
- Sequence of Conductor Types Consistent in Code. The sequence of the conductor types was rearranged to be consistent with how they are listed in other parts of the Code. The code panel did not provide any technical substantiation as to why the sequence in this section should not be consistent with the rest of the Code as stated in the original PI 2122 substantiation. The overall paragraph was further subdivided for clarity to users of the differing requirements and to permit better enforcement by Authorities Having Jurisdiction.
- Copper-Clad Aluminum Material Criteria. The original PI 2122 established four criteria for the material requirements of copper-clad aluminum. These are:
  - The 10% copper cladding by cross-section
  - The use of AA 8000 series aluminum for the core
  - Markings with the designation “MB”, and
  - Listing requirement.

Only the 10% cladding and requirement for AA- 8000 series aluminum are presented in the first draft. The code panel did not provide any technical substantiation for not including the marking requirement and that copper-clad aluminum bimetal materials needed to be listed. This public comment has attached information concerning the UL DVVU2 listing program designed to specifically to verify that the Copper Clad Aluminum of any particular conductor meets ASTM B-566, the governing Standard for this material.

- Listing is Important for Consistency with all Manufacturers. While the suggested marking may not be seen as important, the listing requirement is very critical in the NEC. The listing is the only means to ensure that the 10% cladding is provided on the conductor as required in ASTM B566, which UL adopted for the conductor recognized component listing. The presently UL listed copper-clad aluminum conductors have both a recognized component listing for the bimetal conductor material as well as an overall listing for the insulated conductors for the insulation (THHN/THWN, XHHW, THW) or cable assembly (NMB, SE, SER) being manufactured.
- Ensure Consistency for All Manufacturers with Listing Requirement. Without this requirement, copycat manufacturers using another testing laboratory could put copper-clad aluminum in the marketplace that did not have the metallurgically bonded oxygen free copper cladding bonded to the AA 8000 series aluminum core.

Related Item

- 2122

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 28 08:35:23 EDT 2018
Committee: NEC-P06

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Revised Text

310.3(B) Conductor Material.

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

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

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

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

WIRE AND CABLE

Limited-Power Wire and Cable Using Copper-Clad Aluminum Conductors

UL is pleased to offer a new service for wire and cable manufacturers who source components for use in limited-power applications (0.5mA/15W maximum or 30V/15W maximum)

Wire and Cable Incorporating Copper-Clad Aluminum (CCA) Conductors - Category OWLC2

This new category is designed for cable manufacturers to certify wires using CCA conductors for use in limited-power applications. This provides an additional certification option for wire and cable manufacturers who are looking for a cost-effective, limited evaluation program for products used in very specific applications.

Wires covered under this category are rated a maximum 80C. Any thermoplastic or thermoset insulation and/or jacket may be used. Any construction, including single and multi-conductor, jacketed, integrally insulated and jacketed or insulated conductors may be certified. The copper-clad aluminum (CCA) conductor used in these limited-power cables may be evaluated in the finished product or certified asa Recognized Component copper-clad aluminum conductor material.

The wires are evaluated in accordance with the Outline of Investigation SU 2880 for limited-power wire and cable using copper-clad aluminum conductors.

Program Benefits

- Clear differentiation in the highly competitive market
- Limited test program geared to the limited-power applications
- Gain global market acceptance through well-proven global programs
- Opportunity for product promotion through the new, optional features of UL's IQ™ Family of Databases
- Address the growing concern of safety and compliance in the consumer electronics industry
- Enhance product traceability and support customers' global manufacturing and procurement footprint
- Reduce redundant testing, accelerate time-to-market and protect company reputation
- Ensure compliance and reduce liability and risk to all stakeholders in the supply chain
- Build customer trust and brand equity in a sustainable way
- Protect products through our valuable Anti-Counterfeiting Program

Copper-Clad Aluminum Conductor Material - Category DVVU2

The Outline of Investigation for limited-power wire and cable using copper-clad aluminum conductors includes the requirements for the conductor material. If a Recognized Componentcopper-clad aluminum conductor material is sourced, several tests may be eliminated from the evaluation of the finished limited-power cable. Using a certified CCA conductor places the responsibility of maintaining a compliant conductor with the manufacturer of the conductor.

Conductor material evaluated under this program meets the tensile strength, elongation, resistivity and copper thickness requirements of ASTM B 566, the standard specification for copper-clad aluminum wire in sizes 36 AWG – 1/0. Two grades are available:

- Class 10A for those annealed conductors with a nominal 10% copper by volume
- Class 15A for those annealed conductors with a nominal 15% copper by volume

Please reach out to your UL representative via UL.com/contactwc.

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Public Comment No. 1721-NFPA 70-2018 [Section No. 310.4]

310.4 Conductor Constructions and Applications.

Insulated conductors shall comply with Table 310.4(A) andTable 310.4(B).

Informational Note: Thermoplastic insulation may stiffen at temperatures lower than −10°C (+14°F). Thermoplastic insulation may also be deformed at normal temperatures where subjected to pressure, such as at points of support.

Table 310.4(A) Conductor Applications and Insulations Rated 600 Volts[1]

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation				C Cov
					AWG or kcmil	mm	mils		
Fluorinated ethylene propylene	FEP or FEPB	90°C (194°F)	Dry and damp locations	Fluorinated ethylene propylene	14–10	0.51	20		Non
					8–2	0.76	30		-
		200°C (392°F)			14–8	0.36	14		Glas
			Dry locations — special applications[3]	Fluorinated ethylene propylene	6–2	0.36	14		Glas othe suita braid mat
Mineral insulation (metal sheathed)	MI	90°C (194°F)	Dry and wet locations	Magnesium oxide	18–16[4]	0.58	23		Cop alloy
		250°C (482°F)	For special applications[3]		16–10	0.91	36		
					9–4	1.27	50		
					3–500	1.40	55		
Moisture-, heat-, and oil-resistant thermoplastic	MTW	60°C (140°F)	Machine tool wiring in wet locations	Flame-retardant, moisture-, heat-, and oil-resistant thermoplastic	-		(A)	(B) (A)	
		90°C (194°F)	Machine tool wiring in dry locations.		22–12	0.76	0.38	30 15	
			-		10	0.76	0.51	30 20	
			-		-	8	1.14	0.76 45	
			-			6	1.52	0.76 60	
			-		Informational Note: See NFPA 79.	4–2	1.52	1.02 60	
			-			1–4/0	2.03	1.27 80	
			-			213–500	2.41	1.52 95	
			-			501–1000	2.79	1.78 110	
Paper	-		85°C (185°F)	For underground service conductors, or by special permission	Paper	-	-	-	
Perfluoro-alkoxy	PFA	90°C (194°F)	Dry and damp locations	Perfluoro-alkoxy	14–10	0.51	20		Non
					8–2	0.76	30		
		200°C (392°F)	Dry locations — special applications[3]		1–4/0	1.14	45		
					-	-	-		
Perfluoro-alkoxy	PFAH	250°C (482°F)	Dry locations only. Only for leads within apparatus or within raceways connected to apparatus (nickel or nickel-coated copper only)	Perfluoro-alkoxy	14–10	0.51	20		Non
					8–2	0.76	30		

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation			C Cov
					AWG or kcmil	mm	mils	
					1–4/0	1.14	45	
Thermoset	RHH	90°C (194°F)	Dry and damp locations	-		14-10	1.14	4
						8–2	1.52	6
						1–4/0	2.03	8
						213–500	2.41	9
						501–1000	2.79	11
						1001–2000	3.18	12
Moisture-resistant thermoset	RHW	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoset	14–10	1.14	45	Mois resis flam reta non cove
					8–2	1.52	60	
					1–4/0	2.03	80	
	RHW-2	90°C (194°F)			213–500	2.41	95	
					501–1000	2.79	110	
					1001–2000	3.18	125	
Silicone	SA	90°C (194°F) 200°C (392°F)	Dry and damp locations For special application[3]	Silicone rubber	14–10	1.14	45	Glas othe suita braid mat
					8–2	1.52	60	
					1–4/0	2.03	80	
					213–500	2.41	95	
					501–1000	2.79	110	
					1001–2000	3.18	125	
Thermoset	SIS	90°C (194°F)	Switchboard and switchgear wiring only	Flame-retardant thermoset	14–10	0.76	30	Non
					8–2	1.14	45	
					1–4/0	~~2~~ 1 .41 40	55	
Thermoplastic and fibrous outer braid	TBS	90°C (194°F)	Switchboard and switchgear wiring only	Thermoplastic	14–10	0.76	30	Flan reta non cove
					8	1.14	45	
					6–2	1.52	60	
					1–4/0	2.03	80	
Extended polytetra-fluoro-ethylene	TFE	250°C (482°F)	Dry locations only. Only for leads within apparatus or within raceways connected to apparatus, or as open wiring (nickel or nickel-coated copper only)	Extruded polytetra-fluoroethylene	14–10	0.51	20	Non
					8–2	0.76	30	
					1–4/0	1.14	45	
Heat-resistant thermoplastic	THHN	90°C (194°F)	Dry and damp locations	Flame-retardant, heat-resistant thermoplastic	14–12	0.38	15	Nylo jack equi
					10	0.51	20	
					8–6	0.76	30	
					4–2	1.02	40	
					1–4/0	1.27	50	
					250–500	1.52	60	
					501–1000	1.78	70	
Moisture- and heat-resistant thermoplastic	THHW	75°C (167°F)	Wet location	Flame-retardant, moisture- and	14–10	0.76	30	Non
					8	1.14	45	
					6–2	1.52	60	

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation			C Cov
					AWG or kcmil	mm	mils	
		90°C (194°F)	Dry location	heat-resistant thermoplastic	1–4/0 213–500 501–1000 1001–2000	2.03 2.41 2.79 3.18	80 95 110 125	
Moisture- and heat-resistant thermoplastic	THW	75°C (167°F) 90°C (194°F)	Dry and wet locations Special applications within electric discharge lighting equipment. Limited to 1000 open-circuit volts or less. (Size 14-8 only as permitted in 410.68.)	Flame-retardant, moisture- and heat-resistant thermoplastic	14–10 8 6–2 1–4/0 213–500 501–1000 1001–2000	0.76 1.14 1.52 2.03 2.41 2.79 3.18	30 45 60 80 95 110 125	Non
	-	THW-2	90°C (194°F)	Dry and wet locations	-	-	-	-
Moisture- and heat-resistant thermoplastic	THWN	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture- and heat-resistant thermoplastic	14–12 10 8–6 4–2	0.38 0.51 0.76 1.02	15 20 30 40	Nylo jack equi
	THWN-2	90°C (194°F)			1–4/0 250–500 501–1000	1.27 1.52 1.78	50 60 70	
Moisture-resistant thermoplastic	TW	60°C (140°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoplastic	14–10 8 6–2 1–4/0 213–500 501–1000 1001–2000	0.76 1.14 1.52 2.03 2.41 2.79 3.18	30 45 60 80 95 110 125	Non
Underground feeder and branch-circuit cable — single conductor (for Type UF cable employing more than one conductor, see Article 340).	UF	60°C (140°F) 75°C (167°F)[5]	See Article 340.	Moisture-resistant Moisture- and heat-resistant	14–10 8–2 1–4/0	1.52 2.03 2.41	60[6] 80[6] 95[6]	Inte with insu
Underground service-	USE	75°C (167°F)[5]	See Article 338.	Heat- and moisture-	14–10 8–2	1.14 1.52	45 60	Mois resis

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation			C Cov
					AWG or kcmil	mm	mils	
entrance cable — single conductor (for Type USE cable employing more than one conductor, see Article 338).				resistant	1–4/0	2.03	80	nonı cove (See 338.
					213–500	2.41	95 [7]	
					501–1000	2.79	110	
					1001–2000	3.18	125	
	USE-2	90°C (194°F)	Dry and wet locations					
Thermoset	XHH	90°C (194°F)	Dry and damp locations	Flame-retardant thermoset	14–10	0.76	30	Non
					8–2	1.14	45	
					1–4/0	1.40	55	
					213–500	1.65	65	
					501–1000	2.03	80	
					1001–2000	2.41	95	
Thermoset	XHHN	90°C (194°F)	Dry and damp locations	Flame-retardant thermoset	14–12	0.38	15	Nylc jack equi
					10	0.51	20	
					8–6	0.76	30	
					4–2	1.02	40	
					1–4/0	1.27	50	
					250–500	1.52	60	
					501–1000	1.78	70	
Moisture-resistant thermoset	XHHW	90°C (194°F)	Dry and damp locations	Flame-retardant, moisture-resistant thermoset	14–10	0.76	30	Non
					8–2	1.14	45	
		75°C (167°F)	Wet locations		1–4/0	1.40	55	
					213–500	1.65	65	
					501–1000	2.03	80	
					1001–2000	2.41	95	
Moisture-resistant thermoset	XHHW-2	90°C (194°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoset	14–10	0.76	30	Non
					8–2	1.14	45	
					1–4/0	1.40	55	
					213–500	1.65	65	
					501–1000	2.03	80	
					1001–2000	2.41	95	
Moisture-resistant thermoset	XHWN	75°C (167°F)	Dry and wet locations	Flame-retardant, moisture-resistant thermoset	14–12	0.38	15	Nylc jack equi
					10	0.51	20	
					8–6	0.76	30	
	XHWN-2	90°C (194°F)			4–2	1.02	40	
					1–4/0	1.27	50	
					250–500	1.52	60	
					501–1000	1.78	70	
Modified ethylene tetrafluoro-ethylene	Z	90°C (194°F)	Dry and damp locations	Modified ethylene tetrafluoro-ethylene	14–12	0.38	15	Non
					10	0.51	20	
		150°C	Dry locations		8–4	0.64	25	

Trade Name	Type Letter	Maximum Operating Temperature	Application Provisions	Insulation	Thickness of Insulation			C Cov
					AWG or kcmil	mm	mils	
		(302°F)	— special applications[3]		3–1 1/0–4/0	0.89 1.14	35 45	
Modified ethylene tetrafluoro-ethylene	ZW	75°C (167°F)	Wet locations	Modified ethylene tetrafluoro-ethylene	14–10	0.76	30	Non
		90°C (194°F)	Dry and damp locations					
		150°C (302°F)	Dry locations — special applications[3]		8–2	1.14	45	
	ZW-2	90°C (194°F)	Dry and wet locations					

[1]Conductors shall be permitted to be rated up to 1000 volts if listed and marked.

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

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

[4] ~~For signaling circuits permitting 300-volt insulation.~~

~~[5] For ampacity limitation, see~~

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

[6]

~~Includes~~

Type UF insulation thickness shall include the integral jacket.

[7] Insulation thickness shall be permitted to be 2.03 mm (80 mils) for listed Type USE conductors that have been subjected to special investigations. The nonmetallic covering over individual rubber-covered conductors of aluminum-sheathed cable and of lead-sheathed or multiconductor cable shall not be required to be flame retardant.

~~For Type MC cable, see 330.104. For nonmetallic-sheathed cable, see Article 334, Part III. For Type UF cable, see Article 340, Part III.~~

-

Table 310.4(B) Thickness of Insulation for Nonshielded Types RHH and RHW Solid Dielectric Insulated Conductors Rated 2000 Volts

Conductor Size (AWG or kcmil)
-
Column A [1]
-
Column B [2]
-
mm mils
-
mm mils

	mm	mils
14–10		
-		
2.03	80	
-		
1.52	60	
8		
-		
2.03	80	
-		
1.78	70	
6–2		
-		
2.41	95	
-		
1.78	70	
1–2/0		
-		
2.79	110	
-		
2.29	90	
3/0–4/0		
-		
2.79	110	
-		
2.29	90	
213–500		
-		
3.18	125	
-		
2.67	105	
501–1000		
-		
3.56	140	
-		
3.05	120	
1001–2000		

-

3.56	140

-

3.56	140

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

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

Statement of Problem and Substantiation for Public Comment

The mm equivalent of 55 mils for SIS cable was corrected from 2.41 to 1.40. The notes at the bottom of the table were edited to mandatory language. I could not find Note 4 in the table, so I deleted that language.
(Terra underlined far more than the changes I made.)

Related Item

• FR 8030

Submitter Information Verification

Submitter Full Name: Christel Hunter
Organization: Cerro Wire
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 29 18:11:02 EDT 2018
Committee: NEC-P06

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Public Comment No. 455-NFPA 70-2018 [Section No. 310.6(C)]

(C) Ungrounded Conductors.

Conductors that are intended for use as ungrounded conductors, whether used as a single conductor or in multiconductor cables, shall be finished to be clearly distinguishable from grounded, ~~grounding,~~ and bonding conductors. Distinguishing markings shall not conflict in any manner with the surface markings required by 310.8(B)(1). Branch-circuit ungrounded conductors shall be identified in accordance with 210.5(C). Feeders shall be identified in accordance with 215.12.

Exception: Conductor identification shall be permitted in accordance with 200.7.

Statement of Problem and Substantiation for Public Comment

PI 3340 should be accepted in part.

The submitter is correct that the section needs to specify what grounding conductors. The words "equipment grounding conductors" should be added, but the term "grounding conductors" should be deleted. There is no code requirement that specifies the color of the grounding electrode conductor. The current wording and the proposed wording would prohibit the use of any conductor with a finish of the same color as any ungrounded conductor from being used as a grounding electrode conductor. Black is the most common conductor finish used for grounding electrode conductors, but its use is prohibited by both the existing language and the language in this PI.

Related Item

• Public Input No. 3340-NFPA 70-2017

Submitter Information Verification

Submitter Full Name: Don Ganiere
Organization: [Not Specified]
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 07 19:32:44 EDT 2018
Committee: NEC-P06

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Public Comment No. 575-NFPA 70-2018 [Section No. 310.6(C)]

(C) Ungrounded Conductors.

~~Conductors~~ The insulation on conductors that are intended for use as ungrounded conductors, whether used as a single conductor or in multiconductor cables, shall be finished to be clearly distinguishable from grounded, ~~grounding,~~ and ~~bonding conductors~~ equipment grounding conductors . Distinguishing markings shall not conflict in any manner with the surface markings required by 310.8(B)(1). Branch-circuit ungrounded conductors shall be identified in accordance with 210.5(C). Feeders shall be identified in accordance with 215.12.

Exception: Conductor insulation identification shall be permitted in accordance with 200.7.

Statement of Problem and Substantiation for Public Comment

Though it may be understood by some that it is the insulation rather than the conductor that has the color or marking, here's an opportunity to make that distinction.
The term "grounding conductor" is no longer used in the NEC.
Equipment bonding jumpers are to be identified the same as equipment grounding conductors. There is no color identification in the NEC for other bonding conductors such as supply-side bonding jumpers. .

Related Item

• FR-8030

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 12 00:19:58 EDT 2018
Committee: NEC-P06

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Public Comment No. 1227-NFPA 70-2018 [Section No. 310.8(B)(1)]

(1) Surface Marking.

The following conductors and cables shall be durably marked on the surface. The AWG size or circular mil area shall be repeated at intervals not exceeding 610 mm (24 in.). All other markings shall be repeated at intervals not exceeding 1.0 m (40 in.).

(1) Single-conductor and multiconductor rubber- and thermoplastic-insulated wire and cable

(2) Nonmetallic-sheathed cable

(3) Service-entrance cable

(4) Underground feeder and branch-circuit cable

(5) Tray cable

(6) Irrigation cable

(7) Power-limited tray cable

(8) Instrumentation tray cable

Additional Proposed Changes

File Name	Description	Approved
CN_8.pdf	70_CN8	

Statement of Problem and Substantiation for Public Comment

NOTE: This Public Comment appeared as CC Note No. 8 in the First Draft Report.

The Correlating Committee directs that the panel reconsider the location of text, “The AWG size or circular mil area shall be repeated at intervals not
exceeding 610 mm (24 in.). All other markings shall be repeated at intervals not exceeding 1.0 m (40 in.).” to be relocated for clarity to appear after list
item number (8). This action will be considered as a public comment.

Related Item

• Correlating Committee Note No. 8

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC
Organization: NEC Correlating Committee
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 24 13:41:56 EDT 2018
Committee: NEC-P06

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Correlating Committee Note No. 8-NFPA 70-2018 [Section No. 310.8(B)(1)]

Submitter Information Verification

Submitter Full Name: Sarah Caldwell
Committee:
Submittal Date: Wed May 09 11:54:12 EDT 2018

Committee Statement and Meeting Notes

Committee Statement: The Correlating Committee directs that the panel reconsider the location of text, "The AWG size or circular mil area shall be repeated at intervals not exceeding 610 mm (24 in.). All other markings shall be repeated at intervals not exceeding 1.0 m (40 in.)." to be relocated for clarity to appear after list item number (8). This action will be considered as a public comment.

Ballot Results

This item has passed ballot

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

Affirmative All

Brunssen, James E.
Dressman, Kevin L.
Hickman, Palmer L.
Hittinger, David L.
Holub, Richard A.
Johnston, Michael J.
Kovacik, John R.
Manche, Alan
McDaniel, Roger D.
Pierce, James F.
Saporita, Vincent J.
Williams, David A.

Public Comment No. 1724-NFPA 70-2018 [Section No. 310.8(B)(1)]

(1) Surface Marking.

The following conductors and cables shall be durably marked on the surface. ~~The AWG size or circular mil area shall be repeated at intervals not exceeding 610 mm (24 in.). All other markings shall be repeated at intervals not exceeding 1.0 m (40 in.).~~

(1) Single-conductor and multiconductor ~~rubber~~ thermoset - and thermoplastic-insulated wire and cable

(2) Nonmetallic-sheathed cable

(3) Service-entrance cable

(4) Underground feeder and branch-circuit cable

(5) Tray cable

(6) Irrigation cable

(7) Power-limited tray cable

(8) Instrumentation tray cable

The AWG size or circular mil area shall be repeated at intervals not exceeding 610 mm (24 in.). All other markings shall be repeated at intervals not exceeding 1.0 m (40 in.).

Statement of Problem and Substantiation for Public Comment

Rubber was changed to thermoset to harmonize with changes made elsewhere in the NEC. Two sentences were moved after the list for clarity.

Related Item

• FR 8030

Submitter Information Verification

Submitter Full Name: Christel Hunter
Organization: Cerro Wire
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 29 18:22:02 EDT 2018
Committee: NEC-P06

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Public Comment No. 1229-NFPA 70-2018 [Section No. 310.8(B)(2)]

(2) Marker Tape.

Metal-covered multiconductor cables shall employ a marker tape located within the cable and running for its complete length.

Exception No. 1: Type MI cable.

Exception No. 2: Type AC cable.

Exception No. 3: The information required in 310.8(A) shall be permitted to be durably marked on the outer nonmetallic covering of Type MC, Type ITC, or Type PLTC cables at intervals not exceeding 1.0 m (40 in.).

Exception No. 4: The information required in 310.8(A) shall be permitted to be durably marked on a nonmetallic covering under the metallic sheath of Type ITC or Type PLTC cable at intervals not exceeding 1.0 m (40 in.).

Informational Note: Included in the group of metal-covered cables are Type AC cable (Article 320), Type MC cable (Article 330), and lead-sheathed cable.

Additional Proposed Changes

File Name	Description	Approved
CN_9.pdf	70_CN9	

Statement of Problem and Substantiation for Public Comment

NOTE: This Public Comment appeared as CC Note No. 9 in the First Draft Report.

The Correlating Committee directs that Exception No. 1 and Exception No. 2 be rewritten as complete sentences and in mandatory text in
accordance with the NEC® Style Manual. This action will be considered as a public comment.

Related Item

• Correlating Committee Note No. 9

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC
Organization: NEC Correlating Committee
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 24 13:44:08 EDT 2018
Committee: NEC-P06

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Correlating Committee Note No. 9-NFPA 70-2018 [Section No. 310.8(B)(2)]

Submitter Information Verification

Submitter Full Name: Sarah Caldwell
Committee:
Submittal Date: Wed May 09 11:59:01 EDT 2018

Committee Statement and Meeting Notes

Committee Statement: The Correlating Committee directs that Exception No. 1 and Exception No. 2 be rewritten as complete sentences and in mandatory text in accordance with the NEC® Style Manual. This action will be considered as a public comment.

Ballot Results

This item has passed ballot

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

Affirmative All

Brunssen, James E.
Dressman, Kevin L.
Hickman, Palmer L.
Hittinger, David L.
Holub, Richard A.
Johnston, Michael J.
Kovacik, John R.
Manche, Alan
McDaniel, Roger D.
Pierce, James F.
Saporita, Vincent J.
Williams, David A.

Public Comment No. 956-NFPA 70-2018 [New Section after 310.8(D)]

TITLE OF NEW CONTENT

310.6E Installation of Conductor and Cable Markings

An effort to install conductors and cables shall be made in a manner that does not conceal manufacturer markings at all enclosures, junction boxes, cabinets, pull points, and similar conductor and cable accessible points.

Statement of Problem and Substantiation for Public Comment

It is difficult for inspectors to inspect a job, service electricians to do their work, estimators, etc. when you can't read manufacturer markings on the conductors or cables. This new code proposal would mean it would now be a violation to phase tape the entire exposed length of a conductor within an enclosure. This would work nicely with things like 200.6B4 and 250.119A2c. It also means, install the conductors facing the enclosure opening. This is all within reason considering the manufacturer marking intervals on conductors and cables. That's why I wrote "An effort to install…" in the proposal. It considers manufacturer interval markings, varied conductor length, concealment by adjacent conductors, etc.
This proposal would apply more to conductors than cables since cable jackets are removed at their enclosure destinations.

Related Item

• 310.6E formerly 310.120

Submitter Information Verification

Submitter Full Name: Norman Feck
Organization: State of Colorado
Street Address:
City:
State:
Zip:
Submittal Date: Mon Aug 20 18:47:59 EDT 2018
Committee: NEC-P06

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Public Comment No. 410-NFPA 70-2018 [Section No. 310.10(G)(5)]

(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.

Statement of Problem and Substantiation for Public Comment

EGCs are not required to comply with 310.10(H/G)(1), sized 1/0 AWG and larger. Having '1/0 AWG in 310.10(H)(5) adds confusion.

Related Item

• PI-2436

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 05 09:17:06 EDT 2018
Committee: NEC-P06

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Public Comment No. 1242-NFPA 70-2018 [Section No. 310.12]

310.12 Single-Phase Dwelling Services and Feeders.

For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, service and feeder conductors supplied by a single-phase, 120/240-volt system shall be permitted to be sized in accordance with 310.12(A) through (D).

For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, single-phase feeder conductors consisting of 2 ungrounded conductors and the neutral conductor from a 208Y/120 volt system shall be permitted to be sized in accordance with 310.12(A) through (D).

(A)

For a service rated 100 amperes through 400 amperes, the service conductors supplying the entire load associated with a one-family dwelling, or the service conductors supplying the entire load associated with an individual dwelling unit in a two-family or multifamily dwelling, shall be permitted to have an ampacity not less than 83 percent of the service rating. If no adjustment or correction factors are required, Table 310.12 shall be permitted to be applied.

(B)

For a feeder rated 100 amperes through 400 amperes, the feeder conductors supplying the entire load associated with a one-family dwelling, or the feeder conductors supplying the entire load associated with an individual dwelling unit in a two-family or multifamily dwelling, shall be permitted to have an ampacity not less than 83 percent of the feeder rating. If no adjustment or correction factors are required, Table 310.12 shall be permitted to be applied.

(C)

In no case shall a feeder for an individual dwelling unit be required to have an ampacity greater than that specified in 310.12(A) or (B).

(D)

Grounded conductors shall be permitted to be sized smaller than the ungrounded conductors, if the requirements of 220.61 and 230.42 for service conductors or the requirements of 215.2 and 220.61 for feeder conductors are met.

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

Informational Note No. 1: The service or feeder ratings addressed by this section are based on the standard ampere ratings for fuses and inverse time circuit breakers from 240.6(A).

Informational Note No. 2: See Example D7 in Annex D.

Table 310.12 Single-Phase Dwelling Services and Feeders

-	Conductor (AWG or kcmil)	
Service or Feeder Rating(Amperes)	Copper	Aluminum or Copper-Clad Aluminum
100	4	2
110	3	1
125	2	1/0
150	1	2/0
175	1/0	3/0
200	2/0	4/0
225	3/0	250
250	4/0	300
300	250	350
350	350	500
400	400	600

Note: If no adjustment or correction factors are required, this table shall be permitted to be applied.

Additional Proposed Changes

File Name	Description	Approved
CN_10.pdf	70_CN10	

Statement of Problem and Substantiation for Public Comment

NOTE: This Public Comment appeared as CC Note No. 10 in the First Draft Report.

The Correlating Committee directs that the panel use a list item format in this section in accordance with the NEC® Style Manual. As written, these
are not first level subdivisions. This action will be considered as a public comment.

Related Item

• Correlating Committee Note No. 10

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC
Organization: NEC Correlating Committee
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 24 14:24:09 EDT 2018
Committee: NEC-P06

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Correlating Committee Note No. 10-NFPA 70-2018 [Section No. 310.12]

Submitter Information Verification

Submitter Full Name: Sarah Caldwell
Committee:
Submittal Date: Wed May 09 12:01:19 EDT 2018

Committee Statement and Meeting Notes

Committee Statement: The Correlating Committee directs that the panel use a list item format in this section in accordance with the NEC® Style Manual. As written, these are not first level subdivisions. This action will be considered as a public comment.

Ballot Results

This item has passed ballot

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

Affirmative All

Brunssen, James E.
Dressman, Kevin L.
Hickman, Palmer L.
Hittinger, David L.
Holub, Richard A.
Johnston, Michael J.
Kovacik, John R.
Manche, Alan
McDaniel, Roger D.
Pierce, James F.
Saporita, Vincent J.
Williams, David A.

Public Comment No. 388-NFPA 70-2018 [Section No. 310.12]

310.12 Single-Phase Dwelling Services and Feeders.

~~For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, service and feeder conductors supplied by a single-phase, 120/240-volt system shall be permitted to be sized in accordance with 310.12(A) through (D).~~

~~For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, single-phase feeder conductors consisting of 2 ungrounded conductors and the neutral conductor from a 208Y/120 volt system shall be permitted to be sized in accordance with 310.12(A) through (D).~~

~~**(A)**~~

~~For a service rated 100 amperes through 400 amperes, the service conductors supplying the entire load associated with a one-family dwelling, or the service conductors supplying the entire load associated with an individual dwelling unit in a two-family or multifamily dwelling, shall be permitted to have an ampacity not less than 83 percent of the service rating. If no adjustment or correction factors are required, Table 310.12 shall be permitted to be applied.~~

~~**(B)**~~

~~For a feeder rated 100 amperes through 400 amperes, the feeder conductors supplying the entire load associated with a one-family dwelling, or the feeder conductors supplying the entire load associated with an individual dwelling unit in a two-family or multifamily dwelling, shall be permitted to have an ampacity not less than 83 percent of the feeder rating. If no adjustment or correction factors are required, Table 310.12 shall be permitted to be applied.~~

~~**(C)**~~

~~In no case shall a feeder for an individual dwelling unit be required to have an ampacity greater than that specified in 310.12(A) or (B).~~

~~**(D)**~~

~~Grounded conductors shall be permitted to be sized smaller than the ungrounded conductors, if the requirements of 220.61 and 230.42 for service conductors or the requirements of 215.2 and 220.61 for feeder conductors are met.~~

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

> ~~Informational Note No. 1: The service or feeder ratings addressed by this section are based on the standard ampere ratings for fuses and inverse time circuit breakers from 240.6(A).~~
>
> ~~Informational Note No. 2: See Example D7 in Annex D.~~

~~Table 310.12 Single-Phase Dwelling Services and Feeders~~

~~Conductor (AWG or kcmil) Service or Feeder Rating(Amperes) Copper Aluminum or Copper-Clad Aluminum 100 4 2 110 3 1 125 2 1/0 150 1 2/0 175 1/0 3/0 200 2/0 4/0 225 3/0 250 250 4/0 300 300 250 350 350 350 500 400 400 600~~

~~Note: If no adjustment or correction factors are required, this table shall be permitted to be applied.~~

DELETE

Statement of Problem and Substantiation for Public Comment

Delete this rule because it violates 240.4 which states that "Conductors, other than flexible cords, flexible cables, and fixture wires, shall be protected against overcurrent in accordance with their ampacities specified in 310.15, unless otherwise permitted or required in 240.4(A) through (G)." Nothing in 240.4(A) through (G) permits the overcurrent protection device to exceed the ampacity of dwelling unit feeder/service conductors as contained in 310.12.

The effect of sizing the conductor to '83%' of the service disconnect results in the following violations of 240.4.

100A service, 4 AWG rated 85A, protected with a 100A OCPD - violation of 240.4.

110A service, 3 AWG rated 100A, protected with a 110A OCPD - violation of 240.4.

125A service, 2 AWG rated 115A, protected with a 125A OCPD - violation of 240.4.

150A service, 1 AWG rated 130A, protected with a 150A OCPD - okay per 240.4(B).

175A service, 1/0 AWG rated 150A, protected with a 175A OCPD - violation of 240.4.
200A service, 2/0 AWG rated 175A, protected with a 200A OCPD - violation of 240.4.
225A service, 3/0 AWG rated 200A, protected with a 225A OCPD - violation of 240.4.
250A service, 4/0 AWG rated 230A, protected with a 250A OCPD - okay per 240.4(B).
300A service, 250 kcmil rated 285A, protected with a 300A OCPD - okay per 240.4(B).
350A service, 350 kcmil rated 310A, protected with a 350A OCPD - violation of 240.4.
400A service, 400 kcmil rated 335A, protected with a 400A OCPD - violation of 240.4.
Recommendation No. 1: If code panel 6 feels that the load calculations contained in Article 220 for dwelling units are too high and want to feeder/service conductors sized to 83% of the calculated load, then code panel 6 should submit a comment to panel 2 for such a change.
Recommendation No. 2: If code panel 6 feels that the 'ampacity of these conductors' should be raised to accommodate the 83% rule so that they don't violate 240.4, then the code panel should make this change.
Recommendation No. 3: If code panel 6 feels that the load calculations contained in Article 220 for dwelling units are too high and want to feeder/service conductors sized to 83% of the calculated load and be protected as contained in this section, then code panel 6 should submit a comment to code panel 10 to recognize this condition in 240.4.
Good luck guys…

Related Item

• PI-1528

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Sat Aug 04 15:34:32 EDT 2018
Committee: NEC-P06

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Public Comment No. 576-NFPA 70-2018 [Section No. 310.12(D)]

(D)

Grounded conductors shall be permitted to be sized smaller than the ungrounded conductors, if the requirements of 220.61 and 230.42 for service conductors or the requirements of 215.2 and 220.61 for feeder conductors are met.

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

Informational Note No. 1: The service or feeder ratings addressed by this section are based on the standard ampere ratings for fuses and inverse time circuit breakers from 240.6(A).

Informational Note No. 2: See Example D7 in Annex D.

Table 310.12 Single-Phase Dwelling Services and Feeders

	Conductor (AWG or kcmil)	
Service or Feeder Rating(Amperes)	Copper	Aluminum or Copper-Clad Aluminum
100	4	2
110	3	1
125	2	1/0
150	1	2/0
175	1/0	3/0
200	2/0	4/0
225	3/0	250
250	4/0	300
300	250	350
350	350	500
400	400	600

Note: If no adjustment or correction factors are required, this table shall be permitted to be applied.

Statement of Problem and Substantiation for Public Comment

The temperature rating of concern is that of the insulation not the rating of the conductor material.

Related Item

- FR-8030

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 12 00:33:21 EDT 2018
Committee: NEC-P06

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Public Comment No. 1727-NFPA 70-2018 [Section No. 310.12 [Excluding any Sub-Sections]]

For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, service and feeder conductors supplied by a single-phase, 120/240-volt system shall be permitted to be sized in accordance with 310.12(A) through (D).

For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, single-phase feeder conductors consisting of 2 ungrounded conductors and the neutral conductor from a 208Y/120 volt system shall be permitted to be sized in accordance with 310.12(A) through (~~D~~ C).

Statement of Problem and Substantiation for Public Comment

The reference for a 208Y/120 system was changed from D to C, since the grounded conductor is not permitted to be sized smaller than the ungrounded conductors. This change corrects an editorial mistake and reflects the requirements as found in the 2017 NEC.

Related Item

- FR 8030

Submitter Information Verification

Submitter Full Name: Christel Hunter
Organization: Cerro Wire
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 29 18:28:15 EDT 2018
Committee: NEC-P06

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Public Comment No. 677-NFPA 70-2018 [Section No. 310.12 [Excluding any Sub-Sections]]

For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, service and feeder conductors supplied by a single-phase, 120/240-volt system shall be permitted to be sized in accordance with 310.12(A) through (D).

For one-family dwellings and the individual dwelling units of two-family and multifamily dwellings, single-phase feeder conductors consisting of 2 ungrounded conductors and the neutral conductor from a 208Y/120 volt system shall be permitted to be sized in accordance with 310.12(A) through (~~D~~ C).

Statement of Problem and Substantiation for Public Comment

I don't believe it was the intent of the committee to allow the 3 phase, 3 wire (2 ungrounded conductors with a neutral) installation, to reduce the size of the neutral conductor which is implied by (D).

Related Item

- FR 8030

Submitter Information Verification

Submitter Full Name: Dean Hunter
Organization: Minnesota Department of Labor
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 15 11:16:51 EDT 2018
Committee: NEC-P06

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Public Comment No. 1970-NFPA 70-2018 [New Section after 310.15(B)]

105 Degree C
Correction Factor
Correction Factor
Correction Factor
Correction Factor
Correction Factor
Correction Factor
Correction Factor
Correction Factor
Correction Factor

Statement of Problem and Substantiation for Public Comment

rooftop environments have extreme heat at the roof surface where wiring is located. Providing a correction factor column that applies to conductors and cables rated 105 allows increased safety and material flexibility when choosing a wiring method. There are available conductor types for use in applications under 2000V (residential service voltages and 3 phase commeicial voltages), but the NEC doesn't have a clear table for reference when applying correction factors.

Related Item

- FR-8918

Submitter Information Verification

Submitter Full Name: Christopher Fox
Organization: SunPower
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 30 13:16:23 EDT 2018
Committee: NEC-P06

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Public Comment No. 1976-NFPA 70-2018 [New Section after 310.15(B)]

Exception: Type XHHW-2 insulated conductors shall not be subject to this ampacity adjustment.

Statement of Problem and Substantiation for Public Comment

This exception has been in many code cycles and isn't here in the First Draft Report. I suspect it's a clerical error but it needs to be inserted back into this section.

Related Item

• FR-8918

Submitter Information Verification

Submitter Full Name: Christopher Fox
Organization: SunPower
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 30 13:24:34 EDT 2018
Committee: NEC-P06

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Public Comment No. 1420-NFPA 70-2018 [Section No. 310.15(B)]

(B) Ambient Temperature Correction Factors.

Ampacities for ambient temperatures other than those shown in the ampacity tables shall be corrected in accordance with Table 310.15(B)(1) or Table 310.15(B)(2), or shall be permitted to be calculated using Equation 310.15(B).

$$I' = I\sqrt{\frac{T_c - T_a'}{T_c - T_a}} \qquad \textbf{[310.15(B)]}$$

where:

I' = ampacity corrected for ambient temperature

I = ampacity shown in the tables

T_c = temperature rating of conductor (°C)

T_a' = new ambient temperature (°C)

T_a = ambient temperature used in the table (°C)

[Proposed table and text]

(c) *Raceways and Cables Exposed to Sunlight on Rooftops.*

Where raceways or cables are exposed to direct

sunlight on or above rooftops

~~. Where the distance above the roof to the bottom of the raceway or cable is less than 23 mm (7/8 in.), a temperature adder of 33°C (60°F)~~

, the adjustments shown in

Table 310.15(B)(3)(x) shall be added to the outdoor temperature

to determine the applicable ambient temperature for

application of the correction factors in

~~Table~~

tables...

Table 310.15(B)(
~~1) or Table 310.15(B)(2).~~
3)(x) Ambient Temperature Adjustment for Raceways or Cables Exposed to Sunlight on or Above Rooftops

Distance Above Roof to Bottom of Raceway or Cable	Temperature Adder °C	Temperature Adder °F
On roof 0 – 13 mm (0 — 1/2 in.)	33	60
Above 13 mm - 90 mm (1/2 in.- 3 1/2 in)	22	40
Above 90 mm – 300 mm (3 1/2 in. – 12 in.)	17	30
Above 300 mm – 900 mm (12 in. – 36 in.)	14	25

Table 310.15(B)(1) Ambient Temperature Correction Factors Based on 30°C (86°F)

For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor			Ambient Temperature (°F)
	60°C	75°C	90°C	
10 or less	1.29	1.20	1.15	50 or less
11–15	1.22	1.15	1.12	51–59
16–20	1.15	1.11	1.08	60–68
21–25	1.08	1.05	1.04	69–77
26–30	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	132–140
61–65	—	0.47	0.65	141–149
66–70	—	0.33	0.58	150–158
71–75	—	—	0.50	159–167
76–80	—	—	0.41	168–176
81–85	—	—	0.29	177–185

Table 310.15(B)(2) Ambient Temperature Correction Factors Based on 40ºC (104ºF)

For ambient temperatures other than 40°C (104°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor						Ambient Temperature (ºF)
	60°C	75°C	90°C	150°C	200°C	250°C	
10 or less	1.58	1.36	1.26	1.13	1.09	1.07	50 or less
11–15	1.50	1.31	1.22	1.11	1.08	1.06	51–59
16–20	1.41	1.25	1.18	1.09	1.06	1.05	60–68
21–25	1.32	1.2	1.14	1.07	1.05	1.04	69–77
26–30	1.22	1.13	1.10	1.04	1.03	1.02	78–86
31–35	1.12	1.07	1.05	1.02	1.02	1.01	87–95
36–40	1.00	1.00	1.00	1.00	1.00	1.00	96–104
41–45	0.87	0.93	0.95	0.98	0.98	0.99	105–113
46–50	0.71	0.85	0.89	0.95	0.97	0.98	114–122
51–55	0.50	0.76	0.84	0.93	0.95	0.96	123–131
56–60	—	0.65	0.77	0.90	0.94	0.95	132–140
61–65	—	0.53	0.71	0.88	0.92	0.94	141–149
66–70	—	0.38	0.63	0.85	0.90	0.93	150–158
71–75	—	—	0.55	0.83	0.88	0.91	159–167
76–80	—	—	0.45	0.80	0.87	0.90	168–176
81–90	—	—	—	0.74	0.83	0.87	177–194
91–100	—	—	—	0.67	0.79	0.85	195–212
101–110	—	—	—	0.60	0.75	0.82	213–230
111–120	—	—	—	0.52	0.71	0.79	231–248
121–130	—	—	—	0.43	0.66	0.76	249–266
131–140	—	—	—	0.30	0.61	0.72	267–284
141–160	—	—	—	—	0.50	0.65	285–320

For ambient temperatures other than 40°C (104°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor						Ambient Temperature (ºF)
	60°C	75°C	90°C	150°C	200°C	250°C	
161–180	—	—	—	—	0.35	0.58	321–356
181–200	—	—	—	—	—	0.49	357–392
201–225	—	—	—	—	—	0.35	393–437

Statement of Problem and Substantiation for Public Comment

The proposed change would restore Table 310.15(B)(3)(c) from the 2014 NEC language. Rooftop temperature adjustment factors in the 2014 NEC were placed in the code to augment existing rules as a result of exhaustive research were the quality of this research was intrinsically planned reviewed and verified by oversight of a leading nationally recognized third party research firm. The concepts and derived values of this multi year research program was then accepted and codified by NEC code panel 6 successively over a period of several code cycles. Other public inputs providing negative commentary to this topic were not held the the same standard and were not required to not required to provide proof of oversight. The decisions made by NEC Panel 6 to negate the long standing values exhibited in the text and table were thus based on unverified work, and where research was performed it was not properly peer reviewed or evaluated by a qualified third party agency . The text and table of 2014 NEC 310.15(B(3)(C) should therefore be reinstated.

Related Item

• Public Input No. 3481-NFPA 70-2017 [Section No. 310.15(B)(3)] Rooftop Temperature

Submitter Information Verification

Submitter Full Name: Travis Lindsey
Organization: TLC Services
Affiliation: Copper Development Association
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 28 12:05:14 EDT 2018
Committee: NEC-P06

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Public Comment No. 1729-NFPA 70-2018 [Section No. 310.15(B)]

(B) Ambient Temperature Correction Factors.

Ampacities for ambient temperatures other than those shown in the ampacity tables shall be corrected in accordance with Table 310.15(B)(1) or Table 310.15(B)(2), or shall be permitted to be calculated using Equation 310.15(B).

$$I' = I\sqrt{\frac{T_c - T_a'}{T_c - T_a}} \qquad \textbf{[310.15(B)]}$$

where:

I' = ampacity corrected for ambient temperature

I = ampacity shown in the tables

T_c = temperature rating of conductor (°C)

T_a' = new ambient temperature (°C)

T_a = ambient temperature used in the table (°C)

~~Raceways~~ For raceways or cables exposed to direct sunlight on or above rooftops ~~. Where~~ where the distance above the roof to the bottom of the raceway or cable is less than 23 mm (7/8 in.), a temperature adder of 33°C (60°F) shall be added to the outdoor temperature to determine the applicable ambient temperature for application of the correction factors in Table 310.15(B)(1) or Table 310.15(B)(2) .

Exception: Type XHHW-2 insulated conductors shall not be subject to this ampacity adjustment.

Informational Note: One source for the ambient temperature in various locations is the *ASHRAE Handbook - Fundamentals.*

Table 310.15(B)(1) Ambient Temperature Correction Factors Based on 30°C (86°F)

For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor			Ambient Temperature (°F)
	60°C	75°C	90°C	
10 or less	1.29	1.20	1.15	50 or less
11–15	1.22	1.15	1.12	51–59
16–20	1.15	1.11	1.08	60–68
21–25	1.08	1.05	1.04	69–77
26–30	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	132–140
61–65	—	0.47	0.65	141–149
66–70	—	0.33	0.58	150–158
71–75	—	—	0.50	159–167
76–80	—	—	0.41	168–176
81–85	—	—	0.29	177–185

Table 310.15(B)(2) Ambient Temperature Correction Factors Based on 40ºC (104ºF)

For ambient temperatures other than 40°C (104°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor						Ambient Temperature (ºF)
	60°C	75°C	90°C	150°C	200°C	250°C	
10 or less	1.58	1.36	1.26	1.13	1.09	1.07	50 or less
11–15	1.50	1.31	1.22	1.11	1.08	1.06	51–59
16–20	1.41	1.25	1.18	1.09	1.06	1.05	60–68

For ambient temperatures other than 40°C (104°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor						Ambient Temperature (ºF)
	60°C	75°C	90°C	150°C	200°C	250°C	
21–25	1.32	1.2	1.14	1.07	1.05	1.04	69–77
26–30	1.22	1.13	1.10	1.04	1.03	1.02	78–86
31–35	1.12	1.07	1.05	1.02	1.02	1.01	87–95
36–40	1.00	1.00	1.00	1.00	1.00	1.00	96–104
41–45	0.87	0.93	0.95	0.98	0.98	0.99	105–113
46–50	0.71	0.85	0.89	0.95	0.97	0.98	114–122
51–55	0.50	0.76	0.84	0.93	0.95	0.96	123–131
56–60	—	0.65	0.77	0.90	0.94	0.95	132–140
61–65	—	0.53	0.71	0.88	0.92	0.94	141–149
66–70	—	0.38	0.63	0.85	0.90	0.93	150–158
71–75	—	—	0.55	0.83	0.88	0.91	159–167
76–80	—	—	0.45	0.80	0.87	0.90	168–176
81–90	—	—	—	0.74	0.83	0.87	177–194
91–100	—	—	—	0.67	0.79	0.85	195–212
101–110	—	—	—	0.60	0.75	0.82	213–230
111–120	—	—	—	0.52	0.71	0.79	231–248
121–130	—	—	—	0.43	0.66	0.76	249–266
131–140	—	—	—	0.30	0.61	0.72	267–284
141–160	—	—	—	—	0.50	0.65	285–320
161–180	—	—	—	—	0.35	0.58	321–356
181–200	—	—	—	—	—	0.49	357–392
201–225	—	—	—	—	—	0.35	393–437

Statement of Problem and Substantiation for Public Comment

This is an editorial change to make the requirement into a complete sentence. Additionally, the Exception and Informational Note were relocated to the correct location after the rooftop requirement.

Related Item

- FR 8030

Submitter Information Verification

Submitter Full Name: Christel Hunter
Organization: Cerro Wire
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 29 18:37:50 EDT 2018
Committee: NEC-P06

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Public Comment No. 389-NFPA 70-2018 [Section No. 310.15(B)]

(B) Ambient Temperature Correction Factors.

Ampacities for ambient temperatures other than those shown in the ampacity tables shall be corrected in accordance with Table 310.15(B)(1) or Table 310.15(B)(2), or shall be permitted to be calculated using Equation 310.15(B).

$$I' = I\sqrt{\frac{T_c - T_a'}{T_c - T_a}} \qquad \textbf{[310.15(B)]}$$

where:

I' = ampacity corrected for ambient temperature

I = ampacity shown in the tables

T_c = temperature rating of conductor (°C)

T_a' = new ambient temperature (°C)

T_a = ambient temperature used in the table (°C)

Raceways or cables exposed to direct sunlight on or above rooftops. Where the distance above the roof to the bottom of the raceway or cable is less than 23 mm (⅞ in.), a temperature adder of 33°C (60°F) shall be added to the outdoor temperature to determine the applicable ambient temperature for application of the correction factors in Table 310.15(B)(1) or Table 310.15(B)(2).

Exception: Type XHHW-2 insulated conductors shall not be subject to this ampacity adjustment.

Table 310.15(B)(1) Ambient Temperature Correction Factors Based on 30°C (86°F)

For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor			Ambient Temperature (°F)
	60°C	75°C	90°C	
10 or less	1.29	1.20	1.15	50 or less
11–15	1.22	1.15	1.12	51–59
16–20	1.15	1.11	1.08	60–68
21–25	1.08	1.05	1.04	69–77
26–30	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	132–140
61–65	—	0.47	0.65	141–149
66–70	—	0.33	0.58	150–158
71–75	—	—	0.50	159–167
76–80	—	—	0.41	168–176
81–85	—	—	0.29	177–185

Table 310.15(B)(2) Ambient Temperature Correction Factors Based on 40ºC (104ºF)

For ambient temperatures other than 40°C (104°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor						Ambient Temperature (ºF)
	60°C	75°C	90°C	150°C	200°C	250°C	
10 or less	1.58	1.36	1.26	1.13	1.09	1.07	50 or less
11–15	1.50	1.31	1.22	1.11	1.08	1.06	51–59
16–20	1.41	1.25	1.18	1.09	1.06	1.05	60–68
21–25	1.32	1.2	1.14	1.07	1.05	1.04	69–77
26–30	1.22	1.13	1.10	1.04	1.03	1.02	78–86

For ambient temperatures other than 40°C (104°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor						Ambient Temperature (ºF)
	60°C	75°C	90°C	150°C	200°C	250°C	
31–35	1.12	1.07	1.05	1.02	1.02	1.01	87–95
36–40	1.00	1.00	1.00	1.00	1.00	1.00	96–104
41–45	0.87	0.93	0.95	0.98	0.98	0.99	105–113
46–50	0.71	0.85	0.89	0.95	0.97	0.98	114–122
51–55	0.50	0.76	0.84	0.93	0.95	0.96	123–131
56–60	—	0.65	0.77	0.90	0.94	0.95	132–140
61–65	—	0.53	0.71	0.88	0.92	0.94	141–149
66–70	—	0.38	0.63	0.85	0.90	0.93	150–158
71–75	—	—	0.55	0.83	0.88	0.91	159–167
76–80	—	—	0.45	0.80	0.87	0.90	168–176
81–90	—	—	—	0.74	0.83	0.87	177–194
91–100	—	—	—	0.67	0.79	0.85	195–212
101–110	—	—	—	0.60	0.75	0.82	213–230
111–120	—	—	—	0.52	0.71	0.79	231–248
121–130	—	—	—	0.43	0.66	0.76	249–266
131–140	—	—	—	0.30	0.61	0.72	267–284
141–160	—	—	—	—	0.50	0.65	285–320
161–180	—	—	—	—	0.35	0.58	321–356
181–200	—	—	—	—	—	0.49	357–392
201–225	—	—	—	—	—	0.35	393–437

Statement of Problem and Substantiation for Public Comment

The exception for roof top ampacity correction 15(B) was accidently place in the conductor ampacity adjustment 15(C)(1). So please add it back, if that is the intent.

Related Item

- FR8918

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Sat Aug 04 16:20:56 EDT 2018
Committee: NEC-P06

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Public Comment No. 464-NFPA 70-2018 [Section No. 310.15(B)]

(B) Ambient Temperature Correction Factors.

Ampacities for ambient temperatures other than those shown in the ampacity tables shall be corrected in accordance with Table 310.15(B)(1) or Table 310.15(B)(2), or shall be permitted to be calculated using Equation 310.15(B).

$$I' = I\sqrt{\frac{T_c - T_a'}{T_c - T_a}} \qquad \textbf{[310.15(B)]}$$

where:

I' = ampacity corrected for ambient temperature

I = ampacity shown in the tables

T_c = temperature rating of conductor (°C)

T_a' = new ambient temperature (°C)

T_a = ambient temperature used in the table (°C)

Raceways or cables exposed to direct sunlight on or above rooftops. Where the distance above the roof to the bottom of the raceway or cable is less than 23 mm (⅞ in.), a temperature adder of 33°C (60°F) shall be added to the outdoor temperature to determine the applicable ambient temperature for application of the correction factors in Table 310.15(B)(1) or Table 310.15(B)(2).

Table 310.15(B)(1) Ambient Temperature Correction Factors Based on 30°C (86°F)

For ambient temperatures other than 30°C (86°F), multiply the ~~allowable~~ ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor			Ambient Temperature (°F)
	60°C	75°C	90°C	
10 or less	1.29	1.20	1.15	50 or less
11–15	1.22	1.15	1.12	51–59
16–20	1.15	1.11	1.08	60–68
21–25	1.08	1.05	1.04	69–77
26–30	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	132–140
61–65	—	0.47	0.65	141–149
66–70	—	0.33	0.58	150–158
71–75	—	—	0.50	159–167
76–80	—	—	0.41	168–176
81–85	—	—	0.29	177–185

Table 310.15(B)(2) Ambient Temperature Correction Factors Based on 40ºC (104ºF)

For ambient temperatures other than 40°C (104°F), multiply the ~~allowable~~ ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor						Ambient Temperature (ºF)
	60°C	75°C	90°C	150°C	200°C	250°C	
10 or less	1.58	1.36	1.26	1.13	1.09	1.07	50 or less
11–15	1.50	1.31	1.22	1.11	1.08	1.06	51–59
16–20	1.41	1.25	1.18	1.09	1.06	1.05	60–68
21–25	1.32	1.2	1.14	1.07	1.05	1.04	69–77
26–30	1.22	1.13	1.10	1.04	1.03	1.02	78–86
31–35	1.12	1.07	1.05	1.02	1.02	1.01	87–95

For ambient temperatures other than 40°C (104°F), multiply the ~~allowable~~ ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor						Ambient Temperature (ºF)
	60°C	75°C	90°C	150°C	200°C	250°C	
36–40	1.00	1.00	1.00	1.00	1.00	1.00	96–104
41–45	0.87	0.93	0.95	0.98	0.98	0.99	105–113
46–50	0.71	0.85	0.89	0.95	0.97	0.98	114–122
51–55	0.50	0.76	0.84	0.93	0.95	0.96	123–131
56–60	—	0.65	0.77	0.90	0.94	0.95	132–140
61–65	—	0.53	0.71	0.88	0.92	0.94	141–149
66–70	—	0.38	0.63	0.85	0.90	0.93	150–158
71–75	—	—	0.55	0.83	0.88	0.91	159–167
76–80	—	—	0.45	0.80	0.87	0.90	168–176
81–90	—	—	—	0.74	0.83	0.87	177–194
91–100	—	—	—	0.67	0.79	0.85	195–212
101–110	—	—	—	0.60	0.75	0.82	213–230
111–120	—	—	—	0.52	0.71	0.79	231–248
121–130	—	—	—	0.43	0.66	0.76	249–266
131–140	—	—	—	0.30	0.61	0.72	267–284
141–160	—	—	—	—	0.50	0.65	285–320
161–180	—	—	—	—	0.35	0.58	321–356
181–200	—	—	—	—	—	0.49	357–392
201–225	—	—	—	—	—	0.35	393–437

Statement of Problem and Substantiation for Public Comment

The langue "allowable ampacity" has been removed in many throughout this code as a result of the work of an Ampacity Task Group. The task group consisted of the following members: Thomas Domitrovich, Dave Mercier, Christine Porter, Derrick Atkins, and Christel Hunter. Ampacity is the maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating. The term used in this section should be "ampacity" and not "allowable ampacity" as it is the intent for this section to determine the ampacity of the conductor based upon its condition of use.

Related Item

• FR 8918 • PI 883 • PI 884 • PI 928 • PI 929 • PI 931 • PI 932 • PI 933 • PI 934 • PI 935 • PI 936 • PI 937 • PI 938 • PI 939 • PI 940 • PI 941 • PI 942

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
Organization: Eaton Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 08 16:18:55 EDT 2018
Committee: NEC-P06

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Public Comment No. 577-NFPA 70-2018 [Sections 310.15(B), 310.15(C)]

Sections 310.15(B), 310.15(C)

(B) Ambient Temperature Correction Factors.

Ampacities for ambient temperatures other than those shown in the ampacity tables shall be corrected in accordance with Table 310.15(B)(1) or Table 310.15(B)(2), or shall be permitted to be calculated using Equation 310.15(B).

$$I' = I\sqrt{\frac{T_c - T_a'}{T_c - T_a}} \qquad \textbf{[310.15(B)]}$$

where:

I' = ampacity corrected for ambient temperature

I = ampacity shown in the tables

T_c = temperature rating of conductor (°C)

T_a' = new ambient temperature (°C)

T_a = ambient temperature used in the table (°C)

~~Raceways or cables exposed to direct sunlight on or above rooftops. Where the distance above the roof to the bottom of the raceway or cable is less than 23 mm (7/8 in.), a temperature adder of 33°C (60°F) shall be added to the outdoor temperature to determine the applicable ambient temperature for application of the correction factors in Table 310.15(B)(1) or Table 310.15(B)(2).~~

Table 310.15(B)(1) Ambient Temperature Correction Factors Based on 30°C (86°F)

For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor Insulation			Ambient Temperature (°F)
	60°C	75°C	90°C	
10 or less	1.29	1.20	1.15	50 or less
11–15	1.22	1.15	1.12	51–59
16–20	1.15	1.11	1.08	60–68
21–25	1.08	1.05	1.04	69–77
26–30	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	132–140
61–65	—	0.47	0.65	141–149
66–70	—	0.33	0.58	150–158
71–75	—	—	0.50	159–167
76–80	—	—	0.41	168–176
81–85	—	—	0.29	177–185

Table 310.15(B)(2) Ambient Temperature Correction Factors Based on 40ºC (104ºF)

For ambient temperatures other than 40°C (104°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.

Ambient Temperature (°C)	Temperature Rating of Conductor Insulation						Ambient Temperature (ºF)
	60°C	75°C	90°C	150°C	200°C	250°C	
10 or less	1.58	1.36	1.26	1.13	1.09	1.07	50 or less
11–15	1.50	1.31	1.22	1.11	1.08	1.06	51–59
16–20	1.41	1.25	1.18	1.09	1.06	1.05	60–68
21–25	1.32	1.2	1.14	1.07	1.05	1.04	69–77
26–30	1.22	1.13	1.10	1.04	1.03	1.02	78–86

31–35	1.12	1.07	1.05	1.02	1.02	1.01	87–95
36–40	1.00	1.00	1.00	1.00	1.00	1.00	96–104
41–45	0.87	0.93	0.95	0.98	0.98	0.99	105–113
46–50	0.71	0.85	0.89	0.95	0.97	0.98	114–122
51–55	0.50	0.76	0.84	0.93	0.95	0.96	123–131
56–60	—	0.65	0.77	0.90	0.94	0.95	132–140
61–65	—	0.53	0.71	0.88	0.92	0.94	141–149
66–70	—	0.38	0.63	0.85	0.90	0.93	150–158
71–75	—	—	0.55	0.83	0.88	0.91	159–167
76–80	—	—	0.45	0.80	0.87	0.90	168–176
81–90	—	—	—	0.74	0.83	0.87	177–194
91–100	—	—	—	0.67	0.79	0.85	195–212
101–110	—	—	—	0.60	0.75	0.82	213–230
111–120	—	—	—	0.52	0.71	0.79	231–248
121–130	—	—	—	0.43	0.66	0.76	249–266
131–140	—	—	—	0.30	0.61	0.72	267–284
141–160	—	—	—	—	0.50	0.65	285–320
161–180	—	—	—	—	0.35	0.58	321–356
181–200	—	—	—	—	—	0.49	357–392
201–225	—	—	—	—	—	0.35	393–437

(3) Raceways and Cables Exposed to Sunlight on Rooftops. Where raceways or cables are exposed to direct sunlight on or above rooftops, the adjustments shown in Table 310.15(B)(3) shall be added to the outdoor temperature to determine the applicable ambient temperature for application of the correction factors in Table 310.15(B)(1) or Table 310.15(B)(2).

Exception: Type XHHW-2 insulated conductors shall not be subject to this ampacity adjustment.

Informational Note: One source for the ambient temperatures in various locations is the ASHRAE Handbook Fundamentals.

Table 310.15(B)(3) Ambient Temperature Adjustment for Raceways or Cables Exposed to Sunlight on or Above Rooftops

	Temperature Adder	
Distance Above the Roof to Bottom of Raceway or Cable	°C	°F
On roof to 13 mm (0 - ½ in) above	33	60
13 to 90 mm (½ to 3½ in.) above roof	22	40
90 to 300 mm (3½ to 12 in.) above roof	17	30
300 to 900 mm (12 to 36 in.) above roof	14	25

Informational Note to Table 310.15(B)(3): The temperature adders in Table 310.15(B)(3) are based on the measured temperature rise above the local climatic ambient temperatures due to sunlight heating.

(C) Adjustment Factors.

(1) More than Three Current-Carrying Conductors.

The ampacity of each conductor shall be reduced as shown in Table 310.15(C)(1) where the number of current-carrying conductors in a raceway or cable exceeds three, or where single conductors or multiconductor cables not installed in raceways are installed without maintaining spacing for a continuous length longer than 600 mm (24 in.). Each current-carrying conductor of a paralleled set of conductors shall be counted as a current-carrying conductor.

Table 310.15(C)(1) Adjustment Factors for More Than Three Current-Carrying Conductors

Number of Conductors*	**Percent of Values in Table 310.16 Through Table 310.19 as Adjusted for Ambient Temperature if Necessary**
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

* Number of conductors is the total number of conductors in the raceway or cable, including spare conductors. The count shall be adjusted in accordance with 310.15(E) and (F). The count shall not include conductors that are connected to electrical components that cannot be simultaneously energized.

Note:

Spacing between raceways shall be maintained.

~~*Exception: Type XHHW-2 insulated conductors shall not be subject to this ampacity adjustment.*~~

~~Informational Note: One source for the ambient temperatures in various locations is the ASHRAE *Handbook — Fundamentals* .~~

Where conductors of different systems, as provided in 300.3 , are installed in a common raceway or cable, the adjustment factors shown in Table 310.15(C)(1) shall apply only to the number of power and lighting conductors (Articles 210 , 215 , 220 , and 230).

Informational Note No. 1: See Annex B for adjustment factors for more than three current-carrying conductors in a raceway or cable with load diversity.

Informational Note No. 2: See 366.23 for adjustment factors for conductors and ampacity for bare copper and aluminum bars in auxiliary gutters and 376.22(B) for adjustment factors for conductors in metal wireways.

(a) Where conductors are installed in cable trays, the provisions of 392.80 shall apply.

(b) Adjustment factors shall not apply to conductors in raceways having a length not exceeding 600 mm (24 in.).

(c) Adjustment factors shall not apply to underground conductors entering or leaving an outdoor trench if those conductors have physical protection in the form of rigid metal conduit, intermediate metal conduit, rigid polyvinyl chloride conduit (PVC), or reinforced thermosetting resin conduit (RTRC) having a length not exceeding 3.05 m (10 ft), and if the number of conductors does not exceed four.

(d) Adjustment factors shall not apply to Type AC cable or to Type MC cable under the following conditions:

(5) The cables do not have an overall outer jacket.

(6) Each cable has not more than three current-carrying conductors.

(7) The conductors are 12 AWG copper.

(8) Not more than 20 current-carrying conductors are installed without maintaining spacing, are stacked, or are supported on “bridle rings.”

Exception to (4): If cables meeting the requirements in 310.15(C)(1)(d)(1) through (C)(1)(d)(3) with more than 20 current-carrying conductors are installed longer than 600 mm (24 in.) without maintaining spacing, are stacked, or are supported on bridle rings, a 60 percent adjustment factor shall be applied.

Additional Proposed Changes

File Name	Description	Approved
Fact_Finding_Report_final_draft-_Ambient_Temperature_Adjustment_10-10-2011_.pdf	UL Fact-Finding Report of Rooftop Temperatures	

Statement of Problem and Substantiation for Public Comment

The limiting factors for application of correction and adjustment factors is the rating of the insulation on the conductor and not the conductor material itself. This is corrected in the title of Tables 310.15(B)(1) and B)(2).
The requirements for raceways and cables that are exposed to sunlight on rooftops has become located improperly in the reorganization of 310.15 in TerraView. This Comment proposes to move it to follow Table 310.15(B)(2). The heights above the rooftop have been corrected in this Comment.
In addition, this Comment intends to restore the Table 310.15(B)(3(c) from the 2014 NEC. It was based on the only valid and scientifically documented study of the actual temperatures that are experienced in raceways that are exposed to direct sunlight on rooftops. This was an unbiased and scientifically defensible Fact-Finding Study performed by Underwriters Laboratories. It is attached for this Code Panel's information.
The documentation for the change made to this section by the previous Code Panel during the 2017 NEC cycle was flawed, illogical and biased. The Task Group that submitted the documentation was not balanced and was populated by a group that set out to defeat the rooftop requirement. It fails the logic test to be almost embarrassing! It is difficult to imagine that anyone could believe, much less endorse, that the temperature adder goes from 60°F to zero below and above 7/8 inch!
To comply with the NEC Style Manual, this subdivision needs to have a number in sequence. See the NEC Style Manual Section 2.1. This Comment proposes to number the subdivision as 310.15(B)(3). It also proposes to make the existing title for the subdivision bold-faced in compliance with the NEC Style Manual.
This Comment also proposes to delete the unnecessary words regarding adding a temperature adder. Those words are unnecessary and can add confusion,

Related Item

- FR-8030

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 12 01:01:57 EDT 2018
Committee: NEC-P06

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File IN16969
Project 11CA25532

October 10, 2011

Fact-Finding Report on Ambient Temperature Adjustment for Raceway and Cable Systems Exposed to Sunlight on Rooftops

Prepared for Travis Lindsay Consulting Services, Inc.
Las Vegas, Nevada 89146

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EXECUTIVE SUMMARY

The 2011 National Electrical Code® (NEC®) requires for circular raceways exposed to sunlight on rooftops, an adjustment temperature be added to the outdoor temperature when determining ambient temperature and associated correction factors for calculating the ampacity of conductors. This adjustment temperature adder for circular raceways exposed to sunlight on rooftops is to account for solar heating, and is needed to assure that no conductor is used in a manner such that its operating temperature exceeds that for which it is designed.

In preparing for the 2011 NEC, a proposal was submitted to include cables into the scope of this requirement. Although supporting documentation included a report of testing with MC cables, the Code Panel chose to reject this proposal since the term “cables” was too general, and that testing was insufficient since only MC cable in a single size was tested. Some of the Code Panel members also noted the need for a more comprehensive research project to determine the effects of sunlight on wiring systems in general when installed on rooftops.

This is a report of a Fact-Finding Investigation intended to provide technical data and other pertinent facts regarding the safety aspects of installing raceways and cables to direct sunlight on or above rooftops. The investigation included tests on 17 different types and sizes of wiring systems, each of which were installed at four different elevations above the roof at an outdoor test facility in Las Vegas, Nevada. In addition to temperature measurements on the wiring system conductors, outdoor ambient temperature, wind speed, and solar irradiance were also recorded during the summer months of 2011. By calculating the difference between the temperature on the wiring system conductors and the outdoor ambient temperature during the period of peak solar irradiance during selected days of full sun and minimum wind, inferences could be made about the effects of solar heating on these wiring systems.

A statistical analysis of the data also provided insights into how solar heating affects wiring systems in general when installed on or above a rooftop. For all wiring systems mounted directly on the roof, the maximum temperature rise above outdoor ambient with a 95% confidence interval would statistically be 62.2 ^{o}F. For all wiring systems mounted at a distance above the roof (1/2 inch and greater) the maximum temperature rise above outdoor ambient with a 95% confidence interval would statistically be 51.4 ^{o}F.

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GENERAL

A proposal was accepted for the 2008 National Electrical Code® (NEC®), which recommended that for conduits exposed to sunlight on rooftops, an adjustment temperature be added to the outdoor temperature when determining ambient temperature for the correction factors in Tables 310.16 and 310.18. The substantiation for this proposal noted that Section 310.10 required that no conductor shall be used in such a manner that its operating temperature exceeds that designated for the type of insulated conductor involved. It also cited testing that showed the air inside conduits in direct sunlight to be significantly hotter than the surrounding air. This proposal resulted in new Section 310.15(B)(2)(c) and new Table 310.15(B)(2)(c) for the 2008 NEC[1].

For the 2011 NEC, a similar proposal was submitted to include cables into the scope of this requirement. Although supporting documentation included a report of testing with MC cables, the Code Panel chose to reject this proposal since the term “cables” was too general, and that testing was insufficient since only MC cable in a single size was tested. Some of the Code Panel members noted the need for a more comprehensive research project to determine the effects of sunlight on conduits, MC cable, and cable in general when installed on rooftops.

[1] For the 2011 NEC, Sec. 310.10 became Sec. 310.15(A)(3), Sec. 310.15(B)(2)(c) became Sec. 310.15(B)(3)(c), and Table 310.15(B)(2)(c) became Table 310.15(B)(3)(c).

OBJECTIVE

The objective for this Fact-Finding Investigation is to provide technical data and other pertinent facts regarding the safety aspects of installing raceways and cables to direct sunlight on or above rooftops.

Travis Lindsey Consulting Services Inc. proposes to submit a public proposal to revise Section 310.15(B)(3)(c) of the 2011 NEC as follows:

> (c) ~~*Circular*~~ *Raceways and Cables Exposed to Sunlight on Rooftops*. Where conductors ~~or cables~~ are installed in ~~circular~~ raceways <u>or where in cables</u> exposed to direct sunlight on or above rooftops, the adjustments shown in Table 310.15(B)(3)(c) shall be added to the outdoor temperature to determine the applicable ambient temperature for application of the correction factors in Table 310.15(B)(2)(a) or 310.15(B)(2)(b).

Table 310.15(B)(3)(c) Ambient Temperature Adjustment for ~~Circular~~ Raceways or Cables Exposed to Sunlight on or Above Rooftops

Distance Above Roof to Bottom of ~~Conduit~~ <u>Raceway or Cable</u>	Temperature Adder	
	°C	°F
0-13 mm (1/2 in.)	33	60
Above 13 mm (1/2 in.) - 90 mm (3-1/2) in.)	22	40
Above 90 mm (3-1/2 in.) - 300 mm (12 in.)	17	30
Above 300 mm (12 in.) - 900 mm (36 in.)	14	25

WIRING SYSTEMS AND ROOFTOPS

NEC Requirements

Wiring methods and materials are described in Chapter 3 of the NEC. Included in Chapter 3 are various Articles for different cable types and raceways for containing conductors for general wiring, including wiring that may be installed on a rooftop and exposed to sunlight. Although the “uses permitted” for these various cables and raceways do not specifically mention rooftops, it could be assumed that if permitted for outdoor use and/or wet locations, and resistant to sunlight, a particular wiring system could be installed on a rooftop exposed to sunlight. Tables 1 and 2 include the various cable and raceway systems from Chapter 3 that could typically be installed on or above rooftops exposed to sunlight as permitted by the NEC. Also included in these tables are the specific NEC Chapter 3 Article, the UL standard, and the range of sizes that would be permitted or could be listed.

Table 1 – Cables Suitable for Installation on Rooftops Exposed to Sunlight

Type	NEC Article	UL Standard	Wire Size Min	Wire Size Max	Comment
MV	328	1072	8	2000	If identified for use in direct sunlight, or as "MV or MC"
MC	330	1569	18	2000	
MI	332	1581	16	500	Max 4 AWG for 2 & 3 conductor; 6 AWG for 4 conductor; 10 AWG for a 7 conductor
UF	340	493	14	4/0	For use with PV (rooftop) systems; Max 6 AWG for multiple conductors. This can also include single conductor cable listed as PV wire.
TC	336	1277	18	1000	When marked "Sunlight Resistant"
SE	338	854	14	unspecified	

Table 2 – Conduits and Raceways Suitable for Installation on Rooftops Exposed to Sunlight

Type	NEC Article	UL Standard	Trade Size Min	Trade Size Max	Comment
IMC	342	1242	1/2	4	
RMC	344	6/6A	3/8	6	
LFMC	350	360	3/8	4	
PVC	352	651	1/2	6	
LFNC	356	1660	3/8	4	When listed as suitable for outdoors
EMT	358	797/797A	1/2	4	
Auxiliary Gutters	366	870			When listed for exposure to sunlight and wet locations
Cable Bus	370				When identified for outdoor use
Metal Wireways	376	870			When listed for wet locations
Nonmetallic Wireways	378	879/5A			When listed for wet locations

COMPREHENSIVE TEST PROGRAM TO ADDRESS WIRING SYSTEMS EXPOSED TO SUNLIGHT ON ROOFTOPS

Test Sample Selection

Various test samples were chosen because of their expected use on rooftops exposed to sunlight, and their similarity to other raceway and cable systems that were not tested, but considered to be representative of these other wiring systems for test purposes. For cables, Type MC cable was chosen to represent metal clad and metal sheathed cables and conduits (e.g. Type MC, MI, LFMC, etc.). Sizes 12 AWG, 1/0 AWG, and 500 kcmil were chosen to represent cables of the smaller, medium, and larger sizes. Type SE and TC cable was also chosen in the 1/0 AWG size to represent jacketed cables (e.g. Type SE, TC, MV, UF, etc.) For conduits and tubings, Type RMC and EMT were chosen to represent circular metal raceways (e.g. RMC, IMC, EMT, etc.). To represent the smaller sizes, trade size ½ was chosen for RMC, and trade size ¾ was chosen for EMT. For the medium and larger sizes, trade sizes 1-1/2 and 4 respectively were chosen. Type PVC was chosen to represent nonmetallic conduits and raceways. To represent the smaller sizes, trade size ¾ was chosen, and for the medium and larger sizes, trade sizes 1-1/2 and 4 respectively were chosen. For other metal wiring systems (e.g. metal wireways, gutters, etc.), metal raceway was chosen in the 4x4 inch and 8x8 inch sizes to represent smaller and larger raceways in general.

Table 3 is a summary of the proposed testing to consider a comprehensive research program to determine the effects of direct sunlight when conduit, MC cable, and wiring systems in general are installed on or above a rooftop.

Table 3 – Summary of Test Samples

Raceway/ Cable Type	Conductor Size*	Trade Size	Installed Conductor Size*	Number of Conductors
MC	12			3
MC	1/0			3
MC	500			3
SE	1/0			3
TC	1/0			3
RMC		1/2	12	7
RMC		1-1/2	1/0	4
RMC		4	500	3
PVC		3/4	12	3
PVC		1-1/2	1/0	3
PVC		4	500	3
EMT		3/4	12	3
EMT		1-1/2	1/0	5
EMT		4	500	3
Metal Raceway		4x4 in.	1/0	3
Metal Raceway		8x8 in.	500	3

* - AWG or kcmil (copper), Type THHN/THWN.

Test Considerations

Laboratory Site – The testing was conducted at an outdoor laboratory site located in Las Vegas, Nevada. This area was chosen for its broad range of days with higher solar radiation intensity.

Fig. 1 – Las Vegas, Nevada Outdoor Test Site

Roof - To support Table 310.15(B)(3)(c) from the 2011 NEC, each wiring system was tested directly on the roof, and at distances of 1/2, 3-1/2, and 12 inches above the roof[2]. For wiring systems tested directly on the roof and at 1/2 inch above the roof, the roof was asphalt painted black in color to account for additional heating from solar absorption on the roof. For wiring systems tested at distances greater than 1/2 inch above the roof, the roof surface was asphalt painted white in color to account for additional heating from solar reflection from the roof. Each roof structure was flat, approximately five feet off the ground, and measured 13-1/2 by 10 feet, with R19 fiberglass batt insulation under the roof deck.

Fig. 2 – Samples Mounted Directly on Black Roof

Fig. 3 – Samples Mounted 12 Inches off White Roof

Test Samples – Each test sample was 10 feet long exposed along the horizontal length of the roof surface. A thermocouple was secured to each conductor insulation midway along the length of the sample. The thermocouples were type T, No. 24 AWG, with welded junctions. For the Type MC cable samples, the thermocouple was secured near the conductor. For samples with more than three conductors, a maximum of three thermocouples were used. See Appendix A for a thorough description of each test sample. The ends of each wiring system were closed with surgical cotton to restrict air flow. The wires were not energized during the testing since the object of the testing was to obtain a measurement of the wiring system temperature increase due to the influence of exposure to the sun.

[2] Although the breakpoints in Table 310.15(B)(3)(c) are for distances of above (greater than) ½, 3-1/2, and 12 inches above the roof, the test samples were located at these breakpoint distances to represent a worst-case test condition.

Fig. 4 – Thermocouples Installed on Conductors

Fig. 5 – Cotton Used to Close Ends of Wireways

Data Measurements - Temperatures were measured at 1 minute increments throughout the day, and the maximum of the 1 minute increments for a 5 minute time period was recorded. This resulted in 12 recorded measurements per hour. In addition to the measurement of temperature of the conductor insulation of each test sample, the near-by outdoor air temperature was measured in two aspirated enclosures located approximately 8 feet and 13 feet above grade level in the vicinity of the roofs and test samples. Wind speed was similarly measured in the same vicinity using two anemometers. Solar irradiance was measured using a pyranometer located in the same plane as the roof surface.

Fig. 6 – Aspirated Enclosure for Outdoor Temperature

Fig. 7 – Anemometer for Wind Speed Measurement

Solar irradiance and wind speed was recorded along with the test sample temperatures. Measurements were recorded during the months of June, July and August of 2011. Sufficient data was recorded to enable supportable and statistical inferences regarding expected ambient temperatures for raceway and cable systems exposed to sunlight on rooftops.

Solar Irradiance - Solar irradiance, or radiation from the sun, is measured as power density in Watts per square meter (W/m^2). This solar radiation reaching the earth can vary depending on several factors, including as time-of-day, time-of-year, atmospheric conditions such as clouds, haze, rain, etc., as well as geographical location. The maximum solar radiation reaching the earth's atmosphere can approach 1400 W/m^2, however, 1000 – 1200 W/m^2 is more typical of maximum surface irradiance on a sunny day in many parts of the United States, and can be less during the winter, and much less on cloudy days.

Solar photovoltaic (PV) modules are tested and rated under what is referred to as standard test conditions, or STC for short. These standard test conditions are solar irradiance of 1000 W/m^2 and air temperature of 25 ^oC.[3] In the NEC, PV system components, such as wire size and overcurrent protection, are based on these standard test conditions, with adjustment factors for periods of time where the maximum solar irradiance can exceed 1000 W/m^2.[4]

Figure 8 shows a graph of the solar irradiance at the test site incident to the test roofs on June 22, 2011. The day was full sun, maximum outdoor ambient temperature of 110 ^oF, and near the time of summer solstice. The solar irradiance that day exceeded 1000 W/m^2 for a three-hour period beginning at 11:10 am. The NEC defines in Article 100 a "continuous load" as a load where the maximum current is expected to continue for 3 hours or more.

[3] Underwriters Laboratories Inc., *UL Standard for Safety for Flat-Plate Photovoltaic Modules and Panels*, UL 1703. See Glossary Section 2.17 for definition of Standard Test Conditions.

[4] As an example, see NEC Sec. 690.8 where calculations for maximum circuit current and conductor ampacity involve multipliers of 125%.

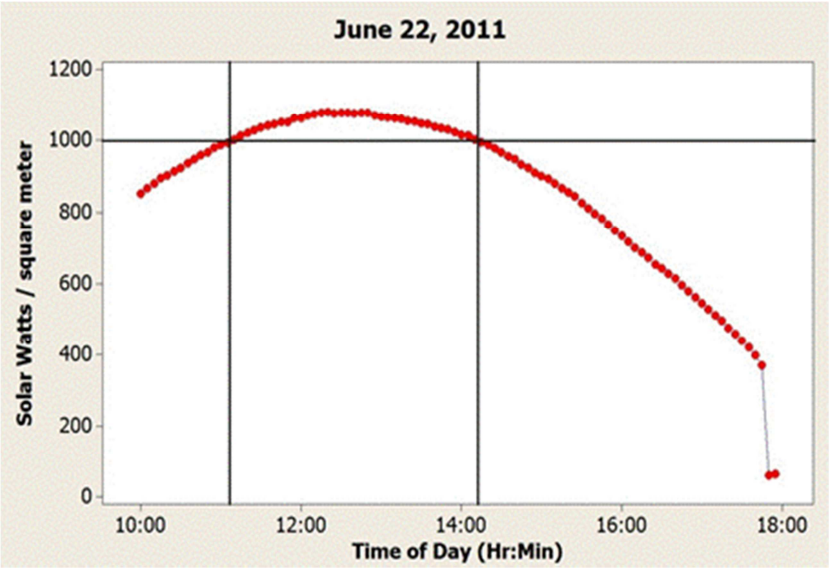


Fig. 8 – Solar Irradiance for June 22, 2011 at Las Vegas Test Site

Test Results

Data measurements were recorded during the months of June, July and August of 2011. This time of the year also produced many days of large amounts of solar radiation for the longest periods of time. During these months there were many days of full sun throughout the day where outside temperature exceeded 100 ^{o}F, and solar irradiance exceeded 1000 W/m^2. The solar irradiance for days of prolonged full sun peaked near solar noon, which occurred at about 12:45 pm in Las Vegas that time of year (daylight savings time). For analysis of results purposes, 10 days were chosen during this time period where that solar irradiance exceeded 1000 W/m^2 for a prolonged period of time. Although wind speed could not be controlled, these days were also chosen where the wind speed was minimized. This resulted in 5 days in late June, and 5 days in early August as shown in Table 4. For each of these 10 days, the temperature data were analyzed for the period of time that day were the solar irradiance was greater than or equal to 1000 W/m^2. Depending upon the day, this resulted in elapsed times of 3 hours and 5 minutes to 2 hours and 15 minutes as shown in the table. This table also includes the average wind speed and maximum outdoor ambient temperature for that period of time. See Appendix C for complete graphs of the daily outdoor ambient temperature, solar irradiance, and wind speed.

Table 4 – 10 Days of Analyzed Data

Day (2011)	Period of Solar Radiation ≥ 1000 W/m^2 (Hours:Minutes) Beginning	End	Elapsed Time	Avg Wind Speed (MPH)	Outdoor Ambient Deg F
June 21	11:15	14:05	2 hr 50 min	2.8	101
June 22	11:10	14:10	3 hr 00 min	3.1	109
June 23	11:20	14:15	2 hr 55 min	4.4	108
June 25	11:05	14:10	3 hr 05 min	3.1	103
June 26	11:10	14:15	3 hr 05 min	2.7	103
August 4	11:35	14:00	2 hr 25 min	6.0	105
August 5	11:30	14:05	2 hr 35 min	6.4	103
August 6	11:35	13:50	2 hr 15 min	5.7	102
August 8	11:35	14:00	2 hr 25 min	6.3	106
August 9	11:45	14:00	2 hr 15 min	5.5	106

For each test sample, the rise above outdoor ambient temperature for the three thermocouple temperatures were averaged for each five-minute increment to record the temperature rise above outdoor ambient of the test sample for that time measurement increment. An analysis of the variance for the three thermocouple readings of each test sample typically showed a variance of less than 1 ^{o}F, except for the tray cable (TC) samples, where the variance was greater because of the orientation of the three thermocouples around the circumference of the cable. For that reason, the maximum temperature of the three thermocouple readings for the tray cable was used for this test sample because of the importance of recording the hottest temperature being experienced by the cable.

For each of the ten chosen days, the maximum, minimum, 90th, 75th, and 50th percentile temperatures were calculated for each test sample at each elevation for the period of time that day when the solar irradiance was greater than or equal to 1000 W/m^2. For the accumulated ten days, the overall maximum, minimum, and averages of the 90th, 75th and 50th percentile temperatures were then tabulated. The tables below show that complied data.

Table 5

Maximum Temperature Rise Above Outdoor Ambient (°F)

		Distance Above Roof			
		1 Foot	3-1/2 inch	1/2 inch	On Roof
Circular Raceway - Metal	3/4" EMT	42.9	39.2	48.0	62.9
	1/2" RMC	34.2	35.1	38.7	66.5
	1-1/2" EMT	34.9	36.1	37.4	51.2
	1-1/2" RMC	48.5	47.0	34.8	55.7
	4" EMT	35.2	38.9	35.3	43.8
	4" RMC	45.7	48.1	40.9	47.5
Circular Raceway - Plastic	3/4" PVC	42.2	46.5	42.3	63.6
	1-1/2" PVC	43.1	47.3	43.9	58.5
	4" PVC	46.3	48.4	43.0	52.3
Square Raceway - Metal	4" DUCT	51.1	54.9	46.1	59.9
	8" DUCT	46.7	46.3	38.7	52.1
Cables	#12 MC	45.4	53.0	47.8	71.4
	#1/0 MC	52.8	55.1	50.7	66.6
	#1/0 SE	39.7	43.0	43.5	58.3
	Tray 1/0 SE	36.6	39.4	40.1	47.8
	Tray 1/0 TC	59.6	65.0	53.3	60.3
	#500 MC	55.1	58.3	51.8	62.2
	NEC Adder	25	30	40	60

Table 6

Minimum Temperature Rise Above Outdoor Ambient (°F)

		Distance Above Roof			
		1 Foot	3-1/2 inch	1/2 inch	On Roof
Circular Raceway - Metal	3/4" EMT	26.3	22.1	28.4	42.0
	1/2" RMC	21.2	22.3	23.2	39.8
	1-1/2" EMT	22.8	25.6	24.7	31.7
	1-1/2" RMC	30.9	31.3	20.1	31.0
	4" EMT	23.2	25.7	21.7	25.9
	4" RMC	29.3	30.3	23.4	25.7
Circular Raceway - Plastic	1/2" RMC	21.2	22.3	23.2	39.8
	1-1/2" PVC	29.9	33.7	27.0	35.7
	4" PVC	28.2	28.8	23.0	26.1
Square Raceway - Metal	4" DUCT	33.3	37.5	27.6	36.3
	8" DUCT	31.0	31.0	22.0	23.7
Cables	#12 MC	31.1	34.6	27.9	41.5
	#1/0 MC	36.9	39.5	33.8	42.7
	#1/0 SE	27.6	30.9	29.0	37.2
	Tray 1/0 SE	24.8	28.0	26.5	31.3
	Tray 1/0 TC	40.3	47.9	36.9	41.5
	#500 MC	36.3	37.9	31.2	35.3
	NEC Adder	25	30	40	60

Table 7

90th Percentile Temperature Rise Above Outdoor Ambient (°F)

		Distance Above Roof			
		1 Foot	3-1/2 inch	1/2 inch	On Roof
Circular Raceway - Metal	3/4" EMT	36.3	30.9	40.9	55.8
	1/2" RMC	29.2	29.9	33.0	56.0
	1-1/2" EMT	29.4	31.2	32.1	43.3
	1-1/2" RMC	40.0	39.5	28.3	45.0
	4" EMT	29.7	33.2	29.9	36.5
	4" RMC	38.7	40.7	33.9	39.9
Circular Raceway - Plastic	3/4" PVC	37.0	40.8	35.5	53.3
	1-1/2" PVC	37.4	41.3	36.9	49.4
	4" PVC	38.5	40.2	35.3	42.9
Square Raceway - Metal	4" DUCT	43.5	47.2	38.6	50.3
	8" DUCT	39.7	39.9	31.8	43.8
Cables	#12 MC	40.3	45.2	40.2	60.1
	#1/0 MC	46.3	48.5	43.7	56.8
	#1/0 SE	34.9	38.0	37.8	49.8
	Tray 1/0 SE	31.5	34.6	34.4	41.1
	Tray 1/0 TC	51.0	59.1	46.9	53.0
	#500 MC	47.6	50.6	43.9	52.7
	NEC Adder	25	30	40	60

Table 8

75th Percentile Temperature Rise Above Outdoor Ambient (°F)

		Distance Above Roof			
		1 Foot	3-1/2 inch	1/2 inch	On Roof
Circular Raceway - Metal	3/4" EMT	35.1	29.9	39.7	54.5
	1/2" RMC	28.3	29.0	32.0	54.7
	1-1/2" EMT	28.9	30.7	31.5	42.6
	1-1/2" RMC	39.4	38.8	27.7	44.3
	4" EMT	29.1	32.5	29.3	35.8
	4" RMC	38.0	40.1	33.1	39.2
Circular Raceway - Plastic	3/4" PVC	36.2	39.9	34.5	52.1
	1-1/2" PVC	36.7	40.6	36.2	48.7
	4" PVC	37.9	39.6	34.6	42.2
Square Raceway - Metal	4" DUCT	42.7	46.5	37.8	49.6
	8" DUCT	39.0	39.2	31.0	43.1
Cables	#12 MC	39.2	44.2	39.1	58.9
	#1/0 MC	45.5	47.8	43.0	56.1
	#1/0 SE	34.2	37.3	37.2	49.1
	Tray 1/0 SE	30.9	34.0	33.7	40.4
	Tray 1/0 TC	50.0	58.3	46.3	52.3
	#500 MC	46.9	49.9	43.1	52.0
	NEC Adder	25	30	40	60

Table 9

50th Percentile Temperature Rise Above Outdoor Ambient (^{o}F)

		Distance Above Roof			
		1 Foot	3-1/2 inch	1/2 inch	On Roof
Circular Raceway - Metal	3/4" EMT	33.6	28.0	37.6	52.1
	1/2" RMC	27.1	27.9	30.6	52.3
	1-1/2" EMT	27.9	29.7	30.6	41.6
	1-1/2" RMC	38.2	37.7	26.8	43.1
	4" EMT	28.1	31.5	28.3	34.6
	4" RMC	36.6	38.6	31.7	37.1
Circular Raceway - Plastic	3/4" PVC	34.9	38.4	33.1	50.1
	1-1/2" PVC	35.6	39.6	35.2	47.4
	4" PVC	36.5	38.1	33.1	40.0
Square Raceway - Metal	4" DUCT	41.1	44.9	36.4	48.2
	8" DUCT	37.9	38.1	30.0	41.3
Cables	#12 MC	37.9	42.7	37.3	56.2
	#1/0 MC	44.2	46.6	41.8	54.8
	#1/0 SE	33.1	36.3	36.0	47.9
	Tray 1/0 SE	29.9	32.9	32.7	39.3
	Tray 1/0 TC	48.5	56.8	44.7	50.7
	#500 MC	45.5	48.2	41.7	50.0
	NEC Adder	25	30	40	60

Data Analysis

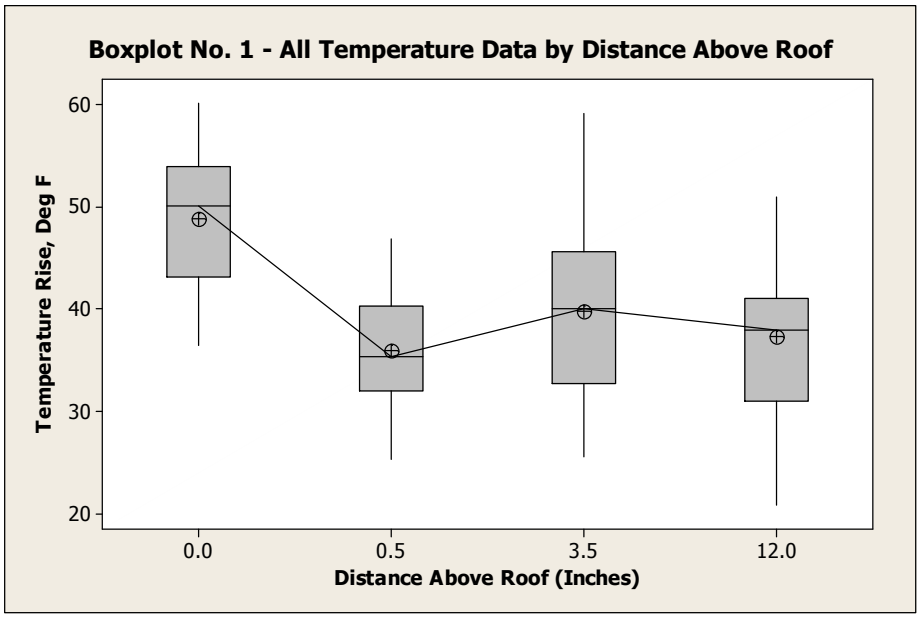
To analyze the differences between wiring systems at different distances from the roof, a compilation of all of the wiring system 90th percentile temperature rises (Table 7)[5] for the period of time each day where the solar irradiance was greater than or equal to 1000 W/m^2 was made for each of the four elevations. This analysis is shown in Boxplot[6] No.1. Note that for the wiring systems at distances 0.0 and 0.5 inches above the roof, the roof color was black, and for distances 3.5 and 12.0 inches above the roof, the roof color was white. Previous research[7] had shown that at the 0.5 inch distance, there was no significant difference between the black and white roof colors affecting the temperature of the wiring systems. For that reason black was chosen for the color of the roof at that distance. However, this previous research was only conducted with smaller size raceways and cable. It is possible that larger size raceways and cables could have absorbed more of the reflected solar radiation off the roof had the roof been white. This could explain why the mean temperature rise for the wirings systems at 0.5 inches above the roof were less than those at 3.5 and 12.0 inches above the roof.

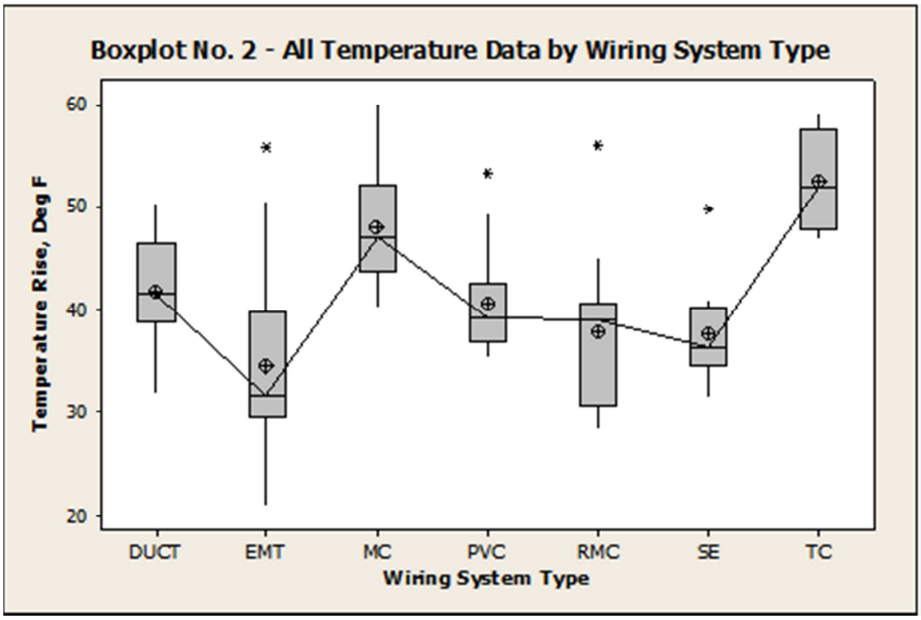
To analyze the differences between the different individual wiring systems, a compilation of all of the different wiring system 90th percentile temperature rises for the period of time each day where the solar irradiance was greater than or equal to 1000 W/m^2 was made. This analysis is shown in Boxplot No.2. Note that the MC and TC cables were black in color, and the SE cable was light gray in color.

[5] The 90th percentile values were used to eliminate the maximum temperatures that were only being experienced for a very short period of time when the solar irradiance peaked for that day. Note however, there was typically only a few degrees F or less difference between the 90th and 75th percentile values. See Tables 7 and 8.

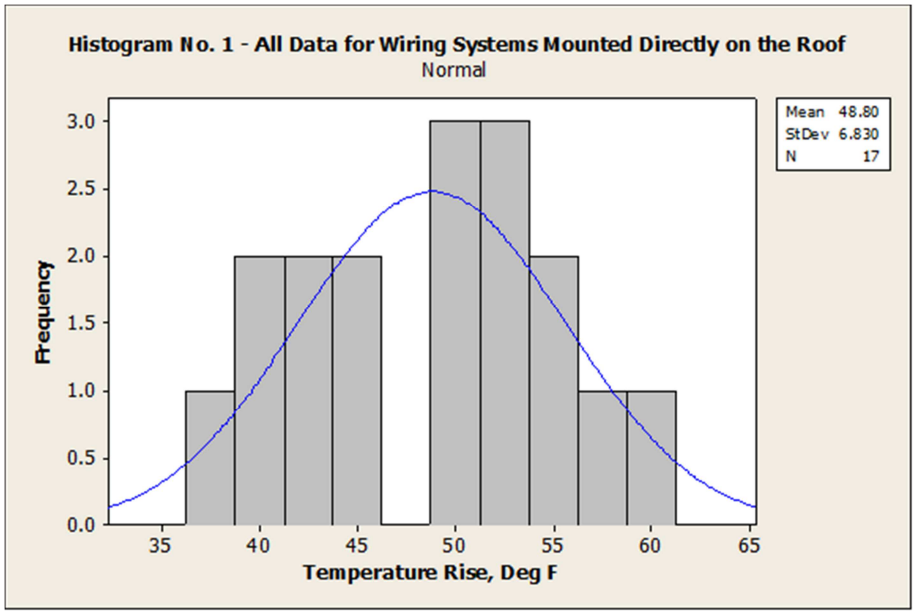
[6] See Appendix D for a description of boxplots.

[7] "*Effect of Rooftop Exposure on Cable Temperatures*," November 2008, by Travis C. Lindsey. Available for review at the National Fire Protection Association (NFPA) Headquarters, Quincy, MA. Reference Report on Proposals – June 2010, Proposal 6-66, Log #2751, NEC-P06. See Fig. 3, Temperature Rise as Function of Roof Color.

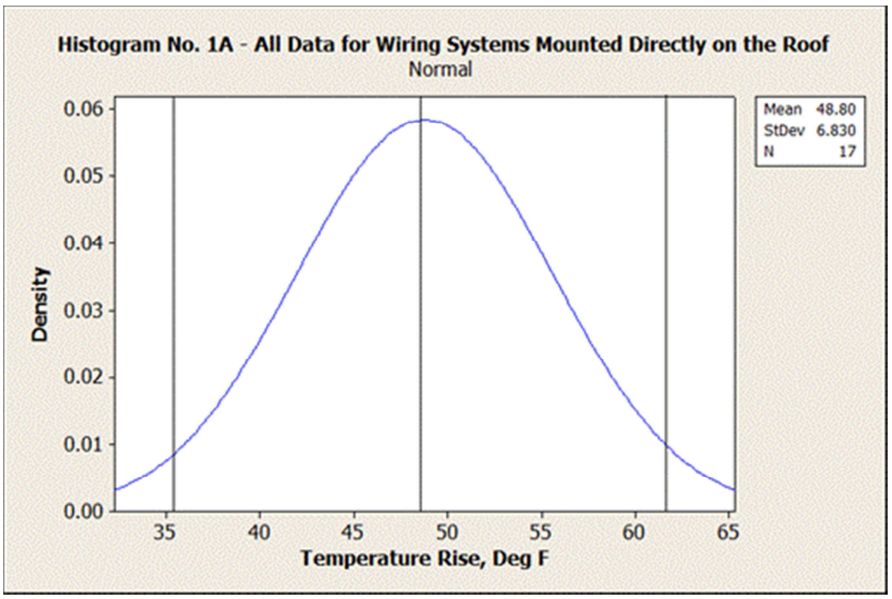

Boxplot No. 1 - All Temperature Data by Distance Above Roof
Temperature Rise, Deg F
60
50
40
30
20
0.0
0.5
3.5
12.0
Distance Above Roof (Inches)


Boxplot No. 2 - All Temperature Data by Wiring System Type
Temperature Rise, Deg F
60
50
40
30
20
DUCT
EMT
MC
PVC
RMC
SE
TC
Wiring System Type

Histogram No. 1 shows the 90th percentile temperature rise data for wiring systems directly on the roof for the period of time each day where the solar irradiance was greater than or equal to 1000 W/m^2.



This analysis shows that for all of the 17 test samples of wiring systems mounted directly on the roof, the mean (average) temperature rise was 48.8 ^{o}F with a standard deviation of 6.83 ^{o}F. Confidence intervals (C.I) are often used as a statistical estimate to bracket data parameters with a known degree of certainty. A 95% C.I. is suggested as an appropriate safety factor to represent the true population of the data from the sampled population (tested samples). A 95% C.I. is calculated (two-sided) as the mean plus/minus 1.96 times the standard deviation. For this case, maximum temperature rise for all wiring systems mounted directly on the roof with a 95% C.I. would be 62.2 ^{o}F. Histogram 1A shows a representation of this with vertical lines at the mean and 95% C.I. points.



An observation from Boxplot No. 1 appears to show that there is little difference between mean temperature rises for test samples of wiring systems mounted 0.5, 3.5, and 12.0 inches above the roof. Neglecting any heat convection or reradiation from the surface of the roof, this would be expected since the distance from the sun to the surface of the earth is large as compared to the distance between the three wiring systems. To verify this, an analysis of variance (ANOVA) was conducted with this data for the three distances from the roof. This analysis, shown in Fig. 9, demonstrates there is little difference between the mean temperature rises for all test data from each of the three wiring systems mounted 0.5, 3.5, and 12.0 inches above the roof. This is exemplified by the low value for R_{sq}, which shows that varying the distance from the roof between 0.5 and 12.0 inches does not have any significant effect on the temperature rise within the raceway or cable. It is expected that distances greater than 12.0 inches will also show this minimal difference.

One-way ANOVA: 90th Percentile Data versus Distance from Roof (0.5, 3.5, and 12.0 inches)

Source	DF	SS	MS	F	P
Distance	2	137.6	68.8	1.62	0.209
Error	48	2043.1	42.6		
Total	50	2180.8			

S = 6.6 R-Sq = 6.31% R-Sq(adj) = 2.41%

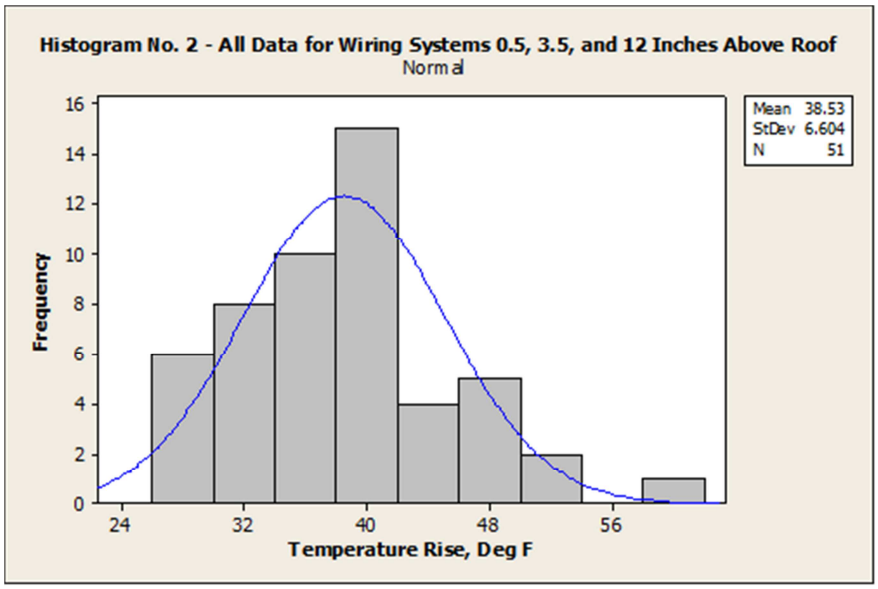
DF = Degrees of Freedom
SS = Sum of squares
MS = Mean square
S = Standard deviation
F = F ratio
P = p-value
R = Correlation coefficient

Individual 95% C.I.s for Mean Based on Pooled Standard Deviation of 6.6

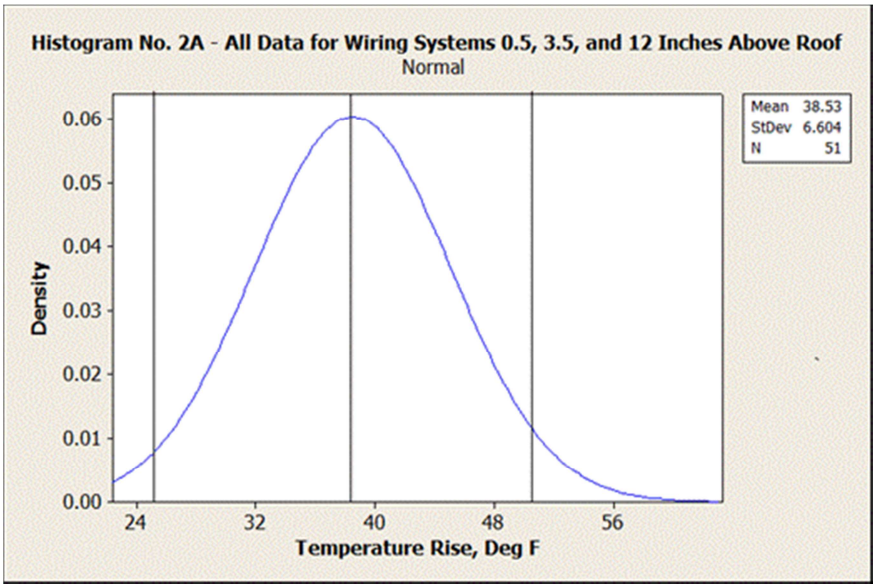
```
Level   N    Mean  StDev  --------+---------+---------+---------+-
 0.5   17  36.640  5.186  (---------*----------)
 3.5   17  40.644  7.769              (---------*----------)
12.0   17  38.297  6.359       (----------*---------)
                          --------+---------+---------+---------+-
                               36.0      39.0      42.0      45.0
```

Fig. 9 – Analysis of Variance for Wiring Systems Mounted Off Roof

Histogram No. 2 shows the 90th percentile temperature rise data for all wiring systems mounted 0.5, 3.5, and 12.0 inches above the roof for the period of time each day where the solar irradiance was greater than or equal to 1000 W/m^2.



This analysis shows that for all of the 51 test samples of wiring systems mounted off the roof (0.5, 3.5, and 12.0 inches), the mean temperature rise was 38.5 ^{o}F with a standard deviation of 6.60 ^{o}F. The maximum temperature rise for all wiring systems mounted off on the roof with a 95% C.I. would be 51.4 ^{o}F. Histogram 2A shows a representation of this with vertical lines at the mean and 95% C.I. points.



SUMMARY

1. Of the 17 different wiring systems tested, nine are currently addressed by the 2011 NEC Sec. 310.15(B)(3)(c) requirement for circular raceways exposed to sunlight on rooftops, *e.g.*, EMT, RMC, and PVC, and eight are not, *e.g.*, square raceway and cables. Using the maximum temperature rises from Table 5:
    a. All of the wiring systems mounted 12 inches from the roof and 3-1/2 inches from the roof exceeded the NEC Table 310.(B)(3)(c) temperature adders of 25 ^{o}F and 30 ^{o}F respectively. For wiring systems mounted 12 inches from the roof, this ranged from 34.2 to 59.6 ^{o}F, and for wiring systems 3-1/2 inches from the roof this ranged from 35.1 to 65.0 ^{o}F.
    b. For wiring systems mounted ½ inch off the roof, all of the cables, and the 4 inch square metal duct exceeded the 40 ^{o}F NEC temperature adder. Five of the nine circular raceways also exceeded this 40 ^{o}F adder. The range in temperature rises for wiring systems mounted ½ inch off the roof was 34.8 to 53.3 ^{o}F.
    c. For wiring systems mounted on the roof, four of the cables exceeded the 60 ^{o}F temperature adder, and three of the circular raceways also exceeded this 60 ^{o}F adder. The range in temperature rises for wiring systems mounted on the roof was 43.8 to 71.4 ^{o}F.

2. In general, the smaller size wiring systems reached a hotter temperature than wiring systems of the same type but larger. This was especially true of the metallic wiring systems, and when the wiring systems were mounted directly on the roof. This was expected because the larger wiring systems had a larger ratio of surface area to mass, and thus took longer to heat up and cool down. This greater mass could also absorb the radiated heat from the sun (and the conducted heat from the roof) over a greater volume. See Tables 5 – 9.

3. The 1/0 SE cable operated much cooler than the similar sized 1/0 MC and 1/0 TC cables. This was expected due to the black outer jacked of the 1/0 MC and 1/0 TC cables having greater absorption properties, *e.g.*, higher emissivity, than the lighter colored SE cable. See Boxplot No. 2.

4. Wiring systems mounted 3-1/2 inches off the white roof usually operated hotter than similar wiring systems mounted ½ inch off the black roof. This was likely because of the solar reflection off the white roof producing additional solar power that could be absorbed by the underside of the wiring system 3-1/3 inches from the roof. These results may have been different had the wiring systems mounted ½ inch off the roof been tested with a white roof. However, wiring systems mounted directly on the roof most always operated significantly hotter than wiring systems of the same type mounted off the roof. See Boxplot No. 1.

5. For all wiring systems mounted directly on the roof, the 90th percentile mean temperature rise above outdoor ambient for the period of time each day where the solar irradiance was greater than or equal to 1000 W/m^2 was 48.8 ^{o}F with a standard deviation 6.8. For this case, maximum temperature rise above outdoor ambient for all wiring systems mounted directly on the roof with a 95% confidence interval (C.I.) would be 62.2 ^{o}F.

6. A statistical analysis of variance of the data for temperature rise above outdoor ambient showed that all test data from wiring systems mounted 0.5, 3.5, and 12.0 inches above the roof were not affected significantly by distance. Therefore, distances greater than 0.5 inches above the roof can be considered far from the roof and roof distance does not need to be a consideration in calculating temperature rise. For all wiring systems mounted 0.5, 3.5, and 12.0 inches above the roof, the 90th percentile mean temperature rise above outdoor ambient for the period of time each day where the solar irradiance was greater than or equal to 1000 W/m^2 was 38.5 ^{o}F with a standard deviation 6.6. For this case, maximum temperature rise above outdoor ambient for all wiring systems mounted off on the roof with a 95% confidence interval (C.I.) would statistically be 51.4 ^{o}F.

Report by:

David A. Dini, P.E.
Research Engineer I
Corporate Research
Underwriters Laboratories Inc.

Reviewed by:

Paul W. Brazis Jr., PhD
Research Manager
Corporate Research
Underwriters Laboratories Inc.

APPENDIX A

Test Samples

1. Metal-Clad Cable, Type MC, No. 12 AWG/3 with No. 12 AWG ground. Aluminum interlocked armor with black PVC jacket. Copper THHN/THWN conductors.

2. Rigid Metal Conduit, Type RMC, Trade Size ½. Metallic silver in color. Seven No. 12 AWG copper conductors, Type THHN/THWN installed.

3. Rigid Polyvinyl Chloride Conduit, Type PVC, Trade ¾. Natural gray in color. Three No. 12 AWG copper conductors, Type THHN/THWN installed.

Fig. A1 – No. 12 MC (1), ½ RMC (2), ¾ PVC (3)

4. Electrical Metallic Tubing, Type EMT, Trade Size ¾. Metallic silver in color. Three No. 12 AWG copper conductors, Type THHN/THWN installed.

5. Metal-Clad Cable, Type MC, No. 1/0 AWG/3 with No. 6 AWG ground. Aluminum interlocked armor with black PVC jacket. Copper THHN/THWN conductors.

6. Service-Entrance Cable, Type SE, No. 1/0 AWG/3 with No. 2 AWG ground. Sunlight resistant with light gray jacket. Copper THHN/THWN conductors.

7. Rigid Metal Conduit, Type RMC, Trade Size 1-½. Metallic silver in color. Four No. 1/0 AWG copper conductors, Type THHN/THWN installed.

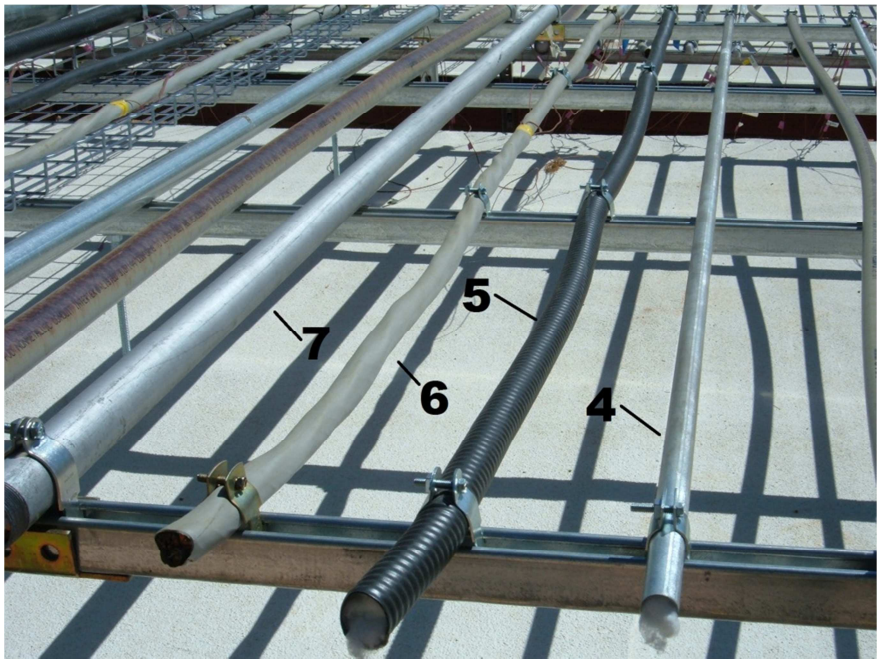


Fig. A2 – ¾ EMT (4), No. 1/0 MC (5), No. 1/0 SE (6), 1-1/2 RMC (7)

8. Rigid Polyvinyl Chloride Conduit, Type PVC, Trade1-1/2. Natural gray in color. Three No. 1/0 AWG copper conductors, Type THHN/THWN installed.

9. Electrical Metallic Tubing, Type EMT, Trade Size 1-1/2. Metallic silver in color. Five No. 1/0 AWG copper conductors, Type THHN/THWN installed.

Fig. A3 – 1-1/2 PVC (8), 1-1/2 EMT (9)

10. Service-Entrance Cable, Type SE, No. 1/0 AWG/3 with No. 2 AWG ground. Sunlight resistant with light gray jacket. Copper THHN/THWN conductors. Installed in a cable tray, basket type.

11. Power and Control Tray Cable, Type TC, No. 1/0 AWG/3 with No. 6 AWG bare ground. Sunlight resistant with black jacket. Copper THHN/THWN conductors. Installed in a cable tray, basket type.

Fig. A4 – No. 1/0 SE (10), No. 1/0 TC (11), Installed in Cable Tray

12. Metal-Clad Cable, Type MC, No. 500 kcmil/3 with No. 2 AWG ground. Aluminum interlocked armor with black PVC jacket. Copper THHN/THWN conductors.

13. Rigid Metal Conduit, Type RMC, Trade Size 4. Metallic silver in color. Three No. 500 kcmil copper conductors, Type THHN/THWN installed.

Fig. A5 – No. 500 MC (12), 4 RMC (13)

14. Rigid Polyvinyl Chloride Conduit, Type PVC, 4. Natural gray in color. Three No. 500 kcmil copper conductors, Type THHN/THWN installed.

15. Electrical Metallic Tubing, Type EMT, Trade Size 4. Metallic silver in color. Three No. 500 kcmil copper conductors, Type THHN/THWN installed.

Fig. A6 – 4 PVC (14), 4 EMT (15)

16. Metal Wireway, 4 in. by 4 in., 16 gauge steel. Gray in color. Three No. 1/0 AWG copper conductors, Type THHN/THWN installed.

17. Metal Wireway, 8 in. by 8 in., 14 gauge steel. Gray in color. Three No. 500 kcmil copper conductors, Type THHN/THWN installed.

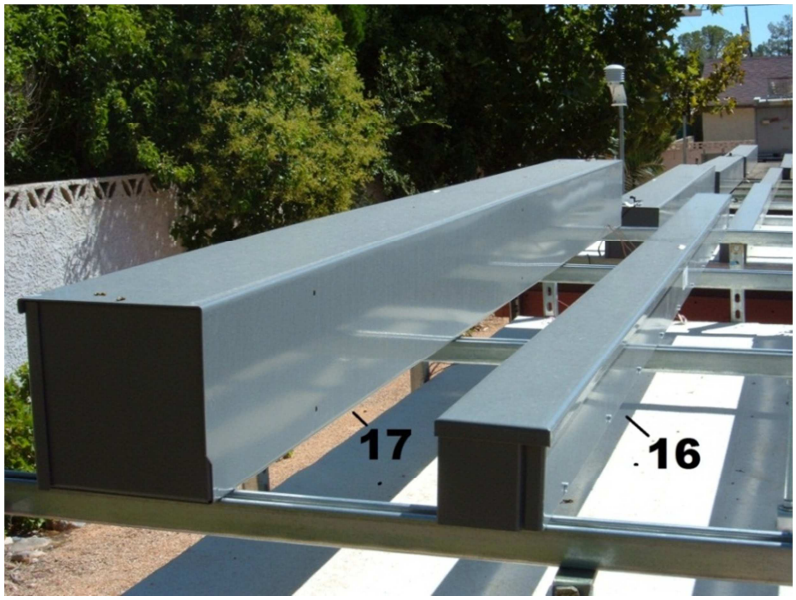


Fig. A7 – 4 In. Duct (16), 8 In. Duct (17)

APPENDIX B

Test Instrumentation

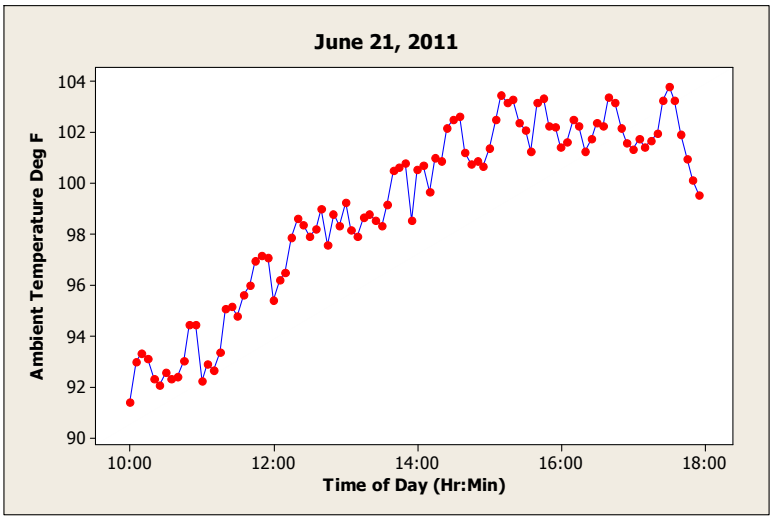
Pyranometer – Campbell Scientific, CS300 apogee silicon pyranometer.

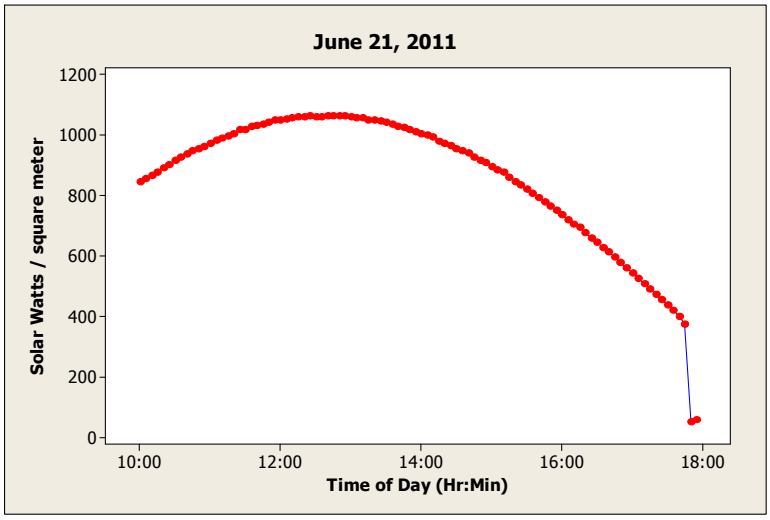
Anemometer - Campbell Scientific, 03101 three-cup anemometer.

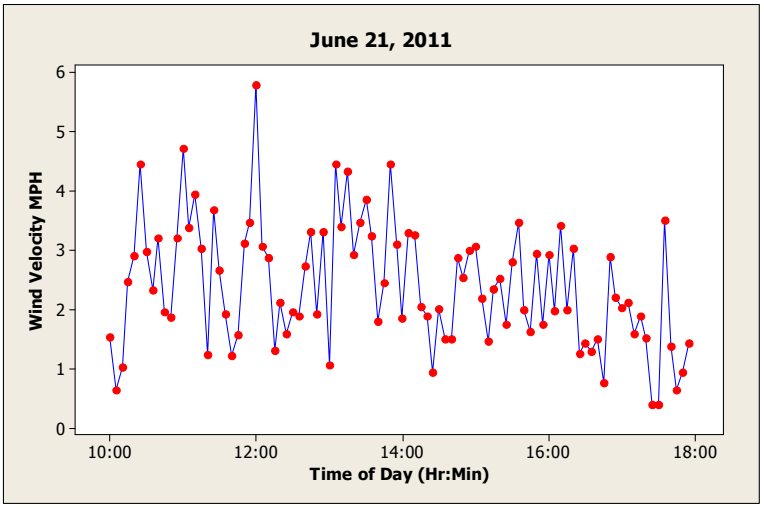
Data Acquisition System - Campbell Scientific, CR5000 Measurement and Control System. Serial No. 1315. Date of last calibration, April 15, 2011, by Campbell Scientific (A2LA accredited).

APPENDIX C

Graphs of Daily Outdoor Ambient Temperature, Solar Irradiance, and Wind Speed


June 21, 2011
Ambient Temperature Deg F
104
102
100
98
96
94
92
90
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)


June 21, 2011
Solar Watts / square meter
1200
1000
800
600
400
200
0
10:00
12:00
14:00
16:00
18:00
Time of Day (Hr:Min)


June 21, 2011
Wind Velocity MPH
6
5
4
3
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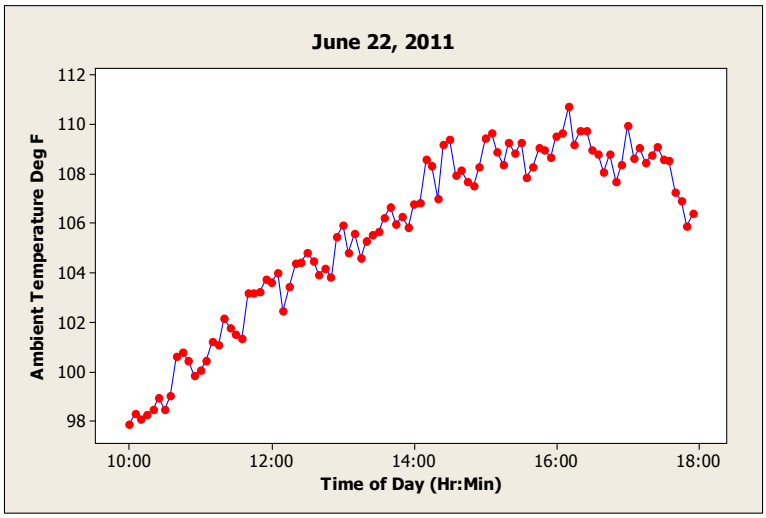
Time of Day (Hr:Min)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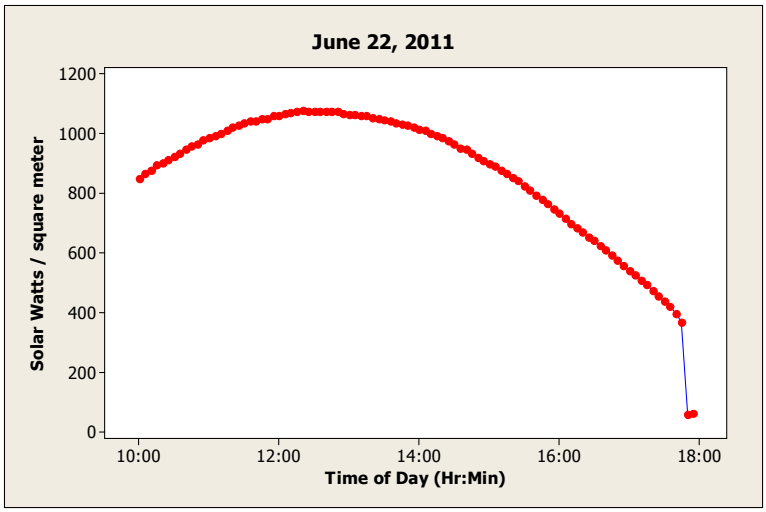
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Solar Watts / square meter
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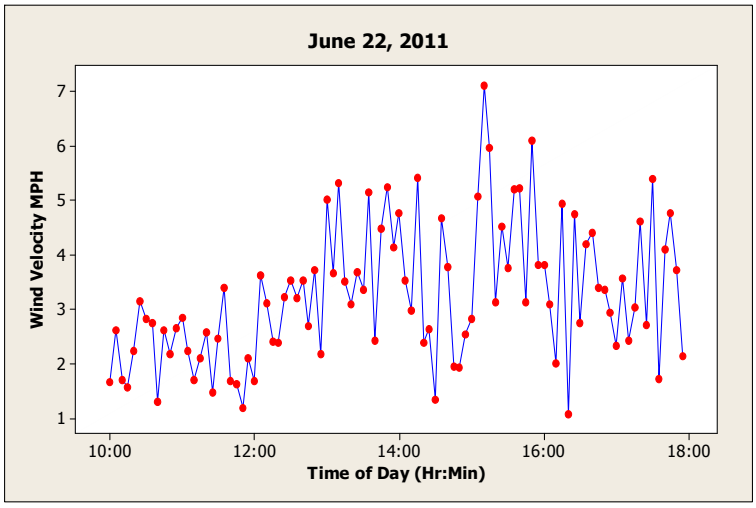
Time of Day (Hr:Min)


June 22, 2011
Wind Velocity MPH
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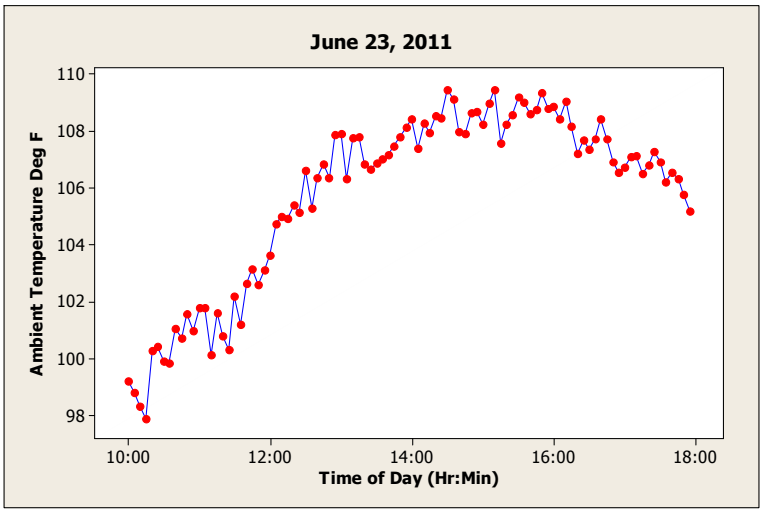
Time of Day (Hr:Min)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Ambient Temperature Deg F
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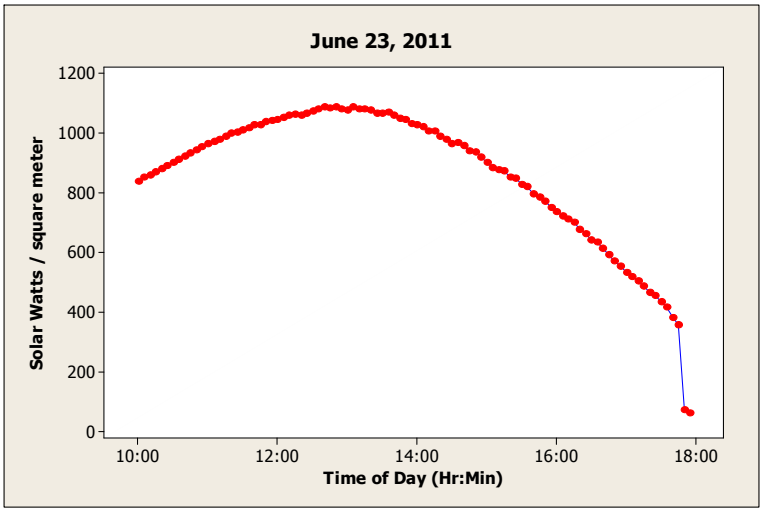
Time of Day (Hr:Min)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Solar Watts / square meter
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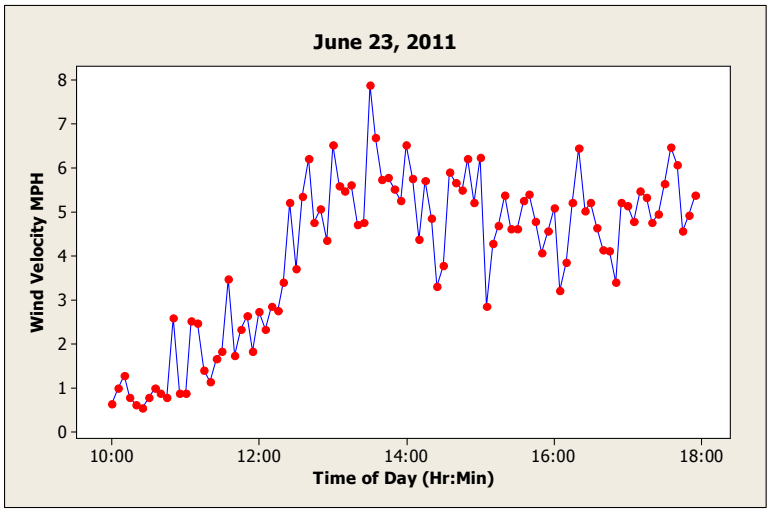
Time of Day (Hr:Min)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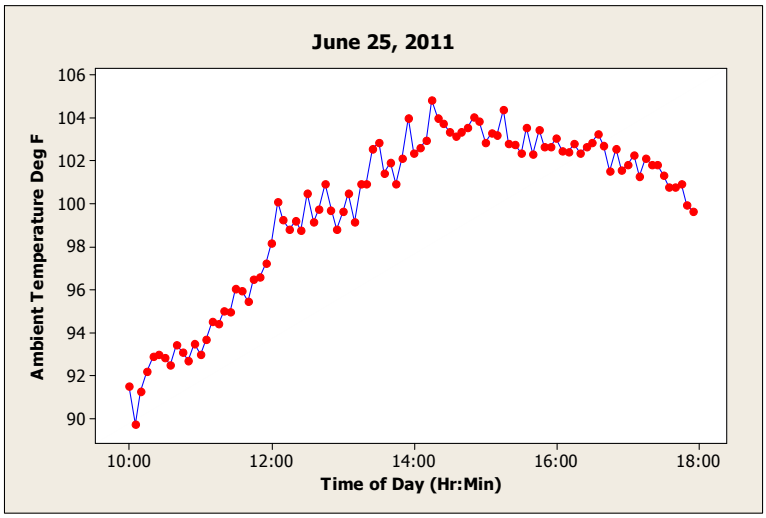
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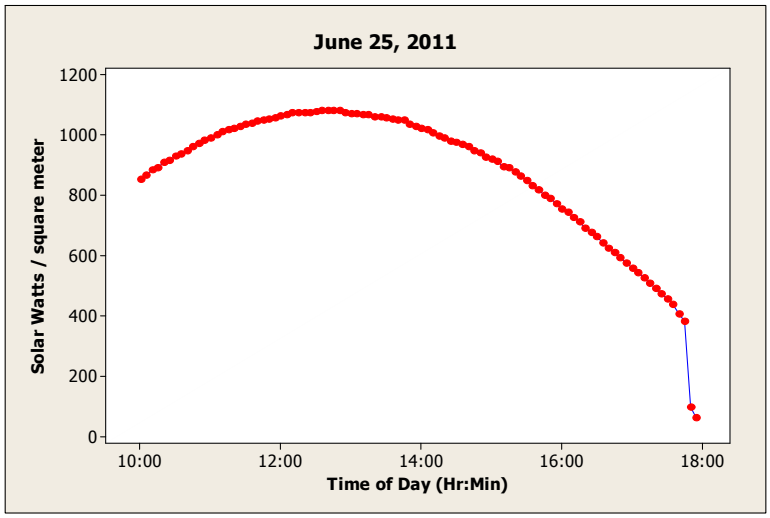
Time of Day (Hr:Min)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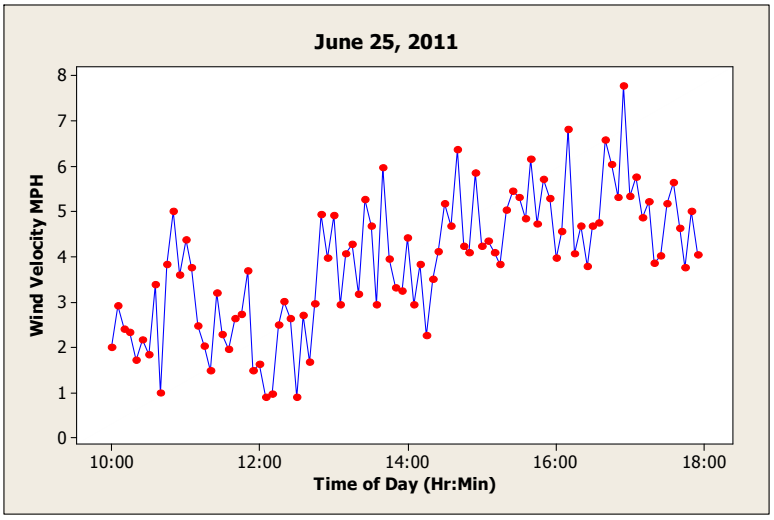
Time of Day (Hr:Min)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Wind Velocity MPH
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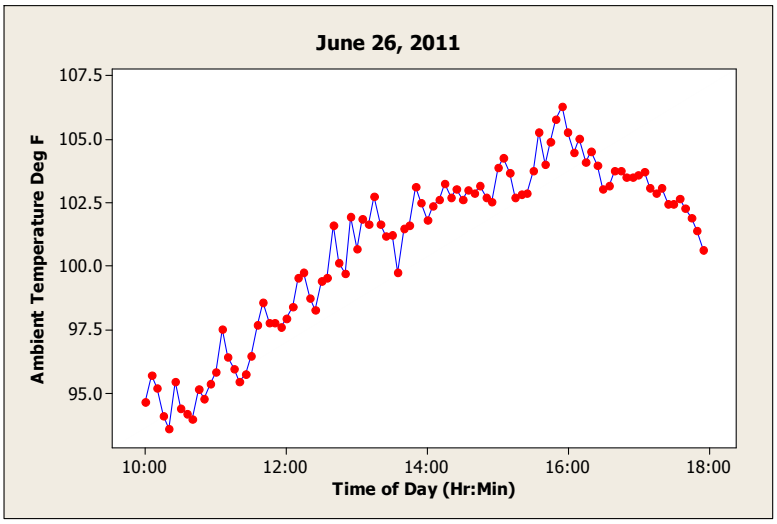
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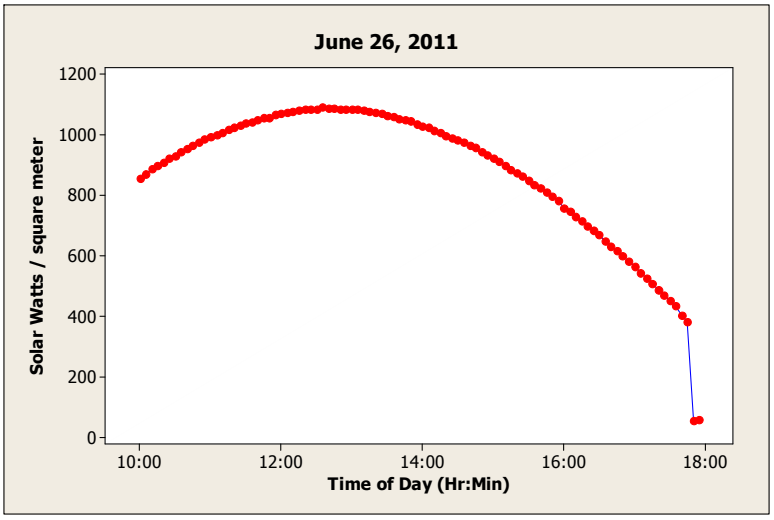
Time of Day (Hr:Min)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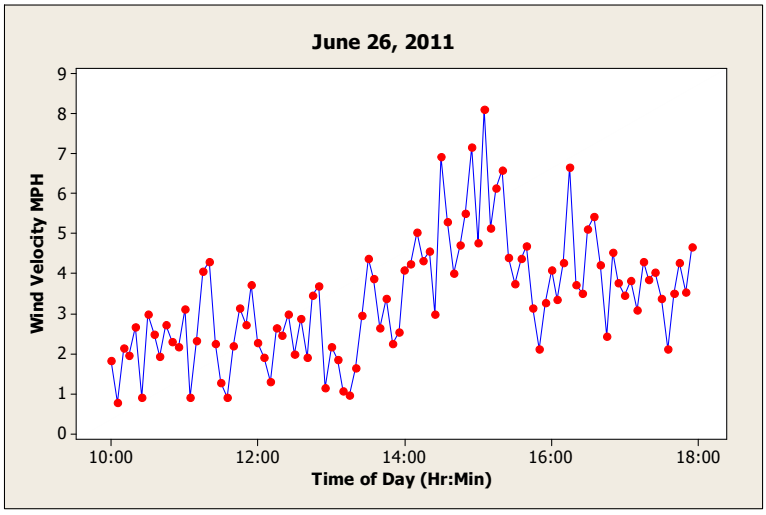
Time of Day (Hr:Min)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Wind Velocity MPH
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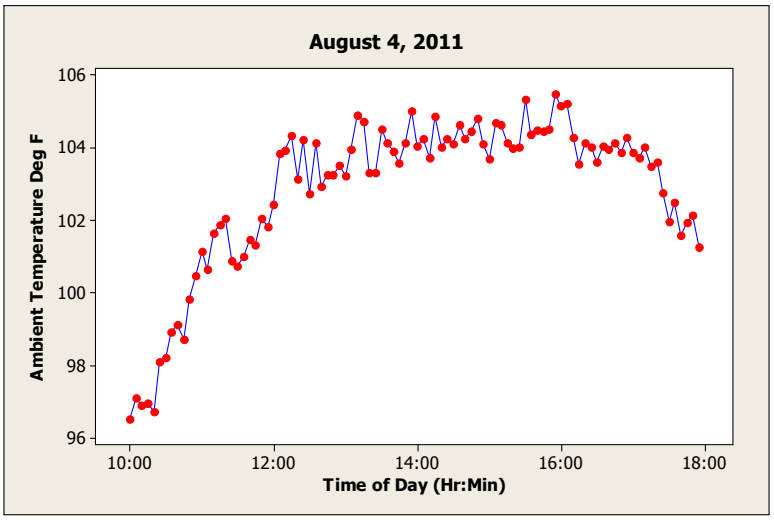
Time of Day (Hr:Min)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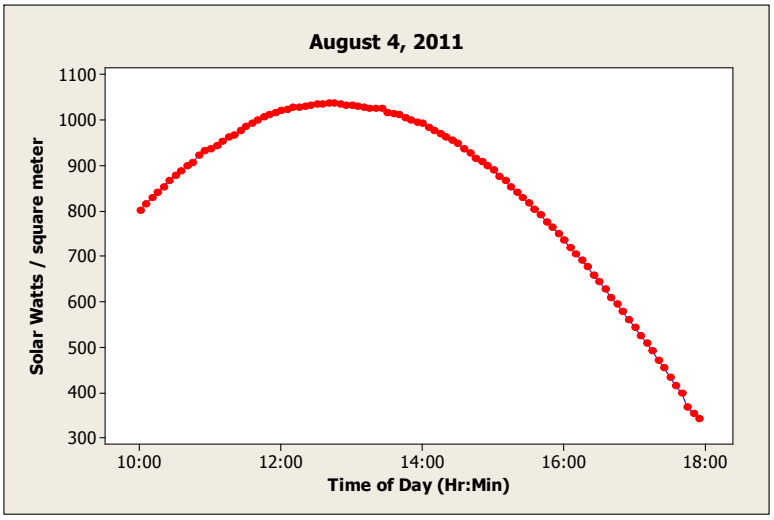
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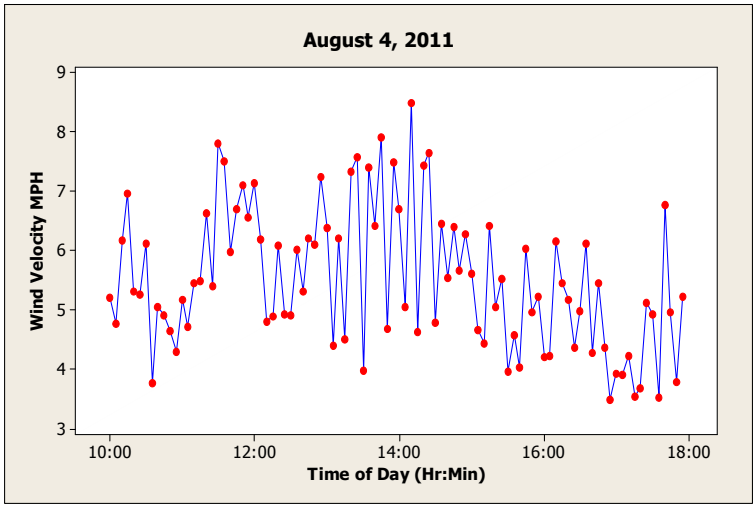
Time of Day (Hr:Min)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Wind Velocity MPH
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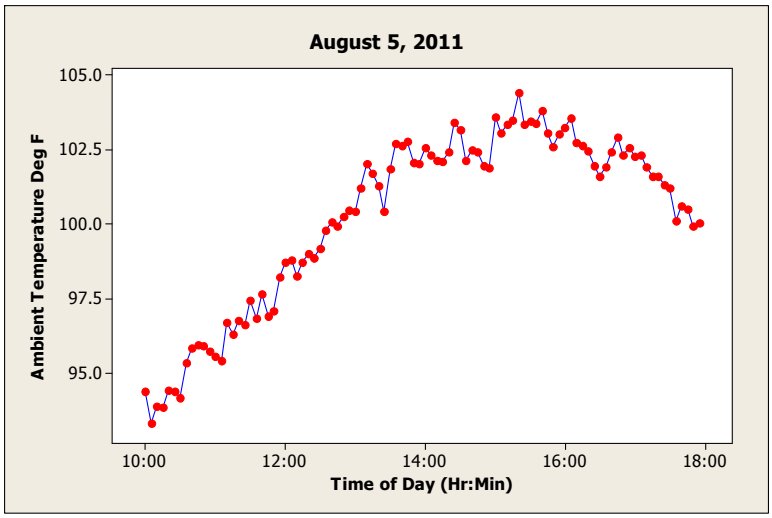
Time of Day (Hr:Min)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Ambient Temperature Deg F
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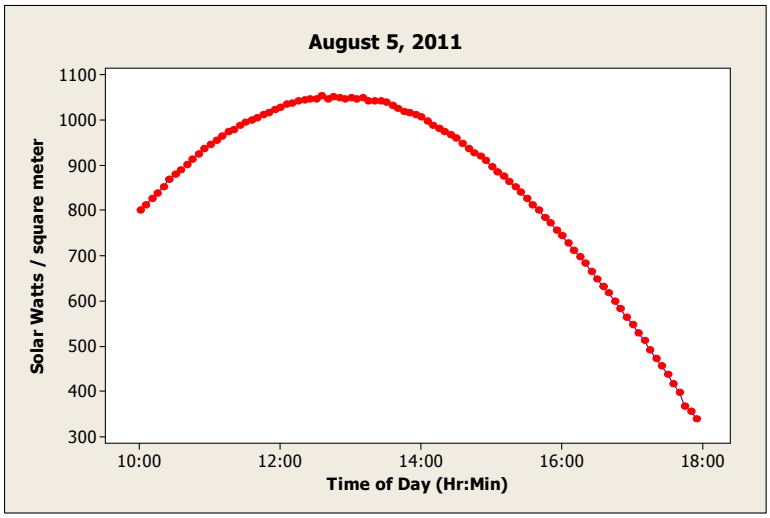
Time of Day (Hr:Min)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Solar Watts / square meter
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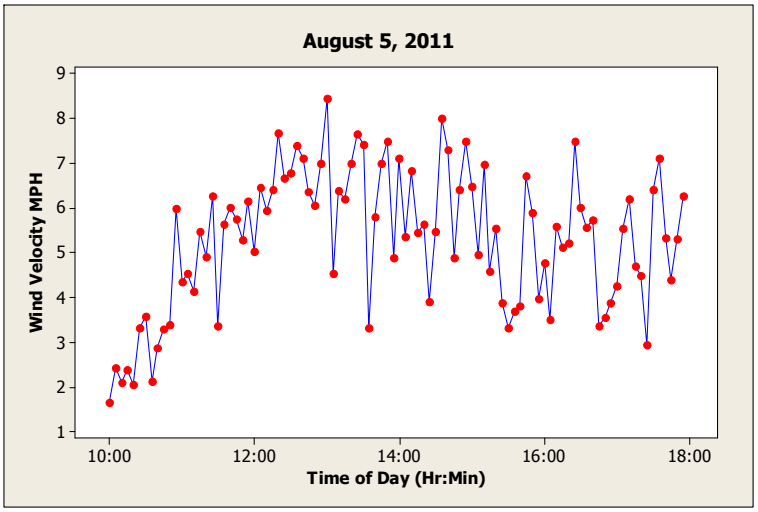
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Wind Velocity MPH
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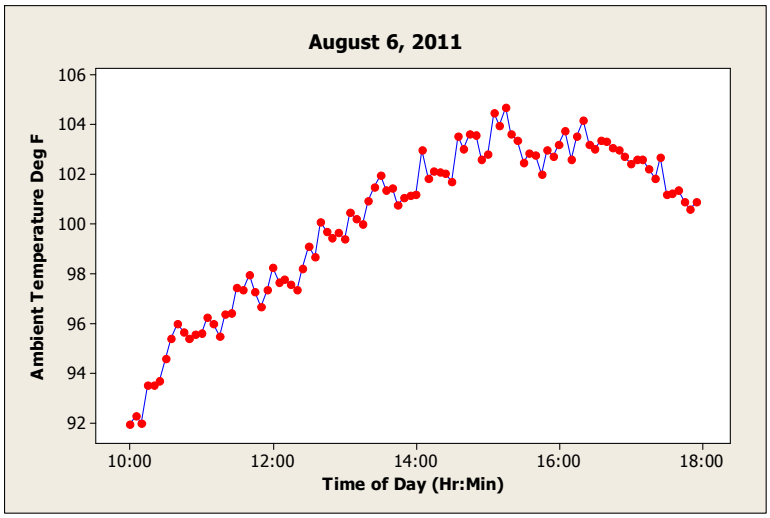
Time of Day (Hr:Min)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Ambient Temperature Deg F
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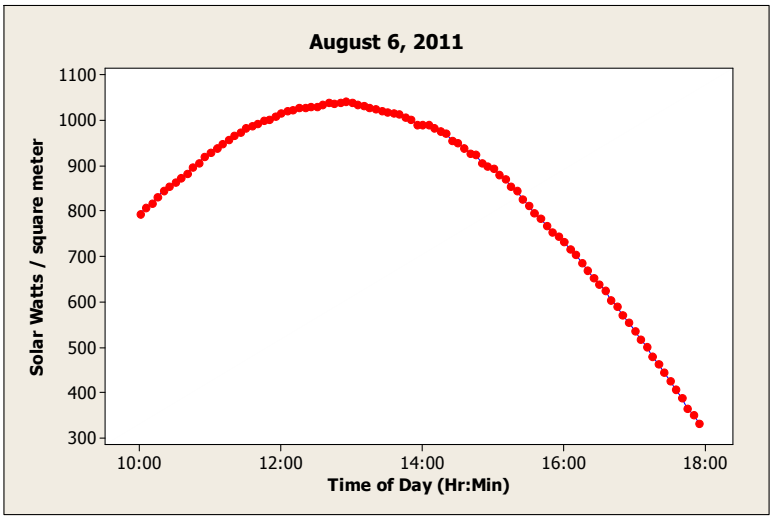
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Solar Watts / square meter
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600
500
400
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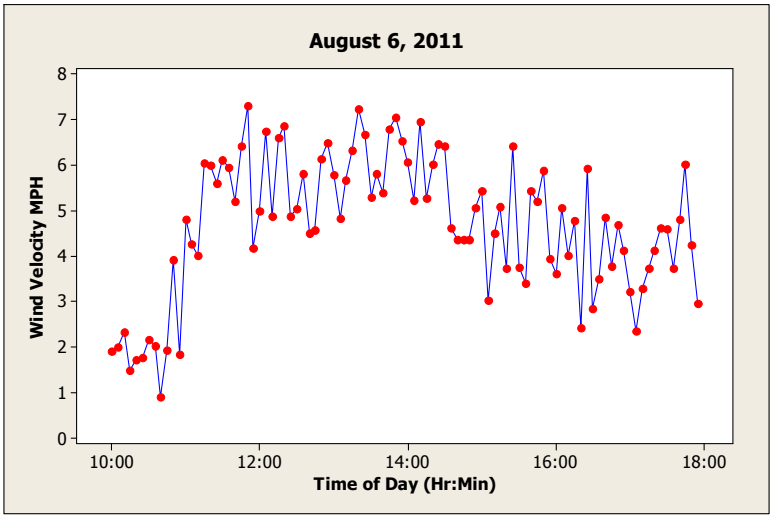
18:00
Time of Day (Hr:Min)


August 6, 2011
Wind Velocity MPH
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7
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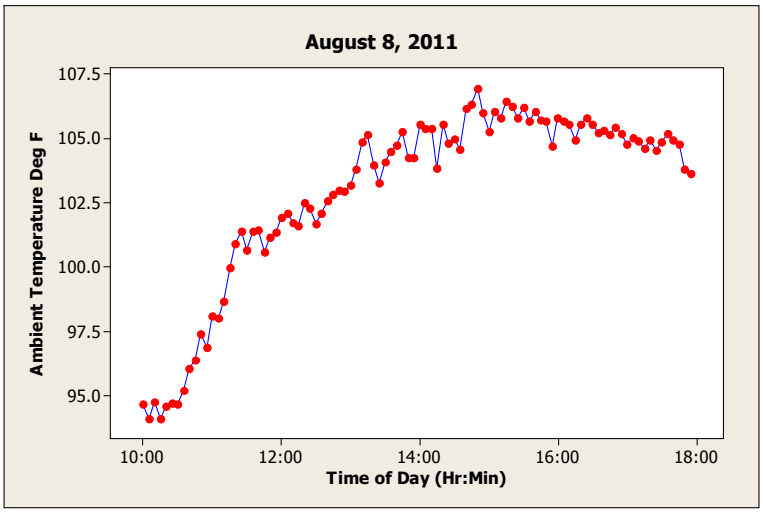
Time of Day (Hr:Min)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Ambient Temperature Deg F
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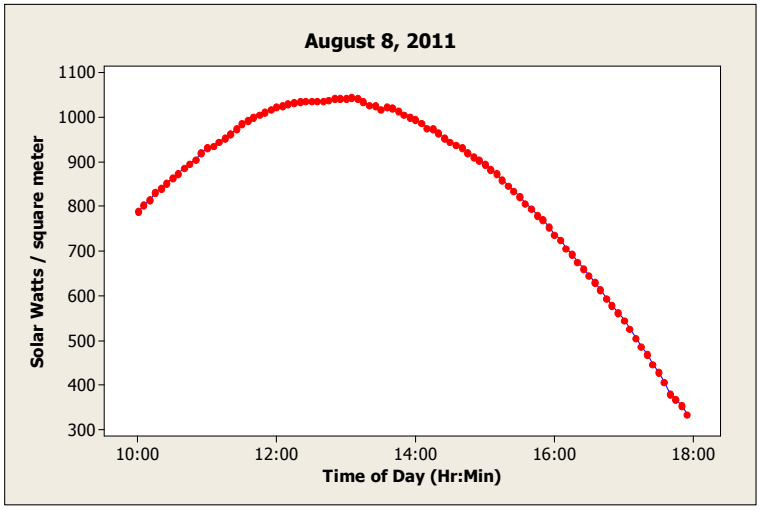
18:00
Time of Day (Hr:Min)


August 8, 2011
Solar Watts / square meter
1100
1000
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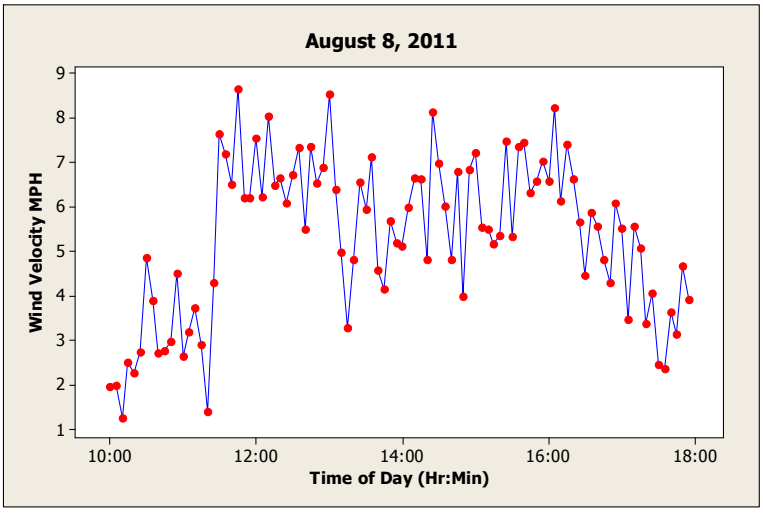
Time of Day (Hr:Min)


August 8, 2011
Wind Velocity MPH
9
8
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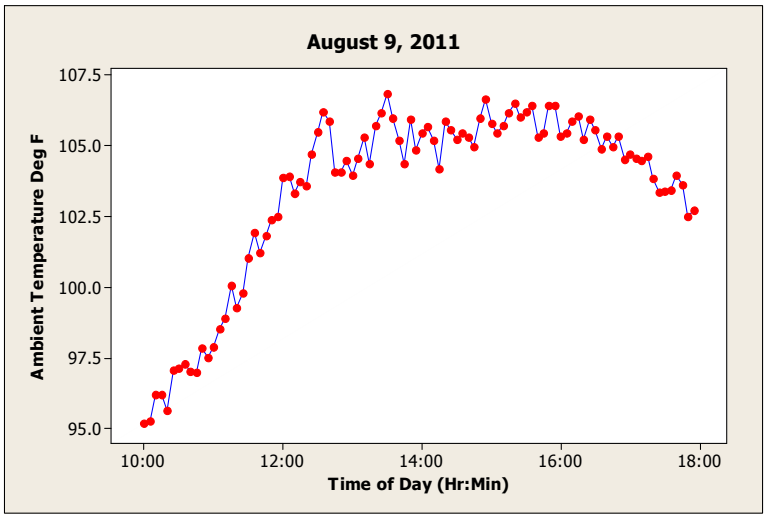
Time of Day (Hr:Min)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Ambient Temperature Deg F
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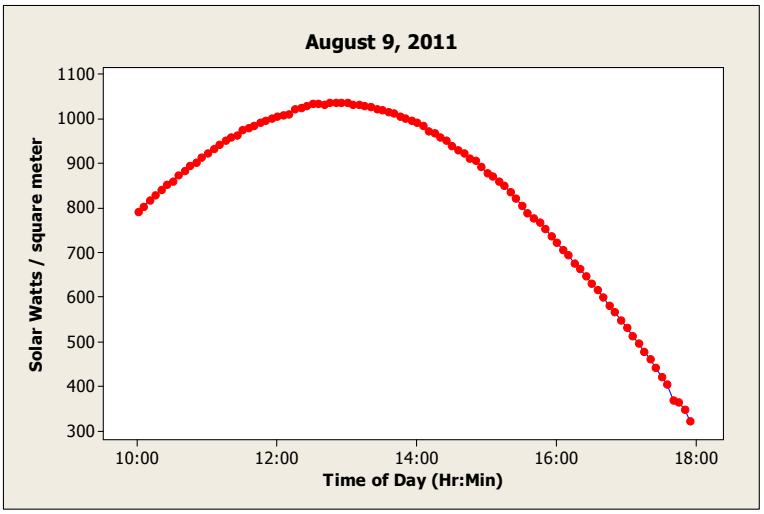
Time of Day (Hr:Min)


August 9, 2011
Solar Watts / square meter
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1000
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600
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400
300
10:00
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14:00
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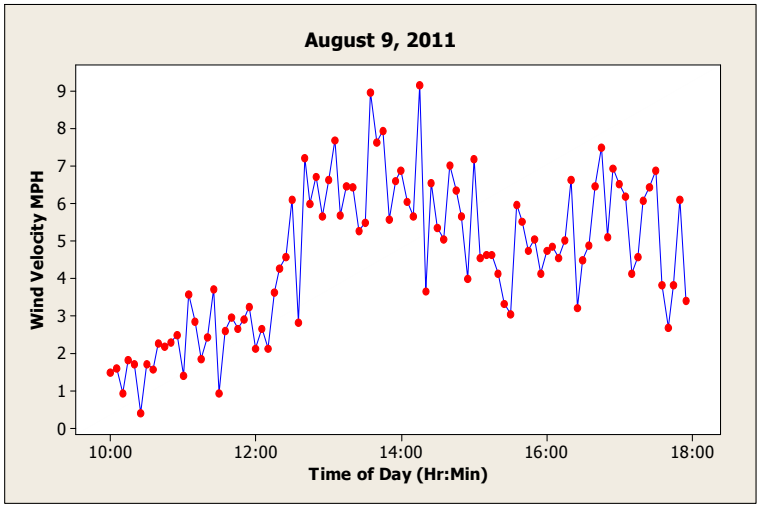
18:00
Time of Day (Hr:Min)


August 9, 2011
Wind Velocity MPH
9
8
7
6
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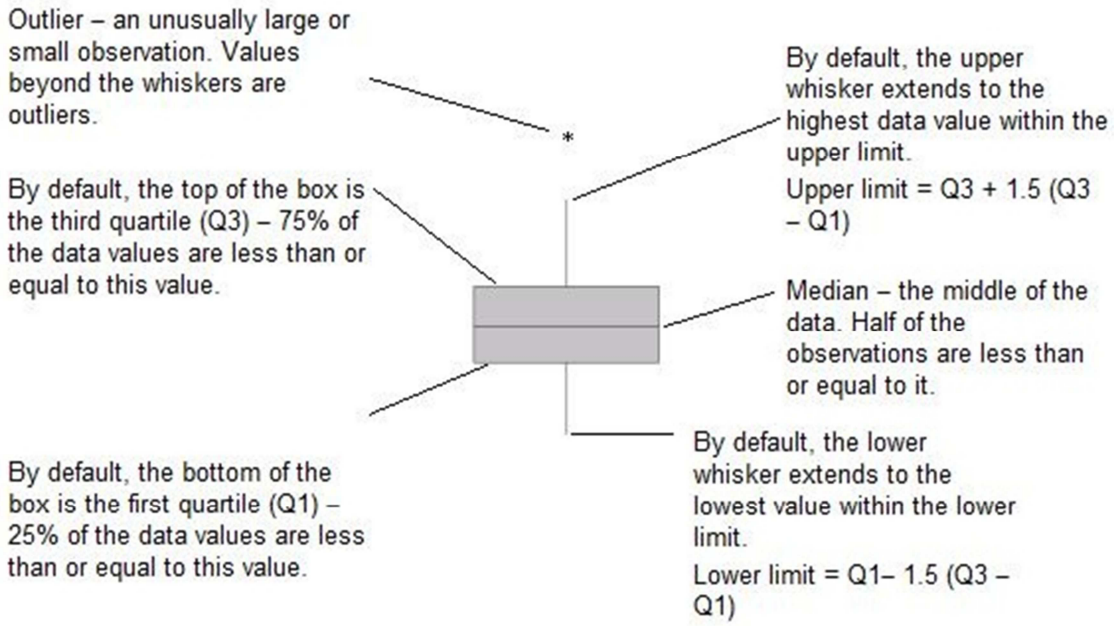
18:00
Time of Day (Hr:Min)

APPENDIX D

Description of Boxplot Diagrams for Data Analysis



Note – A crosshairs within a box also represents the mean (average) of the data.

Public Comment No. 1731-NFPA 70-2018 [Section No. 310.15(C)]

(C) Adjustment Factors.

(1) More than Three Current-Carrying Conductors.

The ampacity of each conductor shall be reduced as shown in Table 310.15(C)(1) where the number of current-carrying conductors in a raceway or cable exceeds three, or where single conductors or multiconductor cables not installed in raceways are installed without maintaining spacing for a continuous length longer than 600 mm (24 in.). Each current-carrying conductor of a paralleled set of conductors shall be counted as a current-carrying conductor.

Table 310.15(C)(1) Adjustment Factors for More Than Three Current-Carrying Conductors

Number of Conductors*	Percent of Values in Table 310.16 Through Table 310.19 as Adjusted for Ambient Temperature if Necessary
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

*Number of conductors is the total number of conductors in the raceway or cable, including spare conductors. The count shall be adjusted in accordance with 310.15(E) and (F). The count shall not include conductors that are connected to electrical components that cannot be simultaneously energized.

~~Note:~~

~~Spacing between raceways shall be maintained.~~

~~*Exception: Type XHHW-2 insulated conductors shall not be subject to this ampacity adjustment.*~~

~~Informational Note: One source for the ambient temperatures in various locations is the ASHRAE *Handbook — Fundamentals* .~~

Where conductors of different systems, as provided in 300.3, are installed in a common raceway or cable, the adjustment factors shown in Table 310.15(C)(1) shall apply only to the number of power and lighting conductors (Articles 210, 215, 220, and 230).

Informational Note No. 1: See Annex B for adjustment factors for more than three current-carrying conductors in a raceway or cable with load diversity.

Informational Note No. 2: See 366.23 for adjustment factors for conductors and ampacity for bare copper and aluminum bars in auxiliary gutters and 376.22(B) for adjustment factors for conductors in metal wireways.

(a) Where conductors are installed in cable trays, the provisions of 392.80 shall apply.

(b) Adjustment factors shall not apply to conductors in raceways having a length not exceeding 600 mm (24 in.).

(c) Adjustment factors shall not apply to underground conductors entering or leaving an outdoor trench if those conductors have physical protection in the form of rigid metal conduit, intermediate metal conduit, rigid polyvinyl chloride conduit (PVC), or reinforced thermosetting resin conduit (RTRC) having a length not exceeding 3.05 m (10 ft), and if the number of conductors does not exceed four.

(d) Adjustment factors shall not apply to Type AC cable or to Type MC cable under the following conditions:

(5) The cables do not have an overall outer jacket.

(6) Each cable has not more than three current-carrying conductors.

(7) The conductors are 12 AWG copper.

(8) Not more than 20 current-carrying conductors are installed without maintaining spacing, are stacked, or are supported on “bridle rings.”

Exception to (4): If cables meeting the requirements in 310.15(C)(1)(d)(1) through (C)(1)(d)(3) with more than 20 current-carrying conductors are installed longer than 600 mm (24 in.) without maintaining spacing, are stacked, or are supported on bridle rings, a 60 percent adjustment factor shall be applied.

(2) *Raceway Spacing. Spacing between raceways shall be maintained.*

Statement of Problem and Substantiation for Public Comment

The exception and IN for rooftop were deleted and moved to the correct location in another PC.
The requirement for raceway spacing was incorrectly located as a note, so it was deleted and then added as list item (C)(2).

Related Item

- FR 8030

Submitter Information Verification

Submitter Full Name: Christel Hunter
Organization: Cerro Wire
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 29 18:54:55 EDT 2018
Committee: NEC-P06

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Public Comment No. 1422-NFPA 70-2018 [Section No. 310.15(C)(1)]

(1) More than Three Current-Carrying Conductors.

The ampacity of each conductor shall be reduced as shown in Table 310.15(C)(1) where the number of current-carrying conductors in a raceway or cable exceeds three, or where single conductors or multiconductor cables not installed in raceways are installed without maintaining spacing for a continuous length longer than 600 mm (24 in.). Each current-carrying conductor of a paralleled set of conductors shall be counted as a current-carrying conductor.

Table 310.15(C)(1) Adjustment Factors for More Than Three Current-Carrying Conductors

Number of Conductors*	Percent of Values in Table 310.16 Through Table 310.19 as Adjusted for Ambient Temperature if Necessary
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

*Number of conductors is the total number of conductors in the raceway or cable, including spare conductors. The count shall be adjusted in accordance with 310.15(E) and (F). The count shall not include conductors that are connected to electrical components that cannot be simultaneously energized.

Note:

Spacing between raceways shall be maintained.

~~*Exception: Type XHHW-2 insulated conductors shall not be subject to this ampacity adjustment.*~~

~~Informational Note: One source for the ambient temperatures in various locations is the ASHRAE *Handbook — Fundamentals* .~~

Where conductors of different systems, as provided in 300.3 , are installed in a common raceway or cable, the adjustment factors shown in Table 310.15(C)(1) shall apply only to the number of power and lighting conductors (Articles 210, 215, 220, and 230).

Informational Note No. 1: See Annex B for adjustment factors for more than three current-carrying conductors in a raceway or cable with load diversity.

Informational Note No. 2: See 366.23 for adjustment factors for conductors and ampacity for bare copper and aluminum bars in auxiliary gutters and 376.22(B) for adjustment factors for conductors in metal wireways.

(a) Where conductors are installed in cable trays, the provisions of 392.80 shall apply.

(b) Adjustment factors shall not apply to conductors in raceways having a length not exceeding 600 mm (24 in.).

(c) Adjustment factors shall not apply to underground conductors entering or leaving an outdoor trench if those conductors have physical protection in the form of rigid metal conduit, intermediate metal conduit, rigid polyvinyl chloride conduit (PVC), or reinforced thermosetting resin conduit (RTRC) having a length not exceeding 3.05 m (10 ft), and if the number of conductors does not exceed four.

(d) Adjustment factors shall not apply to Type AC cable or to Type MC cable under the following conditions:

(5) The cables do not have an overall outer jacket.

(6) Each cable has not more than three current-carrying conductors.

(7) The conductors are 12 AWG copper.

(8) Not more than 20 current-carrying conductors are installed without maintaining spacing, are stacked, or are supported on “bridle rings.”

Exception to (4): If cables meeting the requirements in 310.15(C)(1)(d)(1) through (C)(1)(d)(3) with more than 20 current-carrying conductors are installed longer than 600 mm (24 in.) without maintaining spacing, are stacked, or are supported on bridle rings, a 60 percent adjustment factor shall be applied.

Statement of Problem and Substantiation for Public Comment

Although this exception should not exist at all anywhere in the NEC, The exception and the following informational note were editorially placed in this subsection apparently by mistake, and should follow the rooftop temperature requirements where these were originated.

Related Item

- Public Input No. 3450-NFPA 70-2017

Submitter Information Verification

Submitter Full Name: Travis Lindsey
Organization: TLC Services
Affiliation: Copper Development Associaton
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 28 12:33:09 EDT 2018
Committee: NEC-P06

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Public Comment No. 390-NFPA 70-2018 [Section No. 310.15(C)(1)]

(1) More than Three Current-Carrying Conductors.

The ampacity of each conductor shall be reduced as shown in Table 310.15(C)(1) where the number of current-carrying conductors in a raceway or cable exceeds three, or where single conductors or multiconductor cables not installed in raceways are installed without maintaining spacing for a continuous length longer than 600 mm (24 in.). Each current-carrying conductor of a paralleled set of conductors shall be counted as a current-carrying conductor.

Table 310.15(C)(1) Adjustment Factors for More Than Three Current-Carrying Conductors

Number of Conductors*	Percent of Values in Table 310.16 Through Table 310.19 as Adjusted for Ambient Temperature if Necessary
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

*Number of conductors is the total number of conductors in the raceway or cable, including spare conductors. The count shall be adjusted in accordance with 310.15(E) and (F). The count shall not include conductors that are connected to electrical components that cannot be simultaneously energized.

Note:

Spacing between raceways shall be maintained.

~~*Exception: Type XHHW-2 insulated conductors shall not be subject to this ampacity adjustment.*~~

Informational Note: One source for the ambient temperatures in various locations is the ASHRAE *Handbook — Fundamentals*.

Where conductors of different systems, as provided in 300.3, are installed in a common raceway or cable, the adjustment factors shown in Table 310.15(C)(1) shall apply only to the number of power and lighting conductors (Articles 210, 215, 220, and 230).

Informational Note No. 1: See Annex B for adjustment factors for more than three current-carrying conductors in a raceway or cable with load diversity.

~~Informational Note No. 2: See 366.23 for adjustment factors for conductors and ampacity for bare copper and aluminum bars in auxiliary gutters and 376.22(B) for adjustment factors for conductors in metal wireways.~~

(a) ~~Where conductors are installed in cable trays, the provisions of 392.80 shall apply.~~ Where conductors are installed in cable trays, the provisions of 392.80 shall apply, where conductors are installed in metal auxiliary gutters the provisions of 366.23(A) shall apply, and where conductors are installed in metal wireways the provisions of 376.22(B) shall apply

(b) Adjustment factors shall not apply to conductors in raceways having a length not exceeding 600 mm (24 in.).

(c) Adjustment factors shall not apply to underground conductors entering or leaving an outdoor trench if those conductors have physical protection in the form of rigid metal conduit, intermediate metal conduit, rigid polyvinyl chloride conduit (PVC), or reinforced thermosetting resin conduit (RTRC) having a length not exceeding 3.05 m (10 ft), and if the number of conductors does not exceed four.

(d) Adjustment factors shall not apply to Type AC cable or to Type MC cable under the following conditions:

(5) The cables do not have an overall outer jacket.

(6) Each cable has not more than three current-carrying conductors.

(7) The conductors are 12 AWG copper.

(8) Not more than 20 current-carrying conductors are installed without maintaining spacing, are stacked, or are supported on “bridle rings.”

Exception to (4): If cables meeting the requirements in 310.15(C)(1)(d)(1) through (C)(1)(d)(3) with more than 20 current-carrying conductors are installed longer than 600 mm (24 in.) without maintaining spacing, are stacked, or are supported on bridle rings, a 60 percent adjustment factor shall be applied.

Statement of Problem and Substantiation for Public Comment

1. Delete the exception, since it belongs to 310.15(B), not 310.15(C).
2. Delete Note 2 and take the text and incorporate it into the rule, since Informational Notes are not Code.

Related Item

• FR-8918

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Sat Aug 04 16:25:05 EDT 2018
Committee: NEC-P06

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Public Comment No. 408-NFPA 70-2018 [Section No. 310.15(E)]

(E) Neutral Conductor.

(1) A neutral conductor that carries only the unbalanced current from other conductors of the same circuit shall not be required to be counted when applying the provisions of 310.15(C)(1).

(2) In a 3-wire circuit consisting of two phase conductors and the neutral conductor of a 4-wire, 3-phase, wye-connected system, ~~a common conductor carries approximately the same current as the line-to-neutral load currents of the other conductors and shall be counted when applying~~ the neutral conductor shall be considered a current-carrying conductor when apply the provisions of 310.15(C)(1).

(3) On a 4-wire, 3-phase wye circuit where ~~the major portion of the load consists of nonlinear loads, harmonic currents are present in the neutral conductor; the neutral conductor shall therefore~~ nonlinear loads exceed fifty percent of the conductor ampacity, the neutral conductor shall be considered a current-carrying conductor when apply the provisions of 310 .15(C)(1).

Statement of Problem and Substantiation for Public Comment

Edits to (b) include the removal of the 'theory' in the rule that does not help in application. This is not typically how Code is written. Practically all Code rules are based on some 'theory.'
Edits to (c) include the removal of the 'theory' in the rule that does not help in application and the major portion measurement is not based on the load but based on the conductor ampacity.
For example: If you have a 400A service with 500 kcmil ungrounded and neutral conductors, with a calculated load of 305A and 160A of this load is nonlinear. The neutral conductor is considered current carrying. The purpose of conductor adjustment is based on 'heat', clearly a 500 kcmil rated 380A neutral should not be considered current carrying for conductor ampacity.

Related Item

• PI-2168

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 05 08:38:08 EDT 2018
Committee: NEC-P06

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Public Comment No. 492-NFPA 70-2018 [Section No. 310.15(E)]

(E) Neutral Conductor.

~~A neutral conductor that carries only the unbalanced current from other conductors of the same circuit shall not be required to be counted~~

(1) Neutral conductors shall be considered current carrying conductors when applying the provisions of 310.15(C)(1)

~~.~~

(1)

- ~~In a 3-wire circuit consisting of two phase conductors and the neutral conductor of a 4-wire, 3-phase, wye-connected system, a common conductor carries approximately the same current as the line-to-neutral load currents of the other conductors and shall be counted when applying the provisions of 310.15(C)(1).~~

~~On a 4-wire, 3-phase wye~~

Exception #1 - The neutral conductor carrying only the unbalanced current from other conductors of the same multiphase feeder where the major portion of the load being served are not non-linear loads and harmonics are not present in the neutral conductor

Exception #2 - The common shared neutral conductor carrying only the unbalanced current from other conductors of a multiphase branch circuit where the major portion of the

~~load consists of nonlinear loads, harmonic currents are~~

loads being served are not non-linear loads and harmonics are not present in the neutral conductor

~~; the neutral conductor shall therefore be considered a current-carrying conductor.~~

Statement of Problem and Substantiation for Public Comment

There is continuing confusion on when a neutral is considered current carrying and when it is not. This would resolve a large amount of the issue as it will always be considered current carrying with two very specific exceptions.

Related Item

• PI #241

Submitter Information Verification

Submitter Full Name: Kevin Rohr
Organization: Greiner Electric
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 09 10:58:32 EDT 2018
Committee: NEC-P06

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Public Comment No. 2184-NFPA 70-2018 [Section No. 310.15 [Excluding any Sub-Sections]]

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

The temperature correction and adjustment factors shall be permitted to be applied to the ampacity for the temperature rating of the conductor, if the corrected and adjusted ampacity does not exceed the ampacity for the temperature rating of the termination in accordance with the provisions of 110.14(C).

Informational Note No. 1: Table 310.16 through Table 310.19 are application tables for use in determining conductor sizes on loads calculated in accordance with Article 220. Ampacities result from consideration of one or more of the following:

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

(2) Coordination with circuit and system overcurrent protection.

(3) Compliance with the requirements of product listings or certifications. See 110.3(B).

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

Informational Note No. 2: For conductor area see Chapter 9, Table 8, Conductor Properties.

Informational Note No. 3: For the ampacities of flexible cords and cables, see 400.5. For the ampacities of fixture wires, see 402.5.

Additional Proposed Changes

File Name	Description	Approved
MTW.jpg	Table 310.15(A)(1)	

Statement of Problem and Substantiation for Public Comment

Previously there was an informational note that referenced the user to NFPA 79 for the ampacities for MTW insulated conductors. This informational note has been deleted and no longer exists. adding this table to somewhere in section 310 would allow users who do control work to find the ampacities for MTW insulated conductors without searching other NFPA documents for the ampacity. These users would be using the same NEC for all wiring and not have to have multiple NFPA documents.

Related Item

• 310.15

Submitter Information Verification

Submitter Full Name: Dennis Querry
Organization: Trinity River Authority
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 30 22:21:43 EDT 2018
Committee: NEC-P06

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Table 310.15(A)(1)(a)

Conductor Ampacity Based on Copper Conductors with 60°C (140°F), 75°C (167°F), and 90°C (194°F) Insulation in an Ambient Temperature of 30°C (86°F)

Conductor Size (AWG)	MTW Ampacity		
	60°C (140°F)	75°C (167°F)	90°C (194°F)
30	—	0.5	0.5
28	—	0.8	0.8
26	—	1	1
24	2	2	2
22	3	3	3
20	5	5	5
18	7	7	14
16	10	10	18
14	20	20	25
12	25	25	30
10	30	35	40
8	40	50	55
6	55	65	75
4	70	85	95
3	85	100	110
2	95	115	130
1	110	130	150
1/0	125	150	170
2/0	145	175	195
3/0	165	200	225
4/0	195	230	260
250	215	255	290
300	240	285	320
350	260	310	350
400	280	335	380
500	320	380	430
600	355	420	475
700	385	460	520
750	400	475	535
800	410	490	555
900	435	520	585
1000	455	545	615

Notes:

(1) Wire types listed in 12.3.1 shall be permitted to be used at the ampacities listed in this table.

(2) The sources for the ampacities in this table are Table 310.15(B)(16)

Public Comment No. 579-NFPA 70-2018 [Section No. 310.15 [Excluding any Sub-Sections]]

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

The temperature correction and adjustment factors shall be permitted to be applied to the ampacity for the temperature rating of the conductor, if the corrected and adjusted ampacity does not exceed the ampacity for the temperature rating of the termination in accordance with the provisions of 110.14(C).

Informational Note No. 1: Table 310.16 through Table 310.19 are application tables for use in determining conductor sizes on loads calculated in accordance with Article 220. Ampacities result from consideration of one or more of the following:

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

(2) Coordination with circuit and system overcurrent protection.

(3) Compliance with the requirements of product listings or certifications. See 110.3(B).

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

Informational Note No. 2: For conductor area see Chapter 9, Table 8, Conductor Properties.

Informational Note No. 3: For the ampacities of flexible cords and cables, see 400.5. For the ampacities of fixture wires, see 402.5.

Statement of Problem and Substantiation for Public Comment

The words "circular mil" must be added to clarify that the interpolation is not based on the square mil or inch area but on the conductor's circular mil area.

Related Item

• FR-8030

Submitter Information Verification

Submitter Full Name: Phil Simmons
Organization: Simmons Electrical Services
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 12 10:11:06 EDT 2018
Committee: NEC-P06

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Public Comment No. 1434-NFPA 70-2018 [New Section after 310.16]

Insulation additions to Tables 310.15(B)(16) and (B)(17)

Add MTW to the 60DegC column

Add MTW, PFA, XHHN, Z, and ZW to the 90DegC columns

Statement of Problem and Substantiation for Public Comment

This comment is meant to apply to the current (2017) table 310.15(B)(16) and (B)(17)

It seems like the table has been moved, and i can't find it in the first draft.

Not all the insulation types in table 310.104(A) appear in the aforementioned tables. These may have been omitted on purpose. In any event, this comment is simply meant to bring it to the attention of the Panel.

This is a comment on PI 2524. In the PDF that includes this PI, the PI is shown as 310.15(B)(7). I'm not sure what happened here.

Related Item

• 2524-NFPA 70-2017

Submitter Information Verification

Submitter Full Name: Eric Stromberg
Organization: Los Alamos National Laboratory
Affiliation: Self
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 28 14:41:02 EDT 2018
Committee: NEC-P06

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Public Comment No. 1733-NFPA 70-2018 [Section No. 310.16]

310.~~16~~ ~~Allowable~~ 16 Ampacities of Insulated Conductors in Raceway, Cable, or Earth (Directly Buried).

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

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

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

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

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

Statement of Problem and Substantiation for Public Comment

The CMP agreed to delete the word "allowable" in response to PIs submitted by an Ampacity Task Group.

Related Item

• FR 8030

Submitter Information Verification

Submitter Full Name: Christel Hunter
Organization: Cerro Wire
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 29 19:02:49 EDT 2018
Committee: NEC-P06

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Public Comment No. 467-NFPA 70-2018 [Section No. 310.16]

310.16 ~~Allowable~~ 16 Ampacities of Insulated Conductors in Raceway, Cable, or Earth (Directly Buried).

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

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

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

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

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

Statement of Problem and Substantiation for Public Comment

The langue "allowable ampacity" has been removed in many throughout this code as a result of the work of an Ampacity Task Group. The task group consisted of the following members: Thomas Domitrovich, Dave Mercier, Christine Porter, Derrick Atkins, and Christel Hunter. Ampacity is the maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating. The term used in this section should be "ampacity" and not "allowable ampacity" as it is the intent for this section to determine the ampacity of the conductor based upon its condition of use.

Related Item

• FR 8030

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
Organization: Eaton Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 08 16:47:41 EDT 2018
Committee: NEC-P06

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Public Comment No. 632-NFPA 70-2018 [Section No. 310.16]

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

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

(1) Conductors are rated 0 volts up to and including 2000 volts.

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

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

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

Statement of Problem and Substantiation for Public Comment

Revised language to insure that 2000 volts is allowed.

Related Item

• FR 8918

Submitter Information Verification

Submitter Full Name: David Kendall
Organization: Thomas & Betts Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 14 11:17:37 EDT 2018
Committee: NEC-P06

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Public Comment No. 1734-NFPA 70-2018 [Section No. 310.17]

310.17 ~~Allowable~~ 17 Ampacities of Single-Insulated Conductors in Free Air.

The maximum ~~allowable~~ ampacities shall be as specified in Table 310.17 where all of the following conditions apply:

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

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

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

Statement of Problem and Substantiation for Public Comment

The CMP agreed to delete the word "allowable" in response to PIs submitted by an Ampacity Task Group.

Related Item

• FR 8030

Submitter Information Verification

Submitter Full Name: Christel Hunter
Organization: Cerro Wire
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 29 19:07:18 EDT 2018
Committee: NEC-P06

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Public Comment No. 468-NFPA 70-2018 [Section No. 310.17]

310.17 ~~Allowable~~ 17 Ampacities of Single-Insulated Conductors in Free Air.

The maximum ~~allowable~~ ampacities shall be as specified in Table 310.17 where all of the following conditions apply:

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

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

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

Statement of Problem and Substantiation for Public Comment

The langue "allowable ampacity" has been removed in many throughout this code as a result of the work of an Ampacity Task Group. The task group consisted of the following members: Thomas Domitrovich, Dave Mercier, Christine Porter, Derrick Atkins, and Christel Hunter. Ampacity is the maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating. The term used in this section should be "ampacity" and not "allowable ampacity" as it is the intent for this section to determine the ampacity of the conductor based upon its condition of use.

Related Item

• FR 8030

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
Organization: Eaton Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 08 16:53:01 EDT 2018
Committee: NEC-P06

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Public Comment No. 636-NFPA 70-2018 [Section No. 310.17]

310.17 Allowable Ampacities of Single-Insulated Conductors in Free Air.

The maximum allowable ampacities shall be as specified in Table 310.17 where all of the following conditions apply:

(1) Conductors are rated 0 volts up to and including 2000 volts.

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

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

Statement of Problem and Substantiation for Public Comment

Revised language to insure that 2000 volts is allowed.

Related Item

• FR 8918

Submitter Information Verification

Submitter Full Name: David Kendall
Organization: Thomas & Betts Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 14 11:23:06 EDT 2018
Committee: NEC-P06

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Public Comment No. 1736-NFPA 70-2018 [Section No. 310.18]

310.18 ~~Allowable~~ Ampacities of Insulated Conductors in Raceway or Cable.

The maximum ~~allowable~~ ampacities shall be as specified in Table 310.18 where all of the following conditions apply:

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

(2) Conductors are rated 150°C (302°F), 200°C (392°F), or 250°C (482°F).

(3) Wiring is installed in a 40°C (86°F) ambient temperature.

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

Statement of Problem and Substantiation for Public Comment

The CMP agreed to delete the word "allowable" in response to PIs submitted by an Ampacity Task Group.

Related Item

• FR 8030

Submitter Information Verification

Submitter Full Name: Christel Hunter
Organization: Cerro Wire
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 29 19:08:04 EDT 2018
Committee: NEC-P06

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Public Comment No. 469-NFPA 70-2018 [Section No. 310.18]

310.18 ~~Allowable~~ 18 Ampacities of Insulated Conductors in Raceway or Cable.

The maximum ~~allowable~~ ampacities shall be as specified in Table 310.18 where all of the following conditions apply:

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

(2) Conductors are rated 150°C (302°F), 200°C (392°F), or 250°C (482°F).

(3) Wiring is installed in a 40°C (86°F) ambient temperature.

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

Statement of Problem and Substantiation for Public Comment

The langue "allowable ampacity" has been removed in many throughout this code as a result of the work of an Ampacity Task Group. The task group consisted of the following members: Thomas Domitrovich, Dave Mercier, Christine Porter, Derrick Atkins, and Christel Hunter. Ampacity is the maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating. The term used in this section should be "ampacity" and not "allowable ampacity" as it is the intent for this section to determine the ampacity of the conductor based upon its condition of use.

Related Item

• FR 8030

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
Organization: Eaton Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 08 16:55:26 EDT 2018
Committee: NEC-P06

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Public Comment No. 624-NFPA 70-2018 [Section No. 310.18]

310.18 Allowable Ampacities of Insulated Conductors in Raceway or Cable.

The maximum allowable ampacities shall be as specified in Table 310.18 where all of the following conditions apply:

(1) Conductors are rated 0 volts up to and including 2000 volts.

(2) Conductors are rated 150°C (302°F), 200°C (392°F), or 250°C (482°F).

(3) Wiring is installed in a 40°C (~~86°F~~ 104°F) ambient temperature.

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

Statement of Problem and Substantiation for Public Comment

Editorial correction for 104 degrees F. Revised language to mirror what is currently in the 2018 NEC Table 310.18 to be clear that 2000 volts is included.

Related Item

• FR-8918

Submitter Information Verification

Submitter Full Name: David Kendall
Organization: Thomas & Betts Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 14 10:57:32 EDT 2018
Committee: NEC-P06

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Public Comment No. 626-NFPA 70-2018 [Section No. 310.18]

310.18 Allowable Ampacities of Insulated Conductors in Raceway or Cable.

The maximum allowable ampacities shall be as specified in Table 310.18 where all of the following conditions apply:

(1) Conductors are ~~rated 0 volts to 2000~~ rated up to and including 2000 volts.

(2) Conductors are rated 150°C (302°F), 200°C (392°F), or 250°C (482°F).

(3) Wiring is installed in a 40°C (~~86°F~~ 104°F) ambient temperature.

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

Statement of Problem and Substantiation for Public Comment

The changes made are editorial to make the text in 310.18 match the wording in the title of table 310.18 also wanted to correct the temperature rating since 40 degree C is 104 degree F.

Related Item

• FR8918

Submitter Information Verification

Submitter Full Name: Raymond Horner
Organization: Atkore International
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 14 11:03:44 EDT 2018
Committee: NEC-P06

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Public Comment No. 1737-NFPA 70-2018 [Section No. 310.19]

310.19 ~~Allowable~~ 19 Ampacities of Single-Insulated Conductors in Free Air.

The maximum ~~allowable~~ ampacities shall be as specified in Table 310.19 where all of the following conditions apply:

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

(2) Conductors are rated up to 250°C (482°F).

(3) Wiring is installed in a 40°C (86°F) ambient temperature.

Statement of Problem and Substantiation for Public Comment

The CMP agreed to delete the word "allowable" in response to PIs submitted by an Ampacity Task Group.

Related Item

• FR 8030

Submitter Information Verification

Submitter Full Name: Christel Hunter
Organization: Cerro Wire
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 29 19:10:17 EDT 2018
Committee: NEC-P06

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Public Comment No. 470-NFPA 70-2018 [Section No. 310.19]

310.19 ~~Allowable~~ 19 Ampacities of Single-Insulated Conductors in Free Air.

The maximum ~~allowable~~ ampacities shall be as specified in Table 310.19 where all of the following conditions apply:

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

(2) Conductors are rated up to 250°C (482°F).

(3) Wiring is installed in a 40°C (86°F) ambient temperature.

Statement of Problem and Substantiation for Public Comment

The langue "allowable ampacity" has been removed in many throughout this code as a result of the work of an Ampacity Task Group. The task group consisted of the following members: Thomas Domitrovich, Dave Mercier, Christine Porter, Derrick Atkins, and Christel Hunter. Ampacity is the maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating. The term used in this section should be "ampacity" and not "allowable ampacity" as it is the intent for this section to determine the ampacity of the conductor based upon its condition of use.

Related Item

• FR 8030

Submitter Information Verification

Submitter Full Name: Thomas Domitrovich
Organization: Eaton Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 08 16:56:57 EDT 2018
Committee: NEC-P06

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Public Comment No. 627-NFPA 70-2018 [Section No. 310.19]

310.19 Allowable Ampacities of Single-Insulated Conductors in Free Air.

The maximum allowable ampacities shall be as specified in Table 310.19 where all of the following conditions apply:

(1) Conductors are ~~rated 0 volts to 2000~~ rated up to and including 2000 volts.

(2) Conductors are rated up to 250°C (482°F).

(3) Wiring is installed in a 40°C (~~86°F~~ 104°F) ambient temperature.

Statement of Problem and Substantiation for Public Comment

Editorial changes made to correct temperature rating.

Related Item

• FR8918

Submitter Information Verification

Submitter Full Name: Raymond Horner
Organization: Atkore International
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 14 11:09:36 EDT 2018
Committee: NEC-P06

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Public Comment No. 628-NFPA 70-2018 [Section No. 310.19]

310.19 Allowable Ampacities of Single-Insulated Conductors in Free Air.

The maximum allowable ampacities shall be as specified in Table 310.19 where all of the following conditions apply:

(1) Conductors are rated 0 volts up to and including 2000 volts.

(2) Conductors are rated up to 250°C (482°F).

(3) Wiring is installed in a 40°C (~~86°F~~ 104°F) ambient temperature.

Statement of Problem and Substantiation for Public Comment

Editorial correction for 104 degrees F. Revised language to insure that 2000 volts is allowable.

Related Item

• FR 8918

Submitter Information Verification

Submitter Full Name: David Kendall
Organization: Thomas & Betts Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 14 11:09:47 EDT 2018
Committee: NEC-P06

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Public Comment No. 629-NFPA 70-2018 [Section No. 310.20]

310.20 Ampacities of Conductors Supported on a Messenger.

The maximum ampacities shall be as specified in Table 310.20 where all of the following conditions apply:

(1) Conductors are rated 0 volts up to and including 2000 volts.

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

(3) Wiring is installed in a 40°C (~~86°F~~ 104°F) ambient temperature.

(4) There are not more than three single-insulated conductors.

Statement of Problem and Substantiation for Public Comment

Editorial for 104 degrees F. Revised language to insure that 2000 volts is allowed.

Related Item

• FR 8918

Submitter Information Verification

Submitter Full Name: David Kendall
Organization: Thomas & Betts Corporation
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Submittal Date: Tue Aug 14 11:13:03 EDT 2018
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Public Comment No. 630-NFPA 70-2018 [Section No. 310.20]

310.20 Ampacities of Conductors Supported on a Messenger.

The maximum ampacities shall be as specified in Table 310.20 where all of the following conditions apply:

(1) Conductors ~~are rated 0 volts to~~ rated up to and including 2000 volts.

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

(3) Wiring is installed in a 40°C (~~86°F~~ 104°F) ambient temperature.

(4) There are not more than three single-insulated conductors.

Statement of Problem and Substantiation for Public Comment

Editorial change to correct temperature rating and voltage range.

Related Item

• FR8918

Submitter Information Verification

Submitter Full Name: Raymond Horner
Organization: Atkore International
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 14 11:13:54 EDT 2018
Committee: NEC-P06

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Public Comment No. 1382-NFPA 70-2018 [Section No. 310.21]

310.21 Ampacities of Bare or Covered Conductors in Free Air.

The maximum 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 (86°F) ambient temperature.

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

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18**	—	—	14	—	—	—	—
16**	—	—	18	—	—	—	—
14**	15	20	25	—	—	—	—
12**	20	25	30	15	20	25	12**
10**	30	35	40	25	30	35	10**
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	445	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
2000	555	665	750	470	560	630	2000

Notes:

Section 310.16 shall be referenced for conditions of use.

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

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

**Refer to 240.4(D) for conductor overcurrent protection limitations.

Table 310.17 Ampacities of Single-Insulated Conductors in Free Air

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18	—	—	18	—	—	—	—
16	—	—	24	—	—	—	—
14**	25	30	35	—	—	—	—
12**	30	35	40	25	30	35	12**
10**	40	50	55	35	40	45	10**
8	60	70	80	45	55	60	8
6	80	95	105	60	75	85	6
4	105	125	140	80	100	115	4
3	120	145	165	95	115	130	3
2	140	170	190	110	135	150	2
1	165	195	220	130	155	175	1
1/0	195	230	260	150	180	205	1/0
2/0	225	265	300	175	210	235	2/0
3/0	260	310	350	200	240	270	3/0
4/0	300	360	405	235	280	315	4/0
250	340	405	455	265	315	355	250
300	375	445	500	290	350	395	300

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
350	420	505	570	330	395	445	350
400	455	545	615	355	425	480	400
500	515	620	700	405	485	545	500
600	575	690	780	455	545	615	600
700	630	755	850	500	595	670	700
750	655	785	885	515	620	700	750
800	680	815	920	535	645	725	800
900	730	870	980	580	700	790	900
1000	780	935	1055	625	750	845	1000
1250	890	1065	1200	710	855	965	1250
1500	980	1175	1325	795	950	1070	1500
1750	1070	1280	1445	875	1050	1185	1750
2000	1155	1385	1560	960	1150	1295	2000

Notes:

Section 310.17 shall be referenced for conditions of use.

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

**Section 240.4(D) shall be referenced for conductor overcurrent protection limitations.

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

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
14	34	36	39	—	14
12	43	45	54	30	12
10	55	60	73	44	10
8	76	83	93	57	8
6	96	110	117	75	6
4	120	125	148	94	4
3	143	152	166	109	3
2	160	171	191	124	2
1	186	197	215	145	1

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
1/0	215	229	244	169	1/0
2/0	251	260	273	198	2/0
3/0	288	297	308	227	3/0
4/0	332	346	361	260	4/0

Notes:

Section 310.18 shall be referenced for conditions of use.

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

*Section 310.15(B) shall be referenced for the ampacity correction factors where the ambient temperature is other than 40°C (104°F).

Table 310.19 Ampacities of Single-Insulated Conductors in Free Air

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL, OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
14	46	54	59	—	14
12	60	68	78	47	12
10	80	90	107	63	10
8	106	124	142	83	8
6	155	165	205	112	6
4	190	220	278	148	4
3	214	252	327	170	3
2	255	293	381	198	2
1	293	344	440	228	1
1/0	339	399	532	263	1/0
2/0	390	467	591	305	2/0
3/0	451	546	708	351	3/0
4/0	529	629	830	411	4/0

Notes:

Section 310.19 shall be referenced for conditions of use.

*Section 310.15(B) shall be referenced for the ampacity correction factors where the ambient temperature is other than 40°C (104°F).

Table 310.20 Ampacities of Conductors on a Messenger

Size AWG	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG
	75°C (167°F)	90°C (194°F)	75°C (167°F)	90°C (194°F)	

or kcmil	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types MI, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types RHW, THW, THWN, THHW, XHHW, XHWN	Types THHN, THHW, RHH, XHHW, RHW-2, XHHW-2, THW-2, THWN-2, XHWN, XHWN-2, USE-2, ZW-2	or kcmil
	COPPER		ALUMINUM OR COPPER-CLAD ALUMINUM		
8	57	66	44	51	8
6	76	89	59	69	6
4	101	117	78	91	4
3	118	138	92	107	3
2	135	158	106	123	2
1	158	185	123	144	1
1/0	183	214	143	167	1/0
2/0	212	247	165	193	2/0
3/0	245	287	192	224	3/0
4/0	287	335	224	262	4/0
250	320	374	251	292	250
300	359	419	282	328	300
350	397	464	312	364	350
400	430	503	339	395	400
500	496	580	392	458	500
600	553	647	440	514	600
700	610	714	488	570	700
750	638	747	512	598	750
800	660	773	532	622	800
900	704	826	572	669	900
1000	748	879	612	716	1000

Notes:

Section 310.20 shall be referenced for conditions of use.

*Section 310.15(B) shall be referenced for the ampacity correction factors where the ambient temperature is other than 40°C (104°F).

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

Table 310.21 Ampacities of Bare or Covered Conductors in Free Air

Copper Conductors				AAC Aluminum Conductors			
Bare		Covered		Bare		Covered	
AWG or kcmil	Amperes	AWG or kcmil	Amperes	AWG or kcmil	Amperes	AWG or kcmil	Amperes
8	98	8	103	8	76	8	80
6	124	6	130	6	96	6	101
4	155	4	163	4	121	4	127
2	209	2	219	2	163	2	171
1/0	282	1/0	297	1/0	220	1/0	231
2/0	329	2/0	344	2/0	255	2/0	268
3/0	382	3/0	401	3/0	297	3/0	312
4/0	444	4/0	466	4/0	346	4/0	364
250	494	250	519	266.8	403	266.8	423
300	556	300	584	336.4	468	336.4	492
500	773	500	812	397.5	522	397.5	548

Copper Conductors				AAC Aluminum Conductors			
Bare		Covered		Bare		Covered	
AWG or kcmil	Amperes	AWG or kcmil	Amperes	AWG or kcmil	Amperes	AWG or kcmil	Amperes
750	1000	750	1050	477.0	588	477.0	617
1000	1193	1000	1253	556.5	650	556.5	682
—	—	—	—	636.0	709	636.0	744
—	—	—	—	795.0	819	795.0	860
—	—	—	—	954.0	920	—	—
—	—	—	—	1033.5	968	1033.5	1017
—	—	—	—	1272	1103	1272	1201
—	—	—	—	1590	1267	1590	1381
—	—	—	—	2000	1454	2000	1527

Note: Section 310.20 shall be referenced for conditions of use.

Additional Proposed Changes

File Name	Description	Approved
Prop_Table_310.15_B_16_.pdf	Proposed Table 310.16 after FDR	
Proposed_Table_310.17_310.15_B_17_.pdf	Proposed Table 310.17 after FDR	
14_AWG_Thermal_Expansion_Summary.pdf	Intertek Report SummaryThermal Stability CCA 14 AWG ASTM E228: CCA and Cu both Extremely Thermally Stable	
ETL.14awgCCA.Thermalstablei6049.04-106-31-r0.pdf	Intertek Report 14 AWG CCA ASTM E228 Lineal Thermal Expansion	
ETL.14awgCu.Thermalstablei6049.03-106-31-r0.pdf	Intertek Report 14 AWG Cu ASTM E228 Lineal Thermal Expansion	
J-00265162_FINAL_Copperweld_FFR-_CCA-Cu_Final_Report_Revised_10-27-17.pdf	NSF NRTL Test Report Fact Finding Heat Rise Data 14, 12 and 10 AWG	
14_AWG_CCA_Summary.NSFvETL.pdf	14 AWG CCA Heat Comparison Btw Two NRTL Reports: NSF AND INTERTEK	
SampleReqForm_-_MEL.pdf	14 AWG CCA Request by UL for Listing NM Cable. Listing based upon Testing of 14 AWG CCA	
Notice_of_Authorization-2017-10-06-4788086098.pdf	UL Listing COPPERWELD NM Notice of Authorization Based Upon 14 AWG CCA Testing	
UL_817_Fiinal.pdf	Intertek Test Report CCA Conductors per UL 817; All Samples Passed. Demonstrates Thermal Stability of CCA Fine Wire and CCA and Brass are Similar Metals	
CONCLUSIONS_FROM_UL_486C_SPRING.pdf	Summary and Conclusions for 14 AWG CCA from UL 486C Spring Action Sequence Test Report by ETL	
Bond_Integrity_in_Aluminum-Copper_Clad_Metals.pdf	White Paper from Materion Explaining in General CCA Metallurgy, Applications and Heat Data	
Intetek.UL486C.SAS.103589128CRT-001A_003_.pdf	Test Report: UL 486C Spring Action Sequence. INTERTEK. CCA with Wago, Ideal Push-in Connectors	

Statement of Problem and Substantiation for Public Comment

Public Comment Response:

- Introduction: PC 1382 asks CMP6 to accept only two changes to Tables 310.16 & 310.17: to recognize 14

AWG CCA and to provide CCA with it's own set of temperature columns. CCA is not aluminum as most users of Code wrongly assume. Divorcing CCA from Aluminum in these critical tables by creating new columns for CCA will fix this problem, and greatly reduce confusion and bias in the mind of the user. Ampacities for CCA within the proposed tables would not change, so PC 1382 does not ask CMP6 to pass a technical judgement on those Ampacities that currently exist. Rather, it is asked that CMP6 analyze the heating and thermal stability data provided to it by credible sources when considering 14 AWG CCA, and to work within the limits of article 310. With the substantiation provided, CMP6 will find that 14 AWG CCA poses no safety hazard at the proposed ampacity of the tables proposed by Public Comment 1382, and that the ampacity of 14 AWG as proposed are in line with those CCA ampacities already in existence in this Code. The scope and purpose of Tables 310.16 & 17, are solely to establish safe ampacity at certain defined temperature ratings of insulation types. Each insulation type pertains to a temperature column. As defined by Article 100, "Ampacity" is “The maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating.”
In simple terms, ampacity is “the level of heat that a conductor achieves when a level of current is imposed under standard test conditions,” (test conditions, generally, being conditions of ambient temperature). Tables 310.15(B)(16) and (17) “Ampacity Rating” by definition do not consider terminal, equipment nor device temperatures, metal compatibility (dissimilar metals), etc.--- these aspects are covered by other parts of the Code and are under the purview of other Code panels.

ANY DATA FROM AN NRTL ELECTRICAL LAB IS CREDIBLE:

- The NFPA Only Requires that Data Presented to CMP’s be “Credible”: There are only 19 NRTL’s in the United States, and only 1/4 of these have electrical labs. Being an NRTL means that a lab upholds the most rigorous standards. NSF is an NRTL that maintains a fully functional electrical division (NSF Electrical) with the following certifications: SCC, File Number 10025, ISO/IEC 17065-2012; OSHA NRTL Program. NSF as an NRTL has the ability to issue formal listings for dozens of electrical products under various product safety standards. There is no technical reason that CMP6 should discount the heat rise data found in the submitted NSF report (with PI 3174 and PC 1382). In conducting the many research and/or testing projects for listing certification, NSF routinely completes temperature testing on conductors, terminals and equipment under specified testing conditions, the same way that ampacity is determined. Therefore, the research report which details a valid test procedure, proper laboratory test conditions and calibrated test and measurement equipment is valid in accordance with NFPA requirements.
- Research and Timeliness Made the NRTL “NSF” the Best Option for Fact Finding of Heat Rise. Copper-Clad Aluminum Conductors Were Already UL listed at the time of the Fact Finding, So No Listing Was Sought at NSF: There is no technical reason that CMP6 should discount the heat rise data found in the NSF report. Because copper-clad aluminum conductors had Listings from UL already in place at the time of the testing, research and timeliness were the driving factors in working with NSF. UL 1581 (Reference Standard for Electrical Wires, Cables and Flexible Cords) is not part of NSF’s Scope of Recognition, meaning simply that NSF cannot offer “Listings” under OSHA’s overview for wire and cable products like they would for those many other electrical products within their Scope of Recognition. It should be noted that the standards that "an NRTL is OSHA recognized for" are based on work-place safety standards adopted by OSHA. UL, Intertek and other “NRTLs” routinely have many “listings” for products outside of their OSHA scopes of recognition and their certifications are still widely accepted in the marketplace. Examples can be found in areas of new technologies, renewable energy, and medical equipment.

This simply means that NSF Electrical is capable of conducting credible research with electrical products where NSF listings are not offered. Such research is routine. Further, heat rise testing is elemental to any electrical lab, even more so with an electrical lab working under the credentials of an NRTL.
After communicating with NRTL’s with Wire & Cable in their Scopes of Recognition, it was realized that NSF was the only NRTL with a certified electrical lab able to agree to prioritize the work in accordance to the proposed time-line. In that a listing was not sought, but rather conducting RESEARCH was sought, NSF’s NRTL certified electrical lab was the logical option.

- Standards or Test Procedures to Determine Ampacity: When two of the NRTLs were approached to complete the fact-finding study as requested through the panel statement, it became obvious that neither NRTL had a standard, a test procedure or clear understanding of how to accomplish the necessary testing.

For any testing of terminations, devices and equipment, the applicable standards for those items require finding the proper conductor based on the allowed ampacity from wire size, AWG, and insulation provided, and accounting for what are specified temperature limitations for the terminal, equipment or device. Not having 14 AWG copper-clad aluminum in these tables creates a chicken and egg problem for anyone that wanted to do testing for suitability of copper-clad aluminum with their terminal, device or equipment.

THREE NRTL’S INVOLVED IN FACT FINDING OF 14 AWG Copper-Clad Aluminum: UL, Intertek and NSF. 14 AWG Copper-Clad Aluminum Poses No Safety Hazard, and Is Notably More Thermally Stable than 14 AWG ETP Copper at 90°C:

- 14 AWG Copper-Clad Aluminum Was Used in Testing to Acquire UL Listing for NMB: Having a UL Listing means that a wire & cable product was tested and met the applicable requirements of UL 1581 under the present Listings. While in the employ of a copper-clad aluminum manufacturer, UL tested 14/2 NMB copper-clad aluminum NMB cable as the test size for listing, which, after successful testing, lead to a listing for NMB cables in sizes 12/2 AWG and larger. Not having a listing for a 14 AWG copper-clad aluminum conductor is only due to the NEC not recognizing it. It is also noted that UL has had listings for copper-clad aluminum conductors for over 50 years.

- Intertek Continues Copper-Clad Aluminum "Fact Finding" Research: At CMP6's request, a "Fact Finding" study was conducted by an NRTL with UL 1581 and UL 486C within their Scope of Recognition, Intertek Laboratories. This includes thermal stability testing to ASTM E228 and UL 817 and, even though beyond the needs for conductor ampacity determination, connector testing to UL 486C. The terminal testing was undertaken to determine that in a normal or overcurrent condition, the heat generated by the conductor did not compromise the circuit by destroying the connector.

Temperatures measured on the 14 AWG copper-clad aluminum reference conductors in the Spring Sequence UL 486C test (conducted by Intertek) are equivalent to those found in the NSF Heat Rise Report. Data clearly indicates that 14 AWG copper-clad aluminum poses no safety hazard when used correctly and within the guidelines of the proposed Code changes. There is no technical reason that 14 AWG copper-clad aluminum should not be part of this Code and in the separate columns of the tables as PI 3174 has proposed.

- Intertek and NSF Heat Data is Equivalent, Making NSF Data Even More Credible:

Kindly Review the attached NSF and Intertek data for particular diameters at particular ampacities. These independent finds are having the same temperatures recorded under the test conditions.

- Wire Termination and Connectors Are Under the Purview of Other Code Panels; Conductor Insulation Key to Conductor Ampacity Rating in Article 310: For any testing of terminations, devices and equipment, the applicable standards for those items require finding the proper conductor based on the allowed ampacity from wire size, AWG, and insulation provided, and accounting for what are specified temperature limitations for the terminal, equipment or device. Not having 14 AWG copper-clad aluminum in these tables creates a chicken and egg problem for anyone that desires to do testing for suitability of 14 AWG copper-clad aluminum with their terminal, device or equipment.
- Proposed Rating for 14 AWG Copper-Clad Aluminum is Warranted: The 10-amp rating at 60C for 14 AWG copper-clad aluminum to be included in the tables as proposed is valid, since there are branch circuit overcurrent devices and associated branch circuit panelboards available that would provide overcurrent protection at 60C when the 75C terminal ratings are not present. It is also noted that the standard OCPD sizes found in section 240.6 do not limit manufacturers to make branch circuit rated overcurrent devices with other ratings.

ASTM B566 Copper-Clad Aluminum IS A UNIQUE METAL THAT REQUIRES SEPARATION IN ARTICLE 310 FROM SINGLE-METAL ALUMIMUM:

- The Current Table Formats Found in 310.15 Mislead the User, which Puts Copper-Clad Aluminum at a Commercial Disadvantage and Denies the Industry a Valid Alternative: Users of tables 310.15(B)(16) and (17) mistake copper-clad aluminum and single-metal Aluminum as being the same with all the same limits on use. Due to copper-clad aluminum's copper content (27% by mass), copper-clad aluminum maintains inherent differences and advantages to single-metal aluminum wire. Due to single-metal aluminum's tarnished reputation in certain conductor categories, the table formats in 310.15 make copper-clad aluminum guilty by association of single-metal aluminum's unique and singular history. In addition, users of Code consistently wrongly apply the same limitations on copper-clad aluminum for installation, corrosion inhibitors and other requirements for single metal aluminum conductors -- again guilt by misrepresentation due to the current format of 310.15 tables. The proposed action would allow CMP6 to fix a decades-long problem that the modern economy has made relevant.
- Adding 14 AWG Copper-Clad Aluminum to Article 310 Would Further Differentiate Copper-Clad Aluminum from Single-Metal Aluminum: Creating separate columns for copper-clad aluminum in 310.15 will help to correct this perception error, bring clarity to the users, and guide users to a truer understanding of copper-clad aluminum as both a suitable conductor and as a feasible alternative. Adding 14 AWG copper-clad aluminum to 310.15(B)16 and 17 will further differentiate copper-clad aluminum and single-metal Aluminum in the mind of the user.
- When shown to numerous Authorities Having Jurisdiction, as well as to others. at a number of inspector meetings, the comments on the revised tables as proposed with the separate columns was clearly favorable showing clarity for use of copper-clad aluminum that was not present in the present table format.

Related Item

- 3174

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
Street Address:
City:
State:
Zip:
Submittal Date: Mon Aug 27 16:49:24 EDT 2018
Committee: NEC-P06

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Table 310.15(B)(16) (formerly Table 310.16) Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)*

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.104(A).]									Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	COPPER			COPPER-CLAD ALUMINUM			ALUMINUM ~~OR COPPERCLAD ALUMINUM~~			
18**	-	-	14	-	-	-	-	-	-	-
16**	-	-	18	-	-	-	-	-	-	-
14**	15	20	25	10	15	20	-	-	-	-
12**	20	25	30	15	20	25	15	20	25	12**
10**	30	35	40	25	30	35	25	30	35	10**
8	40	50	55	35	40	45	35	40	45	8
6	55	65	75	40	50	55	40	50	55	6
4	70	85	95	55	65	75	55	65	75	4
3	85	100	115	65	75	85	65	75	85	3
2	95	115	130	75	90	100	75	90	100	2
1	110	130	145	85	100	115	85	100	115	1
1/0	125	150	170	100	120	135	100	120	135	1/0
2/0	145	175	195	115	135	150	115	135	150	2/0
3/0	165	200	225	130	155	175	130	155	175	3/0
4/0	195	230	260	150	180	205	150	180	205	4/0
250	215	255	290	170	205	230	170	205	230	250
300	240	285	320	195	230	260	195	230	260	300
350	260	310	350	210	250	280	210	250	280	350
400	280	335	380	225	270	305	225	270	305	400
500	320	380	430	260	310	350	260	310	350	500
600	350	420	475	285	340	385	285	340	385	600
700	385	460	520	315	375	425	315	375	425	700
750	400	475	535	320	385	435	320	385	435	750
800	410	490	555	330	395	445	330	395	445	800
900	435	520	585	355	425	480	355	425	480	900
1000	455	545	615	375	445	500	375	445	500	1000
1250	495	590	665	405	485	545	405	485	545	1250
1500	525	625	705	435	520	585	435	520	585	1500
1750	545	650	735	455	545	615	455	545	615	1750
2000	555	665	750	470	560	630	470	560	630	2000

*Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F). Refer to 310.15(B)(3)(a) for more than three current-carrying conductors.

**Refer to 240.4(D) for conductor overcurrent protection limitations.

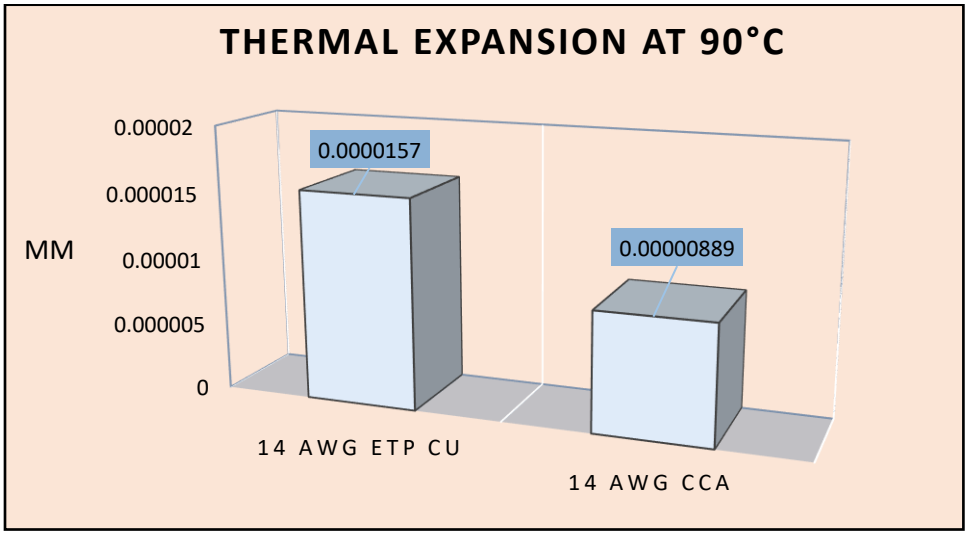
Table 310.15(B)(17) (formerly Table 310.17) Allowable Ampacities of Single-Insulated Conductors Rated Up to and Including2000 Volts in Free Air, Based on Ambient Temperature of 30°C (86°F)*

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.104(A).]									Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW,	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	COPPER			COPPER-CLAD ALUMINUM			ALUMINUM ~~OR COPPERCLAD ALUMINUM~~			
18**	-	-	18	-	-	-	-	-	-	-
16**	-	-	24	-	-	-	-	-	-	-
14**	25	30	35	20	25	30	-	-	-	-
12**	30	35	40	25	35	40	25	30	35	12**
10**	40	50	55	35	40	50	35	40	45	10**
8	60	70	80	45	55	60	45	55	60	8
6	80	95	105	60	75	85	60	75	85	6
4	105	125	140	80	100	115	80	100	115	4
3	120	145	165	95	115	130	95	115	130	3
2	140	170	190	110	135	150	110	135	150	2
1	165	195	220	130	155	175	130	155	175	1
1/0	195	230	260	150	180	205	150	180	205	1/0
2/0	225	265	300	175	210	235	175	210	235	2/0
3/0	260	310	350	200	240	270	200	240	270	3/0
4/0	300	360	405	235	280	315	235	280	315	4/0
250	340	405	455	265	315	355	265	315	355	250
300	375	445	500	290	350	395	290	350	395	300
350	420	505	570	330	395	445	330	395	445	350
400	455	545	615	355	425	480	355	425	480	400
500	515	620	700	405	485	545	405	485	545	500
600	575	690	780	455	545	615	455	545	615	600
700	630	755	850	500	595	670	500	595	670	700
750	655	785	885	515	620	700	515	620	700	750
800	680	815	920	535	645	725	535	645	725	800
900	730	870	980	580	700	790	580	700	790	900
1000	780	935	1055	625	750	845	625	750	845	1000
1250	890	1065	1200	710	855	965	710	855	965	1250
1500	980	1175	1325	795	950	1070	795	950	1070	1500
1750	1070	1280	1445	875	1050	1185	875	1050	1185	1750
2000	1155	1385	1560	960	1150	1295	960	1150	1295	2000

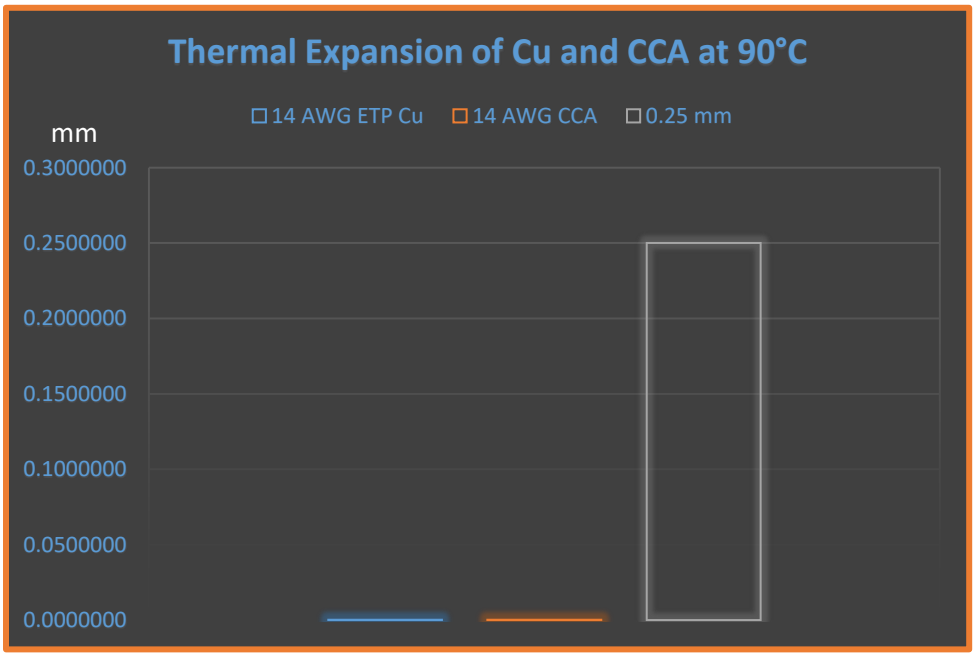
*Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F).
**Refer to 240.4(D) for conductor overcurrent protection limitations.

At 90°C, 14 AWG Copper-Clad Aluminum is nearly Twice as Thermally Stable as 14 AWG ETP Copper

Testing By Intertek B&C Labs per ASTM 228 Linear Thermal Expansion



At 90C, ETP 14 AWG Cu expands nearly twice that of Copper Clad Aluminum 14 AWG



At 90°C, Both Copper Clad Aluminum and Copper are Extremely Thermally Stable

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COPPERWELD BIMETALLICS
TEST REPORT

SCOPE OF WORK
ASTM E228 LINEAR THERMAL EXPANSION EVALUATION OF 14 AWG GAGE COPPER CLAD ALUMINUM (CCA) WIRE

REPORT NUMBER
I6049.04-106-31 R0

TEST DATES
07/12/18 - 07/19/18

ISSUE DATE
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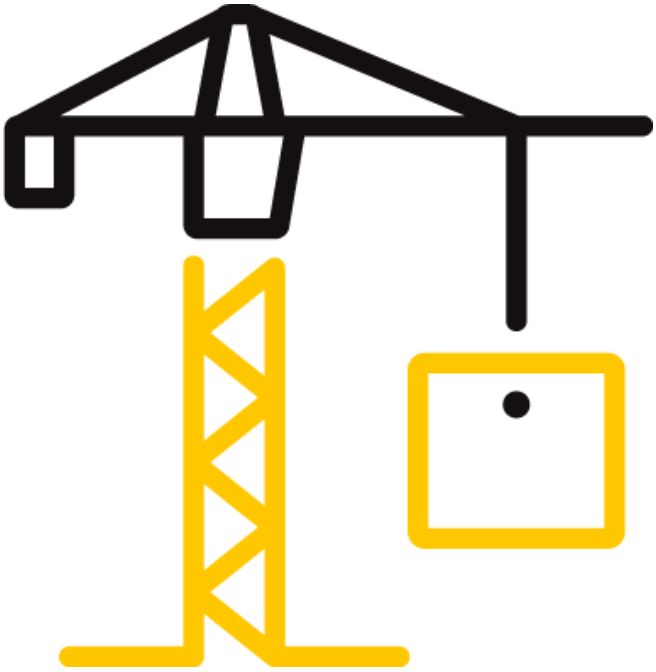

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TEST REPORT FOR COPPERWELD BIMETALLICS

Report No.: I6049.04-106-31 R0
Date: 08/15/18

REPORT ISSUED TO

COPPERWELD BIMETALLICS
254 Cotton Mill Road
Fayetteville, Tennessee 37334

SECTION 1

SCOPE

Products: 14 AWG gage Copper Clad Aluminum (CCA) Wire

Intertek Building & Construction (B&C) was contracted by Copperweld Bimetallics to evaluate 14 AWG gage Copper Clad Aluminum (CCA) Wire in accordance with ASTM E228 for Linear Thermal Expansion properties. Results obtained are tested values and were secured by using the designated test methods. Testing was conducted at the Intertek B&C test facility in York, Pennsylvania.

This report does not constitute certification of this product nor an opinion or endorsement by this laboratory.

SECTION 2

SUMMARY OF TEST RESULTS

COPPER CLAD ALUMINUM (CCA) WIRE AWG GAGE	CLTE (mm/mm/°C) 25°C to 90°C TEMPERATURE RANGE
14	8.89E-06

For INTERTEK B&C:

COMPLETED BY:	Joseph M. Brickner	**REVIEWED BY:**	Dawn M. Chaney
TITLE:	Laboratory Supervisor Materials Laboratory	**TITLE:**	Technician Team Lead Materials laboratory
SIGNATURE:		**SIGNATURE:**	
DATE:	08/15/18	**DATE:**	08/15/18

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SECTION 3
TEST METHOD

The specimens were evaluated in accordance with the following:

> **ASTM E228-17**, *Standard Test Method for Linear Thermal Expansion of Solid Materials with a Push-Rod Dilatometer*

SECTION 4
MATERIAL SOURCE

The test materials were provided by Copperweld Bimetallics. The following was received: One (1), nominally 76 mm copper clad aluminum wire specimens in 14 AWG gage. Refer to the product description photo in Section 10. The material was tested as received except for smoothing the cut ends of each specimen. Representative test specimens will be retained by Intertek B&C for a minimum of four years from the test completion date.

SECTION 5
LIST OF OFFICIAL OBSERVERS

NAME	COMPANY
Joseph M. Brickner	Intertek B&C
Dawn M. Chaney	Intertek B&C

SECTION 6
TEST PROCEDURE

All conditioning of test specimens and test conditions were at standard laboratory conditions unless otherwise reported. Refer to the test related photos in Section 10.

ASTM E228 - Linear Thermal Expansion
One specimen for each wire gage was measured for initial length using a 6" digital caliper (ICN: 65688) and placed in the bottom of an outer glass dilatometer tube with an inner glass tube resting on it. An aluminum support cylinder was utilized to keep the wire oriented in a vertical position. The dilatometer tube was suspended in a heated environment utilizing a muffle furnace (ICN: Y002864) and subjected to exposure conditions of nominally 25°C and 90°C. At the equilibrium of each temperature condition, specimen temperature was measured using a thermocouple reader (ICN: 62101) and a measurement was recorded from a digital indicator (ICN: INT00193) resting on top of the inner tube. The Linear Thermal Expansion between the temperature range was calculated.

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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.04-106-31 R0
Date: 08/15/18

SECTION 7
TEST SPECIMEN DESCRIPTIONS

TEST PROCEDURE	NUMBER OF SPECIMENS	NOMINAL SPECIMEN DIMENSIONS	VISUAL CHARACTERISTICS
ASTM E228 Linear Thermal Expansion	1	75 mm x 14 gage wire thickness	Copper Clad Aluminum wire

SECTION 8
TEST RESULTS

ASTM E228 - Linear Thermal Expansion

Copper Clad Aluminum (CCA) Wire - 14 Gage

All Temperatures

LENGTH (mm)	75.56	
TARGET TEMPERATURE (°C)	25	90
ACTUAL TEMPERATURE (°C)	25.4	90.9
GAGE READING (mm)	6.6070	6.6510
ΔT (°C)		65.5
ΔL (mm)		0.0440
ΔL/ΔT (mm/°C)		6.72E-04
CLTE (mm/mm/°C)		**8.89E-06**

SECTION 9
CONCLUSION

The requested test method did not contain specific performance requirements.

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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.04-106-31 R0
Date: 08/15/18

SECTION 10
PHOTOGRAPHS

Photo No. 1
Copper Clad Aluminum - Specimen Detail

Photo No. 2
ASTM E228 - Equipment Detail

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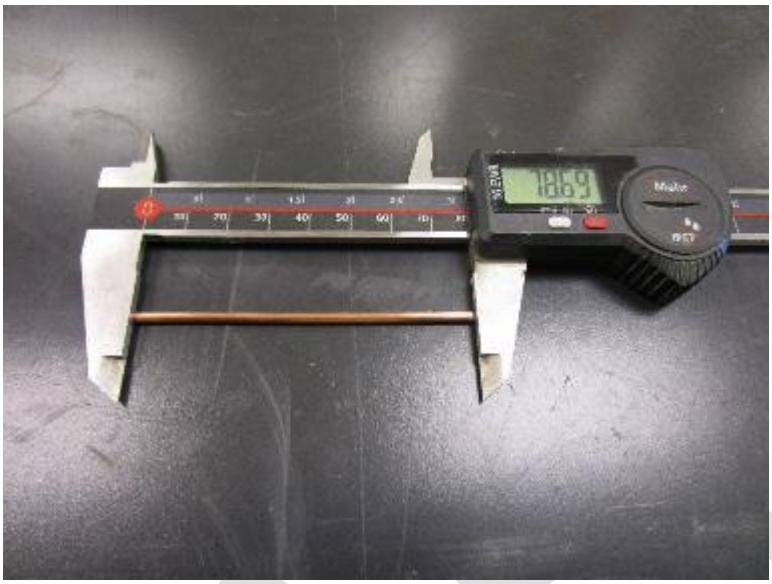

Photo No. 3
ASTM E228 - Length Measurement Equipment Detail

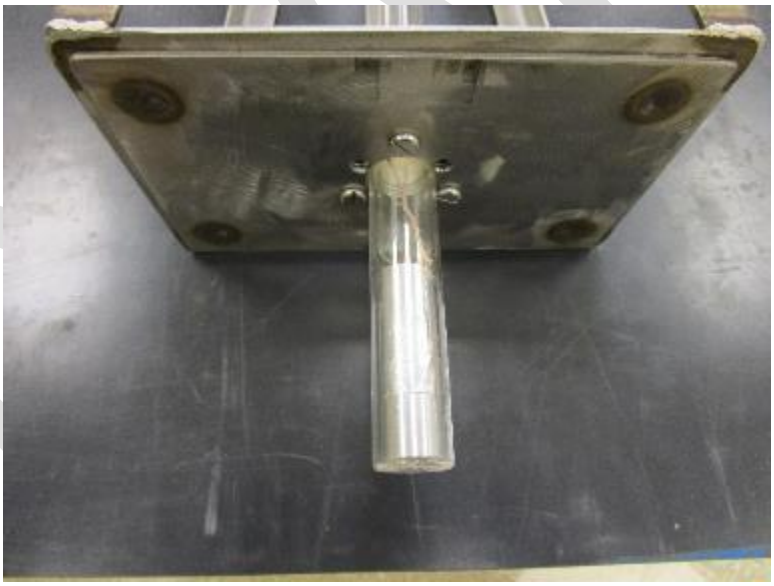

Photo No. 4
ASTM E228 - Specimen Support Detail

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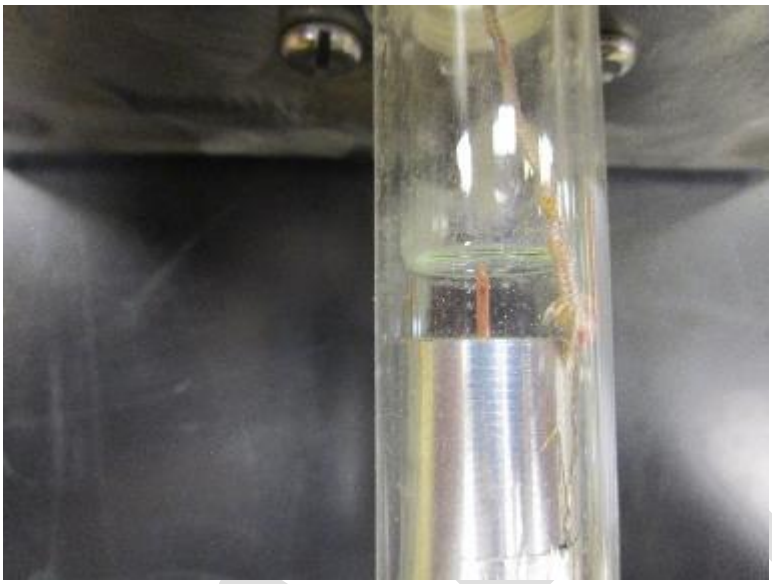

Photo No. 5
ASTM E228 - Specimen Temperature Measurement Detail

Photo No. 6
ASTM E228 - Linear Expansion Measurement Equipment Detail

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COPPERWELD BIMETALLICS
TEST REPORT

SCOPE OF WORK
ASTM E228 LINEAR THERMAL EXPANSION EVALUATION OF 14 AWG GAGE ELECTROLYTIC TOUGH PITCH (ETP) COPPER WIRE

REPORT NUMBER
I6049.03-106-31 R0

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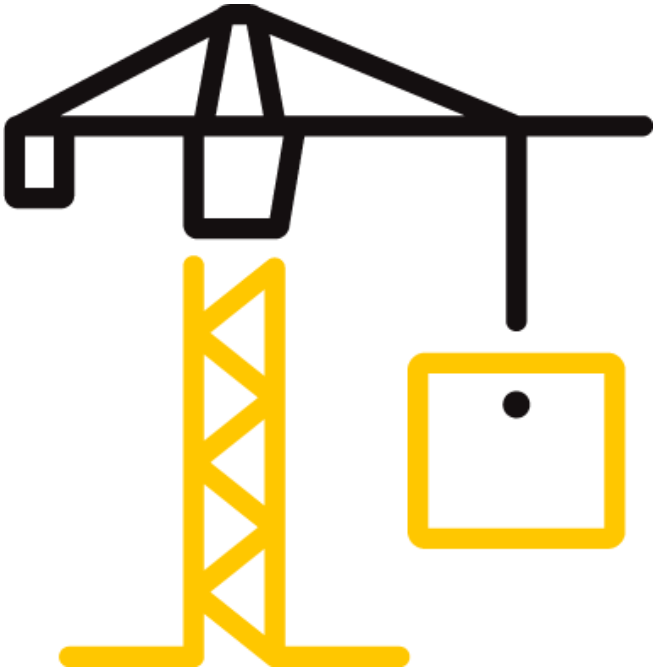

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Report No.: I6049.03-106-31 R0
Date: 08/15/18

REPORT ISSUED TO

COPPERWELD BIMETALLICS
254 Cotton Mill Road
Fayetteville, Tennessee 37334

SECTION 1

SCOPE

Products: 14 AWG gage Electrolytic Tough Pitch (ETP) Wire

Intertek Building & Construction (B&C) was contracted by Copperweld Bimetallics to evaluate 14 AWG gage Electrolytic Tough Pitch (ETP) Wire in accordance with ASTM E228 for Linear Thermal Expansion properties. Results obtained are tested values and were secured by using the designated test methods. Testing was conducted at the Intertek B&C test facility in York, Pennsylvania.

This report does not constitute certification of this product nor an opinion or endorsement by this laboratory.

SECTION 2

SUMMARY OF TEST RESULTS

ELECTROLYTIC TOUGH PITCH (ETP) COPPER WIRE AWG GAGE	CLTE (mm/mm/°C) 25°C to 90°C TEMPERATURE RANGE
14	1.57E-05

For INTERTEK B&C:

COMPLETED BY:	Joseph M. Brickner	**REVIEWED BY:**	Dawn M. Chaney
TITLE:	Laboratory Supervisor Materials Laboratory	**TITLE:**	Technician Team Lead Materials laboratory
SIGNATURE:		**SIGNATURE:**	
DATE:	08/15/18	**DATE:**	08/15/18

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SECTION 3
TEST METHOD

The specimens were evaluated in accordance with the following:

> **ASTM E228-17**, *Standard Test Method for Linear Thermal Expansion of Solid Materials with a Push-Rod Dilatometer*

SECTION 4
MATERIAL SOURCE

The test materials were provided by Copperweld Bimetallics. The following were received: One (1), nominally 76 mm electrolytic tough pitch copper wire specimen in 14 AWG gage. Refer to the product description photo in Section 10. The material was tested as received except for smoothing the cut ends of each specimen. Representative test specimens will be retained by Intertek B&C for a minimum of four years from the test completion date.

SECTION 5
LIST OF OFFICIAL OBSERVERS

NAME	COMPANY
Joseph M. Brickner	Intertek B&C
Dawn M. Chaney	Intertek B&C

SECTION 6
TEST PROCEDURE

All conditioning of test specimens and test conditions were at standard laboratory conditions unless otherwise reported. Refer to the test related photos in Section 10.

ASTM E228 - Linear Thermal Expansion
One specimen for each wire gage was measured for initial length using a 6" digital caliper (ICN: 65688) and placed in the bottom of an outer glass dilatometer tube with an inner glass tube resting on it. An aluminum support cylinder was utilized to keep the wire oriented in a vertical position. The dilatometer tube was suspended in a heated environment utilizing a muffle furnace (ICN: Y002864) and subjected to exposure conditions of nominally 25°C and 90°C. At the equilibrium of each temperature condition, specimen temperature was measured using a thermocouple reader (ICN: 62101) and a measurement was recorded from a digital indicator (ICN: INT00193) resting on top of the inner tube. The Linear Thermal Expansion between the temperature range was calculated.

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SECTION 7
TEST SPECIMEN DESCRIPTIONS

TEST PROCEDURE	NUMBER OF SPECIMENS	NOMINAL SPECIMEN DIMENSIONS	VISUAL CHARACTERISTICS
ASTM E228 Linear Thermal Expansion	1 each	75 mm x 14 gage wire thickness	Electrolytic Tough Pitch Copper wire

SECTION 8
TEST RESULTS

ASTM E228 - Linear Thermal Expansion

Electrolytic Tough Pitch (ETP) Copper Wire - 14 Gage

All Temperatures

LENGTH (mm)	75.60	
TARGET TEMPERATURE (°C)	25	90
ACTUAL TEMPERATURE (°C)	28.7	91.3
GAGE READING (mm)	5.6440	5.7220
ΔT (°C)		62.6
ΔL (mm)		0.0780
ΔL/ΔT (mm/°C)		1.25E-03
CLTE (mm/mm/°C)		**1.57E-05**

SECTION 9
CONCLUSION

The requested test method did not contain specific performance requirements.

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SECTION 10
PHOTOGRAPHS

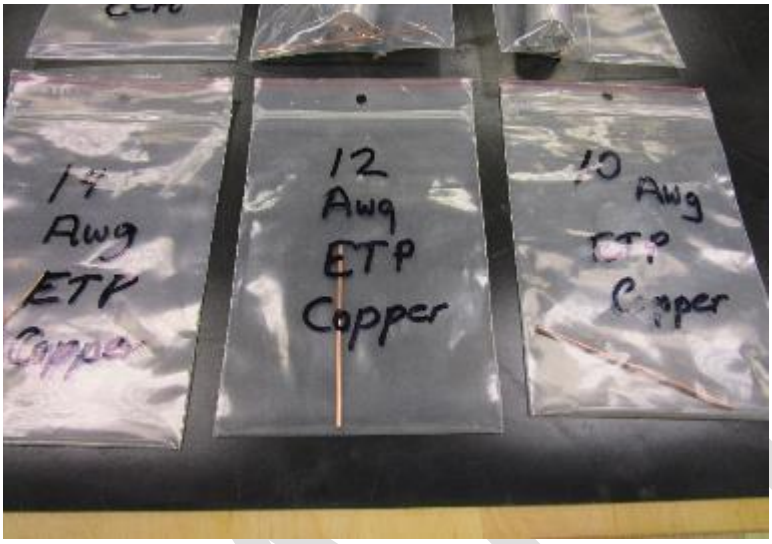

Photo No. 1
Electrolytic Tough Pitch - Specimen Detail

Photo No. 2
ASTM E228 - Equipment Detail

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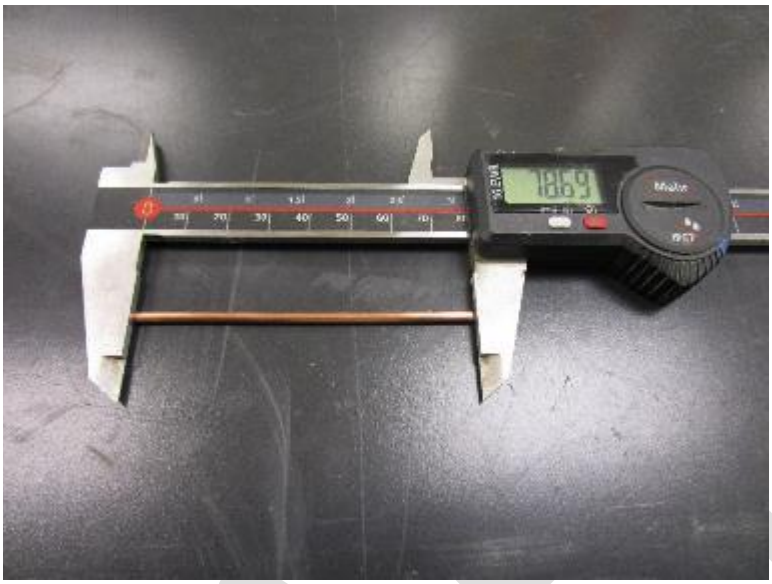

Photo No. 3
ASTM E228 - Length Measurement Equipment Detail

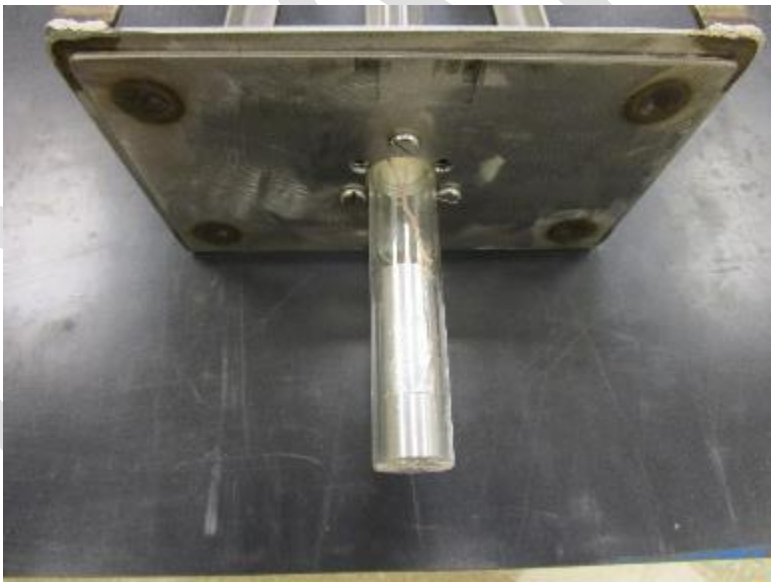

Photo No. 4
ASTM E228 - Specimen Support Detail

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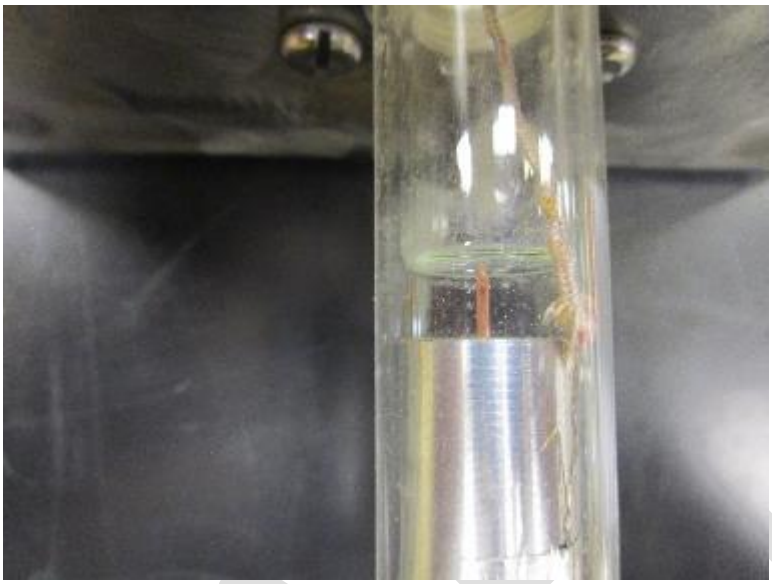

Photo No. 5
ASTM E228 - Specimen Temperature Measurement Detail

Photo No. 6
ASTM E228 - Linear Expansion Measurement Equipment Detail

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Peter Graser
Copperweld Bimetallic
215 Centerview Dr
Brentwood TN 37027

Facility: C0352008
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215 Centerview Dr
Brentwood TN 37027

Report Date: October 27, 2017

Description:	CCA –Cu Ampacity Comparison
Type of Evaluation	Fact Finding Investigation
Job Number	J-00265162
Project Number	0225-104
Project Manager	Don Tottingham
Location	789 Dixboro Road, Ann Arbor
Inspection Dates	August 7- August 18, 2017
Total # of Pages	125 Pages

Evaluated By: _____

Anas Alaghazali- Engineer

Reviewed By: Steve Fabian

Steve Fabian- Senior Technical Manager

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Purpose: The purpose of this testing was to evaluate copper clad aluminum wire (CCA) and copper wire (Cu) as a single conductor, non- -metallic 2 hot conductors, and two conductor in conduit, under the same current condition, and to determine their equivalence in performance

Credentials: NSF International, an accredited Nationally Recognized Testing Laboratory (NRTL), an Accredited Standards Council of Canada (SCC) laboratory, and accredited by the International Standards Organization (ISO) to ISO 14001.

Executive Summary: This Fact-Finding Investigation was conducted to develop a comparative temperature – heat rise database for Copper and Copper-Clad Aluminum Conductors in Sizes No. 14 -10 AWG.

The details of the test procedure for each conductor size, 14-10 AWG, is outlined in the report.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 14 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 18, 29, and 38.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 12 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 50, 61, and 71.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 10 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 87, 100, and 113.

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Test Set- Up/ Layout
14 AWG single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 14AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 14AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 14 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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FIGURE 1
Circuit Layout

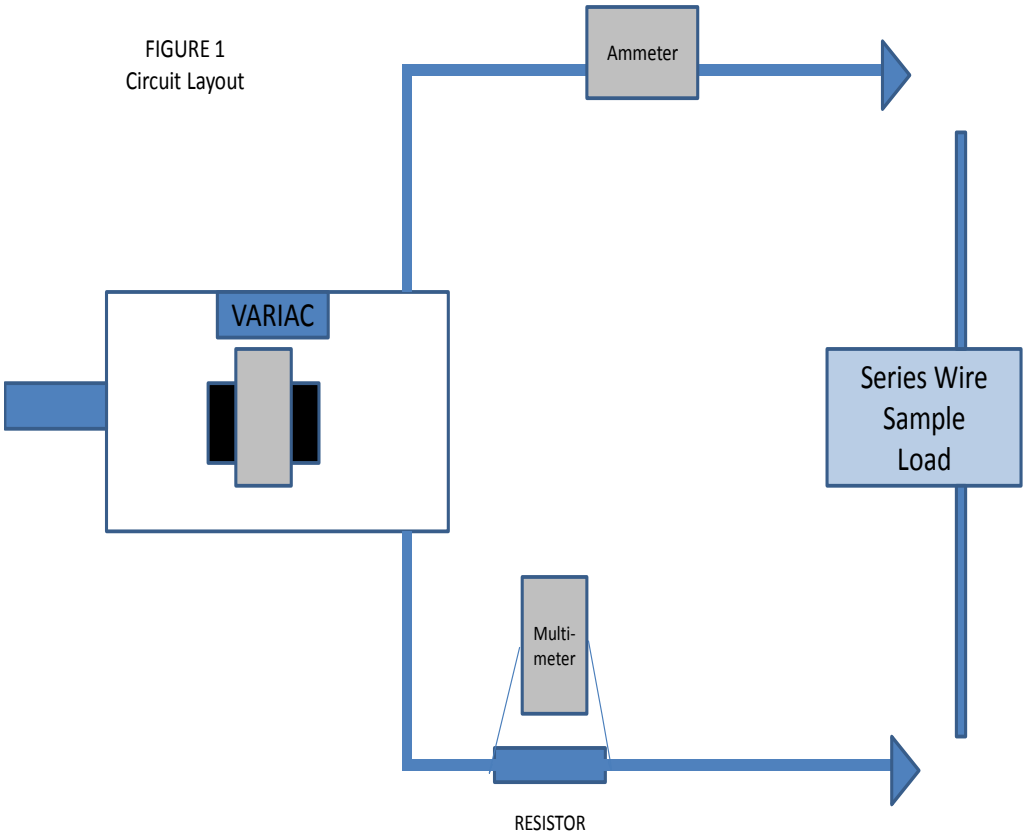

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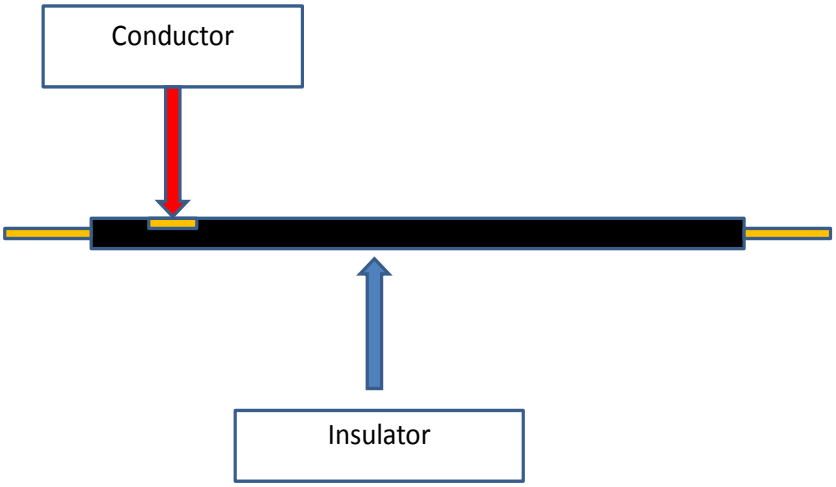
FIGURE 2
Single conductor



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Test Procedure
14 AWG Single Conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	Open air	5	30
14	Open air	10	30
14	Open air	15	30
14	Open air	20	30
14	Open air	25	30
14	Open air	30	30
14	Open air	35	30
14	Open air	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA Single Conductor open Air (Page 1/3))

Scan	Time	Elapsed	212 CU-AL #1 Core	213 CU-AL #1 Insu	203 CU-AL#2 Core	204 CU-AL#2 Insu	205 CU-AL#3 Insu
	5 AMPS						
32.00	42956.43	00:00:30:59	23.66	23.26	23.60	23.45	23.89
		Corrected Ambient	32.38	31.98	32.32	32.17	32.61
		Average	32.31				
		Average Core	32.40				
		Average Insulation	32.20				
	10 AMPS						
62.00	42956.45	00:01:00:59	28.37	28.10	27.74	28.35	28.81
		Corrected Ambient	36.96	36.69	36.33	36.94	37.40
		Average	36.38				
		Average Core	36.52				
		Average Insulation	36.22				
	15 AMPS						
92.00	42956.47	00:01:30:59	33.80	33.78	32.88	33.88	34.50
		Corrected Ambient	42.42	42.40	41.50	42.50	43.12
		Average	41.70				
		Average Core	42.16				
		Average Insulation	41.20				
	20 AMPS						
122.00	42956.49	00:02:00:59	43.82	43.54	42.12	43.28	44.61
		Corrected Ambient	52.04	51.76	50.34	51.50	52.83

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		Average	50.79				
		Average Core	51.77				
		Average Insulation	49.71				
	25 AMPS						
154.00	42956.52	00:02:32:59	53.50	53.49	51.23	52.53	54.61
		Corrected Ambient	61.81	61.80	59.54	60.84	62.92
		Average	60.07				
		Average Core	61.51				
		Average Insulation	58.50				
	30 AMPS						
183.00	42956.54	00:03:01:59	69.00	67.27	65.45	65.49	69.18
		Corrected Ambient	77.08	75.35	73.53	73.57	77.26
		Average	73.57				
		Average Core	75.91				
		Average Insulation	71.02				
	35 AMPS						
216.00	42956.56	00:03:34:59	85.83	83.73	80.52	81.75	86.71
		Corrected Ambient	93.96	91.86	88.65	89.88	94.84
		Average	89.81				
		Average Core	92.67				
		Average Insulation	86.68				

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14 AWG CCA Single Conductor open Air (Page 2/3))

208 CU-AL#3 Core	120 CU-AL #4 Core	211 CU-AL#4 Insu	102 CU-AL#5 Core	110 CU-AL#5 Insu	117 CU-AL#6 Core	116 CU-AL#7 Insul	320 CU-AL#7 Core	113 CU-AL#8 Core
23.51	23.63	23.37	23.62	23.47	23.86	23.44	23.36	23.79
32.23	32.35	32.09	32.34	32.19	32.58	32.16	32.08	32.51
27.61	27.35	26.86	27.79	27.18	27.93	27.43	27.16	27.92
36.20	35.94	35.45	36.38	35.77	36.52	36.02	35.75	36.51
32.59	32.02	31.20	33.01	31.82	33.24	31.93	32.18	33.99
41.21	40.64	39.82	41.63	40.44	41.86	40.55	40.80	42.61
41.25	41.32	38.66	42.34	39.53	43.15	40.71	41.44	44.59
49.47	49.54	46.88	50.56	47.75	51.37	48.93	49.66	52.81

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49.39	49.93	45.71	51.18	46.84	52.51	48.79	50.05	53.67
57.70	58.24	54.02	59.49	55.15	60.82	57.10	58.36	61.98
62.25	62.46	56.14	64.18	58.21	68.21	60.49	63.39	67.06
70.33	70.54	64.22	72.26	66.29	76.29	68.57	71.47	75.14
76.43	76.02	68.71	79.20	71.51	84.64	74.08	77.84	82.07
84.56	84.15	76.84	87.33	79.64	92.77	82.21	85.97	90.20

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14 AWG CCA Single Conductor open Air (Page 3/3))

114 CU-AL#8 Insul	109 CU-AL#9 Core	112 CU-AL#9 Insul	106 CU-AL#10 Core	107 CU-AL#10 Insul	101 CU-AL#11 Core	103 CU-AL#11 Insul	104 CU-AL#12 Core	105 CU-AL#12 Insul
23.65	23.82	23.63	23.82	23.54	23.54	23.19	23.97	23.43
32.37	32.54	32.35	32.54	32.26	32.26	31.91	32.69	32.15
27.87	27.44	27.22	27.77	27.44	28.29	26.84	29.82	27.86
36.46	36.03	35.81	36.36	36.03	36.88	35.43	38.41	36.45
32.54	33.29	31.49	33.60	32.07	34.85	31.62	37.00	33.55
41.16	41.91	40.11	42.22	40.69	43.47	40.24	45.62	42.17
42.59	42.44	39.88	44.38	40.51	46.65	40.27	49.14	42.83

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50.81	50.66	48.10	52.60	48.73	54.87	48.49	57.36	51.05
51.66	51.50	47.77	54.91	48.80	58.73	49.17	61.74	52.68
59.97	59.81	56.08	63.22	57.11	67.04	57.48	70.05	60.99
64.87	64.44	60.00	70.51	61.42	75.50	62.17	81.54	67.10
72.95	72.52	68.08	78.59	69.50	83.58	70.25	89.62	75.18
81.21	80.84	74.81	88.65	76.44	96.72	79.11	105.73	86.00
89.34	88.97	82.94	96.78	84.57	104.85	87.24	113.86	94.13

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14 AWG Cu Single conductor open air (Page 1/2))

Scan	Time	Elapsed	313 CU#1 Insul	312 CU#1 Core	309 CU#2 Core	310 CU#2 Insul	304 CU#3 Core	305 CU#3 Insul
	5 AMPS							
32.00	42956.43	00:00:30:59	22.94	22.76	23.27	22.75	23.19	22.87
		Corrected Ambient	31.66	31.48	31.99	31.47	31.91	31.59
		Average	31.76					
		Average Core	31.82					
		Average Insulation	31.70					
	10 AMPS							
62.00	42956.45	00:01:00:59	26.12	25.30	26.88	25.64	25.98	25.79
		Corrected Ambient	34.71	33.89	35.47	34.23	34.57	34.38
		Average	34.71					
		Average Core	34.68					
		Average Insulation	34.75					
	15 AMPS							
92.00	42956.47	00:01:30:59	29.59	28.15	30.84	28.94	29.08	29.21
		Corrected Ambient	38.21	36.77	39.46	37.56	37.70	37.83
		Average	38.20					
		Average Core	38.06					
		Average Insulation	38.34					

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	20 AMPS							
122.00	42956.49	00:02:00:59	35.06	33.50	38.22	34.03	34.76	34.30
		Corrected Ambient	43.28	41.72	46.44	42.25	42.98	42.52
		Average	43.85					
		Average Core	44.07					
		Average Insulation	43.64					
	25 AMPS							
154.00	42956.52	00:02:32:59	41.11	39.21	44.97	39.53	39.76	39.48
		Corrected Ambient	49.42	47.52	53.28	47.84	48.07	47.79
		Average	49.79					
		Average Core	49.98					
		Average Insulation	49.60					
	30 AMPS							
183.00	42956.54	00:03:01:59	50.05	48.57	55.19	47.04	46.81	46.68
		Corrected Ambient	58.13	56.65	63.27	55.12	54.89	54.76
		Average	58.05					
		Average Core	58.69					
		Average Insulation	57.42					
	35 AMPS							
216.00	42956.56	00:03:34:59	58.77	56.46	67.22	55.89	54.87	54.95
		Corrected Ambient	66.90	64.59	75.35	64.02	63.00	63.08
		Average	67.08					
		Average Core	67.91					
		Average Insulation	66.25					

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14 AWG Cu Single Conductor open Air (Page 2/2))

206 CU#4 Core	302 CU#4 Insul	218 CU#5 Core	220 CU#5 Insul	209 CU#6 Core	214 CU#6 Insul
23.07	23.20	23.11	22.85	23.21	23.30
31.79	31.92	31.83	31.57	31.93	32.02
26.07	26.44	26.00	26.11	26.30	26.84
34.66	35.03	34.59	34.70	34.89	35.43
29.44	30.07	29.34	29.78	29.81	30.74
38.06	38.69	37.96	38.40	38.43	39.36
35.82	35.84	35.94	35.90	36.83	37.36

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44.04	44.06	44.16	44.12	45.05	45.58
41.32	41.65	41.70	41.84	43.06	44.11
49.63	49.96	50.01	50.15	51.37	52.42
50.11	49.91	50.16	49.62	52.82	52.73
58.19	57.99	58.24	57.70	60.90	60.81
59.11	58.81	59.35	57.77	61.68	62.52
67.24	66.94	67.48	65.90	69.81	70.65

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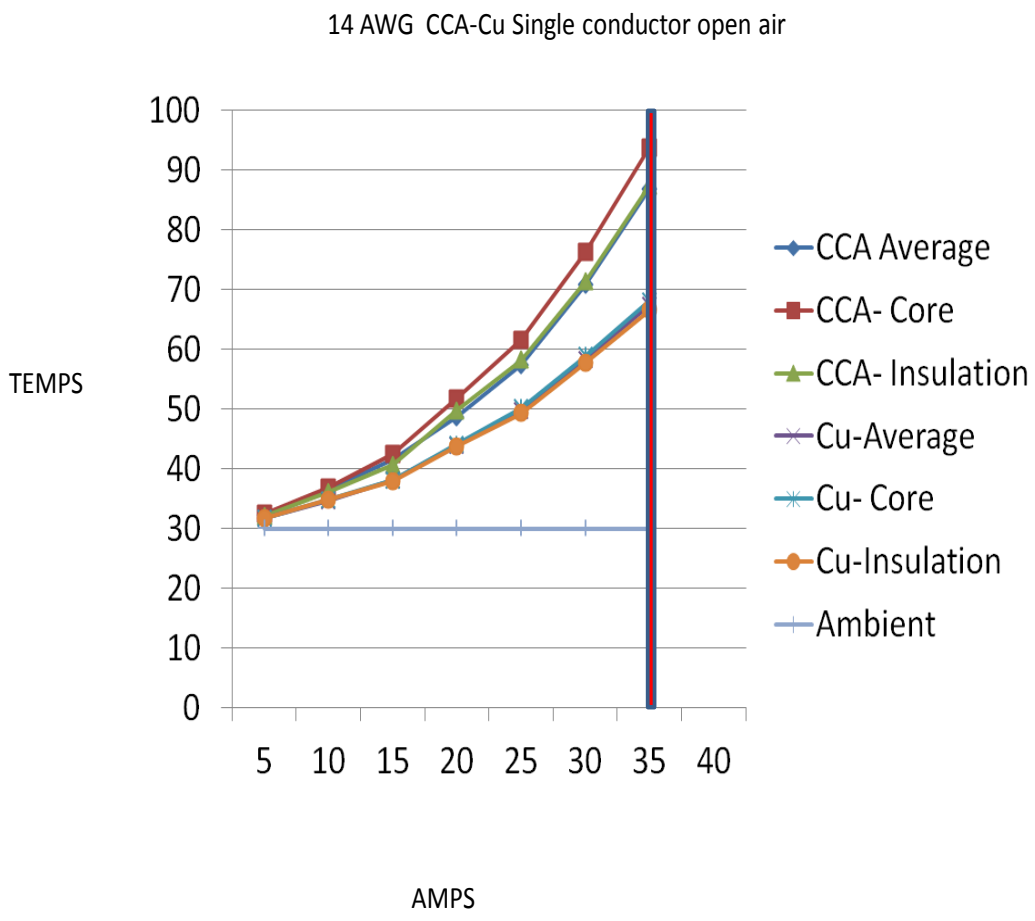

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Test Set- Up/ Layout
14 AWG in non-metallic cable in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 14 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 14 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 14 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used is calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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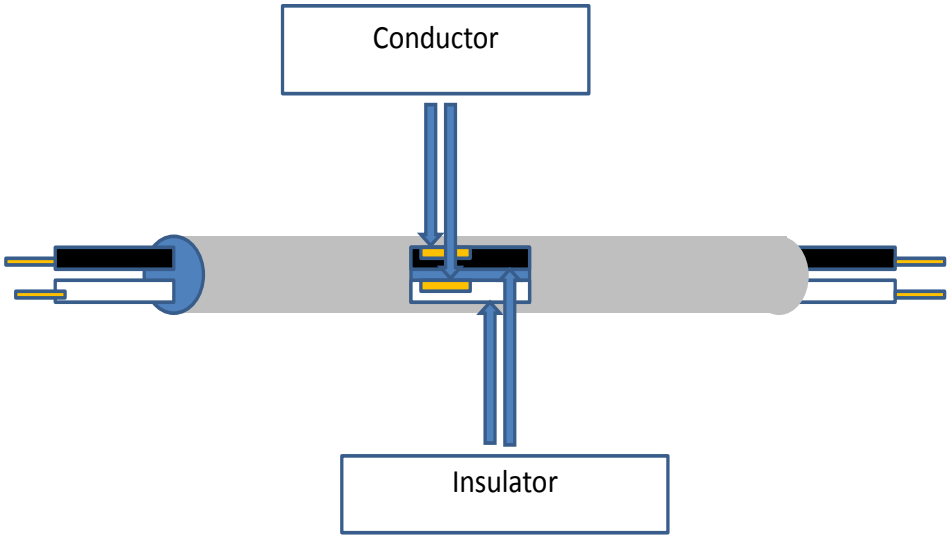
FIGURE 3
Two Line Conductor/ Ground(not connected) Non- metallic Cable



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Test Procedure
14 AWG in Non-metallic cable

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.
.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	NM Cable	5	30
14	NM Cable	10	30
14	NM Cable	15	30
14	NM Cable	20	30
14	NM Cable	25	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA Non Metallic (2 Conductor) open air (Page 1/3)

Scan	Time	Elapsed	101-CU-AL White Cable-Core	103 CU-AL White Cable Insulation	104 CU-AL Black Cable Core	105 CU-AL Black Cable Insulation	106 CU-AL Black Cable Core
29	5 AMPS	00:00:27:59					
30	8/15/2017 12:13	00:00:28:59	24.592	24.57	24.179	24.336	24.308
		Corrected Ambient	32.96	32.94	32.55	32.71	32.68
		Average	32.80				
		Average Core	32.92				
		Average Insulation	32.86				
60	10 AMPS	00:00:58:59	29.924	30.049	28.525	28.47	28.704
61	8/15/2017 12:44	00:00:59:59	29.497	30.014	28.308	28.427	28.595
		Corrected Ambient	37.95	38.46	36.76	36.88	37.04
		Average	37.53				
		Average Core	38.05				
		Average Insulation	38.13				
88	15 AMPS	00:01:26:59					
89	8/15/2017 13:12	00:01:27:59	37.658	38.549	35.166	34.525	34.751
		Corrected Ambient	45.92	46.81	43.43	42.79	43.02
		Average	44.46				
		Average Core	45.13				
		Average Insulation	45.22				
120	20 AMPS	00:01:58:59					
121	8/15/2017 13:44	00:01:59:59	48.404	50.441	43.994	43.521	43.462
		Corrected Ambient	56.61	58.65	52.20	51.73	51.67

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		Average	54.26				
		Average Core	54.78				
		Average Insulation	55.89				
151	25 AMPS	00:02:29:59					
152	8/15/2017 14:15	00:02:30:59	64.72	68.548	57.572	55.957	56.371
		Corrected Ambient	73.02	76.85	65.87	64.26	64.67
		Average	68.95				
		Average Core	69.61				
		Average Insulation	71.60				

14 AWG CCA Non Metallic (2 Conductor) open air (Page 2/3)

107 CU-AL Black Cable Insulation	109 CU-AL White Cable Core	112 CU-AL White Cable# 2 Insulation	113 CU-AL Black Cable#3 Core	114 CU-AL Black Cable #3 Insulation	116 CU-AL White Cable #3 Insulation	320 CU-AL White Cable#3 Core	315 CU-AL Black Cable#4 Core	118 CU-AL Black Cable#4 Insulation	102 CU-AL White Cable #4 Core
24.3	24.745	24.436	24.638	24.609	24.972	25.105	24.416	23.739	24.551
32.67	33.12	32.81	33.01	32.98	33.34	33.48	32.79	32.11	32.92
28.89	29.97	29.341	29.59	29.289	30.546	31.225	29.545	29.786	29.823
28.741	29.96	29.233	29.734	29.38	30.642	31.368	29.462	29.627	29.73
37.19	38.41	37.68	38.18	37.83	39.09	39.82	37.91	38.08	38.18

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35.244	37.473	35.97	36.069	36.113	38.561	39.712	36.608	35.975	37.473
43.51	45.74	44.23	44.33	44.38	46.83	47.98	44.87	44.24	45.74
44.923	47.618	47.015	45.275	46.599	50.61	51.411	46.52	44.202	47.657
53.13	55.83	55.22	53.48	54.81	58.82	59.62	54.73	52.41	55.86
58.491	62.893	62.242	58.51	61.014	67.133	69.89	61.364	57.959	63.192
66.79	71.19	70.54	66.81	69.32	75.43	78.19	69.67	66.26	71.49

14 AWG CCA Non Metallic (2 Conductor) open air (Page 3/3)

110 CU-AL White Cable#4 Insulation	120 CU-AL Black Cable#5 Core	211 CU-AL Black Cable#5 Insulation	205CU-AL White Cable#5 Insulation	208 CU-AL White Cable#5 Core	203 CU-AL Black Cable#6 Core	204 CU-AL Black Cbale#6 Insulation	212 CU-AL White Cable#6 Core	213 CU-AL White Cable#6 Insulation
25.194	24.66	25.029	24.923	24.407	24.321	24.045	24.677	23.717
33.56	33.03	33.40	33.29	32.78	32.69	32.42	33.05	32.09

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31.019	29.933	30.894	30.803	29.33	29.022	29.051	30.233	28.558
31.019	29.959	30.909	30.863	29.348	29.055	28.806	30.238	28.543
39.47	38.41	39.36	39.31	37.80	37.50	37.26	38.69	36.99
39.162	37.293	38.859	38.947	35.984	35.982	36.311	38.22	35.275
47.43	45.56	47.12	47.21	44.25	44.25	44.58	46.48	43.54
51.486	47.619	50.771	50.602	44.739	43.968	46.287	48.202	45.682
59.69	55.83	58.98	58.81	52.95	52.18	54.49	56.41	53.89
69.419	62.641	68.43	68.105	58.395	56.519	61.868	63.671	60.471
77.72	70.94	76.73	76.41	66.70	64.82	70.17	71.97	68.77

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14 AWG Cu Non Metallic (2 Conductor) open air
Page (1/2)

Scan	Time	Elapsed	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core
29	5 AMPS	00:00:27:59					
30	8/15/2017 12:13	00:00:28:59	23.451	23.326	22.977	23.042	22.899
		Corrected Ambient	31.82	31.70	31.35	31.41	31.27
		Average	31.63				
		Average Core	31.61				
		Average Insulation	31.66				
60	10 AMPS	00:00:58:59					
61	8/15/2017 12:44	00:00:59:59	27.177	26.623	25.544	25.678	25.495
		Corrected Ambient	35.63	35.07	33.99	34.13	33.94
		Average	34.60				
		Average Core	34.58				
		Average Insulation	34.62				
88	15 AMPS	00:01:26:59					
89	8/15/2017 13:12	00:01:27:59	32.586	31.152	29.253	29.605	29.106
		Corrected Ambient	40.85	39.42	37.52	37.87	37.37
		Average	38.69				
		Average Core	38.68				
		Average Insulation	38.70				
120	20 AMPS	00:01:58:59					
121	8/15/2017 13:44	00:01:59:59	40.601	37.689	35.231	35.538	35.083
		Corrected Ambient	48.81	45.90	43.44	43.75	43.29

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		Average	44.60				
		Average Core	44.79				
		Average Insulation	44.41				
151	25 AMPS	00:02:29:59					
152	8/15/2017 14:15	00:02:30:59	51.287	47.245	42.544	43.699	41.81
		Corrected Ambient	59.59	55.55	50.85	52.00	50.11
		Average	53.14				
		Average Core	53.05				
		Average Insulation	53.23				

14 AWG Cu Non Metallic (2 Conductor) open air Page (2/2)

302 CU Black Cable#3 Insulation	304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
23.44	23.503	23.264	23.458	23.245	23.126	23.416
31.81	31.87	31.63	31.83	31.62	31.50	31.79
26.374	26.371	26.051	26.426	25.928	25.744	26.369
34.82	34.82	34.50	34.88	34.38	34.19	34.82

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31.135	30.734	30.046	30.955	29.706	29.884	30.947
39.40	39.00	38.31	39.22	37.97	38.15	39.21
37.502	36.586	35.021	37.138	34.631	34.872	36.818
45.71	44.79	43.23	45.35	42.84	43.08	45.03
47.427	44.327	43.744	45.605	42.023	42.908	45.452
55.73	52.63	52.05	53.91	50.32	51.21	53.75

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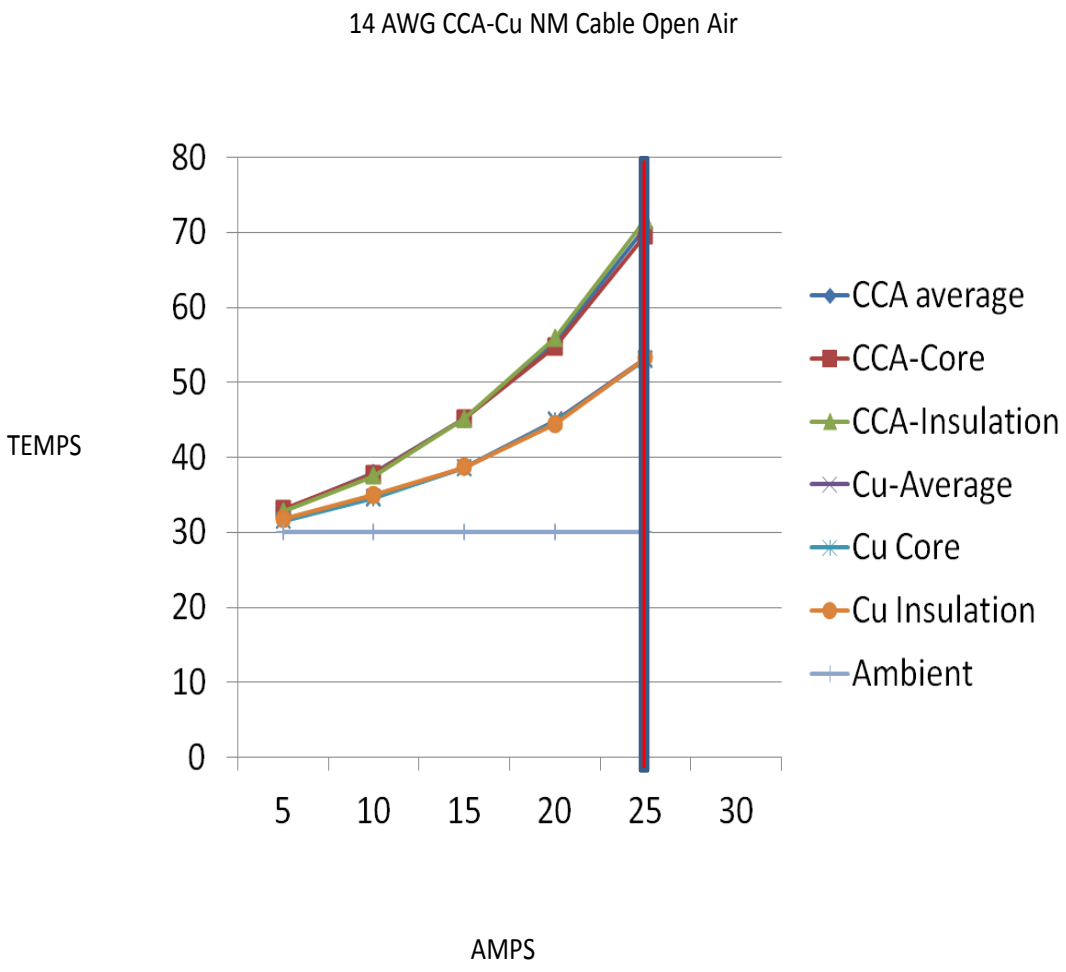

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Test Set- Up/ Layout
14 AWG (2 conductors) in Conduit

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 14 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 14 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 14 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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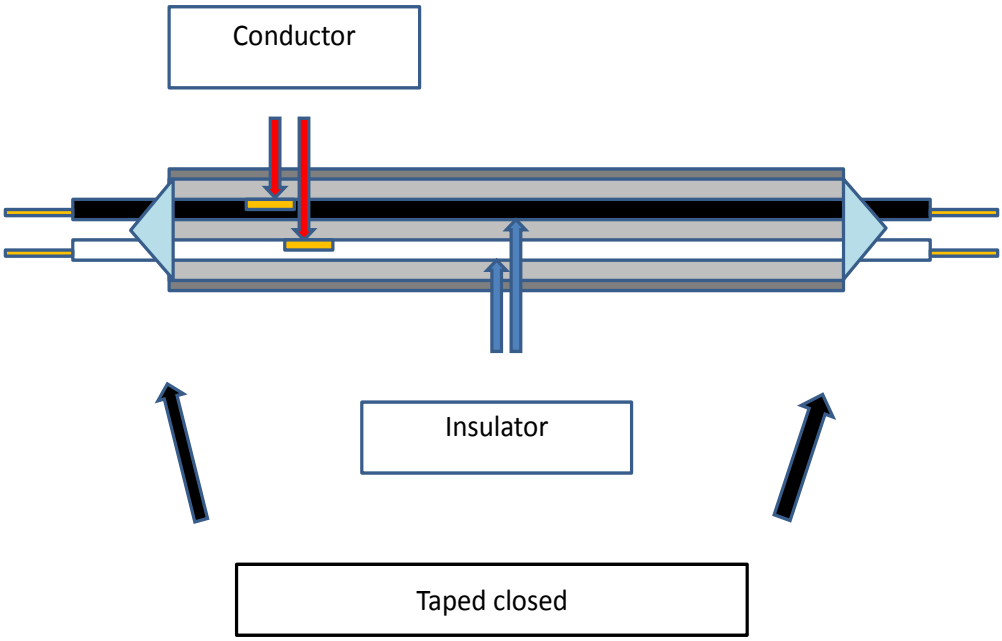
FIGURE 4
Two Conductors in ½ Inch Conduit



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Test Procedure
14 AWG(2 conductors) in Conduit

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 Amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	Conduit	5	30
14	Conduit	10	30
14	Conduit	15	30
14	Conduit	20	30
14	Conduit	25	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA (2 Conductor) in Conduit
Page(1/3)

	101-CCA#1 Core	106 CCA#1 Insulation	107 CCA#2 Core	105 CCA#2 Insulation	112 CCA#3 Core	109 CCA#3 Insulation	113 CCA#4 Core	104 CCA#4 Insulaiton
5 AMPS								
00:00:51:59	24.79	24.61	24.66	24.03	24.04	23.58	23.96	23.72
Corrected Ambient	34.83	34.65	34.70	34.07	34.08	33.62	34.00	33.76
Average	34.19							
Core Average	34.55							
Insulation Average	33.86							
10 AMPS								
00:02:01:59	34.64	34.94	34.84	32.81	32.64	31.25	32.51	31.30
Corrected Ambient	44.83	45.13	45.03	42.99	42.83	41.44	42.70	41.49
Average	43.35							
Core Average	44.12							
Insulation Average	42.64							
15 AMPS								
00:02:52:59	51.48	52.20	52.36	47.74	46.95	43.79	46.60	43.97
Corrected Ambient	61.07	61.78	61.94	57.32	56.53	53.37	56.18	53.55
Average	58.13							
Core Average	59.84							
Insulation Average	56.57							
20 AMPS								
00:03:43:59	72.68	74.44	73.96	66.89	66.02	59.92	64.39	60.07
Corrected Ambient	82.07	83.84	83.35	76.28	75.41	69.31	73.78	69.47
Average	77.26							
Core Average	80.16							
Insulation Average	74.60							
25 AMPS								
00:04:33:59	117.65	117.35	119.71	105.33	107.61	92.87	101.25	92.53
Corrected Ambient	127.06	126.76	129.12	114.74	117.02	102.28	110.66	101.94
Average	117.69							
Core Average	124.41							

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Insulation Average	111.52							

14 AWG CCA (2 Conductor) in Conduit Page(2/3)

120 CCA#5 Core	116 CCA#5 Insulation	110 CCA#6 Core	102 CCA#6 Insulation	118 CCA#7 Insulation	117 CCA#8 Core	103 CCA#8 Insulation	114 CCA#9 Core
24.64	23.92	25.11	24.39	23.42	24.81	23.37	24.43
34.69	33.97	35.15	34.43	33.47	34.85	33.42	34.48
34.64	32.33	35.84	34.63	30.90	33.95	31.16	32.84
44.82	42.52	46.03	44.82	41.09	44.13	41.35	43.03
51.59	46.53	54.59	52.00	43.29	50.64	44.39	47.81
61.17	56.11	64.17	61.58	52.88	60.22	53.97	57.39
73.42	64.63	78.42	73.82	58.67	71.14	60.84	67.02
82.81	74.02	87.81	83.21	68.06	80.53	70.23	76.41
119.35	101.08	128.37	117.64	88.72	117.29	94.74	110.37
128.76	110.49	137.78	127.05	98.13	126.70	104.15	119.78

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14 AWG CCA (2 Conductor) in Conduit Page(3/3)

211 CCA#9 Insulation	212 CCA#10 Core	204 CCA#10 Insulation	220 CCA#11 Core	203 CCA#11 Insulaiton	218 CCA#12 Core	214 CCA#12 Insulation
23.42	24.44	23.75	24.58	24.03	24.15	23.59
33.46	34.48	33.80	34.62	34.07	34.20	33.63
31.17	34.07	33.65	34.69	33.24	32.61	32.04
41.36	44.26	43.84	44.88	43.43	42.80	42.22
45.01	50.94	50.44	52.39	48.40	47.47	46.07
54.59	60.52	60.02	61.97	57.98	57.05	55.65
61.56	71.91	71.23	73.72	67.11	65.73	63.36
70.95	81.30	80.62	83.11	76.50	75.12	72.75
97.96	118.18	113.21	118.54	104.99	106.66	98.95
107.37	127.59	122.62	127.95	114.40	116.07	108.36

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14 AWG Cu (2 Conductor) in Conduit Page 1/2)

	206 CU#1 Core	209 CU#1 Insulation	213 CU#3 Core	208 CU#3 Insualtion	205 CU#5 Core	305 CU#5 Insulation
5 AMPS						
00:00:51:59	22.48	21.97	22.25	22.56	22.77	22.70
Corrected Ambient	32.52	32.02	32.30	32.60	32.81	32.74
Average	32.67					
Core Average	32.81					
Insulation Average	32.53					
10 AMPS						
00:02:01:59	27.37	26.44	27.92	28.45	28.47	28.16
Corrected Ambient	37.56	36.63	38.11	38.63	38.65	38.35
Average	38.29					
Core Average	38.65					
Insulation Average	37.92					
15 AMPS						
00:02:52:59	36.14	34.08	37.61	38.51	38.48	37.28
Corrected Ambient	45.72	43.67	47.19	48.09	48.07	46.86
Average	47.09					
Core Average	47.98					
Insulation Average	46.20					
20 AMPS						
00:03:43:59	45.98	42.87	49.09	50.19	50.16	47.55
Corrected Ambient	55.37	52.26	58.48	59.58	59.56	56.94
Average	57.97					
Core Average	59.56					
Insulation Average	56.39					
25 AMPS						
00:04:33:59	65.98	59.49	71.81	72.52	73.11	68.34
Corrected Ambient	75.39	68.90	81.22	81.93	82.52	77.75
Average	79.54					
Core Average	82.77					
Insulation Average	76.31					

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14 AWG Cu (2 Conductor) in Conduit
Page (2/2)

318 CU#7 Core	315 CU#7 Insulation	310 CU#9 Core	313 CU#9 Insulaiton	304 CU#11 Core	312 CU#11 Insulation
23.00	22.44	23.28	22.62	22.81	22.62
33.04	32.48	33.33	32.66	32.85	32.66
29.12	27.38	29.95	27.92	27.95	28.05
39.31	37.57	40.14	38.11	38.14	38.24
39.72	36.00	41.63	36.70	36.82	37.14
49.30	45.58	51.21	46.28	46.40	46.73
52.56	46.16	55.35	47.13	47.86	48.12
61.95	55.55	64.74	56.52	57.25	57.51
78.19	65.80	82.60	66.20	68.46	69.08
87.60	75.21	92.01	75.61	77.87	78.49

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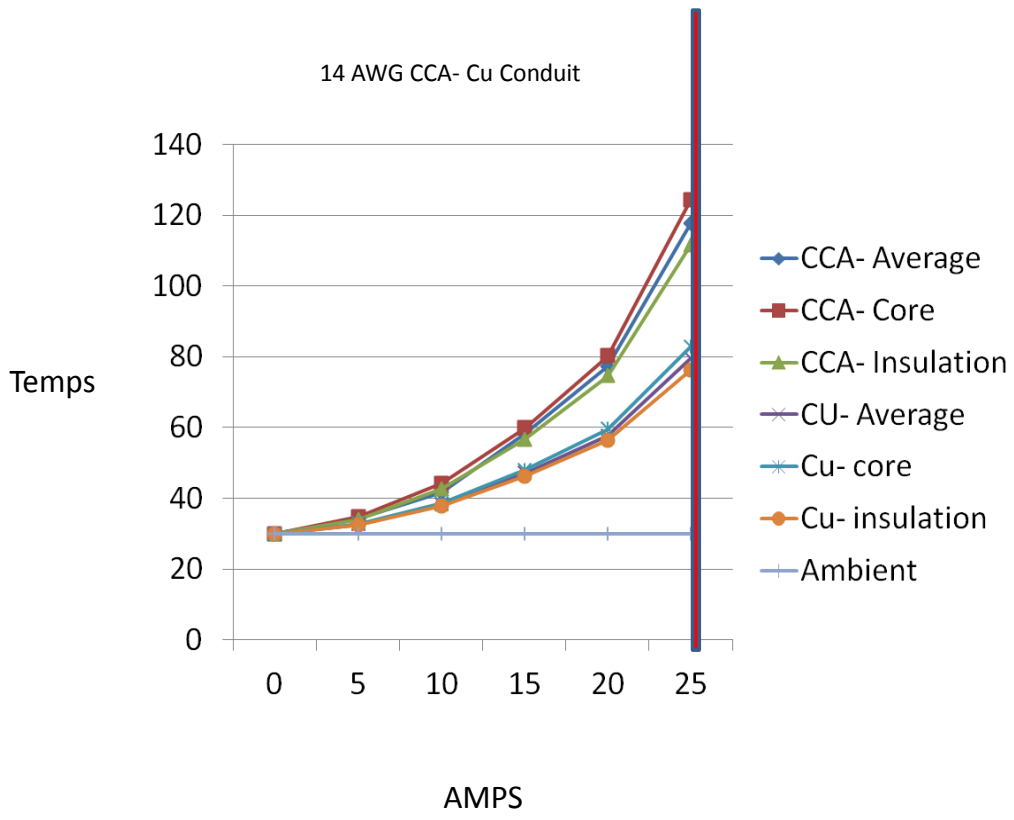

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Test Set- Up/ Layout
12 AWG Single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 12 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 12 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 12 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG single conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	Open air	5	30
12	Open air	10	30
12	Open air	15	30
12	Open air	20	30
12	Open air	25	30
12	Open air	30	30
12	Open air	35	30
12	Open air	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG single conductors
(Page 1 of 3)

Scan	Time	101- CU-AL White Cable#1- Insulation	104 CU-AL Black Cable#1 Core	105 CU-AL Black Cable#1 Insulation	106 CU-AL Black Cable#2 Core	107 CU-AL Black Cable#2 Insulation	109 CU-AL White Cable#2 Core
	5 AMPS						
30	8/16/2017 14:54	23.5	23.719	23.597	24.101	23.626	23.882
	Corrected Ambient	31.925	32.144	32.022	32.526	32.051	32.307
	Average	31.86845					
	Average Core	32.1068					
	Average Insulation	31.66983					
	10 AMPS						
60	8/16/2017 15:24	26.487	26.702	26.788	27.393	26.714	26.989
	Corrected Ambient	35	35.215	35.301	35.906	35.227	35.502
	Average	34.92791					
	Average Core	35.3563					
	Average Insulation	34.57092					
	15 AMPS						
91	8/16/2017 15:55	30.559	30.658	30.656	32.374	30.779	31.249
	Corrected Ambient	38.79	38.889	38.887	40.605	39.01	39.48
	Average	38.64927					
	Average Core	39.4042					
	Average Insulation	38.02017					
	20 AMPS						
121	8/16/2017 16:25	35.826	35.837	35.678	38.337	35.742	36.622
	Corrected Ambient	44.421	44.432	44.273	46.932	44.337	45.217
	Average	43.80986					
	Average Core	45.065					
	Average Insulation	42.76392					

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	25 AMPS						
152	8/16/2017 16:56	42.958	43.207	43.137	48.117	43.123	44.441
	Corrected Ambient	51.22	51.469	51.399	56.379	51.385	52.703
	Average	50.82832					
	Average Core	52.8027					
	Average Insulation	49.183					
	30 AMPS						
182	8/16/2017 17:26	50.663	51.573	51.558	58.75	51.353	52.748
	Corrected Ambient	59.164	60.074	60.059	67.251	59.854	61.249
	Average	58.849					
	Average Core	61.1368					
	Average Insulation	56.9425					
	35 AMPS						
213	8/16/2017 17:57	59.241	60.489	60.736	70.389	59.671	62.631
	Corrected Ambient	67.397	68.645	68.892	78.545	67.827	70.787
	Average	67.43436					
	Average Core	70.5558					
	Average Insulation	64.83317					
	40 AMPS						
244	8/16/2017 18:28	67.579	70.938	69.371	84.754	68.417	73.658
	Corrected Ambient	75.86	79.219	77.652	93.035	76.698	81.939
	Average	76.85605					
	Average Core	80.71511					
	Average Insulation	72.72958					

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12 AWG Single conductor
(Page 2 of 3)

112 CU-AL White Cable# 2 Insulation	113 CU-AL Black Cable#3 Core	114 CU-AL Black Cable #3 Insulation	116 CU-AL White Cable #3 Insulation	320 CU-AL White Cable#4 Core	118 CU-AL Black Cable#4 Insulation
23.57	23.62	23.4	23.285	23.776	23.093
31.995	32.045	31.825	31.71	32.201	31.518
26.464	26.507	26.264	25.822	26.845	25.692
34.977	35.02	34.777	34.335	35.358	34.205
30.073	30.291	29.915	29.382	31.533	29.206
38.304	38.522	38.146	37.613	39.764	37.437
34.775	34.982	34.305	33.662	37.097	32.398
43.37	43.577	42.9	42.257	45.692	40.993
41.606	42.027	41.564	40.681	46.895	35.318

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49.868	50.289	49.826	48.943	55.157	43.58
49.167	49.465	49.303	47.244	55.947	45.015
57.668	57.966	57.804	55.745	64.448	53.516
57.152	57.789	57.623	54.861	67.265	52.7
65.308	65.945	65.779	63.017	75.421	60.856
66.056	67.263	67.276	63.756	81.93	48.048
74.337	75.544	75.557	72.037	90.211	56.329

12 AWG Single conductor
(Page 3 of 3)

110 CU-AL White Cable#4 Core	120 CU-AL Black Cable#5 Core	211 CU-AL Black Cable#5 Insulation	205CU-AL White Cable#5 Insulation	208 CU-AL White Cable#6 Core	203 CU-AL Black Cable#6 Core	204 CU-AL Black Cbale#6 Insulation
23.509	23.482	23.149	23.038	23.485	23.786	22.755
31.934	31.907	31.574	31.463	31.91	32.211	31.18

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26.402	26.539	25.762	25.861	26.673	27.668	25.409
34.915	35.052	34.275	34.374	35.186	36.181	33.922
30.025	30.717	29.685	29.704	31.023	32.791	28.963
38.256	38.948	37.916	37.935	39.254	41.022	37.194
34.209	35.835	33.848	34.108	36.344	39.108	32.692
42.804	44.43	42.443	42.703	44.939	47.703	41.287
40.855	43.7	41.307	41.654	44.03	48.851	39.803
49.117	51.962	49.569	49.916	52.292	57.113	48.065
47.49	51.417	48.521	49.376	51.659	58.336	46.401
55.991	59.918	57.022	57.877	60.16	66.837	54.902

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55.696	61.164	57.106	58.492	61.252	69.982	53.979
63.852	69.32	65.262	66.648	69.408	78.138	62.135
63.039	72.843	66.826	67.72	70.828	83.361	63.75
71.32	81.124	75.107	76.001	79.109	91.642	72.031

12 AWG Cu Single conductors
(Page 1 of 2)

Scan	Time	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core
	5 AMPS					
30	8/16/2017 14:54	22.678	22.601	23.084	22.862	23.1
	Corrected Ambient	31.103	31.026	31.509	31.287	31.525
	Average	31.28				
	Average Core	31.346				
	Average Insulation	31.214				
	10 AMPS					
60	8/16/2017 15:24	24.574	24.195	25.492	24.984	25.629
	Corrected Ambient	33.087	32.708	34.005	33.497	34.142
	Average	33.44408				
	Average Core	33.63167				
	Average Insulation	33.2565				
	15 AMPS					

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91	8/16/2017 15:55	27.938	27.51	29.234	28.369	29.346
	Corrected Ambient	36.169	35.741	37.465	36.6	37.577
	Average	36.27708				
	Average Core	36.65483				
	Average Insulation	35.89933				
	20 AMPS					
121	8/16/2017 16:25	31.89	31.073	33.381	32.19	33.634
	Corrected Ambient	40.485	39.668	41.976	40.785	42.229
	Average	40.2505				
	Average Core	40.86083				
	Average Insulation	39.64017				
	25 AMPS					
152	8/16/2017 16:56	37.908	36.251	39.895	37.963	40.79
	Corrected Ambient	46.17	44.513	48.157	46.225	49.052
	Average	45.57908				
	Average Core	46.602				
	Average Insulation	44.55617				
	30 AMPS					
182	8/16/2017 17:26	45.629	44.793	46.939	43.77	47.443
	Corrected Ambient	54.13	53.294	55.44	52.271	55.944
	Average	51.87658				
	Average Core	53.18617				
	Average Insulation	50.567				
	35 AMPS					
213	8/16/2017 17:57	53.356	52.266	54.603	50.492	54.888
	Corrected Ambient	61.512	60.422	62.759	58.648	63.044
	Average	58.39692				
	Average Core	60.13967				
	Average Insulation	56.65417				
	40 AMPS					
244	8/16/2017 18:28	62.217	61.357	63.891	59.265	64.258
	Corrected Ambient	70.498	69.638	72.172	67.546	72.539

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	Average	66.52817				
	Average Core	69.18933				
	Average Insulation	63.867				

12 AWG Cu Single conductors
(Page 1 of 2)

	Time	304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
	5 AMPS						
30	8/16/2017 14:54	22.672	22.586	23.069	22.909	22.923	22.74
	Corrected Ambient	31.097	31.011	31.494	31.334	31.348	31.165
	10 AMPS						
60	8/16/2017 15:24	24.713	24.647	25.355	24.993	24.949	24.515
	Corrected Ambient	33.226	33.16	33.868	33.506	33.462	33.028
	15 AMPS						
91	8/16/2017 15:55	27.693	27.514	28.674	27.745	27.658	26.826
	Corrected Ambient	35.924	35.745	36.905	35.976	35.889	35.057
	20 AMPS						
121	8/16/2017 16:25	31.304	30.91	32.491	31.202	30.895	29.56
	Corrected Ambient	39.899	39.505	41.086	39.797	39.49	38.155

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	25 AMPS						
152	8/16/2017 16:56	36.656	36.446	39.125	36.545	35.666	33.819
	Corrected Ambient	44.918	44.708	47.387	44.807	43.928	42.081
	30 AMPS						
182	8/16/2017 17:26	42.269	41.429	45.709	41.914	40.122	38.201
	Corrected Ambient	50.77	49.93	54.21	50.415	48.623	46.702
	35 AMPS						
213	8/16/2017 17:57	50.113	48.676	53.39	48.317	45.552	43.055
	Corrected Ambient	58.269	56.832	61.546	56.473	53.708	51.211
	40 AMPS						
244	8/16/2017 18:28	55.495	53.591	66.664	55.887	52.925	47.744
	Corrected Ambient	63.776	61.872	74.945	64.168	61.206	56.025

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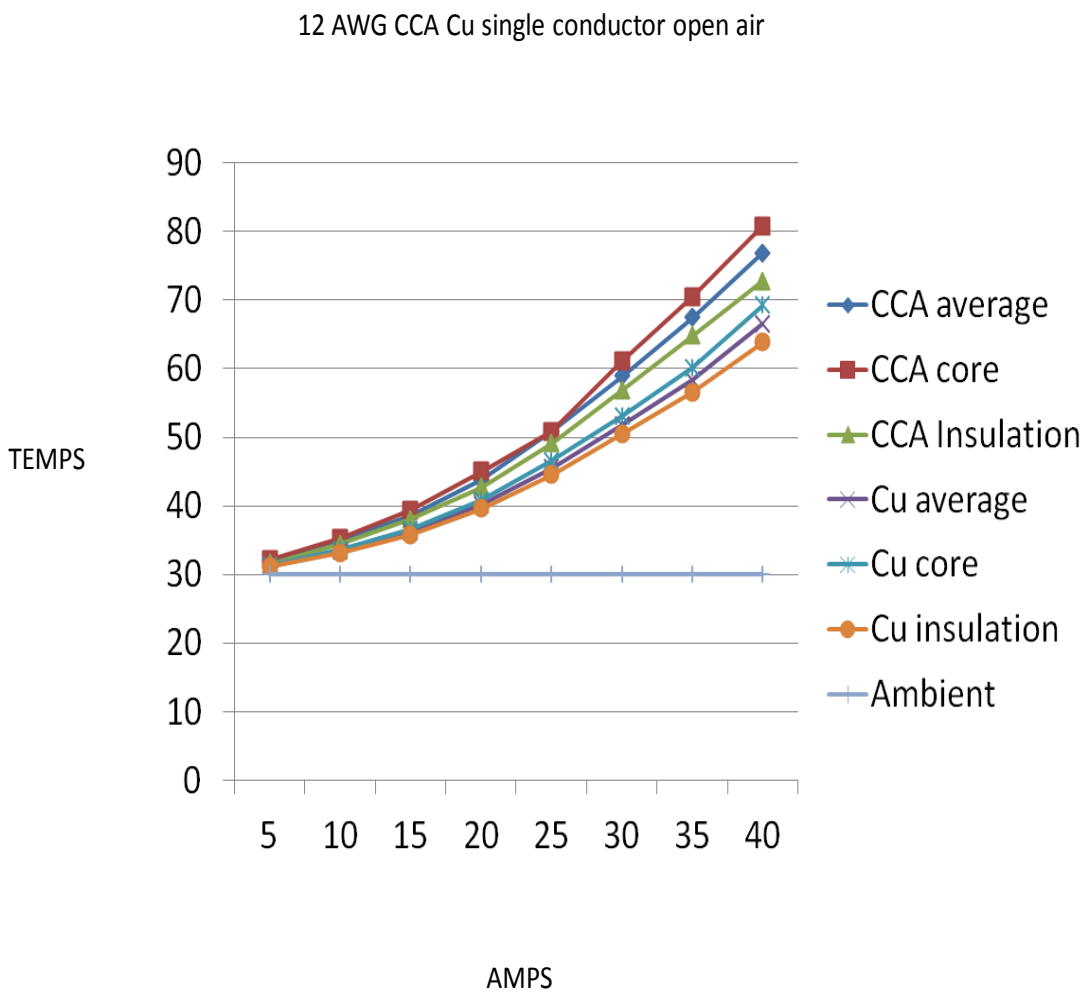

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Test Set- Up/ Layout
12 AWG in non-metallic cable (2 Conductor) in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 12 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 12 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 12 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG In (2 conductor) non-metallic cable

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	NM Cable	5	30
12	NM Cable	10	30
12	NM Cable	15	30
12	NM Cable	20	30
12	NM Cable	25	30
12	NM Cable	30	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 1 of 3)

Scan	Time	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	208 CU-AL Black Cable#2 Core	205 CU-AL Black Cable#2 Insulation
	5 AMPS					
30	**8/17/2017 10:29**	**22.67**	**22.926**	**23.13**	**23.256**	**23.015**
	Corrected Ambient	31.08	31.335	31.539	31.665	31.424
	Average	31.68				
	Average Core	31.73				
	Average Insulation	31.63				
	10 AMPS					
61	8/17/2017 11:00	25.93	26.059	26.92	26.863	26.217
	Corrected Ambient	34.32	34.443	35.304	35.247	34.601
	Average	34.88				
	Average Core	35.09				
	Average Insulation	34.68				
	15 AMPS					
91	8/17/2017 11:30	30.31	30.408	32.809	32.228	31.062
	Corrected Ambient	38.40	38.497	40.898	40.317	39.151
	Average	39.36				
	Average Core	39.90				
	Average Insulation	38.87				
	20 AMPS					
121	8/17/2017 12:00	35.95	36.03	40.071	39.839	36.86
	Corrected Ambient	44.35	44.426	48.467	48.235	45.256

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	Average	45.56				
	Average core	46.67				
	Average Insulation	44.54				
	25 AMPS					
152	8/17/2017 12:31	41.34	41.083	45.352	45.612	42.454
	Corrected Ambient	49.85	49.598	53.867	54.127	50.969
	Average	51.67				
	Average Core	53.50				
	Average Insulation	50.00				
	30 AMPS					
182	8/17/2017 13:01	47.44	47.015	53.341	52.596	50.518
	Corrected Ambient	55.74	55.316	61.642	60.897	58.819
	Average	59.54				
	Average Core	62.19				
	Average Insulation	57.11				

12 AWG CCA In non-metallic cable(2 conductor)
(Page 2 of 3)

211 CU-AL White Cable# 2 Insulation	102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #3 Insulation
23.196	**23.139**	**23.493**	**23.536**
31.605	31.548	31.902	31.945
26.208	26.16	26.433	26.599
34.592	34.544	34.817	34.983

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30.375	30.414	30.425	31.929
38.464	38.503	38.514	40.018
35.556	35.329	35.55	36.683
43.952	43.725	43.946	45.079
41.089	40.342	41.332	41.256
49.604	48.857	49.847	49.771
48.436	46.618	48.28	47.403
56.737	54.919	56.581	55.704

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 3of 3)

116 CU-AL Black Cable#4 Insulation	113 CU-AL White Cable #4 Core	114 CU-AL White Cable#4 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#5 Insulation
23.222	**23.2**	**23.399**	**23.443**	**23.14**
31.631	31.609	31.808	31.852	31.549
25.734	26.056	26.523	26.702	25.713
34.118	34.44	34.907	35.086	34.097
28.997	31.638	30.56	30.878	29.977
37.086	39.727	38.649	38.967	38.066
33.062	37.403	35.681	36.471	35.027
41.458	45.799	44.077	44.867	43.423

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37.425	44.796	40.903	42.529	40.103
45.94	53.311	49.418	51.044	48.618
43.655	55.384	48.43	51.204	48.229
51.956	63.685	56.731	59.505	56.53

12 AWG Cu In non-metallic cable(2 Conductor)
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30	**8/17/2017 10:29**	**22.614**	**22.554**	**22.891**	**22.59**	**22.796**	**22.882**
	Corrected Ambient	31.023	30.963	31.3	30.999	31.205	31.291
	Average	31.22208					
	Average Core	31.295					
	Average Insulation	31.14917					
	10 AMPS						
61	8/17/2017 11:00	25.114	24.271	25.231	24.387	24.977	24.9
	Corrected Ambient	33.498	32.655	33.615	32.771	33.361	33.284
	Average	33.271					

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	Average Core	33.58917					
	Average Insulation	32.95283					
	15 AMPS						
91	8/17/2017 11:30	28.333	27.255	28.517	27.065	28.032	28.006
	Corrected Ambient	36.422	35.344	36.606	35.154	36.121	36.095
	Average	36.00508					
	Average Core	36.45233					
	Average Insulation	35.55783					
	20 AMPS						
121	8/17/2017 12:00	32.461	30.737	32.806	30.378	32.047	31.754
	Corrected Ambient	40.857	39.133	41.202	38.774	40.443	40.15
	Average	40.02075					
	Average core	40.70133					
	Average Insulation	39.34017					
	25 AMPS						
152	8/17/2017 12:31	37.317	35.362	38.138	34.253	36.101	35.718
	Corrected Ambient	45.832	43.877	46.653	42.768	44.616	44.233
	Average	44.385					
	Average Core	45.3695					
	Average Insulation	43.4005					
	30 AMPS						
182	8/17/2017 13:01	43.719	41.111	44.969	39.04	42.173	41.491
	Corrected Ambient	52.02	49.412	53.27	47.341	50.474	49.792
	Average	49.96617					
	Average Core	51.36633					
	Average Insulation	48.566					

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 2 of 2)

305 CU White Cable#3 Insulation	309 CU Black Cable#2 Core	310 CU Black Cable#2 Insulation	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.726	**23.1**	**22.833**	**22.872**	**22.856**
31.135	31.509	31.242	31.281	31.265
24.487	25.693	24.642	24.877	24.726
32.871	34.077	33.026	33.261	33.11
27.237	29.01	27.541	27.932	27.709
35.326	37.099	35.63	36.021	35.798
30.746	33.217	31.041	31.343	31.009
39.142	41.613	39.437	39.739	39.405

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34.482	37.831	34.853	35.499	34.645
42.997	46.346	43.368	44.014	43.16
39.792	44.397	39.901	41.125	40.255
48.093	52.698	48.202	49.426	48.556

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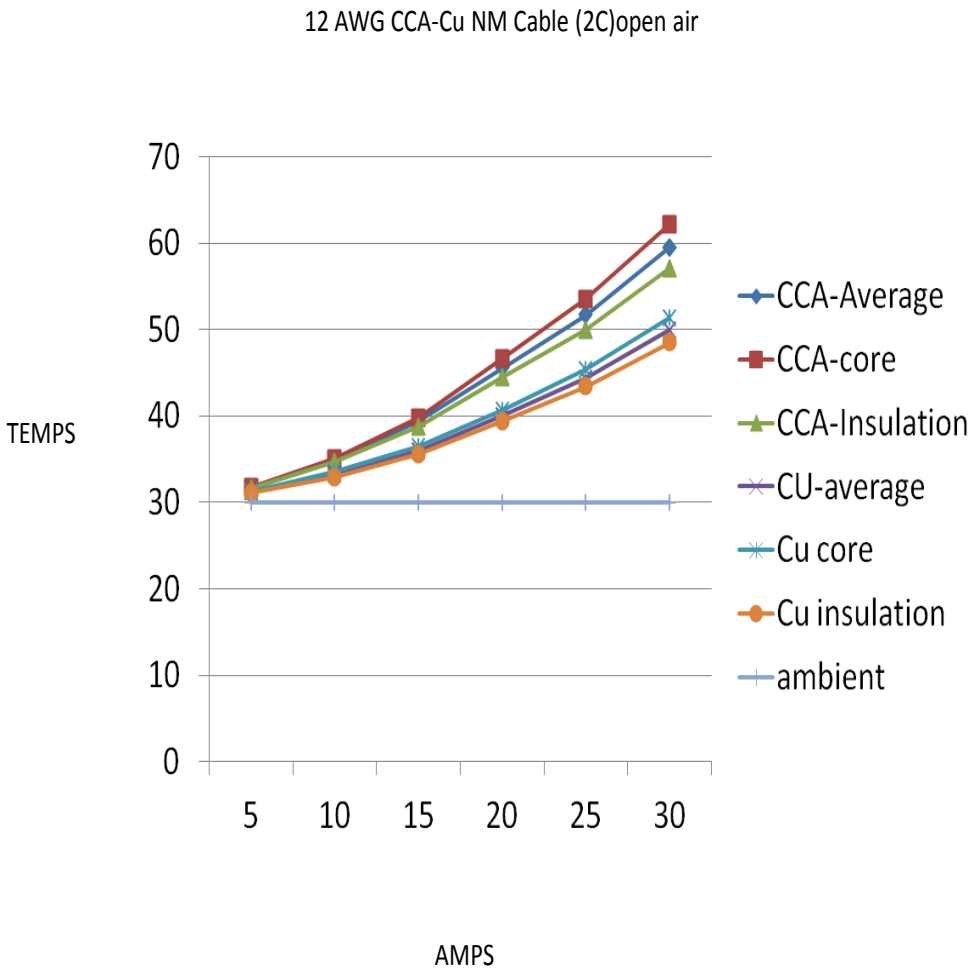

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Test Set- Up/ Layout
12 AWG in Conduit (2 conductors)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 12 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 12 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 12 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG In conduit (2 conductors)

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	Conduit	5	30
12	Conduit	10	30
12	Conduit	15	30
12	Conduit	20	30
12	Conduit	25	30
12	Conduit	30	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG CCA In conduit (2 conductors)
(Page 1 of 3)

Scan	Time	101- CU-AL White Cable-Core	103 CU-AL White Cable Insulation	104 CU-AL Black Cable Core	105 CU-AL Black Cable Insulation	106 CU-AL Black Cable Core	107 CU-AL Black Cable Insulation
	5 AMPS						
34.00	42,963.45	24.80	24.55	24.92	24.52	25.20	24.98
	Corrected Ambient	33.20	32.95	33.32	32.92	33.60	33.38
	Average	32.92					
	Average core	33.12					
	Average Insulation	32.75					
	10 Amps						
66.00	42,963.47	30.79	29.98	30.50	29.05	31.64	30.86
	Corrected Ambient	39.24	38.43	38.95	37.50	40.09	39.30
	Average	38.30					
	Average core	38.54					
	Average Insulation	38.71					
	15 Amps						
98.00	42,963.49	39.83	38.14	39.13	35.99	41.35	39.89
	Corrected Ambient	48.24	46.54	47.54	44.40	49.75	48.30
	Average	46.26					
	Average core	47.36					
	Average Insulation	45.34					
	20 AMPS						
130.00	42,963.51	53.93	51.10	52.57	46.42	56.43	53.62
	Corrected Ambient	62.34	59.51	60.98	54.83	64.84	62.03
	Average	58.48					

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	Average core	60.33					
	Average Insulation	56.95					
	25 AMPS						
162.00	42,963.54	71.01	66.92	68.93	58.87	75.38	70.30
	Corrected Ambient	79.37	75.29	77.29	67.23	83.74	78.66
	Average	73.37					
	Average core	76.31					
	Average Insulation	70.92					
	30 AMPS						
208.00	42,963.57	95.27	88.98	92.19	76.76	102.19	93.33
	Corrected Ambient	103.67	97.37	100.58	85.15	110.58	101.72
	Average	94.77					
	Average core	99.22					
	Average Insulation	91.05					

12 AWG CCA in Conduit (2 Conductors)
Page (2 of 3)

109 CU-AL White Cable Core	112 CU-AL White Cable Insulation	113 CU-AL Black Cable Core	114 CU-AL Black Cable Insulation	116 CU-AL White Cable Insulation	320 CU-AL White Cable Core
25.06	24.79	24.97	24.89	24.38	24.57
33.46	33.19	33.36	33.29	32.78	32.97
30.95	29.96	30.85	30.45	28.75	29.93
39.40	38.41	39.30	38.89	37.19	38.38

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39.93	38.02	39.99	39.25	35.66	38.12
48.34	46.43	48.40	47.65	44.07	46.53
53.56	50.15	53.76	52.46	45.78	50.35
61.97	58.57	62.17	60.87	54.19	58.76
70.65	65.52	71.23	69.04	58.58	65.18
79.02	73.88	79.59	77.40	66.95	73.54
94.77	86.67	95.96	92.55	76.17	86.50
103.16	95.06	104.35	100.95	84.56	94.89

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12 AWG CCA in Conduit (2 Conductors)
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315 CU-AL Black Cable Core	118 CU-AL Black Cable Insulation	102 CU-AL White Cable Insulation	110 CU-AL White Cable Core	211 CU-AL Black Cable Insulation	205CU-AL White Cable Insulation
24.41	24.04	24.69	25.09	24.46	24.15
32.81	32.44	33.08	33.49	32.86	32.55
29.90	27.86	30.58	31.01	30.08	29.09
38.35	36.31	39.03	39.46	38.52	37.54
38.26	34.03	39.40	40.19	38.41	36.46
46.67	42.44	47.80	48.60	46.82	44.87
50.81	45.67	52.82	53.77	51.24	47.67
59.23	54.08	61.23	62.19	59.65	56.08

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66.35	55.12	68.87	70.60	68.22	62.30
74.72	63.48	77.23	78.97	76.58	70.66
88.26	70.54	92.61	94.54	93.37	83.09
96.65	78.93	101.00	102.93	101.76	91.48

12 AWG Cu In conduit (2 Conductors)
(Page 1 of 2)

Scan	Time	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core	302 CU Black Cable#3 Insulation
	5 AMPS						
34.00	42,963.45	23.58	23.40	23.92	23.37	23.59	23.54
	Corrected Ambient	31.98	31.79	32.32	31.77	31.99	31.93
	Average	32.04					
	Average core	32.16					
	Average Insulation	31.92					
	10 Amps						
66.00	42,963.47	27.28	26.39	28.16	26.32	27.09	25.98
	Corrected Ambient	35.73	34.84	36.61	34.77	35.54	34.43
	Average	35.49					
	Average core	35.99					
	Average Insulation	34.99					
	15 Amps						

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98.00	42,963.49	32.59	30.64	34.57	30.92	32.40	30.16
	Corrected Ambient	40.99	39.05	42.98	39.32	40.81	38.57
	Average	40.68					
	Average core	41.67					
	Average Insulation	39.68					
	20 AMPS						
130.00	42,963.51	41.24	37.72	44.71	38.16	40.68	36.33
	Corrected Ambient	49.66	46.14	53.12	46.58	49.10	44.74
	Average	48.81					
	Average core	50.65					
	Average Insulation	46.96					
	25 AMPS						
162.00	42,963.54	52.09	46.85	57.21	46.77	50.75	44.10
	Corrected Ambient	60.45	55.21	65.57	55.14	59.11	52.46
	Average	58.67					
	Average core	61.52					
	Average Insulation	55.81					
	30 AMPS						
208.00	42,963.57	67.48	59.62	74.44	58.61	64.15	54.26
	Corrected Ambient	75.87	68.01	82.83	67.01	72.54	62.65
	Average	72.19					
	Average core	76.53					
	Average Insulation	67.86					

12 AWG Cu In conduit (2 Conductors)
(Page 2 of 2)

304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
23.91	23.65	23.81	23.67	23.76	23.55

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32.30	32.04	32.20	32.07	32.15	31.94
27.70	26.94	27.55	27.04	27.49	26.59
36.15	35.39	36.00	35.48	35.94	35.04
33.58	32.18	33.20	32.27	33.25	31.45
41.99	40.59	41.60	40.68	41.66	39.85
42.62	40.10	42.09	40.23	42.11	38.73
51.03	48.52	50.50	48.65	50.53	47.14
53.25	49.79	52.80	49.90	52.88	47.31
61.61	58.15	61.16	58.26	61.24	55.67
67.84	62.54	67.31	62.93	67.59	58.86
76.24	70.93	75.70	71.33	75.98	67.25

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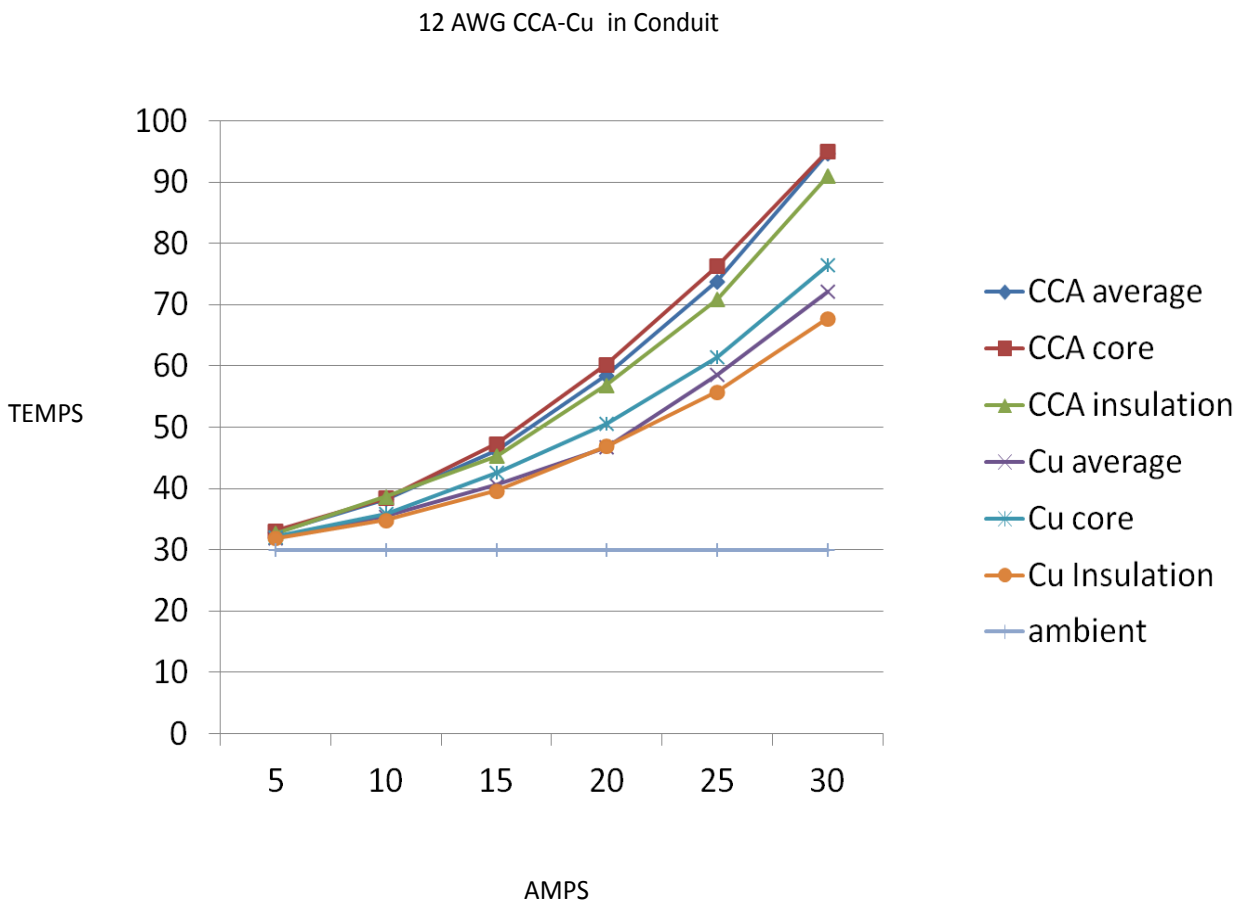

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Test Set- Up/ Layout
10 AWG single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 10 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 10 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 10 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG Single conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	Open air	5	30
10	Open air	10	30
10	Open air	15	30
10	Open air	20	30
10	Open air	25	30
10	Open air	30	30
10	Open air	35	30
10	Open air	40	30
10	Open air	45	30
10	Open air	50	30
10	Open air	55	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA Single conductor Open Air
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Scan	Time	Elapsed	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	208 CU-AL Black Cable#1 Core	205 CU-AL Black Cable#2 Insulation	120 CU-AL White Cable#2 Core	211 CU-AL White Cable#2 Insulation
	5 AMPS							
30.00	42965.59	00:00:28:59	22.27	22.95	22.82	22.50	23.18	22.75
	Corrected Ambient		30.81	31.49	31.36	31.04	31.72	31.28
	Average		31.47					
	Average core		31.47					
	Average Insulation		31.47					
	10 AMPS							
60.00	42965.62	00:00:58:59	24.20	25.01	24.70	24.41	25.11	24.60
	Corrected Ambient		32.71	33.52	33.20	32.91	33.61	33.10
	Average		33.30					
	Average core		33.34					
	Average Insulation		33.25					
	15 AMPS							
94.00	42965.64	00:01:32:59	27.20	28.61	27.87	27.26	28.29	27.43
94.00	Corrected Ambient		35.60	37.01	36.27	35.66	36.69	35.83
	Average		36.09					
	Average core		36.22					
	Average Insulation		35.94					
	20 AMPS							
121.00	42965.66	00:01:59:59	30.94	33.08	31.72	30.92	32.64	31.08
	Corrected Ambient		39.39	41.52	40.17	39.36	41.08	39.52
	Average		39.81					
	Average core		40.07					
	Average Insulation		39.52					

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	25 AMPS							
152.00	42965.68	00:02:30:59	35.76	39.24	36.76	34.98	37.75	35.59
	Corrected Ambient		44.20	47.67	45.20	43.41	46.19	44.03
	Average		44.24					
	Average core		44.68					
	Average Insulation		43.78					
	30 AMPS							
182.00	42965.70	00:03:00:59	39.98	43.90	41.39	39.49	42.72	39.71
	Corrected Ambient		48.45	52.37	49.85	47.96	51.19	48.18
	Average		48.75					
	Average core		49.39					
	Average Insulation		48.05					
	36 AMPS							
214.00	42965.72	00:03:32:59	47.04	48.39	48.73	46.42	50.45	46.40
	Corrected Ambient		55.61	56.97	57.30	54.99	59.03	54.97
	Average		55.57					
	Average core		56.61					
	Average Insulation		54.48					
	40 AMPS							
243.00	42965.74	00:04:01:59	52.41	53.30	54.36	51.59	56.81	51.39
	Corrected Ambient		60.70	61.59	62.65	59.88	65.10	59.68
	Average		60.64					
	Average core		62.02					
	Average Insulation		59.17					
	45 AMPS							
273.00	42965.76	00:04:31:59	59.93	60.57	61.45	59.16	64.82	58.73
	Corrected Ambient		68.43	69.07	69.94	67.66	73.32	67.23
	Average		68.02					
	Average core		69.86					

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	Average Insulation		66.10					
	50 AMPS							
304.00	42965.78	00:05:02:59	68.58	66.89	70.98	67.58	75.68	67.24
	Corrected Ambient		76.79	75.10	79.19	75.80	83.89	75.45
	Average		76.51					
	Average core		78.99					
	Average Insulation		73.93					
	55 AMPS							
334.00	42965.81	00:05:32:59	77.66	75.32	80.26	77.00	85.13	75.41
	Corrected Ambient		86.08	83.74	88.68	85.42	93.54	83.83
	Average		85.54					
	Average core		88.62					
	Average Insulation		82.30					

10 AWG CCA Single conductor Open Air
(Page 2 of 3)

102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #3 Insulation	315 CU-AL White Cable#4 Core	320 CU-AL Black Cable#4 Core	116 CU-AL Black Cable#4 Insulation
22.98	23.06	23.06	22.84	23.14	23.11
31.51	31.60	31.60	31.37	31.67	31.64
24.95	24.87	24.76	24.78	25.11	24.95

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33.46	33.37	33.27	33.29	33.61	33.46
27.94	27.66	27.49	28.04	28.49	27.92
36.34	36.06	35.89	36.45	36.89	36.32
31.97	31.21	31.04	32.09	32.60	31.53
40.41	39.65	39.48	40.54	41.04	39.98
36.86	35.52	34.62	36.88	37.56	35.94
45.30	43.96	43.05	45.32	46.00	44.38
41.65	40.19	38.87	41.54	42.71	40.19
50.12	48.66	47.34	50.00	51.18	48.66
49.26	47.09	45.20	48.99	50.60	47.06
57.83	55.66	53.78	57.57	59.17	55.63

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55.51	52.71	50.13	54.95	56.69	52.01
63.79	60.99	58.42	63.24	64.98	60.29
63.32	59.97	55.29	63.12	65.06	58.74
71.81	68.47	63.79	71.61	73.55	67.23
74.74	68.93	64.75	72.42	74.12	66.84
82.95	77.14	72.96	80.63	82.34	75.05
84.59	77.87	73.40	82.41	84.78	75.05
93.00	86.29	81.82	90.83	93.19	83.47

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10 AWG CCA Single conductor Open Air
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113 CU-AL White Cable #5 Core	114 CU-AL White Cable#5 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#6 Insulation	107 CU-AL White Cable#6 Insulation	106 CU-AL White Cable#6 Core
23.07	22.99	23.03	23.10	22.96	23.24
31.60	31.52	31.57	31.64	31.49	31.78
24.79	24.58	24.88	24.94	24.88	25.30
33.30	33.08	33.38	33.45	33.38	33.80
27.39	27.03	27.64	27.62	27.50	28.42
35.79	35.43	36.04	36.03	35.90	36.82
30.90	30.18	31.18	31.06	30.77	32.25
39.34	38.62	39.62	39.51	39.22	40.70

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34.92	33.57	35.29	35.22	34.83	37.20
43.36	42.01	43.73	43.65	43.27	45.64
39.04	37.63	40.14	39.22	39.04	42.06
47.51	46.10	48.60	47.69	47.50	50.53
45.69	43.45	46.83	45.74	45.25	49.22
54.26	52.02	55.40	54.32	53.83	57.79
50.91	48.17	52.61	50.82	50.25	55.22
59.19	56.46	60.90	59.10	58.54	63.51
58.10	54.41	60.26	57.35	56.69	63.45
66.59	62.90	68.75	65.85	65.18	71.95

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66.27	61.46	69.66	65.42	64.96	73.26
74.48	69.67	77.87	73.64	73.17	81.47
74.81	69.25	79.65	72.63	73.00	82.89
83.23	77.67	88.07	81.04	81.42	91.30

10 AWG Cu Single conductor Open Air
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Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30.00	42965.59	22.07	22.56	22.62	22.55	22.48	22.67
	Corrected Ambient	30.60	31.10	31.16	31.09	31.01	31.20
	Average	31.02					
	Average core	30.96					
	Average Insulation	31.08					
	10 AMPS						
60.00	42965.62	23.25	23.92	23.69	23.51	23.81	23.90
	Corrected Ambient	31.76	32.42	32.19	32.01	32.31	32.41
	Average	32.23					
	Average core	32.20					

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	Average Insulation	32.27					
	15 AMPS						
94.00	42965.64	25.17	26.29	25.70	25.23	26.09	25.97
94.00	Corrected Ambient	33.57	34.69	34.11	33.63	34.49	34.38
	Average	34.26					
	Average core	34.25					
	Average Insulation	34.28					
	20 AMPS						
121.00	42965.66	27.66	29.10	28.12	27.45	28.84	28.45
	Corrected Ambient	36.11	37.54	36.57	35.90	37.28	36.90
	Average	36.90					
	Average core	36.93					
	Average Insulation	36.86					
	25 AMPS						
152.00	42965.68	30.70	32.92	31.23	30.03	32.55	31.95
	Corrected Ambient	39.14	41.36	39.67	38.47	40.99	40.39
	Average	40.29					
	Average core	40.41					
	Average Insulation	40.18					
	30 AMPS						
182.00	42965.70	33.65	36.60	34.35	32.85	36.08	35.22
	Corrected Ambient	42.12	45.07	42.82	41.32	44.55	43.69
	Average	43.76					
	Average core	43.89					
	Average Insulation	43.63					
	36 AMPS						
214.00	42965.72	38.55	42.08	39.00	36.69	41.07	39.69
	Corrected Ambient	47.12	50.65	47.57	45.26	49.64	48.26
	Average	48.80					
	Average core	49.09					
	Average Insulation	48.51					

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	40 AMPS						
243.00	42965.74	41.71	46.30	42.78	40.04	45.42	43.45
	Corrected Ambient	50.00	54.59	51.07	48.33	53.71	51.74
	Average	52.54					
	Average core	52.83					
	Average Insulation	52.24					
	45 AMPS						
273.00	42965.76	47.71	51.95	47.60	43.96	50.47	48.26
	Corrected Ambient	56.20	60.44	56.09	52.45	58.97	56.75
	Average	58.05					
	Average core	58.61					
	Average Insulation	57.49					
	50 AMPS						
304.00	42965.78	53.84	59.41	54.11	49.30	57.74	54.24
	Corrected Ambient	62.05	67.62	62.32	57.52	65.96	62.45
	Average	64.37					
	Average core	65.11					
	Average Insulation	63.63					
	55 AMPS						
334.00	42965.81	60.19	63.55	59.83	53.97	58.77	58.08
	Corrected Ambient	68.60	71.96	68.24	62.39	67.18	66.50
	Average	69.97					
	Average core	70.96					
	Average Insulation	68.98					

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10 AWG Cu Single conductor Open Air
(Page 2 of 2)

304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Insulation	310 CU Black Cable#2 Core	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.23	22.47	22.49	22.70	22.46	22.50
30.77	31.01	31.03	31.24	30.99	31.04
23.53	23.74	23.77	24.13	23.77	23.74
32.03	32.25	32.28	32.64	32.28	32.24
25.65	25.95	26.07	26.49	25.96	25.75
34.05	34.35	34.47	34.89	34.37	34.16
28.23	28.61	28.70	29.55	28.52	28.20
36.68	37.05	37.14	38.00	36.97	36.64

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31.72	32.05	32.16	33.52	32.13	31.34
40.15	40.49	40.59	41.96	40.57	39.78
35.53	35.86	35.80	37.45	35.48	34.67
44.00	44.33	44.27	45.91	43.95	43.14
40.84	41.40	40.65	43.30	40.35	39.11
49.41	49.97	49.23	51.87	48.92	47.68
44.87	45.96	44.94	48.11	44.39	43.05
53.16	54.25	53.23	56.40	52.68	51.33
51.56	51.64	50.42	53.97	49.37	47.77
60.06	60.14	58.92	62.46	57.87	56.26

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57.88	58.65	56.87	61.91	55.93	54.05
66.10	66.86	65.08	70.12	64.14	62.26
64.75	65.59	62.39	70.14	61.61	59.85
73.17	74.00	70.80	78.55	70.03	68.26

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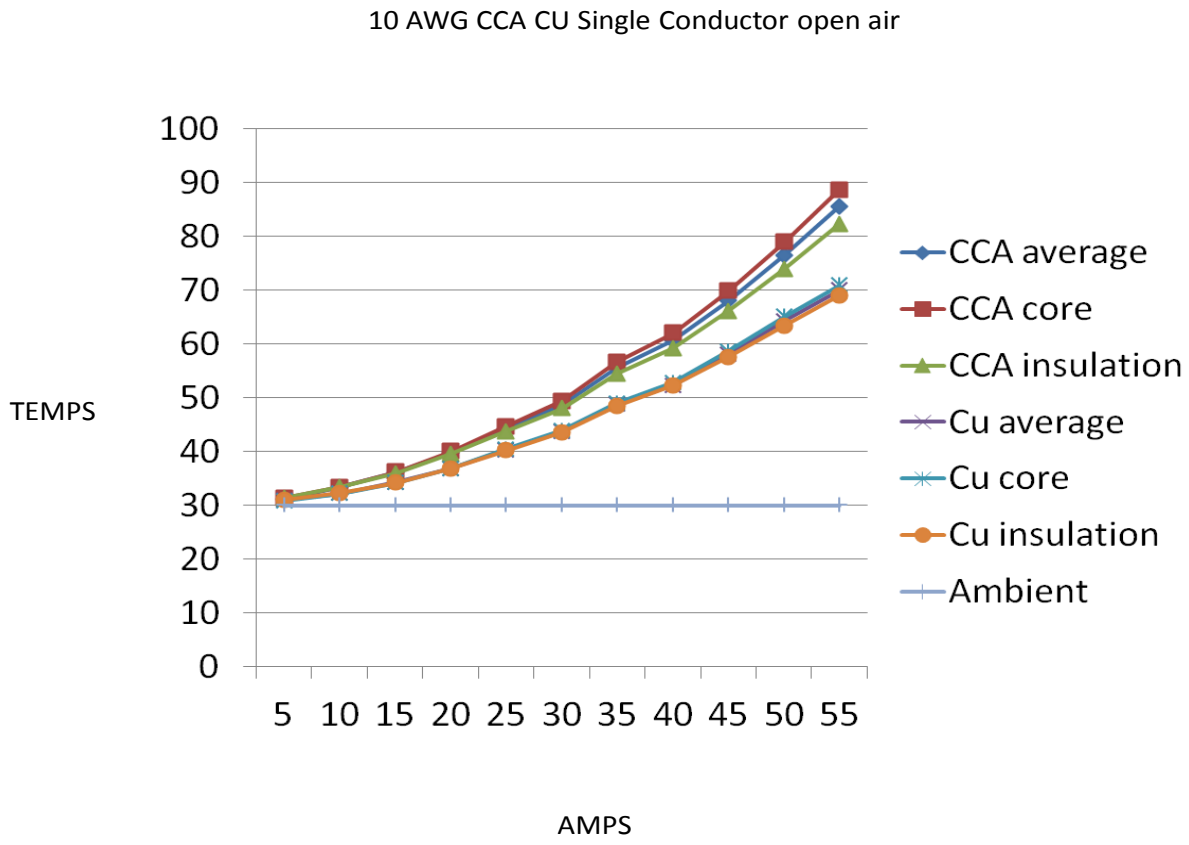

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Test Set- Up/ Layout
10 AWG in non-metallic cable in open air (2 Conductor)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 10 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 10 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 10 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG in Non-Metallic Cable (2 Conductors)

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	NM Cable	5	30
10	NM Cable	10	30
10	NM Cable	15	30
10	NM Cable	20	30
10	NM Cable	25	30
10	NM Cable	30	30
10	NM Cable	35	30
10	NM Cable	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA Non-Metallic Open Air (2 Conductor)

Page 1 of 3

Scan	Time	203 CU-AL White Cable#1-Core	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	208 CU-AL Black Cable#2 Core	120 CU-AL White Cable#2 Core	211 CU-AL White Cable# 2 Insulation
	5 AMPS						
29.00	42965.31	22.56	22.00	22.22	22.70	22.86	22.80
	Corrected Ambient	31.01	30.45	30.67	31.15	31.31	31.25
	Average	31.22					
	Average Core	31.25					
	Average Insulation	31.18					
	10 AMPS						
59.00	42965.34	24.64	24.13	24.46	24.90	25.31	25.33
	Corrected Ambient	33.21	32.70	33.02	33.47	33.88	33.90
	Average	33.48					
	Average Core	33.59					
	Average Insulation	33.34					
	15 AMPS						
90.00	42965.36	27.20	26.74	27.08	27.30	28.47	28.45
	Corrected Ambient	35.98	35.52	35.86	36.09	37.25	37.24
	Average	36.34					
	Average Core	36.53					
	Average Insulation	36.10					
	20 AMPS						
120.00	42965.38	30.31	29.56	30.82	31.04	32.46	31.76
120.00	Corrected Ambient	38.92	38.18	39.43	39.65	41.08	40.38
	Average	39.47					
	Average Core	39.91					
	Average Insulation	38.94					

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	25 AMPS						
151.00	42965.40	34.17	34.26	34.09	33.82	36.82	36.81
	Corrected Ambient	42.70	42.79	42.62	42.35	45.35	45.34
	Average	43.20					
	Average Core	43.67					
	Average Insulation	42.63					
	30 AMPS						
181.00	8/18/2017	40.14	40.25	39.61	39.67	44.07	43.95
	Corrected Ambient	48.87	48.97	48.34	48.40	52.80	52.68
	Average	49.73					
	Average Core	50.27					
	Average Insulation	49.07					
	35 AMPS						
211.00	8/18/2017	45.43	45.21	44.93	45.04	50.87	50.51
	Corrected Ambient	53.94	53.71	53.44	53.55	59.38	59.01
	Average	55.39					
	Average Core	56.18					
	Average Insulation	54.43					
	40 AMPS						
242.00	8/18/2017	50.84	50.96	50.37	51.04	58.24	57.38
	Corrected Ambient	59.52	59.63	59.04	59.71	66.92	66.05
	Average	61.97					
	Average Core	62.84					
	Average Insulation	60.91					

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10 AWG CCA Non-Metallic Open Air (2 Conductor)
(Page 2 of 3)

102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #4 Insulation	315 CU-AL White Cable#3 Core	320 CU-AL Black Cable#4 Core	116 CU-AL Black Cable#4 Insulation
22.96	22.92	22.95	22.83	22.89	22.68
31.41	31.37	31.40	31.29	31.35	31.13
25.39	24.90	25.21	25.08	25.02	24.41
33.96	33.47	33.77	33.65	33.59	32.98
28.53	27.32	28.01	27.79	27.59	26.58
37.31	36.10	36.79	36.58	36.37	35.36
32.18	30.26	31.60	31.28	30.79	29.22
40.80	38.87	40.21	39.89	39.40	37.83

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36.38	33.53	35.13	35.47	34.88	32.40
44.91	42.06	43.65	43.99	43.41	40.93
43.55	39.91	41.12	41.92	41.13	37.92
52.27	48.64	49.85	50.64	49.85	46.65
50.62	45.49	46.83	48.46	47.36	42.93
59.13	53.99	55.34	56.97	55.87	51.43
56.97	51.48	52.58	55.03	54.43	49.04
65.65	60.15	61.26	63.70	63.10	57.71

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10 AWG CCA Non-Metallic Open Air (2 Conductor)
(Page 3 of 3)

114 CU-AL White Cable#6 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#5 Insulation	107 CU-AL White Cable#6 Insulation	106 CU-AL White Cable#5 Core	103 CU-AL Black Cable#6 Core
22.86	23.16	22.83	22.75	23.01	22.61
31.31	31.62	31.28	31.21	31.46	31.06
24.90	25.52	24.59	24.68	25.19	24.49
33.46	34.08	33.16	33.25	33.76	33.06
27.45	28.59	26.81	26.95	27.86	26.80
36.23	37.37	35.59	35.73	36.64	35.58
30.62	32.31	29.51	29.96	31.51	29.93
39.23	40.93	38.12	38.57	40.12	38.54

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34.23	36.96	32.84	33.64	35.02	33.09
42.76	45.49	41.37	42.17	43.55	41.62
40.58	44.15	38.29	40.01	41.40	38.66
49.31	52.87	47.02	48.74	50.13	47.39
46.42	51.15	43.40	45.61	47.21	43.99
54.93	59.66	51.91	54.12	55.71	52.50
53.18	58.34	49.24	52.19	53.82	49.96
61.86	67.01	57.92	60.86	62.49	58.63

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10 AWG Cu in non-metallic cable (2 Conductor) in open air
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
29.00	42965.31	22.35	22.15	22.22	22.08	22.35	22.41
	Corrected Ambient	30.80	30.60	30.67	30.53	30.80	30.86
	Average	30.77					
	Average Core	30.79					
	Average Insulation	30.75					
	10 AMPS						
59.00	42965.34	23.86	23.34	23.35	23.28	23.64	23.74
	Corrected Ambient	32.42	31.91	31.92	31.85	32.21	32.31
	Average	32.18					
	Average Core	32.25					
	Average Insulation	32.12					
	15 AMPS						
90.00	42965.36	25.78	24.85	24.84	24.85	25.28	25.45
	Corrected Ambient	34.56	33.63	33.62	33.64	34.06	34.23
	Average	34.05					
	Average Core	34.14					
	Average Insulation	33.97					
	20 AMPS						
120.00	42965.38	28.46	26.70	26.84	26.63	27.38	27.39
120.00	Corrected Ambient	37.07	35.32	35.45	35.24	35.99	36.01
	Average	35.93					
	Average Core	36.20					
	Average Insulation	35.65					

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	25 AMPS						
151.00	42965.40	31.70	29.22	29.24	29.04	30.00	29.99
	Corrected Ambient	40.23	37.75	37.77	37.57	38.53	38.52
	Average	38.40					
	Average Core	38.78					
	Average Insulation	38.03					
	30 AMPS						
181.00	8/18/2017	36.74	33.05	33.55	33.39	33.88	34.40
	Corrected Ambient	45.47	41.78	42.28	42.12	42.61	43.13
	Average	42.80					
	Average Core	43.21					
	Average Insulation	42.39					
	35 AMPS						
211.00	8/18/2017	41.63	36.87	37.11	36.85	37.80	38.22
	Corrected Ambient	50.14	45.37	45.61	45.36	46.30	46.73
	Average	46.58					
	Average Core	47.13					
	Average Insulation	46.03					
	40 AMPS						
242.00	8/18/2017	47.11	41.04	41.32	40.92	42.28	42.42
	Corrected Ambient	55.78	49.71	50.00	49.59	50.96	51.10
	Average	51.05					
	Average Core	51.88					
	Average Insulation	50.21					

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10 AWG Cu in non-metallic cable (2 Conductor) in open air

Page 2 of 2

304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Core	310 CU Black Cable#2 Insulation	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.46	22.17	22.34	22.44	22.34	22.52
30.91	30.62	30.79	30.89	30.80	30.97
23.89	23.29	23.74	23.72	23.64	23.93
32.46	31.86	32.31	32.28	32.20	32.50
25.78	24.68	25.27	25.47	25.21	25.82
34.56	33.46	34.05	34.25	33.99	34.60
27.95	26.31	27.57	27.28	27.34	27.92
36.56	34.92	36.18	35.89	35.95	36.54

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30.76	28.50	30.31	29.75	29.47	30.49
39.29	37.03	38.84	38.28	38.00	39.02
35.55	32.13	34.15	34.05	33.00	34.97
44.28	40.86	42.88	42.77	41.73	43.70
40.14	35.60	38.38	38.05	36.70	39.58
48.65	44.11	46.89	46.56	45.21	48.08
44.88	38.92	43.18	42.00	40.48	43.95
53.55	47.60	51.85	50.67	49.16	52.62

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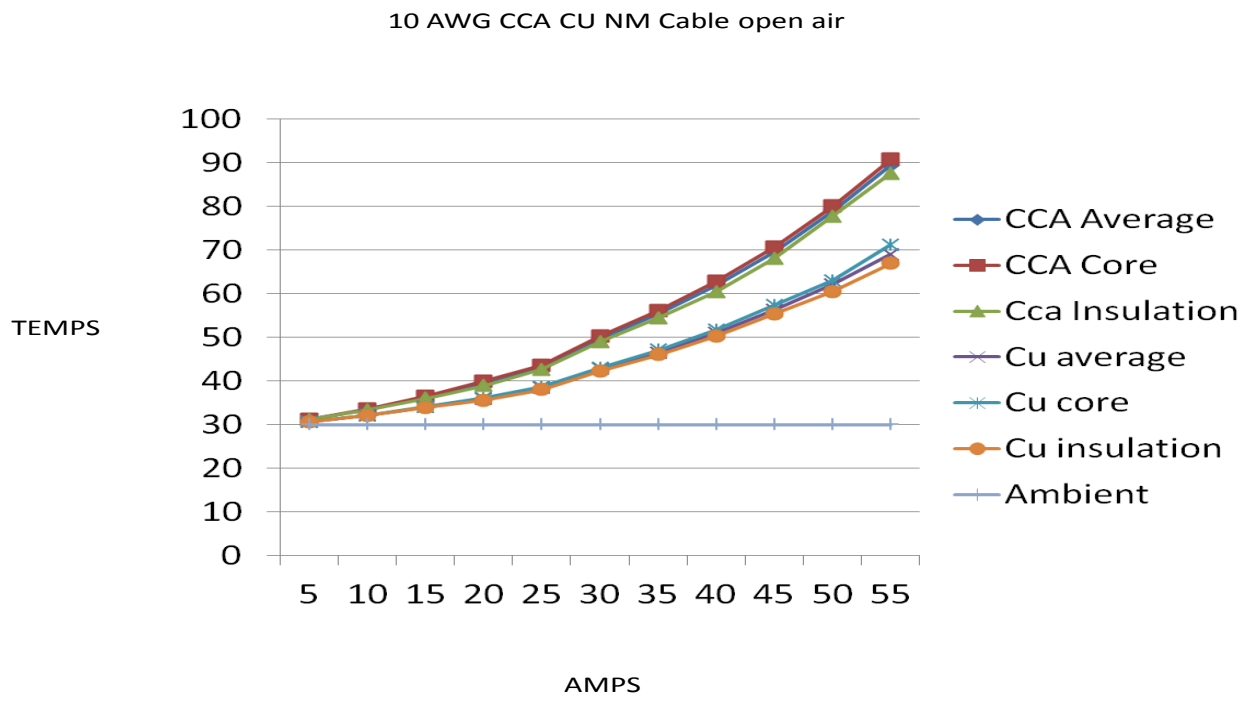

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Test Set- Up/ Layout
10 AWG in Conduit (2 Conductor)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 10 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 10 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 10 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG Conduit

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	Conduit	5	30
10	Conduit	10	30
10	Conduit	15	30
10	Conduit	20	30
10	Conduit	25	30
10	Conduit	30	30
10	Conduit	35	30
10	Conduit	40	30

Equilibrium: With reference to the test, test was continued until constant temperatures were attained. Thermal equilibrium is considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicate no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA in Conduit (2 Conductor)

(Page 1 of 3)

Scan	Time	203 CU-AL White Cable#1-Core	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	205 CU-AL Black Cable#2 Insulation	120 CU-AL White Cable#2 Core
	5 AMPS						
30.00	42966.40	23.32	22.63	22.90	23.15	23.26	23.40
	Corrected Ambient	31.77	31.08	31.35	31.59	31.70	31.85
	Average	31.85					
	Average core	31.89					
	Average insulation	31.80					
	10 AMPS						
64.00	42966.42	26.59	25.43	26.27	25.92	26.52	26.56
	Corrected Ambient	34.93	33.76	34.60	34.25	34.85	34.90
	Average	34.75					
	Average core	34.84					
	Average insulation	34.66					
	15 AMPS						
95.00	42966.44	31.92	29.65	31.74	30.41	31.65	31.89
	Corrected Ambient	40.23	37.96	40.05	38.72	39.97	40.21
	Average	39.72					
	Average core	39.93					
	Average insulation	39.49					
	20 AMPS						
132.00	42966.47	38.70	35.07	38.69	36.15	38.16	38.61
	Corrected Ambient	46.73	43.10	46.72	44.18	46.19	46.64
	Average	45.82					
	Average core	46.15					

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	Average insulation	45.45					
	26 AMPS						
162.00	42966.49	47.38	42.40	47.49	43.29	46.07	46.97
	Corrected Ambient	55.50	50.51	55.61	51.40	54.18	55.09
	Average	53.85					
	Average core	54.35					
	Average insulation	53.30					
	30 AMPS						
192.00	42966.51	57.44	50.50	57.79	51.44	55.09	56.93
	Corrected Ambient	65.41	58.46	65.75	59.40	63.05	64.90
	Average	62.99					
	Average core	63.71					
	Average insulation	62.17					
	35 AMPS						
222.00	42966.53	70.55	60.57	71.31	61.86	66.91	69.78
	Corrected Ambient	78.66	68.68	79.42	69.97	75.02	77.89
	Average	75.21					
	Average core	76.27					
	Average insulation	74.01					
	40 AMPS						
260.00	42966.56	86.35	74.81	87.61	74.53	81.18	86.55
	Corrected Ambient	94.33	82.80	95.59	82.51	89.16	94.53
	Average	89.94					
	Average core	91.36					
	Average insulation	88.34					

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10 AWG CCA in Conduit (2 Conductor)
(Page 2 of 3)

211 CU-AL White Cable# 3 Insulation	102 CU-AL Black Cable#3 Core	320 CU-AL Black Cable#4 Core	113 CU-AL White Cable #4 Core	114 CU-AL White Cable#4 Insulation	109 CU-AL Black Cable#5 Core
23.26	23.49	23.53	23.64	23.57	23.74
31.70	31.94	31.98	32.08	32.01	32.18
26.21	26.62	26.66	26.73	26.46	26.83
34.54	34.96	35.00	35.07	34.80	35.17
30.86	31.75	31.93	32.02	31.42	32.03
39.17	40.06	40.24	40.33	39.73	40.34
36.72	38.39	38.61	38.74	37.61	38.57
44.75	46.42	46.64	46.77	45.64	46.60

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43.72	46.74	46.85	47.03	45.17	46.62
51.83	54.86	54.96	55.14	53.28	54.74
51.86	56.42	56.62	56.89	54.04	56.27
59.83	64.38	64.58	64.86	62.00	64.23
62.45	69.09	69.33	69.71	65.42	68.98
70.56	77.20	77.43	77.81	73.53	77.09
74.86	84.65	84.99	85.42	79.26	84.28
82.84	92.63	92.97	93.40	87.25	92.26

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10 AWG CCA in Conduit (2 Conductor)
(Page 3 of 3)

107 CU-AL White Cable#5 Insulation	103 CU-AL Black Cable#5 Core	101 CU-AL Black Cbale#6 Insulation	104 CU-AL White Cable#6 Core	105 CU-AL White Cable#6 Insulation
23.63	23.30	23.62	23.65	23.71
32.08	31.75	32.07	32.09	32.16
26.63	25.87	26.80	26.40	26.61
8.34	8.34	8.34	8.34	8.34
34.97	34.21	35.14	34.73	34.94
31.70	30.22	32.18	31.08	31.53
8.31	8.31	8.31	8.31	8.31
40.01	38.53	40.49	39.39	39.85
38.35	35.78	39.22	37.02	38.08
8.03	8.03	8.03	8.03	8.03
46.38	43.81	47.25	45.05	46.11

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46.57	42.58	48.00	44.44	46.26
54.68	50.69	56.12	52.55	54.38
56.53	50.33	58.28	53.07	55.91
64.50	58.29	66.24	61.04	63.87
69.86	60.42	71.69	64.34	68.46
77.97	68.52	79.80	72.44	76.57
86.55	72.57	88.22	77.95	83.47
94.53	80.55	96.20	85.93	91.45

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10 AWG Cu in Conduit (2 Conductor)

(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30.00	42966.40	22.82	22.91	22.98	22.94	22.84	23.12
	Corrected Ambient	31.26	31.36	31.43	31.39	31.28	31.57
	Average	31.43					
	Average core	31.41					
	Average insulation	31.46					
	10 AMPS						
64.00	42966.42	24.81	24.98	24.84	24.87	24.60	24.72
	Corrected Ambient	33.14	33.32	33.18	33.21	32.94	33.06
	Average	33.21					
	Average core	33.19					
	Average insulation	33.23					
	15 AMPS						
95.00	42966.44	28.18	28.33	28.05	28.18	27.66	27.71
	Corrected Ambient	36.49	36.64	36.36	36.49	35.97	36.02
	Average	36.47					
	Average core	36.46					
	Average insulation	36.49					
	20 AMPS						
132.00	42966.47	32.50	32.63	32.33	32.54	31.64	31.58
	Corrected Ambient	40.53	40.66	40.36	40.57	39.67	39.61
	Average	40.49					
	Average core	40.48					
	Average insulation	40.50					
	26 AMPS						

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162.00	42966.49	37.65	37.76	37.74	37.82	36.46	36.24
	Corrected Ambient	45.76	45.87	45.85	45.93	44.58	44.35
	Average	45.73					
	Average core	45.75					
	Average insulation	45.72					
	30 AMPS						
192.00	42966.51	43.85	43.86	43.85	44.09	42.10	41.80
	Corrected Ambient	51.81	51.83	51.82	52.05	50.06	49.76
	Average	51.69					
	Average core	51.72					
	Average insulation	51.67					
	35 AMPS						
222.00	42966.53	51.88	51.82	51.54	52.18	49.45	48.85
	Corrected Ambient	59.99	59.93	59.65	60.29	57.56	56.95
	Average	59.66					
	Average core	59.67					
	Average insulation	59.65					
	40 AMPS						
260.00	42966.56	61.89	61.68	59.87	62.27	58.36	57.45
	Corrected Ambient	69.87	69.66	67.86	70.25	66.34	65.43
	Average	69.09					
	Average core	68.99					
	Average insulation	69.19					

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10 AWG Cu in Conduit (2 Conductor)

(Page 2 of 2)

304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Insulation	310 CU Black Cable#2 Core	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
23.07	22.92	23.07	23.03	23.07	23.10
31.52	31.37	31.51	31.48	31.51	31.54
24.81	24.45	25.07	24.82	25.23	25.25
33.15	32.79	33.41	33.16	33.56	33.58
27.97	27.26	28.60	28.02	29.02	28.99
36.28	35.57	36.91	36.33	37.33	37.30
32.12	30.89	33.22	32.16	33.93	33.93
40.15	38.92	41.25	40.19	41.96	41.96

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37.07	35.14	38.79	37.10	39.78	39.86
45.19	43.26	46.90	45.22	47.90	47.98
43.01	40.14	45.40	42.95	46.77	46.95
50.97	48.10	53.36	50.92	54.73	54.92
50.52	46.53	53.82	50.33	55.67	56.04
58.62	54.64	61.93	58.43	63.78	64.14
60.04	54.32	64.29	59.29	66.58	67.26
68.02	62.30	72.28	67.27	74.57	75.24

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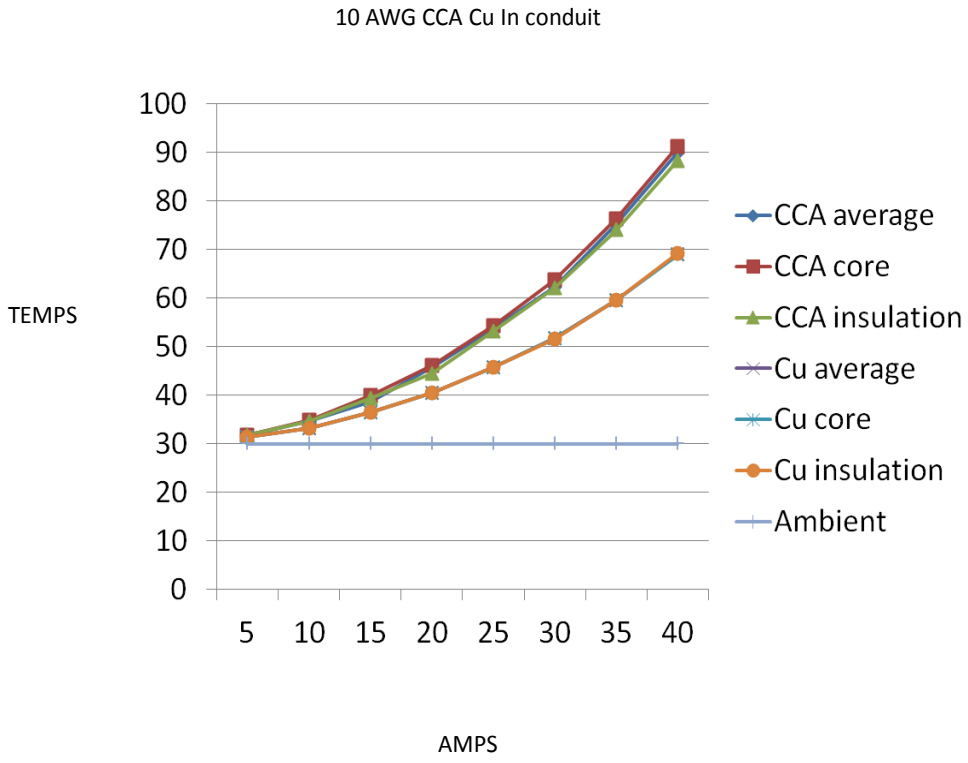

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Summary

14 AWG						
Max Temps	Single conductor@35A		NM cable@25A		Conduit@25A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	89.81	67.08	68.95	53.14	117.69	79.54
Average Core	92.67	67.91	69.61	53.05	124.41	82.77
Average Insulation	86.68	66.25	71.60	53.23	111.52	76.31

12 AWG						
Max Temps	Single conductor@40A		NM cable@30A		Conduit@30A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	76.85605	66.52817	59.54	49.96617	94.77	72.19
Average Core	80.71511	69.18933	62.19	51.36633	99.22	76.53
Average Insulation	72.72958	63.867	57.11	48.566	91.05	67.86

10 AWG						
Max Temps	Single conductor@55		NM cable@40A		Conduit@40 A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	85.54	69.97	61.97	51.05	89.94	69.09
Average Core	88.62	70.96	62.84	51.88	91.36	68.99
Average Insulation	82.30	68.98	60.91	50.21	88.34	69.19

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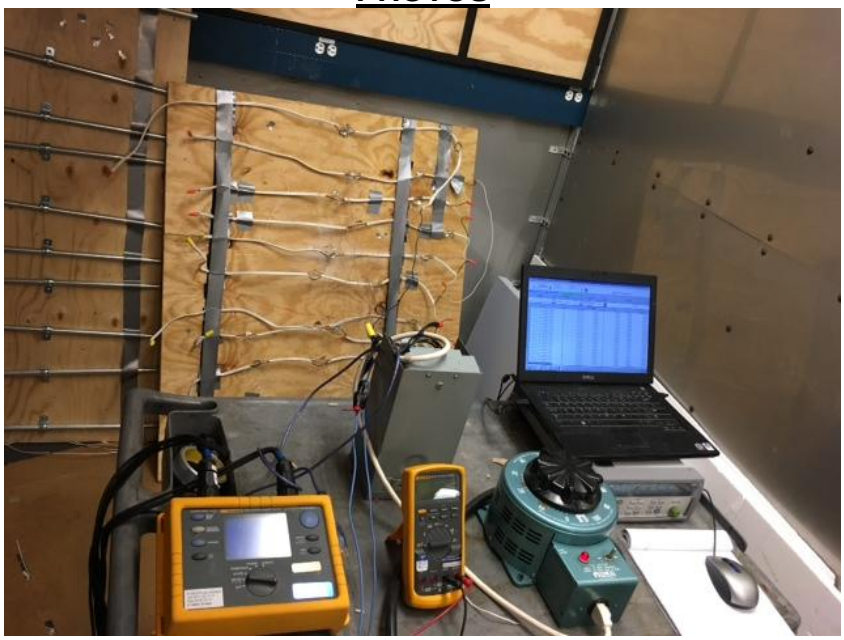
APPENDIX A
PHOTOS



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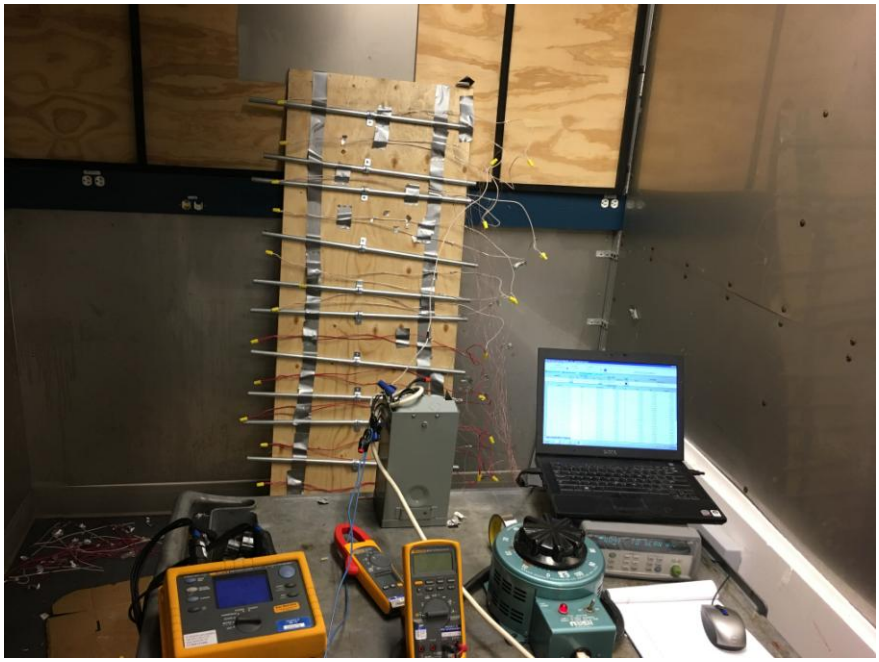

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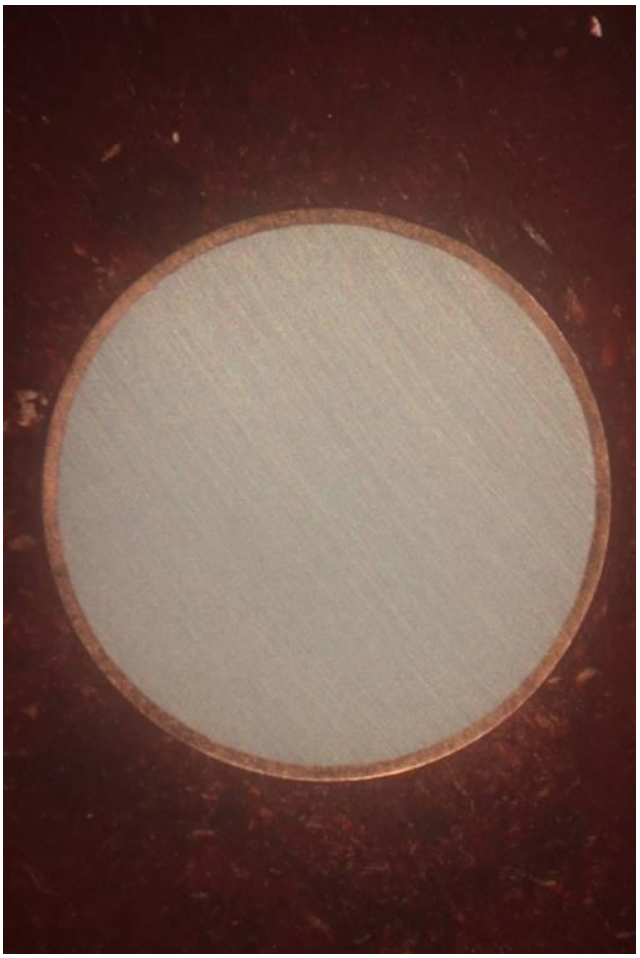

Cross Sectional view of the CCA

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APPENDIX B
EQUIPMENT LIST

Equipment	PL Code	Calibration
Transformer	PL004985	N/A
Agilent Temperature Data Acquisition system	PL005628	N/A
Thermocouples Cartridge, Type J	PL004988 PL003269 PL003268	Calibrated Daily or before each usage.
Simpson Model 06713100 Current shunt	PL002161	See Certificate Below Appendix C
Fluke multi meter, model 87V	PL004935	See Certificate Below Appendix C
Fluke Digital Clamp Meter, model 374FC	PL005812	See Certificate Below Appendix C
Thermocouples	Same as above	Conducted Daily
Power Logger	PL003379	See Certificate Below Appendix C

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APPENDIX C
CALIBRATION

Trescal

Certificate #: *3869120002 e* *W*

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	374FC
Description:	Clamp Meter
Serial Number:	37421743WS
Asset Number:	PL005812
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	05/01/2017
Due Date:	05/01/2018
Temperature:	73.00 **deg. F**
Humidity:	40.00 **%**
Baro. Press.:	
Procedure:	DCN 50442
Reference:	TO 33K1-4-853-1 Rev. 30 Jun 2008
Dept:	

Incoming Remarks:
w/case

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390482	Fluke	5522A	Multifunction Calibrator	11/22/2016	11/22/2017

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Trescal

Certificate #: *3765740001 e* *W*

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	87V
Description:	DMM
Serial Number:	26270081
Asset Number:	PL004935
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	01/31/2017
Due Date:	01/31/2018
Temperature:	74.00 **deg. F**
Humidity:	20.00 **%**
Baro. Press.:	
Procedure:	DCN 07074
Reference:	manufacturer's manual
Dept:	

Incoming Remarks:
w/case/leads/holster

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390169	Fluke	5500A	Multifunction Calibrator	04/26/2016	04/26/2017

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Trescal

Certificate #: *3869120002 e* *W*

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	374FC
Description:	Clamp Meter
Serial Number:	37421743WS
Asset Number:	PL005812
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	05/01/2017
Due Date:	05/01/2018
Temperature:	73.00 deg. F
Humidity:	40.00 %
Baro. Press.:	
Procedure:	DCN 50442
Reference:	TO 33K1-4-853-1 Rev. 30 Jun 2008
Dept:	

Incoming Remarks:
w/case

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390482	Fluke	5522A	Multifunction Calibrator	11/22/2016	11/22/2017

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ACCREDITED
Calibration Cert# 2165.01

FLUKE

Certificate of Calibration

Everett Service Center

Certificate Number:	322693		
Data Type:	As-Left	**Calibration Date:**	27-Feb-2017
Result Summary:	Measurement Results < Limits		
Manufacturer:	Fluke	**Certificate Date:**	28-Feb-2017
Model:	1735	**Temperature:**	23.6 °C
Serial Number:	S090503258B6	**Humidity:**	28.1 %
Description:	Power Quality Logger		
Procedure:	Fluke 1735:(2 year) ACAL VER RS-232/5520	**Revision:**	2.1
Customer:	NSF INTERNATIONAL		
City:	ANN ARBOR	**Country:**	US
State:	MI		
Purchase Order:	CCS CALIBRATION LAB - NSF INTERNATIONAL	**RMA:**	31194022
Asset ID:	PL003379		

This calibration is traceable to the International System of Units (SI), through National Metrology Institutes (NIST, PTB, NRC, NPL, etc.), ratiometric techniques, or natural physical constants. This certificate applies only to the item identified and shall not be reproduced either than in full, without the specific written approval by Fluke Corporation. Calibration certificates without signature are not valid. The calibration has been completed in accordance with Fluke Electronics Corporation Quality System Document 111.0 Revision 11B 8/2014 and/or Fluke 17025 Quality Manual QSD 111.41 Revision 005 8/2014.

The Data Type found in this certificate must be interpreted as:

- As - Found Calibration data collected before the unit is adjusted and / or repaired.
- As - Left Calibration data collected after the unit has been adjusted and / or repaired.
- Found-Left Calibration data collected without any adjustment and / or repair performed.

This calibration conforms to the requirements of ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994 (R2002).

In the attached measurement results, deviation may be expressed with units, Measured Value (MV) - Nominal Value (NV) or as a proportion of the nominal value ((MV-NV)/NV), expressed without units with a scalar multiplier such as % (0.01), or as a ratio of the units (mA/A, µ/V, etc.) Descriptions such as µA/A, µV/V, and others, where used to annotate results or column headings are the preferred replacements for what was historically labeled as "ppm" or parts-per-million and described the results in that column, unless otherwise noted by units symbols.

Where applicable, the expanded uncertainty of measurement at the time of test is given in the following pages. They are calculated in accordance with the method described in the ISO Guide to the Expression of Uncertainty in Measurement (GUM). The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k, such that the confidence level approximates 95%.

This calibration certificate may contain data that is not covered by the A2LA Scope of Accreditation. Unaccredited material, where applicable is indicated by an asterisk (*), or confined to clearly marked sections. Functional (Pass / Fail) tests are not accredited.

No statement of compliance with specifications is made or implied on this certificate. However, measurement results are reviewed, where applicable, to establish where any measurement result exceeded the manufacturer's specifications.

Measurement results greater than limits of error are indicated by '!'.

Accredited FLUKE

Cert # 322693
Cal Date 27-Feb-2017
S/N S090503258B6
www.fluke.com

Cert # 322693
Date 27/2/2017
www.fluke.com

Rolly Sherwood
Calibration Technician

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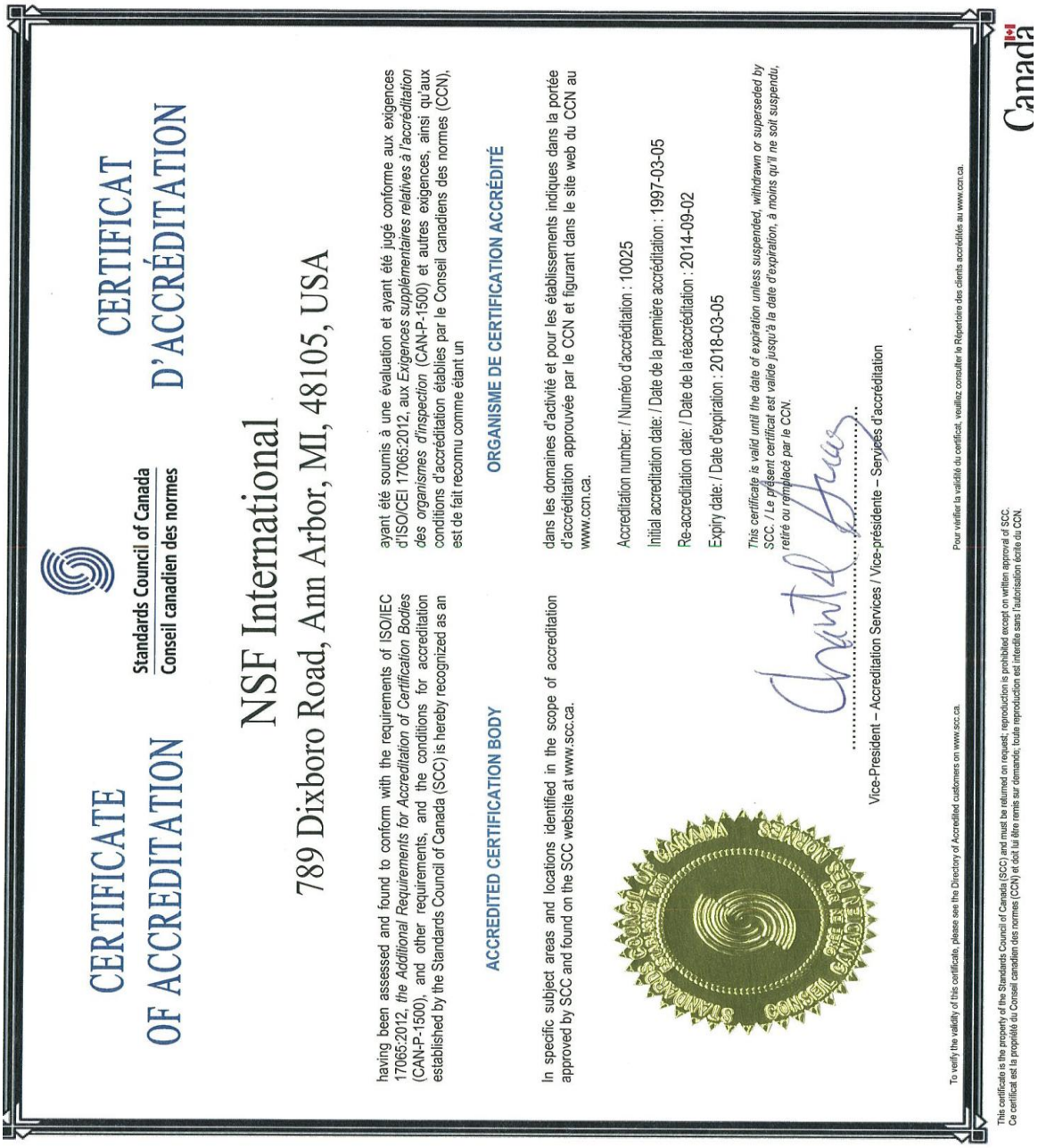
APPENDIX D
LABORATORY CERTIFICATIONS



CERTIFICATE OF ACCREDITATION

Standards Council of Canada
Conseil canadien des normes

CERTIFICAT D'ACCRÉDITATION

NSF International
789 Dixboro Road, Ann Arbor, MI, 48105, USA

having been assessed and found to conform with the requirements of ISO/IEC 17065:2012, *the Additional Requirements for Accreditation of Certification Bodies* (CAN-P-1500), and other requirements, and the conditions for accreditation established by the Standards Council of Canada (SCC) is hereby recognized as an

ayant été soumis à une évaluation et ayant été jugé conforme aux exigences d'ISO/CEI 17065:2012, aux *Exigences supplémentaires relatives à l'accréditation des organismes d'inspection* (CAN-P-1500) et autres exigences, ainsi qu'aux conditions d'accréditation établies par le Conseil canadiens des normes (CCN), est de fait reconnu comme étant un

ACCREDITED CERTIFICATION BODY

ORGANISME DE CERTIFICATION ACCRÉDITÉ

In specific subject areas and locations identified in the scope of accreditation approved by SCC and found on the SCC website at www.scc.ca.

dans les domaines d'activité et pour les établissements indiques dans la portée d'accréditation approuvée par le CCN et figurant dans le site web du CCN au www.ccn.ca.

Accreditation number: / Numéro d'accréditation : 10025

Initial accreditation date: / Date de la première accréditation : 1997-03-05

Re-accreditation date: / Date de la réaccréditation : 2014-09-02

Expiry date: / Date d'expiration : 2018-03-05

This certificate is valid until the date of expiration unless suspended, withdrawn or superseded by SCC. / Le présent certificat est valide jusqu'à la date d'expiration, à moins qu'il ne soit suspendu, retiré ou remplacé par le CCN.

STANDARDS COUNCIL OF CANADA
CONSEIL CANADIEN DES NORMES

Vice-President – Accreditation Services / Vice-présidente – Services d'accréditation

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CERTIFICATE

Certificate Number: 140920.00

The Environmental Management System and implementation of:

NSF International
789 N. Dixboro Road
Ann Arbor, MI 48105
United States

meets the requirements of the standard:

ISO 14001:2015

Scope:
Laboratory testing, product certification, and domestic (U.S.) auditing associated with the facility located at 789 N. Dixboro Road, Ann Arbor, Michigan. NSF-ISR operations are excluded from the scope of registration.

Certificate Expires:	July 04, 2018
Re-issued:	August 08, 2017
Certificate Issued:	July 05, 2015
Certified Since:	July 05, 2006

Dr. Cem O. Onus
Managing Director, Business Assurance
DEKRA Certification, Inc.
1120 Welsh Road, Suite 210
North Wales, PA 19454 USA
(215) 997-4519
dekra-certification.us

ANAB ACCREDITED ISO/IEC 17021 MANAGEMENT SYSTEMS CERTIFICATION BODY

MEMBER OF MULTILATERAL RECOGNITION ARRANGEMENT IAF

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Occupational Safety and Health Administration

Nationally Recognized Testing Laboratory Program

NRTLP

Certificate of Recognition

NSF International

with headquarters at:

789 Dixboro Road
Ann Arbor, Michigan 48105
United States

is recognized by the Occupational Safety and Health Administration (OSHA) as meeting the requirements for a Nationally Recognized Testing Laboratory (NRTL) established under Section 1910.7 of *Title 29, Code of Federal Regulations.* This recognition is limited to testing and certification only within the current scope of recognition and is subject to all other terms set forth in the letter of recognition and in applicable *Federal Register* notices and as summarized on OSHA's website. This recognition continues in force beyond the "*Effective through*" date below provided the NRTL has filed a timely request for renewal with OSHA. For current recognition status and other recognition information, contact the OSHA NRTL Program or visit *https://www.osha.gov/dts/otpca/nrtl/*

July 14, 2019
Effective Through

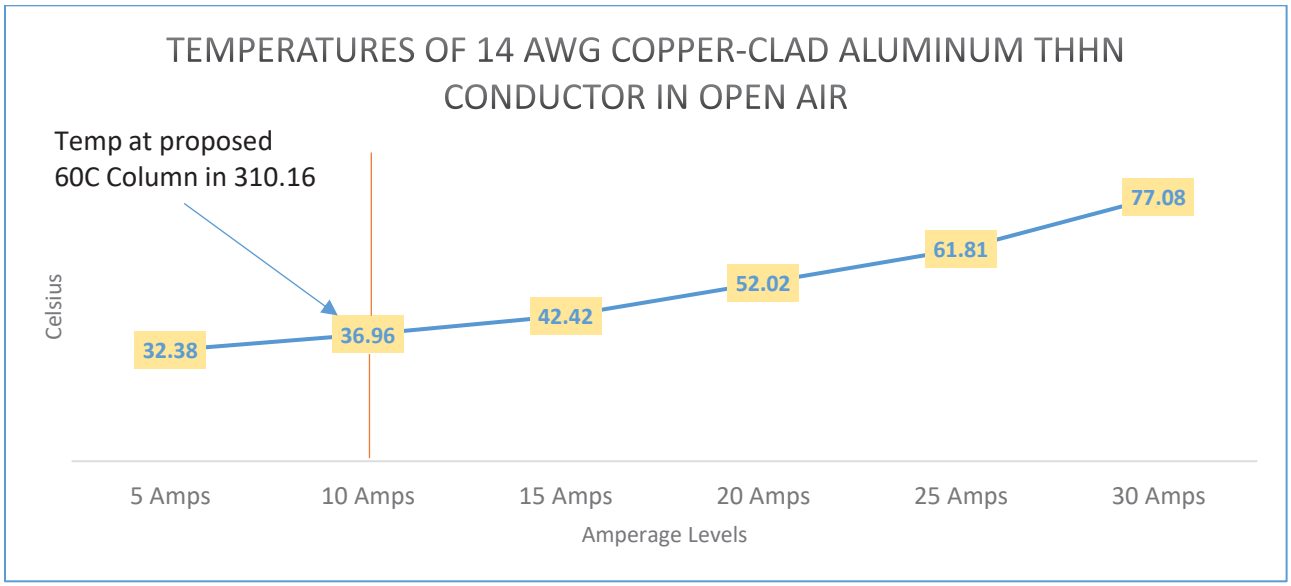
David Michaels, PhD, MPH
Assistant Secretary of Labor for
Occupational Safety and Health Administration

UNITED STATES OF AMERICA · DEPARTMENT OF LABOR

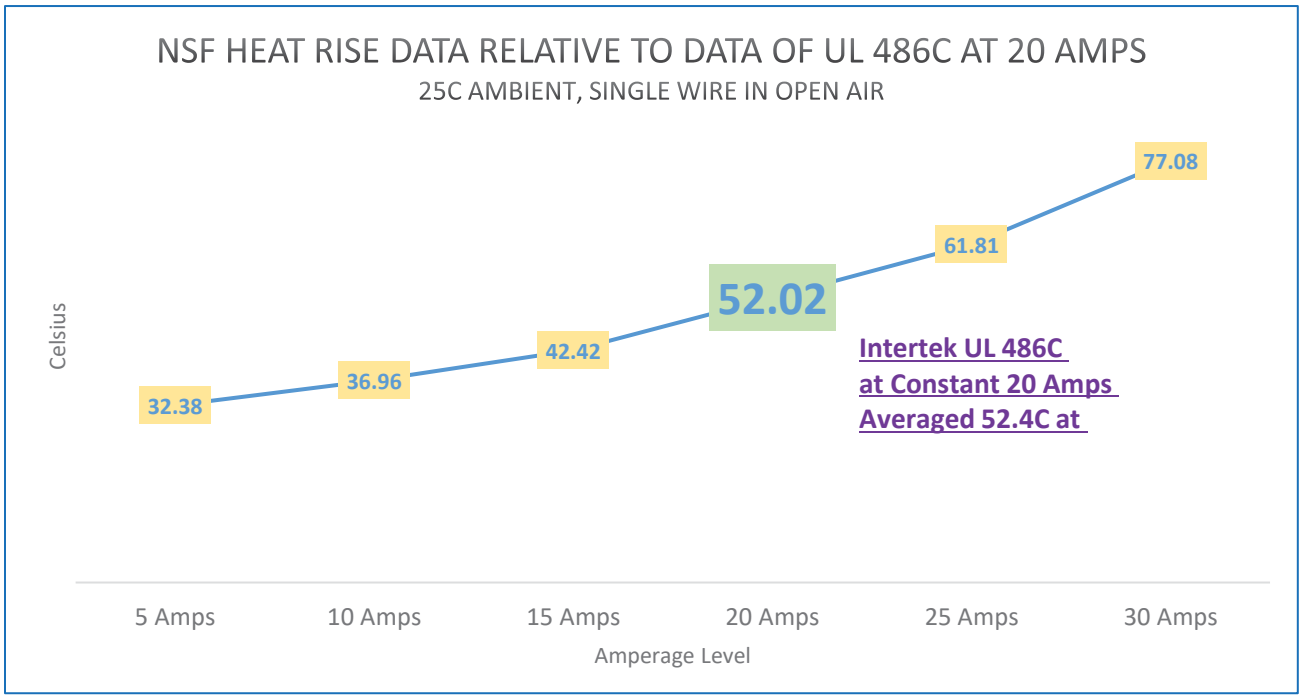
This report shall not be reproduced, except in its entirety, without the written approval of NSF. This report does not represent NSF Certification or authorization to use the NSF Mark. Authorization to use the NSF Mark is limited to products appearing in the Company's Official NSF Listing (www.nsf.org). The results relate only to those items tested, in the condition received at the laboratory

14 AWG CCA SAFE AT PROPOSED AMPERAGE OF TABLE 310.16:

UL 486C Testing Confirms NSF Data



Data Results of Fact Finding from NRTL Certified Electrical Lab, NSF. Orange Line Indicates Proposed Amperage of 14 AWG Copper-Clad Aluminum (ASTM B566) at 60C in Table 310.16



Average Heat Generated at 20 Amps by 14 AWG Copper-Clad Aluminum (ASTM B-566) is practically the same when comparing the testing done by NSF Electrical and that done by Intertek. Both labs are NRTL's with OSHA certified electrical labs. For 14 AWG CCA, NSF averaged 52.02C at 20 Amps, whereas Intertek Averaged 52.4C at 20 Amps.

14 AWG CCA SAFE AT PROPOSED AMPERAGE OF TABLE 310.16:

UL 486C Testing Confirms NSF Data

CONCLUSION:

At a temperature of 36.96 C° at Full Circuit of 10 Amps in the 60C column of proposed table 310.16, 14 AWG Copper-Clad Aluminum (ASTM B-566) is SAFE even considering elevated ambient temperatures. 75°C is the minimum temperature rating of insulation for the vast majority of general wiring applications, with the most utilized insulation types (THHN, XHHW, for example) rated at 90°C. All modern branch circuit components (switches, connectors, equipment and receptacles) are rated at a minimum of 75°C, most at 90°C. Even in severe overcurrent conditions, heat rise temperatures of 14 AWG Copper-Clad Aluminum (ASTM B-566) are well below the rating of the wire insulation and circuit components. OCPD's exist today for 10 Amp circuits, thus making 14 AWG Copper-Clad Aluminum wire a viable option. LED and Energy Star Equipment are driving the trend for more efficient circuits.

NRTL Credentials for NSF

Occupational Safety and Health Administration

Nationally Recognized Testing Laboratory Program

NRTLP

Certificate of Recognition

NSF International

with headquarters at:

789 Dixboro Road
Ann Arbor, Michigan 48105
United States

is recognized by the Occupational Safety and Health Administration (OSHA) as meeting the requirements for a Nationally Recognized Testing Laboratory (NRTL) established under Section 1910.7 of *Title 29, Code of Federal Regulations*. This recognition is limited to testing and certification only within the current scope of recognition and is subject to all other terms set forth in the letter of recognition and in applicable *Federal Register* notices and as summarized on OSHA's website. This recognition continues in force beyond the "*Effective through*" date below provided the NRTL has filed a timely request for renewal with OSHA. For current recognition status and other recognition information, contact the OSHA NRTL Program or visit *https://www.osha.gov/dts/otpca/nrtl/*

July 14, 2019
Effective Through

David Michaels, PhD, MPH
Assistant Secretary of Labor for
Occupational Safety and Health Administration

OSHA Scope of Recognition for NSF Electrical: https://www.osha.gov/dts/otpca/nrtl/nsf.html

Among other electrical equipment and circuit components, the NSF Scope of Recognition Includes Small Electrical Appliances, Wired Cabinets, Luminaires, Washers, Driers, Residential Water Heaters, Electric Ranges and Temperature Measuring Equipment. Heat Rise Testing is Routine at NSF.

SHIPPING FORM FOR SENDING SAMPLES TO UL

To

UL LLC
1285 Walt Whitman Rd.
Melville NY 11747-3081 USA

Order #: 11882073
Service Request #: N/A
Industry Group:
Requestor: BRIAN CAVALLI

Barcode for Project: 1000306419
1000306419

Samples Requested:

1080076	*1080076*	(Quantity: 1) 250 feet of 2/C, No. 14 AWG FLAT Type NM-B, employing THHN copper-clad aluminium conductors, bare grounding conductor, and overall PVC jacket with thickness in accordance with the Standard. (designation tbd)
1080077	*1080077*	(Quantity: 1) 250 feet of 3/C, No. 14 AWG ROUND Type NM-B, employing THHN copper-clad aluminium conductors, bare grounding conductor, and overall PVC jacket with thickness in accordance with the Standard. (designation tbd)

Completed by Customer

Note: Samples should be sent to the address location shown above with a copy of this form provided with each shipping container. To ensure prompt processing of your sample upon arrival, the information requested on this form MUST be included with the shipment. Incomplete or missing information will result in a delay of processing your sample, and possible return or disposal of the sample prematurely.

Samples included with this shipment (Please list in the box below):

What would you like UL to do with your sample(s) when work is complete? (Choose one)
Please Note: It is a UL policy that we return all hazardous materials unless prohibited by applicable laws.

☐ **Destroy** - UL will destroy the samples when work is complete and dispose of them in accordance with local disposal guidelines.

☐ **Customer to Pick Up at UL** - You will arrange for the samples to be picked up from the UL office. If samples are not picked up within 30 days, UL will arrange for the samples to be returned to you. Please provide the name of a shipping company, shipping account number, insurance value and confirm the return shipping information below.

☐ **Ship/Return at your expense** - UL will arrange for the samples to be returned to you. Please provide the name of a shipping company, shipping account number, insurance value, and confirm the return shipping information below. If you do not provide your shipping account number, the shipping charges will be added to your UL project invoice.

Sample Being Shipped to UL From:		**UL Should Return Sample to (complete if sample to be returned and address different than at left):**
Company Name:	Copperweld Bimetallics LLC	Company Name:
Company Address:	254 Cotton Mill Rd Fayetteville TN 37334	Company Address:
Contact Person:	Peter Graser	Contact Person:
Contact Phone:		Contact Phone:
Contact Email:	petergraser@intexpco.com	Contact Email:
		Shipping Company:
		Shipping Account Number:

NOTICE OF COMPLETION
AND
AUTHORIZATION TO APPLY THE UL MARK

2017.10.06

Peter Graser
Copperweld Bimetallics LLC
254 Cotton Mill Rd
Fayetteville, TN, 37334, US

Our Reference:	File E492024, Vol 1	Order:	11882073
		Project:	4788086098
Your Reference:	Peter Graser 7/24/2017		
Project Scope:	Testing to add NM-B wire to NEW Copperweld Nonmetallic Sheathed-Cable File Construction will employ recognized CCA, and Listed Type THHN & PVC jacket		

Dear Peter Graser:

Congratulations! UL's investigation of your product(s) has been completed under the above Reference Number and the product was determined to comply with the applicable requirements. This letter temporarily supplements the UL Follow-Up Services Procedure and serves as authorization to apply the UL Mark at authorized factories under UL's Follow-Up Service Program. To provide your manufacturer(s) with the intended authorization to use the UL Mark, you must send a copy of this notice to each manufacturing location currently authorized under File e492024, Vol 1.

Records in the Follow-Up Services Procedure covering the product are now being prepared and will be sent in the near future. Until then, this letter authorizes application of the UL Mark for 90 days from the date indicated above.

Additional requirements related to your responsibilities as the Applicant can be found in the document "Applicant responsibilities related to Early Authorizations" that can be found at the following web-site: http://www.ul.com/EAResponsibilities

Any information and documentation provided to you involving UL Mark services are provided on behalf of UL LLC (UL) or any authorized licensee of UL.

We are excited you are now able to apply the UL Mark to your products and appreciate your business. Feel free to contact me or any of our Customer Service representatives if you have any questions.

Very truly yours,

Brian Cavalli
Engineering Associate
Brian.Cavalli@ul.com

Reviewed by:

Bruce A. Mahrenholz
CPO Director
Bruce.A.Mahrenholz@ul.com

d1ee6431-b01c-4fdc-ac75-c9d5fae7e357

3933 US Route 11
Cortland, NY. 13045

Telephone: 607-753-6711
Facsimile: 607-758-6661
www.intertek-etlsemko.com

April 13, 2011

Mr. Peter Graser
Commscope Inc
723 Gardenside Circle
Marietta, GA 30067 USA

Intertek Test Report: 100366212CRT-001

Dear Peter Graser:

Intertek has completed our testing and evaluation of the Power Cables to the indicated requirements of **UL 817, 11th Ed. 03/16/2001: Cord Sets and Power Supply Cords and UL 858 15th Ed. 04/12/2005 Standard for safety Household Electric Ranges**. The test samples were received on 3/20/2011 in working condition. The evaluation was performed at Intertek, Cortland, NY, on 3/28/2011 through 4/10/2011. The results of these tests are as indicated as follows:

Standard	Clause	Test Completed	Pass / Fail
UL 817	81	Conductor Secureness	Pass
UL 817	82	Security of Blades test	Pass
UL 817	88	Dielectric Voltage-Withstand Test	Pass
UL 817	95	Terminal Blade Pull Force Test	Pass
UL 858	55	Terminal Blade Connection Resistance	Pass

The Power Cables were found to be in compliance with the indicated requirements of **UL 817, 11th Ed. 03/16/2001: Cord Sets and Power Supply Cords and UL 858 15th Ed. 04/12/2005 Standard for safety Household Electric Ranges**. This Test Report concludes the work anticipated for this phase of your project under Intertek quote number 500292165. If there are any questions regarding this report please contact the undersigned at 607-758-6523.

Tested by

Michael Amaro
Engineering Team Leader

Reviewed by

Eric Burns
Project Engineer

This report is for the exclusive use of Intertek's Client and is provided pursuant to the agreement between Intertek and its Client. Intertek's responsibility and liability are limited to the terms and conditions of the agreement. Intertek assumes no liability to any party, other than to the Client in accordance with the agreement, for any loss, expense or damage occasioned by the use of this report. Only the Client is authorized to permit copying or distribution of this report and then only in its entirety. Any use of the Intertek name or one of its marks for the sale or advertisement of the tested material, product or service must first be approved in writing by Intertek. The observations and test results in this report are relevant only the sample tested. This report by itself does not imply that the material, product or service is or has ever been under an Intertek certification program.

Intertek Test Data Sheets

Transcribed Test Data

Client: Electrolux
Engineer: Mike Amaro
Job No.: G100366212
Tested By: Christopher Duhan
Date: 04/11/2011
Product: Power Cords 2 models
Reviewed By: Eric Burns
Date:
Model No.: Power Cables
Standard(s): **UL 817, 11th Ed. 03/16/2001: Cord Sets and Power Supply Cords and UL 858 15th Ed. 04/12/2005 Standard for safety Household Electric Ranges**
Sample Control Number(s):

Tests to be Performed					
Required	**Page**	**Standard**	**Clause**	**Test Description**	**Pass/Fail**
NA	1	NA	NA	Report	NA
NA	2	NA	NA	Tests to be Performed	NA
NA	3	NA	NA	Test Equipment	NA
NA	4	NA	NA	Product Photos	NA
(X)	6	UL 817	81	Conductor Secureness	Pass
(X)	7	UL 817	82	Security of Blades test	Pass
(X)	8	UL 817	88	Dielectric Voltage-Withstand Test	Pass
(X)	9	UL 817	95	Terminal Blade Pull Force Test	Pass
(X)	10	UL 858	61	Strain Relief Test	N/A
(X)	11	UL 858	55	Terminal Blade Connection Resistance	Pass

Intertek Test Data Sheets

Transcribed Test Data

Client: Electrolux
Engineer: Mike Amaro
Job No.: G100366212
Tested By: Christopher Duhan
Date: 04/11/2011
Product: Power Cords 2 models
Reviewed By: Eric Burns
Date:
Model No.: Power Cables
Standard(s): **UL 817, 11th Ed. 03/16/2001: Cord Sets and Power Supply Cords and UL 858 15th Ed. 04/12/2005 Standard for safety Household Electric Ranges**
Sample Control Number(s):

Test Equipment

#	ITS #	Description	Manufacturer	Model No.	Serial No.	Cal. Date	Cal. Due
1	T1196	Environment Monitor	Control Company	99760-00	72041527	03-16-2011	03-16-2012
2	S200S	Force Gauge	Shimpo	FGE-100	E958H046	09-17-2010	09-17-2011
3	N1280	Digital Calipers	Mitutoyo	CD-S6”	10022885	05-28-2010	05-28-2011
4	V304	Hypot Tester	Associated Research	03670	9331173	03-16-2011	03-16-2012
5	N1024	Stopwatch	Sper Scientific	810032	N1024	08-30-2010	08-30-2011
6	G042S	Ground Impedance Tester	Hypatia	309	0323	09-17-2010	09-17-2011
7	S222S	Scale	Acculab	SV-30	0318AP021	04-30-2010	04-30-2011

Intertek Test Data Sheets

Transcribed Test Data

Client:	Electrolux	Engineer:	Mike Amaro		
Job No.:	G100366212	Tested By:	Christopher Duhan	Date:	04/11/2011
Product:	Power Cords 2 models	Reviewed By:	Eric Burns	Date:	
Model No.:	Power Cables	Standard(s):	**UL 817, 11th Ed. 03/16/2001: Cord Sets and Power Supply Cords and UL 858 15th Ed. 04/12/2005 Standard for safety Household Electric Ranges**		

Sample Control Number(s):

Product Photos:	

Intertek Test Data Sheets

Transcribed Test Data

Client: Electrolux
Engineer: Mike Amaro
Job No.: G100366212
Tested By: Christopher Duhan
Date: 04/11/2011
Product: Power Cords 2 models
Reviewed By: Eric Burns
Date:
Model No.: Power Cables
Standard(s): **UL 817, 11th Ed. 03/16/2001: Cord Sets and Power Supply Cords and UL 858 15th Ed. 04/12/2005 Standard for safety Household Electric Ranges**
Sample Control Number(s):

Conductor Secureness Test (UL 817, Section 81): **Pass:** X **Fail:**

Test Purpose:
To test the samples ability to withstand a pull force when applied to the conductor and element (male pin or female contact).

Test Parameters:	
Test Sample:	6 of each
Conductor Size:	
Pull Force:	20lbf
Test Time:	1 minute

Test Results:

Sample	Connection Tested	Results	Pass/Fail
9325-A	Cord	No pullout	Pass
9325-B	Cord	No pullout	Pass
9325-C	Cord	No pullout	Pass
9325-D	Cord	No pullout	Pass
9325-E	Cord	No pullout	Pass
9325-F	Cord	No pullout	Pass
9326-A	Cord	No pullout	Pass
9326-B	Cord	No pullout	Pass
9326-C	Cord	No pullout	Pass
9326-D	Cord	No pullout	Pass
9326-E	Cord	No pullout	Pass
9326-F	Cord	No pullout	Pass

To Comply:
The conductor and element (male pin or female contact) connection shall not separate when a pulling force is applied.

Intertek Comments:

X The product complies with all applicable requirements of this test.

The product does not comply with the requirements of this test.

Test Date: 03/31/2011 Tested By: Christopher Duhan

Environmental Conditions During Testing: Humidity: 25% rh Pressure: 966 hpa Ambient: 22°C

Equipment Used (See page 2 for details): 1 | 7 | | | | | | | | |

Intertek Test Data Sheets

Transcribed Test Data

Client: Electrolux | Engineer: Mike Amaro

Job No.: G100366212 | Tested By: Christopher Duhan | Date: 04/11/2011

Product: Power Cords 2 models | Reviewed By: Eric Burns | Date:

Model No.: Power Cables | Standard(s): **UL 817, 11th Ed. 03/16/2001: Cord Sets and Power Supply Cords and UL 858 15th Ed. 04/12/2005 Standard for safety Household Electric Ranges**

Sample Control Number(s):

Security of Blades (UL 817, Section 82): **Pass:** X **Fail:**

Test Purpose:
To verify the will not displace with specified force applied

Test Parameters:	
Pull Force:	20lbf
Pull Force Direction:	Perpendicular to the plane of the cord entry hole.
Sample	6 of each cord type
Test Time:	2 minute
	To determine that an attachment plug or current tap complies with 82.1, the fitting is to be wired in the intended manner and then supported on a horizontal steel plate with the blades or pins, or both, projecting downward through a single hole sufficiently just large enough to permit the blades or pins, or both, to pass through it. A weight that exerts 20 lbf (89 N) is to be supported by each blade or pin in succession no more than 2.4mm displacement allowed.

Test Results:

Sample	Pin/Blade tested	Force applied	Duration	Displacement	Pass/Fail
9325-A	L1	20.76 lbs	2 minutes	None	Pass
	L2	20.76 lbs	2 minutes	None	Pass
	L3	20.76 lbs	2 minutes	None	Pass
	GND	20.76 lbs	2 minutes	None	Pass
9325-B	L1	20.76 lbs	2 minutes	None	Pass
	L2	20.76 lbs	2 minutes	None	Pass
	L3	20.76 lbs	2 minutes	None	Pass
	GND	20.76 lbs	2 minutes	None	Pass
9325-C	L1	20.76 lbs	2 minutes	None	Pass
	L2	20.76 lbs	2 minutes	None	Pass
	L3	20.76 lbs	2 minutes	None	Pass
	GND	20.76 lbs	2 minutes	None	Pass
9325-D	L1	20.76 lbs	2 minutes	None	Pass
	L2	20.76 lbs	2 minutes	None	Pass
	L3	20.76 lbs	2 minutes	None	Pass
	GND	20.76 lbs	2 minutes	None	Pass
9325-E	L1	20.76 lbs	2 minutes	None	Pass
	L2	20.76 lbs	2 minutes	None	Pass
	L3	20.76 lbs	2 minutes	None	Pass
	GND	20.76 lbs	2 minutes	None	Pass
9326-F	L1	20.76 lbs	2 minutes	None	Pass
	L2	20.76 lbs	2 minutes	None	Pass
	L3	20.76 lbs	2 minutes	None	Pass
	GND	20.76 lbs	2 minutes	None	Pass

Environmental Conditions During Testing: Humidity: 25% rh Pressure: 960 hpa Ambient: 21°C

Equipment Used (See page 2 for details): 1 | 3 | 5 | 7

Intertek Test Data Sheets

Transcribed Test Data

Client: Electrolux
Engineer: Mike Amaro
Job No.: G100366212
Tested By: Christopher Duhan
Date: 04/11/2011
Product: Power Cords 2 models
Reviewed By: Eric Burns
Date:
Model No.: Power Cables
Standard(s): **UL 817, 11th Ed. 03/16/2001: Cord Sets and Power Supply Cords and UL 858 15th Ed. 04/12/2005 Standard for safety Household Electric Ranges**
Sample Control Number(s):

Test Results:

Sample	Pin/Blade tested	Force applied	Duration	Displacement	Pass/Fail
9326-A	L1	20.76 lbs	2 minutes	None	Pass
	L2	20.76 lbs	2 minutes	None	Pass
	L3	20.76 lbs	2 minutes	None	Pass
	GND	20.76 lbs	2 minutes	None	Pass
9326-B	L1	20.76 lbs	2 minutes	None	Pass
	L2	20.76 lbs	2 minutes	None	Pass
	L3	20.76 lbs	2 minutes	None	Pass
	GND	20.76 lbs	2 minutes	None	Pass
9326-C	L1	20.76 lbs	2 minutes	None	Pass
	L2	20.76 lbs	2 minutes	None	Pass
	L3	20.76 lbs	2 minutes	None	Pass
	GND	20.76 lbs	2 minutes	None	Pass
9326-D	L1	20.76 lbs	2 minutes	None	Pass
	L2	20.76 lbs	2 minutes	None	Pass
	L3	20.76 lbs	2 minutes	None	Pass
	GND	20.76 lbs	2 minutes	None	Pass
9326-E	L1	20.76 lbs	2 minutes	None	Pass
	L2	20.76 lbs	2 minutes	None	Pass
	L3	20.76 lbs	2 minutes	None	Pass
	GND	20.76 lbs	2 minutes	None	Pass
9326-F	L1	20.76 lbs	2 minutes	None	Pass
	L2	20.76 lbs	2 minutes	None	Pass
	L3	20.76 lbs	2 minutes	None	Pass
	GND	20.76 lbs	2 minutes	None	Pass

To Comply:

The blade cannot displace more than 2.4mm

Intertek Comments:

X The product complies with all applicable requirements of this test.

____ The product does not comply with the requirements of this test.

Test Date: 04/05-04/07/2011 Tested By: Christopher Duhan

Environmental Conditions During Testing: Humidity: 25% rh Pressure: 960 hpa Ambient: 21°C

Equipment Used (See page 2 for details): 1 | 3 | 5 | 7 | | | | | | |

Intertek Test Data Sheets

Transcribed Test Data

Client: Electrolux | Engineer: Mike Amaro

Job No.: G100366212 | Tested By: Christopher Duhan | Date: 04/11/2011

Product: Power Cords 2 models | Reviewed By: Eric Burns | Date:

Model No.: Power Cables | Standard(s): **UL 817, 11th Ed. 03/16/2001: Cord Sets and Power Supply Cords and UL 858 15th Ed. 04/12/2005 Standard for safety Household Electric Ranges**

Sample Control Number(s):

Dielectric Voltage Withstand Test (UL 817, Section 88): **Pass:** X **Fail:**

Test Purpose:	
To test the product's ability to withstand, without breakdown, the application of a high voltage shock.	
Test Parameters:	
Test Voltage:	1480
Test Frequency:	60HZ
Test Time:	1 minute

Test Results:

Sample	Area Tested	Results	Pass/Fail
9325-A	L1-L2	No breakdown	Pass
	L1-L3	No breakdown	Pass
	L1-Gnd	No breakdown	Pass
	L2-L3	No breakdown	Pass
	L2-Gnd	No breakdown	Pass
	L3-Gnd	No breakdown	Pass
9325-B	L1-L2	No breakdown	Pass
	L1-L3	No breakdown	Pass
	L1-Gnd	No breakdown	Pass
	L2-L3	No breakdown	Pass
	L2-Gnd	No breakdown	Pass
	L3-Gnd	No breakdown	Pass
9325-C	L1-L2	No breakdown	Pass
	L1-L3	No breakdown	Pass
	L1-Gnd	No breakdown	Pass
	L2-L3	No breakdown	Pass
	L2-Gnd	No breakdown	Pass
	L3-Gnd	No breakdown	Pass
9325-D	L1-L2	No breakdown	Pass
	L1-L3	No breakdown	Pass
	L1-Gnd	No breakdown	Pass
	L2-L3	No breakdown	Pass
	L2-Gnd	No breakdown	Pass
	L3-Gnd	No breakdown	Pass
9325-E	L1-L2	No breakdown	Pass
	L1-L3	No breakdown	Pass
	L1-Gnd	No breakdown	Pass
	L2-L3	No breakdown	Pass
	L2-Gnd	No breakdown	Pass
	L3-Gnd	No breakdown	Pass
9325-F	L1-L2	No breakdown	Pass
	L1-L3	No breakdown	Pass
	L1-Gnd	No breakdown	Pass
	L2-L3	No breakdown	Pass
	L2-Gnd	No breakdown	Pass

Environmental Conditions During Testing: Humidity: 25% rh Pressure: 966 hpa Ambient: 22°C

Equipment Used (See page 2 for details): 1 | 4 | | | | | | | | |

Intertek Test Data Sheets

Transcribed Test Data

Client: Electrolux | Engineer: Mike Amaro

Job No.: G100366212 | Tested By: Christopher Duhan | Date: 04/11/2011

Product: Power Cords 2 models | Reviewed By: Eric Burns | Date:

Model No.: Power Cables | Standard(s): **UL 817, 11th Ed. 03/16/2001: Cord Sets and Power Supply Cords and UL 858 15th Ed. 04/12/2005 Standard for safety Household Electric Ranges**

Sample Control Number(s):

	L3-Gnd	No breakdown	Pass

Test Results:

Sample	Area Tested	Results	Pass/Fail
9326-A	L1-L2	No breakdown	Pass
	L1-L3	No breakdown	Pass
	L1-Gnd	No breakdown	Pass
	L2-L3	No breakdown	Pass
	L2-Gnd	No breakdown	Pass
	L3-Gnd	No breakdown	Pass
9326-B	L1-L2	No breakdown	Pass
	L1-L3	No breakdown	Pass
	L1-Gnd	No breakdown	Pass
	L2-L3	No breakdown	Pass
	L2-Gnd	No breakdown	Pass
	L3-Gnd	No breakdown	Pass
9326-C	L1-L2	No breakdown	Pass
	L1-L3	No breakdown	Pass
	L1-Gnd	No breakdown	Pass
	L2-L3	No breakdown	Pass
	L2-Gnd	No breakdown	Pass
	L3-Gnd	No breakdown	Pass
9326-D	L1-L2	No breakdown	Pass
	L1-L3	No breakdown	Pass
	L1-Gnd	No breakdown	Pass
	L2-L3	No breakdown	Pass
	L2-Gnd	No breakdown	Pass
	L3-Gnd	No breakdown	Pass
9326-E	L1-L2	No breakdown	Pass
	L1-L3	No breakdown	Pass
	L1-Gnd	No breakdown	Pass
	L2-L3	No breakdown	Pass
	L2-Gnd	No breakdown	Pass
	L3-Gnd	No breakdown	Pass
9326-F	L1-L2	No breakdown	Pass
	L1-L3	No breakdown	Pass
	L1-Gnd	No breakdown	Pass
	L2-L3	No breakdown	Pass
	L2-Gnd	No breakdown	Pass
	L3-Gnd	No breakdown	Pass

To Comply:

There shall be no breakdown.

Intertek Comments:

X The product complies with all applicable requirements of this test.

____ The product does not comply with the requirements of this test.

Environmental Conditions During Testing: Humidity: 25% rh Pressure: 966 hpa Ambient: 22°C

Equipment Used (See page 2 for details): 1 | 4 | | | | | | | | |

Intertek Test Data Sheets

Transcribed Test Data

Client:	Electrolux	Engineer:	Mike Amaro		
Job No.:	G100366212	Tested By:	Christopher Duhan	Date:	04/11/2011
Product:	Power Cords 2 models	Reviewed By:	Eric Burns	Date:	
Model No.:	Power Cables	Standard(s):	**UL 817, 11th Ed. 03/16/2001: Cord Sets and Power Supply Cords and UL 858 15th Ed. 04/12/2005 Standard for safety Household Electric Ranges**		

Sample Control Number(s):

Test Date: 03/31/2011 Tested By: Christopher Duhan

Environmental Conditions During Testing: Humidity: 25% rh Pressure: 966 hpa Ambient: 22°C

Equipment Used (See page 2 for details):	1	4								

Intertek Test Data Sheets

Transcribed Test Data

Client: Electrolux | Engineer: Mike Amaro

Job No.: G100366212 | Tested By: Christopher Duhan | Date: 04/11/2011

Product: Power Cords 2 models | Reviewed By: Eric Burns | Date:

Model No.: Power Cables | Standard(s): **UL 817, 11th Ed. 03/16/2001: Cord Sets and Power Supply Cords and UL 858 15th Ed. 04/12/2005 Standard for safety Household Electric Ranges**

Sample Control Number(s):

Terminal Blade Pull Force (UL 817, Section 95): **Pass:** X **Fail:**

Test Purpose:
To determine that the blade are mounted securely when heated.

Test Parameters:	
Each of six representative attachment plugs or current taps molded to a length of cord no more than 6 inches (152.4 mm) long is to have a line scribed on both sides and both edges of the blades to indicate the point where the blade enters the device body. Each attachment plug or current tap is then to be securely mounted so that the line blades are positioned downward through a circular hole (diameter just large enough to allow the line blades and any grounding pin to pass through) in a 1/4 inch (6.4 mm) thick steel plate mounted horizontally within an air circulating oven that has been heated to 60°C (140°F). After the fittings have been positioned, a weight that exerts 10 lbf (44.5 N) is to be attached to each of the individual line blades. The oven is then to be maintained at 60°C (140°F) for 4 hours after which the weights are to be removed and the attachment plugs or current taps taken from the oven and allowed to cool to room temperature. The displacement of the blades from their original position shall then be determined as described in 95.4.	
Temperature	60C
	The distance from the scribed lines, on each of the sides and both edges of the blades, to the face is to be measured after the thermal conditioning. The average of the four measurements for each blade shall be used to determine compliance with the 1/16 inch (1.6 mm) maximum displacement requirement.

Test Results:

Sample	Blade/Pin	Force Applied	Duration	Direction of Pull	Distance Displaced	Pass/Fail
9325-A	L1	10.77 lbs	4 hours	Down	No displacement	Pass
	L2	10.65 lbs	4 hours	Down	No displacement	Pass
	L3	10.66 lbs	4 hours	Down	No displacement	Pass
	Gnd	10.51 lbs	4 hours	Down	No displacement	Pass
9325-B	L1	10.77 lbs	4 hours	Down	No displacement	Pass
	L2	10.65 lbs	4 hours	Down	No displacement	Pass
	L3	10.66 lbs	4 hours	Down	No displacement	Pass
	Gnd	10.51 lbs	4 hours	Down	No displacement	Pass
9325-C	L1	10.77 lbs	4 hours	Down	No displacement	Pass
	L2	10.65 lbs	4 hours	Down	No displacement	Pass
	L3	10.66 lbs	4 hours	Down	No displacement	Pass
	Gnd	10.51 lbs	4 hours	Down	No displacement	Pass
9325-D	L1	10.77 lbs	4 hours	Down	No displacement	Pass
	L2	10.65 lbs	4 hours	Down	No displacement	Pass
	L3	10.66 lbs	4 hours	Down	No displacement	Pass
	Gnd	10.51 lbs	4 hours	Down	No displacement	Pass
9325-E	L1	10.77 lbs	4 hours	Down	No displacement	Pass
	L2	10.65 lbs	4 hours	Down	No displacement	Pass
	L3	10.66 lbs	4 hours	Down	No displacement	Pass
	Gnd	10.51 lbs	4 hours	Down	No displacement	Pass
9325-F	L1	10.77 lbs	4 hours	Down	No displacement	Pass
	L2	10.65 lbs	4 hours	Down	No displacement	Pass

Environmental Conditions During Testing: Humidity: 39% rh Pressure: 957 hpa Ambient: 60°C

Equipment Used (See page 2 for details): 1 | 3 | 5 | 7

Intertek Test Data Sheets

Transcribed Test Data

Client: Electrolux | Engineer: Mike Amaro

Job No.: G100366212 | Tested By: Christopher Duhan | Date: 04/11/2011

Product: Power Cords 2 models | Reviewed By: Eric Burns | Date:

Model No.: Power Cables | Standard(s): **UL 817, 11th Ed. 03/16/2001: Cord Sets and Power Supply Cords and UL 858 15th Ed. 04/12/2005 Standard for safety Household Electric Ranges**

Sample Control Number(s):

	L3	10.66 lbs	4 hours	Down	No displacement	Pass
	Gnd	10.51 lbs	4 hours	Down	No displacement	Pass

Test Results:

Sample	Blade/Pin	Force Applied	Duration	Direction of Pull	Distance Displaced	Pass/Fail
9326-A	L1	10.77 lbs	4 hours	Down	No displacement	Pass
	L2	10.65 lbs	4 hours	Down	No displacement	Pass
	L3	10.66 lbs	4 hours	Down	No displacement	Pass
	Gnd	10.51 lbs	4 hours	Down	No displacement	Pass
9326-B	L1	10.77 lbs	4 hours	Down	No displacement	Pass
	L2	10.65 lbs	4 hours	Down	No displacement	Pass
	L3	10.66 lbs	4 hours	Down	No displacement	Pass
	Gnd	10.51 lbs	4 hours	Down	No displacement	Pass
9326-C	L1	10.77 lbs	4 hours	Down	No displacement	Pass
	L2	10.65 lbs	4 hours	Down	No displacement	Pass
	L3	10.66 lbs	4 hours	Down	No displacement	Pass
	Gnd	10.51 lbs	4 hours	Down	No displacement	Pass
9326-D	L1	10.77 lbs	4 hours	Down	No displacement	Pass
	L2	10.65 lbs	4 hours	Down	No displacement	Pass
	L3	10.66 lbs	4 hours	Down	No displacement	Pass
	Gnd	10.51 lbs	4 hours	Down	No displacement	Pass
9326-E	L1	10.77 lbs	4 hours	Down	No displacement	Pass
	L2	10.65 lbs	4 hours	Down	No displacement	Pass
	L3	10.66 lbs	4 hours	Down	No displacement	Pass
	Gnd	10.51 lbs	4 hours	Down	No displacement	Pass
9326-F	L1	10.77 lbs	4 hours	Down	No displacement	Pass
	L2	10.65 lbs	4 hours	Down	No displacement	Pass
	L3	10.66 lbs	4 hours	Down	No displacement	Pass
	Gnd	10.51 lbs	4 hours	Down	No displacement	Pass

To Comply:

The blade shall not displace more than 1/16 of an inch.

Intertek Comments:

X The product complies with all applicable requirements of this test.

____ The product does not comply with the requirements of this test.

Test Date: 04/07-04/12 Tested By: Christopher Duhan

Environmental Conditions During Testing: Humidity: 39% rh Pressure: 957 hpa Ambient: 60°C

Equipment Used (See page 2 for details): 1 | 3 | 5 | 7 | | | | | | |

Intertek Test Data Sheets

Transcribed Test Data

Client: Electrolux | Engineer: Mike Amaro

Job No.: G100366212 | Tested By: Christopher Duhan | Date: 04/11/2011

Product: Power Cords 2 models | Reviewed By: Eric Burns | Date:

Model No.: Power Cables | Standard(s): **UL 817, 11th Ed. 03/16/2001: Cord Sets and Power Supply Cords and UL 858 15th Ed. 04/12/2005 Standard for safety Household Electric Ranges**

Sample Control Number(s):

Strain Relief Test (UL 858, Section 61): **Pass:** _____ **Fail:** _____

Test Purpose:
To test the construction of the strain relief of a cord fitting.

Test Parameters:	
Pull Force:	
Pull Force Direction:	Perpendicular to the plane of the cord entry hole.
Means of Pull Force:	Apply weights to create the pull force
Test Time:	1 minute

Test Results:

Sample	Results	Pass/Fail
9325-A		
9325-B		
9325-C		
9325-D		
9325-E		
9325-F		
9326-A		
9326-B		
9326-C		
9326-D		
9326-E		
9326-F		

To Comply:
A pull exerted on a cord shall not be transmitted directly to the terminals of a fitting.

Intertek Comments:

_____ The product complies with all applicable requirements of this test.

_____ The product does not comply with the requirements of this test.

Test Date: Tested By:

Environmental Conditions During Testing: : _____ Humidity: 25% rh Ambient: 22°C

Equipment Used (See page 2 for details): 1 | 7 | | | | | | | | |

Intertek Test Data Sheets

Transcribed Test Data

Client: Electrolux
Engineer: Mike Amaro
Job No.: G100366212
Tested By: Christopher Duhan
Date: 04/11/2011
Product: Power Cords 2 models
Reviewed By: Eric Burns
Date:
Model No.: Power Cables
Standard(s): **UL 817, 11th Ed. 03/16/2001: Cord Sets and Power Supply Cords and UL 858 15th Ed. 04/12/2005 Standard for safety Household Electric Ranges**
Sample Control Number(s):

Terminal Blade Connection Resistance (UL 858, Section 55): **Pass:** X **Fail:**

Test Purpose:
Verify the resistance at of the cord does not exceed 25mohms on each line

Test Parameters:	
Sample qty	6 of each conductor
Max Resistance	25mOhms

Test Results:	**Resistance Measured**					
Sample	**L1**	**L2**	**L3**	**GND**	**Max allowed**	**Pass/Fail**
9325-A	9.57	8.40	7.92	8.42	25mohms	Pass
9325-B	7.96	8.57	7.00	9.25	25mohms	Pass
9325-C	7.87	9.74	6.71	8.09	25mohms	Pass
9325-D	8.53	8.92	8.29	9.61	25mohms	Pass
9325-E	8.04	8.37	8.99	7.86	25mohms	Pass
9325-F	9.58	9.00	9.57	9.21	25mohms	Pass
9326-A	4.47	4.82	4.55	7.77	25mohms	Pass
9326-B	4.43	5.97	4.67	7.50	25mohms	Pass
9326-C	4.37	7.61	6.15	6.04	25mohms	Pass
9326-D	5.59	7.13	4.35	5.96	25mohms	Pass
9326-E	4.70	7.03	4.34	5.95	25mohms	Pass
9326-F	4.56	8.10	5.90	8.76	25mohms	Pass

To Comply:
No line shall have a resistance over 25mOhms

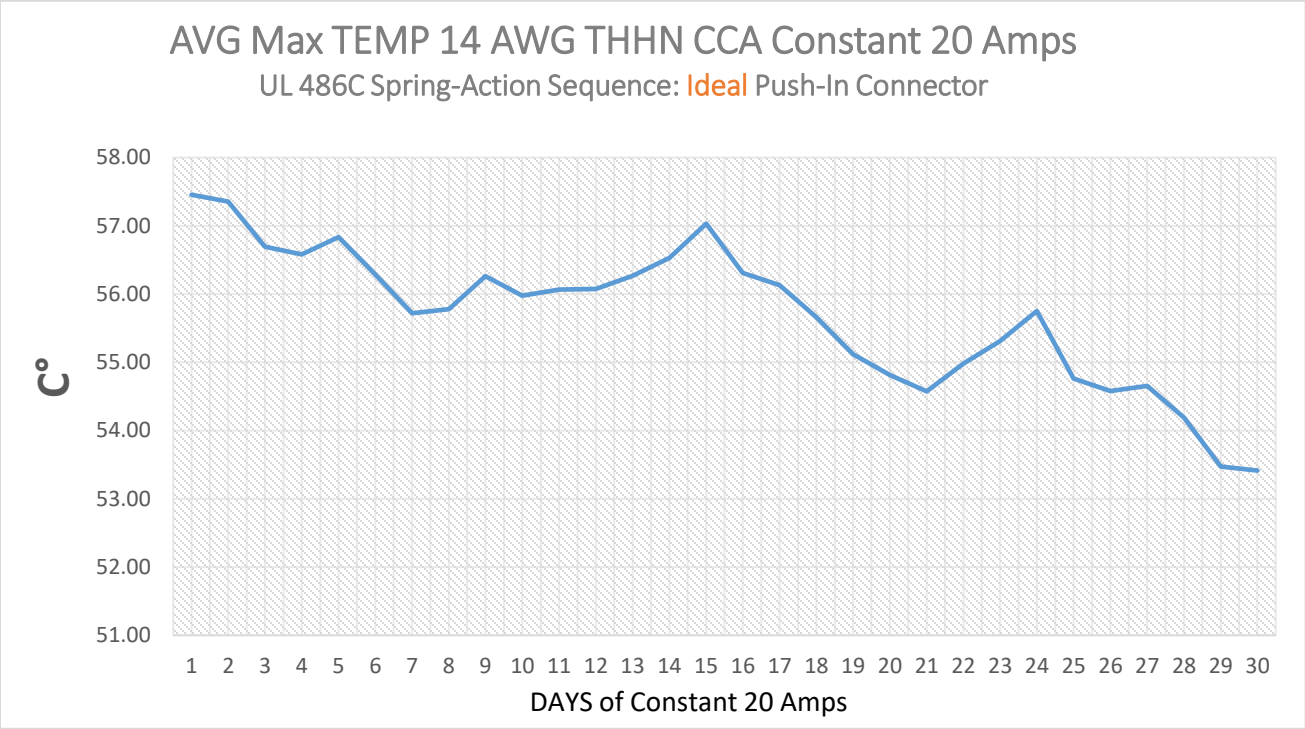
Intertek Comments:	
X	The product complies with all applicable requirements of this test.
	The product does not comply with the requirements of this test.
	Test Date: 03/31/2011 Tested By: Christopher Duhan

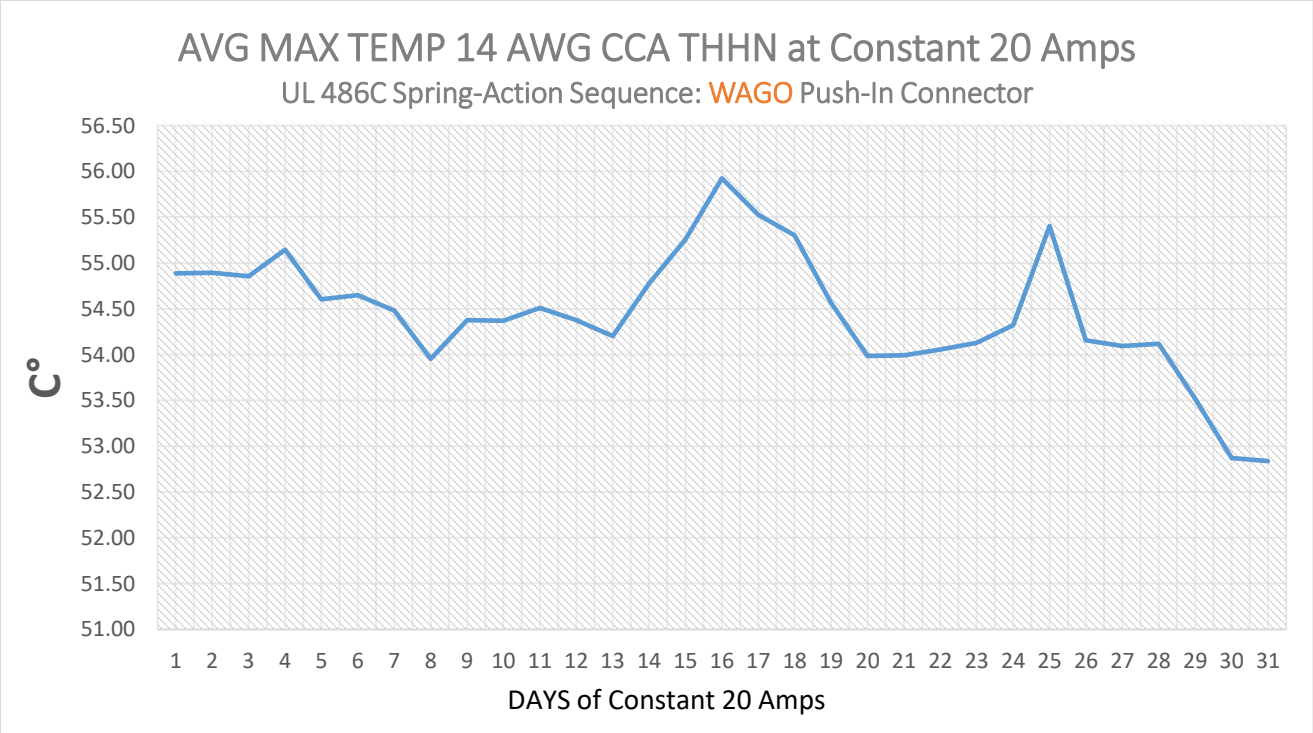
Environmental Conditions During Testing: : Humidity: 25% rh Ambient: 22°C

Equipment Used (See page 2 for details): 1 | 7 | | | | | | | | |

Performance of
14 AWG CCA THHN Under EXTREME OVERCURRENT CONDITION

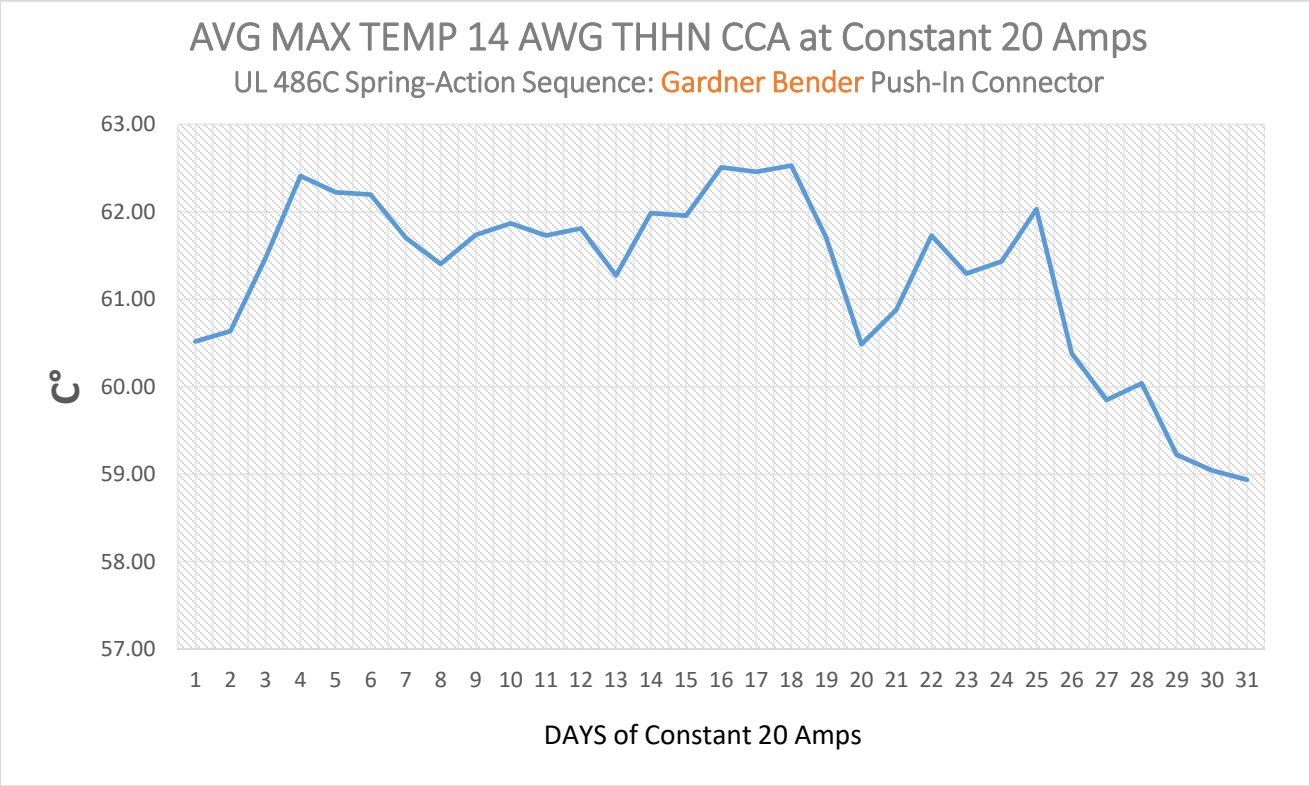
Three Push-In Connectors Tested By Intertek (NRTL with Wire & Cable in Scope of Recognition) to UL 486C Spring-Action Sequence





Performance of
14 AWG CCA THHN Under EXTREME OVERCURRENT CONDITION

Three Push-In Connectors Tested By Intertek (NRTL with Wire & Cable in Scope of Recognition) to UL 486C Spring-Action Sequence



CONCLUSIONS FROM UL 486C SPRING-Action SEQUENCE TESTING REG 14 AWG THHN MADE WITH ASTM B566 COPPER-CLAD ALUMINUM WIRE:

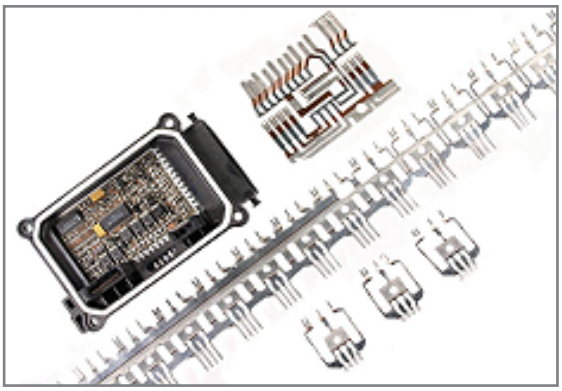
- The THHN Insulation (Rated at 90°C) Remained in Good Condition Throughout the Test
- Over 30 Days at Constant 20 Amps (twice the amperage of the proposed amperage at 60°C column requested by Public Comment 1402), the highest temperature registered by 14 AWG CCA was under 63°C. Over Current Protection Devices (OCPD's) are in place in a circuit to keep wire from over-heating. OCPD's will open the circuit when the amperage limit (10 amps in case of 14 AWG CCA) is reached.
- Ambient Temperature of 23°C Over 30 Days, Standard Deviation of ½ °C
- Average Max Temperatures decreased by 3°C over the month when connected to the three brands of push-in connectors
- The Gardner Bender Connector created more heat (+/- 6°C) within the wire than the other two test subjects
- Of the nine push-in connectors tested (three different brands), not one saw degradation or damage due to excessive heat, despite the constant over-current condition applied to the wire
- The wire remained thermally stable at the points of termination over all nine push-in connectors, and no arc-faulting was observed due to thermal expansion of the wire

MATERION

TECH BRIEFS

Bond Integrity in Aluminum-Copper Clad Metals

Aluminum clad copper (Al/Cu) or copper clad aluminum (Cu/Al) composite metals have been widely used for over 40 years. These mature and well tested clad metal systems are used industrially in a variety of applications. The inherent properties and behavior of both copper and aluminum combine to provide unique performance advantages. Copper's electrical and thermal conductivity along with its solderability make it a critical industrial metal. The characteristics of aluminum also provide above average thermal and electrical conductivity, low density and a stable oxide layer. A common application in our daily life is cookware where either Cu/Al or Cu/Al/Stainless Steel clad metals are used to make premium pots and pans.



Industrial applications include electrical power protection. Here Cu/Al clad metal systems have been used for buss bar and circuit breaker devices. More than 300,000 pounds of thin copper clad aluminum metals are produced each year for global power safety devices.

In the automotive industry, aluminum is clad over copper alloys in either inlay or overlay techniques. The aluminum acts as a bond pad location for wire bonding of hybrid circuits. Volumes of Aluminum inlays approach 2 million pounds per year and are used extensively in domestic and European automotive electronics. Hybrid leadframes made from copper/aluminum are used extensively in anti-lock braking, steering control and air bag control systems. The effect of under-the-hood temperatures on the Cu/Al interface was extensively studied over the past several decades. The stability of the interface below 250° C has been well documented. Figure 2 illustrates this data. The Copper Aluminum system has performed very robustly in a variety of automotive applications where service temperature ranges are typically from –40° C to 150° C.

Copper clad aluminum materials are also used for thermal management in automotive and computer applications. Components such as heat fins and heat exchangers rely on thin copper skins for solderability while aluminum provides a low-cost, lightweight substrate.

The following table provides an estimate of Al/Cu clad metal production servicing a variety of industrial applications over the past 5 years.

Clad Products	Applications	lbs. / 5yrs.	Applications
Al Inlay Copper Alloys	85	9,000,000	Wire bond leadframes for auto hybrid circuits
Copper clad Aluminum	30	300,000	Heat sink and heat exchanger components
Cu overlay on Al	13	1,500,000	Bus bar components

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5 Wellington Road
Lincoln, RI 02865
phone: 401.333.1700 fax: 401.333.2848
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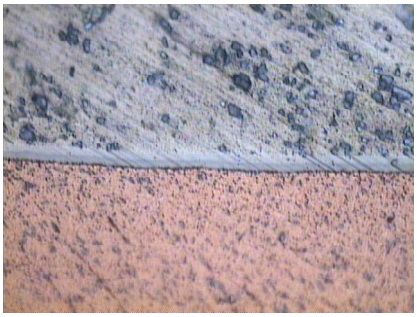
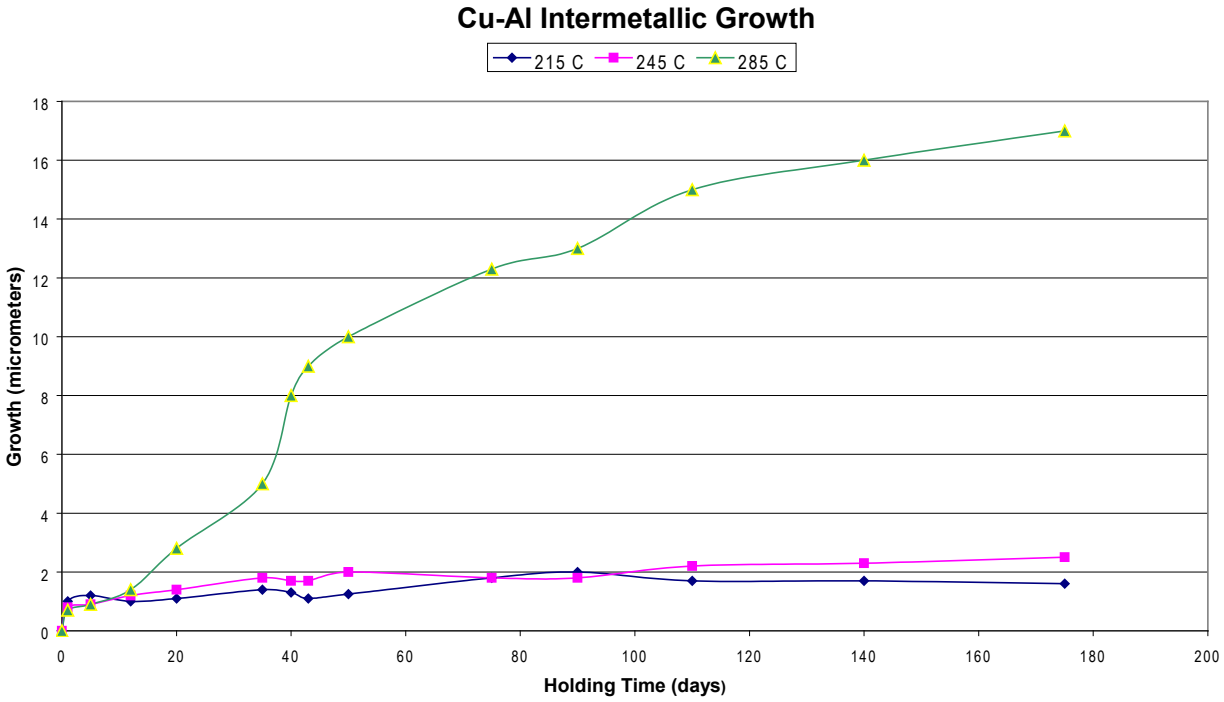
Al/Cu clad metal systems are most commonly produced by continuous roll-bonding technologies. This can be conducted either at ambient temperature or via hot bonding. Most commonly this bonding is carried out without external heating similiar to the process used to produce U.S. currency. Ambient temperature bonding is followed by a carefully controlled annealing process providing thermal diffusion at the interface and the creation of reliable bond integrity between Al and Cu. Subsequent rolling and processing to finish size serves to further strengthen the interface.

Excellent metallurgical adhesion between Cu and Al layers is achieved through the controlled formation of a thin intermetallic compound layer. The picture to the right shows the interface between Al and Cu in an Al/Cu clad metal manufactured via the cold bonding process.



Al/Cu clad systems have been successfully utilized in electrical and electronic components worldwide. Designers should avoid applications where components will be exposed to prolonged exposure to excessive heat (above 250° C) or to very high temperatures such as those generated during arc welding.

The number of applications utilizing Cu/Al clad products continues to expand. This is based upon decades of reliable engineered performance in many challenging designs.



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5 Wellington Road
Lincoln, RI 02865
phone: 401.333.1700 fax: 401.333.2848
www.materion.com/technicalmaterials

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Cortland, NY 13045
Telephone: 1-607-753-6711
Facsimile: 1-607-758-6595
www.intertek.com

TEST LETTER REPORT

Copperweld Bimetallics, LLC
Test Report

SCOPE OF WORK
PERFORMANCE TESTING – PRODUCT TYPE PER STANDARD

REPORT NUMBER
103589128CRT-001A

ISSUE DATE	**[REVISED DATE]**
27-Aug-2018	28-Aug-2018

PAGES
14

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TEST LETTER REPORT

27-Aug-2018

Intertek Report No.: 103589128CRT-001A
Intertek Project No.: G103589128

Mr. Peter Graser
Copperweld Bimetallics, LLC
215 Centerview Drive
Suite 360
Brentwood, TN 37027

Ph: (770) 952-6445
email: pgraser@copperweld.com

Subject: Static Heating test of Push-in Wire Connectors on CCA Conductors in accordance with Claus 9.12 Spring-action sequence per UL 486C.

Dear Mr. Peter Graser,

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

> **UL 486C / CSA C22.2 No. 188-18 –** Splicing Wire Connectors, Seventh Edition, Dated January 26, 2018

SECTION 1
SUMMARY

This investigation was authorized by signed proposal number Qu-00894894, dated 29-June-2018. A production sample was received on 26-June-2018 and tested from 23-Jul-2018 to 27-Aug-2018 at the Intertek Cortland facility.

TEST LETTER REPORT

SECTION 2
TESTING

Below is a summary of the tests and results for the entire test period. The test data appears at the end of this report in the Appendix.

Performance testing was carried out in accordance with UL486C, Clause 9.12 Spring-action sequence.

Three test circuits were built in the sizes 14AWG, 12AWG, and 10AWG, each circuit containing Copperweld CCA THHN wire and 3 three specimens each of push-in
wire connectors manufactured by Ideal, Wago, and Gardner and Bender, as available. This setup is a deviation from the standard which requires connectors to be tested separately on individual circuits.

Test currents (20A for 14AWG, 30A for 12AWG and 50A for 10AWG) were selected in accordance with client request rather than per Table 6 static heating columns in UL486C, and additional setup criteria indicated in Clause 9.1 of UL486C will not be used. Test currents were monitored periodically with a clamp style meter.

Ambient thermocouples were placed at least two feet out from the connectors under test, and approximately 3 feet apart, the number of ambient thermocouples is reduced due to the size of the apparatus.

Connector thermocouples are placed on the input and output side of each connector with a reference conductor between each set of three connectors.

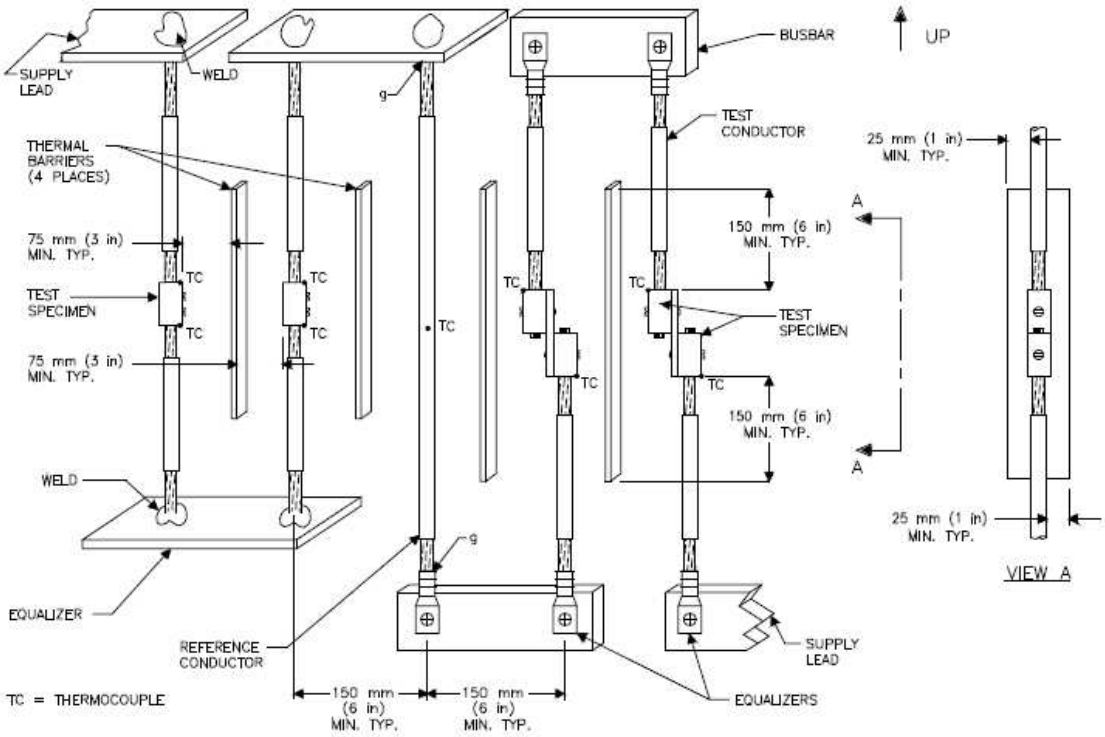
The apparatus is set up in complete compliance with Figure 2 on the next page, no other deviations from the standard were made.

Calibration Information:

Item #	Equipment Type	Asset #	Calibration Due
1	Fluke 365 True RMS Clamp Meter	M262	04/06/2019
2	Fluke Hydra Temperature Recorder	T1152	04/20/2019
3	Fluke Hydra Temperature Recorder	U080	07/16/2019
4	Fluke Hydra Temperature Recorder	T834S	02/13/2019
5	Fluke Hydra Temperature Recorder	T1565	09/27/2018

TEST LETTER REPORT

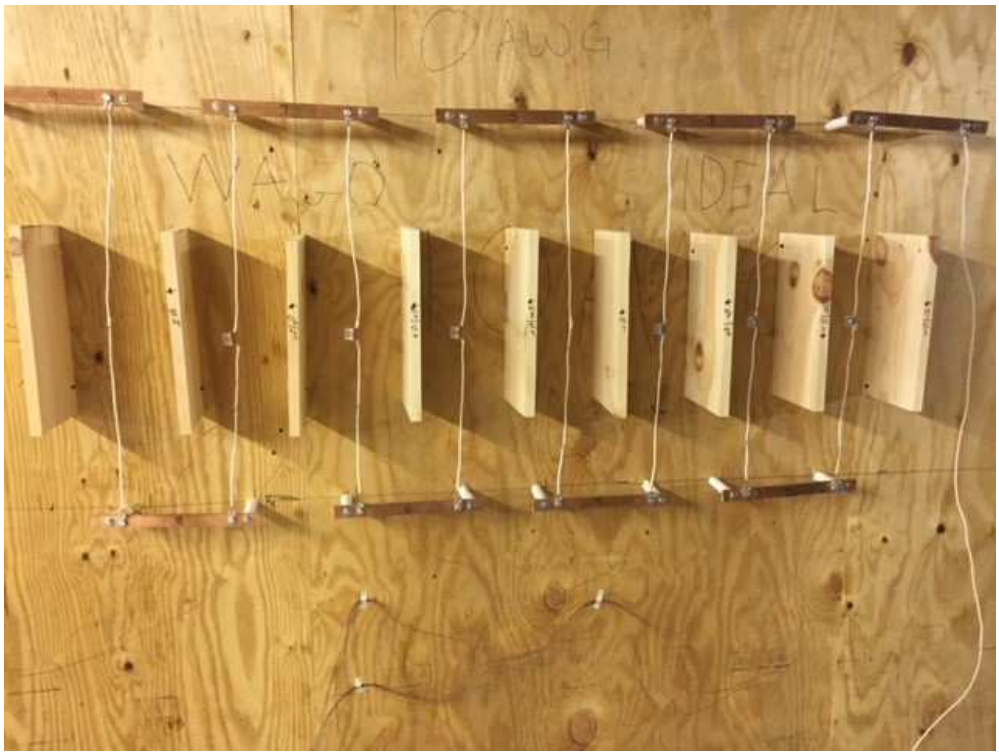
Figure 2
Vertical arrangement of specimen for current-cycling test
(Clause 9.1.10.7)



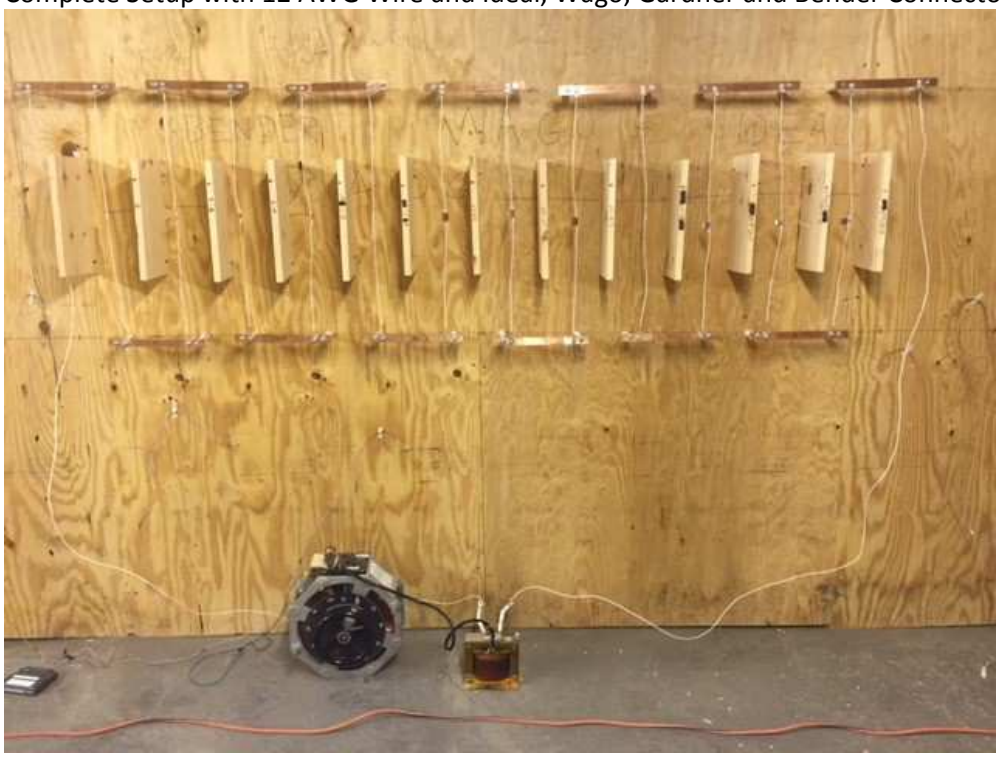
TEST LETTER REPORT

SECTION 3
PHOTOGRAPHS

10AWG Wire with IDEAL and WAGO connectors

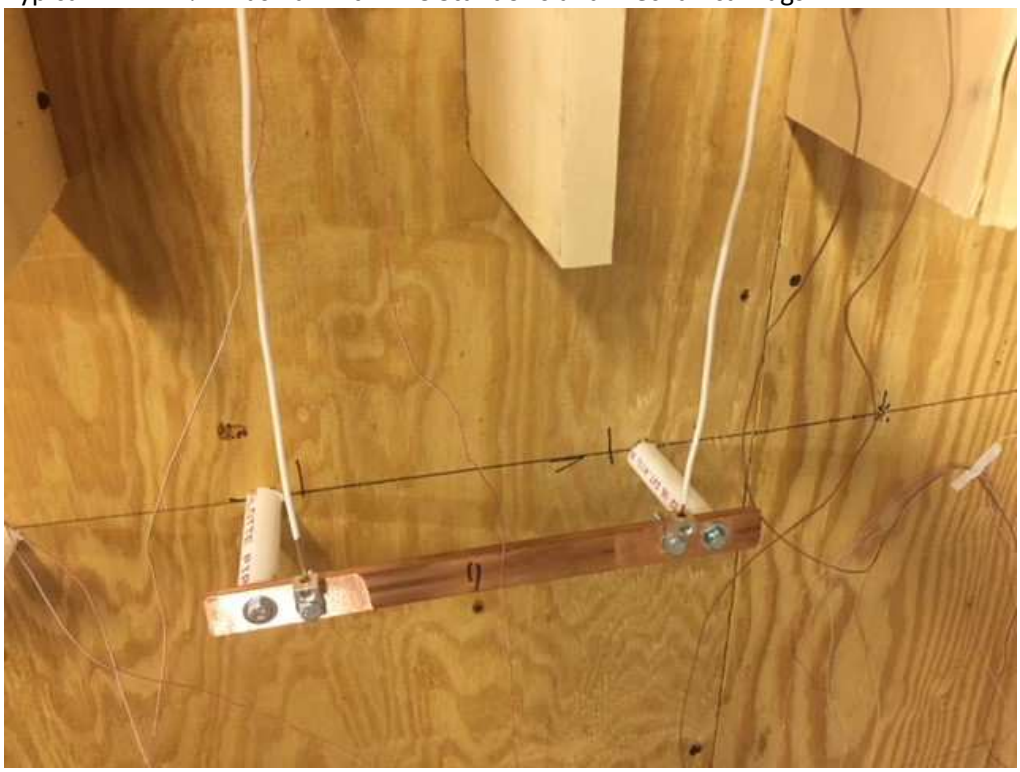


Complete Setup with 12 AWG Wire and Ideal, Wago, Gardner and Bender Connectors

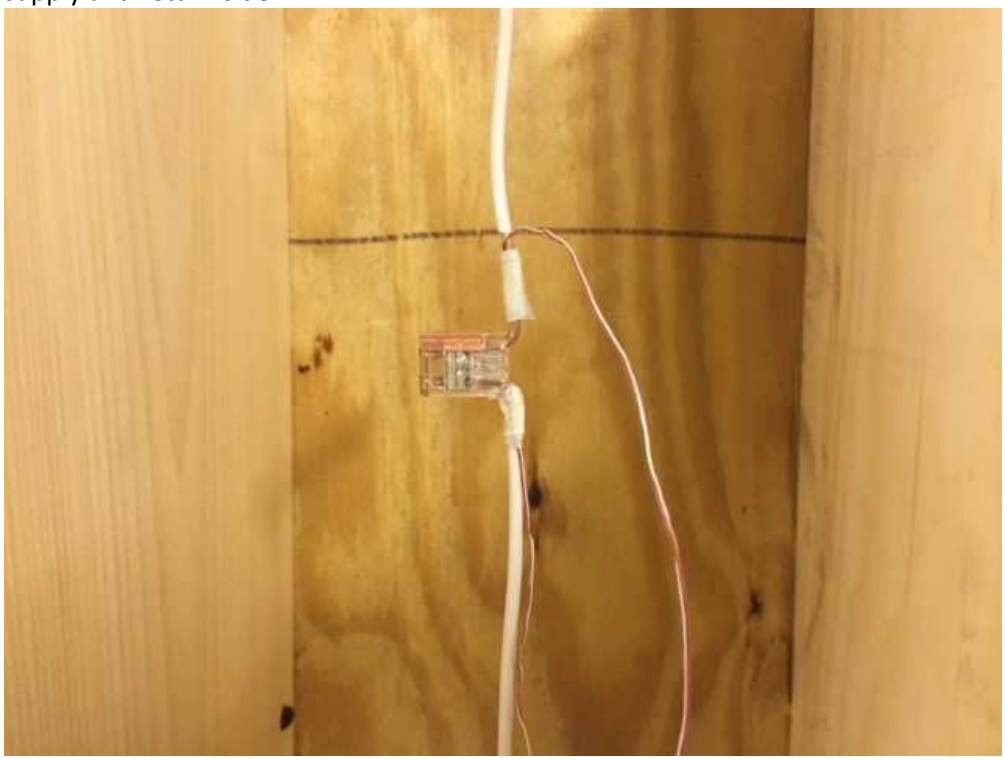


TEST LETTER REPORT

Typical 12 x 1 x ¼" Bus Bar with PVC Standoffs and Mechanical Lugs



Typical Connector, Gardner and Bender Shown, TC attached within 1/2" of the connector on supply and return side



TEST LETTER REPORT

SECTION 4
PROJECT STATUS & ACTION

One set of thermocouples did not record results on the first day of testing on one of the data recorders in use. Intertek performed a full 31 days of testing to capture a minimum of 30 days these thermocouples in question, at the request of the client.

One ambient thermocouple stopped recording at the end of the last day of testing, on the Ideal connectors for the 20A test setup. Data is recorded as “No Data” due to this malfunction. The seven remaining thermocouples reading ambient temperature show normal results.

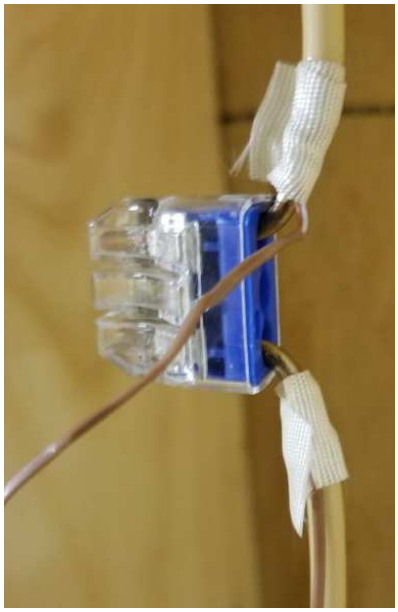
All testing is now complete.

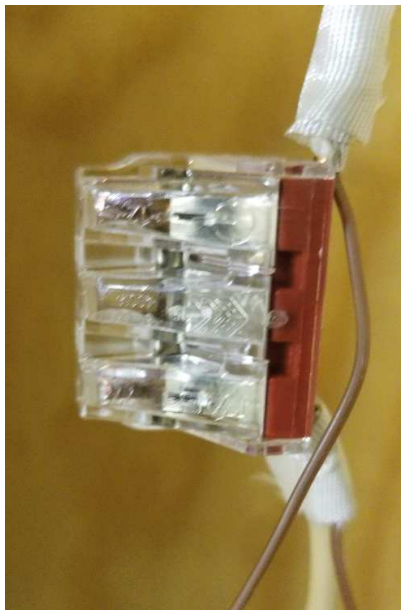
SECTION 5
CONCLUSION

The results contained in this report are to be evaluated by the client. This data is not to be used for certification of these products.

Upon completion of the test, there was no visible damage to any of the connectors contained within this report. There was however a visible change to the coloration of the insulation on the conductors involved in the 50A test on the 10 AWG conductors; no other conductors involved in the test exhibited this discoloration. The consistent temperatures recorded during the test, indicate that there is no evidence of arcing at the connectors.

10 AWG Connectors (Left to Right: Ideal, Wago):





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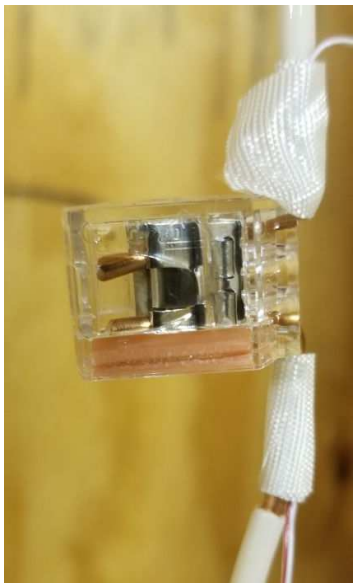
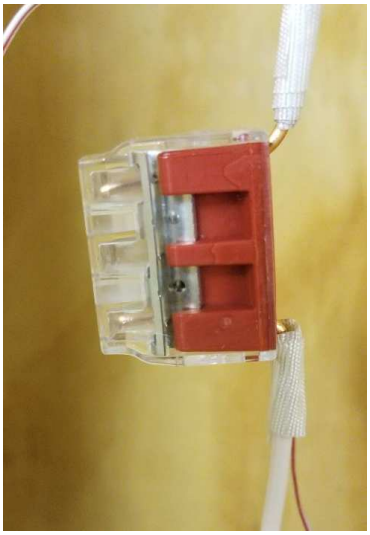
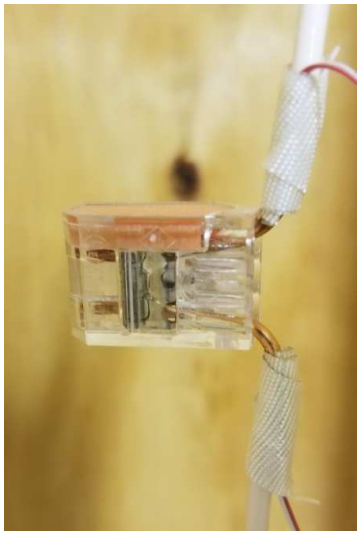
12 AWG Connectors (Left to right: Ideal, Wago, Gardner and Bender):



14 AWG Connectors (Left to right: Ideal, Wago, Gardner and Bender):

TEST LETTER REPORT

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

Completed by:	Joshua O'Connor	Reviewed by:	James Diescher
Title:	Engineering Team Lead	Title:	Technical Lead
Signature:		Signature	
Date	08/28/2018	Date:	08/28/2018

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

Revision History

08/28/2018: Added information in the conclusions about the condition of the connectors and conductors at the end of the test. Added example pictures of each connector for each test setup at the completion of the test.

TEST LETTER REPORT

APPENDIX

MAX TEMP (50A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		1	104.82	101.00	100.66	99.70	98.60	98.79	98.82	98.52	97.64	98.16	97.79	97.82	97.16	97.85	97.85	98.06	97.49	97.63	97.64	97.06	96.68	97.02	96.45	96.65	97.49	Power Outage			98.90	96.25	97.02	96.45	96.40	96.40
	1	2	83.92	81.32	81.26	80.73	80.09	80.76	80.48	80.18	79.64	80.31	79.79	79.55	79.49	80.47	79.93	80.34	80.07	79.59	79.50	79.27	79.02	78.94	78.79	78.94	79.93				80.77	78.35	78.70	78.40	78.30	78.26
		3	90.28	90.79	91.78	90.78	90.16	91.16	91.82	90.89	91.38	91.08	91.32	91.26	90.70	90.75	92.09	92.63	92.46	92.58	91.78	91.17	91.46	91.99	91.87	91.58	92.43				92.03	91.35	91.57	91.57	91.17	91.48
	2	4	77.14	77.62	78.16	77.92	77.83	78.34	77.99	77.93	78.12	78.28	78.10	78.06	77.93	77.76	79.17	79.25	79.16	79.14	78.74	78.29	78.55	78.53	78.67	78.38	79.24				78.86	78.68	78.79	78.53	78.25	78.37
		5	89.40	88.00	88.06	87.39	87.14	87.66	87.95	87.41	87.60	87.22	87.75	87.22	86.90	86.69	87.59	88.87	88.31	88.06	87.62	87.42	87.39	87.85	87.47	87.94	88.26				87.35	87.09	86.96	87.18	86.77	86.46
	3	6	92.73	91.58	92.06	91.46	91.54	91.75	92.33	92.00	92.01	91.28	91.62	91.88	90.90	90.83	92.07	93.37	92.96	92.68	92.04	91.75	92.20	92.29	92.00	92.57	92.69				92.26	91.65	91.54	92.05	91.31	91.72
	Ref	7	86.70	86.98	87.33	87.63	87.71	87.57	88.23	88.32	88.19	87.94	88.14	88.45	88.04	88.34	88.47	90.28	89.05	89.39	89.32	88.39	89.12	89.10	88.61	88.89	88.95				88.30	88.79	88.18	88.82	87.86	87.96
WAGO		8	81.37	80.88	80.74	80.56	80.08	79.93	79.18	79.02	78.45	79.39	79.33	79.00	79.07	79.55	79.65	79.63	79.81	79.52	78.93	77.99	78.56	78.44	78.10	78.43	78.26				79.39	77.75	77.91	77.48	76.92	77.02
	4	9	87.95	87.91	88.06	88.05	87.56	87.44	87.70	87.40	86.31	87.10	87.04	86.49	86.47	86.60	87.34	86.86	87.23	87.05	86.03	84.97	85.43	85.51	84.84	84.26	83.99				87.60	82.66	82.59	83.04	82.02	81.62
		10	87.19	87.84	87.90	88.43	87.66	87.34	86.86	86.11	86.57	87.48	87.70	87.54	87.20	87.45	87.88	87.92	88.00	86.61	86.52	85.52	85.46	85.47	85.73	86.22	86.18				87.75	85.60	85.48	85.31	85.87	85.36
	5	11	82.99	83.08	82.87	82.89	82.67	82.08	81.59	80.97	81.03	81.96	82.48	81.96	81.56	81.82	82.39	82.34	82.33	81.56	80.99	80.17	80.20	80.27	80.35	80.94	80.77				81.80	79.82	79.83	79.33	79.68	79.62
		12	85.43	85.05	85.09	85.12	84.61	84.80	84.10	83.59	83.47	84.12	84.26	84.58	84.16	84.36	84.31	84.97	84.57	84.23	83.86	83.73	83.34	83.49	83.12	84.01	83.75				84.34	83.84	83.04	83.06	83.41	83.41
	6	13	89.14	88.21	88.76	88.48	88.17	88.23	87.82	87.01	87.15	87.56	87.82	88.05	88.09	87.89	88.53	88.38	88.30	88.18	87.92	88.06	87.42	87.56	87.31	87.99	87.42				88.68	87.93	86.71	86.83	88.01	87.86
	Ref	14	88.72	89.64	91.45	90.71	91.45	91.75	91.57	91.95	91.31	90.84	92.18	92.33	92.35	91.99	92.78	92.10	93.57	93.63	92.06	91.81	92.52	93.07	92.84	94.56	92.34				91.83	91.48	91.76	90.88	91.75	92.01

MIN TEMP (50A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		1	22.29	95.90	95.73	93.01	91.23	93.56	92.72	93.94	92.48	90.88	92.40	92.03	91.11	91.39	90.62	91.45	91.51	91.06	89.73	93.36	91.73	91.20	89.59	91.80	90.50	Power Outage			88.57	89.43	88.66	87.20	89.04	88.91
	1	2	22.78	75.58	76.48	74.61	74.09	74.86	73.01	75.43	74.83	73.38	74.29	74.35	73.76	73.98	73.51	74.34	73.20	72.76	72.79	75.75	73.99	71.52	71.85	73.85	73.60				70.57	71.15	71.60	70.77	72.03	72.00
		3	22.32	86.68	86.59	86.16	86.30	86.08	83.75	86.01	85.92	86.01	86.10	86.12	86.44	86.39	86.00	87.18	85.73	86.73	84.95	86.06	85.97	85.69	84.59	86.34	86.40				86.41	84.28	82.96	83.55	86.01	86.60
	2	4	23.01	73.41	74.53	73.82	73.74	73.90	71.63	74.62	74.23	73.44	74.07	74.11	74.11	74.10	73.74	74.07	73.55	74.16	73.04	75.59	74.45	72.99	72.67	75.16	74.60				73.70	71.28	72.09	72.66	74.55	74.63
		5	22.81	82.43	83.23	81.87	81.43	81.93	82.40	83.10	83.04	81.18	81.53	82.37	82.07	81.62	80.99	81.31	82.41	83.19	83.08	83.34	83.08	83.36	82.56	82.89	81.89				83.00	80.76	80.45	78.26	82.23	82.20
	3	6	22.78	88.40	88.90	87.84	87.42	88.03	87.74	88.31	88.04	87.25	87.44	88.02	87.65	87.71	87.08	87.91	88.31	88.13	88.39	87.65	87.47	88.14	87.58	88.05	88.04				87.82	87.69	86.02	85.31	86.77	86.95
	Ref	7	22.80	81.99	82.99	82.63	83.18	82.18	83.80	84.81	83.61	82.84	83.48	83.28	83.82	83.52	82.89	82.37	84.23	85.36	85.18	85.16	84.67	85.61	84.25	85.09	83.40				85.03	84.55	82.60	82.30	84.22	84.61
WAGO		8	22.80	76.69	76.90	75.55	75.53	75.70	76.45	76.09	75.90	74.84	75.21	75.08	75.48	74.30	73.94	74.72	75.67	75.74	76.09	75.53	75.31	75.63	75.48	75.29	73.59				75.39	75.23	74.02	73.67	74.40	74.30
	4	9	22.75	83.28	83.55	82.80	83.07	82.84	83.59	82.50	82.47	81.84	82.09	81.47	81.66	81.43	80.58	81.16	81.56	81.90	81.02	81.21	80.95	80.60	80.67	79.89	78.46				78.59	78.57	76.50	76.81	77.42	78.12
		10	22.75	82.20	82.69	81.78	82.24	82.32	82.49	81.70	82.03	81.84	81.99	81.63	81.98	81.22	81.81	81.26	82.31	82.46	82.27	82.11	82.40	82.79	82.36	81.77	81.11				81.76	81.86	80.13	80.89	82.58	82.28
	5	11	22.70	78.01	77.83	76.59	77.48	77.09	77.56	77.03	77.05	76.60	76.94	76.43	76.92	75.85	76.32	75.92	77.07	77.78	77.22	77.46	77.68	77.94	77.27	76.76	75.78				76.67	77.06	75.06	74.97	77.20	77.02
		12	22.73	79.80	79.49	79.39	79.38	79.26	79.13	78.50	78.95	78.66	78.39	78.53	78.81	77.70	78.11	78.08	78.59	79.55	79.11	79.58	80.09	80.23	79.47	79.04	78.20				80.03	80.00	77.96	78.62	80.09	80.09
	6	13	22.70	83.65	83.07	83.06	82.47	82.70	81.87	82.49	82.24	82.41	82.51	82.69	82.38	82.30	82.45	82.67	82.99	83.63	82.82	83.27	83.53	82.79	82.66	83.04	82.52				83.28	82.88	81.04	81.24	83.12	83.10
	Ref	14	22.75	83.42	83.49	83.33	83.15	83.16	84.08	83.31	83.25	83.72	83.44	84.10	83.54	83.30	83.76	83.49	84.07	85.48	84.55	84.60	84.76	86.01	86.22	84.12	83.95				85.18	86.83	84.58	85.39	86.90	86.05

AVE TEMP (50A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		1	99.09	97.98	98.38	96.49	96.29	96.22	96.29	96.62	95.90	94.68	94.80	95.19	94.67	94.22	93.82	94.56	95.24	94.85	95.27	95.51	94.83	95.38	94.79	94.84	93.99	Power Outage			94.89	94.26	94.24	94.20	94.00	93.87
	1	2	78.62	77.88	78.84	77.46	77.72	77.86	77.92	78.29	77.87	76.79	76.90	77.39	76.91	76.46	76.14	76.80	77.45	77.10	77.47	77.66	76.99	77.46	76.86	77.13	76.46				77.03	76.21	76.26	76.30	76.08	75.89
		3	87.84	88.16	88.53	88.23	88.08	88.11	88.28	89.15	88.37	87.83	87.96	88.17	88.13	88.01	88.27	88.92	88.91	88.76	89.17	89.46	89.14	89.83	89.40	88.87	88.33				89.35	89.23	89.23	89.66	89.13	89.13
	2	4	74.75	75.56	76.47	75.77	76.01	76.19	76.27	76.75	76.46	75.81	76.07	76.44	76.22	76.03	75.91	76.52	77.05	76.92	77.14	77.29	76.93	77.37	76.97	76.95	76.55				77.40	77.13	77.02	77.23	76.91	76.87
		5	85.18	85.31	86.02	84.86	84.92	85.09	85.23	85.58	85.08	84.29	84.65	84.97	84.72	84.37	84.00	84.77	85.68	85.51	85.55	85.51	85.35	85.90	85.44	85.27	84.63				85.15	85.01	84.98	85.35	84.70	84.57
	3	6	89.99	89.95	90.10	89.68	89.52	89.54	89.60	89.92	89.43	89.14	89.38	89.37	89.34	89.25	89.24	89.79	90.18	90.00	90.00	89.89	89.87	90.32	89.99	89.55	89.44				89.70	89.75	89.67	90.16	89.29	89.23
	Ref	7	83.50	85.01	86.15	85.57	85.88	86.06	86.26	86.37	86.24	85.89	86.32	86.57	86.42	86.21	85.84	86.43	87.54	87.24	87.07	86.83	86.84	87.13	86.83	86.82	86.54				86.65	86.66	86.39	86.75	86.16	86.09
WAGO		8	78.35	79.13	79.27	78.39	78.35	78.06	77.90	77.38	77.23	77.29	77.47	77.56	77.44	77.45	77.14	77.46	78.23	77.77	77.39	76.77	76.84	76.80	76.83	76.98	76.73				76.63	76.32	76.04	75.97	75.51	75.42
	4	9	84.58	85.48	86.36	85.50	85.75	85.54	85.61	85.08	84.72	84.50	84.67	84.86	84.45	84.21	83.69	84.00	84.92	84.05	83.52	82.87	82.82	82.80	82.74	82.61	81.91				80.89	80.74	80.41	80.61	79.86	79.65
		10	83.91	85.12	86.05	85.11	85.40	85.17	85.01	84.69	84.79	84.74	85.01	85.30	85.06	84.91	84.51	84.81	85.78	84.94	84.53	84.03	84.08	84.17	84.11	84.43	84.03				84.44	84.26	83.59	83.64	83.85	83.81
	5	11	80.26	80.70	81.22	80.18	80.42	80.17	79.78	79.44	79.60	79.51	79.76	80.01	79.81	79.68	79.25	79.58	80.47	79.72	79.44	79.06	78.99	79.14	78.99	79.44	78.90				78.97	78.61	77.87	77.75	78.20	78.18
		12	82.32	82.81	83.38	82.23	82.52	82.39	81.93	81.68	81.73	81.45	81.71	82.35	82.02	81.68	81.38	81.71	82.58	82.39	81.91	81.77	81.72	81.78	81.45	81.81	80.94				82.08	81.76	80.74	80.37	81.44	81.64
	6	13	85.70	86.01	86.62	85.59	85.98	85.86	85.30	84.99	85.27	85.14	85.34	85.96	85.64	85.40	85.22	85.48	86.23	86.10	85.59	85.45	85.37	85.27	85.02	85.68	85.04				85.73	85.16	83.85	83.47	84.99	85.23
	Ref	14	84.72	85.98	87.39	86.49	86.92	87.91	88.34	89.19	88.00	86.86	87.38	88.68	88.21	87.26	87.03	87.49	88.69	89.53	89.36	89.39	89.47	90.37	89.71	89.12	87.38				88.84	89.23	88.46	87.94	88.82	89.13

MAX TEMP (30A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		15	68.57	62.14	61.07	60.48	60.15	59.65	59.37	58.88	59.40	59.21	59.03	59.59	59.52	59.65	59.99	60.38	60.45	59.45	59.20	58.92	58.77	58.79	58.81	58.92	59.54	Power Outage			59.22	59.20	59.03	57.81	58.09	58.50
	7	16	70.43	68.41	67.93	68.09	68.43	67.89	67.69	67.60	68.16	68.53	68.28	68.40	68.92	69.05	69.48	69.99	69.51	68.90	68.62	68.40	68.22	68.39	68.44	68.78	69.62				69.42	69.18	69.09	67.95	68.09	68.48
		17	80.39	65.87	64.23	64.36	64.12	64.12	63.84	63.72	63.63	63.62	63.27	63.19	63.31	63.70	64.09	64.17	63.63	62.92	62.82	62.44	62.19	62.22	61.94	62.91	62.70				61.81	61.15	61.09	59.86	59.84	60.07
	8	18	85.75	73.23	72.38	72.61	72.10	71.52	71.15	70.74	71.21	71.51	70.95	71.21	71.18	71.59	71.92	71.56	71.49	70.52	70.30	69.77	69.93	70.05	70.06	70.05	70.87				69.84	69.72	69.64	68.99	68.71	68.62
		19	65.78	64.66	64.04	64.77	64.75	63.82	63.62	63.56	63.54	63.56	63.63	63.38	63.44	63.94	64.33	64.51	64.62	63.36	63.50	63.00	63.26	63.48	63.70	63.34	63.57				63.36	63.25	62.99	62.38	62.04	61.95
	9	20	66.27	65.63	64.73	65.12	65.13	64.40	63.75	63.91	63.97	64.18	64.01	63.92	63.94	64.15	64.53	64.88	64.45	63.56	63.36	63.26	63.32	63.22	63.41	63.25	63.63				63.27	63.16	63.19	62.11	61.91	62.00
	Ref	21	67.20	67.35	66.97	67.88	67.89	67.24	67.55	67.53	67.24	66.93	67.88	67.56	67.55	67.87	68.14	68.77	68.16	68.30	68.23	67.37	68.14	67.45	68.48	67.70	67.67				68.10	68.36	67.75	67.62	67.07	67.07
WAGO		22	65.17	64.36	64.07	64.63	64.25	63.61	63.37	63.14	62.95	62.40	63.08	63.02	63.03	63.12	63.70	63.99	63.60	63.24	63.14	62.71	62.44	62.43	62.68	62.38	62.81				62.04	61.98	61.88	61.51	61.12	61.12
	10	23	68.15	67.25	66.94	67.10	66.98	66.28	65.89	65.83	65.73	65.47	65.73	65.81	65.53	65.73	66.41	66.67	66.20	65.39	65.46	64.95	64.75	64.86	64.97	64.77	65.26				64.25	64.38	64.25	63.67	63.45	63.45
		24	65.42	64.44	64.92	64.86	64.90	64.75	64.43	64.46	64.20	64.16	64.51	64.42	64.44	64.71	65.24	65.05	64.99	64.41	64.53	64.13	63.94	63.86	63.69	63.81	64.36				63.36	63.76	63.50	63.13	63.11	63.11
	11	25	64.28	61.42	61.21	61.24	61.13	60.69	60.29	60.28	60.01	60.01	60.27	60.29	60.44	59.64	59.79	59.84	59.96	59.49	59.24	58.74	58.55	58.60	58.17	58.42	58.97				57.57	57.58	57.45	57.45	56.89	56.89
		26	64.38	63.89	64.46	64.34	64.05	63.46	63.45	63.50	63.01	62.61	63.23	63.18	63.08	63.01	63.75	63.17	63.81	62.80	63.06	62.42	61.96	62.39	61.92	62.32	62.88				61.77	61.14	60.99	60.83	60.72	60.72
	12	27	67.34	67.23	67.54	67.26	67.17	67.19	66.53	66.41	65.93	65.99	66.46	66.16	66.28	66.03	66.53	66.53	66.88	66.02	65.95	65.53	65.04	65.08	65.23	65.31	66.17				64.83	64.29	64.23	64.03	63.79	63.79
	Ref	28	60.36	60.63	61.31	61.58	61.70	61.36	60.77	60.95	60.41	60.41	61.25	61.03	61.14	60.78	61.20	61.14	61.63	60.92	61.26	60.79	60.38	60.18	60.48	60.56	60.90				60.27	60.70	60.18	59.65	59.69	59.69
Gardner Bender		29	62.68	62.96	63.23	62.97	63.25	62.90	62.67	62.94	62.30	62.38	62.95	62.66	63.07	62.67	63.11	62.55	63.57	63.03	62.65	62.57	62.16	62.00	62.31	62.55	62.56				61.79	61.47	61.62	61.09	60.97	60.97
	13	30	64.06	64.02	64.43	64.32	64.44	64.32	64.04	64.15	63.91	63.98	64.28	64.22	64.51	64.26	64.75	64.44	65.41	64.22	64.25	64.16	63.74	63.55	64.06	64.11	64.33				63.81	63.81	63.91	63.13	63.08	63.08
		31	67.09	66.75	67.66	67.43	67.57	67.25	67.46	67.18	66.81	66.98	67.50	67.36	67.36	67.46	67.60	67.32	68.12	67.12	67.60	67.16	66.68	66.65	67.04	67.10	67.15				67.34	66.88	67.05	66.51	66.23	66.23
	14	32	No Data	67.16	67.72	67.56	67.82	67.27	67.57	67.43	66.98	67.55	67.95	67.50	67.50	67.33	67.63	67.41	68.28	67.21	67.96	67.42	66.89	66.79	67.33	67.49	67.43				67.86	66.79	66.94	66.31	66.25	66.25
		33	No Data	68.57	68.92	68.71	68.94	68.61	68.47	68.64	68.06	68.67	68.83	68.89	68.52	68.42	68.78	68.61	68.92	67.98	68.57	68.39	67.78	67.47	68.01	68.15	67.96				68.29	67.33	67.37	66.91	66.81	66.81
	15	34	No Data	65.91	65.94	65.52	65.62	65.33	65.00	64.92	64.42	64.83	65.17	65.19	64.34	64.53	64.76	64.51	64.68	63.67	64.28	64.26	63.49	63.09	63.76	63.87	63.44				63.23	62.80	62.35	61.87	61.92	61.92
	Ref	35	No Data	65.03	65.01	64.45	64.81	64.77	64.45	64.50	64.22	64.68	64.79	64.49	64.74	64.36	64.70	64.42	65.08	64.28	64.36	64.39	64.27	63.92	63.98	64.55	64.63				64.18	64.33	64.26	63.69	63.50	63.50

MIN TEMP (30A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		15	22.77	57.58	56.18	55.47	56.17	56.05	54.30	56.03	54.67	55.31	54.34	54.49	56.15	55.24	55.12	54.89	55.83	55.52	53.60	56.59	55.37	54.74	56.06	54.83	54.52	Power Outage			56.05	55.18	53.01	53.28	55.20	55.76
	7	16	22.75	64.48	64.38	63.99	64.72	64.79	63.90	65.26	64.38	65.44	64.65	64.53	66.23	65.24	65.00	64.95	65.76	66.08	64.69	65.90	66.02	65.34	65.89	65.79	65.72				66.20	66.45	63.80	64.49	66.06	66.17
		17	22.72	60.87	60.38	60.22	60.35	60.73	60.20	60.58	59.82	60.60	59.59	60.37	60.44	59.53	59.53	59.51	59.88	59.76	59.66	59.65	59.09	59.07	59.20	59.21	58.97				58.75	58.51	56.75	56.91	57.43	57.44
	8	18	22.73	69.00	69.03	68.30	68.23	68.70	68.06	68.73	67.88	68.03	67.70	67.69	68.59	67.68	67.31	66.96	67.95	67.89	67.32	68.39	68.31	67.35	68.10	67.69	66.99				67.27	67.55	64.94	65.56	67.07	67.37
		19	22.73	59.98	60.15	59.82	59.93	60.23	60.98	60.99	59.94	59.98	59.26	60.02	59.92	59.93	60.20	59.29	60.47	59.96	60.62	61.18	60.87	60.36	60.73	60.00	59.11				60.39	60.55	58.06	58.78	60.52	60.37
	9	20	22.70	61.16	61.38	61.20	61.55	61.51	61.68	61.04	60.78	60.90	60.68	61.06	60.54	61.25	60.92	60.34	61.25	61.27	61.53	61.29	61.40	60.79	61.06	60.77	60.38				60.64	60.93	59.00	59.81	60.22	60.27
	Ref	21	23.00	62.21	62.84	62.36	63.25	63.69	64.05	64.89	63.00	62.62	63.53	62.58	64.50	63.99	63.41	63.48	63.79	64.67	64.44	65.95	65.58	64.06	64.49	63.65	62.50				64.62	64.74	61.88	62.35	63.63	63.63
WAGO		22	23.02	59.21	59.42	58.74	58.99	59.38	59.33	60.21	58.13	57.78	58.80	57.64	59.60	58.67	57.99	58.01	58.48	58.96	58.93	60.69	60.04	57.83	58.84	58.02	56.75				58.68	58.52	56.02	56.86	57.95	57.95
	10	23	23.00	62.52	62.21	61.72	61.82	61.94	62.50	63.04	60.80	60.67	61.60	60.52	62.47	61.55	60.96	60.80	61.47	61.81	61.33	63.19	62.51	60.66	61.53	60.82	59.77				61.51	61.43	59.00	59.92	60.68	60.68
		24	23.02	60.65	60.80	60.62	60.81	61.46	60.99	61.87	60.15	60.26	60.59	59.96	61.62	60.89	60.49	60.46	60.95	61.58	61.47	62.36	61.67	60.51	60.98	60.13	59.75				60.48	60.99	58.22	59.69	59.84	59.84
	11	25	23.07	57.07	56.58	56.68	56.69	56.88	56.66	57.07	56.35	55.85	56.35	55.84	56.70	55.53	54.59	54.30	55.11	55.45	55.37	56.38	55.05	54.50	53.48	53.09	52.24				52.13	53.09	50.44	50.89	51.40	51.40
		26	23.05	58.73	58.77	58.40	59.00	58.48	58.52	59.16	57.75	57.96	57.86	57.39	58.41	58.42	57.88	57.79	58.09	58.42	58.22	60.13	58.57	57.41	57.14	57.18	57.05				57.66	57.98	55.59	56.70	56.63	56.63
	12	27	23.02	62.05	62.29	61.74	62.48	62.06	62.35	62.57	61.59	61.31	61.82	61.22	61.92	61.95	61.74	61.41	61.80	62.12	61.41	63.02	62.21	61.25	61.29	60.89	60.91				61.45	61.74	59.33	60.39	60.26	60.26
	Ref	28	23.05	55.09	54.46	54.76	56.16	55.22	55.92	56.42	55.98	55.79	56.10	55.70	56.37	55.77	56.14	56.02	55.91	56.25	56.33	57.81	56.53	55.96	55.80	55.62	55.48				56.30	57.54	55.38	55.88	56.27	56.27
Gardner Bender		29	23.03	56.09	55.54	55.72	56.34	55.68	56.74	56.71	56.14	55.32	56.25	56.46	57.26	57.41	56.92	56.71	56.27	56.76	55.89	59.38	58.23	56.04	55.97	55.91	56.04				56.30	57.15	55.72	56.01	56.10	56.10
	13	30	23.00	58.88	58.14	58.57	58.60	58.83	59.15	59.75	58.92	57.87	59.21	59.46	60.23	60.13	59.37	59.43	58.80	59.60	59.40	61.86	60.54	59.05	59.15	58.59	58.51				59.47	60.48	58.94	59.36	59.27	59.27
		31	22.91	60.43	59.64	59.94	60.71	60.63	61.05	62.26	59.81	59.70	60.51	60.80	62.60	60.70	61.36	60.98	59.79	61.30	60.67	63.95	62.40	60.33	60.62	60.06	60.39				61.77	62.93	61.23	62.62	62.11	62.11
	14	32	No Data	59.91	59.38	59.83	60.02	59.62	60.37	61.40	59.30	59.39	60.35	60.12	61.55	60.39	60.74	60.75	59.19	60.49	59.97	63.98	61.42	59.87	59.67	59.61	60.27				60.89	62.15	60.49	61.70	61.62	61.62
		33	No Data	63.35	62.04	61.80	61.88	61.90	61.99	62.92	61.26	61.57	61.88	62.11	62.91	61.98	62.67	62.15	60.99	61.71	61.53	64.55	62.26	61.06	60.82	60.58	61.22				61.39	62.68	61.00	62.39	61.60	61.60
	15	34	No Data	60.13	58.82	58.25	58.86	58.51	58.42	59.14	57.44	57.34	57.62	58.39	59.05	57.74	57.98	58.19	56.76	57.66	56.81	60.03	58.20	56.55	56.50	55.56	55.44				56.14	57.06	55.99	56.96	55.70	55.70
	Ref	35	No Data	60.01	59.16	59.60	59.57	59.61	59.71	60.18	58.88	59.50	59.28	59.95	59.52	59.73	59.97	60.38	59.10	58.74	59.26	60.50	60.06	58.98	58.66	58.36	58.92				59.41	60.12	59.63	59.35	58.66	58.66

AVE TEMP (30A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		15	62.96	60.51	59.09	58.64	58.55	58.25	57.68	57.73	57.72	57.76	57.63	57.85	57.93	58.04	58.29	58.21	58.34	58.07	57.93	57.80	57.58	57.76	57.69	57.76	57.73	Power Outage			59.22	57.62	56.55	56.00	56.89	57.06
	7	16	67.80	67.05	66.52	66.72	67.00	66.93	66.45	66.53	66.95	67.25	67.21	67.42	67.59	67.88	68.24	68.24	68.21	67.75	67.55	67.36	67.19	67.48	67.42	67.79	67.99				69.42	67.95	66.93	66.42	66.93	67.03
		17	65.55	63.34	62.66	62.44	62.62	62.72	62.34	62.15	62.25	62.03	62.00	62.05	61.92	62.11	62.30	62.10	62.14	61.56	61.34	61.00	60.65	60.79	60.65	60.82	61.01				61.81	59.87	59.11	58.38	58.57	58.64
	8	18	72.98	71.28	70.57	70.55	70.48	70.28	70.02	69.91	70.01	69.88	69.74	69.80	69.82	69.95	70.20	70.00	69.97	69.67	69.44	69.16	69.10	69.11	69.09	69.06	69.14				69.84	69.06	68.06	67.76	68.03	67.95
		19	63.36	62.65	62.53	62.52	62.73	62.50	62.45	62.39	62.30	61.91	61.96	62.23	62.15	62.32	62.58	62.54	62.77	62.48	62.45	62.21	62.22	62.17	62.22	61.94	61.95				63.36	62.22	61.24	61.17	61.36	61.25
	9	20	64.35	63.60	63.29	63.26	63.34	63.07	62.88	62.78	62.81	62.52	62.54	62.70	62.65	62.83	63.13	63.09	63.19	62.76	62.60	62.31	62.28	62.29	62.31	62.13	62.27				63.27	62.29	61.49	61.17	61.22	61.14
	Ref	21	65.33	65.41	65.85	65.71	66.26	66.08	66.19	66.19	66.07	65.58	65.93	66.17	66.12	66.26	66.37	66.42	66.89	66.77	66.78	66.63	66.65	66.55	66.71	66.31	66.16				66.59	66.86	65.65	65.71	65.95	65.95
WAGO		22	62.58	62.44	62.80	61.98	62.48	62.15	62.07	62.04	61.67	61.03	61.45	61.71	61.48	61.61	61.48	61.32	62.01	61.72	61.86	61.82	61.52	61.28	61.37	60.96	60.86				60.90	60.92	59.73	59.76	60.04	60.04
	10	23	65.64	65.47	65.60	64.63	65.20	64.92	64.80	64.78	64.42	63.80	64.13	64.42	64.17	64.35	64.27	64.02	64.64	64.24	64.35	64.21	63.92	63.69	63.75	63.36	63.34				63.25	63.32	62.29	62.28	62.38	62.38
		24	62.85	62.98	63.65	62.98	63.64	63.54	63.40	63.47	63.15	62.78	63.10	63.34	63.28	63.35	63.31	63.07	63.61	63.34	63.55	63.38	63.05	62.88	62.86	62.53	62.58				62.49	62.61	61.70	61.80	62.13	62.13
	11	25	60.31	59.35	59.79	58.99	59.56	59.36	59.24	59.28	58.79	58.22	58.79	59.04	58.79	58.17	57.52	57.30	58.21	57.78	57.87	57.78	57.34	57.14	56.83	56.32	56.22				55.87	55.74	54.77	54.79	55.06	55.06
		26	61.30	61.24	62.45	61.23	62.06	61.91	61.71	61.85	61.09	60.53	61.16	61.49	61.14	61.05	60.66	60.49	61.54	60.94	61.26	61.34	60.62	60.45	60.37	60.09	60.02				59.91	59.63	58.84	58.80	59.08	59.08
	12	27	64.19	64.20	65.46	64.30	65.14	65.04	64.94	65.02	64.40	63.79	64.39	64.74	64.38	64.37	64.07	63.95	64.87	64.32	64.61	64.56	63.94	63.78	63.81	63.45	63.48				63.25	63.17	62.48	62.41	62.46	62.46
	Ref	28	57.47	57.72	59.09	58.44	59.26	59.15	59.27	59.36	58.80	58.33	58.93	59.20	58.99	58.84	58.73	58.77	59.52	59.09	59.48	59.57	59.11	58.86	59.06	58.71	58.72				58.86	59.03	58.42	58.40	58.24	58.24
Gardner Bender		29	59.04	59.48	60.89	59.71	60.70	60.60	60.86	61.05	60.32	59.90	60.47	60.80	60.67	60.35	59.91	59.73	60.83	60.31	60.81	61.18	60.45	60.09	60.32	59.77	59.83				60.09	60.18	59.40	59.29	59.51	59.51
	13	30	61.18	61.58	62.66	61.75	62.61	62.55	62.75	62.87	62.33	62.03	62.47	62.80	62.70	62.55	62.34	62.20	63.04	62.60	62.93	63.07	62.49	62.26	62.41	61.99	62.09				62.39	62.52	62.00	61.85	61.81	61.81
		31	63.63	63.96	65.26	64.15	65.12	65.04	65.34	65.44	64.75	64.54	65.02	65.35	65.21	65.00	64.67	64.27	65.35	64.76	65.45	65.88	65.13	64.65	64.98	64.41	64.43				65.27	65.47	64.84	64.91	64.89	64.89
	14	32	No Data	63.57	65.09	63.76	64.90	64.80	65.09	65.19	64.44	64.24	64.79	65.13	64.99	64.75	64.32	63.82	65.05	64.37	65.16	65.82	64.91	64.39	64.71	64.11	64.22				64.99	65.13	64.34	64.41	64.70	64.70
		33	No Data	65.59	66.72	65.43	66.31	66.22	66.48	66.49	65.93	65.90	66.23	66.44	66.42	66.17	65.90	65.39	66.31	65.78	66.30	66.80	65.80	65.37	65.62	65.14	65.21				65.49	65.58	64.95	64.84	65.21	65.21
	15	34	No Data	62.85	63.73	62.23	62.91	62.69	62.89	62.83	62.23	62.07	62.30	62.46	62.31	61.95	61.63	61.10	62.03	61.39	61.86	62.18	61.33	60.82	61.15	60.53	60.50				60.27	60.41	59.78	59.66	59.80	59.80
	Ref	35	No Data	62.16	63.09	62.21	62.62	62.54	62.89	62.73	62.44	62.48	62.65	62.65	62.71	62.43	62.40	62.23	62.79	62.57	62.68	62.86	62.34	61.95	62.30	61.97	62.19				62.37	62.49	62.19	61.90	61.74	61.74

MAX TEMP (20A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		36	No Data	62.13	61.46	60.56	60.29	60.59	59.48	59.07	58.70	58.95	58.83	58.72	58.61	58.78	58.97	59.81	58.95	58.60	57.88	57.27	57.12	57.72	57.02	57.49	58.02	Power Outage			55.94	56.39	55.77	54.77	54.71	54.52
	16	37	No Data	61.55	61.48	60.69	60.29	60.42	59.33	58.77	58.49	59.20	58.83	58.91	58.80	58.85	59.36	60.28	58.72	58.39	57.21	57.18	56.89	56.21	56.79	57.72	57.67				56.06	55.89	55.26	55.12	54.70	54.71
		38	No Data	53.15	53.64	52.80	52.67	53.02	52.45	52.11	52.09	52.60	52.50	52.54	52.74	52.96	53.10	53.16	52.74	53.18	52.53	51.91	51.67	51.18	51.62	52.10	52.53				52.03	51.42	52.15	51.49	50.43	50.66
	17	39	No Data	53.55	53.88	53.02	53.33	53.47	52.88	52.47	52.77	53.33	53.18	53.27	53.13	53.11	53.64	53.92	53.68	53.27	53.14	52.67	52.14	51.76	52.10	52.54	53.11				52.15	51.65	52.10	51.53	50.89	51.19
		40	No Data	58.52	58.37	57.97	57.89	58.17	58.29	57.23	57.63	57.96	57.56	57.85	57.78	58.40	58.14	58.80	58.13	58.01	57.80	57.28	56.80	56.33	57.45	57.09	57.96				57.14	56.87	57.52	57.04	56.10	55.62
	18	41	56.13	55.83	55.29	55.13	55.00	55.35	55.29	54.68	54.99	55.53	54.95	55.10	55.40	55.49	55.95	56.23	55.65	55.32	55.43	54.40	54.26	54.25	54.91	54.95	55.22				55.24	55.27	55.11	55.20	54.01	53.78
	Ref	42	56.42	56.74	56.50	56.62	56.33	56.28	56.37	56.22	55.96	56.23	56.48	56.54	56.60	56.96	57.50	58.27	57.01	56.53	56.28	55.38	55.46	55.50	55.62	56.07	57.18				56.25	56.25	55.48	55.38	54.02	53.94
WAGO		43	53.75	53.87	53.82	54.10	53.50	53.57	53.50	52.85	53.41	53.48	53.44	53.31	53.17	53.72	54.38	54.62	54.30	54.03	53.64	53.09	52.91	52.87	53.25	53.21	54.05				53.32	53.22	53.29	52.33	51.90	51.89
	19	44	55.89	55.65	55.78	55.82	55.25	55.40	55.26	54.84	55.04	55.27	55.32	54.92	54.82	55.36	56.26	56.63	56.03	55.85	54.97	54.46	54.50	54.34	54.62	54.71	56.00				54.68	54.77	54.47	53.68	53.04	53.04
		45	52.99	52.56	52.37	52.78	52.28	52.39	51.91	51.41	52.14	51.95	52.12	51.92	51.77	52.32	52.70	53.38	53.05	52.99	52.06	51.45	51.56	51.28	51.61	52.00	52.99				51.71	51.64	51.68	51.02	50.29	50.59
	20	46	57.96	57.96	58.00	58.20	57.49	57.50	57.34	56.82	56.96	56.99	57.24	57.16	56.95	57.64	57.95	58.84	58.49	58.11	57.46	56.50	56.58	56.79	56.97	56.85	58.01				56.80	56.91	56.95	56.39	55.60	55.52
		47	53.18	53.28	53.38	53.69	53.55	53.35	53.31	52.74	53.21	53.00	53.30	53.27	52.91	53.47	53.94	54.55	54.36	54.40	53.55	53.10	53.19	53.37	53.15	53.33	54.35				53.02	52.94	52.99	52.49	52.10	51.88
	21	48	55.56	56.03	55.79	56.28	55.54	55.68	55.56	55.06	55.50	55.52	55.63	55.69	55.57	56.12	56.31	57.52	56.93	56.43	55.72	55.31	55.22	55.68	55.18	55.82	57.01				55.40	55.08	55.32	55.19	54.29	54.10
	Ref	49	59.88	59.48	59.52	59.78	59.74	59.54	59.32	58.76	59.02	59.55	59.43	59.60	59.70	60.14	60.29	61.11	60.15	60.55	59.73	58.64	59.01	59.14	58.71	59.67	60.63				59.49	57.94	57.98	57.35	57.49	57.67
Gardner Bender		50	59.35	59.42	59.95	60.32	60.10	59.65	59.22	59.17	59.70	59.58	59.53	59.91	59.58	60.30	60.72	61.01	61.32	61.23	60.14	59.45	59.70	60.72	60.05	60.38	61.19				59.47	59.21	59.74	58.66	58.40	58.24
	22	51	61.96	61.58	61.77	62.22	61.85	61.58	60.92	60.99	61.25	61.51	61.27	61.81	61.27	62.80	62.52	63.28	62.56	62.82	61.88	61.01	60.90	62.66	62.00	62.71	63.59				61.36	60.54	61.33	59.95	59.91	59.67
		52	66.06	66.79	68.72	70.24	70.50	70.99	70.27	69.62	69.82	69.78	69.56	69.39	68.80	69.02	68.78	69.45	69.11	69.08	68.03	66.70	66.93	68.02	67.48	67.56	67.48				65.92	65.69	65.37	64.75	64.53	64.40
	23	53	64.35	65.25	66.55	68.23	68.67	68.51	67.96	67.56	67.49	67.69	67.29	67.03	66.68	66.49	66.51	66.98	66.88	66.84	65.76	64.83	64.73	65.30	65.00	65.00	65.02				63.50	63.06	63.04	62.42	62.02	61.88
		54	55.36	54.87	55.50	56.30	55.60	55.79	55.48	55.15	55.71	55.81	55.94	55.96	55.13	56.22	56.19	56.60	57.05	57.12	56.81	54.97	56.06	56.35	56.19	56.09	56.92				55.52	54.86	54.79	54.18	54.23	54.17
	24	55	56.03	55.91	56.35	57.15	56.61	56.65	56.36	55.93	56.44	56.83	56.78	56.76	56.16	57.08	57.02	57.72	57.82	58.08	57.58	55.95	56.97	57.32	57.03	56.86	57.98				56.51	55.73	55.96	55.38	55.18	55.26
	Ref	56	57.85	57.34	58.14	58.45	58.11	58.29	57.80	57.79	58.00	58.26	58.49	58.19	57.91	58.52	58.96	59.31	59.46	59.75	58.73	58.07	58.74	58.89	58.86	58.61	59.32				58.52	58.03	57.79	57.42	57.41	57.28

MIN TEMP (20A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		36	No Data	59.35	58.63	57.86	57.56	57.20	56.72	56.52	55.94	56.36	56.49	56.26	56.20	56.30	56.63	56.66	56.30	55.87	55.43	54.74	54.82	54.93	54.79	55.20	55.26	Power Outage			54.14	53.70	52.99	52.13	52.45	52.29
	16	37	No Data	57.79	57.06	56.48	56.14	55.91	55.38	55.24	55.21	55.24	55.15	55.20	55.05	55.24	55.58	55.58	55.34	54.86	54.43	53.72	53.84	53.79	53.38	54.02	54.44				53.12	52.87	52.22	51.82	51.65	51.61
		38	No Data	49.75	49.98	49.67	49.75	49.31	49.02	48.63	49.23	49.38	49.51	49.41	49.51	50.28	50.34	50.40	50.06	49.63	49.53	49.25	48.51	48.91	48.37	49.05	49.95				48.12	48.34	48.27	47.40	47.43	47.71
	17	39	No Data	50.82	50.92	50.31	49.90	49.96	49.24	49.84	50.10	50.56	49.98	50.29	50.27	50.79	51.28	50.99	50.57	49.91	49.81	49.54	48.94	49.36	48.70	49.30	50.66				48.65	48.64	48.11	47.65	47.82	48.16
		40	No Data	55.18	55.29	54.75	54.41	54.78	53.98	54.16	53.99	54.52	54.21	54.25	54.66	54.96	55.24	55.12	53.62	54.03	53.64	53.63	52.40	53.14	52.87	52.99	54.58				53.13	52.93	53.08	52.44	52.17	52.41
	18	41	22.86	52.29	52.65	52.48	52.14	52.15	51.89	51.58	52.03	51.88	52.19	52.23	52.31	52.52	53.15	53.36	52.73	51.94	52.08	51.26	51.32	51.46	50.98	51.87	52.47				51.54	51.62	50.85	51.01	50.33	50.86
	Ref	42	22.88	52.07	53.43	52.73	52.59	52.26	52.30	52.58	52.32	52.32	53.09	53.11	52.81	51.80	52.71	51.32	53.41	52.17	52.87	51.55	52.17	51.97	52.11	52.48	52.22				52.56	51.63	51.30	51.25	50.30	50.80
WAGO		43	22.90	50.19	51.07	49.83	50.72	51.22	50.90	51.03	51.03	51.32	50.99	51.53	51.32	50.32	50.18	49.22	50.40	51.92	51.73	51.02	51.08	51.13	51.25	51.43	50.34				51.31	50.96	50.69	50.04	49.93	50.16
	19	44	22.88	51.23	52.25	50.87	51.42	52.09	52.41	52.35	51.81	52.44	51.92	52.60	52.11	51.11	50.86	49.83	50.85	53.18	52.77	51.85	52.01	51.90	52.07	52.15	51.13				52.07	51.60	51.56	50.79	50.53	50.61
		45	22.88	48.73	49.44	48.31	48.85	49.19	48.74	49.27	49.56	49.69	49.07	49.80	49.36	47.50	47.44	47.56	48.58	50.38	49.96	49.51	49.51	49.52	49.61	49.98	48.48				49.70	49.40	49.33	48.42	48.46	48.58
	20	46	22.90	53.18	54.28	53.41	54.27	54.09	53.31	54.01	54.41	54.55	53.91	54.38	54.23	52.66	52.79	52.77	53.34	55.14	54.94	54.69	54.80	54.11	54.50	54.71	53.17				54.70	54.38	54.57	53.62	53.36	53.76
		47	22.86	48.90	49.92	49.34	49.38	49.73	49.55	49.88	50.21	50.20	48.87	50.15	50.08	48.36	48.97	48.64	49.93	51.04	50.75	50.99	50.82	51.28	51.08	51.13	49.94				50.66	51.01	51.08	50.49	49.96	50.68
	21	48	22.85	50.05	50.83	50.24	50.67	50.80	50.55	51.55	52.03	51.66	49.48	51.39	51.07	49.69	50.11	49.68	50.86	52.18	51.95	52.44	52.70	52.49	52.07	52.61	51.19				52.51	52.75	52.82	52.29	51.15	51.94
	Ref	49	22.85	52.31	53.12	52.11	52.79	53.02	53.25	53.67	54.19	53.43	51.96	53.91	53.11	51.78	51.67	52.72	53.34	54.64	53.62	54.57	54.76	54.82	55.01	54.57	53.48				54.76	54.54	54.22	53.79	53.82	54.81
Gardner Bender		50	22.82	53.04	53.91	53.59	54.27	54.49	54.33	54.51	54.63	54.22	54.16	54.86	54.70	53.55	53.28	53.89	54.27	55.96	55.18	55.14	55.77	55.23	56.24	55.22	55.05				56.33	55.73	55.79	56.51	55.47	56.24
	22	51	22.69	53.66	54.11	53.97	54.71	55.02	54.91	55.14	55.52	54.80	54.58	55.20	55.27	53.57	52.89	54.15	54.33	56.56	55.70	55.37	56.50	56.21	56.91	55.79	55.09				56.40	56.89	56.66	57.25	56.09	56.53
		52	22.70	59.15	60.30	61.39	63.00	63.46	63.42	63.63	63.43	62.55	62.30	62.46	62.06	60.52	60.60	60.90	60.69	62.22	61.00	61.81	61.94	61.57	61.16	60.35	59.99				61.06	60.99	60.05	61.57	60.52	61.33
	23	53	22.70	57.96	59.48	60.06	61.63	61.74	60.48	61.87	61.59	61.08	60.51	60.61	59.86	59.36	59.35	59.25	59.30	59.88	59.48	59.78	59.81	59.47	59.70	58.40	58.65				58.92	58.37	58.28	59.16	58.30	59.14
		54	22.69	48.53	48.73	48.85	49.31	49.08	49.33	49.87	49.51	49.40	49.07	49.17	49.49	48.35	48.21	49.38	49.25	50.09	49.37	50.31	50.26	50.98	50.13	50.68	49.76				50.34	50.89	50.78	50.81	50.87	50.56
	24	55	22.67	48.93	49.19	49.36	49.47	49.69	49.29	50.17	49.76	49.93	49.61	49.42	50.01	48.98	48.83	49.55	49.62	51.01	50.24	50.57	50.60	51.09	50.52	50.91	50.31				50.62	51.03	51.01	52.23	51.43	51.51
	Ref	56	22.67	50.30	50.45	50.53	50.97	50.51	50.98	51.60	50.90	51.36	51.00	51.29	51.42	50.75	51.16	51.15	51.30	52.26	51.60	51.74	51.74	52.88	52.04	52.03	51.84				52.01	53.03	53.29	52.89	52.51	53.01

AVE TEMP (20A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		36	No Data	60.77	59.99	59.24	58.80	58.40	58.00	57.49	57.52	57.76	57.57	57.30	57.23	57.33	57.76	57.80	57.64	57.23	56.62	55.92	55.94	55.93	55.88	56.18	56.41	Power Outage			55.04	54.76	54.33	53.61	53.61	53.38
	16	37	No Data	59.73	59.15	58.20	57.97	57.61	57.21	56.61	56.80	57.16	56.97	56.73	56.67	56.83	57.26	57.16	56.99	56.29	55.69	55.13	54.96	54.78	54.74	55.25	55.77				54.45	53.99	53.52	52.73	52.79	52.83
		38	No Data	51.64	51.53	51.16	51.23	51.05	50.88	50.46	50.78	51.23	51.13	51.05	51.16	51.32	51.72	51.89	51.78	51.21	50.92	50.47	50.25	50.03	50.05	50.54	51.13				50.27	50.05	50.06	49.36	48.98	49.14
	17	39	No Data	52.36	52.28	51.85	51.98	51.84	51.62	51.21	51.53	51.98	51.88	51.79	51.87	52.06	52.56	52.70	52.44	51.80	51.50	51.02	50.73	50.55	50.45	51.19	51.86				50.82	50.31	50.14	49.41	49.31	49.63
		40	No Data	57.10	56.83	56.46	56.37	56.22	56.18	55.59	55.98	56.44	56.20	56.06	56.21	56.40	56.80	56.96	56.68	56.18	55.89	55.15	55.04	54.84	54.94	55.52	56.13				55.55	55.12	55.25	54.72	53.96	54.04
	18	41	54.35	54.35	54.11	53.73	53.66	53.51	53.53	53.04	53.48	53.89	53.63	53.60	53.69	53.85	54.28	54.42	54.35	53.89	53.64	52.95	52.89	52.64	52.80	53.23	53.72				53.56	53.41	53.53	53.05	52.25	52.22
	Ref	42	54.46	54.97	54.95	54.71	54.71	54.56	54.52	53.98	54.20	54.69	54.53	54.54	54.65	54.74	55.27	55.60	55.45	55.02	54.56	53.63	53.65	53.55	53.64	54.24	54.82				54.09	53.61	53.64	53.01	52.33	52.35
WAGO		43	52.34	52.86	52.83	52.65	52.62	52.60	52.50	52.13	52.17	52.55	52.49	52.40	52.46	52.56	52.85	53.12	53.35	53.18	52.71	52.00	51.96	51.99	52.03	52.35	52.75				52.16	51.89	51.76	51.15	50.90	50.94
	19	44	53.85	54.41	54.30	54.00	53.94	53.89	53.83	53.35	53.46	53.91	53.75	53.66	53.72	53.80	54.13	54.38	54.58	54.37	53.78	53.02	52.99	52.96	52.95	53.43	53.89				53.19	52.78	52.71	52.01	51.65	51.73
		45	50.72	51.29	51.32	51.11	51.09	51.09	50.95	50.66	50.76	51.10	51.02	50.93	50.92	51.04	51.30	51.57	51.85	51.73	51.16	50.53	50.46	50.43	50.40	50.82	51.21				50.58	50.27	50.16	49.44	49.33	49.44
	20	46	55.98	56.52	56.48	56.35	56.23	56.22	56.14	55.79	55.84	56.15	56.05	55.95	55.94	56.04	56.30	56.56	56.87	56.79	56.22	55.57	55.55	55.52	55.52	55.84	56.16				55.66	55.47	55.45	54.85	54.58	54.61
		47	51.11	51.74	51.95	51.89	51.88	52.04	51.95	51.98	52.00	52.08	52.09	52.14	52.02	52.10	52.29	52.67	52.98	53.07	52.61	52.25	52.21	52.28	52.28	52.43	52.63				52.20	52.09	52.00	51.41	51.24	51.27
	21	48	52.89	53.69	53.92	53.82	53.79	54.02	53.95	53.96	54.15	54.19	54.09	54.18	54.06	54.11	54.26	54.64	54.97	55.03	54.55	54.19	54.18	54.16	54.18	54.41	54.71				54.26	54.06	54.03	53.42	53.12	53.16
	Ref	49	55.39	56.19	56.54	56.47	56.49	56.91	56.47	56.79	56.93	57.03	56.85	56.95	56.66	56.83	57.08	57.66	57.59	57.74	57.32	56.91	56.86	57.09	56.76	57.41	57.60				57.35	56.52	56.08	55.30	55.86	56.14
Gardner Bender		50	55.71	56.39	56.97	57.15	57.15	57.46	57.23	57.60	57.66	57.54	57.44	57.62	57.34	57.48	57.84	58.33	58.40	58.63	58.28	58.15	58.10	58.30	58.26	58.34	58.49				58.28	58.09	58.02	57.49	57.48	57.52
	22	51	57.01	57.72	58.08	58.21	58.23	58.63	58.29	58.74	58.92	58.77	58.59	58.80	58.43	58.63	59.01	59.53	59.52	59.77	59.39	59.19	59.16	59.37	59.28	59.54	59.74				59.43	59.11	58.93	58.28	58.38	58.45
		52	61.13	62.84	64.45	65.90	67.06	67.63	66.98	67.63	67.46	66.66	66.23	66.31	65.41	65.37	65.53	65.90	65.57	65.67	65.29	65.24	64.97	65.14	64.86	64.73	64.52				64.38	64.15	63.84	63.18	63.10	63.09
	23	53	60.07	61.53	62.97	64.21	65.24	65.72	65.02	65.67	65.39	64.69	64.29	64.34	63.48	63.40	63.57	63.87	63.60	63.66	63.37	63.36	63.05	63.27	62.97	62.78	62.55				62.09	61.88	61.63	61.02	60.93	60.90
		54	51.35	51.69	51.99	52.22	52.26	52.59	52.15	53.04	52.90	52.57	52.45	52.70	52.18	52.40	52.98	53.66	53.45	53.67	53.44	53.40	53.28	53.83	53.66	53.82	53.81				53.51	53.33	52.99	52.50	52.79	52.86
	24	55	51.67	52.13	52.52	52.75	52.78	53.22	52.76	53.77	53.72	53.26	53.14	53.43	52.83	53.04	53.59	54.30	54.07	54.37	54.23	54.30	54.19	54.70	54.52	54.63	54.56				54.52	54.43	54.18	53.65	53.87	53.96
	Ref	56	52.96	53.47	54.00	54.16	54.27	54.76	54.18	55.51	55.43	54.79	54.68	55.02	54.35	54.51	55.12	55.81	55.56	55.92	55.88	56.09	55.95	56.60	56.32	56.32	56.07				56.26	56.30	56.11	55.67	56.01	56.06

MAX TEMP (Ambient, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
50A																																				
IDEAL	1-3	1	23.37	23.48	23.45	23.95	23.75	23.61	23.47	23.24	23.33	23.51	23.61	23.55	23.58	23.74	24.22	24.47	24.45	24.44	24.16	23.67	23.68	23.65	23.62	23.84	24.15	24.10	23.45	23.10	23.61	23.43	23.42	22.93	22.84	22.87
WAGO	4-6	2	23.80	23.31	23.32	23.82	23.57	23.47	23.33	23.14	23.19	23.30	23.42	23.41	23.42	23.61	24.07	24.32	24.36	24.36	24.03	23.64	23.56	23.52	23.50	23.66	23.99	24.00	23.43	23.05	23.52	23.34	23.39	22.80	22.77	22.74
30A																																				
IDEAL	7-9	3	23.43	23.19	23.10	23.47	23.40	23.23	23.13	22.93	22.95	23.15	23.23	23.24	23.21	23.43	23.92	24.16	24.20	24.11	23.85	23.38	23.36	23.37	23.31	23.44	23.79	23.77	23.39	22.97	23.29	23.26	23.31	22.77	22.49	22.50
WAGO	10-12	4	23.59	23.19	23.13	23.49	23.41	23.26	23.11	22.92	22.96	23.18	23.27	23.24	23.25	23.51	23.98	24.25	24.16	24.08	23.84	23.38	23.33	23.33	23.28	23.40	23.85	23.80	23.38	22.97	23.23	23.22	23.28	22.75	22.51	22.49
Gardner Bender	13-15	5	23.66	23.21	23.15	23.67	23.49	23.31	23.12	22.92	23.06	23.21	23.30	23.28	23.25	23.56	24.04	24.38	24.19	24.08	23.84	23.37	23.28	23.35	23.27	23.44	24.01	23.82	23.43	23.12	23.21	23.18	23.24	22.73	22.47	22.46
20A																																				
IDEAL	16-18	6	23.58	23.28	23.22	23.76	23.53	23.36	23.16	23.03	23.10	23.31	23.37	23.38	23.38	23.65	24.11	24.30	24.28	24.21	23.93	23.48	23.35	23.44	23.36	23.54	23.97	23.92	23.43	23.10	23.28	23.17	23.23	22.72	22.55	No Data
WAGO	19-21	7	23.66	23.28	23.24	23.61	23.50	23.35	23.17	22.99	23.05	23.27	23.35	23.36	23.37	23.62	24.10	24.25	24.24	24.13	23.89	23.46	23.37	23.44	23.33	23.49	23.83	23.94	23.42	23.02	23.27	23.18	23.22	22.68	22.60	22.59
Gardner Bender	22-24	8	23.70	23.23	23.22	23.55	23.46	23.32	23.15	22.95	23.02	23.26	23.34	23.33	23.36	23.59	24.06	24.22	24.22	24.12	23.85	23.43	23.33	23.41	23.30	23.43	23.83	23.91	23.41	22.98	23.26	23.15	23.17	22.64	22.55	22.54

MIN TEMP (Ambient, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
50A																																				
IDEAL	1-3	1	22.86	23.21	23.18	23.24	23.38	23.21	23.09	23.04	22.91	23.06	23.28	23.23	23.27	23.39	23.69	24.13	24.13	23.99	23.67	23.31	23.28	23.39	23.31	23.36	23.63	23.42	22.87	22.71	22.65	23.16	22.61	22.37	22.37	22.49
WAGO	4-6	2	23.07	23.11	23.07	23.12	23.27	23.11	22.98	22.90	22.81	22.96	23.17	23.13	23.14	23.30	23.58	23.99	24.05	23.89	23.62	23.26	23.19	23.31	23.18	23.21	23.47	23.40	22.81	22.66	22.60	23.09	22.58	22.32	22.29	22.40
30A																																				
IDEAL	7-9	3	22.96	22.95	22.88	22.94	23.12	22.92	22.78	22.74	22.64	22.77	23.00	22.95	22.96	23.12	23.43	23.87	23.89	23.66	23.35	23.07	23.06	23.05	23.00	23.06	23.27	23.34	22.77	22.60	22.55	22.90	22.58	22.28	22.18	22.28
WAGO	10-12	4	22.96	22.99	22.92	22.97	23.15	22.94	22.78	22.71	22.66	22.82	23.03	22.98	22.99	23.13	23.47	23.91	23.92	23.68	23.32	23.06	23.07	23.05	23.01	23.03	23.27	23.35	22.79	22.63	22.55	22.89	22.61	22.26	22.21	22.28
Gardner Bender	13-15	5	22.98	22.99	22.91	22.99	23.15	22.94	22.78	22.71	22.64	22.84	23.01	22.98	22.99	23.13	23.50	23.95	23.90	23.66	23.34	23.06	23.06	23.03	22.98	23.03	23.30	23.37	22.82	22.70	22.57	22.87	22.58	22.21	22.19	22.27
20A																																				
IDEAL	16-18	6	23.06	23.04	23.00	23.05	23.24	23.03	22.82	22.79	22.71	22.95	23.11	23.05	23.07	23.21	23.61	24.07	24.02	23.74	23.44	23.15	23.10	23.16	23.05	23.09	23.37	23.39	22.83	22.70	22.54	22.95	22.55	22.20	22.22	No Data
WAGO	19-21	7	23.07	23.04	22.96	23.03	23.23	23.00	22.81	22.75	22.66	22.92	23.08	23.02	23.04	23.18	23.59	24.04	24.00	23.72	23.42	23.06	23.03	23.16	23.04	23.07	23.35	23.39	22.82	22.67	22.52	22.91	22.54	22.20	22.16	22.26
Gardner Bender	22-24	8	23.06	23.04	22.93	22.98	23.21	22.96	22.79	22.73	22.64	22.89	23.04	23.01	23.01	23.16	23.56	24.00	24.00	23.72	23.36	23.03	23.01	23.11	23.00	23.03	23.30	23.36	22.79	22.65	22.51	22.89	22.50	22.15	22.11	22.22

AVE TEMP (Ambient, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
50A																																				
IDEAL	1-3	1	23.23	23.31	23.29	23.44	23.51	23.41	23.26	23.16	23.07	23.28	23.41	23.40	23.42	23.58	23.99	24.28	24.29	24.18	23.92	23.57	23.47	23.51	23.43	23.58	23.86	23.69	23.24	22.92	23.29	23.28	23.14	22.73	22.68	22.69
WAGO	4-6	2	23.19	23.22	23.17	23.33	23.39	23.29	23.17	23.04	22.95	23.16	23.28	23.27	23.30	23.48	23.90	24.17	24.19	24.09	23.84	23.51	23.39	23.40	23.34	23.45	23.73	23.64	23.22	22.89	23.20	23.20	23.06	22.64	22.59	22.60
30A																																				
IDEAL	7-9	3	23.04	23.05	22.99	23.15	23.23	23.09	22.95	22.82	22.76	22.99	23.10	23.09	23.11	23.30	23.75	24.00	23.99	23.84	23.60	23.26	23.17	23.16	23.10	23.22	23.53	23.55	23.16	22.83	22.99	23.03	22.89	22.51	22.41	22.40
WAGO	10-12	4	23.06	23.07	23.02	23.18	23.26	23.11	22.96	22.83	22.78	23.02	23.13	23.11	23.13	23.33	23.78	24.04	24.01	23.83	23.60	23.27	23.18	23.17	23.10	23.24	23.56	23.56	23.16	22.84	23.00	23.01	22.88	22.50	22.40	22.40
Gardner Bender	13-15	5	23.07	23.08	23.02	23.20	23.26	23.12	22.96	22.82	22.78	23.03	23.14	23.11	23.13	23.34	23.80	24.07	24.02	23.84	23.59	23.24	23.16	23.15	23.08	23.25	23.59	23.59	23.22	22.91	23.00	22.98	22.85	22.46	22.37	22.37
20A																																				
IDEAL	16-18	6	23.18	23.17	23.09	23.26	23.35	23.23	23.04	22.92	22.86	23.13	23.23	23.22	23.24	23.46	23.94	24.20	24.17	23.95	23.71	23.34	23.23	23.25	23.16	23.36	23.68	23.65	23.20	22.90	23.06	23.04	22.89	22.47	22.43	No Data
WAGO	19-21	7	23.20	23.18	23.09	23.26	23.35	23.21	23.03	22.90	22.83	23.11	23.22	23.19	23.22	23.44	23.92	24.18	24.14	23.93	23.68	23.33	23.21	23.25	23.17	23.32	23.65	23.64	23.20	22.88	23.03	23.03	22.91	22.49	22.45	22.45
Gardner Bender	22-24	8	23.18	23.17	23.08	23.25	23.33	23.18	23.01	22.86	22.81	23.10	23.20	23.17	23.20	23.42	23.89	24.14	24.11	23.90	23.64	23.29	23.18	23.21	23.13	23.29	23.61	23.62	23.19	22.87	23.00	23.00	22.88	22.46	22.41	22.40

Public Comment No. 1739-NFPA 70-2018 [Section No. 310.21]

310.21 Ampacities of Bare or Covered Conductors in Free Air.

The maximum 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 (86°F) ambient temperature.

Table 310.~~16 (~~ 16 Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried)

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18**	—	—	14	—	—	—	—
16**	—	—	18	—	—	—	—
14**	15	20	25	—	—	—	—
12**	20	25	30	15	20	25	12**
10**	30	35	40	25	30	35	10**
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	445	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	555	665	750	470	560	630	2000

Notes:

1) Section 310.16 shall be referenced for conditions of use.

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

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

**~~Refer to~~ Section 240.4(D) shall be referenced for conductor overcurrent protection limitations.

Table 310.17 Ampacities of Single-Insulated Conductors in Free Air

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18	—	—	18	—	—	—	—
16	—	—	24	—	—	—	—
14**	25	30	35	—	—	—	—
12**	30	35	40	25	30	35	12**
10**	40	50	55	35	40	45	10**
8	60	70	80	45	55	60	8
6	80	95	105	60	75	85	6
4	105	125	140	80	100	115	4
3	120	145	165	95	115	130	3
2	140	170	190	110	135	150	2
1	165	195	220	130	155	175	1
1/0	195	230	260	150	180	205	1/0
2/0	225	265	300	175	210	235	2/0
3/0	260	310	350	200	240	270	3/0
4/0	300	360	405	235	280	315	4/0
250	340	405	455	265	315	355	250
300	375	445	500	290	350	395	300
350	420	505	570	330	395	445	350
400	455	545	615	355	425	480	400
500	515	620	700	405	485	545	500
600	575	690	780	455	545	615	600
700	630	755	850	500	595	670	700
750	655	785	885	515	620	700	750
800	680	815	920	535	645	725	800
900	730	870	980	580	700	790	900
1000	780	935	1055	625	750	845	1000
1250	890	1065	1200	710	855	965	1250
1500	980	1175	1325	795	950	1070	1500
1750	1070	1280	1445	875	1050	1185	1750
2000	1155	1385	1560	960	1150	1295	2000

Notes:

1) Section 310.17 shall be referenced for conditions of use.

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

**Section 240.4(D) shall be referenced for conductor overcurrent protection limitations.

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

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
14	34	36	39	—	14
12	43	45	54	30	12
10	55	60	73	44	10
8	76	83	93	57	8
6	96	110	117	75	6
4	120	125	148	94	4
3	143	152	166	109	3
2	160	171	191	124	2
1	186	197	215	145	1
1/0	215	229	244	169	1/0
2/0	251	260	273	198	2/0
3/0	288	297	308	227	3/0
4/0	332	346	361	260	4/0

Notes:

1) Section 310.18 shall be referenced for conditions of use.

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

* 3) Section 310.15(B) shall be referenced for ~~the~~ ampacity correction factors where the ambient temperature is other than 40°C (104°F).

Table 310.19 Ampacities of Single-Insulated Conductors in Free Air

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL, OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
14	46	54	59	—	14
12	60	68	78	47	12
10	80	90	107	63	10
8	106	124	142	83	8
6	155	165	205	112	6
4	190	220	278	148	4
3	214	252	327	170	3
2	255	293	381	198	2

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL, OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
1	293	344	440	228	1
1/0	339	399	532	263	1/0
2/0	390	467	591	305	2/0
3/0	451	546	708	351	3/0
4/0	529	629	830	411	4/0

Notes:

1) Section 310.19 shall be referenced for conditions of use.

* 2) Section 310.15(B) shall be referenced for ~~the~~ ampacity correction factors where the ambient temperature is other than 40°C (104°F).

Table 310.20 Ampacities of Conductors on a Messenger

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	75°C (167°F)	90°C (194°F)	75°C (167°F)	90°C (194°F)	
	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types MI, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types RHW, THW, THWN, THHW, XHHW, XHWN	Types THHN, THHW, RHH, XHHW, RHW-2, XHHW-2, THW-2, THWN-2, XHWN, XHWN-2, USE-2, ZW-2	
	COPPER		ALUMINUM OR COPPER-CLAD ALUMINUM		
8	57	66	44	51	8
6	76	89	59	69	6
4	101	117	78	91	4
3	118	138	92	107	3
2	135	158	106	123	2
1	158	185	123	144	1
1/0	183	214	143	167	1/0
2/0	212	247	165	193	2/0
3/0	245	287	192	224	3/0
4/0	287	335	224	262	4/0
250	320	374	251	292	250
300	359	419	282	328	300
350	397	464	312	364	350
400	430	503	339	395	400
500	496	580	392	458	500
600	553	647	440	514	600
700	610	714	488	570	700
750	638	747	512	598	750
800	660	773	532	622	800
900	704	826	572	669	900
1000	748	879	612	716	1000

Notes:

1) Section 310.20 shall be referenced for conditions of use.

* 2) Section 310.15(B) shall be referenced for the ampacity correction factors where the ambient temperature is other than 40°C (104°F).

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

Table 310.21 Ampacities of Bare or Covered Conductors in Free Air

Copper Conductors				AAC Aluminum Conductors			
Bare		Covered		Bare		Covered	
AWG or kcmil	Amperes	AWG or kcmil	Amperes	AWG or kcmil	Amperes	AWG or kcmil	Amperes
8	98	8	103	8	76	8	80
6	124	6	130	6	96	6	101
4	155	4	163	4	121	4	127
2	209	2	219	2	163	2	171
1/0	282	1/0	297	1/0	220	1/0	231
2/0	329	2/0	344	2/0	255	2/0	268
3/0	382	3/0	401	3/0	297	3/0	312
4/0	444	4/0	466	4/0	346	4/0	364
250	494	250	519	266.8	403	266.8	423
300	556	300	584	336.4	468	336.4	492
500	773	500	812	397.5	522	397.5	548
750	1000	750	1050	477.0	588	477.0	617
1000	1193	1000	1253	556.5	650	556.5	682
—	—	—	—	636.0	709	636.0	744
—	—	—	—	795.0	819	795.0	860
—	—	—	—	954.0	920	—	—
—	—	—	—	1033.5	968	1033.5	1017
—	—	—	—	1272	1103	1272	1201
—	—	—	—	1590	1267	1590	1381
—	—	—	—	2000	1454	2000	1527

Note: Section 310.~~20~~ 21 shall be referenced for conditions of use.

Statement of Problem and Substantiation for Public Comment

These are editorial changes to make the notes into mandatory text, provide consistent numbering for the notes (with the exception of the double asterisk for the 240.4(D) references), and add words to clarify certain phrases.

Related Item

• FR 8030

Submitter Information Verification

Submitter Full Name: Christel Hunter
Organization: Cerro Wire
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 29 19:13:18 EDT 2018
Committee: NEC-P06

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Public Comment No. 631-NFPA 70-2018 [Section No. 310.21]

310.21 Ampacities of Bare or Covered Conductors in Free Air.

The maximum 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 (~~86°F~~ 104°F) ambient temperature.

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

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18**	—	—	14	—	—	—	—
16**	—	—	18	—	—	—	—
14**	15	20	25	—	—	—	—
12**	20	25	30	15	20	25	12**
10**	30	35	40	25	30	35	10**
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	445	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
2000	555	665	750	470	560	630	2000

Notes:

Section 310.16 shall be referenced for conditions of use.

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

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

**Refer to 240.4(D) for conductor overcurrent protection limitations.

Table 310.17 Ampacities of Single-Insulated Conductors in Free Air

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18	—	—	18	—	—	—	—
16	—	—	24	—	—	—	—
14**	25	30	35	—	—	—	—
12**	30	35	40	25	30	35	12**
10**	40	50	55	35	40	45	10**
8	60	70	80	45	55	60	8
6	80	95	105	60	75	85	6
4	105	125	140	80	100	115	4
3	120	145	165	95	115	130	3
2	140	170	190	110	135	150	2
1	165	195	220	130	155	175	1
1/0	195	230	260	150	180	205	1/0
2/0	225	265	300	175	210	235	2/0
3/0	260	310	350	200	240	270	3/0
4/0	300	360	405	235	280	315	4/0
250	340	405	455	265	315	355	250

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
300	375	445	500	290	350	395	300
350	420	505	570	330	395	445	350
400	455	545	615	355	425	480	400
500	515	620	700	405	485	545	500
600	575	690	780	455	545	615	600
700	630	755	850	500	595	670	700
750	655	785	885	515	620	700	750
800	680	815	920	535	645	725	800
900	730	870	980	580	700	790	900
1000	780	935	1055	625	750	845	1000
1250	890	1065	1200	710	855	965	1250
1500	980	1175	1325	795	950	1070	1500
1750	1070	1280	1445	875	1050	1185	1750
2000	1155	1385	1560	960	1150	1295	2000

Notes:

Section 310.17 shall be referenced for conditions of use.

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

**Section 240.4(D) shall be referenced for conductor overcurrent protection limitations.

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

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
14	34	36	39	—	14
12	43	45	54	30	12
10	55	60	73	44	10
8	76	83	93	57	8
6	96	110	117	75	6
4	120	125	148	94	4
3	143	152	166	109	3

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
2	160	171	191	124	2
1	186	197	215	145	1
1/0	215	229	244	169	1/0
2/0	251	260	273	198	2/0
3/0	288	297	308	227	3/0
4/0	332	346	361	260	4/0

Notes:

Section 310.18 shall be referenced for conditions of use.

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

*Section 310.15(B) shall be referenced for the ampacity correction factors where the ambient temperature is other than 40°C (104°F).

Table 310.19 Ampacities of Single-Insulated Conductors in Free Air

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL, OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
14	46	54	59	—	14
12	60	68	78	47	12
10	80	90	107	63	10
8	106	124	142	83	8
6	155	165	205	112	6
4	190	220	278	148	4
3	214	252	327	170	3
2	255	293	381	198	2
1	293	344	440	228	1
1/0	339	399	532	263	1/0
2/0	390	467	591	305	2/0
3/0	451	546	708	351	3/0
4/0	529	629	830	411	4/0

Notes:

Section 310.19 shall be referenced for conditions of use.

*Section 310.15(B) shall be referenced for the ampacity correction factors where the ambient temperature is other than 40°C (104°F).

Table 310.20 Ampacities of Conductors on a Messenger

Size	Temperature Rating of Conductor [See Table 310.4(A)]	Size

AWG or kcmil	75°C (167°F)	90°C (194°F)	75°C (167°F)	90°C (194°F)	AWG or kcmil
	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types MI, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types RHW, THW, THWN, THHW, XHHW, XHWN	Types THHN, THHW, RHH, XHHW, RHW-2, XHHW-2, THW-2, THWN-2, XHWN, XHWN-2, USE-2, ZW-2	
	COPPER		ALUMINUM OR COPPER-CLAD ALUMINUM		
8	57	66	44	51	8
6	76	89	59	69	6
4	101	117	78	91	4
3	118	138	92	107	3
2	135	158	106	123	2
1	158	185	123	144	1
1/0	183	214	143	167	1/0
2/0	212	247	165	193	2/0
3/0	245	287	192	224	3/0
4/0	287	335	224	262	4/0
250	320	374	251	292	250
300	359	419	282	328	300
350	397	464	312	364	350
400	430	503	339	395	400
500	496	580	392	458	500
600	553	647	440	514	600
700	610	714	488	570	700
750	638	747	512	598	750
800	660	773	532	622	800
900	704	826	572	669	900
1000	748	879	612	716	1000

Notes:

Section 310.20 shall be referenced for conditions of use.

*Section 310.15(B) shall be referenced for the ampacity correction factors where the ambient temperature is other than 40°C (104°F).

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

Table 310.21 Ampacities of Bare or Covered Conductors in Free Air

Copper Conductors			
-			
AAC Aluminum Conductors			
Bare			
-			
Covered			
-			
Bare			
-			
		Covered	
AWG or kcmil		Amperes	
-			

AWG or kcmil	Amperes
-	
AWG or kcmil	Amperes
-	
AWG or kcmil	Amperes
8	98
-	
8	103
-	
8	76
-	
8	80
6	124
-	
6	130
-	
6	96
-	
6	101
4	155
-	
4	163
-	
4	121
-	
4	127
2	209
-	
2	219
-	
2	163
-	
2	171
1/0	282
-	
1/0	297
-	
1/0	220
-	
1/0	231
2/0	329
-	
2/0	344
-	
2/0	255
-	
2/0	268

3/0 382
-
3/0 401
-
3/0 297
-
3/0 312
4/0 444
-
4/0 466
-
4/0 346
-
4/0 364
250 494
-
250 519
-
266.8 403
-
266.8 423
300 556
-
300 584
-
336.4 468
-
336.4 492
500 773
-
500 812
-
397.5 522
-
397.5 548
750 1000
-
750 1050
-
477.0 588
-
477.0 617
1000 1193
-
1000 1253
-
556.5 650
-

556.5 682

636.0 709

636.0 744

795.0 819

795.0 860

954.0 920

1033.5 968

1033.5 1017

1272 1103

1272 1201

1590 1267

1590 1381

2000 1454

2000	1527

Note: Section 310.20 shall be referenced for conditions of use.

Statement of Problem and Substantiation for Public Comment

Editorial for 104 degrees F.

Related Item

• FR 8918

Submitter Information Verification

Submitter Full Name: David Kendall
Organization: Thomas & Betts Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 14 11:15:12 EDT 2018
Committee: NEC-P06

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Public Comment No. 633-NFPA 70-2018 [Section No. 310.21]

310.21 Ampacities of Bare or Covered Conductors in Free Air.

The maximum 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 (~~86°F~~ 104°F) ambient temperature.

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

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18**	—	—	14	—	—	—	—
16**	—	—	18	—	—	—	—
14**	15	20	25	—	—	—	—
12**	20	25	30	15	20	25	12**
10**	30	35	40	25	30	35	10**
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	350	420	475	285	340	385	600
700	385	460	520	315	375	425	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	445	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	525	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
2000	555	665	750	470	560	630	2000

Notes:

Section 310.16 shall be referenced for conditions of use.

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

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

**Refer to 240.4(D) for conductor overcurrent protection limitations.

Table 310.17 Ampacities of Single-Insulated Conductors in Free Air

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18	—	—	18	—	—	—	—
16	—	—	24	—	—	—	—
14**	25	30	35	—	—	—	—
12**	30	35	40	25	30	35	12**
10**	40	50	55	35	40	45	10**
8	60	70	80	45	55	60	8
6	80	95	105	60	75	85	6
4	105	125	140	80	100	115	4
3	120	145	165	95	115	130	3
2	140	170	190	110	135	150	2
1	165	195	220	130	155	175	1
1/0	195	230	260	150	180	205	1/0
2/0	225	265	300	175	210	235	2/0
3/0	260	310	350	200	240	270	3/0
4/0	300	360	405	235	280	315	4/0
250	340	405	455	265	315	355	250

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, XHWN	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
300	375	445	500	290	350	395	300
350	420	505	570	330	395	445	350
400	455	545	615	355	425	480	400
500	515	620	700	405	485	545	500
600	575	690	780	455	545	615	600
700	630	755	850	500	595	670	700
750	655	785	885	515	620	700	750
800	680	815	920	535	645	725	800
900	730	870	980	580	700	790	900
1000	780	935	1055	625	750	845	1000
1250	890	1065	1200	710	855	965	1250
1500	980	1175	1325	795	950	1070	1500
1750	1070	1280	1445	875	1050	1185	1750
2000	1155	1385	1560	960	1150	1295	2000

Notes:

Section 310.17 shall be referenced for conditions of use.

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

**Section 240.4(D) shall be referenced for conductor overcurrent protection limitations.

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

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
14	34	36	39	—	14
12	43	45	54	30	12
10	55	60	73	44	10
8	76	83	93	57	8
6	96	110	117	75	6
4	120	125	148	94	4
3	143	152	166	109	3

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
2	160	171	191	124	2
1	186	197	215	145	1
1/0	215	229	244	169	1/0
2/0	251	260	273	198	2/0
3/0	288	297	308	227	3/0
4/0	332	346	361	260	4/0

Notes:

Section 310.18 shall be referenced for conditions of use.

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

*Section 310.15(B) shall be referenced for the ampacity correction factors where the ambient temperature is other than 40°C (104°F).

Table 310.19 Ampacities of Single-Insulated Conductors in Free Air

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.4(A)]				Size AWG or kcmil
	150°C (302°F)	200°C (392°F)	250°C (482°F)	150°C (302°F)	
	Type Z	Types FEP, FEPB, PFA, SA	Types PFAH, TFE	Type Z	
	COPPER		NICKEL, OR NICKEL-COATED COPPER	ALUMINUM OR COPPER-CLAD ALUMINUM	
14	46	54	59	—	14
12	60	68	78	47	12
10	80	90	107	63	10
8	106	124	142	83	8
6	155	165	205	112	6
4	190	220	278	148	4
3	214	252	327	170	3
2	255	293	381	198	2
1	293	344	440	228	1
1/0	339	399	532	263	1/0
2/0	390	467	591	305	2/0
3/0	451	546	708	351	3/0
4/0	529	629	830	411	4/0

Notes:

Section 310.19 shall be referenced for conditions of use.

*Section 310.15(B) shall be referenced for the ampacity correction factors where the ambient temperature is other than 40°C (104°F).

Table 310.20 Ampacities of Conductors on a Messenger

Size	Temperature Rating of Conductor [See Table 310.4(A)]	Size

AWG or kcmil	75°C (167°F)	90°C (194°F)	75°C (167°F)	90°C (194°F)	AWG or kcmil
	Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW	Types MI, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHHW, XHHW-2, XHWN, XHWN-2, ZW-2	Types RHW, THW, THWN, THHW, XHHW, XHWN	Types THHN, THHW, RHH, XHHW, RHW-2, XHHW-2, THW-2, THWN-2, XHWN, XHWN-2, USE-2, ZW-2	
	COPPER		ALUMINUM OR COPPER-CLAD ALUMINUM		
8	57	66	44	51	8
6	76	89	59	69	6
4	101	117	78	91	4
3	118	138	92	107	3
2	135	158	106	123	2
1	158	185	123	144	1
1/0	183	214	143	167	1/0
2/0	212	247	165	193	2/0
3/0	245	287	192	224	3/0
4/0	287	335	224	262	4/0
250	320	374	251	292	250
300	359	419	282	328	300
350	397	464	312	364	350
400	430	503	339	395	400
500	496	580	392	458	500
600	553	647	440	514	600
700	610	714	488	570	700
750	638	747	512	598	750
800	660	773	532	622	800
900	704	826	572	669	900
1000	748	879	612	716	1000

Notes:

Section 310.20 shall be referenced for conditions of use.

*Section 310.15(B) shall be referenced for the ampacity correction factors where the ambient temperature is other than 40°C (104°F).

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

Table 310.21 Ampacities of Bare or Covered Conductors in Free Air

Copper Conductors			
-			
AAC Aluminum Conductors			
Bare			
-			
Covered			
-			
Bare			
-			
		Covered	
AWG or kcmil		Amperes	
-			

AWG or kcmil	Amperes
-	
AWG or kcmil	Amperes
-	
AWG or kcmil	Amperes
8	98
-	
8	103
-	
8	76
-	
8	80
6	124
-	
6	130
-	
6	96
-	
6	101
4	155
-	
4	163
-	
4	121
-	
4	127
2	209
-	
2	219
-	
2	163
-	
2	171
1/0	282
-	
1/0	297
-	
1/0	220
-	
1/0	231
2/0	329
-	
2/0	344
-	
2/0	255
-	
2/0	268

3/0 382
-
3/0 401
-
3/0 297
-
3/0 312
4/0 444
-
4/0 466
-
4/0 346
-
4/0 364
250 494
-
250 519
-
266.8 403
-
266.8 423
300 556
-
300 584
-
336.4 468
-
336.4 492
500 773
-
500 812
-
397.5 522
-
397.5 548
750 1000
-
750 1050
-
477.0 588
-
477.0 617
1000 1193
-
1000 1253
-
556.5 650
-

556.5 682

— —

-

— —

-

636.0 709

-

636.0 744

— —

-

— —

-

795.0 819

-

795.0 860

— —

-

— —

-

954.0 920

-

— —

— —

-

— —

-

1033.5 968

-

1033.5 1017

— —

-

— —

-

1272 1103

-

1272 1201

— —

-

— —

-

1590 1267

-

1590 1381

— —

-

— —

-

2000 1454

2000	1527

Note: Section 310.20 shall be referenced for conditions of use.

Statement of Problem and Substantiation for Public Comment

Editorial change to correct the Farenheit temperature.

Related Item

• FR8918

Submitter Information Verification

Submitter Full Name: Raymond Horner
Organization: Atkore International
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 14 11:18:30 EDT 2018
Committee: NEC-P06

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Public Comment No. 641-NFPA 70-2018 [Definition: Electrical Ducts.]

~~**Electrical Ducts.**~~

~~Electrical conduits, or other raceways round in cross section, that are suitable for use underground or embedded in concrete.~~

Statement of Problem and Substantiation for Public Comment

This is a companion Comment to delete the use of "Electrical Ducts" and be replaced with "Raceways" to be consistent with Article 310 and the rest of the Code including the raceway articles.

Related Item

• FR 8030

Submitter Information Verification

Submitter Full Name: David Kendall
Organization: Thomas & Betts Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 14 13:56:55 EDT 2018
Committee: NEC-P06

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Public Comment No. 642-NFPA 70-2018 [Section No. 311.60(D)(3)]

(3) ~~Electrical Ducts~~ Raceways Entering Equipment Enclosures.

At locations where ~~electrical ducts~~ raceways enter equipment enclosures from underground, spacing between such ~~ducts~~ raceways , as shown in Figure 311.60(D)(3), shall be permitted to be reduced without requiring the ampacity of conductors therein to be reduced.

Statement of Problem and Substantiation for Public Comment

This is a companion Comment to delete the use of "Electrical Ducts" and be replaced with "Raceways" to be consistent with Article 310 and the rest of the Code including the raceway articles.

Related Item

- FR 8030

Submitter Information Verification

Submitter Full Name: David Kendall
Organization: Thomas & Betts Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 14 14:02:12 EDT 2018
Committee: NEC-P06

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Public Comment No. 644-NFPA 70-2018 [Section No. 311.60(F)]

(F) Ampacity in Underground ~~Electrical Ducts~~ Raceways and Direct Buried in Earth.

Ampacities for conductors and cables in underground ~~electrical ducts~~ raceways and direct buried in earth shall be as specified in Table 311.60(C)(77) through Table 311.60(C)(86). Ampacities shall be based on the following:

(1) Ambient earth temperature of 20°C (68°F)

(2) Arrangement in accordance with Figure 311.60(D)(3)

(3) 100 percent load factor

(4) Thermal resistance (Rho) of 90

(5) Conductor temperatures 90°C (194°F) and 105°C (221°F)

(6) Minimum burial depths to the top ~~electrical ducts~~ raceways or cables shall be in accordance with 300.50.

(7) Maximum depth to the top of electrical duct banks shall be 750 mm (30 in.), and maximum depth to the top of direct-buried cables shall be 900 mm (36 in.).

Table 311.60(C)(67) Ampacities of Insulated Single Copper Conductor Cables Triplexed in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor	
	2001–5000 Volts Ampacity	
	5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8	65	74
6	90	99
4	100 120	110 130
2	130 160	140 175
1	170 185	195 205
1/0	195 215	225 240
2/0	225 250	255 275
3/0	260 290	295 320
4/0	300 335	340 375
	345	390

250	375	415
-		
	380	430
350	465	515
-		
	470	525
500	580	645
-		
	580	650
750	750	835
-		
	730	820
1000	880	980
-		
850	950	

Note: Refer to 311.60(E) for the basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(68) Ampacities of Insulated Single Aluminum Conductor Cables Triplexed in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor	
	2001–5000 Volts Ampacity	
-		
	5001–35,000 Volts Ampacity	
90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	
-		
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8	50	57
-		
	—	—
6	70	77
-		
	75	84
4	90	100
-		
	100	110
2	125	135
-		
	130	150
1	145	160
-		
	150	175
1/0	170	185
-		
	175	200
2/0	195	215
-		
	200	230

3/0	225	250
-		
	230	265
4/0	265	290
-		
	270	305
250	295	325
-		
	300	335
350	365	405
-		
	370	415
500	460	510
-		
	460	515
750	600	665
-		
	590	660
1000	715	800
-		
700	780	

Note: Refer to 311.60(E) for basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(69) Ampacities of Insulated Single Copper Conductor Isolated in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor	
	2001–5000 Volts Ampacity	
-		
	5001–15,000 Volts Ampacity	
-		
	15,001–35,000 Volts Ampacity	
90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	
-		
90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	
-		
90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	
8 83	93	
-		
—	—	
-		
—	—	
6 110	120	
-		
110	125	
-		
—	—	
4 145	160	

-

150 165

-

— —

2 190 215

-

195 215

-

— —

1 225 250

-

225 250

-

225 250

1/0 260 290

-

260 290

-

260 290

2/0 300 330

-

300 335

-

300 330

3/0 345 385

-

345 385

-

345 380

4/0 400 445

-

400 445

-

395 445

250 445 495

-

445 495

-

440 490

350 550 615

-

550 610

-

545 605

500 695 775

-

685 765

-

	680	755
750	900	1000
-		
885	990	
-		
	870	970
1000	1075	1200
-		
1060	1185	
-		
	1040	1160
1250	1230	1370
-		
1210	1350	
-		
	1185	1320
1500	1365	1525
-		
1345	1500	
-		
	1315	1465
1750	1495	1665
-		
1470	1640	
-		
	1430	1595
2000	1605	1790
-		
1575	1755	
-		
1535	1710	

Note: Refer to 311.60(E) for the basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(70) Ampacities of Insulated Single Aluminum Conductor Isolated in Air

Conductor Size (AWG or kcmil)	**Temperature Rating of Conductor**
	2001–5000 Volts Ampacity
-	
	5001–15,000 Volts Ampacity
-	
	15,001–35,000 Volts Ampacity
90°C (194°F) Type MV-90	**105°C (221°F) Type MV-105**
-	
90°C (194°F) Type MV-90	**105°C (221°F) Type MV-105**
-	
90°C (194°F) Type MV-90	**105°C (221°F) Type MV-105**
8 64	71

-

	—	—

-

	—	—
6	85	95

-

87	97	

-

	—	—
4	115	125

-

115	130	

-

	—	—
2	150	165

-

150	170	

-

	—	—
1	175	195

-

175	195	

-

	175	195
1/0	200	225

-

200	225	

-

	200	225
2/0	230	260

-

235	260	

-

	230	260
3/0	270	300

-

270	300	

-

	270	300
4/0	310	350

-

310	350	

-

	310	345
250	345	385

-

345	385	

-

	345	380
350	430	480
-		
430	480	
-		
	430	475
500	545	605
-		
535	600	
-		
	530	590
750	710	790
-		
700	780	
-		
	685	765
1000	855	950
-		
840	940	
-		
	825	920
1250	980	1095
-		
970	1080	
-		
	950	1055
1500	1105	1230
-		
1085	1215	
-		
	1060	1180
1750	1215	1355
-		
1195	1335	
-		
	1165	1300
2000	1320	1475
-		
1295	1445	
-		
1265	1410	

Note: Refer to 311.60(E) for the basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(71) Ampacities of an Insulated Three-Conductor Copper Cable Isolated in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor
	2001–5000 Volts Ampacity
-	

	5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
-		
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8	59	66
-		
	—	—
6	79	88
-		
	93	105
4	105	115
-		
	120	135
2	140	154
-		
	165	185
1	160	180
-		
	185	210
1/0	185	205
-		
	215	240
2/0	215	240
-		
	245	275
3/0	250	280
-		
	285	315
4/0	285	320
-		
	325	360
250	320	355
-		
	360	400
350	395	440
-		
	435	490
500	485	545
-		
	535	600
750	615	685
-		
	670	745
1000	705	790
-		
770	860	

Note: Refer to 311.60(E) for the basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air

temperature is other than 40°C (104°F).

Table 310.60(C)(72) Ampacities of an Insulated Three-Conductor Aluminum Cable Isolated in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor	
	2001–5000 Volts Ampacity	
	5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8	46	51
6	61	68
4	72 81	80 90
2	95 110	105 120
1	125 125	145 140
1/0	145 145	165 160
2/0	170 170	185 185
3/0	190 195	215 215
4/0	220 225	245 250
250	255 250	285 280
350	280 310	315 345
500	345 385	385 430
750	425 495	475 550

	540	600
1000	585	650
-		
635	705	

Note: Refer to 311.60(E) for the basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(73) Ampacities of an Insulated Triplexed or Three Single-Conductor Copper Cables in ~~Isolated Conduit~~ Isolated Raceway in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor	
	2001–5000 Volts Ampacity	
-		
	5001–35,000 Volts Ampacity	
90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	
-		
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8	55	61
-		
	—	—
6	75	84
-		
	83	93
4	97	110
-		
	110	120
2	130	145
-		
	150	165
1	155	175
-		
	170	190
1/0	180	200
-		
	195	215
2/0	205	225
-		
	225	255
3/0	240	270
-		
	260	290
4/0	280	305
-		
	295	330
250	315	355
-		
	330	365
350	385	430
-		

	395	440
500	475	530
-		
	480	535
750	600	665
-		
	585	655
1000	690	770
-		
675	755	

Note: Refer to 311.60(E) for the basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(74) Ampacities of an Insulated Triplexed or Three Single-Conductor Aluminum Cables in ~~Isolated Conduit~~ Isolated Raceway in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor	
	2001–5000 Volts Ampacity	
-		
	5001–35,000 Volts Ampacity	
90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	
-		
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8 43	48	
-		
	—	—
6	58	65
-		
	65	72
4	76	85
-		
	84	94
2	100	115
-		
	115	130
1	120	135
-		
	130	150
1/0	140	155
-		
	150	170
2/0	160	175
-		
	175	200
3/0	190	210
-		
	200	225
4/0	215	240
-		

	230	260
250	250	280
-		
	255	290
350	305	340
-		
	310	350
500	380	425
-		
	385	430
750	490	545
-		
	485	540
1000	580	645
-		
565	640	

Note: Refer to 311.60(E) for the basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(75) Ampacities of an Insulated Three-Conductor Copper Cable in ~~Isolated Conduit~~ Isolated Raceway in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor	
	2001–5000 Volts Ampacity	
-		
	5001–35,000 Volts Ampacity	
90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	
-		
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8	52	58
-		
	—	—
6	69	77
-		
	83	92
4	91	100
-		
	105	120
2	125	135
-		
	145	165
1	140	155
-		
	165	185
1/0	165	185
-		
	195	215
2/0	190	210
-		

	220	245
3/0	220	245
-		
	250	280
4/0	255	285
-		
	290	320
250	280	315
-		
	315	350
350	350	390
-		
	385	430
500	425	475
-		
	470	525
750	525	585
-		
	570	635
1000	590	660
-		
650	725	

Note: Refer to 311.60(E) for the basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(76) Ampacities of an Insulated Three-Conductor Aluminum Cable in ~~Isolated Conduit~~ Isolated Raceway in Air

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor	
	2001–5000 Volts Ampacity	
-		
	5001–35,000 Volts Ampacity	
90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	
-		
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
8	41	46
-		
	—	—
6	53	59
-		
	64	71
4	71	79
-		
	84	94
2	96	105
-		
	115	125
1	110	125
-		

	130	145
1/0	130	145
-		
	150	170
2/0	150	165
-		
	170	190
3/0	170	190
-		
	195	220
4/0	200	225
-		
	225	255
250	220	245
-		
	250	280
350	275	305
-		
	305	340
500	340	380
-		
	380	425
750	430	480
-		
	470	520
1000	505	560
-		
550	615	

Note: Refer to 311.60(E) for the basis of ampacities, 311.10(A) for conductor maximum operating temperature and application, and 311.60(D)(4) for the ampacity correction factors where the ambient air temperature is other than 40°C (104°F).

Table 311.60(C)(77) Ampacities of Three Single-Insulated Copper Conductors in Underground ~~Electrical Ducts~~ Raceways (Three Conductors per Electrical Duct)

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor	
	2001–5000 Volts Ampacity	
-		
	5001–35,000 Volts Ampacity	
90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	
-		
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit [See Figure 311.60(D)(3), Detail 1.]		
- - - -		
8	64	69
-		
	—	—
6	85	92
-		

	90	97
4	110	120
-		
	115	125
2	145	155
-		
	155	165
1	170	180
-		
	175	185
1/0	195	210
-		
	200	215
2/0	220	235
-		
	230	245
3/0	250	270
-		
	260	275
4/0	290	310
-		
	295	315
250	320	345
-		
	325	345
350	385	415
-		
	390	415
500	470	505
-		
	465	500
750	585	630
-		
	565	610
1000	670	720
-		
640		690
Three Circuits [See Figure 311.60(D)(3), Detail 2.]		
- - - -		
8	56	60
-		
	—	—
6	73	79
-		
	77	83
4	95	100
-		
	99	105

2	125	130
-		
	130	135
1	140	150
-		
	145	155
1/0	160	175
-		
	165	175
2/0	185	195
-		
	185	200
3/0	210	225
-		
	210	225
4/0	235	255
-		
	240	255
250	260	280
-		
	260	280
350	315	335
-		
	310	330
500	375	405
-		
	370	395
750	460	495
-		
	440	475
1000	525	565
-		
495		535
Six Circuits [See Figure 311.60(D)(3), Detail 3.]		
- - - -		
8	48	52
-		
	—	—
6	62	67
-		
	64	68
4	80	86
-		
	82	88
2	105	110
-		
	105	115
1	115	125

	120	125
1/0	135	145
	135	145
2/0	150	160
	150	165
3/0	170	185
	170	185
4/0	195	210
	190	205
250	210	225
	210	225
350	250	270
	245	265
500	300	325
	290	310
750	365	395
	350	375
1000	410	445
390	415	

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Table 311.60(C)(78) Ampacities of Three Single-Insulated Aluminum Conductors in Underground ~~Electrical Ducts~~ Raceways (Three Conductors per Electrical Duct)

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor	
	2001–5000 Volts Ampacity	
	5001–35,000 Volts Ampacity	
90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit [See Figure 311.60(D)(3), Detail 1.]		
8	50	54
	—	—
6	66	71

	70	75
4	86	93
-		
	91	98
2	115	125
-		
	120	130
1	130	140
-		
	135	145
1/0	150	160
-		
	155	165
2/0	170	185
-		
	175	190
3/0	195	210
-		
	200	215
4/0	225	245
-		
	230	245
250	250	270
-		
	250	270
350	305	325
-		
	305	330
500	370	400
-		
	370	400
750	470	505
-		
	455	490
1000	545	590
-		
525		565
Three Circuits [See Figure 311.60(D)(3), Detail 2.]		
- - - -		
8	44	47
-		
	—	—
6	57	61
-		
	60	65
4	74	80
-		
	77	83

| | | |

	90	99
1/0	105	110
	105	110
2/0	115	125
	115	125
3/0	135	145
	130	145
4/0	150	165
	150	160
250	165	180
	165	175
350	195	210
	195	210
500	240	255
	230	250
750	290	315
	280	305
1000	335	360
320	345	

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Table 311.60(C)(79) Ampacities of Three Insulated Copper Conductors Cabled Within an Overall Covering (Three-Conductor Cable) in Underground ~~Electrical Ducts~~ Raceways (One Cable per ~~Electrical Duct~~ Raceway)

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor	
	2001–5000 Volts Ampacity	
	5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit [See Figure 311.60(D)(3), Detail 1.]		
8	59	64
	—	—
6	78	84

	88	95
4	100	110
-		
	115	125
2	135	145
-		
	150	160
1	155	165
-		
	170	185
1/0	175	190
-		
	195	210
2/0	200	220
-		
	220	235
3/0	230	250
-		
	250	270
4/0	265	285
-		
	285	305
250	290	315
-		
	310	335
350	355	380
-		
	375	400
500	430	460
-		
	450	485
750	530	570
-		
	545	585
1000	600	645
-		
615		660
Three Circuits [See Figure 311.60(D)(3), Detail 2.]		
- - - -		
8	53	57
-		
	—	—
6	69	74
-		
	75	81
4	89	96
-		
	97	105

2	115	125
-		
	125	135
1	135	145
-		
	140	155
1/0	150	165
-		
	160	175
2/0	170	185
-		
	185	195
3/0	195	210
-		
	205	220
4/0	225	240
-		
	230	250
250	245	265
-		
	255	270
350	295	315
-		
	305	325
500	355	380
-		
	360	385
750	430	465
-		
	430	465
1000	485	520
-		
485		515
Six Circuits [See Figure 311.60(D)(3), Detail 3.]		
- - - -		
8	46	50
-		
	—	—
6	60	65
-		
	63	68
4	77	83
-		
	81	87
2	98	105
-		
	105	110
1	110	120

	115	125
1/0	125	135
	130	145
2/0	145	155
	150	160
3/0	165	175
	170	180
4/0	185	200
	190	200
250	200	220
	205	220
350	240	270
	245	275
500	290	310
	290	305
750	350	375
	340	365
1000	390	420
380	405	

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Table 311.60(C)(80) Ampacities of Three Insulated Aluminum Conductors Cabled Within an Overall Covering (Three-Conductor Cable) in Underground ~~Electrical Ducts~~ Raceways (One Cable per ~~Electrical Duct~~ Raceway)

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor	
	2001–5000 Volts Ampacity	
	5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit [See Figure 311.60(D)(3), Detail 1.]		
8	46	50
	—	—
6	61	66

	69	74
4	80	86
-		
	89	96
2	105	110
-		
	115	125
1	120	130
-		
	135	145
1/0	140	150
-		
	150	165
2/0	160	170
-		
	170	185
3/0	180	195
-		
	195	210
4/0	205	220
-		
	220	240
250	230	245
-		
	245	265
350	280	310
-		
	295	315
500	340	365
-		
	355	385
750	425	460
-		
	440	475
1000	495	535
-		
510		545
Three Circuits [See Figure 311.60(D)(3), Detail 2.]		
- - - -		
8	41	44
-		
	—	—
6	54	58
-		
	59	64
4	70	75
-		
	75	81

2	90	97
-		
	100	105
1	105	110
-		
	110	120
1/0	120	125
-		
	125	135
2/0	135	145
-		
	140	155
3/0	155	165
-		
	160	175
4/0	175	185
-		
	180	195
250	190	205
-		
	200	215
350	230	250
-		
	240	255
500	280	300
-		
	285	305
750	345	375
-		
	350	375
1000	400	430
-		
400		430
Six Circuits [See Figure 311.60(D)(3), Detail 3.]		
- - - -		
8	36	39
-		
	—	—
6	46	50
-		
	49	53
4	60	65
-		
	63	68
2	77	83
-		
	80	86
1	87	94

	90	98
1/0	99	105
	105	110
2/0	110	120
	115	125
3/0	130	140
	130	140
4/0	145	155
	150	160
250	160	170
	160	170
350	190	205
	190	205
500	230	245
	230	245
750	280	305
	275	295
1000	320	345
315	335	

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Table 311.60(C)(81) Ampacities of Single Insulated Copper Conductors Directly Buried in Earth

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor	
	2001–5000 Volts Ampacity	
	5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit, Three Conductors [See Figure 311.60(D)(3), Detail 9.]		
8	110	115
	—	—
6	140	150
	130	140

4	180		195	
-				
	170		180	
2	230		250	
-				
	210		225	
1	260		280	
-				
		240		260
1/0		295		320
-				
		275		295
2/0		335		365
-				
		310		335
3/0		385		415
-				
		355		380
4/0		435		465
-				
		405		435
250		470		510
-				
		440		475
350		570		615
-				
		535		575
500		690		745
-				
		650		700
750		845		910
-				
		805		865
1000		980		1055
-				
	930			1005
Two Circuits, Six Conductors [See Figure 311.60(D)(3), Detail 10.]				
- - - -				
8	100		110	
-				
		—		—
6	130		140	
-				
	120		130	
4	165		180	
-				
	160		170	
2	215		230	

-		
	195	210
1	240	260
-		
	225	240
1/0	275	295
-		
	255	275
2/0	310	335
-		
	290	315
3/0	355	380
-		
	330	355
4/0	400	430
-		
	375	405
250	435	470
-		
	410	440
350	520	560
-		
	495	530
500	630	680
-		
	600	645
750	775	835
-		
	740	795
1000	890	960
-		
855	920	

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Table 311.60(C)(82) Ampacities of Single Insulated Aluminum Conductors Directly Buried in Earth

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor	
	2001–5000 Volts Ampacity	
-		
	5001–35,000 Volts Ampacity	
90°C (194°F) Type MV-90	105°C (221°F) Type MV-105	
-		
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit, Three Conductors [See Figure 311.60(D)(3), Detail 9.]		

8	85	90
-		
	—	—

6	110	115
-		
	100	110
4	140	150
-		
	130	140
2	180	195
-		
	165	175
1	205	220
-		
	185	200
1/0	230	250
-		
	215	230
2/0	265	285
-		
	245	260
3/0	300	320
-		
	275	295
4/0	340	365
-		
	315	340
250	370	395
-		
	345	370
350	445	480
-		
	415	450
500	540	580
-		
	510	545
750	665	720
-		
	635	680
1000	780	840
-		
740		795
Two Circuits, Six Conductors [See Figure 311.60(D)(3), Detail 10.]		
- - - -		
8	80	85
-		
	—	—
6	100	110
-		
	95	100
4	130	140

-

	125	130
2	165	180

-

	155	165
1	190	200

-

	175	190
1/0	215	230

-

	200	215
2/0	245	260

-

	225	245
3/0	275	295

-

	255	275
4/0	310	335

-

	290	315
250	340	365

-

	320	345
350	410	440

-

	385	415
500	495	530

-

	470	505
750	610	655

-

	580	625
1000	710	765

-

680	730	

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Table 311.60(C)(83) Ampacities of Three Insulated Copper Conductors Cabled Within an Overall Covering (Three-Conductor Cable), Directly Buried in Earth

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor
	2001–5000 Volts Ampacity

-

	5001–35,000 Volts Ampacity
90°C (194°F) Type MV-90	105°C (221°F) Type MV-105

-

90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit [See Figure 311.60(D)(3), Detail 5.]	

- - - -

8	85		89	
-				
		—		—
6	105		115	
-				
	115		120	
4	135		150	
-				
	145		155	
2	180		190	
-				
	185		200	
1	200		215	
-				
		210		225
1/0		230		245
-				
		240		255
2/0		260		280
-				
		270		290
3/0		295		320
-				
		305		330
4/0		335		360
-				
		350		375
250		365		395
-				
		380		410
350		440		475
-				
		460		495
500		530		570
-				
		550		590
750		650		700
-				
		665		720
1000		730		785
-				
	750			810
Two Circuits [See Figure 311.60(D)(3), Detail 6.]				
- - - -				
8	80		84	
-				
		—		—

6	100	105
-		
	105	115
4	130	140
-		
	135	145
2	165	180
-		
	170	185
1	185	200
-		
	195	210
1/0	215	230
-		
	220	235
2/0	240	260
-		
	250	270
3/0	275	295
-		
	280	305
4/0	310	335
-		
	320	345
250	340	365
-		
	350	375
350	410	440
-		
	420	450
500	490	525
-		
	500	535
750	595	640
-		
	605	650
1000	665	715
-		
675	730	

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Table 311.60(C)(84) Ampacities of Three Insulated Aluminum Conductors Cabled Within an Overall Covering (Three-Conductor Cable), Directly Buried in Earth

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor
	2001–5000 Volts Ampacity
-	
	5001–35,000 Volts Ampacity
90°C (194°F) Type MV-90	105°C (221°F) Type MV-105

	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit [See Figure 311.60(D)(3), Detail 5.]		
8	65	70
6	80	88
4	90 105	95 115
2	115 140	125 150
1	145 155	155 170
1/0	165 180	175 190
2/0	185 205	200 220
3/0	210 230	225 250
4/0	240 260	260 280
250	270 285	295 310
350	300 345	320 375
500	360 420	390 450
750	435 520	470 560
1000	540 600	580 650
620		665
Two Circuits [See Figure 311.60(D)(3), Detail 6.]		

8	60	66
-		
	—	—
6	75	83
-		
	80	95
4	100	110
-		
	105	115
2	130	140
-		
	135	145
1	145	155
-		
	150	165
1/0	165	180
-		
	170	185
2/0	190	205
-		
	195	210
3/0	215	230
-		
	220	240
4/0	245	260
-		
	250	270
250	265	285
-		
	275	295
350	320	345
-		
	330	355
500	385	415
-		
	395	425
750	480	515
-		
	485	525
1000	550	590
-		
560	600	

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Table 311.60(C)(85) Ampacities of Three Triplexed Single Insulated Copper Conductors Directly Buried in Earth

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor	
	2001–5000 Volts Ampacity	

	5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit, Three Conductors [See Figure 311.60(D)(3), Detail 7.]		
8	90	95
	—	—
6	120	130
	115	120
4	150	165
	150	160
2	195	205
	190	205
1	225	240
	215	230
1/0	255	270
	245	260
2/0	290	310
	275	295
3/0	330	360
	315	340
4/0	375	405
	360	385
250	410	445
	390	410
350	490	580
	470	505
500	590	635
	565	605
750	725	780
	685	740
1000	825	885

	770			830
Two Circuits, Six Conductors [See Figure 311.60(D)(3), Detail 8.]				
8	85		90	
6	110	—	115	—
4	105 140		115 150	
2	140 180		150 195	
1	175 205		190 220	
1/0		200 235		215 250
2/0		225 265		240 285
3/0		255 300		275 320
4/0		290 340		315 365
250		325 370		350 395
350		355 445		380 480
500		425 535		455 575
750		510 650		545 700
1000		615 740		660 795
690			745	

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Table 311.60(C)(86) Ampacities of Three Triplexed Single Insulated Aluminum Conductors Directly Buried in Earth

Conductor Size (AWG or kcmil)	Temperature Rating of Conductor	
	2001–5000 Volts Ampacity	
	5001–35,000 Volts Ampacity	
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
	90°C (194°F) Type MV-90	105°C (221°F) Type MV-105
One Circuit, Three Conductors [See Figure 311.60(D)(3), Detail 7.]		
8	70	75
6	— 90	— 100
4	90 120	95 130
2	115 155	125 165
1	145 175	155 190
1/0	165 200	175 210
2/0	190 225	205 240
3/0	215 255	230 275
4/0	245 290	265 310
250	280 320	305 350
350	305 385	325 420
500	370 465	400 500
	445	480

750	580	625
-		
	550	590
1000	670	725
-		
635		680

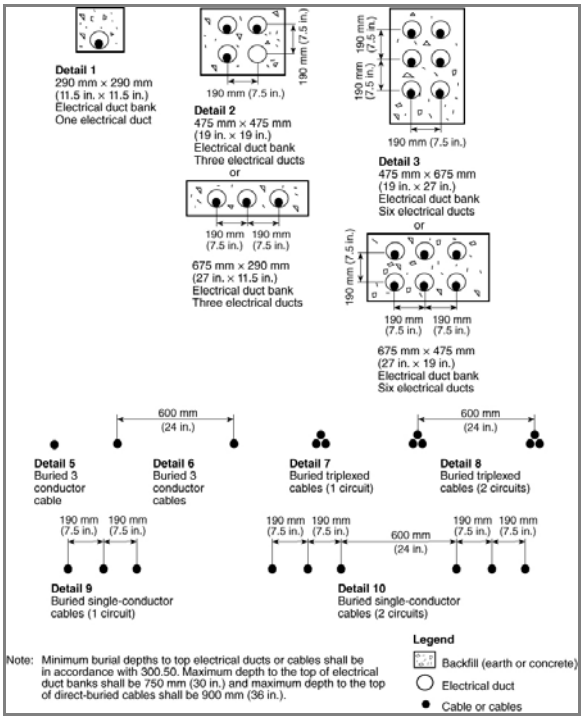
Two Circuits, Six Conductors [See Figure 311.60(D)(3), Detail 8.]

- - - -		
8	65	70
-		
	—	—
6	85	95
-		
	85	90
4	110	120
-		
	105	115
2	140	150
-		
	135	145
1	160	170
-		
	155	170
1/0	180	195
-		
	175	190
2/0	205	220
-		
	200	215
3/0	235	250
-		
	225	245
4/0	265	285
-		
	255	275
250	290	310
-		
	280	300
350	350	375
-		
	335	360
500	420	455
-		
	405	435
750	520	560
-		
	485	525
1000	600	645

565	605

Note: Refer to 311.60(F) for basis of ampacities and Table 311.10(A) for the temperature rating of the conductor.

Figure 311.60(D)(3) Cable Installation Dimensions for Use with Table 311.60(C)(77) Through Table 311.60(C)(86).



Statement of Problem and Substantiation for Public Comment

This is a companion Comment to delete the use of "Electrical Ducts" and "Conduits" and be replaced with "Raceways" to be consistent with Article 310 and the rest of the Code including the raceway articles.

Figure 311.60(D)(3) could not be edited with the Terra System. Figure 311.60(D)(3) needs to replace "Electrical Ducts" to "Raceways". The term "Electrical Duct Bank" is acceptable and should remain as is.

Related Item

• FR 8030

Submitter Information Verification

Submitter Full Name: David Kendall
Organization: Thomas & Betts Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 14 14:05:10 EDT 2018
Committee: NEC-P06

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Public Comment No. 343-NFPA 70-2018 [Section No. 324.60]

324.60 ~~Grounding~~ 60 Electrically Continuous .

All metal shields, boxes, receptacle housings, and self-contained devices shall be electrically continuous to the **equipment grounding conductor** of the supplying branch circuit. All such electrical connections shall be made with connectors identified for this use. The electrical resistivity of such shield system shall not be more than that of one conductor of the Type FCC cable used in the installation.

Statement of Problem and Substantiation for Public Comment

The title improperly uses the term "Grounding". When grounding (connection to the earth) has nothing to do with the text in this section.

The definition of "Grounding" (Article 100) is the 'connection to ground' and the definition of 'Ground' (Article 100) is 'The Earth.' So grounding is the connection to the earth.

Related Item

• FR-8115

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 02 13:16:10 EDT 2018
Committee: NEC-P06

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Public Comment No. 635-NFPA 70-2018 [Article 326]

Article 326 Integrated Gas Spacer Cable: Type IGS

Part I. General

326.1 Scope.

This article covers the use, installation, and construction specifications for integrated gas spacer cable, Type IGS.

326.2 Definition.

The definition in this section shall apply within this article and throughout the *Code* .

Integrated Gas Spacer Cable, Type IGS.

A factory assembly of one or more conductors, each individually insulated and enclosed in a loose fit, nonmetallic flexible conduit as an integrated gas spacer cable rated 0 volts through 600 volts.

Part II. Installation

326.10 Uses Permitted.

Type IGS cable shall be permitted for use underground, including direct burial in the earth, as the following:

(1) Service-entrance conductors

(2) Feeder or branch-circuit conductors

(3) Service conductors, underground

326.12 Uses Not Permitted.

Type IGS cable shall not be used as interior wiring or be exposed in contact with buildings.

326.24 Bending Radius.

Where the coilable nonmetallic conduit and cable are bent for installation purposes or are flexed or bent during shipment or installation, the radius of the curve of the inner edge measured to the inside of the bend shall not be less than specified in Table 326.24 .

Table 326.24 Minimum Radii of Bends

Conduit Size - Minimum Radii Metric Designator Trade Size mm in. 53 2 - 600 24 78 3 - 900 35 103 4 - 1150 45

326.26 Bends.

A run of Type IGS cable between pull boxes or terminations shall not contain more than the equivalent of four quarter bends (360 degrees total), including those bends located immediately at the pull box or terminations.

326.40 Fittings.

Terminations and splices for Type IGS cable shall be identified as a type that is suitable for maintaining the gas pressure within the conduit. A valve and cap shall be provided for each length of the cable and conduit to check the gas pressure or to inject gas into the conduit.

326.80 Ampacity.

The ampacity of Type IGS cable shall not exceed the values shown in Table 326.80 .

Table 326.80 Ampacity of Type IGS Cable

Size (kcmil) Amperes Size
(kcmil) Amperes 250 119 2500 376 500 168 3000 412 750 206 3250 429 1000 238 3500 445 1250 266 3750 461 1

Part III. Construction Specifications

326.104 Conductors.

The conductors shall be solid aluminum rods, laid parallel, consisting of one to nineteen 12.7 mm ($^{1}/_{2}$ in.) diameter rods. The minimum conductor size shall be 250 kcmil, and the maximum size shall be 4750 kcmil.

326.112 Insulation.

~~The insulation shall be dry kraft paper tapes and a pressurized sulfur hexafluoride gas (SF_6), both approved for electrical use. The nominal gas pressure shall be 138 kPa gauge (20 lb/in.^{2} gauge). The thickness of the paper spacer shall be as specified in Table 326.112.~~

~~Table 326.112 Paper Spacer Thickness~~

~~Size (kcmil) Thickness mm in. 250–1000 1.02 0.040 1250–4750 1.52 0.060~~

~~**326.116** Conduit.~~

~~The conduit shall be a medium density polyethylene identified as suitable for use with natural gas rated pipe in metric designator 53, 78, or 103 (trade size 2, 3, or 4). The percent fill dimensions for the conduit are shown in Table 326.116.~~

~~The size of the conduit permitted for each conductor size shall be calculated for a percent fill not to exceed those found in Table 1, Chapter 9.~~

~~Table 326.116 Conduit Dimensions~~

~~Conduit Size - Actual Outside Diameter - Actual Inside Diameter Metric Designator Trade Size - mm in. - mm in. 53 2 - 60 2.375 - 49.46 1.947 78 3 - 89 3.500 - 73.30 2.886 103 4 - 114 4.500 - 94.23 3.710~~

~~**326.120** Marking.~~

~~The cable shall be marked in accordance with 310.8(A), 310.8(B)(1), and 310.8(D).~~

Statement of Problem and Substantiation for Public Comment

I believe this section should be removed entirely from the Code, based on my attempts to purchase it and research there are no manufacturers producing this type of cable. There is no UL listing, and I couldn't find any evidence it was ever produced. My research seems to indicate the idea originated in the 1960's. Given what we now know about Sulfur hexafluoride gas, the Intergovernmental Panel on Climate Change reports that it is the most potent greenhouse gas they have ever evaluated, being over 22,200 times more potent than carbon dioxide. The Code specifies IGS cable as having a nonmetallic coating and being suitable for underground feeder/service use. Given the obvious possibility for rupturing the coating while digging and releasing gas into the atmosphere, it seems doubtful that this will ever be produced in the future.

Upon further research on this matter, it appears that Europe has banned Sulfur hexaflouride gas in all applications except "electrical switchgear" since 2006, in recondition of the environmental hazard caused by release of this substance.

Related Item

• First Draft Report

Submitter Information Verification

Submitter Full Name: John Hill
Organization: [Not Specified]
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 14 11:21:39 EDT 2018
Committee: NEC-P06

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Public Comment No. 1407-NFPA 70-2018 [Section No. 330.104]

330.104 Conductors.

Conductors shall be of copper, aluminum, copper-clad aluminum, nickel or nickel-coated copper, solid or stranded. The minimum conductor size shall be 18 AWG copper, nickel or nickel-coated copper,

~~or~~

or ~~12 AWG aluminum~~

~~or~~

~~or~~ 14 AWG copper-clad aluminum or 12 AWG aluminum .

Additional Proposed Changes

File Name	Description	Approved
Prop_Table_310.16_310.15_B_16_.pdf	Proposed Table 310.16	
Proposed_Table_310.17_310.15_B_17_.pdf	Proposed Table 310.17	
J-00265162_FINAL_Copperweld_FFR-_CCA-Cu_Final_Report_Revised_10-27-17.pdf	NRTL NSF Heat Rise Fact Finding Report CCA vs Cu: 14, 12 and 10 AWG	
14_AWG_Thermal_Expansion_Summary.pdf	Report Summary, ETL: 14 AWG CCA vs 14 AWG ETP Cu per ASTM E228 Linear Thermal Expansion	
ETL.14awgCCA.Thermalstablei6049.04-106-31-r0.pdf	Intertek Report ASTM E228 CCA Lineal Thermal Expansion: 14 AWG CCA	
ETL.14awgCu.Thermalstablei6049.03-106-31-r0.pdf	Intertek Report ASTM E228 Lineal Thermal Expansion: 14 AWG ETP Copper	
SampleReqForm_-_MEL.pdf	UL Request for 14 AWG CCA for Testing for Listing Purposes	
Notice_of_Authorization-2017-10-06-4788086098.pdf	UL Listing Notification of NM Cable Made with CCA based Upon Testing 14 AWG CCA	
CONCLUSIONS_FROM_UL_486C_SPRING.pdf	14 AWG CCA Summary from UL 486C Spring Action Sequence Testing	
Cordage_Photos.pdf	Photos Showing CCA uses diameters smaller Than 14 AWG	
Intetek.UL486C.SAS.103589128CRT-001A_003_.pdf	REPORT: INTERTEK, UL 486C Spring Action Sequence with Copper Only Push-In Connectors	

Statement of Problem and Substantiation for Public Comment

PUBLIC COMMENT RESPONSE:

- NEC Needs to Change First before industry and standards can. Public inputs 3174, 2123, and 2126 were submitted to provide for 14 AWG copper-clad aluminum as a recognized conductor in Articles 310 and 330. It is agreed that the product standard does not recognize 14 AWG copper-clad aluminum but product standards follow what is allowed in the NEC and the standard would not be changed to allow something that is not allowed by the NEC. Therefore, the NEC needs to make the change first deeming 14 AWG copper-clad aluminum suitable for use. Using the lack of product safety standard recognition as reasoning to not allow 14 AWG copper-clad aluminum is creating an untenable catch 22.
- New Technology and Energy Efficiency have ideal Uses for 14 AWG Copper-clad Aluminum. With the evolution of LED lighting and energy efficient equipment, the industry substantiates a need for 14 AWG copper-clad aluminum, even at an ampacity of 10 Amps, where OCPD already exist in the market. For copper-clad aluminum

in general, there is no documented instances of failures that would cause a belief that there is a safety issue. With the ampacity limitations proposed for use of 14 AWG copper-clad aluminum and the testing data that backs it up, there is no technical reason for CMP-6 to not allow for 14 AWG copper-clad aluminum as a suitable conductor.

- History of Safe Use. 14 AWG and "smaller" ASTM B566 copper-clad aluminum wires have been safely used for decades in applications (as the individual strands of stranded conductors forming THHN, SEU, PV, Battery Cable, Large Appliance Cord, Jumper Cable, among others) and Data applications (coaxial and trunk cables). ASTM B566 copper-clad aluminum wire is routinely drawn to 22 AWG for applications in power, and 34 AWG for applications in data. There has been no technical substantiation given by CMP6 as to why 14 AWG ASTM B566 copper-clad aluminum wire made with an AA-8000 series aluminum core is unsuitable to be recognized by article 330. 14 AWG could be included in the UL standard for MC cable if it were recognized by article 310. Thermal Stability, Mechanical Integrity and Electrical Performance have never been questioned.
- Old History Should Not Imped with New Data as Provided. When the initial ampacities for copper-clad aluminum were introduced into the 1971 NEC, copper-clad aluminum and aluminum were grouped together right wrong or indifferent. To not recognize 14 AWG ASTM B566 copper-clad aluminum wire in article 330 appears to be a clear case of CMP6 confusing it with single-metal aluminum wire, which carries historical baggage with single metal aluminum. ASTM B566 copper-clad aluminum wire's safety record is spotless in the electrical field, evidenced by CMP6's lack of ability to site instances of failure. Today's fact finding has documented that 14 AWG copper-clad aluminum is safe for use at the ampacities proposed and has had testing for terminals, corrosion elongation and other aspects conducted for existing UL listings.

Related Item

- 2126

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 28 08:44:51 EDT 2018
Committee: NEC-P06

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Table 310.15(B)(16) (formerly Table 310.16) Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)*

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.104(A).]									Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	COPPER			COPPER-CLAD ALUMINUM			ALUMINUM ~~OR COPPERCLAD ALUMINUM~~			
18**	-	-	14	-	-	-	-	-	-	-
16**	-	-	18	-	-	-	-	-	-	-
14**	15	20	25	10	15	20	-	-	-	-
12**	20	25	30	15	20	25	15	20	25	12**
10**	30	35	40	25	30	35	25	30	35	10**
8	40	50	55	35	40	45	35	40	45	8
6	55	65	75	40	50	55	40	50	55	6
4	70	85	95	55	65	75	55	65	75	4
3	85	100	115	65	75	85	65	75	85	3
2	95	115	130	75	90	100	75	90	100	2
1	110	130	145	85	100	115	85	100	115	1
1/0	125	150	170	100	120	135	100	120	135	1/0
2/0	145	175	195	115	135	150	115	135	150	2/0
3/0	165	200	225	130	155	175	130	155	175	3/0
4/0	195	230	260	150	180	205	150	180	205	4/0
250	215	255	290	170	205	230	170	205	230	250
300	240	285	320	195	230	260	195	230	260	300
350	260	310	350	210	250	280	210	250	280	350
400	280	335	380	225	270	305	225	270	305	400
500	320	380	430	260	310	350	260	310	350	500
600	350	420	475	285	340	385	285	340	385	600
700	385	460	520	315	375	425	315	375	425	700
750	400	475	535	320	385	435	320	385	435	750
800	410	490	555	330	395	445	330	395	445	800
900	435	520	585	355	425	480	355	425	480	900
1000	455	545	615	375	445	500	375	445	500	1000
1250	495	590	665	405	485	545	405	485	545	1250
1500	525	625	705	435	520	585	435	520	585	1500
1750	545	650	735	455	545	615	455	545	615	1750
2000	555	665	750	470	560	630	470	560	630	2000

*Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F). Refer to 310.15(B)(3)(a) for more than three current-carrying conductors.

**Refer to 240.4(D) for conductor overcurrent protection limitations.

Table 310.15(B)(17) (formerly Table 310.17) Allowable Ampacities of Single-Insulated Conductors Rated Up to and Including2000 Volts in Free Air, Based on Ambient Temperature of 30°C (86°F)*

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.104(A).]									Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW,	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	COPPER			COPPER-CLAD ALUMINUM			ALUMINUM ~~OR COPPERCLAD ALUMINUM~~			
18**	-	-	18	-	-	-	-	-	-	-
16**	-	-	24	-	-	-	-	-	-	-
14**	25	30	35	20	25	30	-	-	-	-
12**	30	35	40	25	35	40	25	30	35	12**
10**	40	50	55	35	40	50	35	40	45	10**
8	60	70	80	45	55	60	45	55	60	8
6	80	95	105	60	75	85	60	75	85	6
4	105	125	140	80	100	115	80	100	115	4
3	120	145	165	95	115	130	95	115	130	3
2	140	170	190	110	135	150	110	135	150	2
1	165	195	220	130	155	175	130	155	175	1
1/0	195	230	260	150	180	205	150	180	205	1/0
2/0	225	265	300	175	210	235	175	210	235	2/0
3/0	260	310	350	200	240	270	200	240	270	3/0
4/0	300	360	405	235	280	315	235	280	315	4/0
250	340	405	455	265	315	355	265	315	355	250
300	375	445	500	290	350	395	290	350	395	300
350	420	505	570	330	395	445	330	395	445	350
400	455	545	615	355	425	480	355	425	480	400
500	515	620	700	405	485	545	405	485	545	500
600	575	690	780	455	545	615	455	545	615	600
700	630	755	850	500	595	670	500	595	670	700
750	655	785	885	515	620	700	515	620	700	750
800	680	815	920	535	645	725	535	645	725	800
900	730	870	980	580	700	790	580	700	790	900
1000	780	935	1055	625	750	845	625	750	845	1000
1250	890	1065	1200	710	855	965	710	855	965	1250
1500	980	1175	1325	795	950	1070	795	950	1070	1500
1750	1070	1280	1445	875	1050	1185	875	1050	1185	1750
2000	1155	1385	1560	960	1150	1295	960	1150	1295	2000

*Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F).
**Refer to 240.4(D) for conductor overcurrent protection limitations.

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TEST REPORT

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Peter Graser
Copperweld Bimetallic
215 Centerview Dr
Brentwood TN 37027

Facility: C0352008
Copperweld Bimetallic
215 Centerview Dr
Brentwood TN 37027

Report Date: October 27, 2017

Description:	CCA –Cu Ampacity Comparison
Type of Evaluation	Fact Finding Investigation
Job Number	J-00265162
Project Number	0225-104
Project Manager	Don Tottingham
Location	789 Dixboro Road, Ann Arbor
Inspection Dates	August 7- August 18, 2017
Total # of Pages	125 Pages

Evaluated By: _____

Anas Alaghazali- Engineer

Reviewed By: Steve Fabian

Steve Fabian- Senior Technical Manager

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Purpose: The purpose of this testing was to evaluate copper clad aluminum wire (CCA) and copper wire (Cu) as a single conductor, non- -metallic 2 hot conductors, and two conductor in conduit, under the same current condition, and to determine their equivalence in performance

Credentials: NSF International, an accredited Nationally Recognized Testing Laboratory (NRTL), an Accredited Standards Council of Canada (SCC) laboratory, and accredited by the International Standards Organization (ISO) to ISO 14001.

Executive Summary: This Fact-Finding Investigation was conducted to develop a comparative temperature – heat rise database for Copper and Copper-Clad Aluminum Conductors in Sizes No. 14 -10 AWG.

The details of the test procedure for each conductor size, 14-10 AWG, is outlined in the report.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 14 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 18, 29, and 38.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 12 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 50, 61, and 71.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 10 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 87, 100, and 113.

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Test Set- Up/ Layout
14 AWG single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 14AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 14AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 14 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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FIGURE 1
Circuit Layout

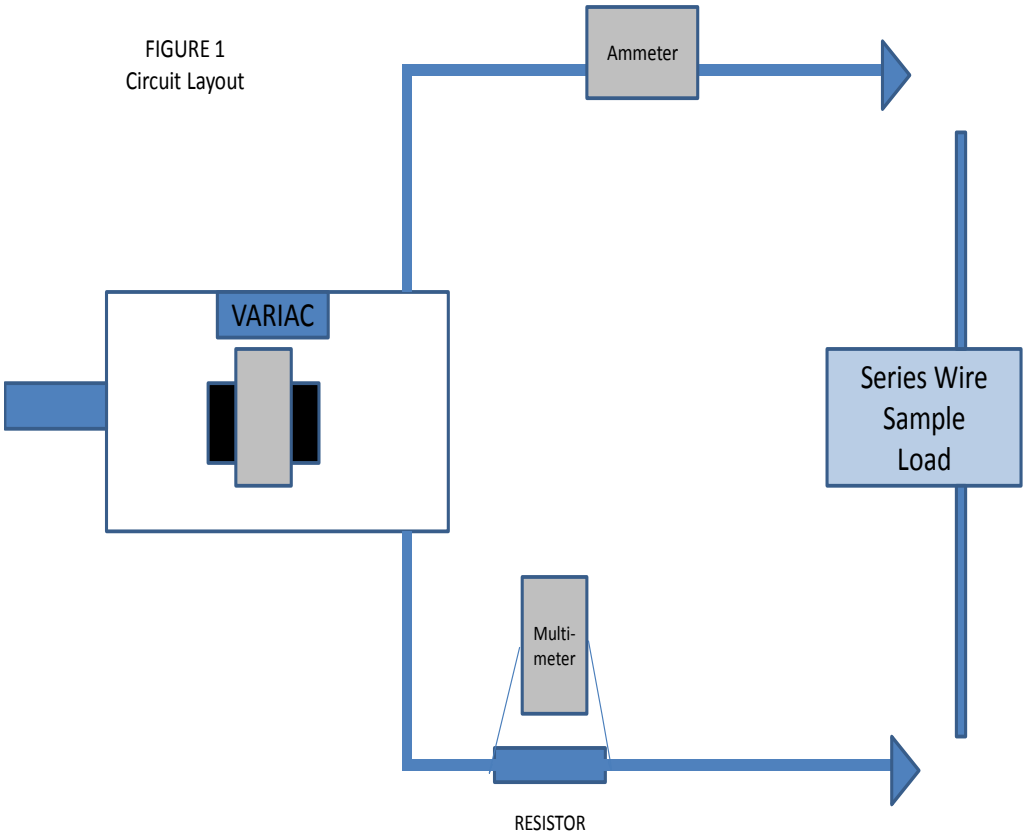

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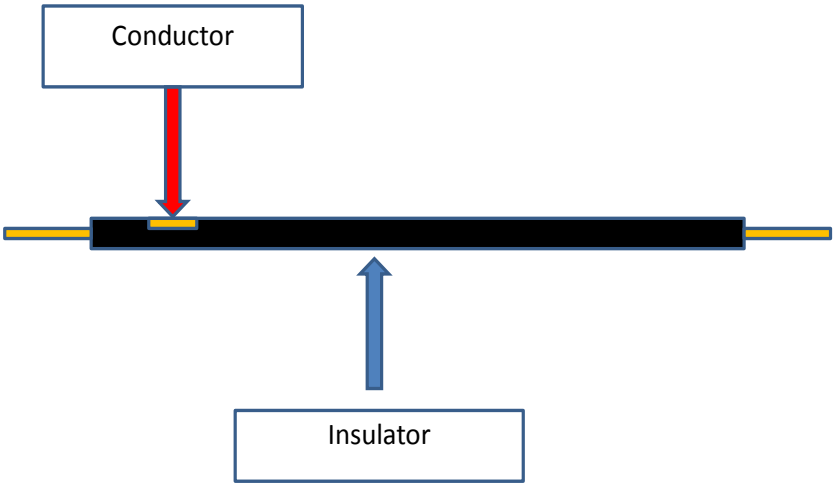
FIGURE 2
Single conductor



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Test Procedure
14 AWG Single Conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	Open air	5	30
14	Open air	10	30
14	Open air	15	30
14	Open air	20	30
14	Open air	25	30
14	Open air	30	30
14	Open air	35	30
14	Open air	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA Single Conductor open Air (Page 1/3))

Scan	Time	Elapsed	212 CU-AL #1 Core	213 CU-AL #1 Insu	203 CU-AL#2 Core	204 CU-AL#2 Insu	205 CU-AL#3 Insu
	5 AMPS						
32.00	42956.43	00:00:30:59	23.66	23.26	23.60	23.45	23.89
		Corrected Ambient	32.38	31.98	32.32	32.17	32.61
		Average	32.31				
		Average Core	32.40				
		Average Insulation	32.20				
	10 AMPS						
62.00	42956.45	00:01:00:59	28.37	28.10	27.74	28.35	28.81
		Corrected Ambient	36.96	36.69	36.33	36.94	37.40
		Average	36.38				
		Average Core	36.52				
		Average Insulation	36.22				
	15 AMPS						
92.00	42956.47	00:01:30:59	33.80	33.78	32.88	33.88	34.50
		Corrected Ambient	42.42	42.40	41.50	42.50	43.12
		Average	41.70				
		Average Core	42.16				
		Average Insulation	41.20				
	20 AMPS						
122.00	42956.49	00:02:00:59	43.82	43.54	42.12	43.28	44.61
		Corrected Ambient	52.04	51.76	50.34	51.50	52.83

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		Average	50.79				
		Average Core	51.77				
		Average Insulation	49.71				
	25 AMPS						
154.00	42956.52	00:02:32:59	53.50	53.49	51.23	52.53	54.61
		Corrected Ambient	61.81	61.80	59.54	60.84	62.92
		Average	60.07				
		Average Core	61.51				
		Average Insulation	58.50				
	30 AMPS						
183.00	42956.54	00:03:01:59	69.00	67.27	65.45	65.49	69.18
		Corrected Ambient	77.08	75.35	73.53	73.57	77.26
		Average	73.57				
		Average Core	75.91				
		Average Insulation	71.02				
	35 AMPS						
216.00	42956.56	00:03:34:59	85.83	83.73	80.52	81.75	86.71
		Corrected Ambient	93.96	91.86	88.65	89.88	94.84
		Average	89.81				
		Average Core	92.67				
		Average Insulation	86.68				

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14 AWG CCA Single Conductor open Air (Page 2/3))

208 CU-AL#3 Core	120 CU-AL #4 Core	211 CU-AL#4 Insu	102 CU-AL#5 Core	110 CU-AL#5 Insu	117 CU-AL#6 Core	116 CU-AL#7 Insul	320 CU-AL#7 Core	113 CU-AL#8 Core
23.51	23.63	23.37	23.62	23.47	23.86	23.44	23.36	23.79
32.23	32.35	32.09	32.34	32.19	32.58	32.16	32.08	32.51
27.61	27.35	26.86	27.79	27.18	27.93	27.43	27.16	27.92
36.20	35.94	35.45	36.38	35.77	36.52	36.02	35.75	36.51
32.59	32.02	31.20	33.01	31.82	33.24	31.93	32.18	33.99
41.21	40.64	39.82	41.63	40.44	41.86	40.55	40.80	42.61
41.25	41.32	38.66	42.34	39.53	43.15	40.71	41.44	44.59
49.47	49.54	46.88	50.56	47.75	51.37	48.93	49.66	52.81

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49.39	49.93	45.71	51.18	46.84	52.51	48.79	50.05	53.67
57.70	58.24	54.02	59.49	55.15	60.82	57.10	58.36	61.98
62.25	62.46	56.14	64.18	58.21	68.21	60.49	63.39	67.06
70.33	70.54	64.22	72.26	66.29	76.29	68.57	71.47	75.14
76.43	76.02	68.71	79.20	71.51	84.64	74.08	77.84	82.07
84.56	84.15	76.84	87.33	79.64	92.77	82.21	85.97	90.20

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14 AWG CCA Single Conductor open Air (Page 3/3))

114 CU-AL#8 Insul	109 CU-AL#9 Core	112 CU-AL#9 Insul	106 CU-AL#10 Core	107 CU-AL#10 Insul	101 CU-AL#11 Core	103 CU-AL#11 Insul	104 CU-AL#12 Core	105 CU-AL#12 Insul
23.65	23.82	23.63	23.82	23.54	23.54	23.19	23.97	23.43
32.37	32.54	32.35	32.54	32.26	32.26	31.91	32.69	32.15
27.87	27.44	27.22	27.77	27.44	28.29	26.84	29.82	27.86
36.46	36.03	35.81	36.36	36.03	36.88	35.43	38.41	36.45
32.54	33.29	31.49	33.60	32.07	34.85	31.62	37.00	33.55
41.16	41.91	40.11	42.22	40.69	43.47	40.24	45.62	42.17
42.59	42.44	39.88	44.38	40.51	46.65	40.27	49.14	42.83

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50.81	50.66	48.10	52.60	48.73	54.87	48.49	57.36	51.05
51.66	51.50	47.77	54.91	48.80	58.73	49.17	61.74	52.68
59.97	59.81	56.08	63.22	57.11	67.04	57.48	70.05	60.99
64.87	64.44	60.00	70.51	61.42	75.50	62.17	81.54	67.10
72.95	72.52	68.08	78.59	69.50	83.58	70.25	89.62	75.18
81.21	80.84	74.81	88.65	76.44	96.72	79.11	105.73	86.00
89.34	88.97	82.94	96.78	84.57	104.85	87.24	113.86	94.13

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14 AWG Cu Single conductor open air (Page 1/2))

Scan	Time	Elapsed	313 CU#1 Insul	312 CU#1 Core	309 CU#2 Core	310 CU#2 Insul	304 CU#3 Core	305 CU#3 Insul
	5 AMPS							
32.00	42956.43	00:00:30:59	22.94	22.76	23.27	22.75	23.19	22.87
		Corrected Ambient	31.66	31.48	31.99	31.47	31.91	31.59
		Average	31.76					
		Average Core	31.82					
		Average Insulation	31.70					
	10 AMPS							
62.00	42956.45	00:01:00:59	26.12	25.30	26.88	25.64	25.98	25.79
		Corrected Ambient	34.71	33.89	35.47	34.23	34.57	34.38
		Average	34.71					
		Average Core	34.68					
		Average Insulation	34.75					
	15 AMPS							
92.00	42956.47	00:01:30:59	29.59	28.15	30.84	28.94	29.08	29.21
		Corrected Ambient	38.21	36.77	39.46	37.56	37.70	37.83
		Average	38.20					
		Average Core	38.06					
		Average Insulation	38.34					

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	20 AMPS							
122.00	42956.49	00:02:00:59	35.06	33.50	38.22	34.03	34.76	34.30
		Corrected Ambient	43.28	41.72	46.44	42.25	42.98	42.52
		Average	43.85					
		Average Core	44.07					
		Average Insulation	43.64					
	25 AMPS							
154.00	42956.52	00:02:32:59	41.11	39.21	44.97	39.53	39.76	39.48
		Corrected Ambient	49.42	47.52	53.28	47.84	48.07	47.79
		Average	49.79					
		Average Core	49.98					
		Average Insulation	49.60					
	30 AMPS							
183.00	42956.54	00:03:01:59	50.05	48.57	55.19	47.04	46.81	46.68
		Corrected Ambient	58.13	56.65	63.27	55.12	54.89	54.76
		Average	58.05					
		Average Core	58.69					
		Average Insulation	57.42					
	35 AMPS							
216.00	42956.56	00:03:34:59	58.77	56.46	67.22	55.89	54.87	54.95
		Corrected Ambient	66.90	64.59	75.35	64.02	63.00	63.08
		Average	67.08					
		Average Core	67.91					
		Average Insulation	66.25					

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14 AWG Cu Single Conductor open Air (Page 2/2))

206 CU#4 Core	302 CU#4 Insul	218 CU#5 Core	220 CU#5 Insul	209 CU#6 Core	214 CU#6 Insul
23.07	23.20	23.11	22.85	23.21	23.30
31.79	31.92	31.83	31.57	31.93	32.02
26.07	26.44	26.00	26.11	26.30	26.84
34.66	35.03	34.59	34.70	34.89	35.43
29.44	30.07	29.34	29.78	29.81	30.74
38.06	38.69	37.96	38.40	38.43	39.36
35.82	35.84	35.94	35.90	36.83	37.36

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44.04	44.06	44.16	44.12	45.05	45.58
41.32	41.65	41.70	41.84	43.06	44.11
49.63	49.96	50.01	50.15	51.37	52.42
50.11	49.91	50.16	49.62	52.82	52.73
58.19	57.99	58.24	57.70	60.90	60.81
59.11	58.81	59.35	57.77	61.68	62.52
67.24	66.94	67.48	65.90	69.81	70.65

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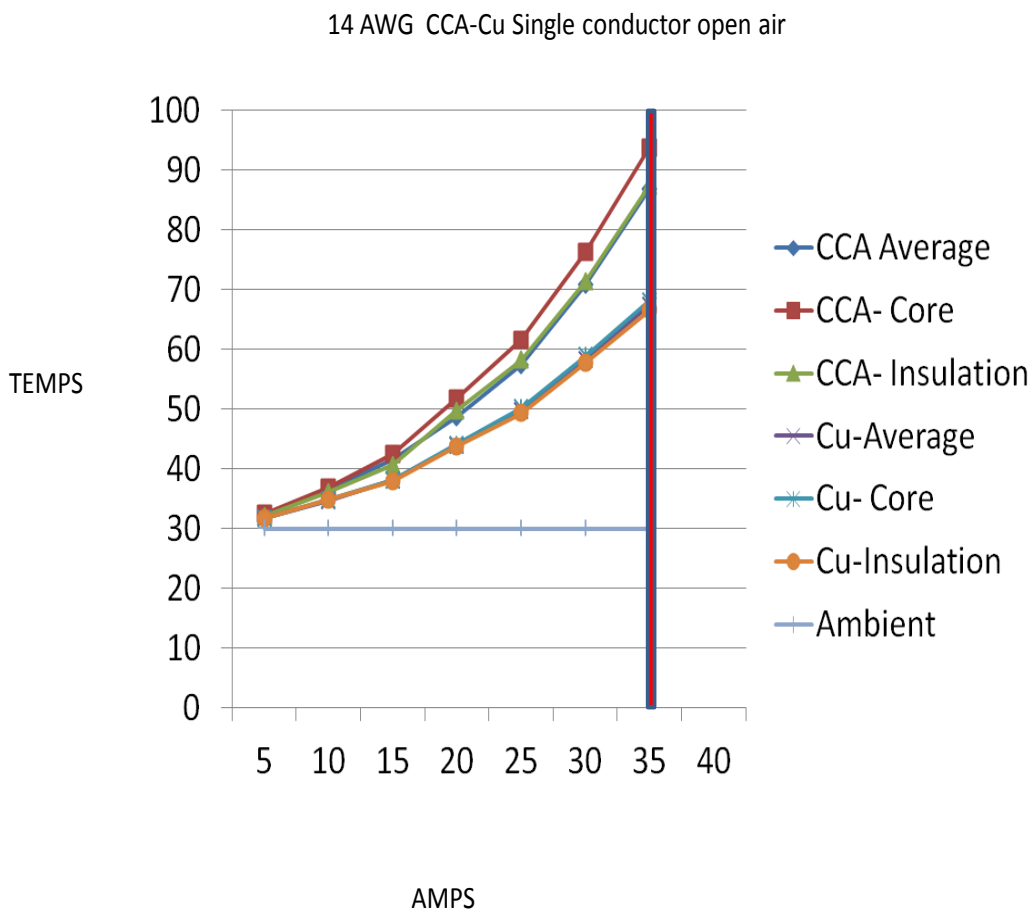

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Test Set- Up/ Layout
14 AWG in non-metallic cable in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 14 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 14 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 14 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used is calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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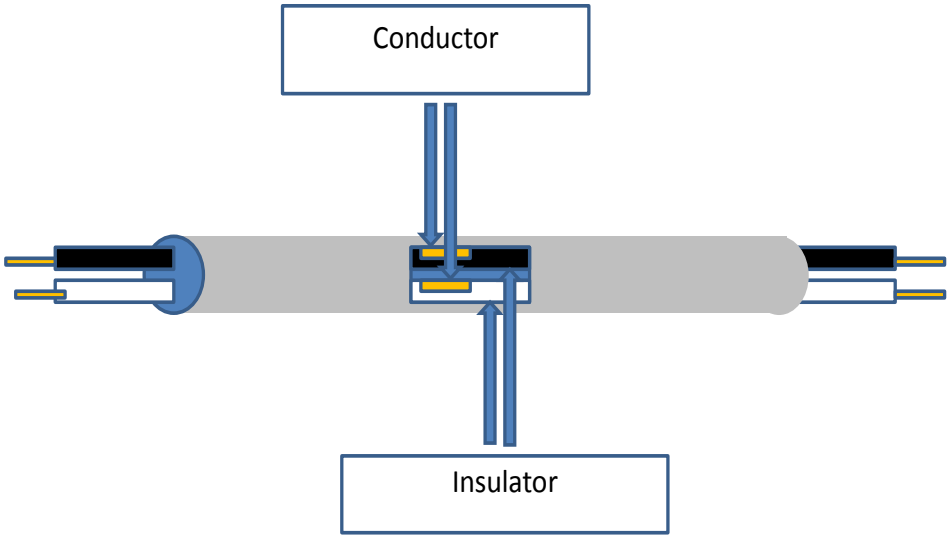
FIGURE 3
Two Line Conductor/ Ground(not connected) Non- metallic Cable



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Test Procedure
14 AWG in Non-metallic cable

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.
.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	NM Cable	5	30
14	NM Cable	10	30
14	NM Cable	15	30
14	NM Cable	20	30
14	NM Cable	25	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA Non Metallic (2 Conductor) open air (Page 1/3)

Scan	Time	Elapsed	101-CU-AL White Cable-Core	103 CU-AL White Cable Insulation	104 CU-AL Black Cable Core	105 CU-AL Black Cable Insulation	106 CU-AL Black Cable Core
29	5 AMPS	00:00:27:59					
30	8/15/2017 12:13	00:00:28:59	24.592	24.57	24.179	24.336	24.308
		Corrected Ambient	32.96	32.94	32.55	32.71	32.68
		Average	32.80				
		Average Core	32.92				
		Average Insulation	32.86				
60	10 AMPS	00:00:58:59	29.924	30.049	28.525	28.47	28.704
61	8/15/2017 12:44	00:00:59:59	29.497	30.014	28.308	28.427	28.595
		Corrected Ambient	37.95	38.46	36.76	36.88	37.04
		Average	37.53				
		Average Core	38.05				
		Average Insulation	38.13				
88	15 AMPS	00:01:26:59					
89	8/15/2017 13:12	00:01:27:59	37.658	38.549	35.166	34.525	34.751
		Corrected Ambient	45.92	46.81	43.43	42.79	43.02
		Average	44.46				
		Average Core	45.13				
		Average Insulation	45.22				
120	20 AMPS	00:01:58:59					
121	8/15/2017 13:44	00:01:59:59	48.404	50.441	43.994	43.521	43.462
		Corrected Ambient	56.61	58.65	52.20	51.73	51.67

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		Average	54.26				
		Average Core	54.78				
		Average Insulation	55.89				
151	25 AMPS	00:02:29:59					
152	8/15/2017 14:15	00:02:30:59	64.72	68.548	57.572	55.957	56.371
		Corrected Ambient	73.02	76.85	65.87	64.26	64.67
		Average	68.95				
		Average Core	69.61				
		Average Insulation	71.60				

14 AWG CCA Non Metallic (2 Conductor) open air (Page 2/3)

107 CU-AL Black Cable Insulation	109 CU-AL White Cable Core	112 CU-AL White Cable# 2 Insulation	113 CU-AL Black Cable#3 Core	114 CU-AL Black Cable #3 Insulation	116 CU-AL White Cable #3 Insulation	320 CU-AL White Cable#3 Core	315 CU-AL Black Cable#4 Core	118 CU-AL Black Cable#4 Insulation	102 CU-AL White Cable #4 Core
24.3	24.745	24.436	24.638	24.609	24.972	25.105	24.416	23.739	24.551
32.67	33.12	32.81	33.01	32.98	33.34	33.48	32.79	32.11	32.92
28.89	29.97	29.341	29.59	29.289	30.546	31.225	29.545	29.786	29.823
28.741	29.96	29.233	29.734	29.38	30.642	31.368	29.462	29.627	29.73
37.19	38.41	37.68	38.18	37.83	39.09	39.82	37.91	38.08	38.18

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35.244	37.473	35.97	36.069	36.113	38.561	39.712	36.608	35.975	37.473
43.51	45.74	44.23	44.33	44.38	46.83	47.98	44.87	44.24	45.74
44.923	47.618	47.015	45.275	46.599	50.61	51.411	46.52	44.202	47.657
53.13	55.83	55.22	53.48	54.81	58.82	59.62	54.73	52.41	55.86
58.491	62.893	62.242	58.51	61.014	67.133	69.89	61.364	57.959	63.192
66.79	71.19	70.54	66.81	69.32	75.43	78.19	69.67	66.26	71.49

14 AWG CCA Non Metallic (2 Conductor) open air (Page 3/3)

110 CU-AL White Cable#4 Insulation	120 CU-AL Black Cable#5 Core	211 CU-AL Black Cable#5 Insulation	205CU-AL White Cable#5 Insulation	208 CU-AL White Cable#5 Core	203 CU-AL Black Cable#6 Core	204 CU-AL Black Cbale#6 Insulation	212 CU-AL White Cable#6 Core	213 CU-AL White Cable#6 Insulation
25.194	24.66	25.029	24.923	24.407	24.321	24.045	24.677	23.717
33.56	33.03	33.40	33.29	32.78	32.69	32.42	33.05	32.09

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31.019	29.933	30.894	30.803	29.33	29.022	29.051	30.233	28.558
31.019	29.959	30.909	30.863	29.348	29.055	28.806	30.238	28.543
39.47	38.41	39.36	39.31	37.80	37.50	37.26	38.69	36.99
39.162	37.293	38.859	38.947	35.984	35.982	36.311	38.22	35.275
47.43	45.56	47.12	47.21	44.25	44.25	44.58	46.48	43.54
51.486	47.619	50.771	50.602	44.739	43.968	46.287	48.202	45.682
59.69	55.83	58.98	58.81	52.95	52.18	54.49	56.41	53.89
69.419	62.641	68.43	68.105	58.395	56.519	61.868	63.671	60.471
77.72	70.94	76.73	76.41	66.70	64.82	70.17	71.97	68.77

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14 AWG Cu Non Metallic (2 Conductor) open air
Page (1/2)

Scan	Time	Elapsed	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core
29	5 AMPS	00:00:27:59					
30	8/15/2017 12:13	00:00:28:59	23.451	23.326	22.977	23.042	22.899
		Corrected Ambient	31.82	31.70	31.35	31.41	31.27
		Average	31.63				
		Average Core	31.61				
		Average Insulation	31.66				
60	10 AMPS	00:00:58:59					
61	8/15/2017 12:44	00:00:59:59	27.177	26.623	25.544	25.678	25.495
		Corrected Ambient	35.63	35.07	33.99	34.13	33.94
		Average	34.60				
		Average Core	34.58				
		Average Insulation	34.62				
88	15 AMPS	00:01:26:59					
89	8/15/2017 13:12	00:01:27:59	32.586	31.152	29.253	29.605	29.106
		Corrected Ambient	40.85	39.42	37.52	37.87	37.37
		Average	38.69				
		Average Core	38.68				
		Average Insulation	38.70				
120	20 AMPS	00:01:58:59					
121	8/15/2017 13:44	00:01:59:59	40.601	37.689	35.231	35.538	35.083
		Corrected Ambient	48.81	45.90	43.44	43.75	43.29

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		Average	44.60				
		Average Core	44.79				
		Average Insulation	44.41				
151	25 AMPS	00:02:29:59					
152	8/15/2017 14:15	00:02:30:59	51.287	47.245	42.544	43.699	41.81
		Corrected Ambient	59.59	55.55	50.85	52.00	50.11
		Average	53.14				
		Average Core	53.05				
		Average Insulation	53.23				

14 AWG Cu Non Metallic (2 Conductor) open air Page (2/2)

302 CU Black Cable#3 Insulation	304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
23.44	23.503	23.264	23.458	23.245	23.126	23.416
31.81	31.87	31.63	31.83	31.62	31.50	31.79
26.374	26.371	26.051	26.426	25.928	25.744	26.369
34.82	34.82	34.50	34.88	34.38	34.19	34.82

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31.135	30.734	30.046	30.955	29.706	29.884	30.947
39.40	39.00	38.31	39.22	37.97	38.15	39.21
37.502	36.586	35.021	37.138	34.631	34.872	36.818
45.71	44.79	43.23	45.35	42.84	43.08	45.03
47.427	44.327	43.744	45.605	42.023	42.908	45.452
55.73	52.63	52.05	53.91	50.32	51.21	53.75

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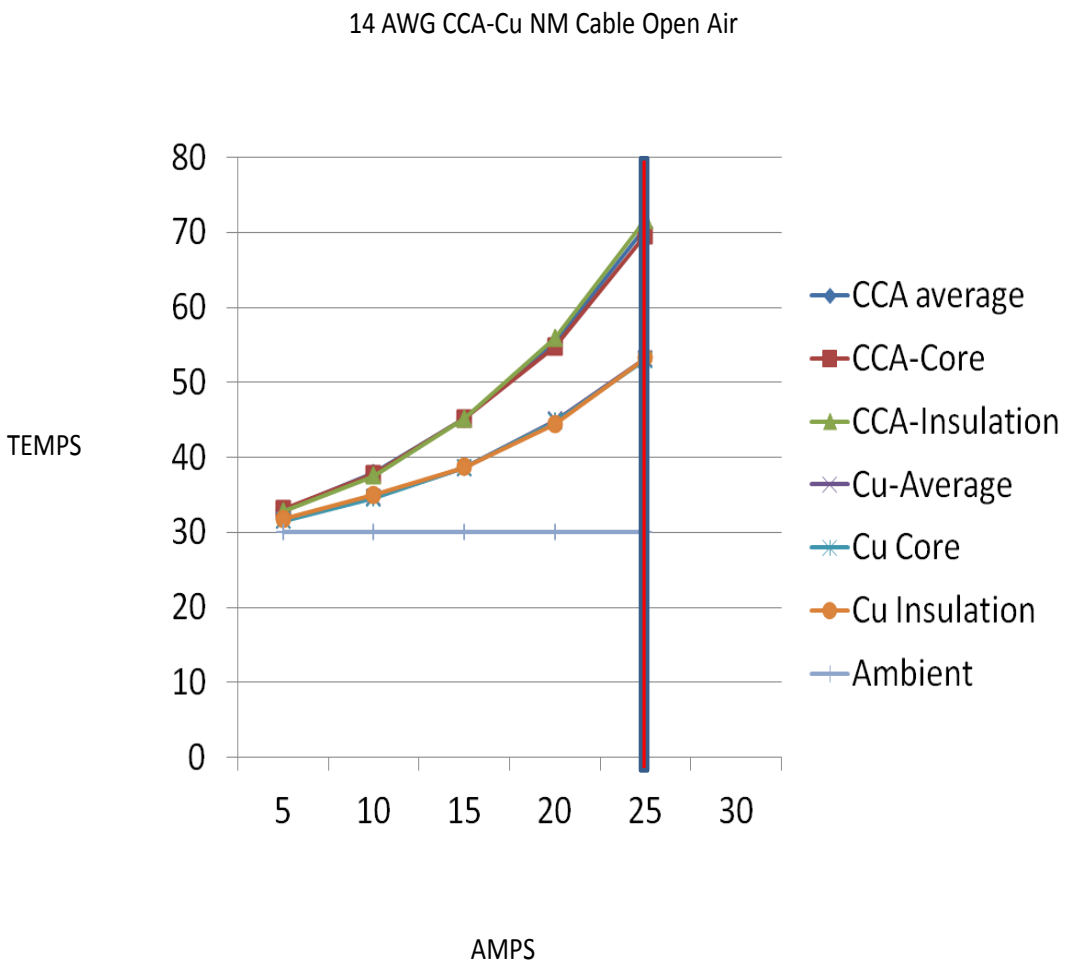

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Test Set- Up/ Layout
14 AWG (2 conductors) in Conduit

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 14 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 14 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 14 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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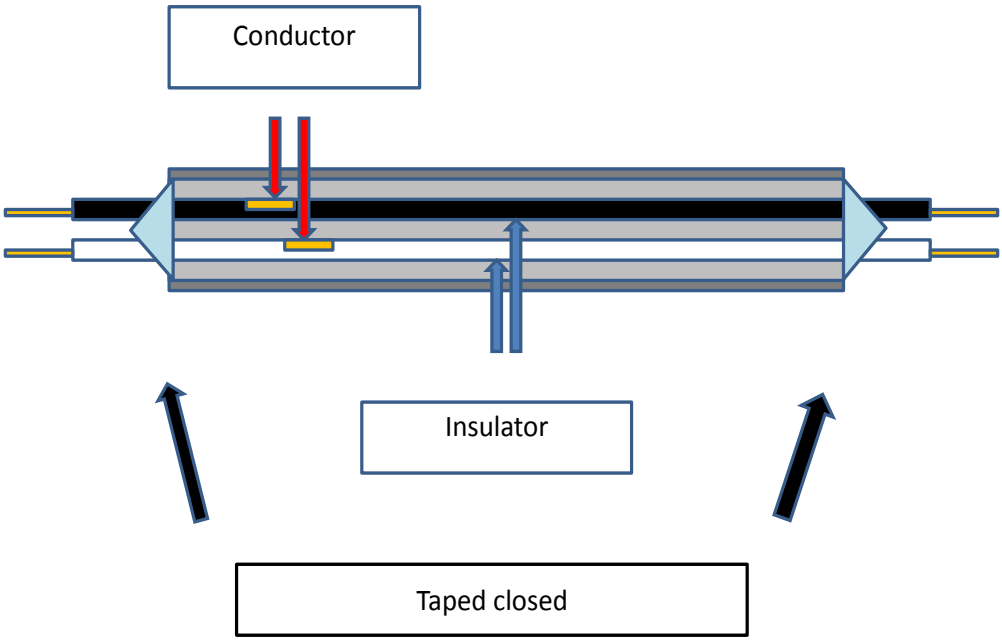
FIGURE 4
Two Conductors in ½ Inch Conduit



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Test Procedure
14 AWG(2 conductors) in Conduit

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 Amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	Conduit	5	30
14	Conduit	10	30
14	Conduit	15	30
14	Conduit	20	30
14	Conduit	25	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA (2 Conductor) in Conduit
Page(1/3)

	101-CCA#1 Core	106 CCA#1 Insulation	107 CCA#2 Core	105 CCA#2 Insulation	112 CCA#3 Core	109 CCA#3 Insulation	113 CCA#4 Core	104 CCA#4 Insulaiton
5 AMPS								
00:00:51:59	24.79	24.61	24.66	24.03	24.04	23.58	23.96	23.72
Corrected Ambient	34.83	34.65	34.70	34.07	34.08	33.62	34.00	33.76
Average	34.19							
Core Average	34.55							
Insulation Average	33.86							
10 AMPS								
00:02:01:59	34.64	34.94	34.84	32.81	32.64	31.25	32.51	31.30
Corrected Ambient	44.83	45.13	45.03	42.99	42.83	41.44	42.70	41.49
Average	43.35							
Core Average	44.12							
Insulation Average	42.64							
15 AMPS								
00:02:52:59	51.48	52.20	52.36	47.74	46.95	43.79	46.60	43.97
Corrected Ambient	61.07	61.78	61.94	57.32	56.53	53.37	56.18	53.55
Average	58.13							
Core Average	59.84							
Insulation Average	56.57							
20 AMPS								
00:03:43:59	72.68	74.44	73.96	66.89	66.02	59.92	64.39	60.07
Corrected Ambient	82.07	83.84	83.35	76.28	75.41	69.31	73.78	69.47
Average	77.26							
Core Average	80.16							
Insulation Average	74.60							
25 AMPS								
00:04:33:59	117.65	117.35	119.71	105.33	107.61	92.87	101.25	92.53
Corrected Ambient	127.06	126.76	129.12	114.74	117.02	102.28	110.66	101.94
Average	117.69							
Core Average	124.41							

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Insulation Average	111.52							

14 AWG CCA (2 Conductor) in Conduit Page(2/3)

120 CCA#5 Core	116 CCA#5 Insulation	110 CCA#6 Core	102 CCA#6 Insulation	118 CCA#7 Insulation	117 CCA#8 Core	103 CCA#8 Insulation	114 CCA#9 Core
24.64	23.92	25.11	24.39	23.42	24.81	23.37	24.43
34.69	33.97	35.15	34.43	33.47	34.85	33.42	34.48
34.64	32.33	35.84	34.63	30.90	33.95	31.16	32.84
44.82	42.52	46.03	44.82	41.09	44.13	41.35	43.03
51.59	46.53	54.59	52.00	43.29	50.64	44.39	47.81
61.17	56.11	64.17	61.58	52.88	60.22	53.97	57.39
73.42	64.63	78.42	73.82	58.67	71.14	60.84	67.02
82.81	74.02	87.81	83.21	68.06	80.53	70.23	76.41
119.35	101.08	128.37	117.64	88.72	117.29	94.74	110.37
128.76	110.49	137.78	127.05	98.13	126.70	104.15	119.78

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14 AWG CCA (2 Conductor) in Conduit Page(3/3)

211 CCA#9 Insulation	212 CCA#10 Core	204 CCA#10 Insulation	220 CCA#11 Core	203 CCA#11 Insulaiton	218 CCA#12 Core	214 CCA#12 Insulation
23.42	24.44	23.75	24.58	24.03	24.15	23.59
33.46	34.48	33.80	34.62	34.07	34.20	33.63
31.17	34.07	33.65	34.69	33.24	32.61	32.04
41.36	44.26	43.84	44.88	43.43	42.80	42.22
45.01	50.94	50.44	52.39	48.40	47.47	46.07
54.59	60.52	60.02	61.97	57.98	57.05	55.65
61.56	71.91	71.23	73.72	67.11	65.73	63.36
70.95	81.30	80.62	83.11	76.50	75.12	72.75
97.96	118.18	113.21	118.54	104.99	106.66	98.95
107.37	127.59	122.62	127.95	114.40	116.07	108.36

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14 AWG Cu (2 Conductor) in Conduit Page 1/2)

	206 CU#1 Core	209 CU#1 Insulation	213 CU#3 Core	208 CU#3 Insualtion	205 CU#5 Core	305 CU#5 Insulation
5 AMPS						
00:00:51:59	22.48	21.97	22.25	22.56	22.77	22.70
Corrected Ambient	32.52	32.02	32.30	32.60	32.81	32.74
Average	32.67					
Core Average	32.81					
Insulation Average	32.53					
10 AMPS						
00:02:01:59	27.37	26.44	27.92	28.45	28.47	28.16
Corrected Ambient	37.56	36.63	38.11	38.63	38.65	38.35
Average	38.29					
Core Average	38.65					
Insulation Average	37.92					
15 AMPS						
00:02:52:59	36.14	34.08	37.61	38.51	38.48	37.28
Corrected Ambient	45.72	43.67	47.19	48.09	48.07	46.86
Average	47.09					
Core Average	47.98					
Insulation Average	46.20					
20 AMPS						
00:03:43:59	45.98	42.87	49.09	50.19	50.16	47.55
Corrected Ambient	55.37	52.26	58.48	59.58	59.56	56.94
Average	57.97					
Core Average	59.56					
Insulation Average	56.39					
25 AMPS						
00:04:33:59	65.98	59.49	71.81	72.52	73.11	68.34
Corrected Ambient	75.39	68.90	81.22	81.93	82.52	77.75
Average	79.54					
Core Average	82.77					
Insulation Average	76.31					

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14 AWG Cu (2 Conductor) in Conduit
Page (2/2)

318 CU#7 Core	315 CU#7 Insulation	310 CU#9 Core	313 CU#9 Insulaiton	304 CU#11 Core	312 CU#11 Insulation
23.00	22.44	23.28	22.62	22.81	22.62
33.04	32.48	33.33	32.66	32.85	32.66
29.12	27.38	29.95	27.92	27.95	28.05
39.31	37.57	40.14	38.11	38.14	38.24
39.72	36.00	41.63	36.70	36.82	37.14
49.30	45.58	51.21	46.28	46.40	46.73
52.56	46.16	55.35	47.13	47.86	48.12
61.95	55.55	64.74	56.52	57.25	57.51
78.19	65.80	82.60	66.20	68.46	69.08
87.60	75.21	92.01	75.61	77.87	78.49

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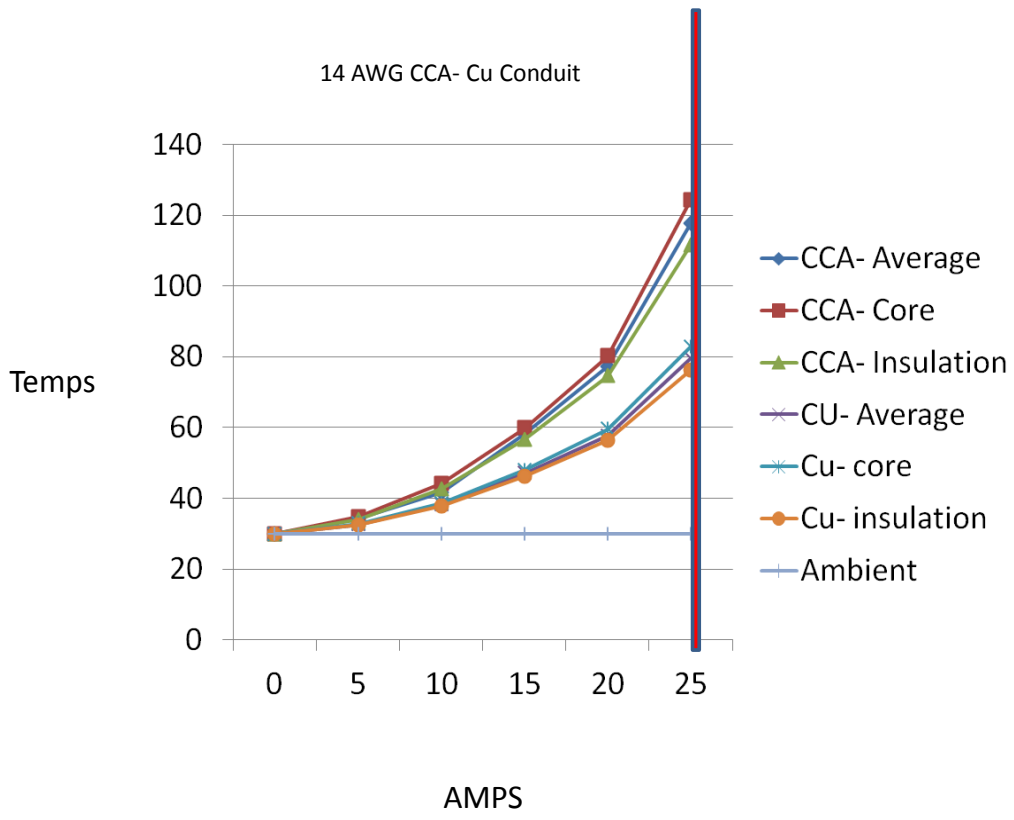

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Test Set- Up/ Layout
12 AWG Single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 12 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 12 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 12 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG single conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	Open air	5	30
12	Open air	10	30
12	Open air	15	30
12	Open air	20	30
12	Open air	25	30
12	Open air	30	30
12	Open air	35	30
12	Open air	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG single conductors
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Scan	Time	101- CU-AL White Cable#1- Insulation	104 CU-AL Black Cable#1 Core	105 CU-AL Black Cable#1 Insulation	106 CU-AL Black Cable#2 Core	107 CU-AL Black Cable#2 Insulation	109 CU-AL White Cable#2 Core
	5 AMPS						
30	8/16/2017 14:54	23.5	23.719	23.597	24.101	23.626	23.882
	Corrected Ambient	31.925	32.144	32.022	32.526	32.051	32.307
	Average	31.86845					
	Average Core	32.1068					
	Average Insulation	31.66983					
	10 AMPS						
60	8/16/2017 15:24	26.487	26.702	26.788	27.393	26.714	26.989
	Corrected Ambient	35	35.215	35.301	35.906	35.227	35.502
	Average	34.92791					
	Average Core	35.3563					
	Average Insulation	34.57092					
	15 AMPS						
91	8/16/2017 15:55	30.559	30.658	30.656	32.374	30.779	31.249
	Corrected Ambient	38.79	38.889	38.887	40.605	39.01	39.48
	Average	38.64927					
	Average Core	39.4042					
	Average Insulation	38.02017					
	20 AMPS						
121	8/16/2017 16:25	35.826	35.837	35.678	38.337	35.742	36.622
	Corrected Ambient	44.421	44.432	44.273	46.932	44.337	45.217
	Average	43.80986					
	Average Core	45.065					
	Average Insulation	42.76392					

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	25 AMPS						
152	8/16/2017 16:56	42.958	43.207	43.137	48.117	43.123	44.441
	Corrected Ambient	51.22	51.469	51.399	56.379	51.385	52.703
	Average	50.82832					
	Average Core	52.8027					
	Average Insulation	49.183					
	30 AMPS						
182	8/16/2017 17:26	50.663	51.573	51.558	58.75	51.353	52.748
	Corrected Ambient	59.164	60.074	60.059	67.251	59.854	61.249
	Average	58.849					
	Average Core	61.1368					
	Average Insulation	56.9425					
	35 AMPS						
213	8/16/2017 17:57	59.241	60.489	60.736	70.389	59.671	62.631
	Corrected Ambient	67.397	68.645	68.892	78.545	67.827	70.787
	Average	67.43436					
	Average Core	70.5558					
	Average Insulation	64.83317					
	40 AMPS						
244	8/16/2017 18:28	67.579	70.938	69.371	84.754	68.417	73.658
	Corrected Ambient	75.86	79.219	77.652	93.035	76.698	81.939
	Average	76.85605					
	Average Core	80.71511					
	Average Insulation	72.72958					

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12 AWG Single conductor
(Page 2 of 3)

112 CU-AL White Cable# 2 Insulation	113 CU-AL Black Cable#3 Core	114 CU-AL Black Cable #3 Insulation	116 CU-AL White Cable #3 Insulation	320 CU-AL White Cable#4 Core	118 CU-AL Black Cable#4 Insulation
23.57	23.62	23.4	23.285	23.776	23.093
31.995	32.045	31.825	31.71	32.201	31.518
26.464	26.507	26.264	25.822	26.845	25.692
34.977	35.02	34.777	34.335	35.358	34.205
30.073	30.291	29.915	29.382	31.533	29.206
38.304	38.522	38.146	37.613	39.764	37.437
34.775	34.982	34.305	33.662	37.097	32.398
43.37	43.577	42.9	42.257	45.692	40.993
41.606	42.027	41.564	40.681	46.895	35.318

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49.868	50.289	49.826	48.943	55.157	43.58
49.167	49.465	49.303	47.244	55.947	45.015
57.668	57.966	57.804	55.745	64.448	53.516
57.152	57.789	57.623	54.861	67.265	52.7
65.308	65.945	65.779	63.017	75.421	60.856
66.056	67.263	67.276	63.756	81.93	48.048
74.337	75.544	75.557	72.037	90.211	56.329

12 AWG Single conductor
(Page 3 of 3)

110 CU-AL White Cable#4 Core	120 CU-AL Black Cable#5 Core	211 CU-AL Black Cable#5 Insulation	205CU-AL White Cable#5 Insulation	208 CU-AL White Cable#6 Core	203 CU-AL Black Cable#6 Core	204 CU-AL Black Cbale#6 Insulation
23.509	23.482	23.149	23.038	23.485	23.786	22.755
31.934	31.907	31.574	31.463	31.91	32.211	31.18

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26.402	26.539	25.762	25.861	26.673	27.668	25.409
34.915	35.052	34.275	34.374	35.186	36.181	33.922
30.025	30.717	29.685	29.704	31.023	32.791	28.963
38.256	38.948	37.916	37.935	39.254	41.022	37.194
34.209	35.835	33.848	34.108	36.344	39.108	32.692
42.804	44.43	42.443	42.703	44.939	47.703	41.287
40.855	43.7	41.307	41.654	44.03	48.851	39.803
49.117	51.962	49.569	49.916	52.292	57.113	48.065
47.49	51.417	48.521	49.376	51.659	58.336	46.401
55.991	59.918	57.022	57.877	60.16	66.837	54.902

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55.696	61.164	57.106	58.492	61.252	69.982	53.979
63.852	69.32	65.262	66.648	69.408	78.138	62.135
63.039	72.843	66.826	67.72	70.828	83.361	63.75
71.32	81.124	75.107	76.001	79.109	91.642	72.031

12 AWG Cu Single conductors
(Page 1 of 2)

Scan	Time	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core
	5 AMPS					
30	8/16/2017 14:54	22.678	22.601	23.084	22.862	23.1
	Corrected Ambient	31.103	31.026	31.509	31.287	31.525
	Average	31.28				
	Average Core	31.346				
	Average Insulation	31.214				
	10 AMPS					
60	8/16/2017 15:24	24.574	24.195	25.492	24.984	25.629
	Corrected Ambient	33.087	32.708	34.005	33.497	34.142
	Average	33.44408				
	Average Core	33.63167				
	Average Insulation	33.2565				
	15 AMPS					

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91	8/16/2017 15:55	27.938	27.51	29.234	28.369	29.346
	Corrected Ambient	36.169	35.741	37.465	36.6	37.577
	Average	36.27708				
	Average Core	36.65483				
	Average Insulation	35.89933				
	20 AMPS					
121	8/16/2017 16:25	31.89	31.073	33.381	32.19	33.634
	Corrected Ambient	40.485	39.668	41.976	40.785	42.229
	Average	40.2505				
	Average Core	40.86083				
	Average Insulation	39.64017				
	25 AMPS					
152	8/16/2017 16:56	37.908	36.251	39.895	37.963	40.79
	Corrected Ambient	46.17	44.513	48.157	46.225	49.052
	Average	45.57908				
	Average Core	46.602				
	Average Insulation	44.55617				
	30 AMPS					
182	8/16/2017 17:26	45.629	44.793	46.939	43.77	47.443
	Corrected Ambient	54.13	53.294	55.44	52.271	55.944
	Average	51.87658				
	Average Core	53.18617				
	Average Insulation	50.567				
	35 AMPS					
213	8/16/2017 17:57	53.356	52.266	54.603	50.492	54.888
	Corrected Ambient	61.512	60.422	62.759	58.648	63.044
	Average	58.39692				
	Average Core	60.13967				
	Average Insulation	56.65417				
	40 AMPS					
244	8/16/2017 18:28	62.217	61.357	63.891	59.265	64.258
	Corrected Ambient	70.498	69.638	72.172	67.546	72.539

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	Average	66.52817				
	Average Core	69.18933				
	Average Insulation	63.867				

12 AWG Cu Single conductors
(Page 1 of 2)

	Time	304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
	5 AMPS						
30	8/16/2017 14:54	22.672	22.586	23.069	22.909	22.923	22.74
	Corrected Ambient	31.097	31.011	31.494	31.334	31.348	31.165
	10 AMPS						
60	8/16/2017 15:24	24.713	24.647	25.355	24.993	24.949	24.515
	Corrected Ambient	33.226	33.16	33.868	33.506	33.462	33.028
	15 AMPS						
91	8/16/2017 15:55	27.693	27.514	28.674	27.745	27.658	26.826
	Corrected Ambient	35.924	35.745	36.905	35.976	35.889	35.057
	20 AMPS						
121	8/16/2017 16:25	31.304	30.91	32.491	31.202	30.895	29.56
	Corrected Ambient	39.899	39.505	41.086	39.797	39.49	38.155

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	25 AMPS						
152	8/16/2017 16:56	36.656	36.446	39.125	36.545	35.666	33.819
	Corrected Ambient	44.918	44.708	47.387	44.807	43.928	42.081
	30 AMPS						
182	8/16/2017 17:26	42.269	41.429	45.709	41.914	40.122	38.201
	Corrected Ambient	50.77	49.93	54.21	50.415	48.623	46.702
	35 AMPS						
213	8/16/2017 17:57	50.113	48.676	53.39	48.317	45.552	43.055
	Corrected Ambient	58.269	56.832	61.546	56.473	53.708	51.211
	40 AMPS						
244	8/16/2017 18:28	55.495	53.591	66.664	55.887	52.925	47.744
	Corrected Ambient	63.776	61.872	74.945	64.168	61.206	56.025

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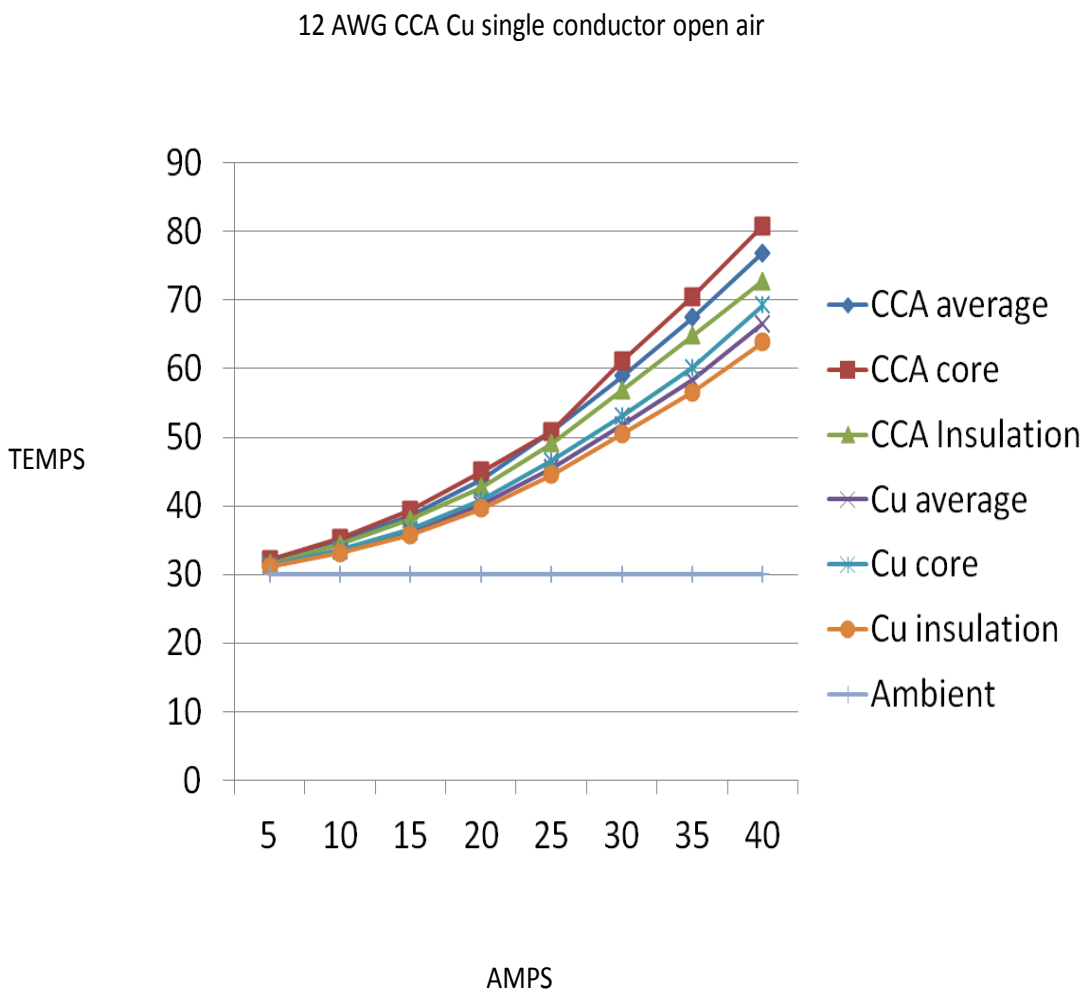

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Test Set- Up/ Layout
12 AWG in non-metallic cable (2 Conductor) in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 12 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 12 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 12 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG In (2 conductor) non-metallic cable

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	NM Cable	5	30
12	NM Cable	10	30
12	NM Cable	15	30
12	NM Cable	20	30
12	NM Cable	25	30
12	NM Cable	30	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG CCA In non-metallic cable(2 conductor)
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Scan	Time	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	208 CU-AL Black Cable#2 Core	205 CU-AL Black Cable#2 Insulation
	5 AMPS					
30	**8/17/2017 10:29**	**22.67**	**22.926**	**23.13**	**23.256**	**23.015**
	Corrected Ambient	31.08	31.335	31.539	31.665	31.424
	Average	31.68				
	Average Core	31.73				
	Average Insulation	31.63				
	10 AMPS					
61	8/17/2017 11:00	25.93	26.059	26.92	26.863	26.217
	Corrected Ambient	34.32	34.443	35.304	35.247	34.601
	Average	34.88				
	Average Core	35.09				
	Average Insulation	34.68				
	15 AMPS					
91	8/17/2017 11:30	30.31	30.408	32.809	32.228	31.062
	Corrected Ambient	38.40	38.497	40.898	40.317	39.151
	Average	39.36				
	Average Core	39.90				
	Average Insulation	38.87				
	20 AMPS					
121	8/17/2017 12:00	35.95	36.03	40.071	39.839	36.86
	Corrected Ambient	44.35	44.426	48.467	48.235	45.256

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	Average	45.56				
	Average core	46.67				
	Average Insulation	44.54				
	25 AMPS					
152	8/17/2017 12:31	41.34	41.083	45.352	45.612	42.454
	Corrected Ambient	49.85	49.598	53.867	54.127	50.969
	Average	51.67				
	Average Core	53.50				
	Average Insulation	50.00				
	30 AMPS					
182	8/17/2017 13:01	47.44	47.015	53.341	52.596	50.518
	Corrected Ambient	55.74	55.316	61.642	60.897	58.819
	Average	59.54				
	Average Core	62.19				
	Average Insulation	57.11				

12 AWG CCA In non-metallic cable(2 conductor)
(Page 2 of 3)

211 CU-AL White Cable# 2 Insulation	102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #3 Insulation
23.196	**23.139**	**23.493**	**23.536**
31.605	31.548	31.902	31.945
26.208	26.16	26.433	26.599
34.592	34.544	34.817	34.983

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30.375	30.414	30.425	31.929
38.464	38.503	38.514	40.018
35.556	35.329	35.55	36.683
43.952	43.725	43.946	45.079
41.089	40.342	41.332	41.256
49.604	48.857	49.847	49.771
48.436	46.618	48.28	47.403
56.737	54.919	56.581	55.704

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12 AWG CCA In non-metallic cable(2 conductor)
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116 CU-AL Black Cable#4 Insulation	113 CU-AL White Cable #4 Core	114 CU-AL White Cable#4 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#5 Insulation
23.222	**23.2**	**23.399**	**23.443**	**23.14**
31.631	31.609	31.808	31.852	31.549
25.734	26.056	26.523	26.702	25.713
34.118	34.44	34.907	35.086	34.097
28.997	31.638	30.56	30.878	29.977
37.086	39.727	38.649	38.967	38.066
33.062	37.403	35.681	36.471	35.027
41.458	45.799	44.077	44.867	43.423

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37.425	44.796	40.903	42.529	40.103
45.94	53.311	49.418	51.044	48.618
43.655	55.384	48.43	51.204	48.229
51.956	63.685	56.731	59.505	56.53

12 AWG Cu In non-metallic cable(2 Conductor)
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30	**8/17/2017 10:29**	**22.614**	**22.554**	**22.891**	**22.59**	**22.796**	**22.882**
	Corrected Ambient	31.023	30.963	31.3	30.999	31.205	31.291
	Average	31.22208					
	Average Core	31.295					
	Average Insulation	31.14917					
	10 AMPS						
61	8/17/2017 11:00	25.114	24.271	25.231	24.387	24.977	24.9
	Corrected Ambient	33.498	32.655	33.615	32.771	33.361	33.284
	Average	33.271					

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	Average Core	33.58917					
	Average Insulation	32.95283					
	15 AMPS						
91	8/17/2017 11:30	28.333	27.255	28.517	27.065	28.032	28.006
	Corrected Ambient	36.422	35.344	36.606	35.154	36.121	36.095
	Average	36.00508					
	Average Core	36.45233					
	Average Insulation	35.55783					
	20 AMPS						
121	8/17/2017 12:00	32.461	30.737	32.806	30.378	32.047	31.754
	Corrected Ambient	40.857	39.133	41.202	38.774	40.443	40.15
	Average	40.02075					
	Average core	40.70133					
	Average Insulation	39.34017					
	25 AMPS						
152	8/17/2017 12:31	37.317	35.362	38.138	34.253	36.101	35.718
	Corrected Ambient	45.832	43.877	46.653	42.768	44.616	44.233
	Average	44.385					
	Average Core	45.3695					
	Average Insulation	43.4005					
	30 AMPS						
182	8/17/2017 13:01	43.719	41.111	44.969	39.04	42.173	41.491
	Corrected Ambient	52.02	49.412	53.27	47.341	50.474	49.792
	Average	49.96617					
	Average Core	51.36633					
	Average Insulation	48.566					

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 2 of 2)

305 CU White Cable#3 Insulation	309 CU Black Cable#2 Core	310 CU Black Cable#2 Insulation	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.726	**23.1**	**22.833**	**22.872**	**22.856**
31.135	31.509	31.242	31.281	31.265
24.487	25.693	24.642	24.877	24.726
32.871	34.077	33.026	33.261	33.11
27.237	29.01	27.541	27.932	27.709
35.326	37.099	35.63	36.021	35.798
30.746	33.217	31.041	31.343	31.009
39.142	41.613	39.437	39.739	39.405

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34.482	37.831	34.853	35.499	34.645
42.997	46.346	43.368	44.014	43.16
39.792	44.397	39.901	41.125	40.255
48.093	52.698	48.202	49.426	48.556

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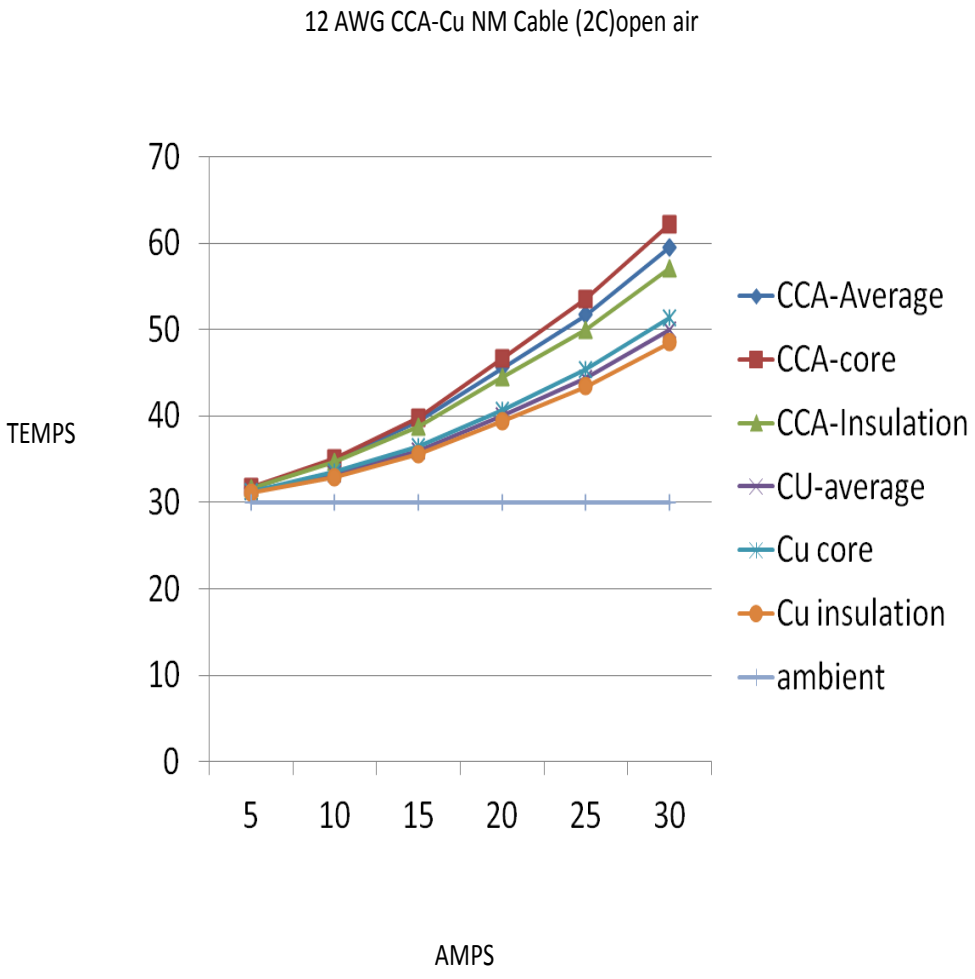

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Test Set- Up/ Layout
12 AWG in Conduit (2 conductors)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 12 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 12 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 12 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG In conduit (2 conductors)

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	Conduit	5	30
12	Conduit	10	30
12	Conduit	15	30
12	Conduit	20	30
12	Conduit	25	30
12	Conduit	30	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG CCA In conduit (2 conductors)
(Page 1 of 3)

Scan	Time	101- CU-AL White Cable-Core	103 CU-AL White Cable Insulation	104 CU-AL Black Cable Core	105 CU-AL Black Cable Insulation	106 CU-AL Black Cable Core	107 CU-AL Black Cable Insulation
	5 AMPS						
34.00	42,963.45	24.80	24.55	24.92	24.52	25.20	24.98
	Corrected Ambient	33.20	32.95	33.32	32.92	33.60	33.38
	Average	32.92					
	Average core	33.12					
	Average Insulation	32.75					
	10 Amps						
66.00	42,963.47	30.79	29.98	30.50	29.05	31.64	30.86
	Corrected Ambient	39.24	38.43	38.95	37.50	40.09	39.30
	Average	38.30					
	Average core	38.54					
	Average Insulation	38.71					
	15 Amps						
98.00	42,963.49	39.83	38.14	39.13	35.99	41.35	39.89
	Corrected Ambient	48.24	46.54	47.54	44.40	49.75	48.30
	Average	46.26					
	Average core	47.36					
	Average Insulation	45.34					
	20 AMPS						
130.00	42,963.51	53.93	51.10	52.57	46.42	56.43	53.62
	Corrected Ambient	62.34	59.51	60.98	54.83	64.84	62.03
	Average	58.48					

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	Average core	60.33					
	Average Insulation	56.95					
	25 AMPS						
162.00	42,963.54	71.01	66.92	68.93	58.87	75.38	70.30
	Corrected Ambient	79.37	75.29	77.29	67.23	83.74	78.66
	Average	73.37					
	Average core	76.31					
	Average Insulation	70.92					
	30 AMPS						
208.00	42,963.57	95.27	88.98	92.19	76.76	102.19	93.33
	Corrected Ambient	103.67	97.37	100.58	85.15	110.58	101.72
	Average	94.77					
	Average core	99.22					
	Average Insulation	91.05					

12 AWG CCA in Conduit (2 Conductors)
Page (2 of 3)

109 CU-AL White Cable Core	112 CU-AL White Cable Insulation	113 CU-AL Black Cable Core	114 CU-AL Black Cable Insulation	116 CU-AL White Cable Insulation	320 CU-AL White Cable Core
25.06	24.79	24.97	24.89	24.38	24.57
33.46	33.19	33.36	33.29	32.78	32.97
30.95	29.96	30.85	30.45	28.75	29.93
39.40	38.41	39.30	38.89	37.19	38.38

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39.93	38.02	39.99	39.25	35.66	38.12
48.34	46.43	48.40	47.65	44.07	46.53
53.56	50.15	53.76	52.46	45.78	50.35
61.97	58.57	62.17	60.87	54.19	58.76
70.65	65.52	71.23	69.04	58.58	65.18
79.02	73.88	79.59	77.40	66.95	73.54
94.77	86.67	95.96	92.55	76.17	86.50
103.16	95.06	104.35	100.95	84.56	94.89

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12 AWG CCA in Conduit (2 Conductors)
(Page 3 of 3)

315 CU-AL Black Cable Core	118 CU-AL Black Cable Insulation	102 CU-AL White Cable Insulation	110 CU-AL White Cable Core	211 CU-AL Black Cable Insulation	205CU-AL White Cable Insulation
24.41	24.04	24.69	25.09	24.46	24.15
32.81	32.44	33.08	33.49	32.86	32.55
29.90	27.86	30.58	31.01	30.08	29.09
38.35	36.31	39.03	39.46	38.52	37.54
38.26	34.03	39.40	40.19	38.41	36.46
46.67	42.44	47.80	48.60	46.82	44.87
50.81	45.67	52.82	53.77	51.24	47.67
59.23	54.08	61.23	62.19	59.65	56.08

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66.35	55.12	68.87	70.60	68.22	62.30
74.72	63.48	77.23	78.97	76.58	70.66
88.26	70.54	92.61	94.54	93.37	83.09
96.65	78.93	101.00	102.93	101.76	91.48

12 AWG Cu In conduit (2 Conductors)
(Page 1 of 2)

Scan	Time	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core	302 CU Black Cable#3 Insulation
	5 AMPS						
34.00	42,963.45	23.58	23.40	23.92	23.37	23.59	23.54
	Corrected Ambient	31.98	31.79	32.32	31.77	31.99	31.93
	Average	32.04					
	Average core	32.16					
	Average Insulation	31.92					
	10 Amps						
66.00	42,963.47	27.28	26.39	28.16	26.32	27.09	25.98
	Corrected Ambient	35.73	34.84	36.61	34.77	35.54	34.43
	Average	35.49					
	Average core	35.99					
	Average Insulation	34.99					
	15 Amps						

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98.00	42,963.49	32.59	30.64	34.57	30.92	32.40	30.16
	Corrected Ambient	40.99	39.05	42.98	39.32	40.81	38.57
	Average	40.68					
	Average core	41.67					
	Average Insulation	39.68					
	20 AMPS						
130.00	42,963.51	41.24	37.72	44.71	38.16	40.68	36.33
	Corrected Ambient	49.66	46.14	53.12	46.58	49.10	44.74
	Average	48.81					
	Average core	50.65					
	Average Insulation	46.96					
	25 AMPS						
162.00	42,963.54	52.09	46.85	57.21	46.77	50.75	44.10
	Corrected Ambient	60.45	55.21	65.57	55.14	59.11	52.46
	Average	58.67					
	Average core	61.52					
	Average Insulation	55.81					
	30 AMPS						
208.00	42,963.57	67.48	59.62	74.44	58.61	64.15	54.26
	Corrected Ambient	75.87	68.01	82.83	67.01	72.54	62.65
	Average	72.19					
	Average core	76.53					
	Average Insulation	67.86					

12 AWG Cu In conduit (2 Conductors)
(Page 2 of 2)

304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
23.91	23.65	23.81	23.67	23.76	23.55

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32.30	32.04	32.20	32.07	32.15	31.94
27.70	26.94	27.55	27.04	27.49	26.59
36.15	35.39	36.00	35.48	35.94	35.04
33.58	32.18	33.20	32.27	33.25	31.45
41.99	40.59	41.60	40.68	41.66	39.85
42.62	40.10	42.09	40.23	42.11	38.73
51.03	48.52	50.50	48.65	50.53	47.14
53.25	49.79	52.80	49.90	52.88	47.31
61.61	58.15	61.16	58.26	61.24	55.67
67.84	62.54	67.31	62.93	67.59	58.86
76.24	70.93	75.70	71.33	75.98	67.25

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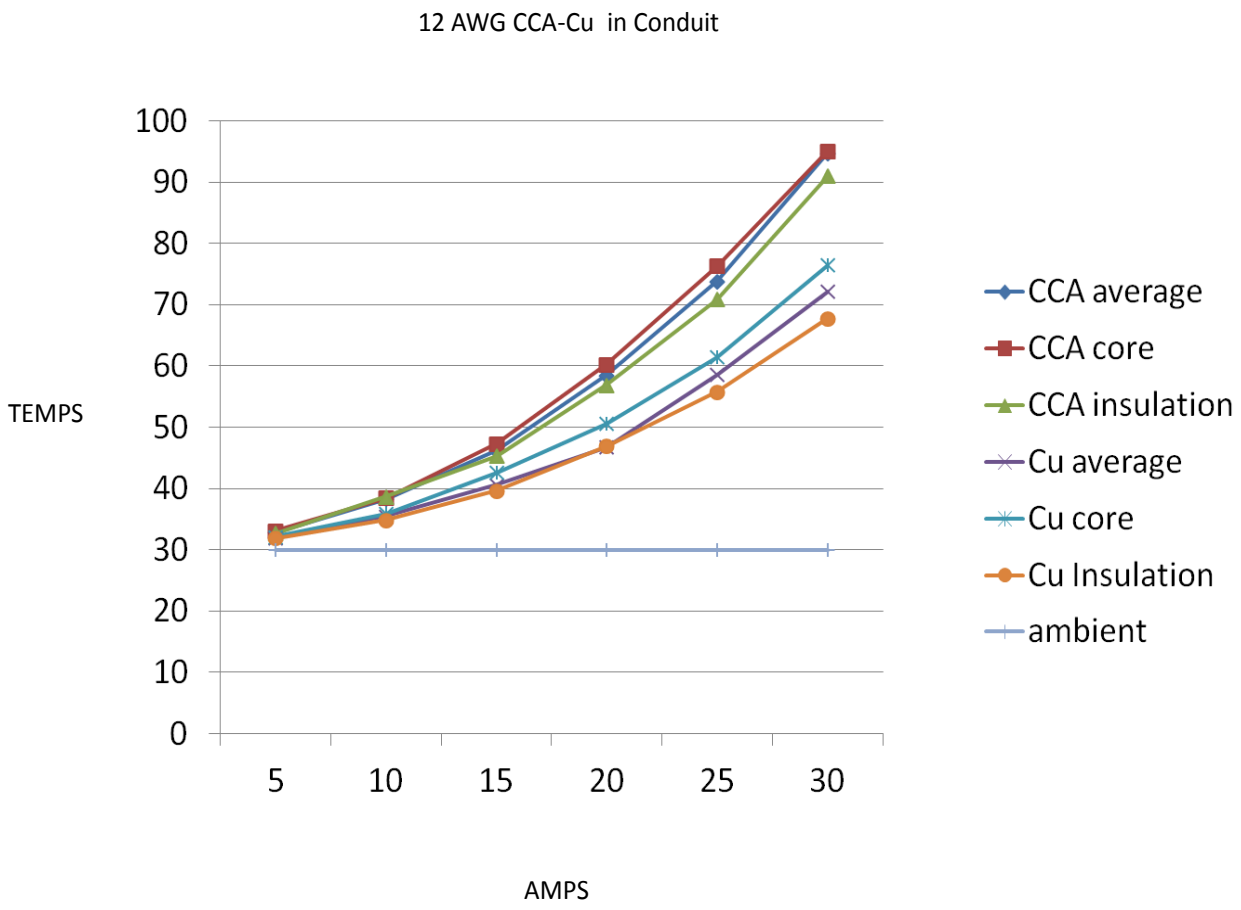

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Test Set- Up/ Layout
10 AWG single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 10 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 10 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 10 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG Single conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	Open air	5	30
10	Open air	10	30
10	Open air	15	30
10	Open air	20	30
10	Open air	25	30
10	Open air	30	30
10	Open air	35	30
10	Open air	40	30
10	Open air	45	30
10	Open air	50	30
10	Open air	55	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA Single conductor Open Air
(Page 1 of 3)

Scan	Time	Elapsed	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	208 CU-AL Black Cable#1 Core	205 CU-AL Black Cable#2 Insulation	120 CU-AL White Cable#2 Core	211 CU-AL White Cable#2 Insulation
	5 AMPS							
30.00	42965.59	00:00:28:59	22.27	22.95	22.82	22.50	23.18	22.75
	Corrected Ambient		30.81	31.49	31.36	31.04	31.72	31.28
	Average		31.47					
	Average core		31.47					
	Average Insulation		31.47					
	10 AMPS							
60.00	42965.62	00:00:58:59	24.20	25.01	24.70	24.41	25.11	24.60
	Corrected Ambient		32.71	33.52	33.20	32.91	33.61	33.10
	Average		33.30					
	Average core		33.34					
	Average Insulation		33.25					
	15 AMPS							
94.00	42965.64	00:01:32:59	27.20	28.61	27.87	27.26	28.29	27.43
94.00	Corrected Ambient		35.60	37.01	36.27	35.66	36.69	35.83
	Average		36.09					
	Average core		36.22					
	Average Insulation		35.94					
	20 AMPS							
121.00	42965.66	00:01:59:59	30.94	33.08	31.72	30.92	32.64	31.08
	Corrected Ambient		39.39	41.52	40.17	39.36	41.08	39.52
	Average		39.81					
	Average core		40.07					
	Average Insulation		39.52					

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	25 AMPS							
152.00	42965.68	00:02:30:59	35.76	39.24	36.76	34.98	37.75	35.59
	Corrected Ambient		44.20	47.67	45.20	43.41	46.19	44.03
	Average		44.24					
	Average core		44.68					
	Average Insulation		43.78					
	30 AMPS							
182.00	42965.70	00:03:00:59	39.98	43.90	41.39	39.49	42.72	39.71
	Corrected Ambient		48.45	52.37	49.85	47.96	51.19	48.18
	Average		48.75					
	Average core		49.39					
	Average Insulation		48.05					
	36 AMPS							
214.00	42965.72	00:03:32:59	47.04	48.39	48.73	46.42	50.45	46.40
	Corrected Ambient		55.61	56.97	57.30	54.99	59.03	54.97
	Average		55.57					
	Average core		56.61					
	Average Insulation		54.48					
	40 AMPS							
243.00	42965.74	00:04:01:59	52.41	53.30	54.36	51.59	56.81	51.39
	Corrected Ambient		60.70	61.59	62.65	59.88	65.10	59.68
	Average		60.64					
	Average core		62.02					
	Average Insulation		59.17					
	45 AMPS							
273.00	42965.76	00:04:31:59	59.93	60.57	61.45	59.16	64.82	58.73
	Corrected Ambient		68.43	69.07	69.94	67.66	73.32	67.23
	Average		68.02					
	Average core		69.86					

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	Average Insulation		66.10					
	50 AMPS							
304.00	42965.78	00:05:02:59	68.58	66.89	70.98	67.58	75.68	67.24
	Corrected Ambient		76.79	75.10	79.19	75.80	83.89	75.45
	Average		76.51					
	Average core		78.99					
	Average Insulation		73.93					
	55 AMPS							
334.00	42965.81	00:05:32:59	77.66	75.32	80.26	77.00	85.13	75.41
	Corrected Ambient		86.08	83.74	88.68	85.42	93.54	83.83
	Average		85.54					
	Average core		88.62					
	Average Insulation		82.30					

10 AWG CCA Single conductor Open Air
(Page 2 of 3)

102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #3 Insulation	315 CU-AL White Cable#4 Core	320 CU-AL Black Cable#4 Core	116 CU-AL Black Cable#4 Insulation
22.98	23.06	23.06	22.84	23.14	23.11
31.51	31.60	31.60	31.37	31.67	31.64
24.95	24.87	24.76	24.78	25.11	24.95

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33.46	33.37	33.27	33.29	33.61	33.46
27.94	27.66	27.49	28.04	28.49	27.92
36.34	36.06	35.89	36.45	36.89	36.32
31.97	31.21	31.04	32.09	32.60	31.53
40.41	39.65	39.48	40.54	41.04	39.98
36.86	35.52	34.62	36.88	37.56	35.94
45.30	43.96	43.05	45.32	46.00	44.38
41.65	40.19	38.87	41.54	42.71	40.19
50.12	48.66	47.34	50.00	51.18	48.66
49.26	47.09	45.20	48.99	50.60	47.06
57.83	55.66	53.78	57.57	59.17	55.63

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55.51	52.71	50.13	54.95	56.69	52.01
63.79	60.99	58.42	63.24	64.98	60.29
63.32	59.97	55.29	63.12	65.06	58.74
71.81	68.47	63.79	71.61	73.55	67.23
74.74	68.93	64.75	72.42	74.12	66.84
82.95	77.14	72.96	80.63	82.34	75.05
84.59	77.87	73.40	82.41	84.78	75.05
93.00	86.29	81.82	90.83	93.19	83.47

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10 AWG CCA Single conductor Open Air
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113 CU-AL White Cable #5 Core	114 CU-AL White Cable#5 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#6 Insulation	107 CU-AL White Cable#6 Insulation	106 CU-AL White Cable#6 Core
23.07	22.99	23.03	23.10	22.96	23.24
31.60	31.52	31.57	31.64	31.49	31.78
24.79	24.58	24.88	24.94	24.88	25.30
33.30	33.08	33.38	33.45	33.38	33.80
27.39	27.03	27.64	27.62	27.50	28.42
35.79	35.43	36.04	36.03	35.90	36.82
30.90	30.18	31.18	31.06	30.77	32.25
39.34	38.62	39.62	39.51	39.22	40.70

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34.92	33.57	35.29	35.22	34.83	37.20
43.36	42.01	43.73	43.65	43.27	45.64
39.04	37.63	40.14	39.22	39.04	42.06
47.51	46.10	48.60	47.69	47.50	50.53
45.69	43.45	46.83	45.74	45.25	49.22
54.26	52.02	55.40	54.32	53.83	57.79
50.91	48.17	52.61	50.82	50.25	55.22
59.19	56.46	60.90	59.10	58.54	63.51
58.10	54.41	60.26	57.35	56.69	63.45
66.59	62.90	68.75	65.85	65.18	71.95

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66.27	61.46	69.66	65.42	64.96	73.26
74.48	69.67	77.87	73.64	73.17	81.47
74.81	69.25	79.65	72.63	73.00	82.89
83.23	77.67	88.07	81.04	81.42	91.30

10 AWG Cu Single conductor Open Air
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30.00	42965.59	22.07	22.56	22.62	22.55	22.48	22.67
	Corrected Ambient	30.60	31.10	31.16	31.09	31.01	31.20
	Average	31.02					
	Average core	30.96					
	Average Insulation	31.08					
	10 AMPS						
60.00	42965.62	23.25	23.92	23.69	23.51	23.81	23.90
	Corrected Ambient	31.76	32.42	32.19	32.01	32.31	32.41
	Average	32.23					
	Average core	32.20					

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	Average Insulation	32.27					
	15 AMPS						
94.00	42965.64	25.17	26.29	25.70	25.23	26.09	25.97
94.00	Corrected Ambient	33.57	34.69	34.11	33.63	34.49	34.38
	Average	34.26					
	Average core	34.25					
	Average Insulation	34.28					
	20 AMPS						
121.00	42965.66	27.66	29.10	28.12	27.45	28.84	28.45
	Corrected Ambient	36.11	37.54	36.57	35.90	37.28	36.90
	Average	36.90					
	Average core	36.93					
	Average Insulation	36.86					
	25 AMPS						
152.00	42965.68	30.70	32.92	31.23	30.03	32.55	31.95
	Corrected Ambient	39.14	41.36	39.67	38.47	40.99	40.39
	Average	40.29					
	Average core	40.41					
	Average Insulation	40.18					
	30 AMPS						
182.00	42965.70	33.65	36.60	34.35	32.85	36.08	35.22
	Corrected Ambient	42.12	45.07	42.82	41.32	44.55	43.69
	Average	43.76					
	Average core	43.89					
	Average Insulation	43.63					
	36 AMPS						
214.00	42965.72	38.55	42.08	39.00	36.69	41.07	39.69
	Corrected Ambient	47.12	50.65	47.57	45.26	49.64	48.26
	Average	48.80					
	Average core	49.09					
	Average Insulation	48.51					

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	40 AMPS						
243.00	42965.74	41.71	46.30	42.78	40.04	45.42	43.45
	Corrected Ambient	50.00	54.59	51.07	48.33	53.71	51.74
	Average	52.54					
	Average core	52.83					
	Average Insulation	52.24					
	45 AMPS						
273.00	42965.76	47.71	51.95	47.60	43.96	50.47	48.26
	Corrected Ambient	56.20	60.44	56.09	52.45	58.97	56.75
	Average	58.05					
	Average core	58.61					
	Average Insulation	57.49					
	50 AMPS						
304.00	42965.78	53.84	59.41	54.11	49.30	57.74	54.24
	Corrected Ambient	62.05	67.62	62.32	57.52	65.96	62.45
	Average	64.37					
	Average core	65.11					
	Average Insulation	63.63					
	55 AMPS						
334.00	42965.81	60.19	63.55	59.83	53.97	58.77	58.08
	Corrected Ambient	68.60	71.96	68.24	62.39	67.18	66.50
	Average	69.97					
	Average core	70.96					
	Average Insulation	68.98					

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10 AWG Cu Single conductor Open Air
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304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Insulation	310 CU Black Cable#2 Core	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.23	22.47	22.49	22.70	22.46	22.50
30.77	31.01	31.03	31.24	30.99	31.04
23.53	23.74	23.77	24.13	23.77	23.74
32.03	32.25	32.28	32.64	32.28	32.24
25.65	25.95	26.07	26.49	25.96	25.75
34.05	34.35	34.47	34.89	34.37	34.16
28.23	28.61	28.70	29.55	28.52	28.20
36.68	37.05	37.14	38.00	36.97	36.64

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31.72	32.05	32.16	33.52	32.13	31.34
40.15	40.49	40.59	41.96	40.57	39.78
35.53	35.86	35.80	37.45	35.48	34.67
44.00	44.33	44.27	45.91	43.95	43.14
40.84	41.40	40.65	43.30	40.35	39.11
49.41	49.97	49.23	51.87	48.92	47.68
44.87	45.96	44.94	48.11	44.39	43.05
53.16	54.25	53.23	56.40	52.68	51.33
51.56	51.64	50.42	53.97	49.37	47.77
60.06	60.14	58.92	62.46	57.87	56.26

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57.88	58.65	56.87	61.91	55.93	54.05
66.10	66.86	65.08	70.12	64.14	62.26
64.75	65.59	62.39	70.14	61.61	59.85
73.17	74.00	70.80	78.55	70.03	68.26

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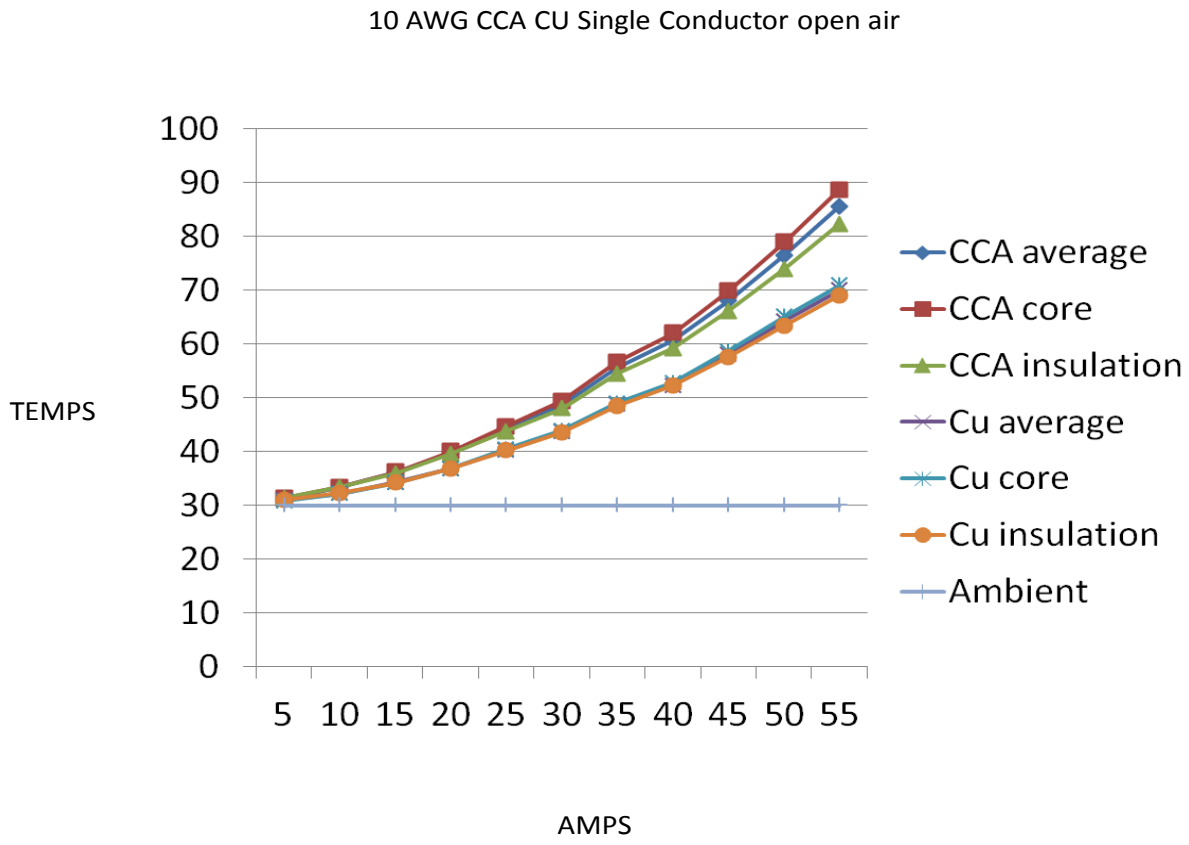

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Test Set- Up/ Layout
10 AWG in non-metallic cable in open air (2 Conductor)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 10 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 10 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 10 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG in Non-Metallic Cable (2 Conductors)

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	NM Cable	5	30
10	NM Cable	10	30
10	NM Cable	15	30
10	NM Cable	20	30
10	NM Cable	25	30
10	NM Cable	30	30
10	NM Cable	35	30
10	NM Cable	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA Non-Metallic Open Air (2 Conductor)

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Scan	Time	203 CU-AL White Cable#1-Core	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	208 CU-AL Black Cable#2 Core	120 CU-AL White Cable#2 Core	211 CU-AL White Cable# 2 Insulation
	5 AMPS						
29.00	42965.31	22.56	22.00	22.22	22.70	22.86	22.80
	Corrected Ambient	31.01	30.45	30.67	31.15	31.31	31.25
	Average	31.22					
	Average Core	31.25					
	Average Insulation	31.18					
	10 AMPS						
59.00	42965.34	24.64	24.13	24.46	24.90	25.31	25.33
	Corrected Ambient	33.21	32.70	33.02	33.47	33.88	33.90
	Average	33.48					
	Average Core	33.59					
	Average Insulation	33.34					
	15 AMPS						
90.00	42965.36	27.20	26.74	27.08	27.30	28.47	28.45
	Corrected Ambient	35.98	35.52	35.86	36.09	37.25	37.24
	Average	36.34					
	Average Core	36.53					
	Average Insulation	36.10					
	20 AMPS						
120.00	42965.38	30.31	29.56	30.82	31.04	32.46	31.76
120.00	Corrected Ambient	38.92	38.18	39.43	39.65	41.08	40.38
	Average	39.47					
	Average Core	39.91					
	Average Insulation	38.94					

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	25 AMPS						
151.00	42965.40	34.17	34.26	34.09	33.82	36.82	36.81
	Corrected Ambient	42.70	42.79	42.62	42.35	45.35	45.34
	Average	43.20					
	Average Core	43.67					
	Average Insulation	42.63					
	30 AMPS						
181.00	8/18/2017	40.14	40.25	39.61	39.67	44.07	43.95
	Corrected Ambient	48.87	48.97	48.34	48.40	52.80	52.68
	Average	49.73					
	Average Core	50.27					
	Average Insulation	49.07					
	35 AMPS						
211.00	8/18/2017	45.43	45.21	44.93	45.04	50.87	50.51
	Corrected Ambient	53.94	53.71	53.44	53.55	59.38	59.01
	Average	55.39					
	Average Core	56.18					
	Average Insulation	54.43					
	40 AMPS						
242.00	8/18/2017	50.84	50.96	50.37	51.04	58.24	57.38
	Corrected Ambient	59.52	59.63	59.04	59.71	66.92	66.05
	Average	61.97					
	Average Core	62.84					
	Average Insulation	60.91					

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10 AWG CCA Non-Metallic Open Air (2 Conductor)
(Page 2 of 3)

102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #4 Insulation	315 CU-AL White Cable#3 Core	320 CU-AL Black Cable#4 Core	116 CU-AL Black Cable#4 Insulation
22.96	22.92	22.95	22.83	22.89	22.68
31.41	31.37	31.40	31.29	31.35	31.13
25.39	24.90	25.21	25.08	25.02	24.41
33.96	33.47	33.77	33.65	33.59	32.98
28.53	27.32	28.01	27.79	27.59	26.58
37.31	36.10	36.79	36.58	36.37	35.36
32.18	30.26	31.60	31.28	30.79	29.22
40.80	38.87	40.21	39.89	39.40	37.83

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36.38	33.53	35.13	35.47	34.88	32.40
44.91	42.06	43.65	43.99	43.41	40.93
43.55	39.91	41.12	41.92	41.13	37.92
52.27	48.64	49.85	50.64	49.85	46.65
50.62	45.49	46.83	48.46	47.36	42.93
59.13	53.99	55.34	56.97	55.87	51.43
56.97	51.48	52.58	55.03	54.43	49.04
65.65	60.15	61.26	63.70	63.10	57.71

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10 AWG CCA Non-Metallic Open Air (2 Conductor)
(Page 3 of 3)

114 CU-AL White Cable#6 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#5 Insulation	107 CU-AL White Cable#6 Insulation	106 CU-AL White Cable#5 Core	103 CU-AL Black Cable#6 Core
22.86	23.16	22.83	22.75	23.01	22.61
31.31	31.62	31.28	31.21	31.46	31.06
24.90	25.52	24.59	24.68	25.19	24.49
33.46	34.08	33.16	33.25	33.76	33.06
27.45	28.59	26.81	26.95	27.86	26.80
36.23	37.37	35.59	35.73	36.64	35.58
30.62	32.31	29.51	29.96	31.51	29.93
39.23	40.93	38.12	38.57	40.12	38.54

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34.23	36.96	32.84	33.64	35.02	33.09
42.76	45.49	41.37	42.17	43.55	41.62
40.58	44.15	38.29	40.01	41.40	38.66
49.31	52.87	47.02	48.74	50.13	47.39
46.42	51.15	43.40	45.61	47.21	43.99
54.93	59.66	51.91	54.12	55.71	52.50
53.18	58.34	49.24	52.19	53.82	49.96
61.86	67.01	57.92	60.86	62.49	58.63

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10 AWG Cu in non-metallic cable (2 Conductor) in open air
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
29.00	42965.31	22.35	22.15	22.22	22.08	22.35	22.41
	Corrected Ambient	30.80	30.60	30.67	30.53	30.80	30.86
	Average	30.77					
	Average Core	30.79					
	Average Insulation	30.75					
	10 AMPS						
59.00	42965.34	23.86	23.34	23.35	23.28	23.64	23.74
	Corrected Ambient	32.42	31.91	31.92	31.85	32.21	32.31
	Average	32.18					
	Average Core	32.25					
	Average Insulation	32.12					
	15 AMPS						
90.00	42965.36	25.78	24.85	24.84	24.85	25.28	25.45
	Corrected Ambient	34.56	33.63	33.62	33.64	34.06	34.23
	Average	34.05					
	Average Core	34.14					
	Average Insulation	33.97					
	20 AMPS						
120.00	42965.38	28.46	26.70	26.84	26.63	27.38	27.39
120.00	Corrected Ambient	37.07	35.32	35.45	35.24	35.99	36.01
	Average	35.93					
	Average Core	36.20					
	Average Insulation	35.65					

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	25 AMPS						
151.00	42965.40	31.70	29.22	29.24	29.04	30.00	29.99
	Corrected Ambient	40.23	37.75	37.77	37.57	38.53	38.52
	Average	38.40					
	Average Core	38.78					
	Average Insulation	38.03					
	30 AMPS						
181.00	8/18/2017	36.74	33.05	33.55	33.39	33.88	34.40
	Corrected Ambient	45.47	41.78	42.28	42.12	42.61	43.13
	Average	42.80					
	Average Core	43.21					
	Average Insulation	42.39					
	35 AMPS						
211.00	8/18/2017	41.63	36.87	37.11	36.85	37.80	38.22
	Corrected Ambient	50.14	45.37	45.61	45.36	46.30	46.73
	Average	46.58					
	Average Core	47.13					
	Average Insulation	46.03					
	40 AMPS						
242.00	8/18/2017	47.11	41.04	41.32	40.92	42.28	42.42
	Corrected Ambient	55.78	49.71	50.00	49.59	50.96	51.10
	Average	51.05					
	Average Core	51.88					
	Average Insulation	50.21					

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10 AWG Cu in non-metallic cable (2 Conductor) in open air

Page 2 of 2

304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Core	310 CU Black Cable#2 Insulation	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.46	22.17	22.34	22.44	22.34	22.52
30.91	30.62	30.79	30.89	30.80	30.97
23.89	23.29	23.74	23.72	23.64	23.93
32.46	31.86	32.31	32.28	32.20	32.50
25.78	24.68	25.27	25.47	25.21	25.82
34.56	33.46	34.05	34.25	33.99	34.60
27.95	26.31	27.57	27.28	27.34	27.92
36.56	34.92	36.18	35.89	35.95	36.54

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30.76	28.50	30.31	29.75	29.47	30.49
39.29	37.03	38.84	38.28	38.00	39.02
35.55	32.13	34.15	34.05	33.00	34.97
44.28	40.86	42.88	42.77	41.73	43.70
40.14	35.60	38.38	38.05	36.70	39.58
48.65	44.11	46.89	46.56	45.21	48.08
44.88	38.92	43.18	42.00	40.48	43.95
53.55	47.60	51.85	50.67	49.16	52.62

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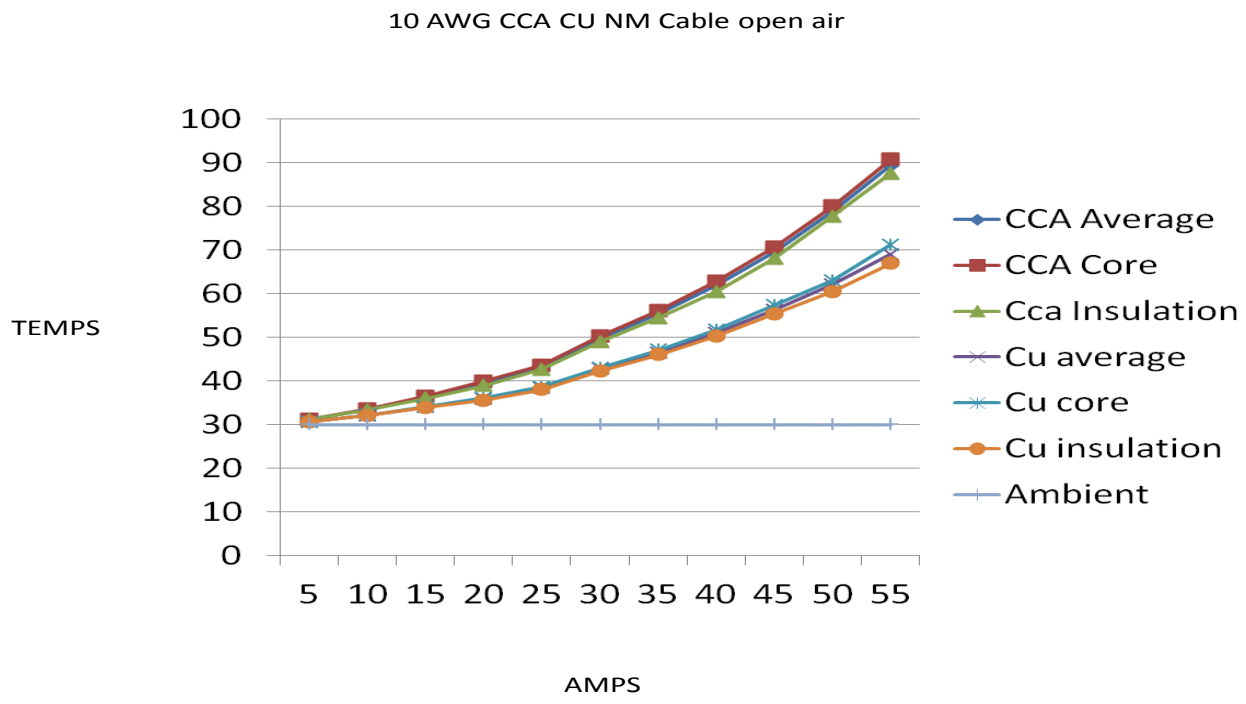

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Test Set- Up/ Layout
10 AWG in Conduit (2 Conductor)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 10 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 10 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 10 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG Conduit

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	Conduit	5	30
10	Conduit	10	30
10	Conduit	15	30
10	Conduit	20	30
10	Conduit	25	30
10	Conduit	30	30
10	Conduit	35	30
10	Conduit	40	30

Equilibrium: With reference to the test, test was continued until constant temperatures were attained. Thermal equilibrium is considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicate no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA in Conduit (2 Conductor)

(Page 1 of 3)

Scan	Time	203 CU-AL White Cable#1-Core	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	205 CU-AL Black Cable#2 Insulation	120 CU-AL White Cable#2 Core
	5 AMPS						
30.00	42966.40	23.32	22.63	22.90	23.15	23.26	23.40
	Corrected Ambient	31.77	31.08	31.35	31.59	31.70	31.85
	Average	31.85					
	Average core	31.89					
	Average insulation	31.80					
	10 AMPS						
64.00	42966.42	26.59	25.43	26.27	25.92	26.52	26.56
	Corrected Ambient	34.93	33.76	34.60	34.25	34.85	34.90
	Average	34.75					
	Average core	34.84					
	Average insulation	34.66					
	15 AMPS						
95.00	42966.44	31.92	29.65	31.74	30.41	31.65	31.89
	Corrected Ambient	40.23	37.96	40.05	38.72	39.97	40.21
	Average	39.72					
	Average core	39.93					
	Average insulation	39.49					
	20 AMPS						
132.00	42966.47	38.70	35.07	38.69	36.15	38.16	38.61
	Corrected Ambient	46.73	43.10	46.72	44.18	46.19	46.64
	Average	45.82					
	Average core	46.15					

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	Average insulation	45.45					
	26 AMPS						
162.00	42966.49	47.38	42.40	47.49	43.29	46.07	46.97
	Corrected Ambient	55.50	50.51	55.61	51.40	54.18	55.09
	Average	53.85					
	Average core	54.35					
	Average insulation	53.30					
	30 AMPS						
192.00	42966.51	57.44	50.50	57.79	51.44	55.09	56.93
	Corrected Ambient	65.41	58.46	65.75	59.40	63.05	64.90
	Average	62.99					
	Average core	63.71					
	Average insulation	62.17					
	35 AMPS						
222.00	42966.53	70.55	60.57	71.31	61.86	66.91	69.78
	Corrected Ambient	78.66	68.68	79.42	69.97	75.02	77.89
	Average	75.21					
	Average core	76.27					
	Average insulation	74.01					
	40 AMPS						
260.00	42966.56	86.35	74.81	87.61	74.53	81.18	86.55
	Corrected Ambient	94.33	82.80	95.59	82.51	89.16	94.53
	Average	89.94					
	Average core	91.36					
	Average insulation	88.34					

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10 AWG CCA in Conduit (2 Conductor)
(Page 2 of 3)

211 CU-AL White Cable# 3 Insulation	102 CU-AL Black Cable#3 Core	320 CU-AL Black Cable#4 Core	113 CU-AL White Cable #4 Core	114 CU-AL White Cable#4 Insulation	109 CU-AL Black Cable#5 Core
23.26	23.49	23.53	23.64	23.57	23.74
31.70	31.94	31.98	32.08	32.01	32.18
26.21	26.62	26.66	26.73	26.46	26.83
34.54	34.96	35.00	35.07	34.80	35.17
30.86	31.75	31.93	32.02	31.42	32.03
39.17	40.06	40.24	40.33	39.73	40.34
36.72	38.39	38.61	38.74	37.61	38.57
44.75	46.42	46.64	46.77	45.64	46.60

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43.72	46.74	46.85	47.03	45.17	46.62
51.83	54.86	54.96	55.14	53.28	54.74
51.86	56.42	56.62	56.89	54.04	56.27
59.83	64.38	64.58	64.86	62.00	64.23
62.45	69.09	69.33	69.71	65.42	68.98
70.56	77.20	77.43	77.81	73.53	77.09
74.86	84.65	84.99	85.42	79.26	84.28
82.84	92.63	92.97	93.40	87.25	92.26

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10 AWG CCA in Conduit (2 Conductor)
(Page 3 of 3)

107 CU-AL White Cable#5 Insulation	103 CU-AL Black Cable#5 Core	101 CU-AL Black Cbale#6 Insulation	104 CU-AL White Cable#6 Core	105 CU-AL White Cable#6 Insulation
23.63	23.30	23.62	23.65	23.71
32.08	31.75	32.07	32.09	32.16
26.63	25.87	26.80	26.40	26.61
8.34	8.34	8.34	8.34	8.34
34.97	34.21	35.14	34.73	34.94
31.70	30.22	32.18	31.08	31.53
8.31	8.31	8.31	8.31	8.31
40.01	38.53	40.49	39.39	39.85
38.35	35.78	39.22	37.02	38.08
8.03	8.03	8.03	8.03	8.03
46.38	43.81	47.25	45.05	46.11

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46.57	42.58	48.00	44.44	46.26
54.68	50.69	56.12	52.55	54.38
56.53	50.33	58.28	53.07	55.91
64.50	58.29	66.24	61.04	63.87
69.86	60.42	71.69	64.34	68.46
77.97	68.52	79.80	72.44	76.57
86.55	72.57	88.22	77.95	83.47
94.53	80.55	96.20	85.93	91.45

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10 AWG Cu in Conduit (2 Conductor)

(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30.00	42966.40	22.82	22.91	22.98	22.94	22.84	23.12
	Corrected Ambient	31.26	31.36	31.43	31.39	31.28	31.57
	Average	31.43					
	Average core	31.41					
	Average insulation	31.46					
	10 AMPS						
64.00	42966.42	24.81	24.98	24.84	24.87	24.60	24.72
	Corrected Ambient	33.14	33.32	33.18	33.21	32.94	33.06
	Average	33.21					
	Average core	33.19					
	Average insulation	33.23					
	15 AMPS						
95.00	42966.44	28.18	28.33	28.05	28.18	27.66	27.71
	Corrected Ambient	36.49	36.64	36.36	36.49	35.97	36.02
	Average	36.47					
	Average core	36.46					
	Average insulation	36.49					
	20 AMPS						
132.00	42966.47	32.50	32.63	32.33	32.54	31.64	31.58
	Corrected Ambient	40.53	40.66	40.36	40.57	39.67	39.61
	Average	40.49					
	Average core	40.48					
	Average insulation	40.50					
	26 AMPS						

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162.00	42966.49	37.65	37.76	37.74	37.82	36.46	36.24
	Corrected Ambient	45.76	45.87	45.85	45.93	44.58	44.35
	Average	45.73					
	Average core	45.75					
	Average insulation	45.72					
	30 AMPS						
192.00	42966.51	43.85	43.86	43.85	44.09	42.10	41.80
	Corrected Ambient	51.81	51.83	51.82	52.05	50.06	49.76
	Average	51.69					
	Average core	51.72					
	Average insulation	51.67					
	35 AMPS						
222.00	42966.53	51.88	51.82	51.54	52.18	49.45	48.85
	Corrected Ambient	59.99	59.93	59.65	60.29	57.56	56.95
	Average	59.66					
	Average core	59.67					
	Average insulation	59.65					
	40 AMPS						
260.00	42966.56	61.89	61.68	59.87	62.27	58.36	57.45
	Corrected Ambient	69.87	69.66	67.86	70.25	66.34	65.43
	Average	69.09					
	Average core	68.99					
	Average insulation	69.19					

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10 AWG Cu in Conduit (2 Conductor)

(Page 2 of 2)

304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Insulation	310 CU Black Cable#2 Core	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
23.07	22.92	23.07	23.03	23.07	23.10
31.52	31.37	31.51	31.48	31.51	31.54
24.81	24.45	25.07	24.82	25.23	25.25
33.15	32.79	33.41	33.16	33.56	33.58
27.97	27.26	28.60	28.02	29.02	28.99
36.28	35.57	36.91	36.33	37.33	37.30
32.12	30.89	33.22	32.16	33.93	33.93
40.15	38.92	41.25	40.19	41.96	41.96

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37.07	35.14	38.79	37.10	39.78	39.86
45.19	43.26	46.90	45.22	47.90	47.98
43.01	40.14	45.40	42.95	46.77	46.95
50.97	48.10	53.36	50.92	54.73	54.92
50.52	46.53	53.82	50.33	55.67	56.04
58.62	54.64	61.93	58.43	63.78	64.14
60.04	54.32	64.29	59.29	66.58	67.26
68.02	62.30	72.28	67.27	74.57	75.24

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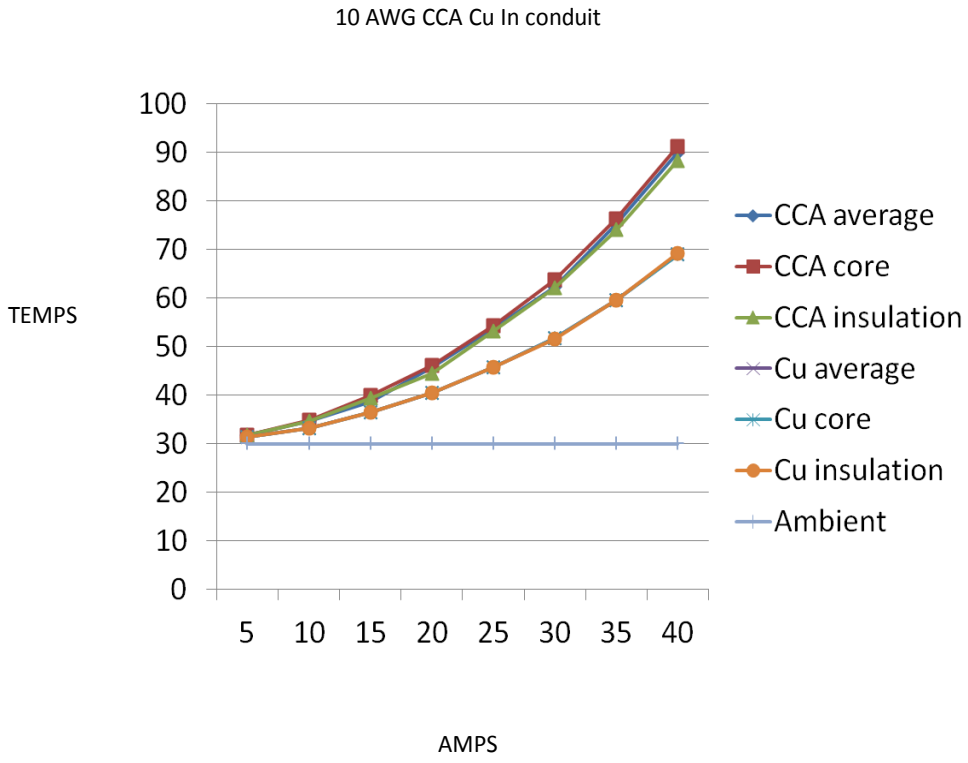

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Summary

14 AWG						
Max Temps	Single conductor@35A		NM cable@25A		Conduit@25A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	89.81	67.08	68.95	53.14	117.69	79.54
Average Core	92.67	67.91	69.61	53.05	124.41	82.77
Average Insulation	86.68	66.25	71.60	53.23	111.52	76.31

12 AWG						
Max Temps	Single conductor@40A		NM cable@30A		Conduit@30A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	76.85605	66.52817	59.54	49.96617	94.77	72.19
Average Core	80.71511	69.18933	62.19	51.36633	99.22	76.53
Average Insulation	72.72958	63.867	57.11	48.566	91.05	67.86

10 AWG						
Max Temps	Single conductor@55		NM cable@40A		Conduit@40 A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	85.54	69.97	61.97	51.05	89.94	69.09
Average Core	88.62	70.96	62.84	51.88	91.36	68.99
Average Insulation	82.30	68.98	60.91	50.21	88.34	69.19

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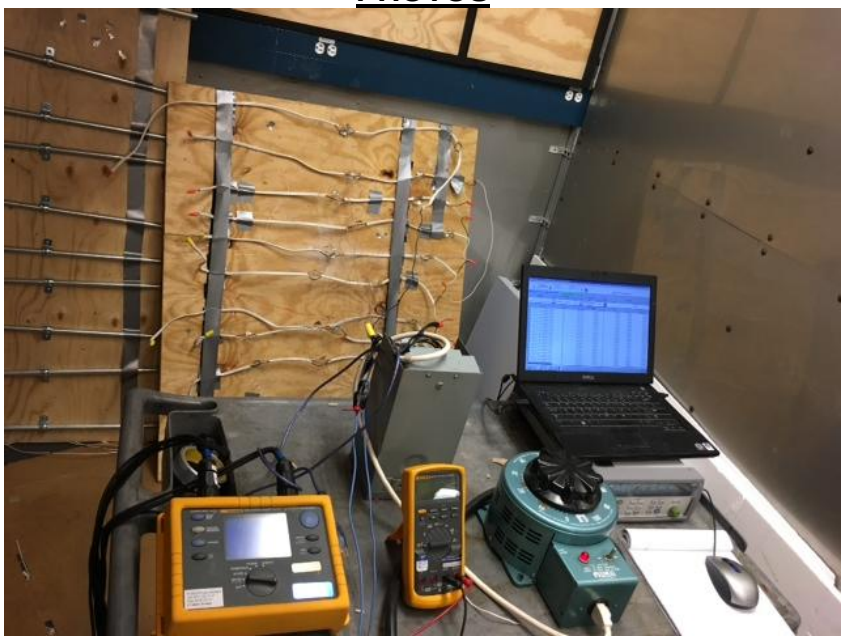
APPENDIX A
PHOTOS



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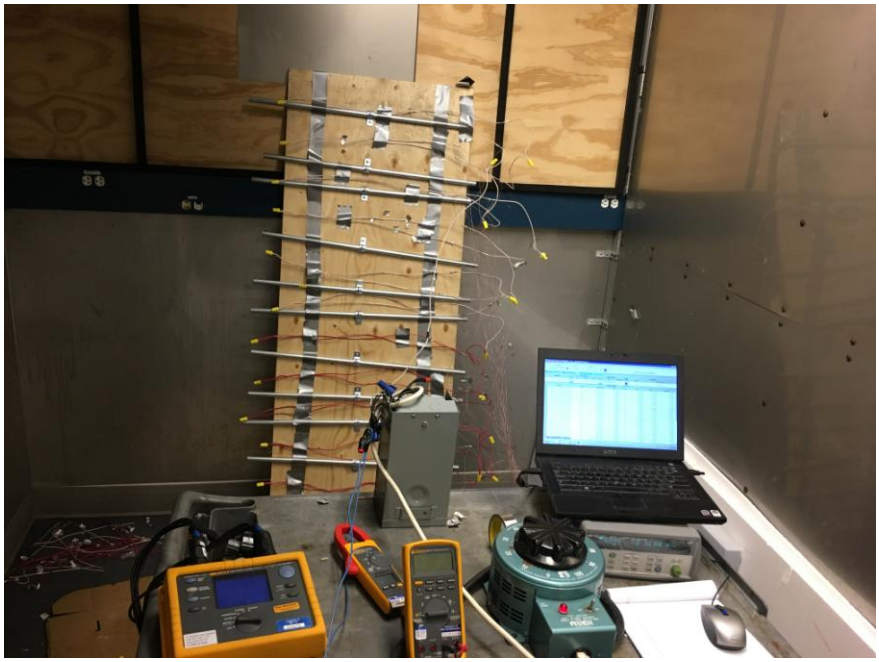

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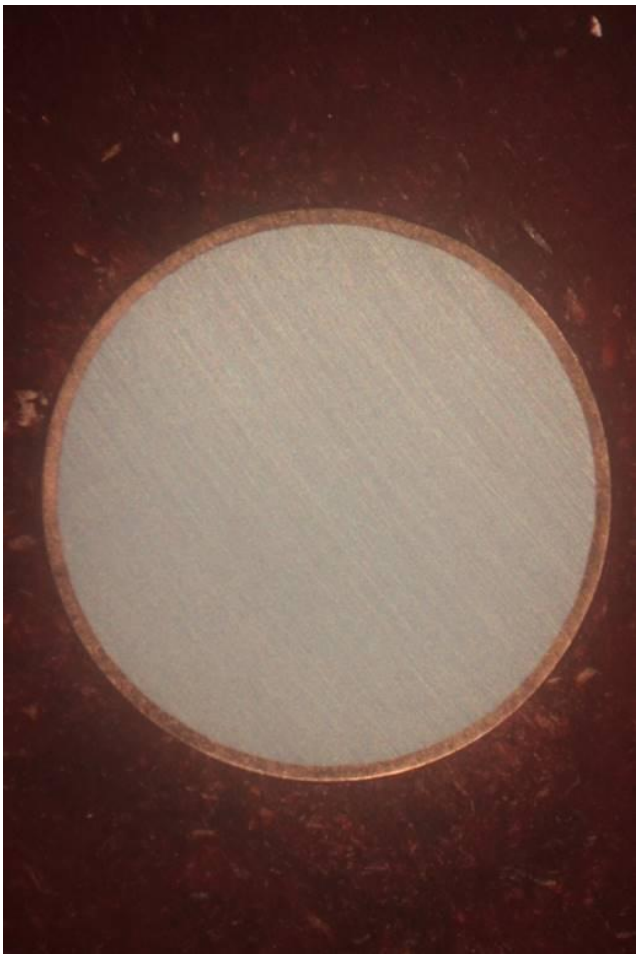

Cross Sectional view of the CCA

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APPENDIX B
EQUIPMENT LIST

Equipment	PL Code	Calibration
Transformer	PL004985	N/A
Agilent Temperature Data Acquisition system	PL005628	N/A
Thermocouples Cartridge, Type J	PL004988 PL003269 PL003268	Calibrated Daily or before each usage.
Simpson Model 06713100 Current shunt	PL002161	See Certificate Below Appendix C
Fluke multi meter, model 87V	PL004935	See Certificate Below Appendix C
Fluke Digital Clamp Meter, model 374FC	PL005812	See Certificate Below Appendix C
Thermocouples	Same as above	Conducted Daily
Power Logger	PL003379	See Certificate Below Appendix C

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APPENDIX C
CALIBRATION

Trescal

Certificate #: *3869120002 e* *W*

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	374FC
Description:	Clamp Meter
Serial Number:	37421743WS
Asset Number:	PL005812
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	05/01/2017
Due Date:	05/01/2018
Temperature:	73.00 **deg. F**
Humidity:	40.00 **%**
Baro. Press.:	
Procedure:	DCN 50442
Reference:	TO 33K1-4-853-1 Rev. 30 Jun 2008
Dept:	

Incoming Remarks:
w/case

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390482	Fluke	5522A	Multifunction Calibrator	11/22/2016	11/22/2017

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Trescal

Certificate #: *3765740001 e* *W*

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	87V
Description:	DMM
Serial Number:	26270081
Asset Number:	PL004935
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	01/31/2017
Due Date:	01/31/2018
Temperature:	74.00 **deg. F**
Humidity:	20.00 **%**
Baro. Press.:	
Procedure:	DCN 07074
Reference:	manufacturer's manual
Dept:	

Incoming Remarks:
w/case/leads/holster

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390169	Fluke	5500A	Multifunction Calibrator	04/26/2016	04/26/2017

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Trescal

Certificate #: *3869120002 e* *W*

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	374FC
Description:	Clamp Meter
Serial Number:	37421743WS
Asset Number:	PL005812
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	05/01/2017
Due Date:	05/01/2018
Temperature:	73.00 deg. F
Humidity:	40.00 %
Baro. Press.:	
Procedure:	DCN 50442
Reference:	TO 33K1-4-853-1 Rev. 30 Jun 2008
Dept:	

Incoming Remarks:
w/case

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390482	Fluke	5522A	Multifunction Calibrator	11/22/2016	11/22/2017

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ACCREDITED
Calibration Cert# 2165.01

FLUKE

Certificate of Calibration

Everett Service Center

Certificate Number:	322693		
Data Type:	As-Left	**Calibration Date:**	27-Feb-2017
Result Summary:	Measurement Results < Limits		
Manufacturer:	Fluke	**Certificate Date:**	28-Feb-2017
Model:	1735	**Temperature:**	23.6 °C
Serial Number:	S090503258B6	**Humidity:**	28.1 %
Description:	Power Quality Logger		
Procedure:	Fluke 1735:(2 year) ACAL VER RS-232/5520	**Revision:**	2.1
Customer:	NSF INTERNATIONAL		
City:	ANN ARBOR	**Country:**	US
State:	MI		
Purchase Order:	CCS CALIBRATION LAB - NSF INTERNATIONAL	**RMA:**	31194022
Asset ID:	PL003379		

This calibration is traceable to the International System of Units (SI), through National Metrology Institutes (NIST, PTB, NRC, NPL, etc.), ratiometric techniques, or natural physical constants. This certificate applies only to the item identified and shall not be reproduced either than in full, without the specific written approval by Fluke Corporation. Calibration certificates without signature are not valid. The calibration has been completed in accordance with Fluke Electronics Corporation Quality System Document 111.0 Revision 11B 8/2014 and/or Fluke 17025 Quality Manual QSD 111.41 Revision 005 8/2014.

The Data Type found in this certificate must be interpreted as:

- As - Found Calibration data collected before the unit is adjusted and / or repaired.
- As - Left Calibration data collected after the unit has been adjusted and / or repaired.
- Found-Left Calibration data collected without any adjustment and / or repair performed.

This calibration conforms to the requirements of ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994 (R2002).

In the attached measurement results, deviation may be expressed with units, Measured Value (MV) - Nominal Value (NV) or as a proportion of the nominal value ((MV-NV)/NV), expressed without units with a scalar multiplier such as % (0.01), or as a ratio of the units (mA/A, µ/V, etc.) Descriptions such as µA/A, µV/V, and others, where used to annotate results or column headings are the preferred replacements for what was historically labeled as "ppm" or parts-per-million and described the results in that column, unless otherwise noted by units symbols.

Where applicable, the expanded uncertainty of measurement at the time of test is given in the following pages. They are calculated in accordance with the method described in the ISO Guide to the Expression of Uncertainty in Measurement (GUM). The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k, such that the confidence level approximates 95%.

This calibration certificate may contain data that is not covered by the A2LA Scope of Accreditation. Unaccredited material, where applicable is indicated by an asterisk (*), or confined to clearly marked sections. Functional (Pass / Fail) tests are not accredited.

No statement of compliance with specifications is made or implied on this certificate. However, measurement results are reviewed, where applicable, to establish where any measurement result exceeded the manufacturer's specifications.

Measurement results greater than limits of error are indicated by '!'.

Accredited FLUKE

Cert # 322693
Cal Date 27-Feb-2017
S/N S090503258B6
www.fluke.com

Cert # 322693
Date 27/2/2017
www.fluke.com

Rolly Sherwood
Calibration Technician

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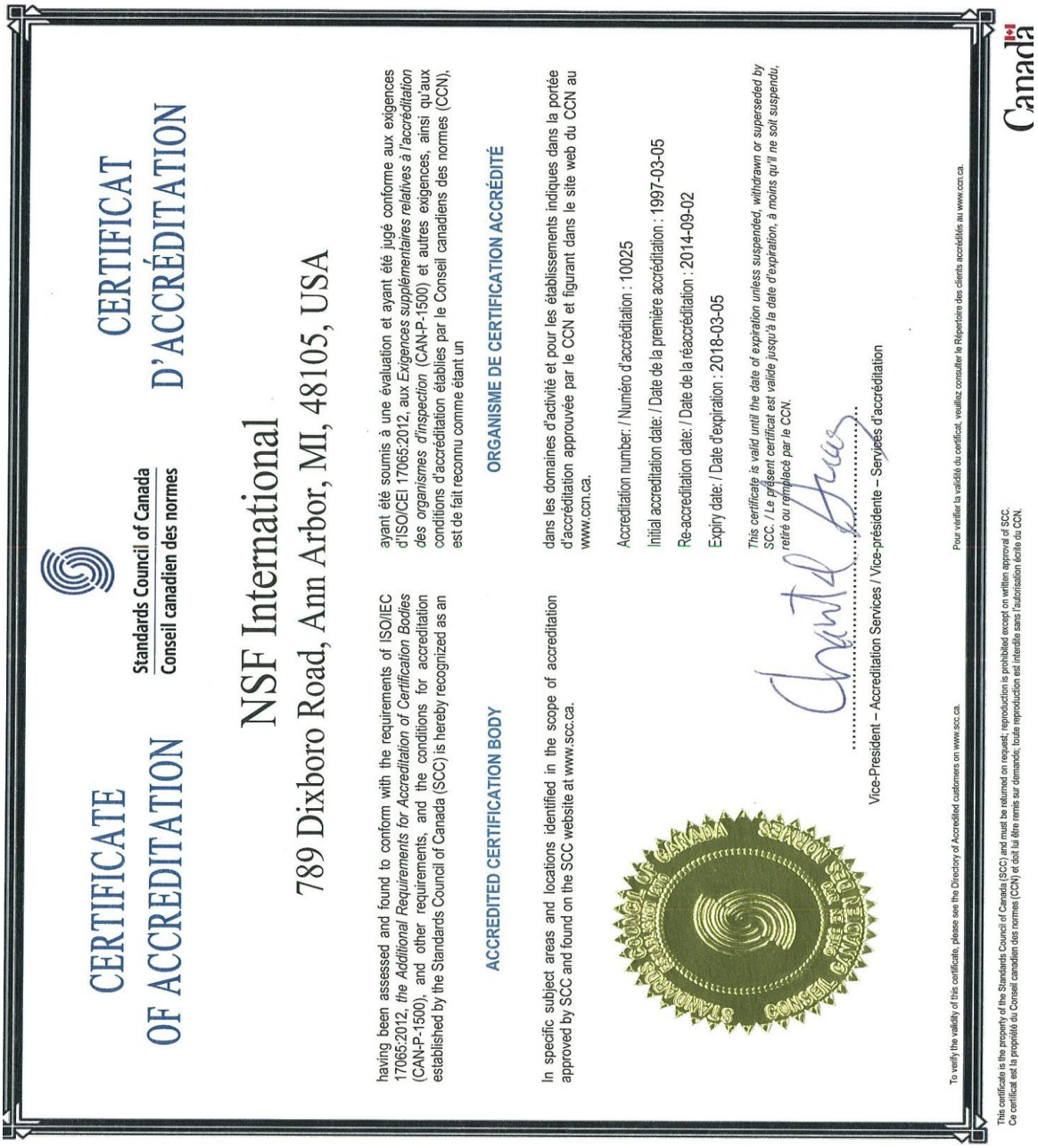
APPENDIX D
LABORATORY CERTIFICATIONS



CERTIFICATE OF ACCREDITATION

Standards Council of Canada
Conseil canadien des normes

CERTIFICAT D'ACCRÉDITATION

NSF International
789 Dixboro Road, Ann Arbor, MI, 48105, USA

having been assessed and found to conform with the requirements of ISO/IEC 17065:2012, *the Additional Requirements for Accreditation of Certification Bodies* (CAN-P-1500), and other requirements, and the conditions for accreditation established by the Standards Council of Canada (SCC) is hereby recognized as an

ayant été soumis à une évaluation et ayant été jugé conforme aux exigences d'ISO/CEI 17065:2012, aux *Exigences supplémentaires relatives à l'accréditation des organismes d'inspection* (CAN-P-1500) et autres exigences, ainsi qu'aux conditions d'accréditation établies par le Conseil canadiens des normes (CCN), est de fait reconnu comme étant un

ACCREDITED CERTIFICATION BODY

ORGANISME DE CERTIFICATION ACCRÉDITÉ

In specific subject areas and locations identified in the scope of accreditation approved by SCC and found on the SCC website at www.scc.ca.

dans les domaines d'activité et pour les établissements indiques dans la portée d'accréditation approuvée par le CCN et figurant dans le site web du CCN au www.ccn.ca.

Accreditation number: / Numéro d'accréditation : 10025

Initial accreditation date: / Date de la première accréditation : 1997-03-05

Re-accreditation date: / Date de la réaccréditation : 2014-09-02

Expiry date: / Date d'expiration : 2018-03-05

This certificate is valid until the date of expiration unless suspended, withdrawn or superseded by SCC. / Le présent certificat est valide jusqu'à la date d'expiration, à moins qu'il ne soit suspendu, retiré ou remplacé par le CCN.

STANDARDS COUNCIL OF CANADA
CONSEIL CANADIEN DES NORMES

Vice-President – Accreditation Services / Vice-présidente – Services d'accréditation

To verify the validity of this certificate, please see the Directory of Accredited customers on www.scc.ca.

Pour vérifier la validité du certificat, veuillez consulter le Répertoire des clients accrédités au www.ccn.ca.

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CERTIFICATE

Certificate Number: 140920.00

The Environmental Management System and implementation of:

NSF International
789 N. Dixboro Road
Ann Arbor, MI 48105
United States

meets the requirements of the standard:

ISO 14001:2015

Scope:
Laboratory testing, product certification, and domestic (U.S.) auditing associated with the facility located at 789 N. Dixboro Road, Ann Arbor, Michigan. NSF-ISR operations are excluded from the scope of registration.

Certificate Expires:	July 04, 2018
Re-issued:	August 08, 2017
Certificate Issued:	July 05, 2015
Certified Since:	July 05, 2006

Dr. Cem O. Onus
Managing Director, Business Assurance
DEKRA Certification, Inc.
1120 Welsh Road, Suite 210
North Wales, PA 19454 USA
(215) 997-4519
dekra-certification.us

ANAB ACCREDITED ISO/IEC 17021 MANAGEMENT SYSTEMS CERTIFICATION BODY

MEMBER OF MULTILATERAL RECOGNITION ARRANGEMENT IAF

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Occupational Safety and Health Administration

Nationally Recognized Testing Laboratory Program

NRTLP

Certificate of Recognition

NSF International

with headquarters at:

789 Dixboro Road
Ann Arbor, Michigan 48105
United States

is recognized by the Occupational Safety and Health Administration (OSHA) as meeting the requirements for a Nationally Recognized Testing Laboratory (NRTL) established under Section 1910.7 of *Title 29, Code of Federal Regulations.* This recognition is limited to testing and certification only within the current scope of recognition and is subject to all other terms set forth in the letter of recognition and in applicable *Federal Register* notices and as summarized on OSHA's website. This recognition continues in force beyond the "*Effective through*" date below provided the NRTL has filed a timely request for renewal with OSHA. For current recognition status and other recognition information, contact the OSHA NRTL Program or visit *https://www.osha.gov/dts/otpca/nrtl/*

July 14, 2019
Effective Through

David Michaels, PhD, MPH
Assistant Secretary of Labor for
Occupational Safety and Health Administration

UNITED STATES OF AMERICA · DEPARTMENT OF LABOR

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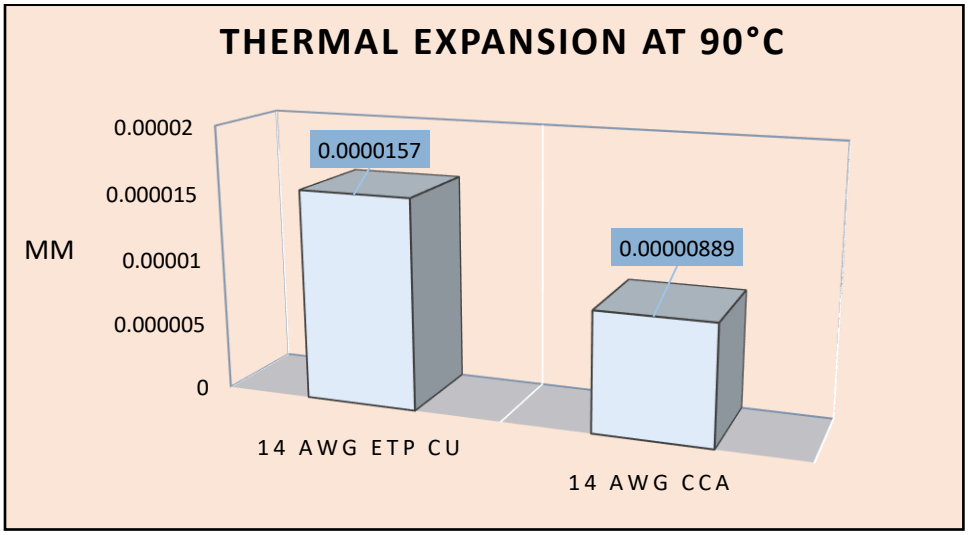
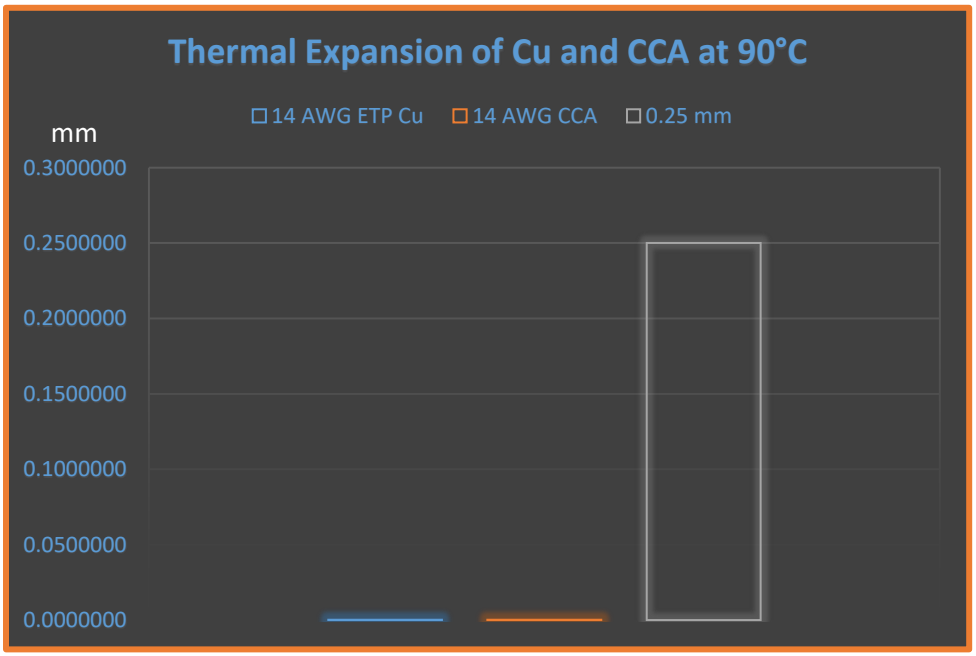
At 90°C, 14 AWG Copper-Clad Aluminum is nearly Twice as Thermally Stable as 14 AWG ETP Copper

Testing By Intertek B&C Labs per ASTM 228 Linear Thermal Expansion



At 90C, ETP 14 AWG Cu expands nearly twice that of Copper Clad Aluminum 14 AWG



At 90°C, Both Copper Clad Aluminum and Copper are Extremely Thermally Stable

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COPPERWELD BIMETALLICS
TEST REPORT

SCOPE OF WORK
ASTM E228 LINEAR THERMAL EXPANSION EVALUATION OF 14 AWG GAGE COPPER CLAD ALUMINUM (CCA) WIRE

REPORT NUMBER
I6049.04-106-31 R0

TEST DATES
07/12/18 - 07/19/18

ISSUE DATE
08/15/18

RECORD RETENTION END DATE
07/26/22

PAGES
8

DOCUMENT CONTROL NUMBER
ATI 00231 (09/05/17)
RT-R-AMER-Test-2827
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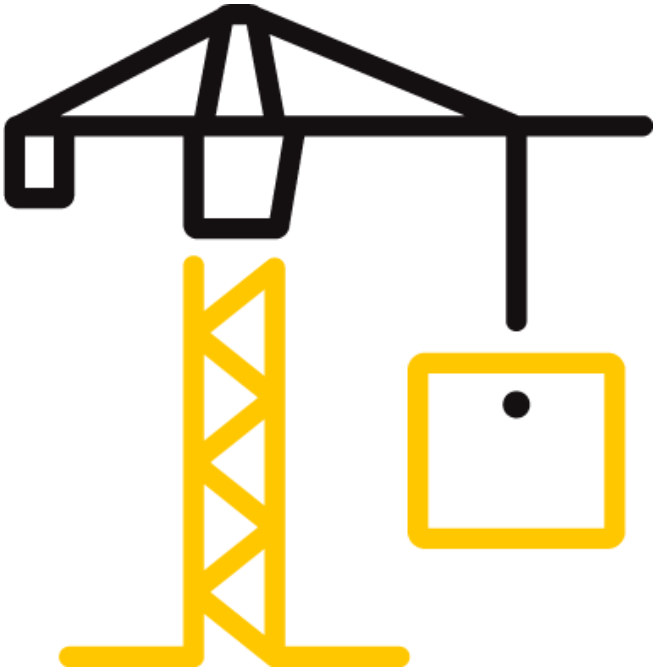

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TEST REPORT FOR COPPERWELD BIMETALLICS

Report No.: I6049.04-106-31 R0
Date: 08/15/18

REPORT ISSUED TO

COPPERWELD BIMETALLICS
254 Cotton Mill Road
Fayetteville, Tennessee 37334

SECTION 1

SCOPE

Products: 14 AWG gage Copper Clad Aluminum (CCA) Wire

Intertek Building & Construction (B&C) was contracted by Copperweld Bimetallics to evaluate 14 AWG gage Copper Clad Aluminum (CCA) Wire in accordance with ASTM E228 for Linear Thermal Expansion properties. Results obtained are tested values and were secured by using the designated test methods. Testing was conducted at the Intertek B&C test facility in York, Pennsylvania.

This report does not constitute certification of this product nor an opinion or endorsement by this laboratory.

SECTION 2

SUMMARY OF TEST RESULTS

COPPER CLAD ALUMINUM (CCA) WIRE AWG GAGE	CLTE (mm/mm/°C) 25°C to 90°C TEMPERATURE RANGE
14	8.89E-06

For INTERTEK B&C:

COMPLETED BY:	Joseph M. Brickner	**REVIEWED BY:**	Dawn M. Chaney
TITLE:	Laboratory Supervisor Materials Laboratory	**TITLE:**	Technician Team Lead Materials laboratory
SIGNATURE:		**SIGNATURE:**	
DATE:	08/15/18	**DATE:**	08/15/18

JMB:dmc/jp

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SECTION 3
TEST METHOD

The specimens were evaluated in accordance with the following:

> **ASTM E228-17**, *Standard Test Method for Linear Thermal Expansion of Solid Materials with a Push-Rod Dilatometer*

SECTION 4
MATERIAL SOURCE

The test materials were provided by Copperweld Bimetallics. The following was received: One (1), nominally 76 mm copper clad aluminum wire specimens in 14 AWG gage. Refer to the product description photo in Section 10. The material was tested as received except for smoothing the cut ends of each specimen. Representative test specimens will be retained by Intertek B&C for a minimum of four years from the test completion date.

SECTION 5
LIST OF OFFICIAL OBSERVERS

NAME	COMPANY
Joseph M. Brickner	Intertek B&C
Dawn M. Chaney	Intertek B&C

SECTION 6
TEST PROCEDURE

All conditioning of test specimens and test conditions were at standard laboratory conditions unless otherwise reported. Refer to the test related photos in Section 10.

ASTM E228 - Linear Thermal Expansion
One specimen for each wire gage was measured for initial length using a 6" digital caliper (ICN: 65688) and placed in the bottom of an outer glass dilatometer tube with an inner glass tube resting on it. An aluminum support cylinder was utilized to keep the wire oriented in a vertical position. The dilatometer tube was suspended in a heated environment utilizing a muffle furnace (ICN: Y002864) and subjected to exposure conditions of nominally 25°C and 90°C. At the equilibrium of each temperature condition, specimen temperature was measured using a thermocouple reader (ICN: 62101) and a measurement was recorded from a digital indicator (ICN: INT00193) resting on top of the inner tube. The Linear Thermal Expansion between the temperature range was calculated.

DRAFT

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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.04-106-31 R0
Date: 08/15/18

SECTION 7
TEST SPECIMEN DESCRIPTIONS

TEST PROCEDURE	NUMBER OF SPECIMENS	NOMINAL SPECIMEN DIMENSIONS	VISUAL CHARACTERISTICS
ASTM E228 Linear Thermal Expansion	1	75 mm x 14 gage wire thickness	Copper Clad Aluminum wire

SECTION 8
TEST RESULTS

ASTM E228 - Linear Thermal Expansion

Copper Clad Aluminum (CCA) Wire - 14 Gage

All Temperatures

LENGTH (mm)	75.56	
TARGET TEMPERATURE (°C)	25	90
ACTUAL TEMPERATURE (°C)	25.4	90.9
GAGE READING (mm)	6.6070	6.6510
ΔT (°C)		65.5
ΔL (mm)		0.0440
ΔL/ΔT (mm/°C)		6.72E-04
CLTE (mm/mm/°C)		**8.89E-06**

SECTION 9
CONCLUSION

The requested test method did not contain specific performance requirements.

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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.04-106-31 R0
Date: 08/15/18

SECTION 10
PHOTOGRAPHS

Photo No. 1
Copper Clad Aluminum - Specimen Detail

Photo No. 2
ASTM E228 - Equipment Detail

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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.04-106-31 R0
Date: 08/15/18

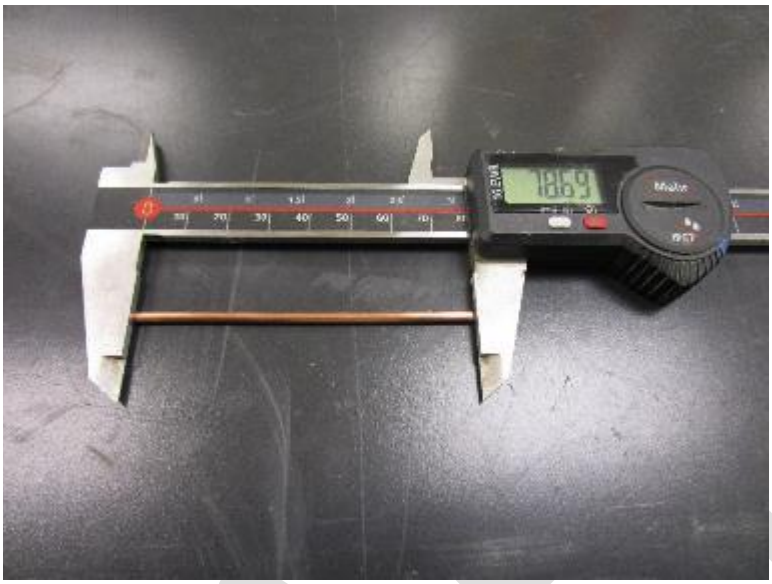

Photo No. 3
ASTM E228 - Length Measurement Equipment Detail

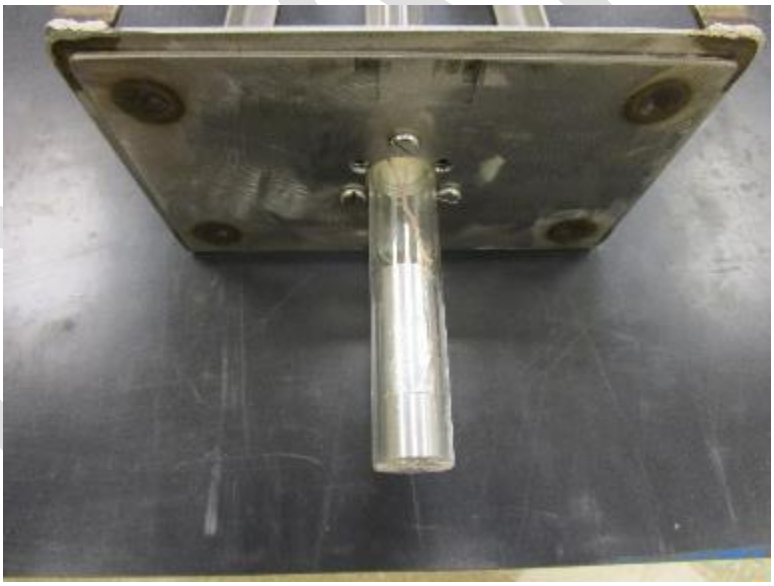

Photo No. 4
ASTM E228 - Specimen Support Detail

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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.04-106-31 R0
Date: 08/15/18

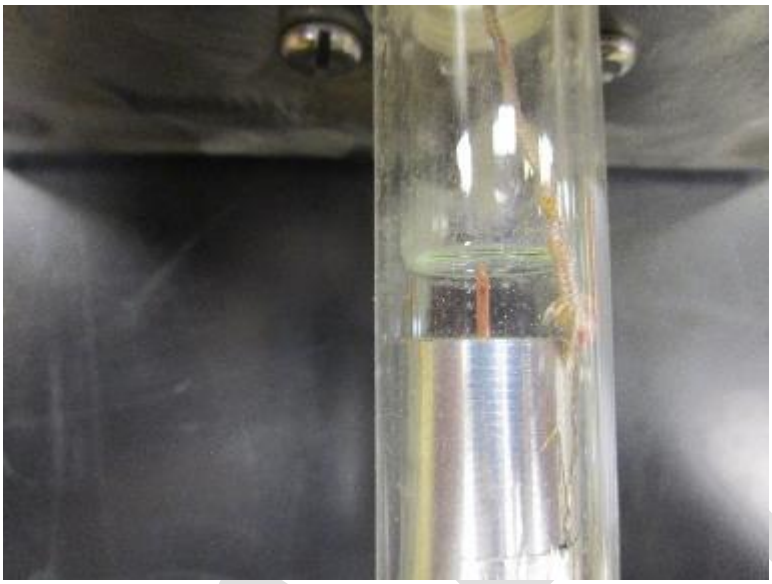

Photo No. 5
ASTM E228 - Specimen Temperature Measurement Detail

Photo No. 6
ASTM E228 - Linear Expansion Measurement Equipment Detail

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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.04-106-31 R0
Date: 08/15/18

SECTION 11
REVISION LOG

REVISION #	DATE	PAGES	REVISION
0	08/15/18	N/A	Original Report Issue

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COPPERWELD BIMETALLICS
TEST REPORT

SCOPE OF WORK
ASTM E228 LINEAR THERMAL EXPANSION EVALUATION OF 14 AWG GAGE ELECTROLYTIC TOUGH PITCH (ETP) COPPER WIRE

REPORT NUMBER
I6049.03-106-31 R0

TEST DATES
07/19/18 - 07/26/18

ISSUE DATE
08/15/18

RECORD RETENTION END DATE
07/26/22

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DOCUMENT CONTROL NUMBER
ATI 00231 (09/05/17)
RT-R-AMER-Test-2827
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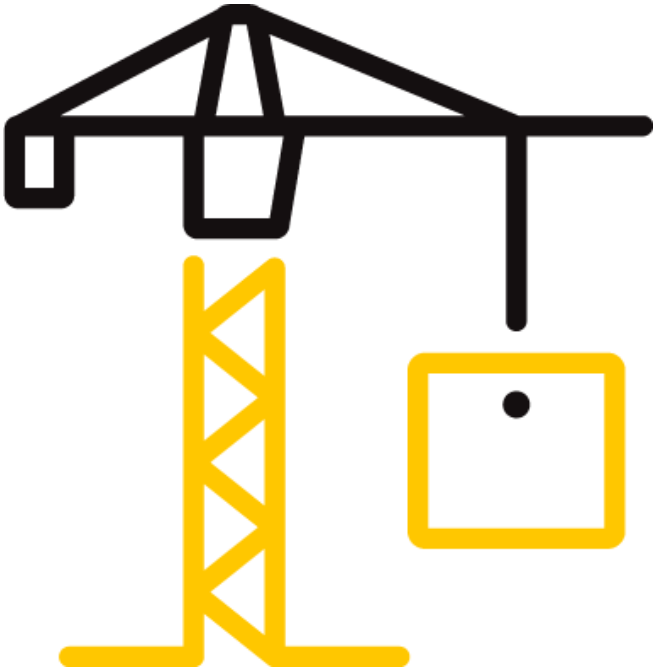

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TEST REPORT FOR COPPERWELD BIMETALLICS

Report No.: I6049.03-106-31 R0
Date: 08/15/18

REPORT ISSUED TO

COPPERWELD BIMETALLICS
254 Cotton Mill Road
Fayetteville, Tennessee 37334

SECTION 1

SCOPE

Products: 14 AWG gage Electrolytic Tough Pitch (ETP) Wire

Intertek Building & Construction (B&C) was contracted by Copperweld Bimetallics to evaluate 14 AWG gage Electrolytic Tough Pitch (ETP) Wire in accordance with ASTM E228 for Linear Thermal Expansion properties. Results obtained are tested values and were secured by using the designated test methods. Testing was conducted at the Intertek B&C test facility in York, Pennsylvania.

This report does not constitute certification of this product nor an opinion or endorsement by this laboratory.

SECTION 2

SUMMARY OF TEST RESULTS

ELECTROLYTIC TOUGH PITCH (ETP) COPPER WIRE AWG GAGE	CLTE (mm/mm/°C) 25°C to 90°C TEMPERATURE RANGE
14	1.57E-05

For INTERTEK B&C:

COMPLETED BY:	Joseph M. Brickner	**REVIEWED BY:**	Dawn M. Chaney
TITLE:	Laboratory Supervisor Materials Laboratory	**TITLE:**	Technician Team Lead Materials laboratory
SIGNATURE:		**SIGNATURE:**	
DATE:	08/15/18	**DATE:**	08/15/18

JMB:dmc/jlp

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SECTION 3
TEST METHOD

The specimens were evaluated in accordance with the following:

> **ASTM E228-17**, *Standard Test Method for Linear Thermal Expansion of Solid Materials with a Push-Rod Dilatometer*

SECTION 4
MATERIAL SOURCE

The test materials were provided by Copperweld Bimetallics. The following were received: One (1), nominally 76 mm electrolytic tough pitch copper wire specimen in 14 AWG gage. Refer to the product description photo in Section 10. The material was tested as received except for smoothing the cut ends of each specimen. Representative test specimens will be retained by Intertek B&C for a minimum of four years from the test completion date.

SECTION 5
LIST OF OFFICIAL OBSERVERS

NAME	COMPANY
Joseph M. Brickner	Intertek B&C
Dawn M. Chaney	Intertek B&C

SECTION 6
TEST PROCEDURE

All conditioning of test specimens and test conditions were at standard laboratory conditions unless otherwise reported. Refer to the test related photos in Section 10.

ASTM E228 - Linear Thermal Expansion
One specimen for each wire gage was measured for initial length using a 6" digital caliper (ICN: 65688) and placed in the bottom of an outer glass dilatometer tube with an inner glass tube resting on it. An aluminum support cylinder was utilized to keep the wire oriented in a vertical position. The dilatometer tube was suspended in a heated environment utilizing a muffle furnace (ICN: Y002864) and subjected to exposure conditions of nominally 25°C and 90°C. At the equilibrium of each temperature condition, specimen temperature was measured using a thermocouple reader (ICN: 62101) and a measurement was recorded from a digital indicator (ICN: INT00193) resting on top of the inner tube. The Linear Thermal Expansion between the temperature range was calculated.

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SECTION 7
TEST SPECIMEN DESCRIPTIONS

TEST PROCEDURE	NUMBER OF SPECIMENS	NOMINAL SPECIMEN DIMENSIONS	VISUAL CHARACTERISTICS
ASTM E228 Linear Thermal Expansion	1 each	75 mm x 14 gage wire thickness	Electrolytic Tough Pitch Copper wire

SECTION 8
TEST RESULTS

ASTM E228 - Linear Thermal Expansion

Electrolytic Tough Pitch (ETP) Copper Wire - 14 Gage

All Temperatures

LENGTH (mm)	75.60	
TARGET TEMPERATURE (°C)	25	90
ACTUAL TEMPERATURE (°C)	28.7	91.3
GAGE READING (mm)	5.6440	5.7220
ΔT (°C)		62.6
ΔL (mm)		0.0780
ΔL/ΔT (mm/°C)		1.25E-03
CLTE (mm/mm/°C)		**1.57E-05**

SECTION 9
CONCLUSION

The requested test method did not contain specific performance requirements.

DRAFT

130 Derry Court
York, Pennsylvania 17406

Telephone: 717-764-7700
Facsimile: 717-764-4129
www.intertek.com/building

TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.03-106-31 R0
Date: 08/15/18

SECTION 10
PHOTOGRAPHS

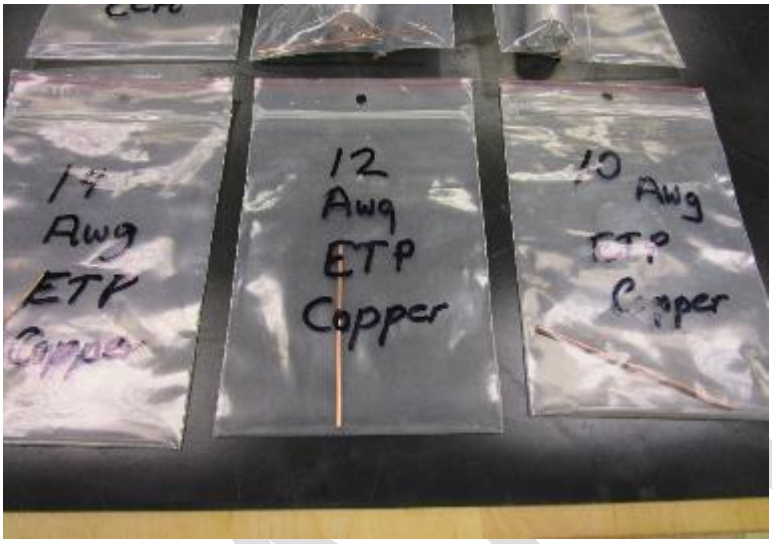

Photo No. 1
Electrolytic Tough Pitch - Specimen Detail

Photo No. 2
ASTM E228 - Equipment Detail

130 Derry Court
York, Pennsylvania 17406

Telephone: 717-764-7700
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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.03-106-31 R0
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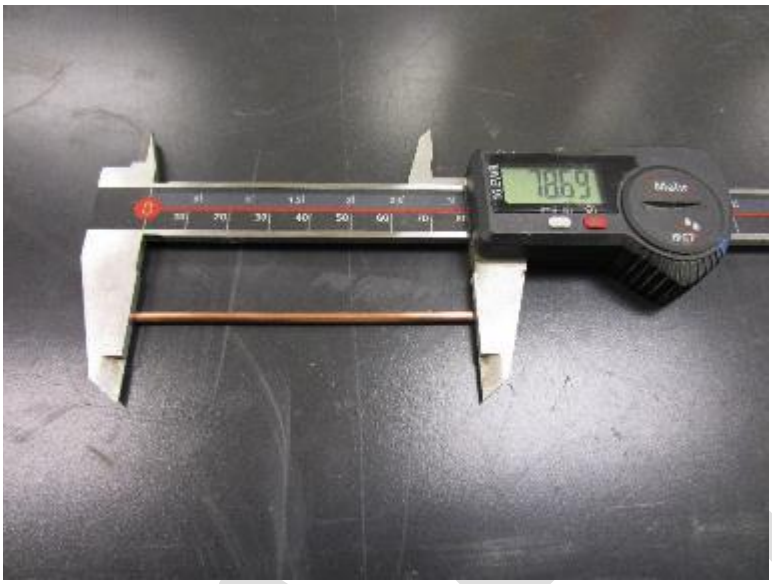

Photo No. 3
ASTM E228 - Length Measurement Equipment Detail

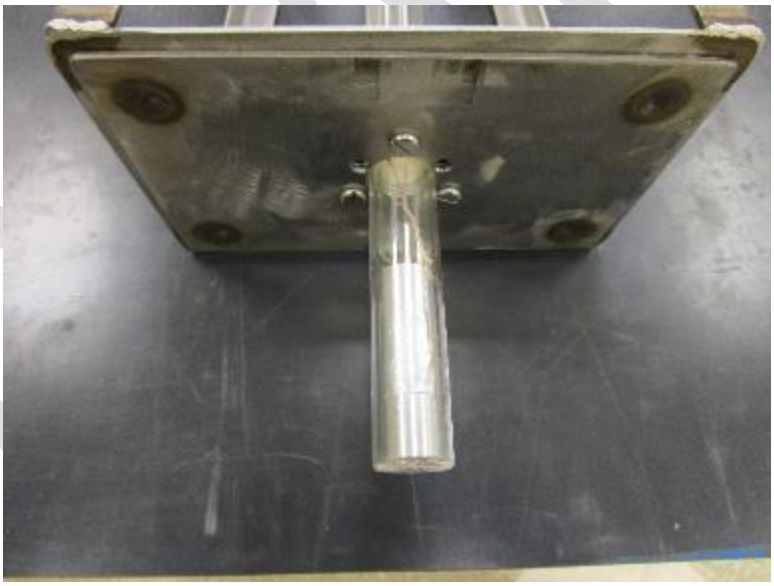

Photo No. 4
ASTM E228 - Specimen Support Detail

130 Derry Court
York, Pennsylvania 17406

Telephone: 717-764-7700
Facsimile: 717-764-4129
www.intertek.com/building

TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.03-106-31 R0
Date: 08/15/18

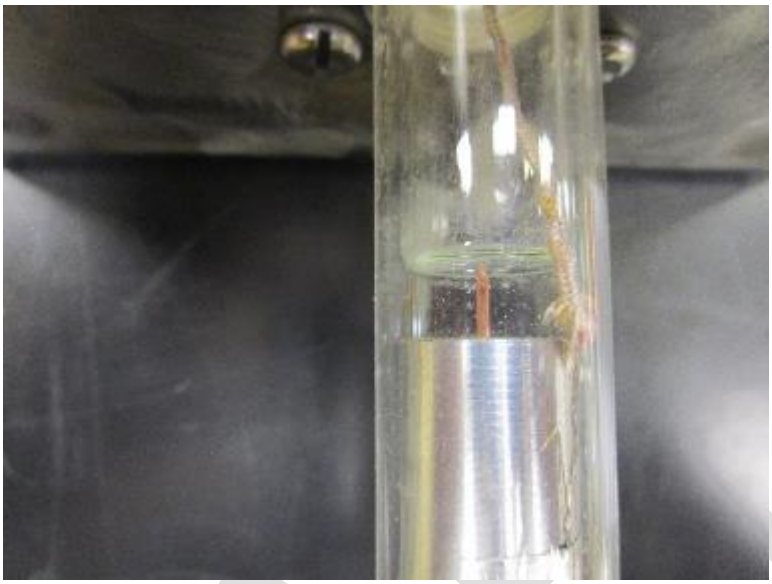

Photo No. 5
ASTM E228 - Specimen Temperature Measurement Detail

Photo No. 6
ASTM E228 - Linear Expansion Measurement Equipment Detail

130 Derry Court
York, Pennsylvania 17406

Telephone: 717-764-7700
Facsimile: 717-764-4129
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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.03-106-31 R0
Date: 08/15/18

SECTION 11
REVISION LOG

REVISION #	DATE	PAGES	REVISION
0	08/15/18	N/A	Original Report Issue

DRAFT

SHIPPING FORM FOR SENDING SAMPLES TO UL

To

UL LLC
1285 Walt Whitman Rd.
Melville NY 11747-3081 USA

Order #: 11882073
Service Request #: N/A
Industry Group:
Requestor: BRIAN CAVALLI

Barcode for Project: 1000306419
1000306419

Samples Requested:

1080076	*1080076*	(Quantity: 1) 250 feet of 2/C, No. 14 AWG FLAT Type NM-B, employing THHN copper-clad aluminium conductors, bare grounding conductor, and overall PVC jacket with thickness in accordance with the Standard. (designation tbd)
1080077	*1080077*	(Quantity: 1) 250 feet of 3/C, No. 14 AWG ROUND Type NM-B, employing THHN copper-clad aluminium conductors, bare grounding conductor, and overall PVC jacket with thickness in accordance with the Standard. (designation tbd)

Completed by Customer

Note: Samples should be sent to the address location shown above with a copy of this form provided with each shipping container. To ensure prompt processing of your sample upon arrival, the information requested on this form MUST be included with the shipment. Incomplete or missing information will result in a delay of processing your sample, and possible return or disposal of the sample prematurely.

Samples included with this shipment (Please list in the box below):

What would you like UL to do with your sample(s) when work is complete? (Choose one)
Please Note: It is a UL policy that we return all hazardous materials unless prohibited by applicable laws.

☐ **Destroy** - UL will destroy the samples when work is complete and dispose of them in accordance with local disposal guidelines.

☐ **Customer to Pick Up at UL** - You will arrange for the samples to be picked up from the UL office. If samples are not picked up within 30 days, UL will arrange for the samples to be returned to you. Please provide the name of a shipping company, shipping account number, insurance value and confirm the return shipping information below.

☐ **Ship/Return at your expense** - UL will arrange for the samples to be returned to you. Please provide the name of a shipping company, shipping account number, insurance value, and confirm the return shipping information below. If you do not provide your shipping account number, the shipping charges will be added to your UL project invoice.

Sample Being Shipped to UL From:		**UL Should Return Sample to (complete if sample to be returned and address different than at left):**
Company Name:	Copperweld Bimetallics LLC	Company Name:
Company Address:	254 Cotton Mill Rd Fayetteville TN 37334	Company Address:
Contact Person:	Peter Graser	Contact Person:
Contact Phone:		Contact Phone:
Contact Email:	petergraser@intexpco.com	Contact Email:
		Shipping Company:
		Shipping Account Number:

NOTICE OF COMPLETION
AND
AUTHORIZATION TO APPLY THE UL MARK

2017.10.06

Peter Graser
Copperweld Bimetallics LLC
254 Cotton Mill Rd
Fayetteville, TN, 37334, US

Our Reference:	File E492024, Vol 1	Order:	11882073
		Project:	4788086098
Your Reference:	Peter Graser 7/24/2017		
Project Scope:	Testing to add NM-B wire to NEW Copperweld Nonmetallic Sheathed-Cable File Construction will employ recognized CCA, and Listed Type THHN & PVC jacket		

Dear Peter Graser:

Congratulations! UL's investigation of your product(s) has been completed under the above Reference Number and the product was determined to comply with the applicable requirements. This letter temporarily supplements the UL Follow-Up Services Procedure and serves as authorization to apply the UL Mark at authorized factories under UL's Follow-Up Service Program. To provide your manufacturer(s) with the intended authorization to use the UL Mark, you must send a copy of this notice to each manufacturing location currently authorized under File e492024, Vol 1.

Records in the Follow-Up Services Procedure covering the product are now being prepared and will be sent in the near future. Until then, this letter authorizes application of the UL Mark for 90 days from the date indicated above.

Additional requirements related to your responsibilities as the Applicant can be found in the document "Applicant responsibilities related to Early Authorizations" that can be found at the following web-site: http://www.ul.com/EAResponsibilities

Any information and documentation provided to you involving UL Mark services are provided on behalf of UL LLC (UL) or any authorized licensee of UL.

We are excited you are now able to apply the UL Mark to your products and appreciate your business. Feel free to contact me or any of our Customer Service representatives if you have any questions.

Very truly yours,

Brian Cavalli
Engineering Associate
Brian.Cavalli@ul.com

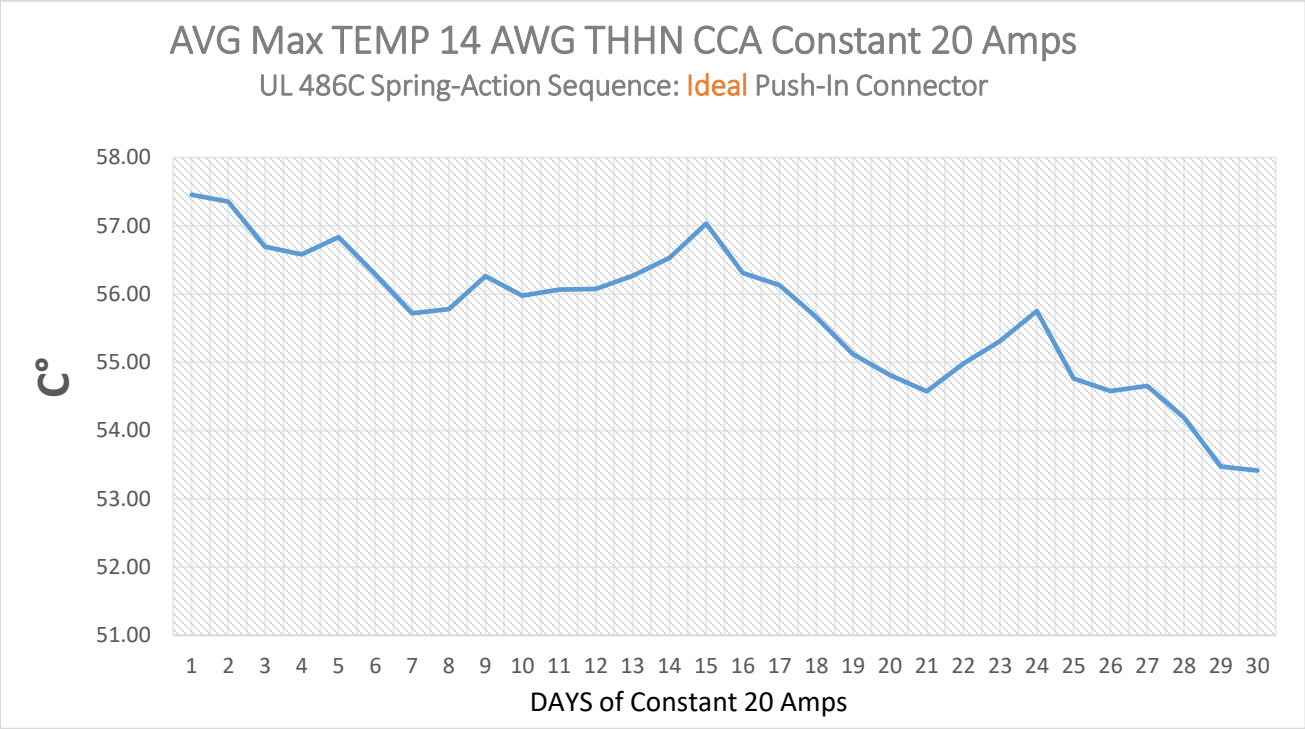
Reviewed by:

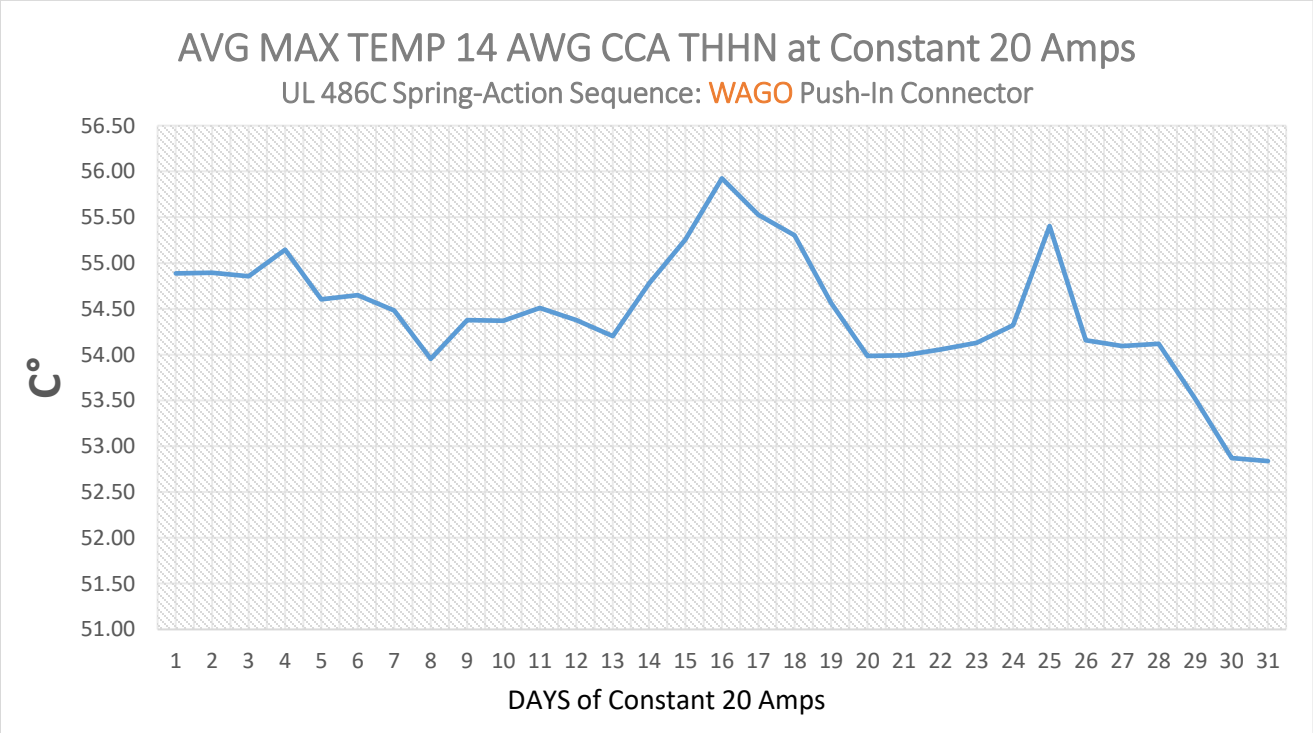
Bruce A. Mahrenholz
CPO Director
Bruce.A.Mahrenholz@ul.com

d1ee6431-b01c-4fdc-ac75-c9d5fae7e357

Performance of
14 AWG CCA THHN Under EXTREME OVERCURRENT CONDITION

Three Push-In Connectors Tested By Intertek (NRTL with Wire & Cable in Scope of Recognition) to UL 486C Spring-Action Sequence





Performance of
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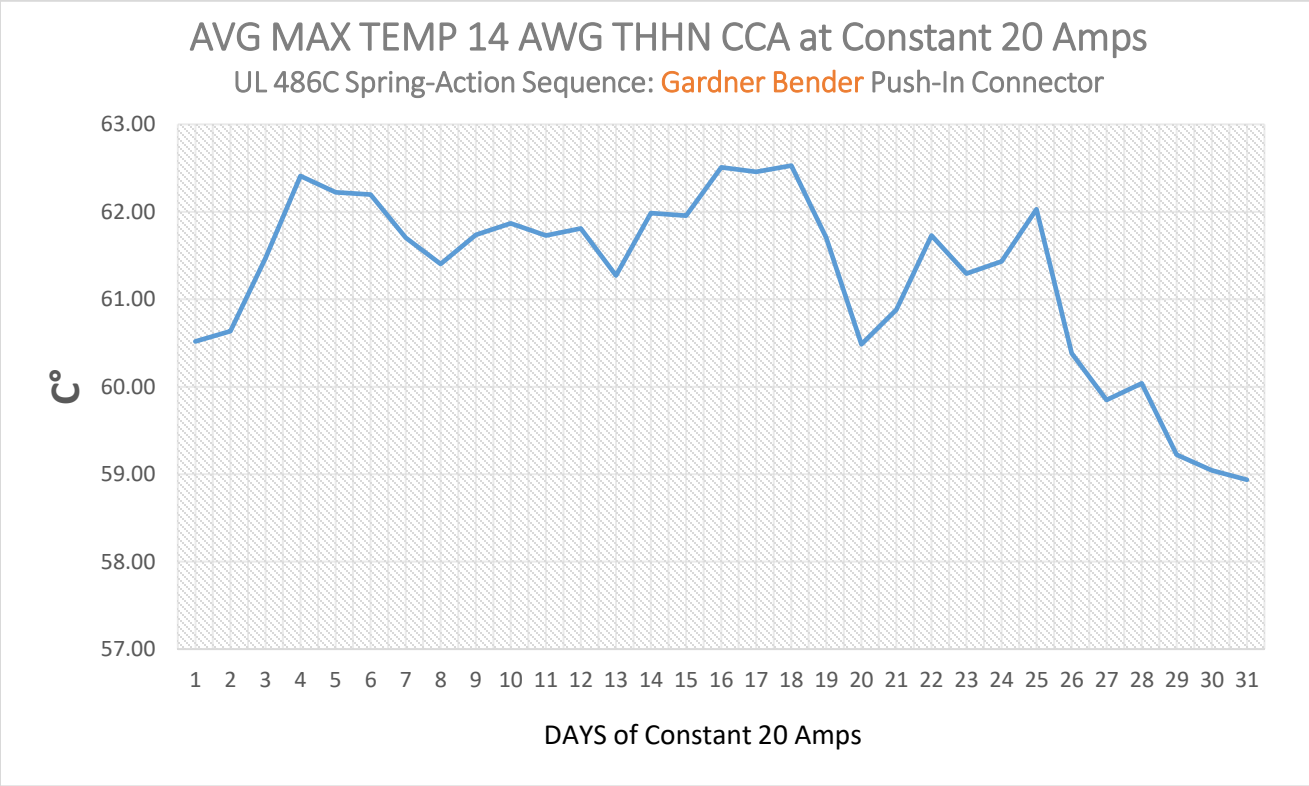
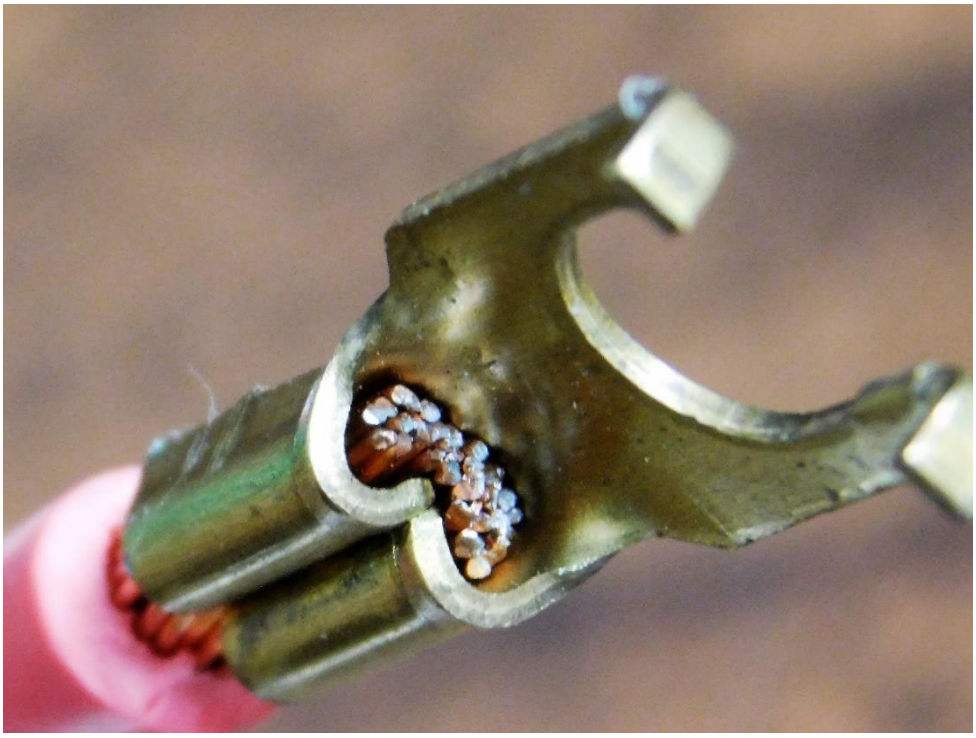


CONCLUSIONS FROM UL 486C SPRING-Action SEQUENCE TESTING REG 14 AWG THHN MADE WITH ASTM B566 COPPER-CLAD ALUMINUM WIRE:

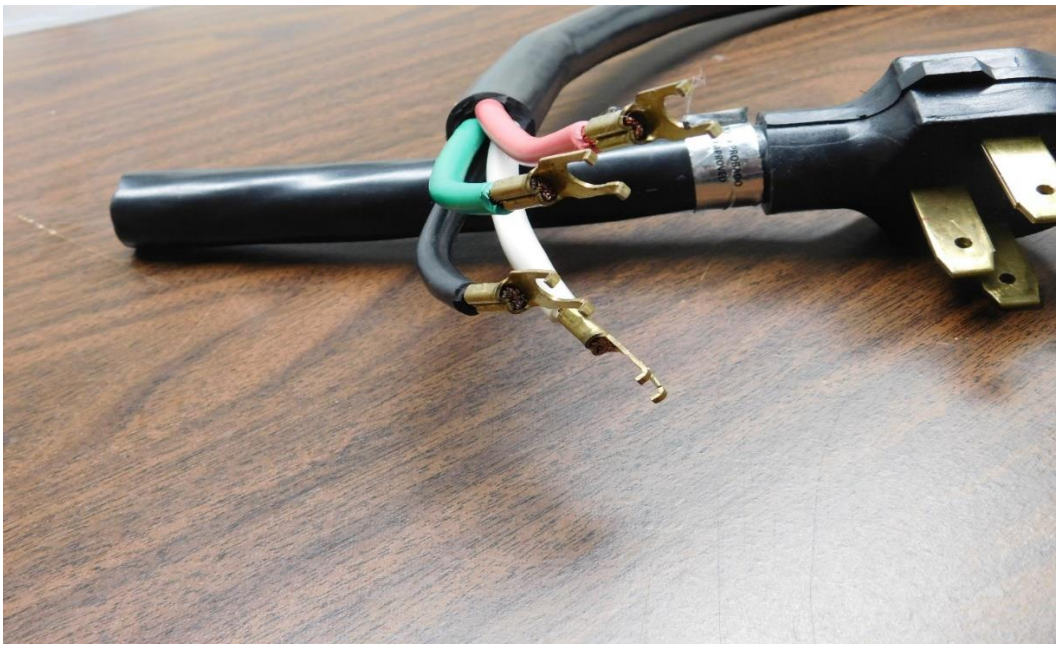
- The THHN Insulation (Rated at 90°C) Remained in Good Condition Throughout the Test
- Over 30 Days at Constant 20 Amps (twice the amperage of the proposed amperage at 60°C column requested by Public Comment 1402), the highest temperature registered by 14 AWG CCA was under 63°C. Over Current Protection Devices (OCPD's) are in place in a circuit to keep wire from over-heating. OCPD's will open the circuit when the amperage limit (10 amps in case of 14 AWG CCA) is reached.
- Ambient Temperature of 23°C Over 30 Days, Standard Deviation of ½ °C
- Average Max Temperatures decreased by 3°C over the month when connected to the three brands of push-in connectors
- The Gardner Bender Connector created more heat (+/- 6°C) within the wire than the other two test subjects
- Of the nine push-in connectors tested (three different brands), not one saw degradation or damage due to excessive heat, despite the constant over-current condition applied to the wire
- The wire remained thermally stable at the points of termination over all nine push-in connectors, and no arc-faulting was observed due to thermal expansion of the wire

2011 ETL Testing: Cu-Clad Cordage Tested By INTERTEK Per UL 817



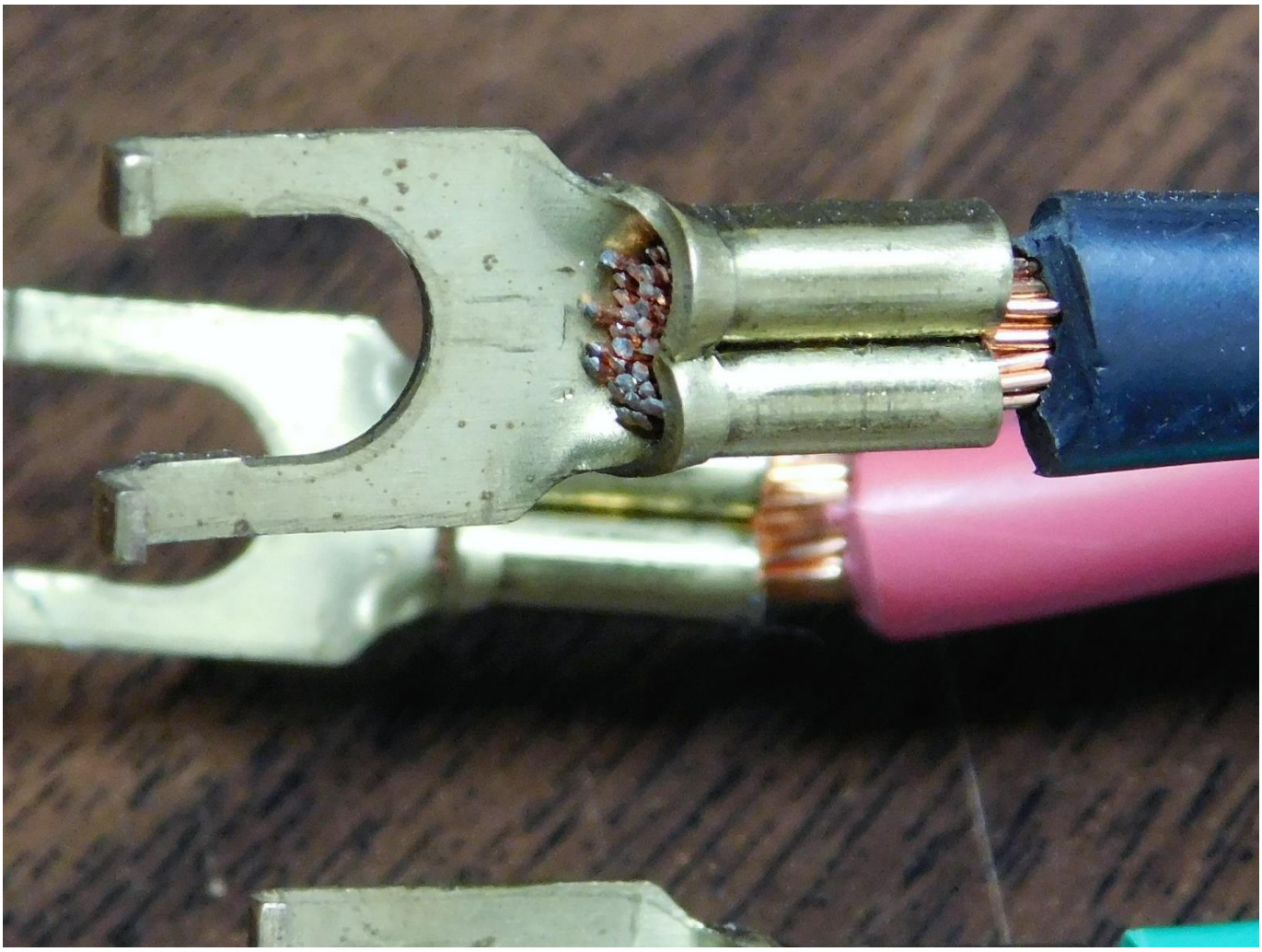
Appearance of Cord Terminals in August 2018

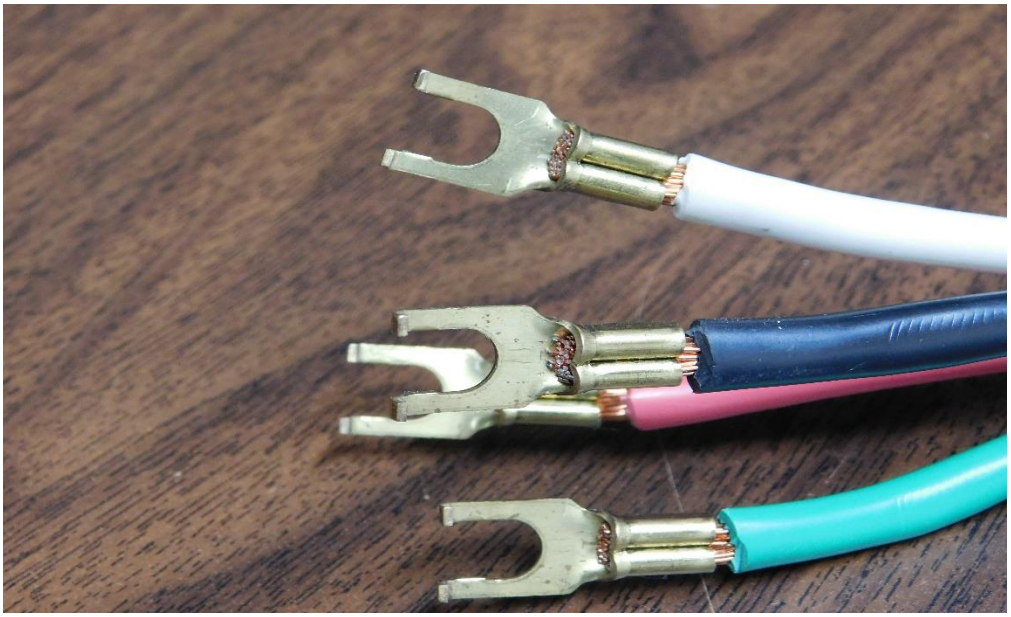
After 87 Consecutive Months of Connection to Brass Crimp Terminals, CCA Wire Samples Show Zero Galvanic Corrosion or loosening due to Atmospheric Conditions



Galvanic Corrosion is Not Evident between Brass and CCA Because the Two Metals are Not Dissimilar

2011 ETL Testing: Cu-Clad Cordage Tested By INTERTEK Per UL 817





Appearance of Cord Terminals in August 2018 after 87 Consecutive Months of Connection: Zero Galvanic Corrosion Because CCA and Brass are not dissimilar

3933 Route 11
Cortland, NY 13045
Telephone: 1-607-753-6711
Facsimile: 1-607-758-6595
www.intertek.com

TEST LETTER REPORT

Copperweld Bimetallics, LLC
Test Report

SCOPE OF WORK
PERFORMANCE TESTING – PRODUCT TYPE PER STANDARD

REPORT NUMBER
103589128CRT-001A

ISSUE DATE	**[REVISED DATE]**
27-Aug-2018	28-Aug-2018

PAGES
14

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TEST LETTER REPORT

27-Aug-2018

Intertek Report No.: 103589128CRT-001A
Intertek Project No.: G103589128

Mr. Peter Graser
Copperweld Bimetallics, LLC
215 Centerview Drive
Suite 360
Brentwood, TN 37027

Ph: (770) 952-6445
email: pgraser@copperweld.com

Subject: Static Heating test of Push-in Wire Connectors on CCA Conductors in accordance with Claus 9.12 Spring-action sequence per UL 486C.

Dear Mr. Peter Graser,

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

> **UL 486C / CSA C22.2 No. 188-18 –** Splicing Wire Connectors, Seventh Edition, Dated January 26, 2018

SECTION 1
SUMMARY

This investigation was authorized by signed proposal number Qu-00894894, dated 29-June-2018. A production sample was received on 26-June-2018 and tested from 23-Jul-2018 to 27-Aug-2018 at the Intertek Cortland facility.

TEST LETTER REPORT

SECTION 2
TESTING

Below is a summary of the tests and results for the entire test period. The test data appears at the end of this report in the Appendix.

Performance testing was carried out in accordance with UL486C, Clause 9.12 Spring-action sequence.

Three test circuits were built in the sizes 14AWG, 12AWG, and 10AWG, each circuit containing Copperweld CCA THHN wire and 3 three specimens each of push-in
wire connectors manufactured by Ideal, Wago, and Gardner and Bender, as available. This setup is a deviation from the standard which requires connectors to be tested separately on individual circuits.

Test currents (20A for 14AWG, 30A for 12AWG and 50A for 10AWG) were selected in accordance with client request rather than per Table 6 static heating columns in UL486C, and additional setup criteria indicated in Clause 9.1 of UL486C will not be used. Test currents were monitored periodically with a clamp style meter.

Ambient thermocouples were placed at least two feet out from the connectors under test, and approximately 3 feet apart, the number of ambient thermocouples is reduced due to the size of the apparatus.

Connector thermocouples are placed on the input and output side of each connector with a reference conductor between each set of three connectors.

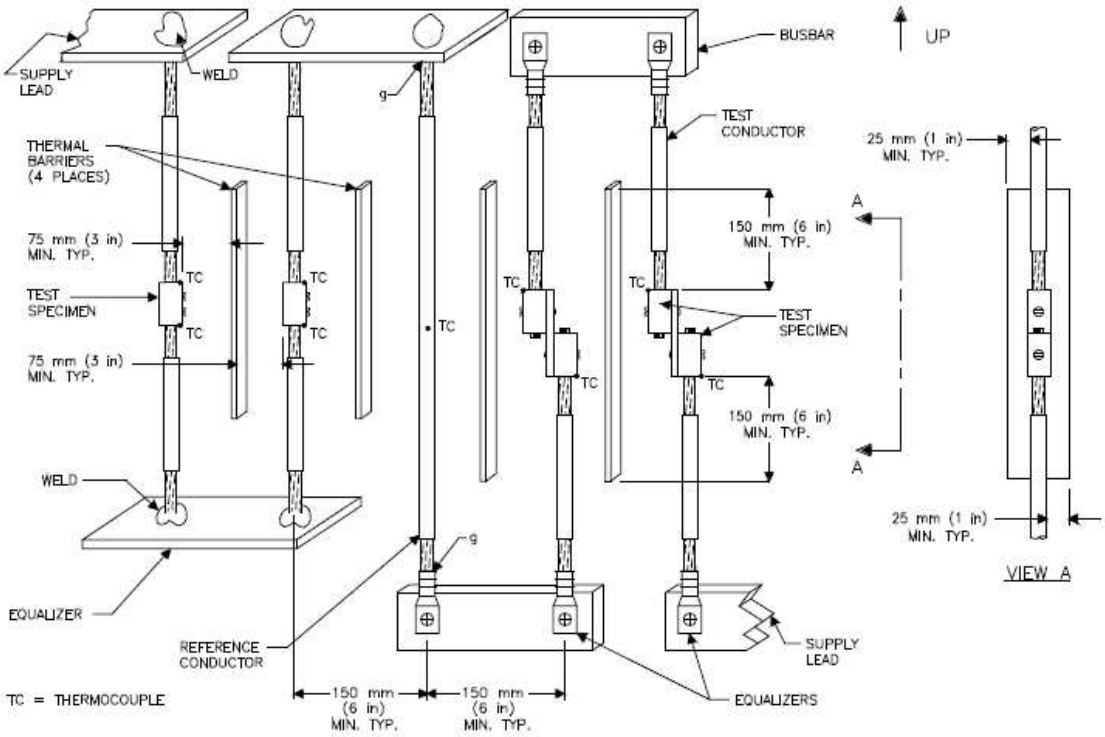
The apparatus is set up in complete compliance with Figure 2 on the next page, no other deviations from the standard were made.

Calibration Information:

Item #	Equipment Type	Asset #	Calibration Due
1	Fluke 365 True RMS Clamp Meter	M262	04/06/2019
2	Fluke Hydra Temperature Recorder	T1152	04/20/2019
3	Fluke Hydra Temperature Recorder	U080	07/16/2019
4	Fluke Hydra Temperature Recorder	T834S	02/13/2019
5	Fluke Hydra Temperature Recorder	T1565	09/27/2018

TEST LETTER REPORT

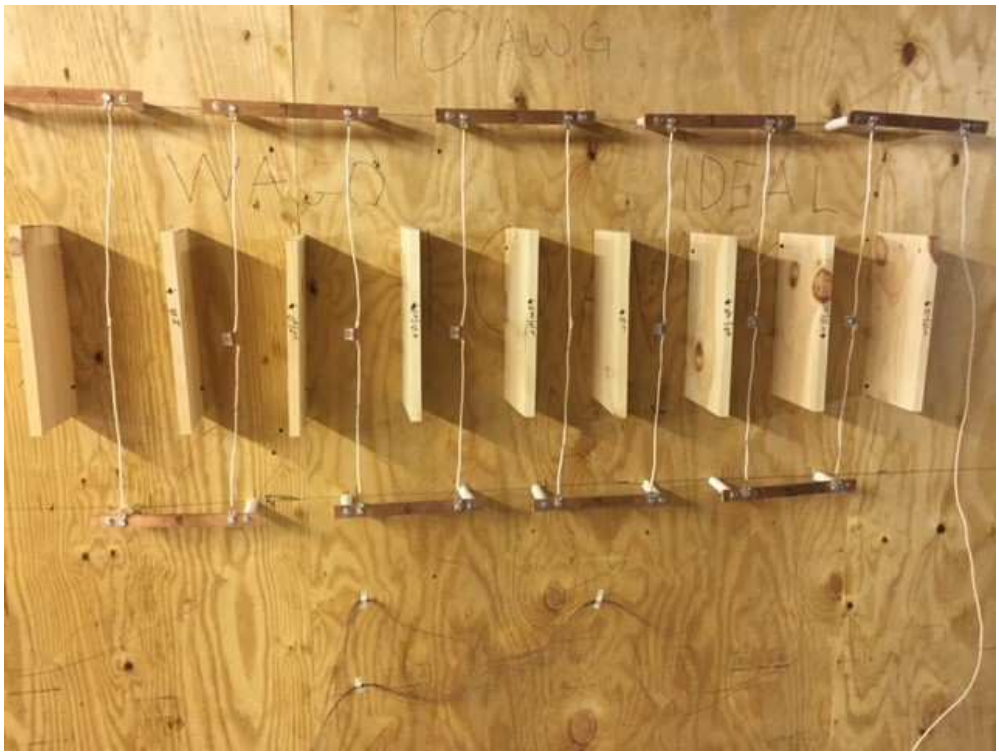
Figure 2
Vertical arrangement of specimen for current-cycling test
(Clause 9.1.10.7)



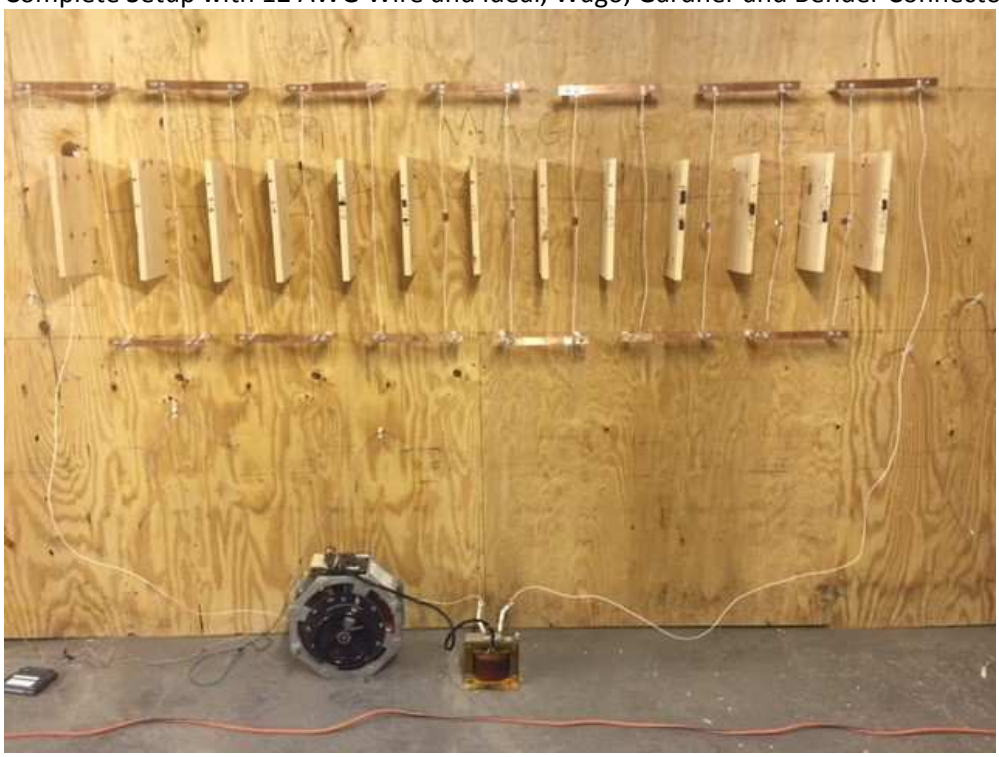
TEST LETTER REPORT

SECTION 3
PHOTOGRAPHS

10AWG Wire with IDEAL and WAGO connectors

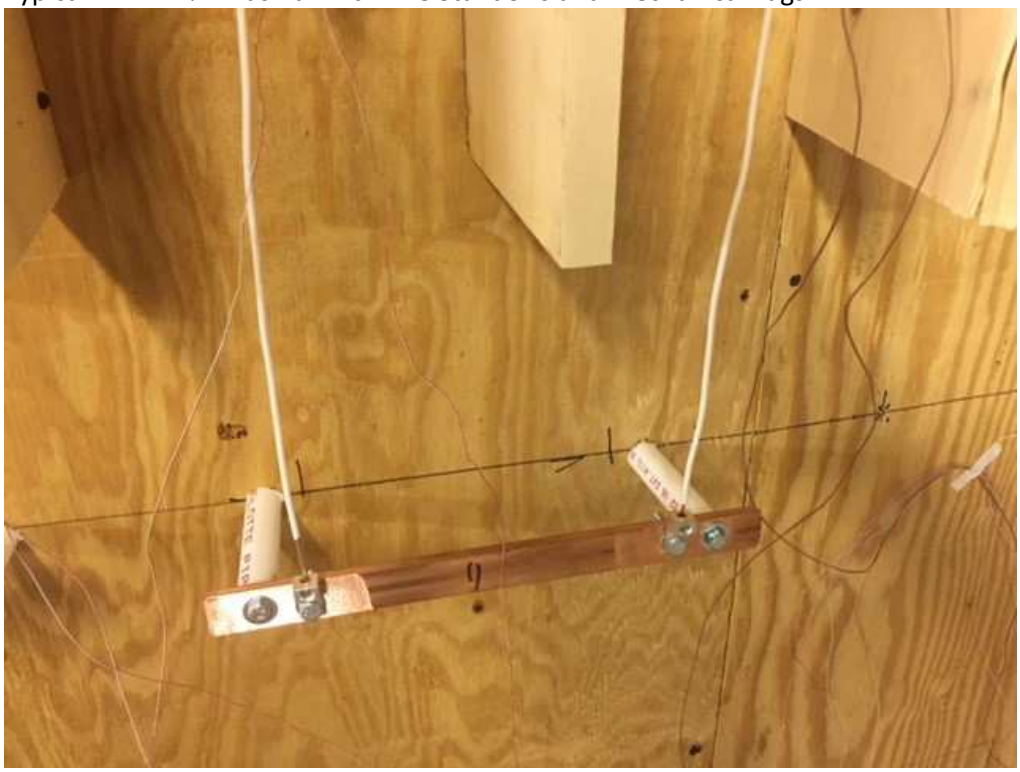


Complete Setup with 12 AWG Wire and Ideal, Wago, Gardner and Bender Connectors

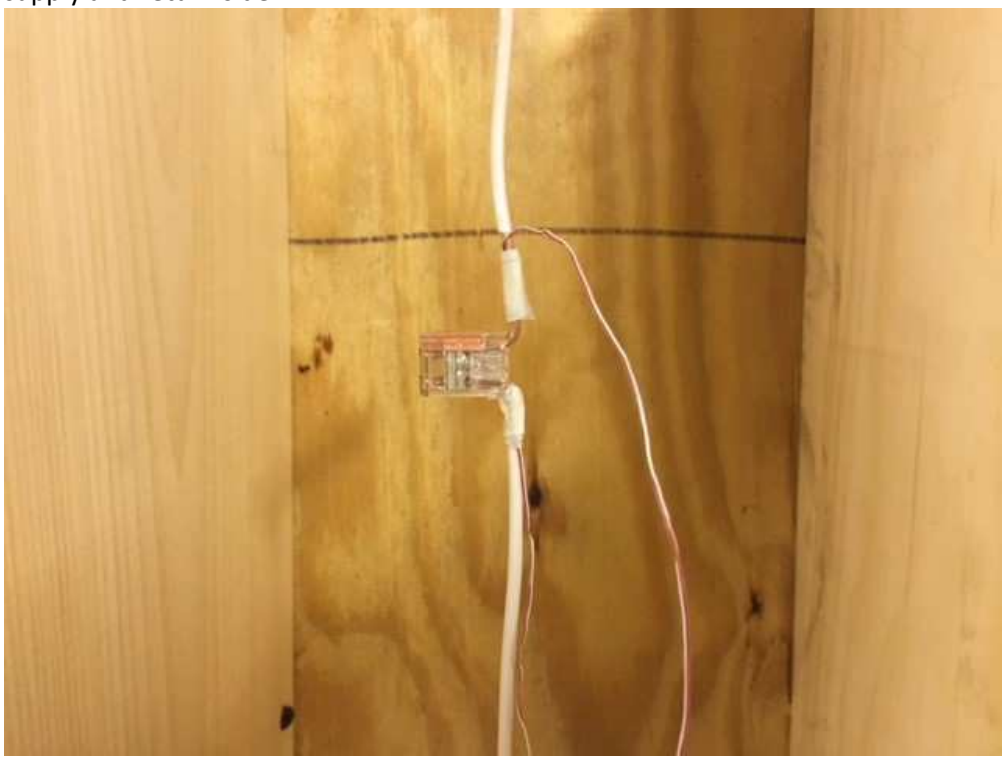


TEST LETTER REPORT

Typical 12 x 1 x ¼" Bus Bar with PVC Standoffs and Mechanical Lugs



Typical Connector, Gardner and Bender Shown, TC attached within 1/2" of the connector on supply and return side



TEST LETTER REPORT

SECTION 4
PROJECT STATUS & ACTION

One set of thermocouples did not record results on the first day of testing on one of the data recorders in use. Intertek performed a full 31 days of testing to capture a minimum of 30 days these thermocouples in question, at the request of the client.

One ambient thermocouple stopped recording at the end of the last day of testing, on the Ideal connectors for the 20A test setup. Data is recorded as “No Data” due to this malfunction. The seven remaining thermocouples reading ambient temperature show normal results.

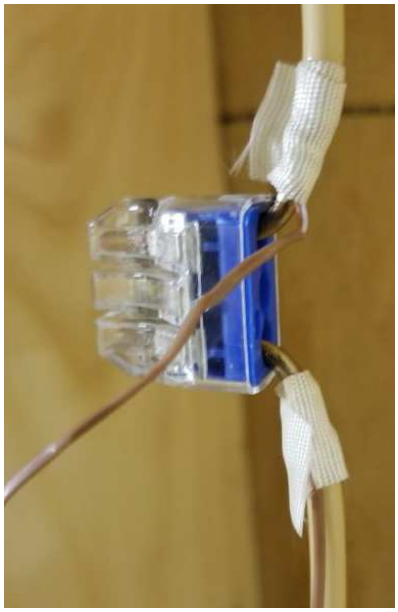
All testing is now complete.

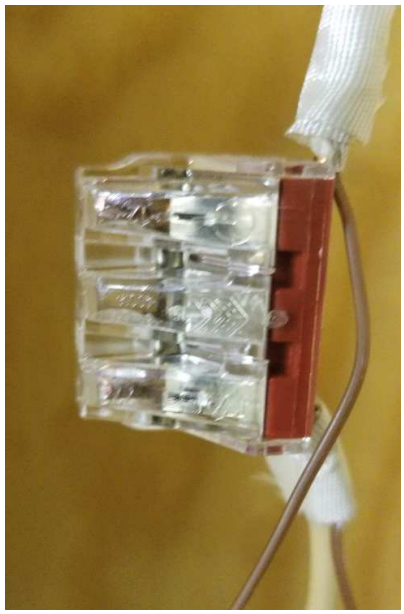
SECTION 5
CONCLUSION

The results contained in this report are to be evaluated by the client. This data is not to be used for certification of these products.

Upon completion of the test, there was no visible damage to any of the connectors contained within this report. There was however a visible change to the coloration of the insulation on the conductors involved in the 50A test on the 10 AWG conductors; no other conductors involved in the test exhibited this discoloration. The consistent temperatures recorded during the test, indicate that there is no evidence of arcing at the connectors.

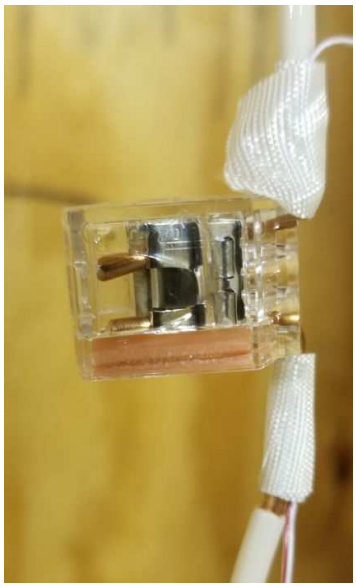
10 AWG Connectors (Left to Right: Ideal, Wago):



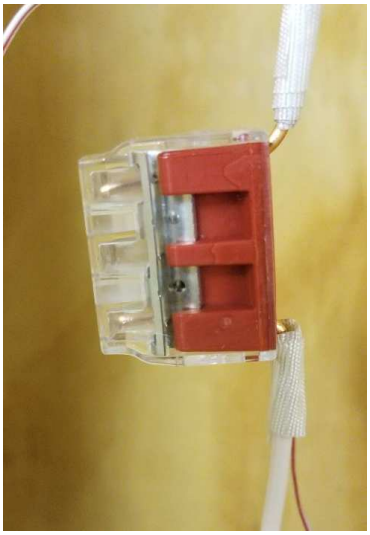
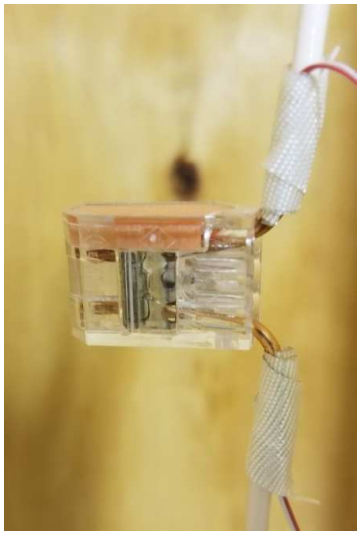


TEST LETTER REPORT

12 AWG Connectors (Left to right: Ideal, Wago, Gardner and Bender):



14 AWG Connectors (Left to right: Ideal, Wago, Gardner and Bender):

TEST LETTER REPORT

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

Completed by:	Joshua O'Connor	Reviewed by:	James Diescher
Title:	Engineering Team Lead	Title:	Technical Lead
Signature:		Signature	
Date	08/28/2018	Date:	08/28/2018

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

Revision History

08/28/2018: Added information in the conclusions about the condition of the connectors and conductors at the end of the test. Added example pictures of each connector for each test setup at the completion of the test.

TEST LETTER REPORT

APPENDIX

MAX TEMP (50A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		1	104.82	101.00	100.66	99.70	98.60	98.79	98.82	98.52	97.64	98.16	97.79	97.82	97.16	97.85	97.85	98.06	97.49	97.63	97.64	97.06	96.68	97.02	96.45	96.65	97.49	Power Outage			98.90	96.25	97.02	96.45	96.40	96.40
	1	2	83.92	81.32	81.26	80.73	80.09	80.76	80.48	80.18	79.64	80.31	79.79	79.55	79.49	80.47	79.93	80.34	80.07	79.59	79.50	79.27	79.02	78.94	78.79	78.94	79.93				80.77	78.35	78.70	78.40	78.30	78.26
		3	90.28	90.79	91.78	90.78	90.16	91.16	91.82	90.89	91.38	91.08	91.32	91.26	90.70	90.75	92.09	92.63	92.46	92.58	91.78	91.17	91.46	91.99	91.87	91.58	92.43				92.03	91.35	91.57	91.57	91.17	91.48
	2	4	77.14	77.62	78.16	77.92	77.83	78.34	77.99	77.93	78.12	78.28	78.10	78.06	77.93	77.76	79.17	79.25	79.16	79.14	78.74	78.29	78.55	78.53	78.67	78.38	79.24				78.86	78.68	78.79	78.53	78.25	78.37
		5	89.40	88.00	88.06	87.39	87.14	87.66	87.95	87.41	87.60	87.22	87.75	87.22	86.90	86.69	87.59	88.87	88.31	88.06	87.62	87.42	87.39	87.85	87.47	87.94	88.26				87.35	87.09	86.96	87.18	86.77	86.46
	3	6	92.73	91.58	92.06	91.46	91.54	91.75	92.33	92.00	92.01	91.28	91.62	91.88	90.90	90.83	92.07	93.37	92.96	92.68	92.04	91.75	92.20	92.29	92.00	92.57	92.69				92.26	91.65	91.54	92.05	91.31	91.72
	Ref	7	86.70	86.98	87.33	87.63	87.71	87.57	88.23	88.32	88.19	87.94	88.14	88.45	88.04	88.34	88.47	90.28	89.05	89.39	89.32	88.39	89.12	89.10	88.61	88.89	88.95				88.30	88.79	88.18	88.82	87.86	87.96
WAGO		8	81.37	80.88	80.74	80.56	80.08	79.93	79.18	79.02	78.45	79.39	79.33	79.00	79.07	79.55	79.65	79.63	79.81	79.52	78.93	77.99	78.56	78.44	78.10	78.43	78.26				79.39	77.75	77.91	77.48	76.92	77.02
	4	9	87.95	87.91	88.06	88.05	87.56	87.44	87.70	87.40	86.31	87.10	87.04	86.49	86.47	86.60	87.34	86.86	87.23	87.05	86.03	84.97	85.43	85.51	84.84	84.26	83.99				87.60	82.66	82.59	83.04	82.02	81.62
		10	87.19	87.84	87.90	88.43	87.66	87.34	86.86	86.11	86.57	87.48	87.70	87.54	87.20	87.45	87.88	87.92	88.00	86.61	86.52	85.52	85.46	85.47	85.73	86.22	86.18				87.75	85.60	85.48	85.31	85.87	85.36
	5	11	82.99	83.08	82.87	82.89	82.67	82.08	81.59	80.97	81.03	81.96	82.48	81.96	81.56	81.82	82.39	82.34	82.33	81.56	80.99	80.17	80.20	80.27	80.35	80.94	80.77				81.80	79.82	79.83	79.33	79.68	79.62
		12	85.43	85.05	85.09	85.12	84.61	84.80	84.10	83.59	83.47	84.12	84.26	84.58	84.16	84.36	84.31	84.97	84.57	84.23	83.86	83.73	83.34	83.49	83.12	84.01	83.75				84.34	83.84	83.04	83.06	83.41	83.41
	6	13	89.14	88.21	88.76	88.48	88.17	88.23	87.82	87.01	87.15	87.56	87.82	88.05	88.09	87.89	88.53	88.38	88.30	88.18	87.92	88.06	87.42	87.56	87.31	87.99	87.42				88.68	87.93	86.71	86.83	88.01	87.86
	Ref	14	88.72	89.64	91.45	90.71	91.45	91.75	91.57	91.95	91.31	90.84	92.18	92.33	92.35	91.99	92.78	92.10	93.57	93.63	92.06	91.81	92.52	93.07	92.84	94.56	92.34				91.83	91.48	91.76	90.88	91.75	92.01

MIN TEMP (50A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		1	22.29	95.90	95.73	93.01	91.23	93.56	92.72	93.94	92.48	90.88	92.40	92.03	91.11	91.39	90.62	91.45	91.51	91.06	89.73	93.36	91.73	91.20	89.59	91.80	90.50	Power Outage			88.57	89.43	88.66	87.20	89.04	88.91
	1	2	22.78	75.58	76.48	74.61	74.09	74.86	73.01	75.43	74.83	73.38	74.29	74.35	73.76	73.98	73.51	74.34	73.20	72.76	72.79	75.75	73.99	71.52	71.85	73.85	73.60				70.57	71.15	71.60	70.77	72.03	72.00
		3	22.32	86.68	86.59	86.16	86.30	86.08	83.75	86.01	85.92	86.01	86.10	86.12	86.44	86.39	86.00	87.18	85.73	86.73	84.95	86.06	85.97	85.69	84.59	86.34	86.40				86.41	84.28	82.96	83.55	86.01	86.60
	2	4	23.01	73.41	74.53	73.82	73.74	73.90	71.63	74.62	74.23	73.44	74.07	74.11	74.11	74.10	73.74	74.07	73.55	74.16	73.04	75.59	74.45	72.99	72.67	75.16	74.60				73.70	71.28	72.09	72.66	74.55	74.63
		5	22.81	82.43	83.23	81.87	81.43	81.93	82.40	83.10	83.04	81.18	81.53	82.37	82.07	81.62	80.99	81.31	82.41	83.19	83.08	83.34	83.08	83.36	82.56	82.89	81.89				83.00	80.76	80.45	78.26	82.23	82.20
	3	6	22.78	88.40	88.90	87.84	87.42	88.03	87.74	88.31	88.04	87.25	87.44	88.02	87.65	87.71	87.08	87.91	88.31	88.13	88.39	87.65	87.47	88.14	87.58	88.05	88.04				87.82	87.69	86.02	85.31	86.77	86.95
	Ref	7	22.80	81.99	82.99	82.63	83.18	82.18	83.80	84.81	83.61	82.84	83.48	83.28	83.82	83.52	82.89	82.37	84.23	85.36	85.18	85.16	84.67	85.61	84.25	85.09	83.40				85.03	84.55	82.60	82.30	84.22	84.61
WAGO		8	22.80	76.69	76.90	75.55	75.53	75.70	76.45	76.09	75.90	74.84	75.21	75.08	75.48	74.30	73.94	74.72	75.67	75.74	76.09	75.53	75.31	75.63	75.48	75.29	73.59				75.39	75.23	74.02	73.67	74.40	74.30
	4	9	22.75	83.28	83.55	82.80	83.07	82.84	83.59	82.50	82.47	81.84	82.09	81.47	81.66	81.43	80.58	81.16	81.56	81.90	81.02	81.21	80.95	80.60	80.67	79.89	78.46				78.59	78.57	76.50	76.81	77.42	78.12
		10	22.75	82.20	82.69	81.78	82.24	82.32	82.49	81.70	82.03	81.84	81.99	81.63	81.98	81.22	81.81	81.26	82.31	82.46	82.27	82.11	82.40	82.79	82.36	81.77	81.11				81.76	81.86	80.13	80.89	82.58	82.28
	5	11	22.70	78.01	77.83	76.59	77.48	77.09	77.56	77.03	77.05	76.60	76.94	76.43	76.92	75.85	76.32	75.92	77.07	77.78	77.22	77.46	77.68	77.94	77.27	76.76	75.78				76.67	77.06	75.06	74.97	77.20	77.02
		12	22.73	79.80	79.49	79.39	79.38	79.26	79.13	78.50	78.95	78.66	78.39	78.53	78.81	77.70	78.11	78.08	78.59	79.55	79.11	79.58	80.09	80.23	79.47	79.04	78.20				80.03	80.00	77.96	78.62	80.09	80.09
	6	13	22.70	83.65	83.07	83.06	82.47	82.70	81.87	82.49	82.24	82.41	82.51	82.69	82.38	82.30	82.45	82.67	82.99	83.63	82.82	83.27	83.53	82.79	82.66	83.04	82.52				83.28	82.88	81.04	81.24	83.12	83.10
	Ref	14	22.75	83.42	83.49	83.33	83.15	83.16	84.08	83.31	83.25	83.72	83.44	84.10	83.54	83.30	83.76	83.49	84.07	85.48	84.55	84.60	84.76	86.01	86.22	84.12	83.95				85.18	86.83	84.58	85.39	86.90	86.05

AVE TEMP (50A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		1	99.09	97.98	98.38	96.49	96.29	96.22	96.29	96.62	95.90	94.68	94.80	95.19	94.67	94.22	93.82	94.56	95.24	94.85	95.27	95.51	94.83	95.38	94.79	94.84	93.99	Power Outage			94.89	94.26	94.24	94.20	94.00	93.87
	1	2	78.62	77.88	78.84	77.46	77.72	77.86	77.92	78.29	77.87	76.79	76.90	77.39	76.91	76.46	76.14	76.80	77.45	77.10	77.47	77.66	76.99	77.46	76.86	77.13	76.46				77.03	76.21	76.26	76.30	76.08	75.89
		3	87.84	88.16	88.53	88.23	88.08	88.11	88.28	89.15	88.37	87.83	87.96	88.17	88.13	88.01	88.27	88.92	88.91	88.76	89.17	89.46	89.14	89.83	89.40	88.87	88.33				89.35	89.23	89.23	89.66	89.13	89.13
	2	4	74.75	75.56	76.47	75.77	76.01	76.19	76.27	76.75	76.46	75.81	76.07	76.44	76.22	76.03	75.91	76.52	77.05	76.92	77.14	77.29	76.93	77.37	76.97	76.95	76.55				77.40	77.13	77.02	77.23	76.91	76.87
		5	85.18	85.31	86.02	84.86	84.92	85.09	85.23	85.58	85.08	84.29	84.65	84.97	84.72	84.37	84.00	84.77	85.68	85.51	85.55	85.51	85.35	85.90	85.44	85.27	84.63				85.15	85.01	84.98	85.35	84.70	84.57
	3	6	89.99	89.95	90.10	89.68	89.52	89.54	89.60	89.92	89.43	89.14	89.38	89.37	89.34	89.25	89.24	89.79	90.18	90.00	90.00	89.89	89.87	90.32	89.99	89.55	89.44				89.70	89.75	89.67	90.16	89.29	89.23
	Ref	7	83.50	85.01	86.15	85.57	85.88	86.06	86.26	86.37	86.24	85.89	86.32	86.57	86.42	86.21	85.84	86.43	87.54	87.24	87.07	86.83	86.84	87.13	86.83	86.82	86.54				86.65	86.66	86.39	86.75	86.16	86.09
WAGO		8	78.35	79.13	79.27	78.39	78.35	78.06	77.90	77.38	77.23	77.29	77.47	77.56	77.44	77.45	77.14	77.46	78.23	77.77	77.39	76.77	76.84	76.80	76.83	76.98	76.73				76.63	76.32	76.04	75.97	75.51	75.42
	4	9	84.58	85.48	86.36	85.50	85.75	85.54	85.61	85.08	84.72	84.50	84.67	84.86	84.45	84.21	83.69	84.00	84.92	84.05	83.52	82.87	82.82	82.80	82.74	82.61	81.91				80.89	80.74	80.41	80.61	79.86	79.65
		10	83.91	85.12	86.05	85.11	85.40	85.17	85.01	84.69	84.79	84.74	85.01	85.30	85.06	84.91	84.51	84.81	85.78	84.94	84.53	84.03	84.08	84.17	84.11	84.43	84.03				84.44	84.26	83.59	83.64	83.85	83.81
	5	11	80.26	80.70	81.22	80.18	80.42	80.17	79.78	79.44	79.60	79.51	79.76	80.01	79.81	79.68	79.25	79.58	80.47	79.72	79.44	79.06	78.99	79.14	78.99	79.44	78.90				78.97	78.61	77.87	77.75	78.20	78.18
		12	82.32	82.81	83.38	82.23	82.52	82.39	81.93	81.68	81.73	81.45	81.71	82.35	82.02	81.68	81.38	81.71	82.58	82.39	81.91	81.77	81.72	81.78	81.45	81.81	80.94				82.08	81.76	80.74	80.37	81.44	81.64
	6	13	85.70	86.01	86.62	85.59	85.98	85.86	85.30	84.99	85.27	85.14	85.34	85.96	85.64	85.40	85.22	85.48	86.23	86.10	85.59	85.45	85.37	85.27	85.02	85.68	85.04				85.73	85.16	83.85	83.47	84.99	85.23
	Ref	14	84.72	85.98	87.39	86.49	86.92	87.91	88.34	89.19	88.00	86.86	87.38	88.68	88.21	87.26	87.03	87.49	88.69	89.53	89.36	89.39	89.47	90.37	89.71	89.12	87.38				88.84	89.23	88.46	87.94	88.82	89.13

MAX TEMP (30A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		15	68.57	62.14	61.07	60.48	60.15	59.65	59.37	58.88	59.40	59.21	59.03	59.59	59.52	59.65	59.99	60.38	60.45	59.45	59.20	58.92	58.77	58.79	58.81	58.92	59.54	Power Outage			59.22	59.20	59.03	57.81	58.09	58.50
	7	16	70.43	68.41	67.93	68.09	68.43	67.89	67.69	67.60	68.16	68.53	68.28	68.40	68.92	69.05	69.48	69.99	69.51	68.90	68.62	68.40	68.22	68.39	68.44	68.78	69.62				69.42	69.18	69.09	67.95	68.09	68.48
		17	80.39	65.87	64.23	64.36	64.12	64.12	63.84	63.72	63.63	63.62	63.27	63.19	63.31	63.70	64.09	64.17	63.63	62.92	62.82	62.44	62.19	62.22	61.94	62.91	62.70				61.81	61.15	61.09	59.86	59.84	60.07
	8	18	85.75	73.23	72.38	72.61	72.10	71.52	71.15	70.74	71.21	71.51	70.95	71.21	71.18	71.59	71.92	71.56	71.49	70.52	70.30	69.77	69.93	70.05	70.06	70.05	70.87				69.84	69.72	69.64	68.99	68.71	68.62
		19	65.78	64.66	64.04	64.77	64.75	63.82	63.62	63.56	63.54	63.56	63.63	63.38	63.44	63.94	64.33	64.51	64.62	63.36	63.50	63.00	63.26	63.48	63.70	63.34	63.57				63.36	63.25	62.99	62.38	62.04	61.95
	9	20	66.27	65.63	64.73	65.12	65.13	64.40	63.75	63.91	63.97	64.18	64.01	63.92	63.94	64.15	64.53	64.88	64.45	63.56	63.36	63.26	63.32	63.22	63.41	63.25	63.63				63.27	63.16	63.19	62.11	61.91	62.00
	Ref	21	67.20	67.35	66.97	67.88	67.89	67.24	67.55	67.53	67.24	66.93	67.88	67.56	67.55	67.87	68.14	68.77	68.16	68.30	68.23	67.37	68.14	67.45	68.48	67.70	67.67				68.10	68.36	67.75	67.62	67.07	67.07
WAGO		22	65.17	64.36	64.07	64.63	64.25	63.61	63.37	63.14	62.95	62.40	63.08	63.02	63.03	63.12	63.70	63.99	63.60	63.24	63.14	62.71	62.44	62.43	62.68	62.38	62.81				62.04	61.98	61.88	61.51	61.12	61.12
	10	23	68.15	67.25	66.94	67.10	66.98	66.28	65.89	65.83	65.73	65.47	65.73	65.81	65.53	65.73	66.41	66.67	66.20	65.39	65.46	64.95	64.75	64.86	64.97	64.77	65.26				64.25	64.38	64.25	63.67	63.45	63.45
		24	65.42	64.44	64.92	64.86	64.90	64.75	64.43	64.46	64.20	64.16	64.51	64.42	64.44	64.71	65.24	65.05	64.99	64.41	64.53	64.13	63.94	63.86	63.69	63.81	64.36				63.36	63.76	63.50	63.13	63.11	63.11
	11	25	64.28	61.42	61.21	61.24	61.13	60.69	60.29	60.28	60.01	60.01	60.27	60.29	60.44	59.64	59.79	59.84	59.96	59.49	59.24	58.74	58.55	58.60	58.17	58.42	58.97				57.57	57.58	57.45	57.45	56.89	56.89
		26	64.38	63.89	64.46	64.34	64.05	63.46	63.45	63.50	63.01	62.61	63.23	63.18	63.08	63.01	63.75	63.17	63.81	62.80	63.06	62.42	61.96	62.39	61.92	62.32	62.88				61.77	61.14	60.99	60.83	60.72	60.72
	12	27	67.34	67.23	67.54	67.26	67.17	67.19	66.53	66.41	65.93	65.99	66.46	66.16	66.28	66.03	66.53	66.53	66.88	66.02	65.95	65.53	65.04	65.08	65.23	65.31	66.17				64.83	64.29	64.23	64.03	63.79	63.79
	Ref	28	60.36	60.63	61.31	61.58	61.70	61.36	60.77	60.95	60.41	60.41	61.25	61.03	61.14	60.78	61.20	61.14	61.63	60.92	61.26	60.79	60.38	60.18	60.48	60.56	60.90				60.27	60.70	60.18	59.65	59.69	59.69
Gardner Bender		29	62.68	62.96	63.23	62.97	63.25	62.90	62.67	62.94	62.30	62.38	62.95	62.66	63.07	62.67	63.11	62.55	63.57	63.03	62.65	62.57	62.16	62.00	62.31	62.55	62.56				61.79	61.47	61.62	61.09	60.97	60.97
	13	30	64.06	64.02	64.43	64.32	64.44	64.32	64.04	64.15	63.91	63.98	64.28	64.22	64.51	64.26	64.75	64.44	65.41	64.22	64.25	64.16	63.74	63.55	64.06	64.11	64.33				63.81	63.81	63.91	63.13	63.08	63.08
		31	67.09	66.75	67.66	67.43	67.57	67.25	67.46	67.18	66.81	66.98	67.50	67.36	67.36	67.46	67.60	67.32	68.12	67.12	67.60	67.16	66.68	66.65	67.04	67.10	67.15				67.34	66.88	67.05	66.51	66.23	66.23
	14	32	No Data	67.16	67.72	67.56	67.82	67.27	67.57	67.43	66.98	67.55	67.95	67.50	67.50	67.33	67.63	67.41	68.28	67.21	67.96	67.42	66.89	66.79	67.33	67.49	67.43				67.86	66.79	66.94	66.31	66.25	66.25
		33	No Data	68.57	68.92	68.71	68.94	68.61	68.47	68.64	68.06	68.67	68.83	68.89	68.52	68.42	68.78	68.61	68.92	67.98	68.57	68.39	67.78	67.47	68.01	68.15	67.96				68.29	67.33	67.37	66.91	66.81	66.81
	15	34	No Data	65.91	65.94	65.52	65.62	65.33	65.00	64.92	64.42	64.83	65.17	65.19	64.34	64.53	64.76	64.51	64.68	63.67	64.28	64.26	63.49	63.09	63.76	63.87	63.44				63.23	62.80	62.35	61.87	61.92	61.92
	Ref	35	No Data	65.03	65.01	64.45	64.81	64.77	64.45	64.50	64.22	64.68	64.79	64.49	64.74	64.36	64.70	64.42	65.08	64.28	64.36	64.39	64.27	63.92	63.98	64.55	64.63				64.18	64.33	64.26	63.69	63.50	63.50

MIN TEMP (30A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		15	22.77	57.58	56.18	55.47	56.17	56.05	54.30	56.03	54.67	55.31	54.34	54.49	56.15	55.24	55.12	54.89	55.83	55.52	53.60	56.59	55.37	54.74	56.06	54.83	54.52	Power Outage			56.05	55.18	53.01	53.28	55.20	55.76
	7	16	22.75	64.48	64.38	63.99	64.72	64.79	63.90	65.26	64.38	65.44	64.65	64.53	66.23	65.24	65.00	64.95	65.76	66.08	64.69	65.90	66.02	65.34	65.89	65.79	65.72				66.20	66.45	63.80	64.49	66.06	66.17
		17	22.72	60.87	60.38	60.22	60.35	60.73	60.20	60.58	59.82	60.60	59.59	60.37	60.44	59.53	59.53	59.51	59.88	59.76	59.66	59.65	59.09	59.07	59.20	59.21	58.97				58.75	58.51	56.75	56.91	57.43	57.44
	8	18	22.73	69.00	69.03	68.30	68.23	68.70	68.06	68.73	67.88	68.03	67.70	67.69	68.59	67.68	67.31	66.96	67.95	67.89	67.32	68.39	68.31	67.35	68.10	67.69	66.99				67.27	67.55	64.94	65.56	67.07	67.37
		19	22.73	59.98	60.15	59.82	59.93	60.23	60.98	60.99	59.94	59.98	59.26	60.02	59.92	59.93	60.20	59.29	60.47	59.96	60.62	61.18	60.87	60.36	60.73	60.00	59.11				60.39	60.55	58.06	58.78	60.52	60.37
	9	20	22.70	61.16	61.38	61.20	61.55	61.51	61.68	61.04	60.78	60.90	60.68	61.06	60.54	61.25	60.92	60.34	61.25	61.27	61.53	61.29	61.40	60.79	61.06	60.77	60.38				60.64	60.93	59.00	59.81	60.22	60.27
	Ref	21	23.00	62.21	62.84	62.36	63.25	63.69	64.05	64.89	63.00	62.62	63.53	62.58	64.50	63.99	63.41	63.48	63.79	64.67	64.44	65.95	65.58	64.06	64.49	63.65	62.50				64.62	64.74	61.88	62.35	63.63	63.63
WAGO		22	23.02	59.21	59.42	58.74	58.99	59.38	59.33	60.21	58.13	57.78	58.80	57.64	59.60	58.67	57.99	58.01	58.48	58.96	58.93	60.69	60.04	57.83	58.84	58.02	56.75				58.68	58.52	56.02	56.86	57.95	57.95
	10	23	23.00	62.52	62.21	61.72	61.82	61.94	62.50	63.04	60.80	60.67	61.60	60.52	62.47	61.55	60.96	60.80	61.47	61.81	61.33	63.19	62.51	60.66	61.53	60.82	59.77				61.51	61.43	59.00	59.92	60.68	60.68
		24	23.02	60.65	60.80	60.62	60.81	61.46	60.99	61.87	60.15	60.26	60.59	59.96	61.62	60.89	60.49	60.46	60.95	61.58	61.47	62.36	61.67	60.51	60.98	60.13	59.75				60.48	60.99	58.22	59.69	59.84	59.84
	11	25	23.07	57.07	56.58	56.68	56.69	56.88	56.66	57.07	56.35	55.85	56.35	55.84	56.70	55.53	54.59	54.30	55.11	55.45	55.37	56.38	55.05	54.50	53.48	53.09	52.24				52.13	53.09	50.44	50.89	51.40	51.40
		26	23.05	58.73	58.77	58.40	59.00	58.48	58.52	59.16	57.75	57.96	57.86	57.39	58.41	58.42	57.88	57.79	58.09	58.42	58.22	60.13	58.57	57.41	57.14	57.18	57.05				57.66	57.98	55.59	56.70	56.63	56.63
	12	27	23.02	62.05	62.29	61.74	62.48	62.06	62.35	62.57	61.59	61.31	61.82	61.22	61.92	61.95	61.74	61.41	61.80	62.12	61.41	63.02	62.21	61.25	61.29	60.89	60.91				61.45	61.74	59.33	60.39	60.26	60.26
	Ref	28	23.05	55.09	54.46	54.76	56.16	55.22	55.92	56.42	55.98	55.79	56.10	55.70	56.37	55.77	56.14	56.02	55.91	56.25	56.33	57.81	56.53	55.96	55.80	55.62	55.48				56.30	57.54	55.38	55.88	56.27	56.27
Gardner Bender		29	23.03	56.09	55.54	55.72	56.34	55.68	56.74	56.71	56.14	55.32	56.25	56.46	57.26	57.41	56.92	56.71	56.27	56.76	55.89	59.38	58.23	56.04	55.97	55.91	56.04				56.30	57.15	55.72	56.01	56.10	56.10
	13	30	23.00	58.88	58.14	58.57	58.60	58.83	59.15	59.75	58.92	57.87	59.21	59.46	60.23	60.13	59.37	59.43	58.80	59.60	59.40	61.86	60.54	59.05	59.15	58.59	58.51				59.47	60.48	58.94	59.36	59.27	59.27
		31	22.91	60.43	59.64	59.94	60.71	60.63	61.05	62.26	59.81	59.70	60.51	60.80	62.60	60.70	61.36	60.98	59.79	61.30	60.67	63.95	62.40	60.33	60.62	60.06	60.39				61.77	62.93	61.23	62.62	62.11	62.11
	14	32	No Data	59.91	59.38	59.83	60.02	59.62	60.37	61.40	59.30	59.39	60.35	60.12	61.55	60.39	60.74	60.75	59.19	60.49	59.97	63.98	61.42	59.87	59.67	59.61	60.27				60.89	62.15	60.49	61.70	61.62	61.62
		33	No Data	63.35	62.04	61.80	61.88	61.90	61.99	62.92	61.26	61.57	61.88	62.11	62.91	61.98	62.67	62.15	60.99	61.71	61.53	64.55	62.26	61.06	60.82	60.58	61.22				61.39	62.68	61.00	62.39	61.60	61.60
	15	34	No Data	60.13	58.82	58.25	58.86	58.51	58.42	59.14	57.44	57.34	57.62	58.39	59.05	57.74	57.98	58.19	56.76	57.66	56.81	60.03	58.20	56.55	56.50	55.56	55.44				56.14	57.06	55.99	56.96	55.70	55.70
	Ref	35	No Data	60.01	59.16	59.60	59.57	59.61	59.71	60.18	58.88	59.50	59.28	59.95	59.52	59.73	59.97	60.38	59.10	58.74	59.26	60.50	60.06	58.98	58.66	58.36	58.92				59.41	60.12	59.63	59.35	58.66	58.66

AVE TEMP (30A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		15	62.96	60.51	59.09	58.64	58.55	58.25	57.68	57.73	57.72	57.76	57.63	57.85	57.93	58.04	58.29	58.21	58.34	58.07	57.93	57.80	57.58	57.76	57.69	57.76	57.73	Power Outage			59.22	57.62	56.55	56.00	56.89	57.06
	7	16	67.80	67.05	66.52	66.72	67.00	66.93	66.45	66.53	66.95	67.25	67.21	67.42	67.59	67.88	68.24	68.24	68.21	67.75	67.55	67.36	67.19	67.48	67.42	67.79	67.99				69.42	67.95	66.93	66.42	66.93	67.03
		17	65.55	63.34	62.66	62.44	62.62	62.72	62.34	62.15	62.25	62.03	62.00	62.05	61.92	62.11	62.30	62.10	62.14	61.56	61.34	61.00	60.65	60.79	60.65	60.82	61.01				61.81	59.87	59.11	58.38	58.57	58.64
	8	18	72.98	71.28	70.57	70.55	70.48	70.28	70.02	69.91	70.01	69.88	69.74	69.80	69.82	69.95	70.20	70.00	69.97	69.67	69.44	69.16	69.10	69.11	69.09	69.06	69.14				69.84	69.06	68.06	67.76	68.03	67.95
		19	63.36	62.65	62.53	62.52	62.73	62.50	62.45	62.39	62.30	61.91	61.96	62.23	62.15	62.32	62.58	62.54	62.77	62.48	62.45	62.21	62.22	62.17	62.22	61.94	61.95				63.36	62.22	61.24	61.17	61.36	61.25
	9	20	64.35	63.60	63.29	63.26	63.34	63.07	62.88	62.78	62.81	62.52	62.54	62.70	62.65	62.83	63.13	63.09	63.19	62.76	62.60	62.31	62.28	62.29	62.31	62.13	62.27				63.27	62.29	61.49	61.17	61.22	61.14
	Ref	21	65.33	65.41	65.85	65.71	66.26	66.08	66.19	66.19	66.07	65.58	65.93	66.17	66.12	66.26	66.37	66.42	66.89	66.77	66.78	66.63	66.65	66.55	66.71	66.31	66.16				66.59	66.86	65.65	65.71	65.95	65.95
WAGO		22	62.58	62.44	62.80	61.98	62.48	62.15	62.07	62.04	61.67	61.03	61.45	61.71	61.48	61.61	61.48	61.32	62.01	61.72	61.86	61.82	61.52	61.28	61.37	60.96	60.86				60.90	60.92	59.73	59.76	60.04	60.04
	10	23	65.64	65.47	65.60	64.63	65.20	64.92	64.80	64.78	64.42	63.80	64.13	64.42	64.17	64.35	64.27	64.02	64.64	64.24	64.35	64.21	63.92	63.69	63.75	63.36	63.34				63.25	63.32	62.29	62.28	62.38	62.38
		24	62.85	62.98	63.65	62.98	63.64	63.54	63.40	63.47	63.15	62.78	63.10	63.34	63.28	63.35	63.31	63.07	63.61	63.34	63.55	63.38	63.05	62.88	62.86	62.53	62.58				62.49	62.61	61.70	61.80	62.13	62.13
	11	25	60.31	59.35	59.79	58.99	59.56	59.36	59.24	59.28	58.79	58.22	58.79	59.04	58.79	58.17	57.52	57.30	58.21	57.78	57.87	57.78	57.34	57.14	56.83	56.32	56.22				55.87	55.74	54.77	54.79	55.06	55.06
		26	61.30	61.24	62.45	61.23	62.06	61.91	61.71	61.85	61.09	60.53	61.16	61.49	61.14	61.05	60.66	60.49	61.54	60.94	61.26	61.34	60.62	60.45	60.37	60.09	60.02				59.91	59.63	58.84	58.80	59.08	59.08
	12	27	64.19	64.20	65.46	64.30	65.14	65.04	64.94	65.02	64.40	63.79	64.39	64.74	64.38	64.37	64.07	63.95	64.87	64.32	64.61	64.56	63.94	63.78	63.81	63.45	63.48				63.25	63.17	62.48	62.41	62.46	62.46
	Ref	28	57.47	57.72	59.09	58.44	59.26	59.15	59.27	59.36	58.80	58.33	58.93	59.20	58.99	58.84	58.73	58.77	59.52	59.09	59.48	59.57	59.11	58.86	59.06	58.71	58.72				58.86	59.03	58.42	58.40	58.24	58.24
Gardner Bender		29	59.04	59.48	60.89	59.71	60.70	60.60	60.86	61.05	60.32	59.90	60.47	60.80	60.67	60.35	59.91	59.73	60.83	60.31	60.81	61.18	60.45	60.09	60.32	59.77	59.83				60.09	60.18	59.40	59.29	59.51	59.51
	13	30	61.18	61.58	62.66	61.75	62.61	62.55	62.75	62.87	62.33	62.03	62.47	62.80	62.70	62.55	62.34	62.20	63.04	62.60	62.93	63.07	62.49	62.26	62.41	61.99	62.09				62.39	62.52	62.00	61.85	61.81	61.81
		31	63.63	63.96	65.26	64.15	65.12	65.04	65.34	65.44	64.75	64.54	65.02	65.35	65.21	65.00	64.67	64.27	65.35	64.76	65.45	65.88	65.13	64.65	64.98	64.41	64.43				65.27	65.47	64.84	64.91	64.89	64.89
	14	32	No Data	63.57	65.09	63.76	64.90	64.80	65.09	65.19	64.44	64.24	64.79	65.13	64.99	64.75	64.32	63.82	65.05	64.37	65.16	65.82	64.91	64.39	64.71	64.11	64.22				64.99	65.13	64.34	64.41	64.70	64.70
		33	No Data	65.59	66.72	65.43	66.31	66.22	66.48	66.49	65.93	65.90	66.23	66.44	66.42	66.17	65.90	65.39	66.31	65.78	66.30	66.80	65.80	65.37	65.62	65.14	65.21				65.49	65.58	64.95	64.84	65.21	65.21
	15	34	No Data	62.85	63.73	62.23	62.91	62.69	62.89	62.83	62.23	62.07	62.30	62.46	62.31	61.95	61.63	61.10	62.03	61.39	61.86	62.18	61.33	60.82	61.15	60.53	60.50				60.27	60.41	59.78	59.66	59.80	59.80
	Ref	35	No Data	62.16	63.09	62.21	62.62	62.54	62.89	62.73	62.44	62.48	62.65	62.65	62.71	62.43	62.40	62.23	62.79	62.57	62.68	62.86	62.34	61.95	62.30	61.97	62.19				62.37	62.49	62.19	61.90	61.74	61.74

MAX TEMP (20A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		36	No Data	62.13	61.46	60.56	60.29	60.59	59.48	59.07	58.70	58.95	58.83	58.72	58.61	58.78	58.97	59.81	58.95	58.60	57.88	57.27	57.12	57.72	57.02	57.49	58.02	Power Outage			55.94	56.39	55.77	54.77	54.71	54.52
	16	37	No Data	61.55	61.48	60.69	60.29	60.42	59.33	58.77	58.49	59.20	58.83	58.91	58.80	58.85	59.36	60.28	58.72	58.39	57.21	57.18	56.89	56.21	56.79	57.72	57.67				56.06	55.89	55.26	55.12	54.70	54.71
		38	No Data	53.15	53.64	52.80	52.67	53.02	52.45	52.11	52.09	52.60	52.50	52.54	52.74	52.96	53.10	53.16	52.74	53.18	52.53	51.91	51.67	51.18	51.62	52.10	52.53				52.03	51.42	52.15	51.49	50.43	50.66
	17	39	No Data	53.55	53.88	53.02	53.33	53.47	52.88	52.47	52.77	53.33	53.18	53.27	53.13	53.11	53.64	53.92	53.68	53.27	53.14	52.67	52.14	51.76	52.10	52.54	53.11				52.15	51.65	52.10	51.53	50.89	51.19
		40	No Data	58.52	58.37	57.97	57.89	58.17	58.29	57.23	57.63	57.96	57.56	57.85	57.78	58.40	58.14	58.80	58.13	58.01	57.80	57.28	56.80	56.33	57.45	57.09	57.96				57.14	56.87	57.52	57.04	56.10	55.62
	18	41	56.13	55.83	55.29	55.13	55.00	55.35	55.29	54.68	54.99	55.53	54.95	55.10	55.40	55.49	55.95	56.23	55.65	55.32	55.43	54.40	54.26	54.25	54.91	54.95	55.22				55.24	55.27	55.11	55.20	54.01	53.78
	Ref	42	56.42	56.74	56.50	56.62	56.33	56.28	56.37	56.22	55.96	56.23	56.48	56.54	56.60	56.96	57.50	58.27	57.01	56.53	56.28	55.38	55.46	55.50	55.62	56.07	57.18				56.25	56.25	55.48	55.38	54.02	53.94
WAGO		43	53.75	53.87	53.82	54.10	53.50	53.57	53.50	52.85	53.41	53.48	53.44	53.31	53.17	53.72	54.38	54.62	54.30	54.03	53.64	53.09	52.91	52.87	53.25	53.21	54.05				53.32	53.22	53.29	52.33	51.90	51.89
	19	44	55.89	55.65	55.78	55.82	55.25	55.40	55.26	54.84	55.04	55.27	55.32	54.92	54.82	55.36	56.26	56.63	56.03	55.85	54.97	54.46	54.50	54.34	54.62	54.71	56.00				54.68	54.77	54.47	53.68	53.04	53.04
		45	52.99	52.56	52.37	52.78	52.28	52.39	51.91	51.41	52.14	51.95	52.12	51.92	51.77	52.32	52.70	53.38	53.05	52.99	52.06	51.45	51.56	51.28	51.61	52.00	52.99				51.71	51.64	51.68	51.02	50.29	50.59
	20	46	57.96	57.96	58.00	58.20	57.49	57.50	57.34	56.82	56.96	56.99	57.24	57.16	56.95	57.64	57.95	58.84	58.49	58.11	57.46	56.50	56.58	56.79	56.97	56.85	58.01				56.80	56.91	56.95	56.39	55.60	55.52
		47	53.18	53.28	53.38	53.69	53.55	53.35	53.31	52.74	53.21	53.00	53.30	53.27	52.91	53.47	53.94	54.55	54.36	54.40	53.55	53.10	53.19	53.37	53.15	53.33	54.35				53.02	52.94	52.99	52.49	52.10	51.88
	21	48	55.56	56.03	55.79	56.28	55.54	55.68	55.56	55.06	55.50	55.52	55.63	55.69	55.57	56.12	56.31	57.52	56.93	56.43	55.72	55.31	55.22	55.68	55.18	55.82	57.01				55.40	55.08	55.32	55.19	54.29	54.10
	Ref	49	59.88	59.48	59.52	59.78	59.74	59.54	59.32	58.76	59.02	59.55	59.43	59.60	59.70	60.14	60.29	61.11	60.15	60.55	59.73	58.64	59.01	59.14	58.71	59.67	60.63				59.49	57.94	57.98	57.35	57.49	57.67
Gardner Bender		50	59.35	59.42	59.95	60.32	60.10	59.65	59.22	59.17	59.70	59.58	59.53	59.91	59.58	60.30	60.72	61.01	61.32	61.23	60.14	59.45	59.70	60.72	60.05	60.38	61.19				59.47	59.21	59.74	58.66	58.40	58.24
	22	51	61.96	61.58	61.77	62.22	61.85	61.58	60.92	60.99	61.25	61.51	61.27	61.81	61.27	62.80	62.52	63.28	62.56	62.82	61.88	61.01	60.90	62.66	62.00	62.71	63.59				61.36	60.54	61.33	59.95	59.91	59.67
		52	66.06	66.79	68.72	70.24	70.50	70.99	70.27	69.62	69.82	69.78	69.56	69.39	68.80	69.02	68.78	69.45	69.11	69.08	68.03	66.70	66.93	68.02	67.48	67.56	67.48				65.92	65.69	65.37	64.75	64.53	64.40
	23	53	64.35	65.25	66.55	68.23	68.67	68.51	67.96	67.56	67.49	67.69	67.29	67.03	66.68	66.49	66.51	66.98	66.88	66.84	65.76	64.83	64.73	65.30	65.00	65.00	65.02				63.50	63.06	63.04	62.42	62.02	61.88
		54	55.36	54.87	55.50	56.30	55.60	55.79	55.48	55.15	55.71	55.81	55.94	55.96	55.13	56.22	56.19	56.60	57.05	57.12	56.81	54.97	56.06	56.35	56.19	56.09	56.92				55.52	54.86	54.79	54.18	54.23	54.17
	24	55	56.03	55.91	56.35	57.15	56.61	56.65	56.36	55.93	56.44	56.83	56.78	56.76	56.16	57.08	57.02	57.72	57.82	58.08	57.58	55.95	56.97	57.32	57.03	56.86	57.98				56.51	55.73	55.96	55.38	55.18	55.26
	Ref	56	57.85	57.34	58.14	58.45	58.11	58.29	57.80	57.79	58.00	58.26	58.49	58.19	57.91	58.52	58.96	59.31	59.46	59.75	58.73	58.07	58.74	58.89	58.86	58.61	59.32				58.52	58.03	57.79	57.42	57.41	57.28

MIN TEMP (20A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		36	No Data	59.35	58.63	57.86	57.56	57.20	56.72	56.52	55.94	56.36	56.49	56.26	56.20	56.30	56.63	56.66	56.30	55.87	55.43	54.74	54.82	54.93	54.79	55.20	55.26	Power Outage			54.14	53.70	52.99	52.13	52.45	52.29
	16	37	No Data	57.79	57.06	56.48	56.14	55.91	55.38	55.24	55.21	55.24	55.15	55.20	55.05	55.24	55.58	55.58	55.34	54.86	54.43	53.72	53.84	53.79	53.38	54.02	54.44				53.12	52.87	52.22	51.82	51.65	51.61
		38	No Data	49.75	49.98	49.67	49.75	49.31	49.02	48.63	49.23	49.38	49.51	49.41	49.51	50.28	50.34	50.40	50.06	49.63	49.53	49.25	48.51	48.91	48.37	49.05	49.95				48.12	48.34	48.27	47.40	47.43	47.71
	17	39	No Data	50.82	50.92	50.31	49.90	49.96	49.24	49.84	50.10	50.56	49.98	50.29	50.27	50.79	51.28	50.99	50.57	49.91	49.81	49.54	48.94	49.36	48.70	49.30	50.66				48.65	48.64	48.11	47.65	47.82	48.16
		40	No Data	55.18	55.29	54.75	54.41	54.78	53.98	54.16	53.99	54.52	54.21	54.25	54.66	54.96	55.24	55.12	53.62	54.03	53.64	53.63	52.40	53.14	52.87	52.99	54.58				53.13	52.93	53.08	52.44	52.17	52.41
	18	41	22.86	52.29	52.65	52.48	52.14	52.15	51.89	51.58	52.03	51.88	52.19	52.23	52.31	52.52	53.15	53.36	52.73	51.94	52.08	51.26	51.32	51.46	50.98	51.87	52.47				51.54	51.62	50.85	51.01	50.33	50.86
	Ref	42	22.88	52.07	53.43	52.73	52.59	52.26	52.30	52.58	52.32	52.32	53.09	53.11	52.81	51.80	52.71	51.32	53.41	52.17	52.87	51.55	52.17	51.97	52.11	52.48	52.22				52.56	51.63	51.30	51.25	50.30	50.80
WAGO		43	22.90	50.19	51.07	49.83	50.72	51.22	50.90	51.03	51.03	51.32	50.99	51.53	51.32	50.32	50.18	49.22	50.40	51.92	51.73	51.02	51.08	51.13	51.25	51.43	50.34				51.31	50.96	50.69	50.04	49.93	50.16
	19	44	22.88	51.23	52.25	50.87	51.42	52.09	52.41	52.35	51.81	52.44	51.92	52.60	52.11	51.11	50.86	49.83	50.85	53.18	52.77	51.85	52.01	51.90	52.07	52.15	51.13				52.07	51.60	51.56	50.79	50.53	50.61
		45	22.88	48.73	49.44	48.31	48.85	49.19	48.74	49.27	49.56	49.69	49.07	49.80	49.36	47.50	47.44	47.56	48.58	50.38	49.96	49.51	49.51	49.52	49.61	49.98	48.48				49.70	49.40	49.33	48.42	48.46	48.58
	20	46	22.90	53.18	54.28	53.41	54.27	54.09	53.31	54.01	54.41	54.55	53.91	54.38	54.23	52.66	52.79	52.77	53.34	55.14	54.94	54.69	54.80	54.11	54.50	54.71	53.17				54.70	54.38	54.57	53.62	53.36	53.76
		47	22.86	48.90	49.92	49.34	49.38	49.73	49.55	49.88	50.21	50.20	48.87	50.15	50.08	48.36	48.97	48.64	49.93	51.04	50.75	50.99	50.82	51.28	51.08	51.13	49.94				50.66	51.01	51.08	50.49	49.96	50.68
	21	48	22.85	50.05	50.83	50.24	50.67	50.80	50.55	51.55	52.03	51.66	49.48	51.39	51.07	49.69	50.11	49.68	50.86	52.18	51.95	52.44	52.70	52.49	52.07	52.61	51.19				52.51	52.75	52.82	52.29	51.15	51.94
	Ref	49	22.85	52.31	53.12	52.11	52.79	53.02	53.25	53.67	54.19	53.43	51.96	53.91	53.11	51.78	51.67	52.72	53.34	54.64	53.62	54.57	54.76	54.82	55.01	54.57	53.48				54.76	54.54	54.22	53.79	53.82	54.81
Gardner Bender		50	22.82	53.04	53.91	53.59	54.27	54.49	54.33	54.51	54.63	54.22	54.16	54.86	54.70	53.55	53.28	53.89	54.27	55.96	55.18	55.14	55.77	55.23	56.24	55.22	55.05				56.33	55.73	55.79	56.51	55.47	56.24
	22	51	22.69	53.66	54.11	53.97	54.71	55.02	54.91	55.14	55.52	54.80	54.58	55.20	55.27	53.57	52.89	54.15	54.33	56.56	55.70	55.37	56.50	56.21	56.91	55.79	55.09				56.40	56.89	56.66	57.25	56.09	56.53
		52	22.70	59.15	60.30	61.39	63.00	63.46	63.42	63.63	63.43	62.55	62.30	62.46	62.06	60.52	60.60	60.90	60.69	62.22	61.00	61.81	61.94	61.57	61.16	60.35	59.99				61.06	60.99	60.05	61.57	60.52	61.33
	23	53	22.70	57.96	59.48	60.06	61.63	61.74	60.48	61.87	61.59	61.08	60.51	60.61	59.86	59.36	59.35	59.25	59.30	59.88	59.48	59.78	59.81	59.47	59.70	58.40	58.65				58.92	58.37	58.28	59.16	58.30	59.14
		54	22.69	48.53	48.73	48.85	49.31	49.08	49.33	49.87	49.51	49.40	49.07	49.17	49.49	48.35	48.21	49.38	49.25	50.09	49.37	50.31	50.26	50.98	50.13	50.68	49.76				50.34	50.89	50.78	50.81	50.87	50.56
	24	55	22.67	48.93	49.19	49.36	49.47	49.69	49.29	50.17	49.76	49.93	49.61	49.42	50.01	48.98	48.83	49.55	49.62	51.01	50.24	50.57	50.60	51.09	50.52	50.91	50.31				50.62	51.03	51.01	52.23	51.43	51.51
	Ref	56	22.67	50.30	50.45	50.53	50.97	50.51	50.98	51.60	50.90	51.36	51.00	51.29	51.42	50.75	51.16	51.15	51.30	52.26	51.60	51.74	51.74	52.88	52.04	52.03	51.84				52.01	53.03	53.29	52.89	52.51	53.01

AVE TEMP (20A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		36	No Data	60.77	59.99	59.24	58.80	58.40	58.00	57.49	57.52	57.76	57.57	57.30	57.23	57.33	57.76	57.80	57.64	57.23	56.62	55.92	55.94	55.93	55.88	56.18	56.41	Power Outage			55.04	54.76	54.33	53.61	53.61	53.38
	16	37	No Data	59.73	59.15	58.20	57.97	57.61	57.21	56.61	56.80	57.16	56.97	56.73	56.67	56.83	57.26	57.16	56.99	56.29	55.69	55.13	54.96	54.78	54.74	55.25	55.77				54.45	53.99	53.52	52.73	52.79	52.83
		38	No Data	51.64	51.53	51.16	51.23	51.05	50.88	50.46	50.78	51.23	51.13	51.05	51.16	51.32	51.72	51.89	51.78	51.21	50.92	50.47	50.25	50.03	50.05	50.54	51.13				50.27	50.05	50.06	49.36	48.98	49.14
	17	39	No Data	52.36	52.28	51.85	51.98	51.84	51.62	51.21	51.53	51.98	51.88	51.79	51.87	52.06	52.56	52.70	52.44	51.80	51.50	51.02	50.73	50.55	50.45	51.19	51.86				50.82	50.31	50.14	49.41	49.31	49.63
		40	No Data	57.10	56.83	56.46	56.37	56.22	56.18	55.59	55.98	56.44	56.20	56.06	56.21	56.40	56.80	56.96	56.68	56.18	55.89	55.15	55.04	54.84	54.94	55.52	56.13				55.55	55.12	55.25	54.72	53.96	54.04
	18	41	54.35	54.35	54.11	53.73	53.66	53.51	53.53	53.04	53.48	53.89	53.63	53.60	53.69	53.85	54.28	54.42	54.35	53.89	53.64	52.95	52.89	52.64	52.80	53.23	53.72				53.56	53.41	53.53	53.05	52.25	52.22
	Ref	42	54.46	54.97	54.95	54.71	54.71	54.56	54.52	53.98	54.20	54.69	54.53	54.54	54.65	54.74	55.27	55.60	55.45	55.02	54.56	53.63	53.65	53.55	53.64	54.24	54.82				54.09	53.61	53.64	53.01	52.33	52.35
WAGO		43	52.34	52.86	52.83	52.65	52.62	52.60	52.50	52.13	52.17	52.55	52.49	52.40	52.46	52.56	52.85	53.12	53.35	53.18	52.71	52.00	51.96	51.99	52.03	52.35	52.75				52.16	51.89	51.76	51.15	50.90	50.94
	19	44	53.85	54.41	54.30	54.00	53.94	53.89	53.83	53.35	53.46	53.91	53.75	53.66	53.72	53.80	54.13	54.38	54.58	54.37	53.78	53.02	52.99	52.96	52.95	53.43	53.89				53.19	52.78	52.71	52.01	51.65	51.73
		45	50.72	51.29	51.32	51.11	51.09	51.09	50.95	50.66	50.76	51.10	51.02	50.93	50.92	51.04	51.30	51.57	51.85	51.73	51.16	50.53	50.46	50.43	50.40	50.82	51.21				50.58	50.27	50.16	49.44	49.33	49.44
	20	46	55.98	56.52	56.48	56.35	56.23	56.22	56.14	55.79	55.84	56.15	56.05	55.95	55.94	56.04	56.30	56.56	56.87	56.79	56.22	55.57	55.55	55.52	55.52	55.84	56.16				55.66	55.47	55.45	54.85	54.58	54.61
		47	51.11	51.74	51.95	51.89	51.88	52.04	51.95	51.98	52.00	52.08	52.09	52.14	52.02	52.10	52.29	52.67	52.98	53.07	52.61	52.25	52.21	52.28	52.28	52.43	52.63				52.20	52.09	52.00	51.41	51.24	51.27
	21	48	52.89	53.69	53.92	53.82	53.79	54.02	53.95	53.96	54.15	54.19	54.09	54.18	54.06	54.11	54.26	54.64	54.97	55.03	54.55	54.19	54.18	54.16	54.18	54.41	54.71				54.26	54.06	54.03	53.42	53.12	53.16
	Ref	49	55.39	56.19	56.54	56.47	56.49	56.91	56.47	56.79	56.93	57.03	56.85	56.95	56.66	56.83	57.08	57.66	57.59	57.74	57.32	56.91	56.86	57.09	56.76	57.41	57.60				57.35	56.52	56.08	55.30	55.86	56.14
Gardner Bender		50	55.71	56.39	56.97	57.15	57.15	57.46	57.23	57.60	57.66	57.54	57.44	57.62	57.34	57.48	57.84	58.33	58.40	58.63	58.28	58.15	58.10	58.30	58.26	58.34	58.49				58.28	58.09	58.02	57.49	57.48	57.52
	22	51	57.01	57.72	58.08	58.21	58.23	58.63	58.29	58.74	58.92	58.77	58.59	58.80	58.43	58.63	59.01	59.53	59.52	59.77	59.39	59.19	59.16	59.37	59.28	59.54	59.74				59.43	59.11	58.93	58.28	58.38	58.45
		52	61.13	62.84	64.45	65.90	67.06	67.63	66.98	67.63	67.46	66.66	66.23	66.31	65.41	65.37	65.53	65.90	65.57	65.67	65.29	65.24	64.97	65.14	64.86	64.73	64.52				64.38	64.15	63.84	63.18	63.10	63.09
	23	53	60.07	61.53	62.97	64.21	65.24	65.72	65.02	65.67	65.39	64.69	64.29	64.34	63.48	63.40	63.57	63.87	63.60	63.66	63.37	63.36	63.05	63.27	62.97	62.78	62.55				62.09	61.88	61.63	61.02	60.93	60.90
		54	51.35	51.69	51.99	52.22	52.26	52.59	52.15	53.04	52.90	52.57	52.45	52.70	52.18	52.40	52.98	53.66	53.45	53.67	53.44	53.40	53.28	53.83	53.66	53.82	53.81				53.51	53.33	52.99	52.50	52.79	52.86
	24	55	51.67	52.13	52.52	52.75	52.78	53.22	52.76	53.77	53.72	53.26	53.14	53.43	52.83	53.04	53.59	54.30	54.07	54.37	54.23	54.30	54.19	54.70	54.52	54.63	54.56				54.52	54.43	54.18	53.65	53.87	53.96
	Ref	56	52.96	53.47	54.00	54.16	54.27	54.76	54.18	55.51	55.43	54.79	54.68	55.02	54.35	54.51	55.12	55.81	55.56	55.92	55.88	56.09	55.95	56.60	56.32	56.32	56.07				56.26	56.30	56.11	55.67	56.01	56.06

MAX TEMP (Ambient, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
50A																																				
IDEAL	1-3	1	23.37	23.48	23.45	23.95	23.75	23.61	23.47	23.24	23.33	23.51	23.61	23.55	23.58	23.74	24.22	24.47	24.45	24.44	24.16	23.67	23.68	23.65	23.62	23.84	24.15	24.10	23.45	23.10	23.61	23.43	23.42	22.93	22.84	22.87
WAGO	4-6	2	23.80	23.31	23.32	23.82	23.57	23.47	23.33	23.14	23.19	23.30	23.42	23.41	23.42	23.61	24.07	24.32	24.36	24.36	24.03	23.64	23.56	23.52	23.50	23.66	23.99	24.00	23.43	23.05	23.52	23.34	23.39	22.80	22.77	22.74
30A																																				
IDEAL	7-9	3	23.43	23.19	23.10	23.47	23.40	23.23	23.13	22.93	22.95	23.15	23.23	23.24	23.21	23.43	23.92	24.16	24.20	24.11	23.85	23.38	23.36	23.37	23.31	23.44	23.79	23.77	23.39	22.97	23.29	23.26	23.31	22.77	22.49	22.50
WAGO	10-12	4	23.59	23.19	23.13	23.49	23.41	23.26	23.11	22.92	22.96	23.18	23.27	23.24	23.25	23.51	23.98	24.25	24.16	24.08	23.84	23.38	23.33	23.33	23.28	23.40	23.85	23.80	23.38	22.97	23.23	23.22	23.28	22.75	22.51	22.49
Gardner Bender	13-15	5	23.66	23.21	23.15	23.67	23.49	23.31	23.12	22.92	23.06	23.21	23.30	23.28	23.25	23.56	24.04	24.38	24.19	24.08	23.84	23.37	23.28	23.35	23.27	23.44	24.01	23.82	23.43	23.12	23.21	23.18	23.24	22.73	22.47	22.46
20A																																				
IDEAL	16-18	6	23.58	23.28	23.22	23.76	23.53	23.36	23.16	23.03	23.10	23.31	23.37	23.38	23.38	23.65	24.11	24.30	24.28	24.21	23.93	23.48	23.35	23.44	23.36	23.54	23.97	23.92	23.43	23.10	23.28	23.17	23.23	22.72	22.55	No Data
WAGO	19-21	7	23.66	23.28	23.24	23.61	23.50	23.35	23.17	22.99	23.05	23.27	23.35	23.36	23.37	23.62	24.10	24.25	24.24	24.13	23.89	23.46	23.37	23.44	23.33	23.49	23.83	23.94	23.42	23.02	23.27	23.18	23.22	22.68	22.60	22.59
Gardner Bender	22-24	8	23.70	23.23	23.22	23.55	23.46	23.32	23.15	22.95	23.02	23.26	23.34	23.33	23.36	23.59	24.06	24.22	24.22	24.12	23.85	23.43	23.33	23.41	23.30	23.43	23.83	23.91	23.41	22.98	23.26	23.15	23.17	22.64	22.55	22.54

MIN TEMP (Ambient, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
50A																																				
IDEAL	1-3	1	22.86	23.21	23.18	23.24	23.38	23.21	23.09	23.04	22.91	23.06	23.28	23.23	23.27	23.39	23.69	24.13	24.13	23.99	23.67	23.31	23.28	23.39	23.31	23.36	23.63	23.42	22.87	22.71	22.65	23.16	22.61	22.37	22.37	22.49
WAGO	4-6	2	23.07	23.11	23.07	23.12	23.27	23.11	22.98	22.90	22.81	22.96	23.17	23.13	23.14	23.30	23.58	23.99	24.05	23.89	23.62	23.26	23.19	23.31	23.18	23.21	23.47	23.40	22.81	22.66	22.60	23.09	22.58	22.32	22.29	22.40
30A																																				
IDEAL	7-9	3	22.96	22.95	22.88	22.94	23.12	22.92	22.78	22.74	22.64	22.77	23.00	22.95	22.96	23.12	23.43	23.87	23.89	23.66	23.35	23.07	23.06	23.05	23.00	23.06	23.27	23.34	22.77	22.60	22.55	22.90	22.58	22.28	22.18	22.28
WAGO	10-12	4	22.96	22.99	22.92	22.97	23.15	22.94	22.78	22.71	22.66	22.82	23.03	22.98	22.99	23.13	23.47	23.91	23.92	23.68	23.32	23.06	23.07	23.05	23.01	23.03	23.27	23.35	22.79	22.63	22.55	22.89	22.61	22.26	22.21	22.28
Gardner Bender	13-15	5	22.98	22.99	22.91	22.99	23.15	22.94	22.78	22.71	22.64	22.84	23.01	22.98	22.99	23.13	23.50	23.95	23.90	23.66	23.34	23.06	23.06	23.03	22.98	23.03	23.30	23.37	22.82	22.70	22.57	22.87	22.58	22.21	22.19	22.27
20A																																				
IDEAL	16-18	6	23.06	23.04	23.00	23.05	23.24	23.03	22.82	22.79	22.71	22.95	23.11	23.05	23.07	23.21	23.61	24.07	24.02	23.74	23.44	23.15	23.10	23.16	23.05	23.09	23.37	23.39	22.83	22.70	22.54	22.95	22.55	22.20	22.22	No Data
WAGO	19-21	7	23.07	23.04	22.96	23.03	23.23	23.00	22.81	22.75	22.66	22.92	23.08	23.02	23.04	23.18	23.59	24.04	24.00	23.72	23.42	23.06	23.03	23.16	23.04	23.07	23.35	23.39	22.82	22.67	22.52	22.91	22.54	22.20	22.16	22.26
Gardner Bender	22-24	8	23.06	23.04	22.93	22.98	23.21	22.96	22.79	22.73	22.64	22.89	23.04	23.01	23.01	23.16	23.56	24.00	24.00	23.72	23.36	23.03	23.01	23.11	23.00	23.03	23.30	23.36	22.79	22.65	22.51	22.89	22.50	22.15	22.11	22.22

AVE TEMP (Ambient, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
50A																																				
IDEAL	1-3	1	23.23	23.31	23.29	23.44	23.51	23.41	23.26	23.16	23.07	23.28	23.41	23.40	23.42	23.58	23.99	24.28	24.29	24.18	23.92	23.57	23.47	23.51	23.43	23.58	23.86	23.69	23.24	22.92	23.29	23.28	23.14	22.73	22.68	22.69
WAGO	4-6	2	23.19	23.22	23.17	23.33	23.39	23.29	23.17	23.04	22.95	23.16	23.28	23.27	23.30	23.48	23.90	24.17	24.19	24.09	23.84	23.51	23.39	23.40	23.34	23.45	23.73	23.64	23.22	22.89	23.20	23.20	23.06	22.64	22.59	22.60
30A																																				
IDEAL	7-9	3	23.04	23.05	22.99	23.15	23.23	23.09	22.95	22.82	22.76	22.99	23.10	23.09	23.11	23.30	23.75	24.00	23.99	23.84	23.60	23.26	23.17	23.16	23.10	23.22	23.53	23.55	23.16	22.83	22.99	23.03	22.89	22.51	22.41	22.40
WAGO	10-12	4	23.06	23.07	23.02	23.18	23.26	23.11	22.96	22.83	22.78	23.02	23.13	23.11	23.13	23.33	23.78	24.04	24.01	23.83	23.60	23.27	23.18	23.17	23.10	23.24	23.56	23.56	23.16	22.84	23.00	23.01	22.88	22.50	22.40	22.40
Gardner Bender	13-15	5	23.07	23.08	23.02	23.20	23.26	23.12	22.96	22.82	22.78	23.03	23.14	23.11	23.13	23.34	23.80	24.07	24.02	23.84	23.59	23.24	23.16	23.15	23.08	23.25	23.59	23.59	23.22	22.91	23.00	22.98	22.85	22.46	22.37	22.37
20A																																				
IDEAL	16-18	6	23.18	23.17	23.09	23.26	23.35	23.23	23.04	22.92	22.86	23.13	23.23	23.22	23.24	23.46	23.94	24.20	24.17	23.95	23.71	23.34	23.23	23.25	23.16	23.36	23.68	23.65	23.20	22.90	23.06	23.04	22.89	22.47	22.43	No Data
WAGO	19-21	7	23.20	23.18	23.09	23.26	23.35	23.21	23.03	22.90	22.83	23.11	23.22	23.19	23.22	23.44	23.92	24.18	24.14	23.93	23.68	23.33	23.21	23.25	23.17	23.32	23.65	23.64	23.20	22.88	23.03	23.03	22.91	22.49	22.45	22.45
Gardner Bender	22-24	8	23.18	23.17	23.08	23.25	23.33	23.18	23.01	22.86	22.81	23.10	23.20	23.17	23.20	23.42	23.89	24.14	24.11	23.90	23.64	23.29	23.18	23.21	23.13	23.29	23.61	23.62	23.19	22.87	23.00	23.00	22.88	22.46	22.41	22.40

Public Comment No. 1335-NFPA 70-2018 [Section No. 330.130]

330.130

Where used in Class I, Division 1 or Zone 1 locations, the cable shall be listed and marked MC-HL and shall have a gas/vapor tight continuous corrugated metallic sheath or an interlocked metallic sheath , an overall jacket of suitable polymeric material, and a separate equipment grounding conductor.

Statement of Problem and Substantiation for Public Comment

CMP-14 has accepted Type MC-HL with an interlocked metallic sheath as a permitted wiring method for Class I, Division 1 locations in 501.10(A)(1)(3)(2) - (FR No. 7569). New section 330.130 needs to be revised to correlate with the new provisions in 501.10(A)(1)(3)(2).

Related Item

• FR 7883

Submitter Information Verification

Submitter Full Name: Vince Baclawski
Organization: Nema
Street Address:
City:
State:
Zip:
Submittal Date: Mon Aug 27 10:50:38 EDT 2018
Committee: NEC-P06

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Public Comment No. 899-NFPA 70-2018 [Section No. 334.6]

334.6 Listing Requirements.

Type NM and Type NMC cables and associated fittings shall be listed.

Additional Proposed Changes

File Name	Description	Approved
CN_3.pdf	70_CN3	

Statement of Problem and Substantiation for Public Comment

NOTE: This Public Comment appeared as CC Note No. 3 in the First Draft Report on First Revision No. 8005, First Revision No. 8045, First Revision No.8047, First Revision No.8048.

The Correlating Committee directs the panel to reconsider the Article title based upon this action and action in FR 8045, FR 8047 and FR 8048.
This action will be considered as a public comment.

Related Item

• First Revision No. 8005 • First Revision No. 8045 • First Revision No. 8047 • First Revision No. 8048

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC
Organization: NEC Correlating Committee
Street Address:
City:
State:
Zip:
Submittal Date: Mon Aug 20 15:10:38 EDT 2018
Committee: NEC-P06

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Correlating Committee Note No. 3-NFPA 70-2018 [Section No. 334.6]

Submitter Information Verification

Submitter Full Name: Sarah Caldwell
Committee:
Submittal Date: Wed May 09 11:34:18 EDT 2018

Committee Statement and Meeting Notes

Committee Statement: The Correlating Committee directs the panel to reconsider the Article title based upon this action and action in FR 8045, FR 8047 and FR 8048. This action will be considered as a public comment.

First Revision No. 8005-NFPA 70-2018 [Section No. 334.6]

First Revision No. 8045-NFPA 70-2018 [Section No. 334.12]

First Revision No. 8047-NFPA 70-2018 [Section No. 334.17]

First Revision No. 8048-NFPA 70-2018 [Section No. 334.24]

Ballot Results

This item has passed ballot

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

Affirmative All

Brunssen, James E.
Dressman, Kevin L.
Hickman, Palmer L.
Hittinger, David L.
Holub, Richard A.
Johnston, Michael J.
Kovacik, John R.
Manche, Alan
McDaniel, Roger D.
Pierce, James F.
Saporita, Vincent J.
Williams, David A.

Public Comment No. 1502-NFPA 70-2018 [Section No. 334.10 [Excluding any Sub-Sections]]

Type NM and Type NMC cables shall be permitted to be used in the following, except as prohibited in 334.12:

(1) One- and two-family dwellings and their attached or detached garages, and their storage buildings.

(2) Multi-family dwellings permitted to be of Types III, IV, and V construction.

(3) Dwelling units within Type I or Type II construction where the cable does not leave the floor or dwelling unit from which the circuits originate.

(4) Other structures permitted to be of Types III, IV, and V construction. Cables shall be concealed within walls, floors, or ceilings that provide a thermal barrier of material that has at least a 15-minute finish rating as identified in listings of fire-rated assemblies.

Informational Note No. 1: Types of building construction and occupancy classifications are defined in NFPA 220-2018, *Standard on Types of Building Construction*, or the applicable building code, or both.

Informational Note No. 2: See Informative Annex E for determination of building types. [NFPA 220, Table 4.1.1]

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

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

(6) Types I and II construction where installed within raceways permitted to be installed in Types I and II construction.

Statement of Problem and Substantiation for Public Comment

The proposed change addressed the concern expressed by the CMP in the response to PI 3943 by limiting the run length of the cable to a single dwelling unit or floor. This will avoid excessively long or complicated runs that might result in grommets being pulled out of place.
The concern expressed about AFCI protection being removed and replaced after occupancy is beyond the responsibility of the CMP and has no bearing on the safety and suitability of this wiring method. NM cable has been installed for decades in single-family, two-family and multi-family dwellings, and it has proven to be a reliable and safe wiring method. Millions of homes and apartments are wired with NM cable, and people are safely occupying those homes and buildings every day with no concern.
The concern expressed regarding improper plenum space installation is clearly an enforcement issue, not a code-making issue, and should not have a bearing on acceptance of this proposed change.

Related Item

• PI 3943

Submitter Information Verification

Submitter Full Name: Christel Hunter
Organization: Cerro Wire
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 29 08:40:48 EDT 2018
Committee: NEC-P06

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Public Comment No. 403-NFPA 70-2018 [Section No. 334.12(A)]

(A) Types NM and NMC.

Types NM and NMC cables shall not be permitted as follows:

(1) In any dwelling or structure not specifically permitted in 334.10(1), (2), (3), and (5)

(2) Exposed within a dropped or suspended ceiling cavity in other than one- and two-family and multifamily dwellings

(3) As service-entrance cable

(4) In commercial garages having hazardous (classified) locations as defined in 511.3

(5) In theaters and similar locations, except where permitted in 518.4(B)

(6) In motion picture studios

(7) In storage battery rooms

(8) In hoistways or on elevators or escalators

(9) Embedded in poured cement, concrete, or aggregate

(10) In hazardous (classified) locations, except where specifically permitted by other articles in this *Code*

(11) Where subject to physical damage

Statement of Problem and Substantiation for Public Comment

Add "Where subject to physical damage" to uses not permitted, so this rule will be similar to 320.13, 330.12, 336.12, 338.12, 340.12, 340.12.

Related Item

• FR-8045

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 05 07:37:19 EDT 2018
Committee: NEC-P06

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Public Comment No. 915-NFPA 70-2018 [Section No. 334.30]

334.30 Securing and Supporting.

Nonmetallic-sheathed cable shall be supported and secured by staples, cable ties listed and identified for securement and support, or straps, hangers, or similar fittings designed and installed so as not to damage the cable, at intervals not exceeding 1.4 m (4½ ft) and within 300 mm (12 in.) of every cable measured no more than 450 mm (18 in.) along the cable sheath, entry into enclosures such as outlet boxes, junction boxes, cabinets, or fittings. Flat cables shall not be stapled on edge.

Sections of cable protected from physical damage by raceway shall not be required to be secured within the raceway.

(A) Horizontal Runs Through Holes and Notches.

In other than vertical runs, cables installed in accordance with 300.4 shall be considered to be supported and secured where such support does not exceed 1.4-m (4½-ft) intervals and the nonmetallic-sheathed cable is securely fastened in place by an approved means within 300 mm (12 in.) of each box, cabinet, conduit body, or other nonmetallic-sheathed cable termination.

Informational Note: See 314.17(B)(1) for support where nonmetallic boxes are used.

(B) Unsupported Cables.

Nonmetallic-sheathed cable shall be permitted to be unsupported where the cable:

(1) Is fished between access points through concealed spaces in finished buildings or structures and supporting is impracticable.

(2) Is not more than 1.4 m (4½ ft) from the last point of cable support to the point of connection to a luminaire or other piece of electrical equipment and the cable and point of connection are within an accessible ceiling in one-, two-, or multifamily dwellings.

(C) Wiring Device Without a Separate Outlet Box.

A wiring device identified for the use, without a separate outlet box, and incorporating an integral cable clamp shall be permitted where the cable is secured in place at intervals not exceeding 1.4 m (4½ ft) and within 300 mm (12 in.) from the wiring device wall opening, and there shall be at least a 300 mm (12 in.) loop of unbroken cable or 150 mm (6 in.) of a cable end available on the interior side of the finished wall to permit replacement.

Additional Proposed Changes

File Name	Description	Approved
CN_4.pdf	70_CN 4	

Statement of Problem and Substantiation for Public Comment

NOTE: This Public Comment appeared as CC Note No. 4 in the First Draft Report on First Revision No. 8049.

The Correlating Committee directs the panel to reconsider the revised sentence for clarity. The measurement is confusing.

This action will be considered as a public comment.

Related Item

• FR 8049

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC

Organization: NEC Correlating Committee

Street Address:
City:
State:
Zip:
Submittal Date: Mon Aug 20 15:55:59 EDT 2018
Committee: NEC-P06

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Correlating Committee Note No. 4-NFPA 70-2018 [Section No. 334.30 [Excluding any Sub-Sections]]

Submitter Information Verification

Submitter Full Name: Sarah Caldwell
Committee:
Submittal Date: Wed May 09 11:35:40 EDT 2018

Committee Statement and Meeting Notes

Committee Statement: The Correlating Committee directs the panel to reconsider the revised sentence for clarity. The measurement is confusing. This action will be considered as a public comment.

First Revision No. 8049-NFPA 70-2018 [Section No. 334.30 [Excluding any Sub-Sections]]

Ballot Results

This item has passed ballot

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

Affirmative All

Brunssen, James E.
Dressman, Kevin L.
Hickman, Palmer L.
Hittinger, David L.
Holub, Richard A.
Johnston, Michael J.
Kovacik, John R.
Manche, Alan
McDaniel, Roger D.
Pierce, James F.
Saporita, Vincent J.
Williams, David A.

Public Comment No. 1264-NFPA 70-2018 [Section No. 334.30 [Excluding any Sub-Sections]]

Nonmetallic-sheathed cable shall be supported and secured by staples, cable ties listed and identified for securement and support, or straps, hangers, or similar fittings designed and installed so as not to damage the cable, at intervals not exceeding 1.4 m (4½ ft) and within 300 mm (12 in.) of every cable, measured no more than 450 mm (18 in.) along the cable sheath, entry into enclosures such as outlet boxes, junction boxes, cabinets, or fittings. Flat cables shall not be stapled on edge.

Sections of cable protected from physical damage by raceway shall not be required to be secured within the raceway.

Statement of Problem and Substantiation for Public Comment

The sentence as written does not make sense. The comma is needed to separate the clause that defines the measuring method from the rest sentence.

Related Item

- First Revision No. 8049-NFPA 70-2018

Submitter Information Verification

Submitter Full Name: Don Ganiere
Organization: [Not Specified]
Street Address:
City:
State:
Zip:
Submittal Date: Fri Aug 24 23:54:14 EDT 2018
Committee: NEC-P06

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Public Comment No. 596-NFPA 70-2018 [Section No. 334.30 [Excluding any Sub-Sections]]

Nonmetallic-sheathed cable shall be supported and secured by staples, cable ties listed and identified for securement and support, or straps, hangers, or similar fittings designed and installed so as not to damage the cable, at intervals not exceeding 1.4 m (4½ ft) and within 300 mm (12 in.) of every ~~cable measured no more than 450 mm (18 in.) along the cable sheath, entry~~ cable entry into enclosures such as outlet boxes, junction boxes, cabinets, or fittings. ~~Flat~~ Additional lengths of cable for future repair (loops) shall be adequately supported at intervals not exceeding 18" along the cable sheath. Flat cables shall not be stapled on edge.

Sections of cable protected from physical damage by raceway shall not be required to be secured within the raceway.

Statement of Problem and Substantiation for Public Comment

To add clarity and enforceability, please consider the general text regarding the typical strapping requirements (1' from a box and 4.5' between) in it's own sentence. The additional lengths of cable should be addressed separately so it is less confusing to the code user.

Related Item

- FR 8049

Submitter Information Verification

Submitter Full Name: Dean Hunter
Organization: Minnesota Department of Labor
Street Address:
City:
State:
Zip:
Submittal Date: Mon Aug 13 15:34:11 EDT 2018
Committee: NEC-P06

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Public Comment No. 1409-NFPA 70-2018 [Section No. 334.80]

334.80 Ampacity.

The ampacity of Types NM

~~and NMC cable~~

~~,~~ and NMC ~~, and NMS~~ cable shall be determined in accordance

~~with 310~~

with 310 .14 .

~~The~~

The ~~allowable~~ ampacity shall not exceed that of a 60°C (140°F) rated conductor. The 90°C (194°F) rating shall be permitted to be used for ampacity adjustment and correction calculations, provided the final calculated ampacity does not exceed that of a 60°C (140°F) rated conductor. The ampacity of Types NM

~~and NMC cable~~

~~,~~ and NMC ~~, and NMS~~ cable installed in cable trays shall be determined in accordance

~~with 392~~

with 392 .80(A) .

Where more than two NM cables containing two or more current-carrying conductors are installed, without maintaining spacing between the cables, through the same opening in wood framing that is to be sealed with thermal insulation, caulk, or sealing foam,

~~the~~

the ~~allowable~~ ampacity of each conductor shall be adjusted in accordance

~~with Table~~

with Table 310.15(C)(1)

~~and~~

and the provisions

~~of 310~~

of 310 .14(A)(2) , Exception, shall not apply.

Where more than two NM cables containing two or more current-carrying conductors are installed in contact with thermal insulation without maintaining spacing between cables,

~~the~~

the ~~allowable~~ ampacity of each conductor shall be adjusted in accordance

~~with Table~~

with Table 310.15(C)(1) .

Exception: The 75°C ampacity of 14 AWG copper-clad aluminum type NM cables shall be permittedto be used if the devices and connectors are listed for copper-clad aluminum conductors and are rated for 75°C

Additional Proposed Changes

File Name	Description	Approved
UL_Standard_NM_Cu-Clad.JPG	UL Standard for NM: The Standard Can Not Change Until the NEC Allows for It	
14_AWG_CCA_Summary.NSFvETL.pdf	For 14 AWG CCA, Heat Data from NRTL's NSF and INTERTEK nearly identical at 20 AMPS	

14_AWG_Thermal_Expansion_Summary.1535458407587_2_.pdf	14 AWG CCA: Intertek Report Summary Based Upon ASTM E228 Lineal Thermal Expansion
CONCLUSIONS_FROM_UL_486C_SPRING.pdf	14 AWG CCA, Summary UL 486C Spring Action Sequence, INTERTEK, With Cu-Only Ideal, Wago Push-In Connectors
Intetek.UL486C.SAS.103589128CRT-001A_003_.pdf	Test Report: UL 486C Spring Action Sequence. INTERTEK. Ideal, Wago, G&B "Cu-Only" Push-In
J-00265162_FINAL_Copperweld_FFR-_CCA-Cu_Final_Report_Revised_10-27-17.pdf	TEST REPORT: NSF Fact Finding Heat Data
ETL.14awgCCA.Thermalstablei6049.04-106-31-r0.pdf	TEST REPORT, INTERTEK: 14 AWG CCA per ASTM E228 Lineal Thermal Expansion
ETL.14awgCu.Thermalstablei6049.03-106-31-r0.pdf	TEST REPORT, INTERTEK: 14 AWG ETP Copper ASTM E228 Lineal Thermal Expansion
Notice_of_Authorization-2017-10-06-4788086098.pdf	UL Listing Notification for Copper Clad Aluminum NM Cables
SampleReqForm_-_MEL.pdf	UL Sample Request Form for listing Purposes: 14 AWG CCA Tested to Acquire NM UL Listing.

Statement of Problem and Substantiation for Public Comment

PUBLIC COMMENT RESPONSE:

- NEC Needs to Change First. Public inputs 3174, 2123, and 3930 were submitted to provide for 14 AWG copper-clad aluminum as a recognized conductor in Articles 310 and 334. It is agreed that the product standard does not recognize 14 AWG copper-clad aluminum but product standards follow what is allowed in the NEC. The product standard would not be changed to allow something that is not allowed by the NEC. Therefore, the NEC needs to make the change first deeming 14 AWG copper-clad aluminum suitable for use. Using the lack of product safety standard recognition as reasoning to not allow 14 AWG copper-clad aluminum is creating an untenable catch 22.
- New Technology and Energy Efficiency have ideal Uses for 14 AWG Copper-clad Aluminum. With the evolution of LED lighting and energy efficient equipment, the industry substantiates a need for 14 AWG copper-clad aluminum, even at an ampacity of 10, a value where OCPD's are already commercially available. For copper-clad aluminum in general, there is no documented instances of failures that would cause a belief that there is a safety issue. With the ampacity limitations proposed for use of 14 AWG copper-clad aluminum and the testing data that backs it up, there is no technical reason for CMP-6 to not allow for 14 AWG copper-clad aluminum as a suitable conductor.
- History of Safe Use. 14 AWG and “smaller” ASTM B566 copper-clad aluminum wires have been safely used for decades in applications (as the individual strands of stranded conductors forming THHN, SEU, PV, Battery Cable, Large Appliance Cord, Jumper Cable, among others) and Data applications (coaxial and trunk cables). ASTM B566 copper-clad aluminum wire is routinely drawn to 22 AWG for applications in power, and 34 AWG for applications in data. There has been no technical substantiation given by CMP6 as to why 14 AWG ASTM B566 copper-clad aluminum wire made with an AA-8000 series aluminum core is unsuitable to be recognized by article 334. 14 AWG could be included in the UL standard for NM cable if it were recognized by article 310. Thermal Stability, Mechanical Integrity and Electrical Performance have never been questioned. Listings for Copper Clad Aluminum NM Cables Exist Today.

- Old History Should Not Imped with New Data as Provided. When the initial ampacities for copper-clad aluminum were introduced into the 1971 NEC, copper-clad aluminum and aluminum were grouped together right, wrong or indifferent. To not recognize 14 AWG ASTM B566 copper-clad aluminum wire in article 334 appears to be a clear case of CMP6 confusing it with single-metal aluminum wire, which carries historical baggage. In contrast to 1350 Aluminum Romex, ASTM CCA wire's record of safety remains untarnished, evidenced by CMP6’s

lack of ability to site instances of failure. Today's fact finding has documented that 14 AWG copper-clad aluminum is safe for use at the ampacity proposed and has had testing for terminals, corrosion, elongation and other aspects conducted for existing listings.

Related Item

• 3930

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 28 09:18:21 EDT 2018
Committee: NEC-P06

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PRODUCT CATEGORY

Nonmetallic-sheathed Cable, PWVX

de Information for Electrical Equipment for Use in Ordinary Locations

USE

category covers Types NM-B and NMC-B nonmetallic-sheathed cable, rated 600 V, intended for use in accordance with Article of ANSI/NFPA 70, "National Electrical Code" (NEC), and certified in copper sizes 14 to 2 AWG inclusive and aluminum or copp aluminum sizes 12 to 2 AWG inclusive.

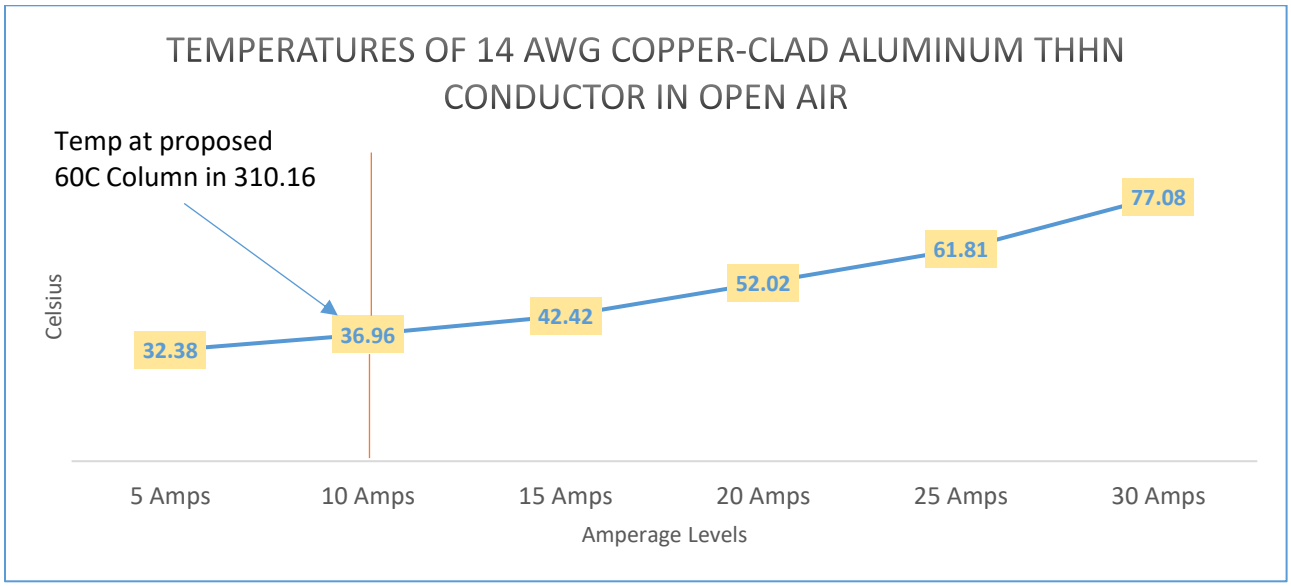
cable contains conductors rated 90°C; however, the ampacities of the cable are those of 60°C conductors as specified in Articl and Table 310.15(B)(16) of the NEC.

PRODUCT MARKINGS

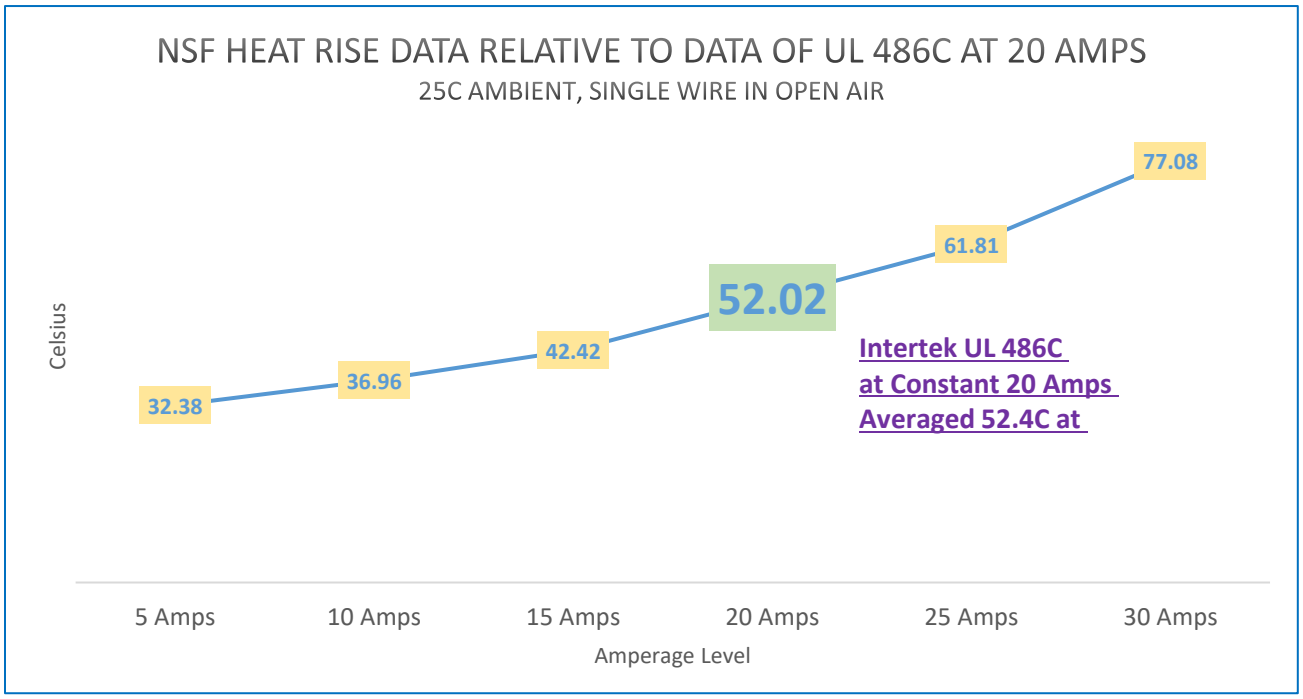
le with copper-clad aluminum conductors is surface marked "AL (CU-CLAD)" or "Cu-clad Al," and cable with aluminum conducto urface marked "AL."

14 AWG CCA SAFE AT PROPOSED AMPERAGE OF TABLE 310.16:

UL 486C Testing Confirms NSF Data



Data Results of Fact Finding from NRTL Certified Electrical Lab, NSF. Orange Line Indicates Proposed Amperage of 14 AWG Copper-Clad Aluminum (ASTM B566) at 60C in Table 310.16



Average Heat Generated at 20 Amps by 14 AWG Copper-Clad Aluminum (ASTM B-566) is practically the same when comparing the testing done by NSF Electrical and that done by Intertek. Both labs are NRTL's with OSHA certified electrical labs. For 14 AWG CCA, NSF averaged 52.02C at 20 Amps, whereas Intertek Averaged 52.4C at 20 Amps.

14 AWG CCA SAFE AT PROPOSED AMPERAGE OF TABLE 310.16:

UL 486C Testing Confirms NSF Data

CONCLUSION:

At a temperature of 36.96 C° at Full Circuit of 10 Amps in the 60C column of proposed table 310.16, 14 AWG Copper-Clad Aluminum (ASTM B-566) is SAFE even considering elevated ambient temperatures. 75°C is the minimum temperature rating of insulation for the vast majority of general wiring applications, with the most utilized insulation types (THHN, XHHW, for example) rated at 90°C. All modern branch circuit components (switches, connectors, equipment and receptacles) are rated at a minimum of 75°C, most at 90°C. Even in severe overcurrent conditions, heat rise temperatures of 14 AWG Copper-Clad Aluminum (ASTM B-566) are well below the rating of the wire insulation and circuit components. OCPD's exist today for 10 Amp circuits, thus making 14 AWG Copper-Clad Aluminum wire a viable option. LED and Energy Star Equipment are driving the trend for more efficient circuits.

NRTL Credentials for NSF

Occupational Safety and Health Administration

Nationally Recognized Testing Laboratory Program

NRTLP

Certificate of Recognition

NSF International

with headquarters at:

789 Dixboro Road
Ann Arbor, Michigan 48105
United States

is recognized by the Occupational Safety and Health Administration (OSHA) as meeting the requirements for a Nationally Recognized Testing Laboratory (NRTL) established under Section 1910.7 of *Title 29, Code of Federal Regulations.* This recognition is limited to testing and certification only within the current scope of recognition and is subject to all other terms set forth in the letter of recognition and in applicable *Federal Register* notices and as summarized on OSHA's website. This recognition continues in force beyond the "*Effective through*" date below provided the NRTL has filed a timely request for renewal with OSHA. For current recognition status and other recognition information, contact the OSHA NRTL Program or visit *https://www.osha.gov/dts/otpca/nrtl/*

July 14, 2019
Effective Through

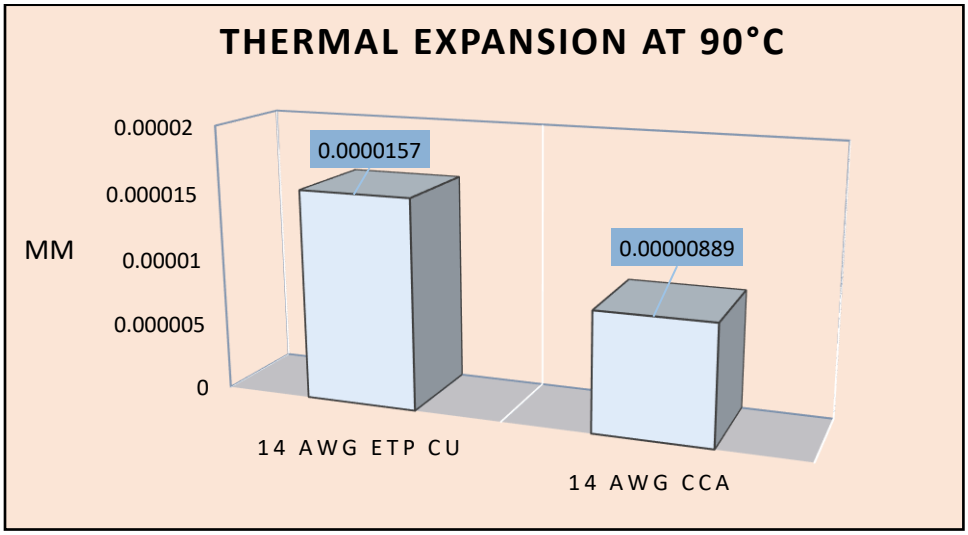
David Michaels, PhD, MPH
Assistant Secretary of Labor for
Occupational Safety and Health Administration

OSHA Scope of Recognition for NSF Electrical: https://www.osha.gov/dts/otpca/nrtl/nsf.html

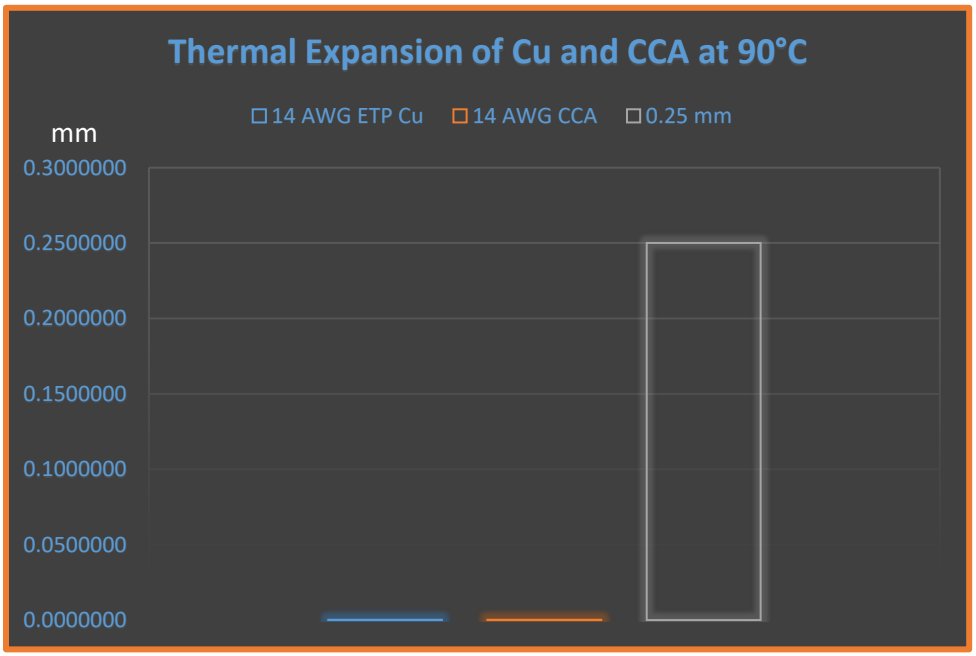
Among other electrical equipment and circuit components, the NSF Scope of Recognition Includes Small Electrical Appliances, Wired Cabinets, Luminaires, Washers, Driers, Residential Water Heaters, Electric Ranges and Temperature Measuring Equipment. Heat Rise Testing is Routine at NSF.

At 90°C, 14 AWG Copper-Clad Aluminum is nearly Twice as Thermally Stable as 14 AWG ETP Copper

Testing By Intertek B&C Labs per ASTM 228 Linear Thermal Expansion



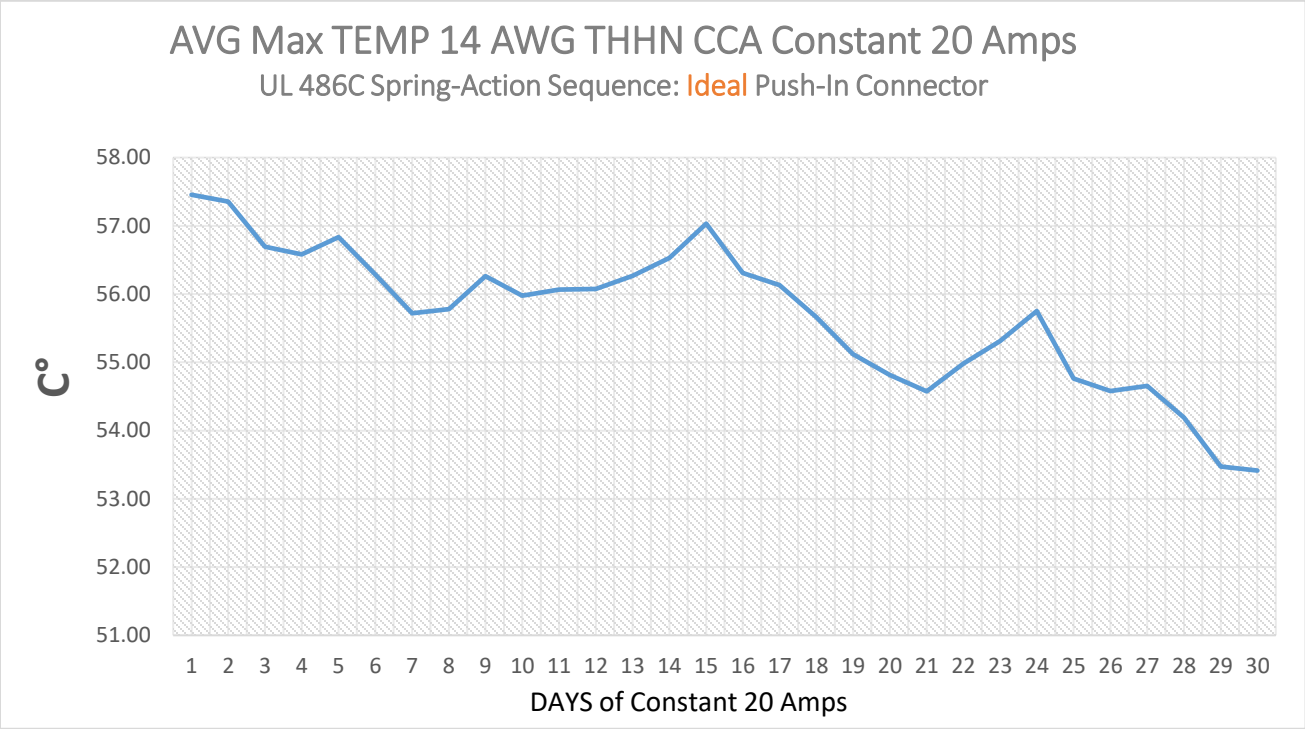
At 90C, ETP 14 AWG Cu expands nearly twice that of Copper Clad Aluminum 14 AWG

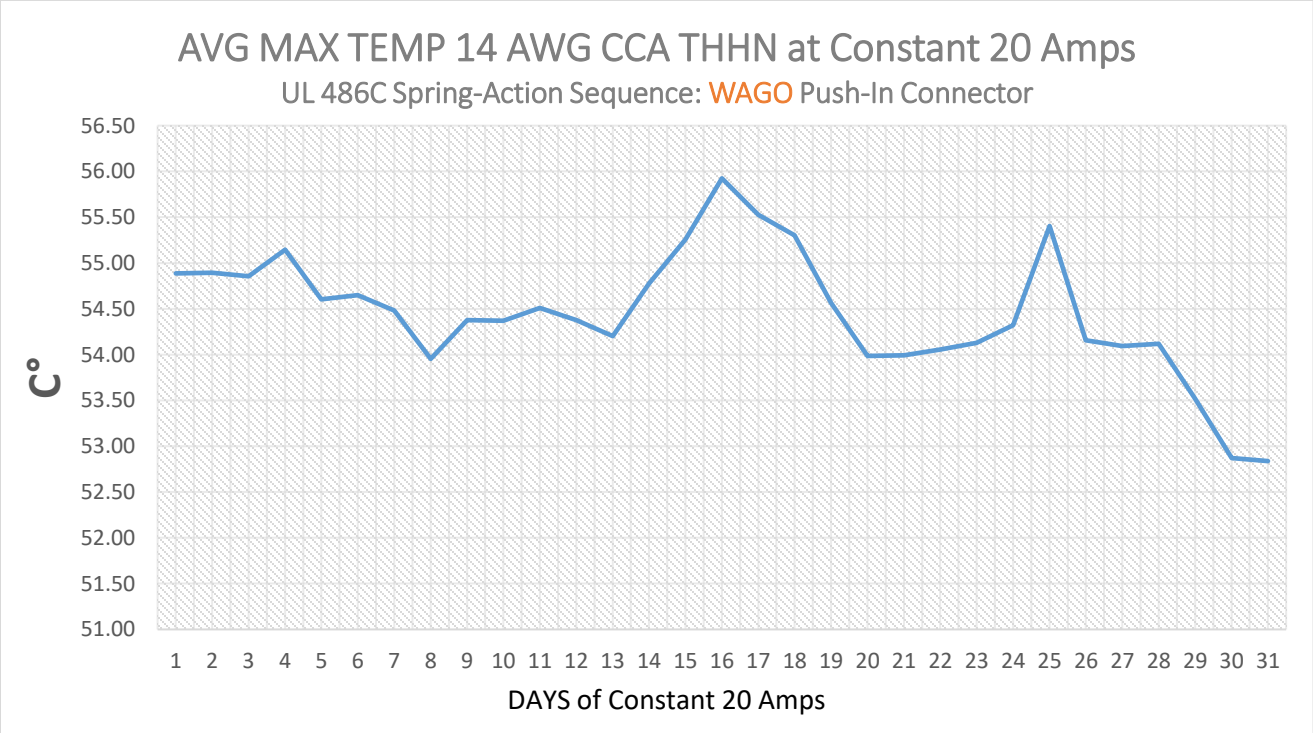


At 90°C, Both Copper Clad Aluminum and Copper are Extremely Thermally Stable

Performance of
14 AWG CCA THHN Under EXTREME OVERCURRENT CONDITION

Three Push-In Connectors Tested By Intertek (NRTL with Wire & Cable in Scope of Recognition) to UL 486C Spring-Action Sequence





Performance of
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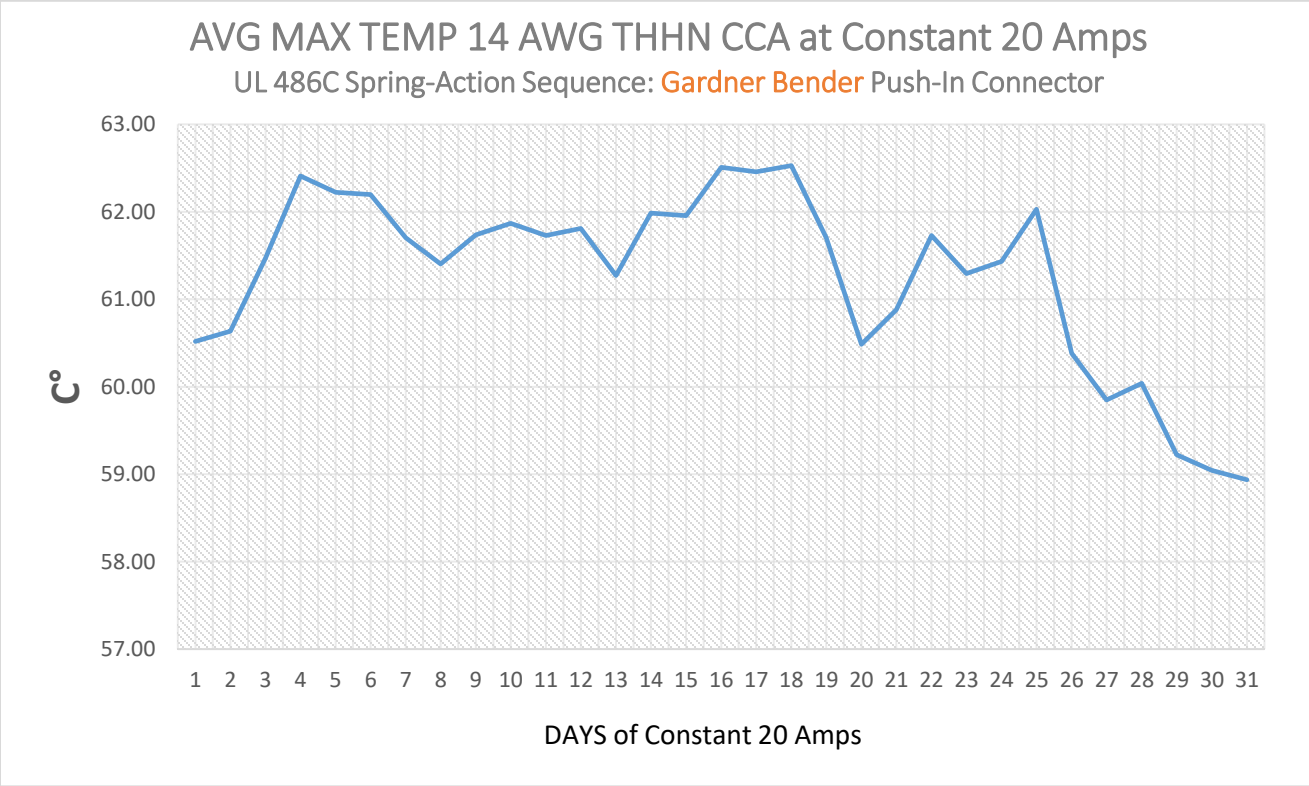

CONCLUSIONS FROM UL 486C SPRING-Action SEQUENCE TESTING REG 14 AWG THHN MADE WITH ASTM B566 COPPER-CLAD ALUMINUM WIRE:

- The THHN Insulation (Rated at 90°C) Remained in Good Condition Throughout the Test
- Over 30 Days at Constant 20 Amps (twice the amperage of the proposed amperage at 60°C column requested by Public Comment 1402), the highest temperature registered by 14 AWG CCA was under 63°C. Over Current Protection Devices (OCPD's) are in place in a circuit to keep wire from over-heating. OCPD's will open the circuit when the amperage limit (10 amps in case of 14 AWG CCA) is reached.
- Ambient Temperature of 23°C Over 30 Days, Standard Deviation of ½ °C
- Average Max Temperatures decreased by 3°C over the month when connected to the three brands of push-in connectors
- The Gardner Bender Connector created more heat (+/- 6°C) within the wire than the other two test subjects
- Of the nine push-in connectors tested (three different brands), not one saw degradation or damage due to excessive heat, despite the constant over-current condition applied to the wire
- The wire remained thermally stable at the points of termination over all nine push-in connectors, and no arc-faulting was observed due to thermal expansion of the wire

3933 Route 11
Cortland, NY 13045
Telephone: 1-607-753-6711
Facsimile: 1-607-758-6595
www.intertek.com

TEST LETTER REPORT

Copperweld Bimetallics, LLC
Test Report

SCOPE OF WORK
PERFORMANCE TESTING – PRODUCT TYPE PER STANDARD

REPORT NUMBER
103589128CRT-001A

ISSUE DATE	**[REVISED DATE]**
27-Aug-2018	28-Aug-2018

PAGES
14

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TEST LETTER REPORT

27-Aug-2018

Intertek Report No.: 103589128CRT-001A
Intertek Project No.: G103589128

Mr. Peter Graser
Copperweld Bimetallics, LLC
215 Centerview Drive
Suite 360
Brentwood, TN 37027

Ph: (770) 952-6445
email: pgraser@copperweld.com

Subject: Static Heating test of Push-in Wire Connectors on CCA Conductors in accordance with Claus 9.12 Spring-action sequence per UL 486C.

Dear Mr. Peter Graser,

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

> **UL 486C / CSA C22.2 No. 188-18 –** Splicing Wire Connectors, Seventh Edition, Dated January 26, 2018

SECTION 1
SUMMARY

This investigation was authorized by signed proposal number Qu-00894894, dated 29-June-2018. A production sample was received on 26-June-2018 and tested from 23-Jul-2018 to 27-Aug-2018 at the Intertek Cortland facility.

TEST LETTER REPORT

SECTION 2
TESTING

Below is a summary of the tests and results for the entire test period. The test data appears at the end of this report in the Appendix.

Performance testing was carried out in accordance with UL486C, Clause 9.12 Spring-action sequence.

Three test circuits were built in the sizes 14AWG, 12AWG, and 10AWG, each circuit containing Copperweld CCA THHN wire and 3 three specimens each of push-in
wire connectors manufactured by Ideal, Wago, and Gardner and Bender, as available. This setup is a deviation from the standard which requires connectors to be tested separately on individual circuits.

Test currents (20A for 14AWG, 30A for 12AWG and 50A for 10AWG) were selected in accordance with client request rather than per Table 6 static heating columns in UL486C, and additional setup criteria indicated in Clause 9.1 of UL486C will not be used. Test currents were monitored periodically with a clamp style meter.

Ambient thermocouples were placed at least two feet out from the connectors under test, and approximately 3 feet apart, the number of ambient thermocouples is reduced due to the size of the apparatus.

Connector thermocouples are placed on the input and output side of each connector with a reference conductor between each set of three connectors.

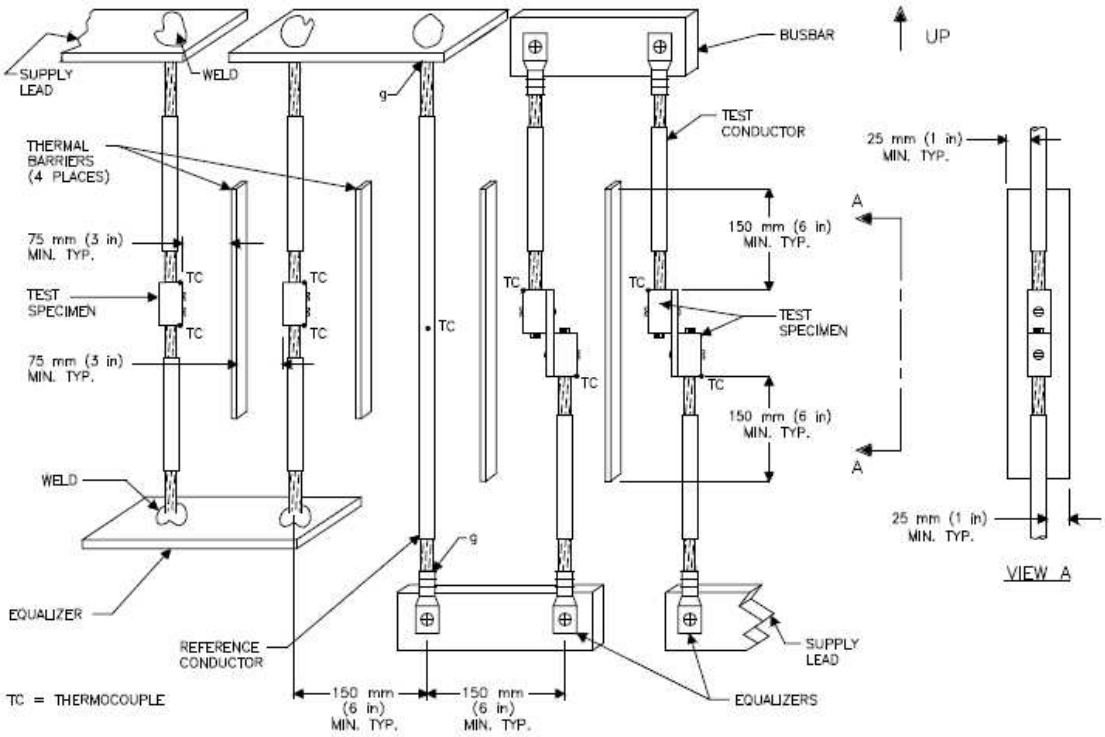
The apparatus is set up in complete compliance with Figure 2 on the next page, no other deviations from the standard were made.

Calibration Information:

Item #	Equipment Type	Asset #	Calibration Due
1	Fluke 365 True RMS Clamp Meter	M262	04/06/2019
2	Fluke Hydra Temperature Recorder	T1152	04/20/2019
3	Fluke Hydra Temperature Recorder	U080	07/16/2019
4	Fluke Hydra Temperature Recorder	T834S	02/13/2019
5	Fluke Hydra Temperature Recorder	T1565	09/27/2018

TEST LETTER REPORT

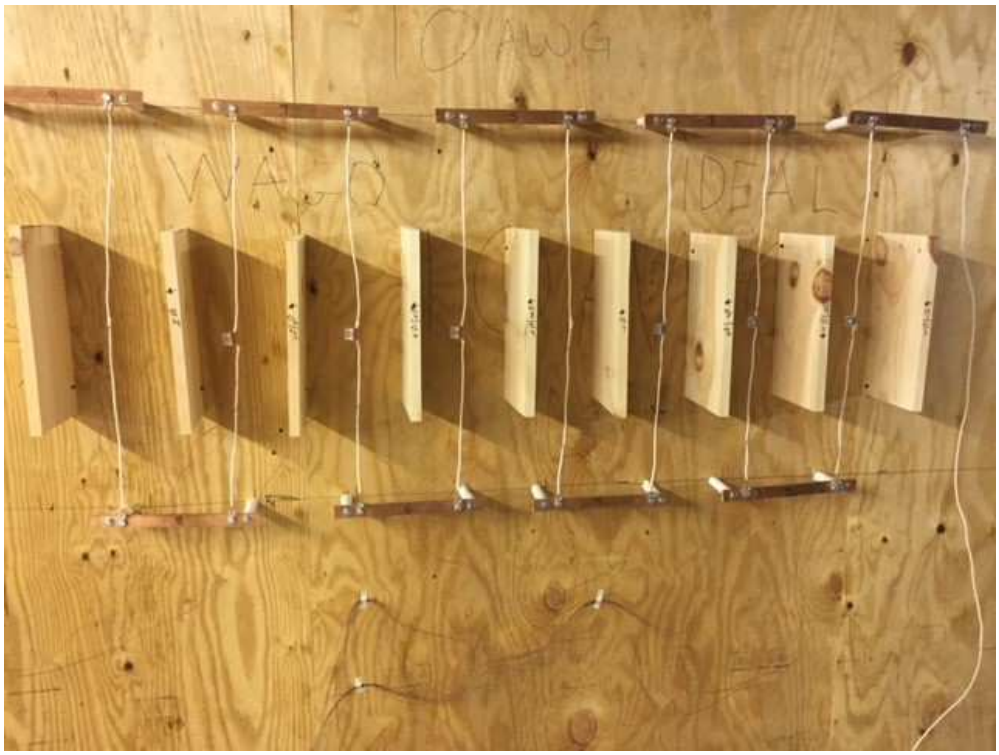
Figure 2
Vertical arrangement of specimen for current-cycling test
(Clause 9.1.10.7)



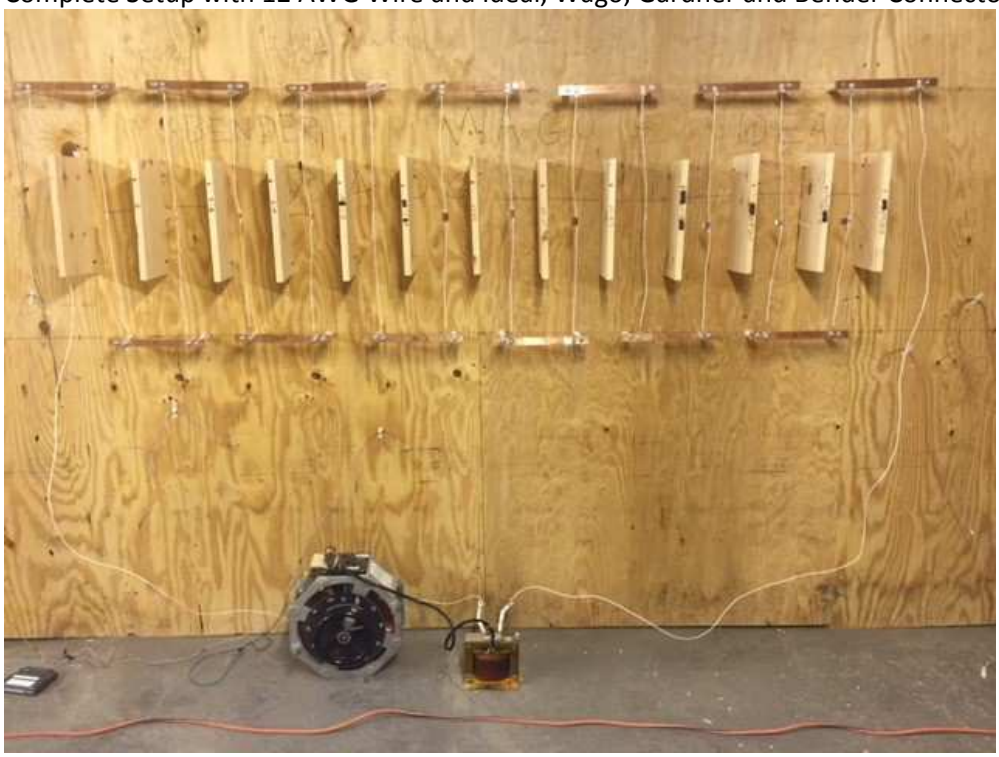
TEST LETTER REPORT

SECTION 3
PHOTOGRAPHS

10AWG Wire with IDEAL and WAGO connectors

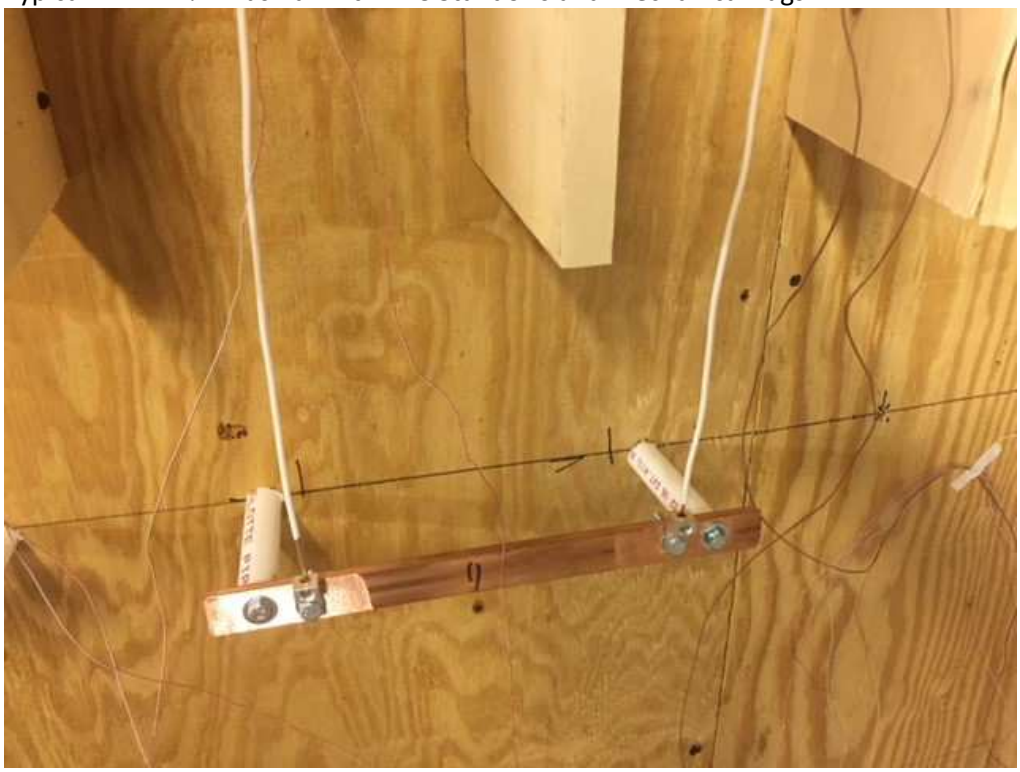


Complete Setup with 12 AWG Wire and Ideal, Wago, Gardner and Bender Connectors

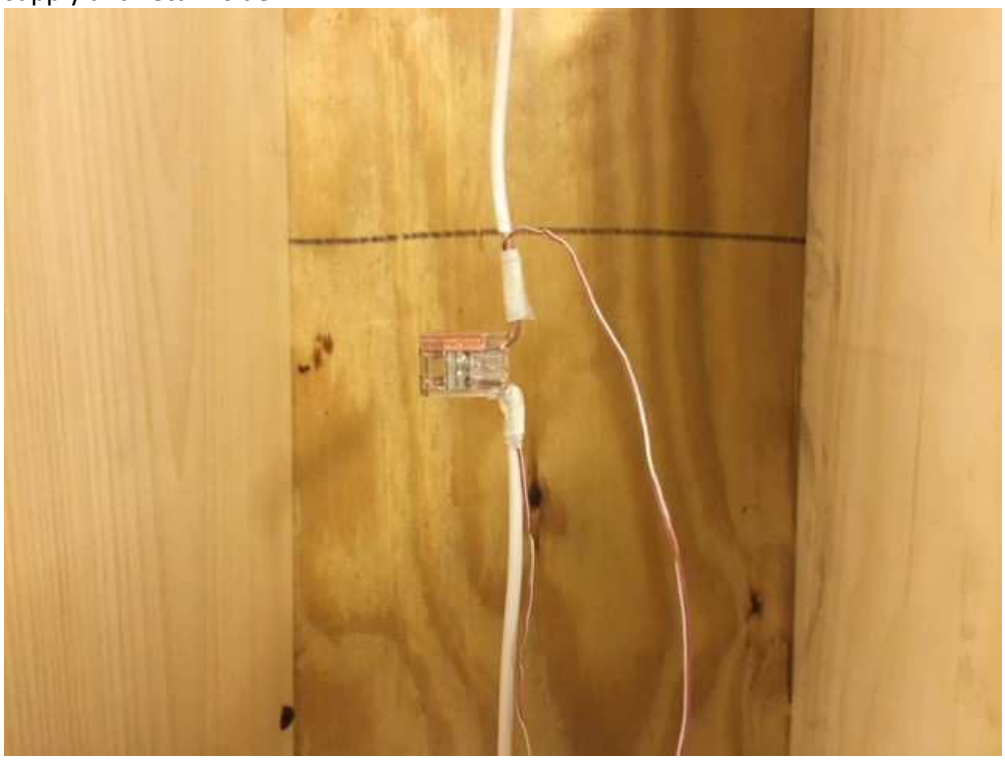


TEST LETTER REPORT

Typical 12 x 1 x ¼" Bus Bar with PVC Standoffs and Mechanical Lugs



Typical Connector, Gardner and Bender Shown, TC attached within 1/2" of the connector on supply and return side



TEST LETTER REPORT

SECTION 4
PROJECT STATUS & ACTION

One set of thermocouples did not record results on the first day of testing on one of the data recorders in use. Intertek performed a full 31 days of testing to capture a minimum of 30 days these thermocouples in question, at the request of the client.

One ambient thermocouple stopped recording at the end of the last day of testing, on the Ideal connectors for the 20A test setup. Data is recorded as “No Data” due to this malfunction. The seven remaining thermocouples reading ambient temperature show normal results.

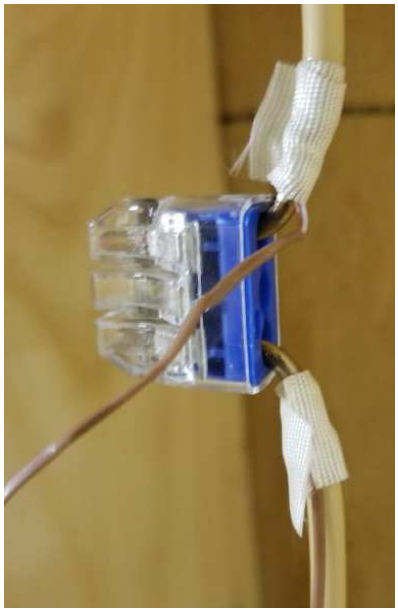
All testing is now complete.

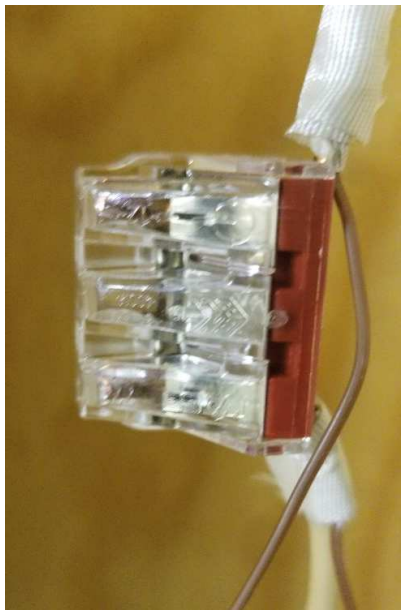
SECTION 5
CONCLUSION

The results contained in this report are to be evaluated by the client. This data is not to be used for certification of these products.

Upon completion of the test, there was no visible damage to any of the connectors contained within this report. There was however a visible change to the coloration of the insulation on the conductors involved in the 50A test on the 10 AWG conductors; no other conductors involved in the test exhibited this discoloration. The consistent temperatures recorded during the test, indicate that there is no evidence of arcing at the connectors.

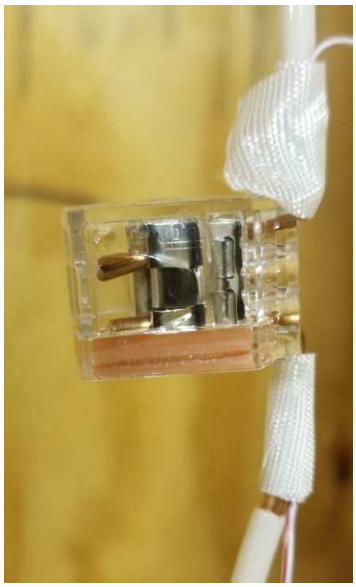
10 AWG Connectors (Left to Right: Ideal, Wago):



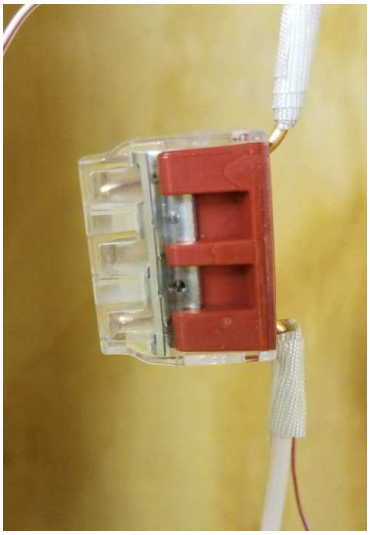
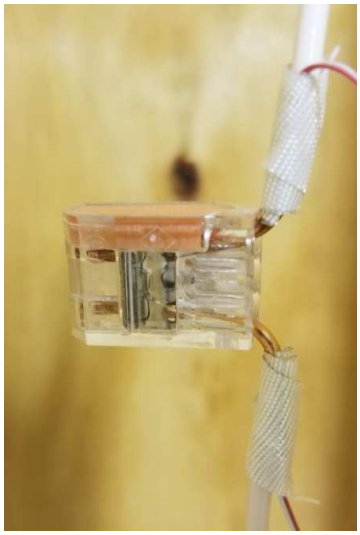


TEST LETTER REPORT

12 AWG Connectors (Left to right: Ideal, Wago, Gardner and Bender):



14 AWG Connectors (Left to right: Ideal, Wago, Gardner and Bender):

TEST LETTER REPORT

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

Completed by:	Joshua O'Connor	Reviewed by:	James Diescher
Title:	Engineering Team Lead	Title:	Technical Lead
Signature:		Signature	
Date	08/28/2018	Date:	08/28/2018

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

Revision History

08/28/2018: Added information in the conclusions about the condition of the connectors and conductors at the end of the test. Added example pictures of each connector for each test setup at the completion of the test.

TEST LETTER REPORT

APPENDIX

MAX TEMP (50A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		1	104.82	101.00	100.66	99.70	98.60	98.79	98.82	98.52	97.64	98.16	97.79	97.82	97.16	97.85	97.85	98.06	97.49	97.63	97.64	97.06	96.68	97.02	96.45	96.65	97.49	Power Outage			98.90	96.25	97.02	96.45	96.40	96.40
	1	2	83.92	81.32	81.26	80.73	80.09	80.76	80.48	80.18	79.64	80.31	79.79	79.55	79.49	80.47	79.93	80.34	80.07	79.59	79.50	79.27	79.02	78.94	78.79	78.94	79.93				80.77	78.35	78.70	78.40	78.30	78.26
		3	90.28	90.79	91.78	90.78	90.16	91.16	91.82	90.89	91.38	91.08	91.32	91.26	90.70	90.75	92.09	92.63	92.46	92.58	91.78	91.17	91.46	91.99	91.87	91.58	92.43				92.03	91.35	91.57	91.57	91.17	91.48
	2	4	77.14	77.62	78.16	77.92	77.83	78.34	77.99	77.93	78.12	78.28	78.10	78.06	77.93	77.76	79.17	79.25	79.16	79.14	78.74	78.29	78.55	78.53	78.67	78.38	79.24				78.86	78.68	78.79	78.53	78.25	78.37
		5	89.40	88.00	88.06	87.39	87.14	87.66	87.95	87.41	87.60	87.22	87.75	87.22	86.90	86.69	87.59	88.87	88.31	88.06	87.62	87.42	87.39	87.85	87.47	87.94	88.26				87.35	87.09	86.96	87.18	86.77	86.46
	3	6	92.73	91.58	92.06	91.46	91.54	91.75	92.33	92.00	92.01	91.28	91.62	91.88	90.90	90.83	92.07	93.37	92.96	92.68	92.04	91.75	92.20	92.29	92.00	92.57	92.69				92.26	91.65	91.54	92.05	91.31	91.72
	Ref	7	86.70	86.98	87.33	87.63	87.71	87.57	88.23	88.32	88.19	87.94	88.14	88.45	88.04	88.34	88.47	90.28	89.05	89.39	89.32	88.39	89.12	89.10	88.61	88.89	88.95				88.30	88.79	88.18	88.82	87.86	87.96
WAGO		8	81.37	80.88	80.74	80.56	80.08	79.93	79.18	79.02	78.45	79.39	79.33	79.00	79.07	79.55	79.65	79.63	79.81	79.52	78.93	77.99	78.56	78.44	78.10	78.43	78.26				79.39	77.75	77.91	77.48	76.92	77.02
	4	9	87.95	87.91	88.06	88.05	87.56	87.44	87.70	87.40	86.31	87.10	87.04	86.49	86.47	86.60	87.34	86.86	87.23	87.05	86.03	84.97	85.43	85.51	84.84	84.26	83.99				87.60	82.66	82.59	83.04	82.02	81.62
		10	87.19	87.84	87.90	88.43	87.66	87.34	86.86	86.11	86.57	87.48	87.70	87.54	87.20	87.45	87.88	87.92	88.00	86.61	86.52	85.52	85.46	85.47	85.73	86.22	86.18				87.75	85.60	85.48	85.31	85.87	85.36
	5	11	82.99	83.08	82.87	82.89	82.67	82.08	81.59	80.97	81.03	81.96	82.48	81.96	81.56	81.82	82.39	82.34	82.33	81.56	80.99	80.17	80.20	80.27	80.35	80.94	80.77				81.80	79.82	79.83	79.33	79.68	79.62
		12	85.43	85.05	85.09	85.12	84.61	84.80	84.10	83.59	83.47	84.12	84.26	84.58	84.16	84.36	84.31	84.97	84.57	84.23	83.86	83.73	83.34	83.49	83.12	84.01	83.75				84.34	83.84	83.04	83.06	83.41	83.41
	6	13	89.14	88.21	88.76	88.48	88.17	88.23	87.82	87.01	87.15	87.56	87.82	88.05	88.09	87.89	88.53	88.38	88.30	88.18	87.92	88.06	87.42	87.56	87.31	87.99	87.42				88.68	87.93	86.71	86.83	88.01	87.86
	Ref	14	88.72	89.64	91.45	90.71	91.45	91.75	91.57	91.95	91.31	90.84	92.18	92.33	92.35	91.99	92.78	92.10	93.57	93.63	92.06	91.81	92.52	93.07	92.84	94.56	92.34				91.83	91.48	91.76	90.88	91.75	92.01

MIN TEMP (50A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		1	22.29	95.90	95.73	93.01	91.23	93.56	92.72	93.94	92.48	90.88	92.40	92.03	91.11	91.39	90.62	91.45	91.51	91.06	89.73	93.36	91.73	91.20	89.59	91.80	90.50	Power Outage			88.57	89.43	88.66	87.20	89.04	88.91
	1	2	22.78	75.58	76.48	74.61	74.09	74.86	73.01	75.43	74.83	73.38	74.29	74.35	73.76	73.98	73.51	74.34	73.20	72.76	72.79	75.75	73.99	71.52	71.85	73.85	73.60				70.57	71.15	71.60	70.77	72.03	72.00
		3	22.32	86.68	86.59	86.16	86.30	86.08	83.75	86.01	85.92	86.01	86.10	86.12	86.44	86.39	86.00	87.18	85.73	86.73	84.95	86.06	85.97	85.69	84.59	86.34	86.40				86.41	84.28	82.96	83.55	86.01	86.60
	2	4	23.01	73.41	74.53	73.82	73.74	73.90	71.63	74.62	74.23	73.44	74.07	74.11	74.11	74.10	73.74	74.07	73.55	74.16	73.04	75.59	74.45	72.99	72.67	75.16	74.60				73.70	71.28	72.09	72.66	74.55	74.63
		5	22.81	82.43	83.23	81.87	81.43	81.93	82.40	83.10	83.04	81.18	81.53	82.37	82.07	81.62	80.99	81.31	82.41	83.19	83.08	83.34	83.08	83.36	82.56	82.89	81.89				83.00	80.76	80.45	78.26	82.23	82.20
	3	6	22.78	88.40	88.90	87.84	87.42	88.03	87.74	88.31	88.04	87.25	87.44	88.02	87.65	87.71	87.08	87.91	88.31	88.13	88.39	87.65	87.47	88.14	87.58	88.05	88.04				87.82	87.69	86.02	85.31	86.77	86.95
	Ref	7	22.80	81.99	82.99	82.63	83.18	82.18	83.80	84.81	83.61	82.84	83.48	83.28	83.82	83.52	82.89	82.37	84.23	85.36	85.18	85.16	84.67	85.61	84.25	85.09	83.40				85.03	84.55	82.60	82.30	84.22	84.61
WAGO		8	22.80	76.69	76.90	75.55	75.53	75.70	76.45	76.09	75.90	74.84	75.21	75.08	75.48	74.30	73.94	74.72	75.67	75.74	76.09	75.53	75.31	75.63	75.48	75.29	73.59				75.39	75.23	74.02	73.67	74.40	74.30
	4	9	22.75	83.28	83.55	82.80	83.07	82.84	83.59	82.50	82.47	81.84	82.09	81.47	81.66	81.43	80.58	81.16	81.56	81.90	81.02	81.21	80.95	80.60	80.67	79.89	78.46				78.59	78.57	76.50	76.81	77.42	78.12
		10	22.75	82.20	82.69	81.78	82.24	82.32	82.49	81.70	82.03	81.84	81.99	81.63	81.98	81.22	81.81	81.26	82.31	82.46	82.27	82.11	82.40	82.79	82.36	81.77	81.11				81.76	81.86	80.13	80.89	82.58	82.28
	5	11	22.70	78.01	77.83	76.59	77.48	77.09	77.56	77.03	77.05	76.60	76.94	76.43	76.92	75.85	76.32	75.92	77.07	77.78	77.22	77.46	77.68	77.94	77.27	76.76	75.78				76.67	77.06	75.06	74.97	77.20	77.02
		12	22.73	79.80	79.49	79.39	79.38	79.26	79.13	78.50	78.95	78.66	78.39	78.53	78.81	77.70	78.11	78.08	78.59	79.55	79.11	79.58	80.09	80.23	79.47	79.04	78.20				80.03	80.00	77.96	78.62	80.09	80.09
	6	13	22.70	83.65	83.07	83.06	82.47	82.70	81.87	82.49	82.24	82.41	82.51	82.69	82.38	82.30	82.45	82.67	82.99	83.63	82.82	83.27	83.53	82.79	82.66	83.04	82.52				83.28	82.88	81.04	81.24	83.12	83.10
	Ref	14	22.75	83.42	83.49	83.33	83.15	83.16	84.08	83.31	83.25	83.72	83.44	84.10	83.54	83.30	83.76	83.49	84.07	85.48	84.55	84.60	84.76	86.01	86.22	84.12	83.95				85.18	86.83	84.58	85.39	86.90	86.05

AVE TEMP (50A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		1	99.09	97.98	98.38	96.49	96.29	96.22	96.29	96.62	95.90	94.68	94.80	95.19	94.67	94.22	93.82	94.56	95.24	94.85	95.27	95.51	94.83	95.38	94.79	94.84	93.99	Power Outage			94.89	94.26	94.24	94.20	94.00	93.87
	1	2	78.62	77.88	78.84	77.46	77.72	77.86	77.92	78.29	77.87	76.79	76.90	77.39	76.91	76.46	76.14	76.80	77.45	77.10	77.47	77.66	76.99	77.46	76.86	77.13	76.46				77.03	76.21	76.26	76.30	76.08	75.89
		3	87.84	88.16	88.53	88.23	88.08	88.11	88.28	89.15	88.37	87.83	87.96	88.17	88.13	88.01	88.27	88.92	88.91	88.76	89.17	89.46	89.14	89.83	89.40	88.87	88.33				89.35	89.23	89.23	89.66	89.13	89.13
	2	4	74.75	75.56	76.47	75.77	76.01	76.19	76.27	76.75	76.46	75.81	76.07	76.44	76.22	76.03	75.91	76.52	77.05	76.92	77.14	77.29	76.93	77.37	76.97	76.95	76.55				77.40	77.13	77.02	77.23	76.91	76.87
		5	85.18	85.31	86.02	84.86	84.92	85.09	85.23	85.58	85.08	84.29	84.65	84.97	84.72	84.37	84.00	84.77	85.68	85.51	85.55	85.51	85.35	85.90	85.44	85.27	84.63				85.15	85.01	84.98	85.35	84.70	84.57
	3	6	89.99	89.95	90.10	89.68	89.52	89.54	89.60	89.92	89.43	89.14	89.38	89.37	89.34	89.25	89.24	89.79	90.18	90.00	90.00	89.89	89.87	90.32	89.99	89.55	89.44				89.70	89.75	89.67	90.16	89.29	89.23
	Ref	7	83.50	85.01	86.15	85.57	85.88	86.06	86.26	86.37	86.24	85.89	86.32	86.57	86.42	86.21	85.84	86.43	87.54	87.24	87.07	86.83	86.84	87.13	86.83	86.82	86.54				86.65	86.66	86.39	86.75	86.16	86.09
WAGO		8	78.35	79.13	79.27	78.39	78.35	78.06	77.90	77.38	77.23	77.29	77.47	77.56	77.44	77.45	77.14	77.46	78.23	77.77	77.39	76.77	76.84	76.80	76.83	76.98	76.73				76.63	76.32	76.04	75.97	75.51	75.42
	4	9	84.58	85.48	86.36	85.50	85.75	85.54	85.61	85.08	84.72	84.50	84.67	84.86	84.45	84.21	83.69	84.00	84.92	84.05	83.52	82.87	82.82	82.80	82.74	82.61	81.91				80.89	80.74	80.41	80.61	79.86	79.65
		10	83.91	85.12	86.05	85.11	85.40	85.17	85.01	84.69	84.79	84.74	85.01	85.30	85.06	84.91	84.51	84.81	85.78	84.94	84.53	84.03	84.08	84.17	84.11	84.43	84.03				84.44	84.26	83.59	83.64	83.85	83.81
	5	11	80.26	80.70	81.22	80.18	80.42	80.17	79.78	79.44	79.60	79.51	79.76	80.01	79.81	79.68	79.25	79.58	80.47	79.72	79.44	79.06	78.99	79.14	78.99	79.44	78.90				78.97	78.61	77.87	77.75	78.20	78.18
		12	82.32	82.81	83.38	82.23	82.52	82.39	81.93	81.68	81.73	81.45	81.71	82.35	82.02	81.68	81.38	81.71	82.58	82.39	81.91	81.77	81.72	81.78	81.45	81.81	80.94				82.08	81.76	80.74	80.37	81.44	81.64
	6	13	85.70	86.01	86.62	85.59	85.98	85.86	85.30	84.99	85.27	85.14	85.34	85.96	85.64	85.40	85.22	85.48	86.23	86.10	85.59	85.45	85.37	85.27	85.02	85.68	85.04				85.73	85.16	83.85	83.47	84.99	85.23
	Ref	14	84.72	85.98	87.39	86.49	86.92	87.91	88.34	89.19	88.00	86.86	87.38	88.68	88.21	87.26	87.03	87.49	88.69	89.53	89.36	89.39	89.47	90.37	89.71	89.12	87.38				88.84	89.23	88.46	87.94	88.82	89.13

MAX TEMP (30A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		15	68.57	62.14	61.07	60.48	60.15	59.65	59.37	58.88	59.40	59.21	59.03	59.59	59.52	59.65	59.99	60.38	60.45	59.45	59.20	58.92	58.77	58.79	58.81	58.92	59.54	Power Outage			59.22	59.20	59.03	57.81	58.09	58.50
	7	16	70.43	68.41	67.93	68.09	68.43	67.89	67.69	67.60	68.16	68.53	68.28	68.40	68.92	69.05	69.48	69.99	69.51	68.90	68.62	68.40	68.22	68.39	68.44	68.78	69.62				69.42	69.18	69.09	67.95	68.09	68.48
		17	80.39	65.87	64.23	64.36	64.12	64.12	63.84	63.72	63.63	63.62	63.27	63.19	63.31	63.70	64.09	64.17	63.63	62.92	62.82	62.44	62.19	62.22	61.94	62.91	62.70				61.81	61.15	61.09	59.86	59.84	60.07
	8	18	85.75	73.23	72.38	72.61	72.10	71.52	71.15	70.74	71.21	71.51	70.95	71.21	71.18	71.59	71.92	71.56	71.49	70.52	70.30	69.77	69.93	70.05	70.06	70.05	70.87				69.84	69.72	69.64	68.99	68.71	68.62
		19	65.78	64.66	64.04	64.77	64.75	63.82	63.62	63.56	63.54	63.56	63.63	63.38	63.44	63.94	64.33	64.51	64.62	63.36	63.50	63.00	63.26	63.48	63.70	63.34	63.57				63.36	63.25	62.99	62.38	62.04	61.95
	9	20	66.27	65.63	64.73	65.12	65.13	64.40	63.75	63.91	63.97	64.18	64.01	63.92	63.94	64.15	64.53	64.88	64.45	63.56	63.36	63.26	63.32	63.22	63.41	63.25	63.63				63.27	63.16	63.19	62.11	61.91	62.00
	Ref	21	67.20	67.35	66.97	67.88	67.89	67.24	67.55	67.53	67.24	66.93	67.88	67.56	67.55	67.87	68.14	68.77	68.16	68.30	68.23	67.37	68.14	67.45	68.48	67.70	67.67				68.10	68.36	67.75	67.62	67.07	67.07
WAGO		22	65.17	64.36	64.07	64.63	64.25	63.61	63.37	63.14	62.95	62.40	63.08	63.02	63.03	63.12	63.70	63.99	63.60	63.24	63.14	62.71	62.44	62.43	62.68	62.38	62.81				62.04	61.98	61.88	61.51	61.12	61.12
	10	23	68.15	67.25	66.94	67.10	66.98	66.28	65.89	65.83	65.73	65.47	65.73	65.81	65.53	65.73	66.41	66.67	66.20	65.39	65.46	64.95	64.75	64.86	64.97	64.77	65.26				64.25	64.38	64.25	63.67	63.45	63.45
		24	65.42	64.44	64.92	64.86	64.90	64.75	64.43	64.46	64.20	64.16	64.51	64.42	64.44	64.71	65.24	65.05	64.99	64.41	64.53	64.13	63.94	63.86	63.69	63.81	64.36				63.36	63.76	63.50	63.13	63.11	63.11
	11	25	64.28	61.42	61.21	61.24	61.13	60.69	60.29	60.28	60.01	60.01	60.27	60.29	60.44	59.64	59.79	59.84	59.96	59.49	59.24	58.74	58.55	58.60	58.17	58.42	58.97				57.57	57.58	57.45	57.45	56.89	56.89
		26	64.38	63.89	64.46	64.34	64.05	63.46	63.45	63.50	63.01	62.61	63.23	63.18	63.08	63.01	63.75	63.17	63.81	62.80	63.06	62.42	61.96	62.39	61.92	62.32	62.88				61.77	61.14	60.99	60.83	60.72	60.72
	12	27	67.34	67.23	67.54	67.26	67.17	67.19	66.53	66.41	65.93	65.99	66.46	66.16	66.28	66.03	66.53	66.53	66.88	66.02	65.95	65.53	65.04	65.08	65.23	65.31	66.17				64.83	64.29	64.23	64.03	63.79	63.79
	Ref	28	60.36	60.63	61.31	61.58	61.70	61.36	60.77	60.95	60.41	60.41	61.25	61.03	61.14	60.78	61.20	61.14	61.63	60.92	61.26	60.79	60.38	60.18	60.48	60.56	60.90				60.27	60.70	60.18	59.65	59.69	59.69
Gardner Bender		29	62.68	62.96	63.23	62.97	63.25	62.90	62.67	62.94	62.30	62.38	62.95	62.66	63.07	62.67	63.11	62.55	63.57	63.03	62.65	62.57	62.16	62.00	62.31	62.55	62.56				61.79	61.47	61.62	61.09	60.97	60.97
	13	30	64.06	64.02	64.43	64.32	64.44	64.32	64.04	64.15	63.91	63.98	64.28	64.22	64.51	64.26	64.75	64.44	65.41	64.22	64.25	64.16	63.74	63.55	64.06	64.11	64.33				63.81	63.81	63.91	63.13	63.08	63.08
		31	67.09	66.75	67.66	67.43	67.57	67.25	67.46	67.18	66.81	66.98	67.50	67.36	67.36	67.46	67.60	67.32	68.12	67.12	67.60	67.16	66.68	66.65	67.04	67.10	67.15				67.34	66.88	67.05	66.51	66.23	66.23
	14	32	No Data	67.16	67.72	67.56	67.82	67.27	67.57	67.43	66.98	67.55	67.95	67.50	67.50	67.33	67.63	67.41	68.28	67.21	67.96	67.42	66.89	66.79	67.33	67.49	67.43				67.86	66.79	66.94	66.31	66.25	66.25
		33	No Data	68.57	68.92	68.71	68.94	68.61	68.47	68.64	68.06	68.67	68.83	68.89	68.52	68.42	68.78	68.61	68.92	67.98	68.57	68.39	67.78	67.47	68.01	68.15	67.96				68.29	67.33	67.37	66.91	66.81	66.81
	15	34	No Data	65.91	65.94	65.52	65.62	65.33	65.00	64.92	64.42	64.83	65.17	65.19	64.34	64.53	64.76	64.51	64.68	63.67	64.28	64.26	63.49	63.09	63.76	63.87	63.44				63.23	62.80	62.35	61.87	61.92	61.92
	Ref	35	No Data	65.03	65.01	64.45	64.81	64.77	64.45	64.50	64.22	64.68	64.79	64.49	64.74	64.36	64.70	64.42	65.08	64.28	64.36	64.39	64.27	63.92	63.98	64.55	64.63				64.18	64.33	64.26	63.69	63.50	63.50

MIN TEMP (30A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		15	22.77	57.58	56.18	55.47	56.17	56.05	54.30	56.03	54.67	55.31	54.34	54.49	56.15	55.24	55.12	54.89	55.83	55.52	53.60	56.59	55.37	54.74	56.06	54.83	54.52	Power Outage			56.05	55.18	53.01	53.28	55.20	55.76
	7	16	22.75	64.48	64.38	63.99	64.72	64.79	63.90	65.26	64.38	65.44	64.65	64.53	66.23	65.24	65.00	64.95	65.76	66.08	64.69	65.90	66.02	65.34	65.89	65.79	65.72				66.20	66.45	63.80	64.49	66.06	66.17
		17	22.72	60.87	60.38	60.22	60.35	60.73	60.20	60.58	59.82	60.60	59.59	60.37	60.44	59.53	59.53	59.51	59.88	59.76	59.66	59.65	59.09	59.07	59.20	59.21	58.97				58.75	58.51	56.75	56.91	57.43	57.44
	8	18	22.73	69.00	69.03	68.30	68.23	68.70	68.06	68.73	67.88	68.03	67.70	67.69	68.59	67.68	67.31	66.96	67.95	67.89	67.32	68.39	68.31	67.35	68.10	67.69	66.99				67.27	67.55	64.94	65.56	67.07	67.37
		19	22.73	59.98	60.15	59.82	59.93	60.23	60.98	60.99	59.94	59.98	59.26	60.02	59.92	59.93	60.20	59.29	60.47	59.96	60.62	61.18	60.87	60.36	60.73	60.00	59.11				60.39	60.55	58.06	58.78	60.52	60.37
	9	20	22.70	61.16	61.38	61.20	61.55	61.51	61.68	61.04	60.78	60.90	60.68	61.06	60.54	61.25	60.92	60.34	61.25	61.27	61.53	61.29	61.40	60.79	61.06	60.77	60.38				60.64	60.93	59.00	59.81	60.22	60.27
	Ref	21	23.00	62.21	62.84	62.36	63.25	63.69	64.05	64.89	63.00	62.62	63.53	62.58	64.50	63.99	63.41	63.48	63.79	64.67	64.44	65.95	65.58	64.06	64.49	63.65	62.50				64.62	64.74	61.88	62.35	63.63	63.63
WAGO		22	23.02	59.21	59.42	58.74	58.99	59.38	59.33	60.21	58.13	57.78	58.80	57.64	59.60	58.67	57.99	58.01	58.48	58.96	58.93	60.69	60.04	57.83	58.84	58.02	56.75				58.68	58.52	56.02	56.86	57.95	57.95
	10	23	23.00	62.52	62.21	61.72	61.82	61.94	62.50	63.04	60.80	60.67	61.60	60.52	62.47	61.55	60.96	60.80	61.47	61.81	61.33	63.19	62.51	60.66	61.53	60.82	59.77				61.51	61.43	59.00	59.92	60.68	60.68
		24	23.02	60.65	60.80	60.62	60.81	61.46	60.99	61.87	60.15	60.26	60.59	59.96	61.62	60.89	60.49	60.46	60.95	61.58	61.47	62.36	61.67	60.51	60.98	60.13	59.75				60.48	60.99	58.22	59.69	59.84	59.84
	11	25	23.07	57.07	56.58	56.68	56.69	56.88	56.66	57.07	56.35	55.85	56.35	55.84	56.70	55.53	54.59	54.30	55.11	55.45	55.37	56.38	55.05	54.50	53.48	53.09	52.24				52.13	53.09	50.44	50.89	51.40	51.40
		26	23.05	58.73	58.77	58.40	59.00	58.48	58.52	59.16	57.75	57.96	57.86	57.39	58.41	58.42	57.88	57.79	58.09	58.42	58.22	60.13	58.57	57.41	57.14	57.18	57.05				57.66	57.98	55.59	56.70	56.63	56.63
	12	27	23.02	62.05	62.29	61.74	62.48	62.06	62.35	62.57	61.59	61.31	61.82	61.22	61.92	61.95	61.74	61.41	61.80	62.12	61.41	63.02	62.21	61.25	61.29	60.89	60.91				61.45	61.74	59.33	60.39	60.26	60.26
	Ref	28	23.05	55.09	54.46	54.76	56.16	55.22	55.92	56.42	55.98	55.79	56.10	55.70	56.37	55.77	56.14	56.02	55.91	56.25	56.33	57.81	56.53	55.96	55.80	55.62	55.48				56.30	57.54	55.38	55.88	56.27	56.27
Gardner Bender		29	23.03	56.09	55.54	55.72	56.34	55.68	56.74	56.71	56.14	55.32	56.25	56.46	57.26	57.41	56.92	56.71	56.27	56.76	55.89	59.38	58.23	56.04	55.97	55.91	56.04				56.30	57.15	55.72	56.01	56.10	56.10
	13	30	23.00	58.88	58.14	58.57	58.60	58.83	59.15	59.75	58.92	57.87	59.21	59.46	60.23	60.13	59.37	59.43	58.80	59.60	59.40	61.86	60.54	59.05	59.15	58.59	58.51				59.47	60.48	58.94	59.36	59.27	59.27
		31	22.91	60.43	59.64	59.94	60.71	60.63	61.05	62.26	59.81	59.70	60.51	60.80	62.60	60.70	61.36	60.98	59.79	61.30	60.67	63.95	62.40	60.33	60.62	60.06	60.39				61.77	62.93	61.23	62.62	62.11	62.11
	14	32	No Data	59.91	59.38	59.83	60.02	59.62	60.37	61.40	59.30	59.39	60.35	60.12	61.55	60.39	60.74	60.75	59.19	60.49	59.97	63.98	61.42	59.87	59.67	59.61	60.27				60.89	62.15	60.49	61.70	61.62	61.62
		33	No Data	63.35	62.04	61.80	61.88	61.90	61.99	62.92	61.26	61.57	61.88	62.11	62.91	61.98	62.67	62.15	60.99	61.71	61.53	64.55	62.26	61.06	60.82	60.58	61.22				61.39	62.68	61.00	62.39	61.60	61.60
	15	34	No Data	60.13	58.82	58.25	58.86	58.51	58.42	59.14	57.44	57.34	57.62	58.39	59.05	57.74	57.98	58.19	56.76	57.66	56.81	60.03	58.20	56.55	56.50	55.56	55.44				56.14	57.06	55.99	56.96	55.70	55.70
	Ref	35	No Data	60.01	59.16	59.60	59.57	59.61	59.71	60.18	58.88	59.50	59.28	59.95	59.52	59.73	59.97	60.38	59.10	58.74	59.26	60.50	60.06	58.98	58.66	58.36	58.92				59.41	60.12	59.63	59.35	58.66	58.66

AVE TEMP (30A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		15	62.96	60.51	59.09	58.64	58.55	58.25	57.68	57.73	57.72	57.76	57.63	57.85	57.93	58.04	58.29	58.21	58.34	58.07	57.93	57.80	57.58	57.76	57.69	57.76	57.73	Power Outage			59.22	57.62	56.55	56.00	56.89	57.06
	7	16	67.80	67.05	66.52	66.72	67.00	66.93	66.45	66.53	66.95	67.25	67.21	67.42	67.59	67.88	68.24	68.24	68.21	67.75	67.55	67.36	67.19	67.48	67.42	67.79	67.99				69.42	67.95	66.93	66.42	66.93	67.03
		17	65.55	63.34	62.66	62.44	62.62	62.72	62.34	62.15	62.25	62.03	62.00	62.05	61.92	62.11	62.30	62.10	62.14	61.56	61.34	61.00	60.65	60.79	60.65	60.82	61.01				61.81	59.87	59.11	58.38	58.57	58.64
	8	18	72.98	71.28	70.57	70.55	70.48	70.28	70.02	69.91	70.01	69.88	69.74	69.80	69.82	69.95	70.20	70.00	69.97	69.67	69.44	69.16	69.10	69.11	69.09	69.06	69.14				69.84	69.06	68.06	67.76	68.03	67.95
		19	63.36	62.65	62.53	62.52	62.73	62.50	62.45	62.39	62.30	61.91	61.96	62.23	62.15	62.32	62.58	62.54	62.77	62.48	62.45	62.21	62.22	62.17	62.22	61.94	61.95				63.36	62.22	61.24	61.17	61.36	61.25
	9	20	64.35	63.60	63.29	63.26	63.34	63.07	62.88	62.78	62.81	62.52	62.54	62.70	62.65	62.83	63.13	63.09	63.19	62.76	62.60	62.31	62.28	62.29	62.31	62.13	62.27				63.27	62.29	61.49	61.17	61.22	61.14
	Ref	21	65.33	65.41	65.85	65.71	66.26	66.08	66.19	66.19	66.07	65.58	65.93	66.17	66.12	66.26	66.37	66.42	66.89	66.77	66.78	66.63	66.65	66.55	66.71	66.31	66.16				66.59	66.86	65.65	65.71	65.95	65.95
WAGO		22	62.58	62.44	62.80	61.98	62.48	62.15	62.07	62.04	61.67	61.03	61.45	61.71	61.48	61.61	61.48	61.32	62.01	61.72	61.86	61.82	61.52	61.28	61.37	60.96	60.86				60.90	60.92	59.73	59.76	60.04	60.04
	10	23	65.64	65.47	65.60	64.63	65.20	64.92	64.80	64.78	64.42	63.80	64.13	64.42	64.17	64.35	64.27	64.02	64.64	64.24	64.35	64.21	63.92	63.69	63.75	63.36	63.34				63.25	63.32	62.29	62.28	62.38	62.38
		24	62.85	62.98	63.65	62.98	63.64	63.54	63.40	63.47	63.15	62.78	63.10	63.34	63.28	63.35	63.31	63.07	63.61	63.34	63.55	63.38	63.05	62.88	62.86	62.53	62.58				62.49	62.61	61.70	61.80	62.13	62.13
	11	25	60.31	59.35	59.79	58.99	59.56	59.36	59.24	59.28	58.79	58.22	58.79	59.04	58.79	58.17	57.52	57.30	58.21	57.78	57.87	57.78	57.34	57.14	56.83	56.32	56.22				55.87	55.74	54.77	54.79	55.06	55.06
		26	61.30	61.24	62.45	61.23	62.06	61.91	61.71	61.85	61.09	60.53	61.16	61.49	61.14	61.05	60.66	60.49	61.54	60.94	61.26	61.34	60.62	60.45	60.37	60.09	60.02				59.91	59.63	58.84	58.80	59.08	59.08
	12	27	64.19	64.20	65.46	64.30	65.14	65.04	64.94	65.02	64.40	63.79	64.39	64.74	64.38	64.37	64.07	63.95	64.87	64.32	64.61	64.56	63.94	63.78	63.81	63.45	63.48				63.25	63.17	62.48	62.41	62.46	62.46
	Ref	28	57.47	57.72	59.09	58.44	59.26	59.15	59.27	59.36	58.80	58.33	58.93	59.20	58.99	58.84	58.73	58.77	59.52	59.09	59.48	59.57	59.11	58.86	59.06	58.71	58.72				58.86	59.03	58.42	58.40	58.24	58.24
Gardner Bender		29	59.04	59.48	60.89	59.71	60.70	60.60	60.86	61.05	60.32	59.90	60.47	60.80	60.67	60.35	59.91	59.73	60.83	60.31	60.81	61.18	60.45	60.09	60.32	59.77	59.83				60.09	60.18	59.40	59.29	59.51	59.51
	13	30	61.18	61.58	62.66	61.75	62.61	62.55	62.75	62.87	62.33	62.03	62.47	62.80	62.70	62.55	62.34	62.20	63.04	62.60	62.93	63.07	62.49	62.26	62.41	61.99	62.09				62.39	62.52	62.00	61.85	61.81	61.81
		31	63.63	63.96	65.26	64.15	65.12	65.04	65.34	65.44	64.75	64.54	65.02	65.35	65.21	65.00	64.67	64.27	65.35	64.76	65.45	65.88	65.13	64.65	64.98	64.41	64.43				65.27	65.47	64.84	64.91	64.89	64.89
	14	32	No Data	63.57	65.09	63.76	64.90	64.80	65.09	65.19	64.44	64.24	64.79	65.13	64.99	64.75	64.32	63.82	65.05	64.37	65.16	65.82	64.91	64.39	64.71	64.11	64.22				64.99	65.13	64.34	64.41	64.70	64.70
		33	No Data	65.59	66.72	65.43	66.31	66.22	66.48	66.49	65.93	65.90	66.23	66.44	66.42	66.17	65.90	65.39	66.31	65.78	66.30	66.80	65.80	65.37	65.62	65.14	65.21				65.49	65.58	64.95	64.84	65.21	65.21
	15	34	No Data	62.85	63.73	62.23	62.91	62.69	62.89	62.83	62.23	62.07	62.30	62.46	62.31	61.95	61.63	61.10	62.03	61.39	61.86	62.18	61.33	60.82	61.15	60.53	60.50				60.27	60.41	59.78	59.66	59.80	59.80
	Ref	35	No Data	62.16	63.09	62.21	62.62	62.54	62.89	62.73	62.44	62.48	62.65	62.65	62.71	62.43	62.40	62.23	62.79	62.57	62.68	62.86	62.34	61.95	62.30	61.97	62.19				62.37	62.49	62.19	61.90	61.74	61.74

MAX TEMP (20A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		36	No Data	62.13	61.46	60.56	60.29	60.59	59.48	59.07	58.70	58.95	58.83	58.72	58.61	58.78	58.97	59.81	58.95	58.60	57.88	57.27	57.12	57.72	57.02	57.49	58.02	Power Outage			55.94	56.39	55.77	54.77	54.71	54.52
	16	37	No Data	61.55	61.48	60.69	60.29	60.42	59.33	58.77	58.49	59.20	58.83	58.91	58.80	58.85	59.36	60.28	58.72	58.39	57.21	57.18	56.89	56.21	56.79	57.72	57.67				56.06	55.89	55.26	55.12	54.70	54.71
		38	No Data	53.15	53.64	52.80	52.67	53.02	52.45	52.11	52.09	52.60	52.50	52.54	52.74	52.96	53.10	53.16	52.74	53.18	52.53	51.91	51.67	51.18	51.62	52.10	52.53				52.03	51.42	52.15	51.49	50.43	50.66
	17	39	No Data	53.55	53.88	53.02	53.33	53.47	52.88	52.47	52.77	53.33	53.18	53.27	53.13	53.11	53.64	53.92	53.68	53.27	53.14	52.67	52.14	51.76	52.10	52.54	53.11				52.15	51.65	52.10	51.53	50.89	51.19
		40	No Data	58.52	58.37	57.97	57.89	58.17	58.29	57.23	57.63	57.96	57.56	57.85	57.78	58.40	58.14	58.80	58.13	58.01	57.80	57.28	56.80	56.33	57.45	57.09	57.96				57.14	56.87	57.52	57.04	56.10	55.62
	18	41	56.13	55.83	55.29	55.13	55.00	55.35	55.29	54.68	54.99	55.53	54.95	55.10	55.40	55.49	55.95	56.23	55.65	55.32	55.43	54.40	54.26	54.25	54.91	54.95	55.22				55.24	55.27	55.11	55.20	54.01	53.78
	Ref	42	56.42	56.74	56.50	56.62	56.33	56.28	56.37	56.22	55.96	56.23	56.48	56.54	56.60	56.96	57.50	58.27	57.01	56.53	56.28	55.38	55.46	55.50	55.62	56.07	57.18				56.25	56.25	55.48	55.38	54.02	53.94
WAGO		43	53.75	53.87	53.82	54.10	53.50	53.57	53.50	52.85	53.41	53.48	53.44	53.31	53.17	53.72	54.38	54.62	54.30	54.03	53.64	53.09	52.91	52.87	53.25	53.21	54.05				53.32	53.22	53.29	52.33	51.90	51.89
	19	44	55.89	55.65	55.78	55.82	55.25	55.40	55.26	54.84	55.04	55.27	55.32	54.92	54.82	55.36	56.26	56.63	56.03	55.85	54.97	54.46	54.50	54.34	54.62	54.71	56.00				54.68	54.77	54.47	53.68	53.04	53.04
		45	52.99	52.56	52.37	52.78	52.28	52.39	51.91	51.41	52.14	51.95	52.12	51.92	51.77	52.32	52.70	53.38	53.05	52.99	52.06	51.45	51.56	51.28	51.61	52.00	52.99				51.71	51.64	51.68	51.02	50.29	50.59
	20	46	57.96	57.96	58.00	58.20	57.49	57.50	57.34	56.82	56.96	56.99	57.24	57.16	56.95	57.64	57.95	58.84	58.49	58.11	57.46	56.50	56.58	56.79	56.97	56.85	58.01				56.80	56.91	56.95	56.39	55.60	55.52
		47	53.18	53.28	53.38	53.69	53.55	53.35	53.31	52.74	53.21	53.00	53.30	53.27	52.91	53.47	53.94	54.55	54.36	54.40	53.55	53.10	53.19	53.37	53.15	53.33	54.35				53.02	52.94	52.99	52.49	52.10	51.88
	21	48	55.56	56.03	55.79	56.28	55.54	55.68	55.56	55.06	55.50	55.52	55.63	55.69	55.57	56.12	56.31	57.52	56.93	56.43	55.72	55.31	55.22	55.68	55.18	55.82	57.01				55.40	55.08	55.32	55.19	54.29	54.10
	Ref	49	59.88	59.48	59.52	59.78	59.74	59.54	59.32	58.76	59.02	59.55	59.43	59.60	59.70	60.14	60.29	61.11	60.15	60.55	59.73	58.64	59.01	59.14	58.71	59.67	60.63				59.49	57.94	57.98	57.35	57.49	57.67
Gardner Bender		50	59.35	59.42	59.95	60.32	60.10	59.65	59.22	59.17	59.70	59.58	59.53	59.91	59.58	60.30	60.72	61.01	61.32	61.23	60.14	59.45	59.70	60.72	60.05	60.38	61.19				59.47	59.21	59.74	58.66	58.40	58.24
	22	51	61.96	61.58	61.77	62.22	61.85	61.58	60.92	60.99	61.25	61.51	61.27	61.81	61.27	62.80	62.52	63.28	62.56	62.82	61.88	61.01	60.90	62.66	62.00	62.71	63.59				61.36	60.54	61.33	59.95	59.91	59.67
		52	66.06	66.79	68.72	70.24	70.50	70.99	70.27	69.62	69.82	69.78	69.56	69.39	68.80	69.02	68.78	69.45	69.11	69.08	68.03	66.70	66.93	68.02	67.48	67.56	67.48				65.92	65.69	65.37	64.75	64.53	64.40
	23	53	64.35	65.25	66.55	68.23	68.67	68.51	67.96	67.56	67.49	67.69	67.29	67.03	66.68	66.49	66.51	66.98	66.88	66.84	65.76	64.83	64.73	65.30	65.00	65.00	65.02				63.50	63.06	63.04	62.42	62.02	61.88
		54	55.36	54.87	55.50	56.30	55.60	55.79	55.48	55.15	55.71	55.81	55.94	55.96	55.13	56.22	56.19	56.60	57.05	57.12	56.81	54.97	56.06	56.35	56.19	56.09	56.92				55.52	54.86	54.79	54.18	54.23	54.17
	24	55	56.03	55.91	56.35	57.15	56.61	56.65	56.36	55.93	56.44	56.83	56.78	56.76	56.16	57.08	57.02	57.72	57.82	58.08	57.58	55.95	56.97	57.32	57.03	56.86	57.98				56.51	55.73	55.96	55.38	55.18	55.26
	Ref	56	57.85	57.34	58.14	58.45	58.11	58.29	57.80	57.79	58.00	58.26	58.49	58.19	57.91	58.52	58.96	59.31	59.46	59.75	58.73	58.07	58.74	58.89	58.86	58.61	59.32				58.52	58.03	57.79	57.42	57.41	57.28

MIN TEMP (20A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		36	No Data	59.35	58.63	57.86	57.56	57.20	56.72	56.52	55.94	56.36	56.49	56.26	56.20	56.30	56.63	56.66	56.30	55.87	55.43	54.74	54.82	54.93	54.79	55.20	55.26	Power Outage			54.14	53.70	52.99	52.13	52.45	52.29
	16	37	No Data	57.79	57.06	56.48	56.14	55.91	55.38	55.24	55.21	55.24	55.15	55.20	55.05	55.24	55.58	55.58	55.34	54.86	54.43	53.72	53.84	53.79	53.38	54.02	54.44				53.12	52.87	52.22	51.82	51.65	51.61
		38	No Data	49.75	49.98	49.67	49.75	49.31	49.02	48.63	49.23	49.38	49.51	49.41	49.51	50.28	50.34	50.40	50.06	49.63	49.53	49.25	48.51	48.91	48.37	49.05	49.95				48.12	48.34	48.27	47.40	47.43	47.71
	17	39	No Data	50.82	50.92	50.31	49.90	49.96	49.24	49.84	50.10	50.56	49.98	50.29	50.27	50.79	51.28	50.99	50.57	49.91	49.81	49.54	48.94	49.36	48.70	49.30	50.66				48.65	48.64	48.11	47.65	47.82	48.16
		40	No Data	55.18	55.29	54.75	54.41	54.78	53.98	54.16	53.99	54.52	54.21	54.25	54.66	54.96	55.24	55.12	53.62	54.03	53.64	53.63	52.40	53.14	52.87	52.99	54.58				53.13	52.93	53.08	52.44	52.17	52.41
	18	41	22.86	52.29	52.65	52.48	52.14	52.15	51.89	51.58	52.03	51.88	52.19	52.23	52.31	52.52	53.15	53.36	52.73	51.94	52.08	51.26	51.32	51.46	50.98	51.87	52.47				51.54	51.62	50.85	51.01	50.33	50.86
	Ref	42	22.88	52.07	53.43	52.73	52.59	52.26	52.30	52.58	52.32	52.32	53.09	53.11	52.81	51.80	52.71	51.32	53.41	52.17	52.87	51.55	52.17	51.97	52.11	52.48	52.22				52.56	51.63	51.30	51.25	50.30	50.80
WAGO		43	22.90	50.19	51.07	49.83	50.72	51.22	50.90	51.03	51.03	51.32	50.99	51.53	51.32	50.32	50.18	49.22	50.40	51.92	51.73	51.02	51.08	51.13	51.25	51.43	50.34				51.31	50.96	50.69	50.04	49.93	50.16
	19	44	22.88	51.23	52.25	50.87	51.42	52.09	52.41	52.35	51.81	52.44	51.92	52.60	52.11	51.11	50.86	49.83	50.85	53.18	52.77	51.85	52.01	51.90	52.07	52.15	51.13				52.07	51.60	51.56	50.79	50.53	50.61
		45	22.88	48.73	49.44	48.31	48.85	49.19	48.74	49.27	49.56	49.69	49.07	49.80	49.36	47.50	47.44	47.56	48.58	50.38	49.96	49.51	49.51	49.52	49.61	49.98	48.48				49.70	49.40	49.33	48.42	48.46	48.58
	20	46	22.90	53.18	54.28	53.41	54.27	54.09	53.31	54.01	54.41	54.55	53.91	54.38	54.23	52.66	52.79	52.77	53.34	55.14	54.94	54.69	54.80	54.11	54.50	54.71	53.17				54.70	54.38	54.57	53.62	53.36	53.76
		47	22.86	48.90	49.92	49.34	49.38	49.73	49.55	49.88	50.21	50.20	48.87	50.15	50.08	48.36	48.97	48.64	49.93	51.04	50.75	50.99	50.82	51.28	51.08	51.13	49.94				50.66	51.01	51.08	50.49	49.96	50.68
	21	48	22.85	50.05	50.83	50.24	50.67	50.80	50.55	51.55	52.03	51.66	49.48	51.39	51.07	49.69	50.11	49.68	50.86	52.18	51.95	52.44	52.70	52.49	52.07	52.61	51.19				52.51	52.75	52.82	52.29	51.15	51.94
	Ref	49	22.85	52.31	53.12	52.11	52.79	53.02	53.25	53.67	54.19	53.43	51.96	53.91	53.11	51.78	51.67	52.72	53.34	54.64	53.62	54.57	54.76	54.82	55.01	54.57	53.48				54.76	54.54	54.22	53.79	53.82	54.81
Gardner Bender		50	22.82	53.04	53.91	53.59	54.27	54.49	54.33	54.51	54.63	54.22	54.16	54.86	54.70	53.55	53.28	53.89	54.27	55.96	55.18	55.14	55.77	55.23	56.24	55.22	55.05				56.33	55.73	55.79	56.51	55.47	56.24
	22	51	22.69	53.66	54.11	53.97	54.71	55.02	54.91	55.14	55.52	54.80	54.58	55.20	55.27	53.57	52.89	54.15	54.33	56.56	55.70	55.37	56.50	56.21	56.91	55.79	55.09				56.40	56.89	56.66	57.25	56.09	56.53
		52	22.70	59.15	60.30	61.39	63.00	63.46	63.42	63.63	63.43	62.55	62.30	62.46	62.06	60.52	60.60	60.90	60.69	62.22	61.00	61.81	61.94	61.57	61.16	60.35	59.99				61.06	60.99	60.05	61.57	60.52	61.33
	23	53	22.70	57.96	59.48	60.06	61.63	61.74	60.48	61.87	61.59	61.08	60.51	60.61	59.86	59.36	59.35	59.25	59.30	59.88	59.48	59.78	59.81	59.47	59.70	58.40	58.65				58.92	58.37	58.28	59.16	58.30	59.14
		54	22.69	48.53	48.73	48.85	49.31	49.08	49.33	49.87	49.51	49.40	49.07	49.17	49.49	48.35	48.21	49.38	49.25	50.09	49.37	50.31	50.26	50.98	50.13	50.68	49.76				50.34	50.89	50.78	50.81	50.87	50.56
	24	55	22.67	48.93	49.19	49.36	49.47	49.69	49.29	50.17	49.76	49.93	49.61	49.42	50.01	48.98	48.83	49.55	49.62	51.01	50.24	50.57	50.60	51.09	50.52	50.91	50.31				50.62	51.03	51.01	52.23	51.43	51.51
	Ref	56	22.67	50.30	50.45	50.53	50.97	50.51	50.98	51.60	50.90	51.36	51.00	51.29	51.42	50.75	51.16	51.15	51.30	52.26	51.60	51.74	51.74	52.88	52.04	52.03	51.84				52.01	53.03	53.29	52.89	52.51	53.01

AVE TEMP (20A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		36	No Data	60.77	59.99	59.24	58.80	58.40	58.00	57.49	57.52	57.76	57.57	57.30	57.23	57.33	57.76	57.80	57.64	57.23	56.62	55.92	55.94	55.93	55.88	56.18	56.41	Power Outage			55.04	54.76	54.33	53.61	53.61	53.38
	16	37	No Data	59.73	59.15	58.20	57.97	57.61	57.21	56.61	56.80	57.16	56.97	56.73	56.67	56.83	57.26	57.16	56.99	56.29	55.69	55.13	54.96	54.78	54.74	55.25	55.77				54.45	53.99	53.52	52.73	52.79	52.83
		38	No Data	51.64	51.53	51.16	51.23	51.05	50.88	50.46	50.78	51.23	51.13	51.05	51.16	51.32	51.72	51.89	51.78	51.21	50.92	50.47	50.25	50.03	50.05	50.54	51.13				50.27	50.05	50.06	49.36	48.98	49.14
	17	39	No Data	52.36	52.28	51.85	51.98	51.84	51.62	51.21	51.53	51.98	51.88	51.79	51.87	52.06	52.56	52.70	52.44	51.80	51.50	51.02	50.73	50.55	50.45	51.19	51.86				50.82	50.31	50.14	49.41	49.31	49.63
		40	No Data	57.10	56.83	56.46	56.37	56.22	56.18	55.59	55.98	56.44	56.20	56.06	56.21	56.40	56.80	56.96	56.68	56.18	55.89	55.15	55.04	54.84	54.94	55.52	56.13				55.55	55.12	55.25	54.72	53.96	54.04
	18	41	54.35	54.35	54.11	53.73	53.66	53.51	53.53	53.04	53.48	53.89	53.63	53.60	53.69	53.85	54.28	54.42	54.35	53.89	53.64	52.95	52.89	52.64	52.80	53.23	53.72				53.56	53.41	53.53	53.05	52.25	52.22
	Ref	42	54.46	54.97	54.95	54.71	54.71	54.56	54.52	53.98	54.20	54.69	54.53	54.54	54.65	54.74	55.27	55.60	55.45	55.02	54.56	53.63	53.65	53.55	53.64	54.24	54.82				54.09	53.61	53.64	53.01	52.33	52.35
WAGO		43	52.34	52.86	52.83	52.65	52.62	52.60	52.50	52.13	52.17	52.55	52.49	52.40	52.46	52.56	52.85	53.12	53.35	53.18	52.71	52.00	51.96	51.99	52.03	52.35	52.75				52.16	51.89	51.76	51.15	50.90	50.94
	19	44	53.85	54.41	54.30	54.00	53.94	53.89	53.83	53.35	53.46	53.91	53.75	53.66	53.72	53.80	54.13	54.38	54.58	54.37	53.78	53.02	52.99	52.96	52.95	53.43	53.89				53.19	52.78	52.71	52.01	51.65	51.73
		45	50.72	51.29	51.32	51.11	51.09	51.09	50.95	50.66	50.76	51.10	51.02	50.93	50.92	51.04	51.30	51.57	51.85	51.73	51.16	50.53	50.46	50.43	50.40	50.82	51.21				50.58	50.27	50.16	49.44	49.33	49.44
	20	46	55.98	56.52	56.48	56.35	56.23	56.22	56.14	55.79	55.84	56.15	56.05	55.95	55.94	56.04	56.30	56.56	56.87	56.79	56.22	55.57	55.55	55.52	55.52	55.84	56.16				55.66	55.47	55.45	54.85	54.58	54.61
		47	51.11	51.74	51.95	51.89	51.88	52.04	51.95	51.98	52.00	52.08	52.09	52.14	52.02	52.10	52.29	52.67	52.98	53.07	52.61	52.25	52.21	52.28	52.28	52.43	52.63				52.20	52.09	52.00	51.41	51.24	51.27
	21	48	52.89	53.69	53.92	53.82	53.79	54.02	53.95	53.96	54.15	54.19	54.09	54.18	54.06	54.11	54.26	54.64	54.97	55.03	54.55	54.19	54.18	54.16	54.18	54.41	54.71				54.26	54.06	54.03	53.42	53.12	53.16
	Ref	49	55.39	56.19	56.54	56.47	56.49	56.91	56.47	56.79	56.93	57.03	56.85	56.95	56.66	56.83	57.08	57.66	57.59	57.74	57.32	56.91	56.86	57.09	56.76	57.41	57.60				57.35	56.52	56.08	55.30	55.86	56.14
Gardner Bender		50	55.71	56.39	56.97	57.15	57.15	57.46	57.23	57.60	57.66	57.54	57.44	57.62	57.34	57.48	57.84	58.33	58.40	58.63	58.28	58.15	58.10	58.30	58.26	58.34	58.49				58.28	58.09	58.02	57.49	57.48	57.52
	22	51	57.01	57.72	58.08	58.21	58.23	58.63	58.29	58.74	58.92	58.77	58.59	58.80	58.43	58.63	59.01	59.53	59.52	59.77	59.39	59.19	59.16	59.37	59.28	59.54	59.74				59.43	59.11	58.93	58.28	58.38	58.45
		52	61.13	62.84	64.45	65.90	67.06	67.63	66.98	67.63	67.46	66.66	66.23	66.31	65.41	65.37	65.53	65.90	65.57	65.67	65.29	65.24	64.97	65.14	64.86	64.73	64.52				64.38	64.15	63.84	63.18	63.10	63.09
	23	53	60.07	61.53	62.97	64.21	65.24	65.72	65.02	65.67	65.39	64.69	64.29	64.34	63.48	63.40	63.57	63.87	63.60	63.66	63.37	63.36	63.05	63.27	62.97	62.78	62.55				62.09	61.88	61.63	61.02	60.93	60.90
		54	51.35	51.69	51.99	52.22	52.26	52.59	52.15	53.04	52.90	52.57	52.45	52.70	52.18	52.40	52.98	53.66	53.45	53.67	53.44	53.40	53.28	53.83	53.66	53.82	53.81				53.51	53.33	52.99	52.50	52.79	52.86
	24	55	51.67	52.13	52.52	52.75	52.78	53.22	52.76	53.77	53.72	53.26	53.14	53.43	52.83	53.04	53.59	54.30	54.07	54.37	54.23	54.30	54.19	54.70	54.52	54.63	54.56				54.52	54.43	54.18	53.65	53.87	53.96
	Ref	56	52.96	53.47	54.00	54.16	54.27	54.76	54.18	55.51	55.43	54.79	54.68	55.02	54.35	54.51	55.12	55.81	55.56	55.92	55.88	56.09	55.95	56.60	56.32	56.32	56.07				56.26	56.30	56.11	55.67	56.01	56.06

MAX TEMP (Ambient, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
50A																																				
IDEAL	1-3	1	23.37	23.48	23.45	23.95	23.75	23.61	23.47	23.24	23.33	23.51	23.61	23.55	23.58	23.74	24.22	24.47	24.45	24.44	24.16	23.67	23.68	23.65	23.62	23.84	24.15	24.10	23.45	23.10	23.61	23.43	23.42	22.93	22.84	22.87
WAGO	4-6	2	23.80	23.31	23.32	23.82	23.57	23.47	23.33	23.14	23.19	23.30	23.42	23.41	23.42	23.61	24.07	24.32	24.36	24.36	24.03	23.64	23.56	23.52	23.50	23.66	23.99	24.00	23.43	23.05	23.52	23.34	23.39	22.80	22.77	22.74
30A																																				
IDEAL	7-9	3	23.43	23.19	23.10	23.47	23.40	23.23	23.13	22.93	22.95	23.15	23.23	23.24	23.21	23.43	23.92	24.16	24.20	24.11	23.85	23.38	23.36	23.37	23.31	23.44	23.79	23.77	23.39	22.97	23.29	23.26	23.31	22.77	22.49	22.50
WAGO	10-12	4	23.59	23.19	23.13	23.49	23.41	23.26	23.11	22.92	22.96	23.18	23.27	23.24	23.25	23.51	23.98	24.25	24.16	24.08	23.84	23.38	23.33	23.33	23.28	23.40	23.85	23.80	23.38	22.97	23.23	23.22	23.28	22.75	22.51	22.49
Gardner Bender	13-15	5	23.66	23.21	23.15	23.67	23.49	23.31	23.12	22.92	23.06	23.21	23.30	23.28	23.25	23.56	24.04	24.38	24.19	24.08	23.84	23.37	23.28	23.35	23.27	23.44	24.01	23.82	23.43	23.12	23.21	23.18	23.24	22.73	22.47	22.46
20A																																				
IDEAL	16-18	6	23.58	23.28	23.22	23.76	23.53	23.36	23.16	23.03	23.10	23.31	23.37	23.38	23.38	23.65	24.11	24.30	24.28	24.21	23.93	23.48	23.35	23.44	23.36	23.54	23.97	23.92	23.43	23.10	23.28	23.17	23.23	22.72	22.55	No Data
WAGO	19-21	7	23.66	23.28	23.24	23.61	23.50	23.35	23.17	22.99	23.05	23.27	23.35	23.36	23.37	23.62	24.10	24.25	24.24	24.13	23.89	23.46	23.37	23.44	23.33	23.49	23.83	23.94	23.42	23.02	23.27	23.18	23.22	22.68	22.60	22.59
Gardner Bender	22-24	8	23.70	23.23	23.22	23.55	23.46	23.32	23.15	22.95	23.02	23.26	23.34	23.33	23.36	23.59	24.06	24.22	24.22	24.12	23.85	23.43	23.33	23.41	23.30	23.43	23.83	23.91	23.41	22.98	23.26	23.15	23.17	22.64	22.55	22.54

MIN TEMP (Ambient, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
50A																																				
IDEAL	1-3	1	22.86	23.21	23.18	23.24	23.38	23.21	23.09	23.04	22.91	23.06	23.28	23.23	23.27	23.39	23.69	24.13	24.13	23.99	23.67	23.31	23.28	23.39	23.31	23.36	23.63	23.42	22.87	22.71	22.65	23.16	22.61	22.37	22.37	22.49
WAGO	4-6	2	23.07	23.11	23.07	23.12	23.27	23.11	22.98	22.90	22.81	22.96	23.17	23.13	23.14	23.30	23.58	23.99	24.05	23.89	23.62	23.26	23.19	23.31	23.18	23.21	23.47	23.40	22.81	22.66	22.60	23.09	22.58	22.32	22.29	22.40
30A																																				
IDEAL	7-9	3	22.96	22.95	22.88	22.94	23.12	22.92	22.78	22.74	22.64	22.77	23.00	22.95	22.96	23.12	23.43	23.87	23.89	23.66	23.35	23.07	23.06	23.05	23.00	23.06	23.27	23.34	22.77	22.60	22.55	22.90	22.58	22.28	22.18	22.28
WAGO	10-12	4	22.96	22.99	22.92	22.97	23.15	22.94	22.78	22.71	22.66	22.82	23.03	22.98	22.99	23.13	23.47	23.91	23.92	23.68	23.32	23.06	23.07	23.05	23.01	23.03	23.27	23.35	22.79	22.63	22.55	22.89	22.61	22.26	22.21	22.28
Gardner Bender	13-15	5	22.98	22.99	22.91	22.99	23.15	22.94	22.78	22.71	22.64	22.84	23.01	22.98	22.99	23.13	23.50	23.95	23.90	23.66	23.34	23.06	23.06	23.03	22.98	23.03	23.30	23.37	22.82	22.70	22.57	22.87	22.58	22.21	22.19	22.27
20A																																				
IDEAL	16-18	6	23.06	23.04	23.00	23.05	23.24	23.03	22.82	22.79	22.71	22.95	23.11	23.05	23.07	23.21	23.61	24.07	24.02	23.74	23.44	23.15	23.10	23.16	23.05	23.09	23.37	23.39	22.83	22.70	22.54	22.95	22.55	22.20	22.22	No Data
WAGO	19-21	7	23.07	23.04	22.96	23.03	23.23	23.00	22.81	22.75	22.66	22.92	23.08	23.02	23.04	23.18	23.59	24.04	24.00	23.72	23.42	23.06	23.03	23.16	23.04	23.07	23.35	23.39	22.82	22.67	22.52	22.91	22.54	22.20	22.16	22.26
Gardner Bender	22-24	8	23.06	23.04	22.93	22.98	23.21	22.96	22.79	22.73	22.64	22.89	23.04	23.01	23.01	23.16	23.56	24.00	24.00	23.72	23.36	23.03	23.01	23.11	23.00	23.03	23.30	23.36	22.79	22.65	22.51	22.89	22.50	22.15	22.11	22.22

AVE TEMP (Ambient, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
50A																																				
IDEAL	1-3	1	23.23	23.31	23.29	23.44	23.51	23.41	23.26	23.16	23.07	23.28	23.41	23.40	23.42	23.58	23.99	24.28	24.29	24.18	23.92	23.57	23.47	23.51	23.43	23.58	23.86	23.69	23.24	22.92	23.29	23.28	23.14	22.73	22.68	22.69
WAGO	4-6	2	23.19	23.22	23.17	23.33	23.39	23.29	23.17	23.04	22.95	23.16	23.28	23.27	23.30	23.48	23.90	24.17	24.19	24.09	23.84	23.51	23.39	23.40	23.34	23.45	23.73	23.64	23.22	22.89	23.20	23.20	23.06	22.64	22.59	22.60
30A																																				
IDEAL	7-9	3	23.04	23.05	22.99	23.15	23.23	23.09	22.95	22.82	22.76	22.99	23.10	23.09	23.11	23.30	23.75	24.00	23.99	23.84	23.60	23.26	23.17	23.16	23.10	23.22	23.53	23.55	23.16	22.83	22.99	23.03	22.89	22.51	22.41	22.40
WAGO	10-12	4	23.06	23.07	23.02	23.18	23.26	23.11	22.96	22.83	22.78	23.02	23.13	23.11	23.13	23.33	23.78	24.04	24.01	23.83	23.60	23.27	23.18	23.17	23.10	23.24	23.56	23.56	23.16	22.84	23.00	23.01	22.88	22.50	22.40	22.40
Gardner Bender	13-15	5	23.07	23.08	23.02	23.20	23.26	23.12	22.96	22.82	22.78	23.03	23.14	23.11	23.13	23.34	23.80	24.07	24.02	23.84	23.59	23.24	23.16	23.15	23.08	23.25	23.59	23.59	23.22	22.91	23.00	22.98	22.85	22.46	22.37	22.37
20A																																				
IDEAL	16-18	6	23.18	23.17	23.09	23.26	23.35	23.23	23.04	22.92	22.86	23.13	23.23	23.22	23.24	23.46	23.94	24.20	24.17	23.95	23.71	23.34	23.23	23.25	23.16	23.36	23.68	23.65	23.20	22.90	23.06	23.04	22.89	22.47	22.43	No Data
WAGO	19-21	7	23.20	23.18	23.09	23.26	23.35	23.21	23.03	22.90	22.83	23.11	23.22	23.19	23.22	23.44	23.92	24.18	24.14	23.93	23.68	23.33	23.21	23.25	23.17	23.32	23.65	23.64	23.20	22.88	23.03	23.03	22.91	22.49	22.45	22.45
Gardner Bender	22-24	8	23.18	23.17	23.08	23.25	23.33	23.18	23.01	22.86	22.81	23.10	23.20	23.17	23.20	23.42	23.89	24.14	24.11	23.90	23.64	23.29	23.18	23.21	23.13	23.29	23.61	23.62	23.19	22.87	23.00	23.00	22.88	22.46	22.41	22.40

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215 Centerview Dr
Brentwood TN 37027

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215 Centerview Dr
Brentwood TN 37027

Report Date: October 27, 2017

Description:	CCA –Cu Ampacity Comparison
Type of Evaluation	Fact Finding Investigation
Job Number	J-00265162
Project Number	0225-104
Project Manager	Don Tottingham
Location	789 Dixboro Road, Ann Arbor
Inspection Dates	August 7- August 18, 2017
Total # of Pages	125 Pages

Evaluated By: _____

Anas Alaghazali- Engineer

Reviewed By: Steve Fabian

Steve Fabian- Senior Technical Manager

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Purpose: The purpose of this testing was to evaluate copper clad aluminum wire (CCA) and copper wire (Cu) as a single conductor, non- -metallic 2 hot conductors, and two conductor in conduit, under the same current condition, and to determine their equivalence in performance

Credentials: NSF International, an accredited Nationally Recognized Testing Laboratory (NRTL), an Accredited Standards Council of Canada (SCC) laboratory, and accredited by the International Standards Organization (ISO) to ISO 14001.

Executive Summary: This Fact-Finding Investigation was conducted to develop a comparative temperature – heat rise database for Copper and Copper-Clad Aluminum Conductors in Sizes No. 14 -10 AWG.

The details of the test procedure for each conductor size, 14-10 AWG, is outlined in the report.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 14 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 18, 29, and 38.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 12 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 50, 61, and 71.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 10 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 87, 100, and 113.

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Test Set- Up/ Layout
14 AWG single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 14AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 14AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 14 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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FIGURE 1
Circuit Layout

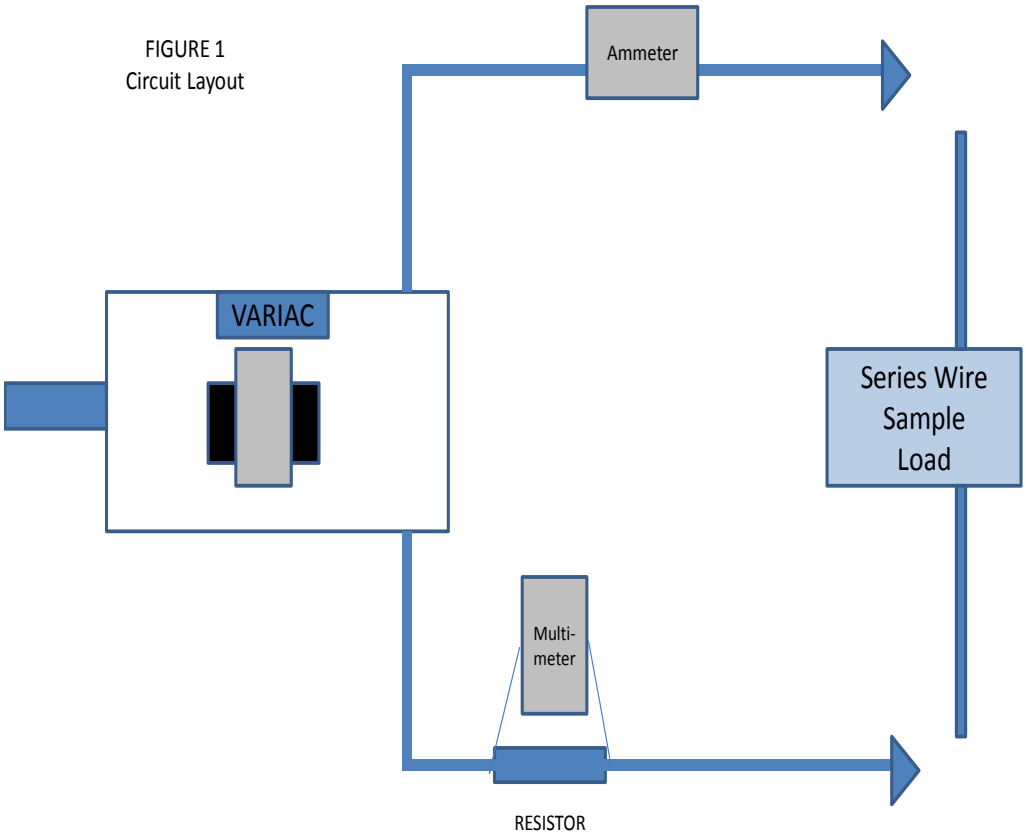

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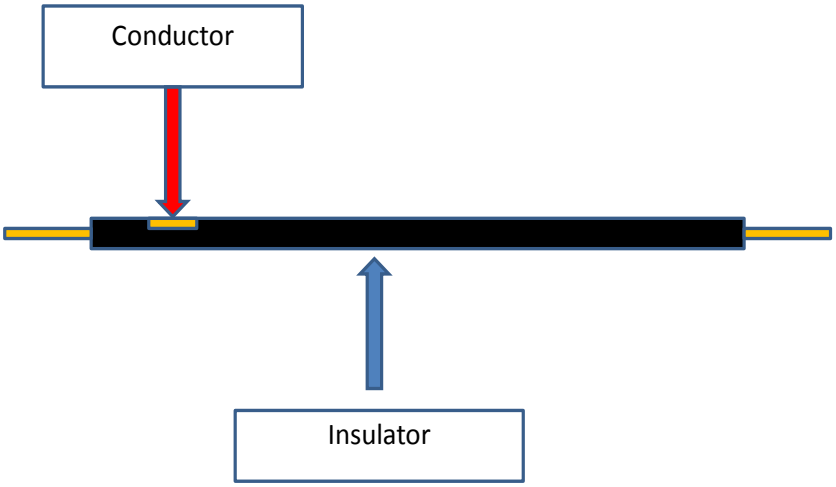
FIGURE 2
Single conductor



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Test Procedure
14 AWG Single Conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	Open air	5	30
14	Open air	10	30
14	Open air	15	30
14	Open air	20	30
14	Open air	25	30
14	Open air	30	30
14	Open air	35	30
14	Open air	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA Single Conductor open Air (Page 1/3))

Scan	Time	Elapsed	212 CU-AL #1 Core	213 CU-AL #1 Insu	203 CU-AL#2 Core	204 CU-AL#2 Insu	205 CU-AL#3 Insu
	5 AMPS						
32.00	42956.43	00:00:30:59	23.66	23.26	23.60	23.45	23.89
		Corrected Ambient	32.38	31.98	32.32	32.17	32.61
		Average	32.31				
		Average Core	32.40				
		Average Insulation	32.20				
	10 AMPS						
62.00	42956.45	00:01:00:59	28.37	28.10	27.74	28.35	28.81
		Corrected Ambient	36.96	36.69	36.33	36.94	37.40
		Average	36.38				
		Average Core	36.52				
		Average Insulation	36.22				
	15 AMPS						
92.00	42956.47	00:01:30:59	33.80	33.78	32.88	33.88	34.50
		Corrected Ambient	42.42	42.40	41.50	42.50	43.12
		Average	41.70				
		Average Core	42.16				
		Average Insulation	41.20				
	20 AMPS						
122.00	42956.49	00:02:00:59	43.82	43.54	42.12	43.28	44.61
		Corrected Ambient	52.04	51.76	50.34	51.50	52.83

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		Average	50.79				
		Average Core	51.77				
		Average Insulation	49.71				
	25 AMPS						
154.00	42956.52	00:02:32:59	53.50	53.49	51.23	52.53	54.61
		Corrected Ambient	61.81	61.80	59.54	60.84	62.92
		Average	60.07				
		Average Core	61.51				
		Average Insulation	58.50				
	30 AMPS						
183.00	42956.54	00:03:01:59	69.00	67.27	65.45	65.49	69.18
		Corrected Ambient	77.08	75.35	73.53	73.57	77.26
		Average	73.57				
		Average Core	75.91				
		Average Insulation	71.02				
	35 AMPS						
216.00	42956.56	00:03:34:59	85.83	83.73	80.52	81.75	86.71
		Corrected Ambient	93.96	91.86	88.65	89.88	94.84
		Average	89.81				
		Average Core	92.67				
		Average Insulation	86.68				

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14 AWG CCA Single Conductor open Air (Page 2/3))

208 CU-AL#3 Core	120 CU-AL #4 Core	211 CU-AL#4 Insu	102 CU-AL#5 Core	110 CU-AL#5 Insu	117 CU-AL#6 Core	116 CU-AL#7 Insul	320 CU-AL#7 Core	113 CU-AL#8 Core
23.51	23.63	23.37	23.62	23.47	23.86	23.44	23.36	23.79
32.23	32.35	32.09	32.34	32.19	32.58	32.16	32.08	32.51
27.61	27.35	26.86	27.79	27.18	27.93	27.43	27.16	27.92
36.20	35.94	35.45	36.38	35.77	36.52	36.02	35.75	36.51
32.59	32.02	31.20	33.01	31.82	33.24	31.93	32.18	33.99
41.21	40.64	39.82	41.63	40.44	41.86	40.55	40.80	42.61
41.25	41.32	38.66	42.34	39.53	43.15	40.71	41.44	44.59
49.47	49.54	46.88	50.56	47.75	51.37	48.93	49.66	52.81

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49.39	49.93	45.71	51.18	46.84	52.51	48.79	50.05	53.67
57.70	58.24	54.02	59.49	55.15	60.82	57.10	58.36	61.98
62.25	62.46	56.14	64.18	58.21	68.21	60.49	63.39	67.06
70.33	70.54	64.22	72.26	66.29	76.29	68.57	71.47	75.14
76.43	76.02	68.71	79.20	71.51	84.64	74.08	77.84	82.07
84.56	84.15	76.84	87.33	79.64	92.77	82.21	85.97	90.20

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14 AWG CCA Single Conductor open Air (Page 3/3))

114 CU-AL#8 Insul	109 CU-AL#9 Core	112 CU-AL#9 Insul	106 CU-AL#10 Core	107 CU-AL#10 Insul	101 CU-AL#11 Core	103 CU-AL#11 Insul	104 CU-AL#12 Core	105 CU-AL#12 Insul
23.65	23.82	23.63	23.82	23.54	23.54	23.19	23.97	23.43
32.37	32.54	32.35	32.54	32.26	32.26	31.91	32.69	32.15
27.87	27.44	27.22	27.77	27.44	28.29	26.84	29.82	27.86
36.46	36.03	35.81	36.36	36.03	36.88	35.43	38.41	36.45
32.54	33.29	31.49	33.60	32.07	34.85	31.62	37.00	33.55
41.16	41.91	40.11	42.22	40.69	43.47	40.24	45.62	42.17
42.59	42.44	39.88	44.38	40.51	46.65	40.27	49.14	42.83

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50.81	50.66	48.10	52.60	48.73	54.87	48.49	57.36	51.05
51.66	51.50	47.77	54.91	48.80	58.73	49.17	61.74	52.68
59.97	59.81	56.08	63.22	57.11	67.04	57.48	70.05	60.99
64.87	64.44	60.00	70.51	61.42	75.50	62.17	81.54	67.10
72.95	72.52	68.08	78.59	69.50	83.58	70.25	89.62	75.18
81.21	80.84	74.81	88.65	76.44	96.72	79.11	105.73	86.00
89.34	88.97	82.94	96.78	84.57	104.85	87.24	113.86	94.13

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14 AWG Cu Single conductor open air (Page 1/2))

Scan	Time	Elapsed	313 CU#1 Insul	312 CU#1 Core	309 CU#2 Core	310 CU#2 Insul	304 CU#3 Core	305 CU#3 Insul
	5 AMPS							
32.00	42956.43	00:00:30:59	22.94	22.76	23.27	22.75	23.19	22.87
		Corrected Ambient	31.66	31.48	31.99	31.47	31.91	31.59
		Average	31.76					
		Average Core	31.82					
		Average Insulation	31.70					
	10 AMPS							
62.00	42956.45	00:01:00:59	26.12	25.30	26.88	25.64	25.98	25.79
		Corrected Ambient	34.71	33.89	35.47	34.23	34.57	34.38
		Average	34.71					
		Average Core	34.68					
		Average Insulation	34.75					
	15 AMPS							
92.00	42956.47	00:01:30:59	29.59	28.15	30.84	28.94	29.08	29.21
		Corrected Ambient	38.21	36.77	39.46	37.56	37.70	37.83
		Average	38.20					
		Average Core	38.06					
		Average Insulation	38.34					

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	20 AMPS							
122.00	42956.49	00:02:00:59	35.06	33.50	38.22	34.03	34.76	34.30
		Corrected Ambient	43.28	41.72	46.44	42.25	42.98	42.52
		Average	43.85					
		Average Core	44.07					
		Average Insulation	43.64					
	25 AMPS							
154.00	42956.52	00:02:32:59	41.11	39.21	44.97	39.53	39.76	39.48
		Corrected Ambient	49.42	47.52	53.28	47.84	48.07	47.79
		Average	49.79					
		Average Core	49.98					
		Average Insulation	49.60					
	30 AMPS							
183.00	42956.54	00:03:01:59	50.05	48.57	55.19	47.04	46.81	46.68
		Corrected Ambient	58.13	56.65	63.27	55.12	54.89	54.76
		Average	58.05					
		Average Core	58.69					
		Average Insulation	57.42					
	35 AMPS							
216.00	42956.56	00:03:34:59	58.77	56.46	67.22	55.89	54.87	54.95
		Corrected Ambient	66.90	64.59	75.35	64.02	63.00	63.08
		Average	67.08					
		Average Core	67.91					
		Average Insulation	66.25					

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14 AWG Cu Single Conductor open Air (Page 2/2))

206 CU#4 Core	302 CU#4 Insul	218 CU#5 Core	220 CU#5 Insul	209 CU#6 Core	214 CU#6 Insul
23.07	23.20	23.11	22.85	23.21	23.30
31.79	31.92	31.83	31.57	31.93	32.02
26.07	26.44	26.00	26.11	26.30	26.84
34.66	35.03	34.59	34.70	34.89	35.43
29.44	30.07	29.34	29.78	29.81	30.74
38.06	38.69	37.96	38.40	38.43	39.36
35.82	35.84	35.94	35.90	36.83	37.36

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44.04	44.06	44.16	44.12	45.05	45.58
41.32	41.65	41.70	41.84	43.06	44.11
49.63	49.96	50.01	50.15	51.37	52.42
50.11	49.91	50.16	49.62	52.82	52.73
58.19	57.99	58.24	57.70	60.90	60.81
59.11	58.81	59.35	57.77	61.68	62.52
67.24	66.94	67.48	65.90	69.81	70.65

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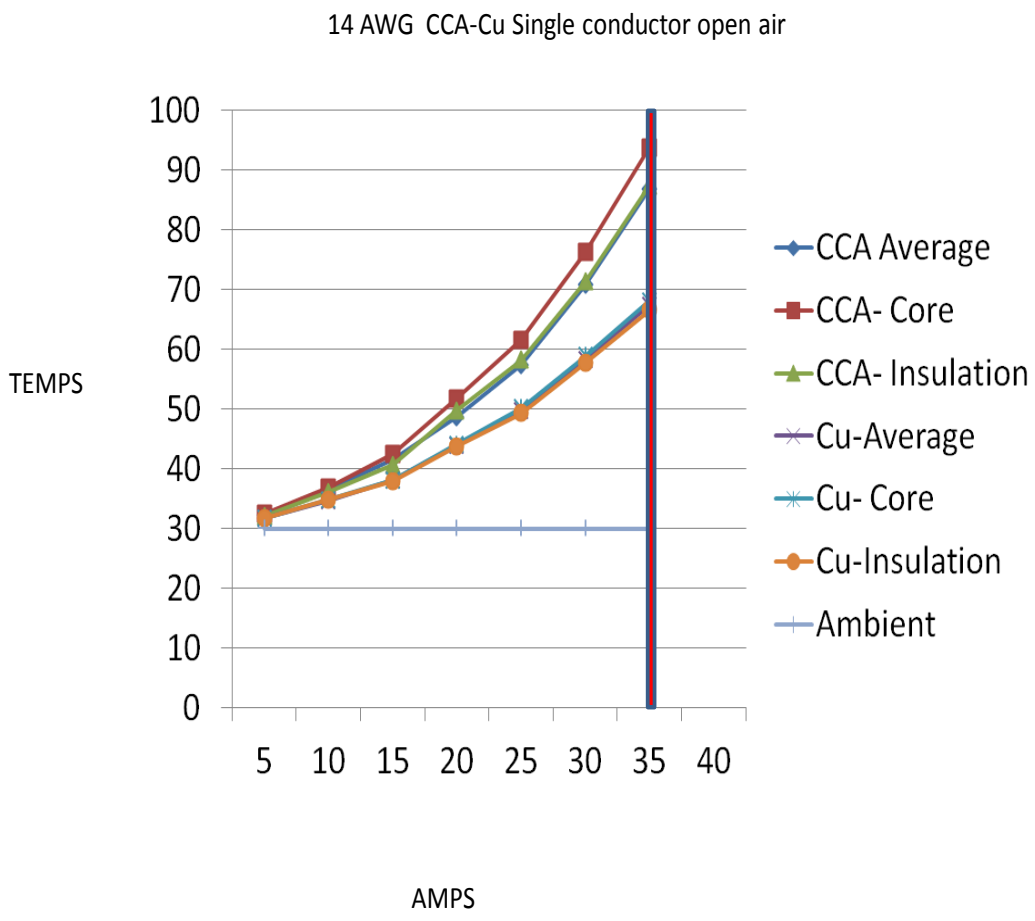

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Test Set- Up/ Layout
14 AWG in non-metallic cable in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 14 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 14 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 14 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used is calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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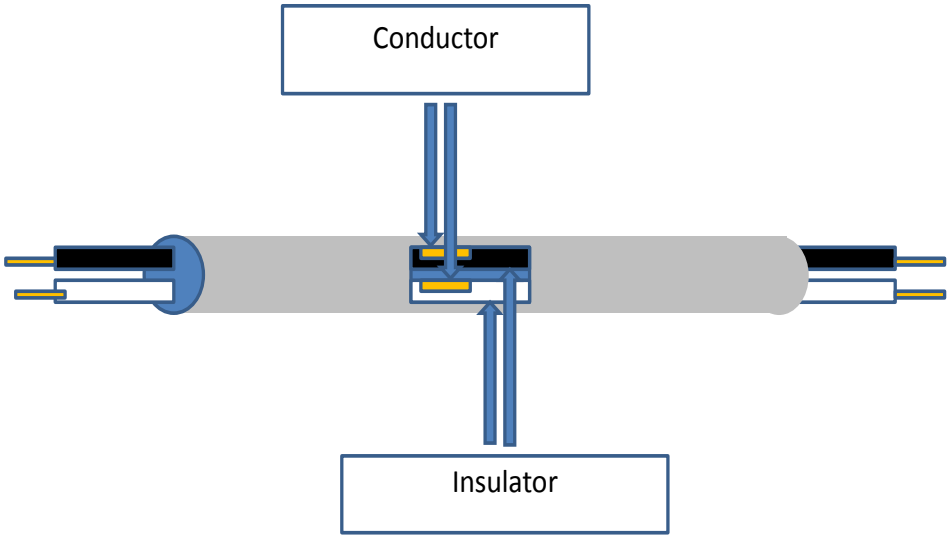
FIGURE 3
Two Line Conductor/ Ground(not connected) Non- metallic Cable



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Test Procedure
14 AWG in Non-metallic cable

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.
.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	NM Cable	5	30
14	NM Cable	10	30
14	NM Cable	15	30
14	NM Cable	20	30
14	NM Cable	25	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA Non Metallic (2 Conductor) open air (Page 1/3)

Scan	Time	Elapsed	101-CU-AL White Cable-Core	103 CU-AL White Cable Insulation	104 CU-AL Black Cable Core	105 CU-AL Black Cable Insulation	106 CU-AL Black Cable Core
29	5 AMPS	00:00:27:59					
30	8/15/2017 12:13	00:00:28:59	24.592	24.57	24.179	24.336	24.308
		Corrected Ambient	32.96	32.94	32.55	32.71	32.68
		Average	32.80				
		Average Core	32.92				
		Average Insulation	32.86				
60	10 AMPS	00:00:58:59	29.924	30.049	28.525	28.47	28.704
61	8/15/2017 12:44	00:00:59:59	29.497	30.014	28.308	28.427	28.595
		Corrected Ambient	37.95	38.46	36.76	36.88	37.04
		Average	37.53				
		Average Core	38.05				
		Average Insulation	38.13				
88	15 AMPS	00:01:26:59					
89	8/15/2017 13:12	00:01:27:59	37.658	38.549	35.166	34.525	34.751
		Corrected Ambient	45.92	46.81	43.43	42.79	43.02
		Average	44.46				
		Average Core	45.13				
		Average Insulation	45.22				
120	20 AMPS	00:01:58:59					
121	8/15/2017 13:44	00:01:59:59	48.404	50.441	43.994	43.521	43.462
		Corrected Ambient	56.61	58.65	52.20	51.73	51.67

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		Average	54.26				
		Average Core	54.78				
		Average Insulation	55.89				
151	25 AMPS	00:02:29:59					
152	8/15/2017 14:15	00:02:30:59	64.72	68.548	57.572	55.957	56.371
		Corrected Ambient	73.02	76.85	65.87	64.26	64.67
		Average	68.95				
		Average Core	69.61				
		Average Insulation	71.60				

14 AWG CCA Non Metallic (2 Conductor) open air (Page 2/3)

107 CU-AL Black Cable Insulation	109 CU-AL White Cable Core	112 CU-AL White Cable# 2 Insulation	113 CU-AL Black Cable#3 Core	114 CU-AL Black Cable #3 Insulation	116 CU-AL White Cable #3 Insulation	320 CU-AL White Cable#3 Core	315 CU-AL Black Cable#4 Core	118 CU-AL Black Cable#4 Insulation	102 CU-AL White Cable #4 Core
24.3	24.745	24.436	24.638	24.609	24.972	25.105	24.416	23.739	24.551
32.67	33.12	32.81	33.01	32.98	33.34	33.48	32.79	32.11	32.92
28.89	29.97	29.341	29.59	29.289	30.546	31.225	29.545	29.786	29.823
28.741	29.96	29.233	29.734	29.38	30.642	31.368	29.462	29.627	29.73
37.19	38.41	37.68	38.18	37.83	39.09	39.82	37.91	38.08	38.18

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35.244	37.473	35.97	36.069	36.113	38.561	39.712	36.608	35.975	37.473
43.51	45.74	44.23	44.33	44.38	46.83	47.98	44.87	44.24	45.74
44.923	47.618	47.015	45.275	46.599	50.61	51.411	46.52	44.202	47.657
53.13	55.83	55.22	53.48	54.81	58.82	59.62	54.73	52.41	55.86
58.491	62.893	62.242	58.51	61.014	67.133	69.89	61.364	57.959	63.192
66.79	71.19	70.54	66.81	69.32	75.43	78.19	69.67	66.26	71.49

14 AWG CCA Non Metallic (2 Conductor) open air (Page 3/3)

110 CU-AL White Cable#4 Insulation	120 CU-AL Black Cable#5 Core	211 CU-AL Black Cable#5 Insulation	205CU-AL White Cable#5 Insulation	208 CU-AL White Cable#5 Core	203 CU-AL Black Cable#6 Core	204 CU-AL Black Cbale#6 Insulation	212 CU-AL White Cable#6 Core	213 CU-AL White Cable#6 Insulation
25.194	24.66	25.029	24.923	24.407	24.321	24.045	24.677	23.717
33.56	33.03	33.40	33.29	32.78	32.69	32.42	33.05	32.09

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31.019	29.933	30.894	30.803	29.33	29.022	29.051	30.233	28.558
31.019	29.959	30.909	30.863	29.348	29.055	28.806	30.238	28.543
39.47	38.41	39.36	39.31	37.80	37.50	37.26	38.69	36.99
39.162	37.293	38.859	38.947	35.984	35.982	36.311	38.22	35.275
47.43	45.56	47.12	47.21	44.25	44.25	44.58	46.48	43.54
51.486	47.619	50.771	50.602	44.739	43.968	46.287	48.202	45.682
59.69	55.83	58.98	58.81	52.95	52.18	54.49	56.41	53.89
69.419	62.641	68.43	68.105	58.395	56.519	61.868	63.671	60.471
77.72	70.94	76.73	76.41	66.70	64.82	70.17	71.97	68.77

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14 AWG Cu Non Metallic (2 Conductor) open air
Page (1/2)

Scan	Time	Elapsed	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core
29	5 AMPS	00:00:27:59					
30	8/15/2017 12:13	00:00:28:59	23.451	23.326	22.977	23.042	22.899
		Corrected Ambient	31.82	31.70	31.35	31.41	31.27
		Average	31.63				
		Average Core	31.61				
		Average Insulation	31.66				
60	10 AMPS	00:00:58:59					
61	8/15/2017 12:44	00:00:59:59	27.177	26.623	25.544	25.678	25.495
		Corrected Ambient	35.63	35.07	33.99	34.13	33.94
		Average	34.60				
		Average Core	34.58				
		Average Insulation	34.62				
88	15 AMPS	00:01:26:59					
89	8/15/2017 13:12	00:01:27:59	32.586	31.152	29.253	29.605	29.106
		Corrected Ambient	40.85	39.42	37.52	37.87	37.37
		Average	38.69				
		Average Core	38.68				
		Average Insulation	38.70				
120	20 AMPS	00:01:58:59					
121	8/15/2017 13:44	00:01:59:59	40.601	37.689	35.231	35.538	35.083
		Corrected Ambient	48.81	45.90	43.44	43.75	43.29

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		Average	44.60				
		Average Core	44.79				
		Average Insulation	44.41				
151	25 AMPS	00:02:29:59					
152	8/15/2017 14:15	00:02:30:59	51.287	47.245	42.544	43.699	41.81
		Corrected Ambient	59.59	55.55	50.85	52.00	50.11
		Average	53.14				
		Average Core	53.05				
		Average Insulation	53.23				

14 AWG Cu Non Metallic (2 Conductor) open air Page (2/2)

302 CU Black Cable#3 Insulation	304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
23.44	23.503	23.264	23.458	23.245	23.126	23.416
31.81	31.87	31.63	31.83	31.62	31.50	31.79
26.374	26.371	26.051	26.426	25.928	25.744	26.369
34.82	34.82	34.50	34.88	34.38	34.19	34.82

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31.135	30.734	30.046	30.955	29.706	29.884	30.947
39.40	39.00	38.31	39.22	37.97	38.15	39.21
37.502	36.586	35.021	37.138	34.631	34.872	36.818
45.71	44.79	43.23	45.35	42.84	43.08	45.03
47.427	44.327	43.744	45.605	42.023	42.908	45.452
55.73	52.63	52.05	53.91	50.32	51.21	53.75

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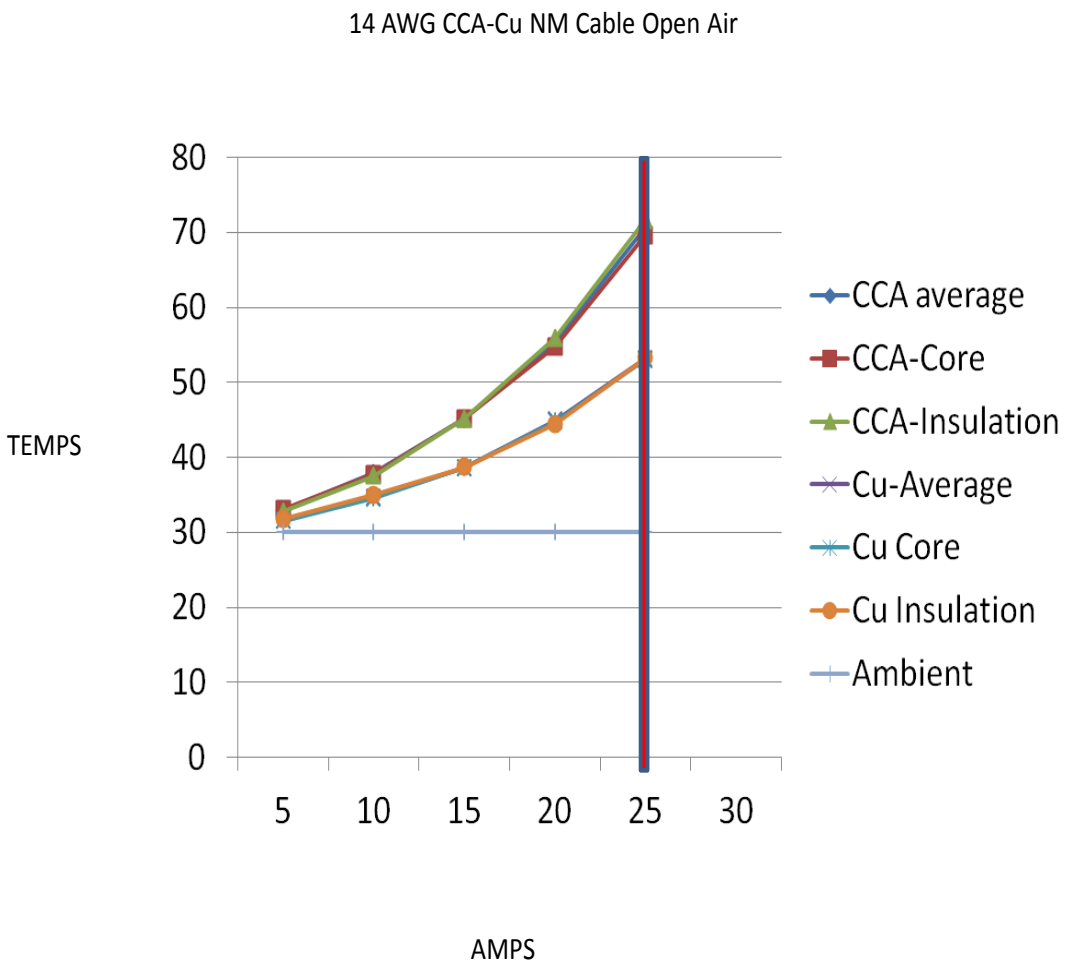

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Test Set- Up/ Layout
14 AWG (2 conductors) in Conduit

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 14 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 14 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 14 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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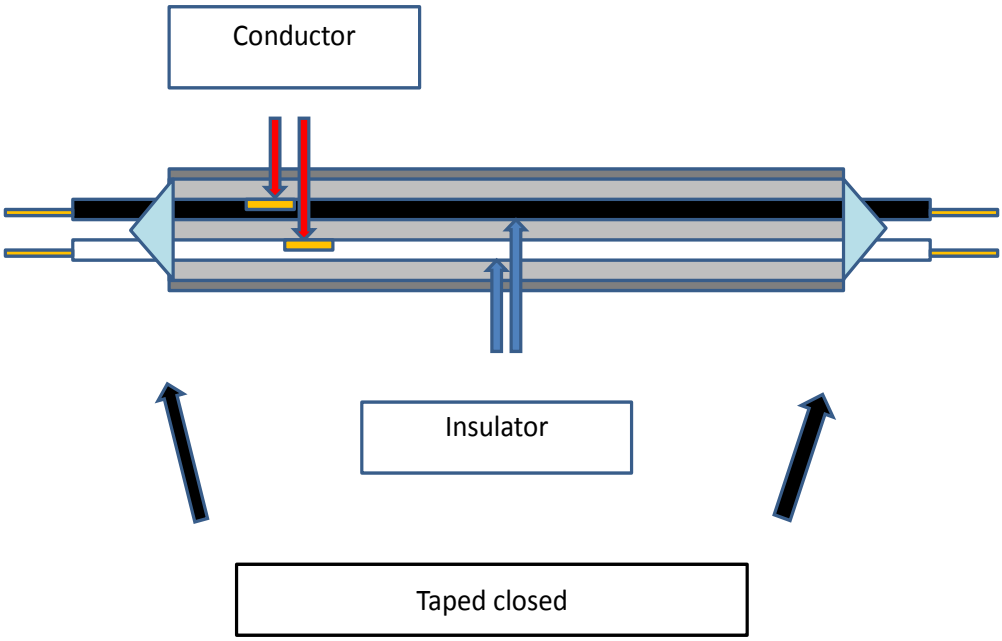
FIGURE 4
Two Conductors in ½ Inch Conduit



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Test Procedure
14 AWG(2 conductors) in Conduit

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 Amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	Conduit	5	30
14	Conduit	10	30
14	Conduit	15	30
14	Conduit	20	30
14	Conduit	25	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA (2 Conductor) in Conduit
Page(1/3)

	101-CCA#1 Core	106 CCA#1 Insulation	107 CCA#2 Core	105 CCA#2 Insulation	112 CCA#3 Core	109 CCA#3 Insulation	113 CCA#4 Core	104 CCA#4 Insulaiton
5 AMPS								
00:00:51:59	24.79	24.61	24.66	24.03	24.04	23.58	23.96	23.72
Corrected Ambient	34.83	34.65	34.70	34.07	34.08	33.62	34.00	33.76
Average	34.19							
Core Average	34.55							
Insulation Average	33.86							
10 AMPS								
00:02:01:59	34.64	34.94	34.84	32.81	32.64	31.25	32.51	31.30
Corrected Ambient	44.83	45.13	45.03	42.99	42.83	41.44	42.70	41.49
Average	43.35							
Core Average	44.12							
Insulation Average	42.64							
15 AMPS								
00:02:52:59	51.48	52.20	52.36	47.74	46.95	43.79	46.60	43.97
Corrected Ambient	61.07	61.78	61.94	57.32	56.53	53.37	56.18	53.55
Average	58.13							
Core Average	59.84							
Insulation Average	56.57							
20 AMPS								
00:03:43:59	72.68	74.44	73.96	66.89	66.02	59.92	64.39	60.07
Corrected Ambient	82.07	83.84	83.35	76.28	75.41	69.31	73.78	69.47
Average	77.26							
Core Average	80.16							
Insulation Average	74.60							
25 AMPS								
00:04:33:59	117.65	117.35	119.71	105.33	107.61	92.87	101.25	92.53
Corrected Ambient	127.06	126.76	129.12	114.74	117.02	102.28	110.66	101.94
Average	117.69							
Core Average	124.41							

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Insulation Average	111.52							

14 AWG CCA (2 Conductor) in Conduit Page(2/3)

120 CCA#5 Core	116 CCA#5 Insulation	110 CCA#6 Core	102 CCA#6 Insulation	118 CCA#7 Insulation	117 CCA#8 Core	103 CCA#8 Insulation	114 CCA#9 Core
24.64	23.92	25.11	24.39	23.42	24.81	23.37	24.43
34.69	33.97	35.15	34.43	33.47	34.85	33.42	34.48
34.64	32.33	35.84	34.63	30.90	33.95	31.16	32.84
44.82	42.52	46.03	44.82	41.09	44.13	41.35	43.03
51.59	46.53	54.59	52.00	43.29	50.64	44.39	47.81
61.17	56.11	64.17	61.58	52.88	60.22	53.97	57.39
73.42	64.63	78.42	73.82	58.67	71.14	60.84	67.02
82.81	74.02	87.81	83.21	68.06	80.53	70.23	76.41
119.35	101.08	128.37	117.64	88.72	117.29	94.74	110.37
128.76	110.49	137.78	127.05	98.13	126.70	104.15	119.78

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14 AWG CCA (2 Conductor) in Conduit Page(3/3)

211 CCA#9 Insulation	212 CCA#10 Core	204 CCA#10 Insulation	220 CCA#11 Core	203 CCA#11 Insulaiton	218 CCA#12 Core	214 CCA#12 Insulation
23.42	24.44	23.75	24.58	24.03	24.15	23.59
33.46	34.48	33.80	34.62	34.07	34.20	33.63
31.17	34.07	33.65	34.69	33.24	32.61	32.04
41.36	44.26	43.84	44.88	43.43	42.80	42.22
45.01	50.94	50.44	52.39	48.40	47.47	46.07
54.59	60.52	60.02	61.97	57.98	57.05	55.65
61.56	71.91	71.23	73.72	67.11	65.73	63.36
70.95	81.30	80.62	83.11	76.50	75.12	72.75
97.96	118.18	113.21	118.54	104.99	106.66	98.95
107.37	127.59	122.62	127.95	114.40	116.07	108.36

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14 AWG Cu (2 Conductor) in Conduit Page 1/2)

	206 CU#1 Core	209 CU#1 Insulation	213 CU#3 Core	208 CU#3 Insualtion	205 CU#5 Core	305 CU#5 Insulation
5 AMPS						
00:00:51:59	22.48	21.97	22.25	22.56	22.77	22.70
Corrected Ambient	32.52	32.02	32.30	32.60	32.81	32.74
Average	32.67					
Core Average	32.81					
Insulation Average	32.53					
10 AMPS						
00:02:01:59	27.37	26.44	27.92	28.45	28.47	28.16
Corrected Ambient	37.56	36.63	38.11	38.63	38.65	38.35
Average	38.29					
Core Average	38.65					
Insulation Average	37.92					
15 AMPS						
00:02:52:59	36.14	34.08	37.61	38.51	38.48	37.28
Corrected Ambient	45.72	43.67	47.19	48.09	48.07	46.86
Average	47.09					
Core Average	47.98					
Insulation Average	46.20					
20 AMPS						
00:03:43:59	45.98	42.87	49.09	50.19	50.16	47.55
Corrected Ambient	55.37	52.26	58.48	59.58	59.56	56.94
Average	57.97					
Core Average	59.56					
Insulation Average	56.39					
25 AMPS						
00:04:33:59	65.98	59.49	71.81	72.52	73.11	68.34
Corrected Ambient	75.39	68.90	81.22	81.93	82.52	77.75
Average	79.54					
Core Average	82.77					
Insulation Average	76.31					

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14 AWG Cu (2 Conductor) in Conduit
Page (2/2)

318 CU#7 Core	315 CU#7 Insulation	310 CU#9 Core	313 CU#9 Insulaiton	304 CU#11 Core	312 CU#11 Insulation
23.00	22.44	23.28	22.62	22.81	22.62
33.04	32.48	33.33	32.66	32.85	32.66
29.12	27.38	29.95	27.92	27.95	28.05
39.31	37.57	40.14	38.11	38.14	38.24
39.72	36.00	41.63	36.70	36.82	37.14
49.30	45.58	51.21	46.28	46.40	46.73
52.56	46.16	55.35	47.13	47.86	48.12
61.95	55.55	64.74	56.52	57.25	57.51
78.19	65.80	82.60	66.20	68.46	69.08
87.60	75.21	92.01	75.61	77.87	78.49

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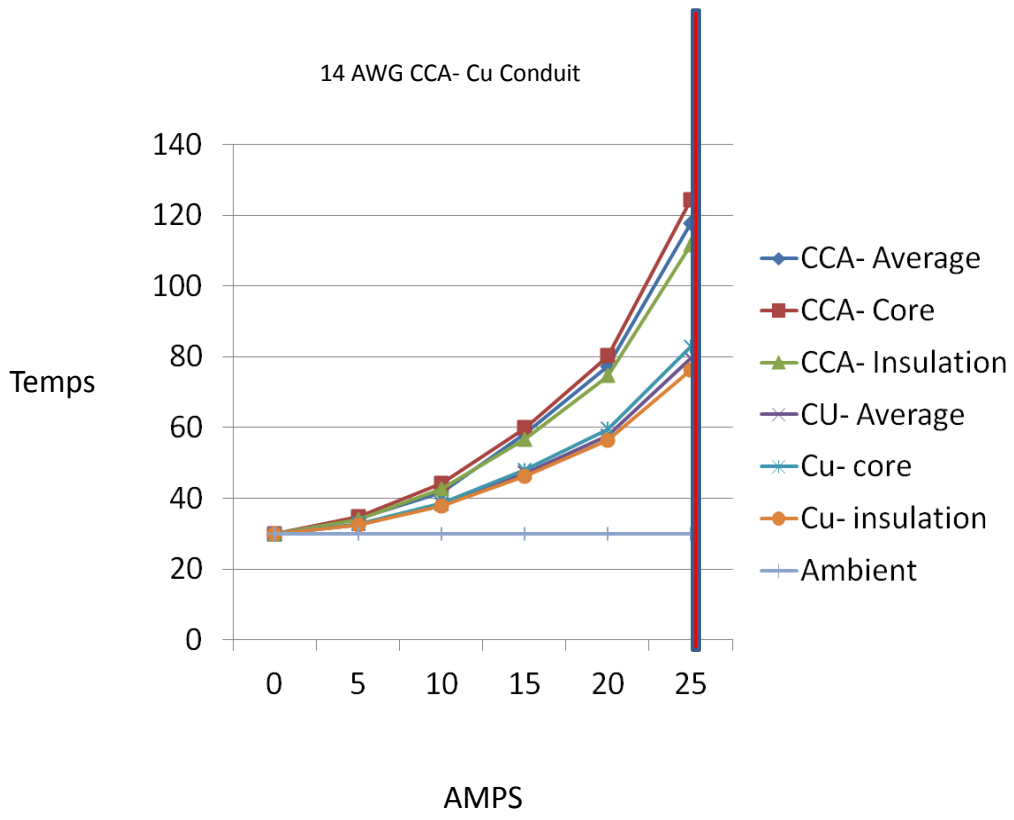

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Test Set- Up/ Layout
12 AWG Single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 12 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 12 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 12 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG single conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	Open air	5	30
12	Open air	10	30
12	Open air	15	30
12	Open air	20	30
12	Open air	25	30
12	Open air	30	30
12	Open air	35	30
12	Open air	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG single conductors
(Page 1 of 3)

Scan	Time	101- CU-AL White Cable#1- Insulation	104 CU-AL Black Cable#1 Core	105 CU-AL Black Cable#1 Insulation	106 CU-AL Black Cable#2 Core	107 CU-AL Black Cable#2 Insulation	109 CU-AL White Cable#2 Core
	5 AMPS						
30	8/16/2017 14:54	23.5	23.719	23.597	24.101	23.626	23.882
	Corrected Ambient	31.925	32.144	32.022	32.526	32.051	32.307
	Average	31.86845					
	Average Core	32.1068					
	Average Insulation	31.66983					
	10 AMPS						
60	8/16/2017 15:24	26.487	26.702	26.788	27.393	26.714	26.989
	Corrected Ambient	35	35.215	35.301	35.906	35.227	35.502
	Average	34.92791					
	Average Core	35.3563					
	Average Insulation	34.57092					
	15 AMPS						
91	8/16/2017 15:55	30.559	30.658	30.656	32.374	30.779	31.249
	Corrected Ambient	38.79	38.889	38.887	40.605	39.01	39.48
	Average	38.64927					
	Average Core	39.4042					
	Average Insulation	38.02017					
	20 AMPS						
121	8/16/2017 16:25	35.826	35.837	35.678	38.337	35.742	36.622
	Corrected Ambient	44.421	44.432	44.273	46.932	44.337	45.217
	Average	43.80986					
	Average Core	45.065					
	Average Insulation	42.76392					

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	25 AMPS						
152	8/16/2017 16:56	42.958	43.207	43.137	48.117	43.123	44.441
	Corrected Ambient	51.22	51.469	51.399	56.379	51.385	52.703
	Average	50.82832					
	Average Core	52.8027					
	Average Insulation	49.183					
	30 AMPS						
182	8/16/2017 17:26	50.663	51.573	51.558	58.75	51.353	52.748
	Corrected Ambient	59.164	60.074	60.059	67.251	59.854	61.249
	Average	58.849					
	Average Core	61.1368					
	Average Insulation	56.9425					
	35 AMPS						
213	8/16/2017 17:57	59.241	60.489	60.736	70.389	59.671	62.631
	Corrected Ambient	67.397	68.645	68.892	78.545	67.827	70.787
	Average	67.43436					
	Average Core	70.5558					
	Average Insulation	64.83317					
	40 AMPS						
244	8/16/2017 18:28	67.579	70.938	69.371	84.754	68.417	73.658
	Corrected Ambient	75.86	79.219	77.652	93.035	76.698	81.939
	Average	76.85605					
	Average Core	80.71511					
	Average Insulation	72.72958					

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12 AWG Single conductor
(Page 2 of 3)

112 CU-AL White Cable# 2 Insulation	113 CU-AL Black Cable#3 Core	114 CU-AL Black Cable #3 Insulation	116 CU-AL White Cable #3 Insulation	320 CU-AL White Cable#4 Core	118 CU-AL Black Cable#4 Insulation
23.57	23.62	23.4	23.285	23.776	23.093
31.995	32.045	31.825	31.71	32.201	31.518
26.464	26.507	26.264	25.822	26.845	25.692
34.977	35.02	34.777	34.335	35.358	34.205
30.073	30.291	29.915	29.382	31.533	29.206
38.304	38.522	38.146	37.613	39.764	37.437
34.775	34.982	34.305	33.662	37.097	32.398
43.37	43.577	42.9	42.257	45.692	40.993
41.606	42.027	41.564	40.681	46.895	35.318

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49.868	50.289	49.826	48.943	55.157	43.58
49.167	49.465	49.303	47.244	55.947	45.015
57.668	57.966	57.804	55.745	64.448	53.516
57.152	57.789	57.623	54.861	67.265	52.7
65.308	65.945	65.779	63.017	75.421	60.856
66.056	67.263	67.276	63.756	81.93	48.048
74.337	75.544	75.557	72.037	90.211	56.329

12 AWG Single conductor
(Page 3 of 3)

110 CU-AL White Cable#4 Core	120 CU-AL Black Cable#5 Core	211 CU-AL Black Cable#5 Insulation	205CU-AL White Cable#5 Insulation	208 CU-AL White Cable#6 Core	203 CU-AL Black Cable#6 Core	204 CU-AL Black Cbale#6 Insulation
23.509	23.482	23.149	23.038	23.485	23.786	22.755
31.934	31.907	31.574	31.463	31.91	32.211	31.18

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26.402	26.539	25.762	25.861	26.673	27.668	25.409
34.915	35.052	34.275	34.374	35.186	36.181	33.922
30.025	30.717	29.685	29.704	31.023	32.791	28.963
38.256	38.948	37.916	37.935	39.254	41.022	37.194
34.209	35.835	33.848	34.108	36.344	39.108	32.692
42.804	44.43	42.443	42.703	44.939	47.703	41.287
40.855	43.7	41.307	41.654	44.03	48.851	39.803
49.117	51.962	49.569	49.916	52.292	57.113	48.065
47.49	51.417	48.521	49.376	51.659	58.336	46.401
55.991	59.918	57.022	57.877	60.16	66.837	54.902

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55.696	61.164	57.106	58.492	61.252	69.982	53.979
63.852	69.32	65.262	66.648	69.408	78.138	62.135
63.039	72.843	66.826	67.72	70.828	83.361	63.75
71.32	81.124	75.107	76.001	79.109	91.642	72.031

12 AWG Cu Single conductors
(Page 1 of 2)

Scan	Time	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core
	5 AMPS					
30	8/16/2017 14:54	22.678	22.601	23.084	22.862	23.1
	Corrected Ambient	31.103	31.026	31.509	31.287	31.525
	Average	31.28				
	Average Core	31.346				
	Average Insulation	31.214				
	10 AMPS					
60	8/16/2017 15:24	24.574	24.195	25.492	24.984	25.629
	Corrected Ambient	33.087	32.708	34.005	33.497	34.142
	Average	33.44408				
	Average Core	33.63167				
	Average Insulation	33.2565				
	15 AMPS					

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91	8/16/2017 15:55	27.938	27.51	29.234	28.369	29.346
	Corrected Ambient	36.169	35.741	37.465	36.6	37.577
	Average	36.27708				
	Average Core	36.65483				
	Average Insulation	35.89933				
	20 AMPS					
121	8/16/2017 16:25	31.89	31.073	33.381	32.19	33.634
	Corrected Ambient	40.485	39.668	41.976	40.785	42.229
	Average	40.2505				
	Average Core	40.86083				
	Average Insulation	39.64017				
	25 AMPS					
152	8/16/2017 16:56	37.908	36.251	39.895	37.963	40.79
	Corrected Ambient	46.17	44.513	48.157	46.225	49.052
	Average	45.57908				
	Average Core	46.602				
	Average Insulation	44.55617				
	30 AMPS					
182	8/16/2017 17:26	45.629	44.793	46.939	43.77	47.443
	Corrected Ambient	54.13	53.294	55.44	52.271	55.944
	Average	51.87658				
	Average Core	53.18617				
	Average Insulation	50.567				
	35 AMPS					
213	8/16/2017 17:57	53.356	52.266	54.603	50.492	54.888
	Corrected Ambient	61.512	60.422	62.759	58.648	63.044
	Average	58.39692				
	Average Core	60.13967				
	Average Insulation	56.65417				
	40 AMPS					
244	8/16/2017 18:28	62.217	61.357	63.891	59.265	64.258
	Corrected Ambient	70.498	69.638	72.172	67.546	72.539

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	Average	66.52817				
	Average Core	69.18933				
	Average Insulation	63.867				

12 AWG Cu Single conductors
(Page 1 of 2)

	Time	304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
	5 AMPS						
30	8/16/2017 14:54	22.672	22.586	23.069	22.909	22.923	22.74
	Corrected Ambient	31.097	31.011	31.494	31.334	31.348	31.165
	10 AMPS						
60	8/16/2017 15:24	24.713	24.647	25.355	24.993	24.949	24.515
	Corrected Ambient	33.226	33.16	33.868	33.506	33.462	33.028
	15 AMPS						
91	8/16/2017 15:55	27.693	27.514	28.674	27.745	27.658	26.826
	Corrected Ambient	35.924	35.745	36.905	35.976	35.889	35.057
	20 AMPS						
121	8/16/2017 16:25	31.304	30.91	32.491	31.202	30.895	29.56
	Corrected Ambient	39.899	39.505	41.086	39.797	39.49	38.155

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	25 AMPS						
152	8/16/2017 16:56	36.656	36.446	39.125	36.545	35.666	33.819
	Corrected Ambient	44.918	44.708	47.387	44.807	43.928	42.081
	30 AMPS						
182	8/16/2017 17:26	42.269	41.429	45.709	41.914	40.122	38.201
	Corrected Ambient	50.77	49.93	54.21	50.415	48.623	46.702
	35 AMPS						
213	8/16/2017 17:57	50.113	48.676	53.39	48.317	45.552	43.055
	Corrected Ambient	58.269	56.832	61.546	56.473	53.708	51.211
	40 AMPS						
244	8/16/2017 18:28	55.495	53.591	66.664	55.887	52.925	47.744
	Corrected Ambient	63.776	61.872	74.945	64.168	61.206	56.025

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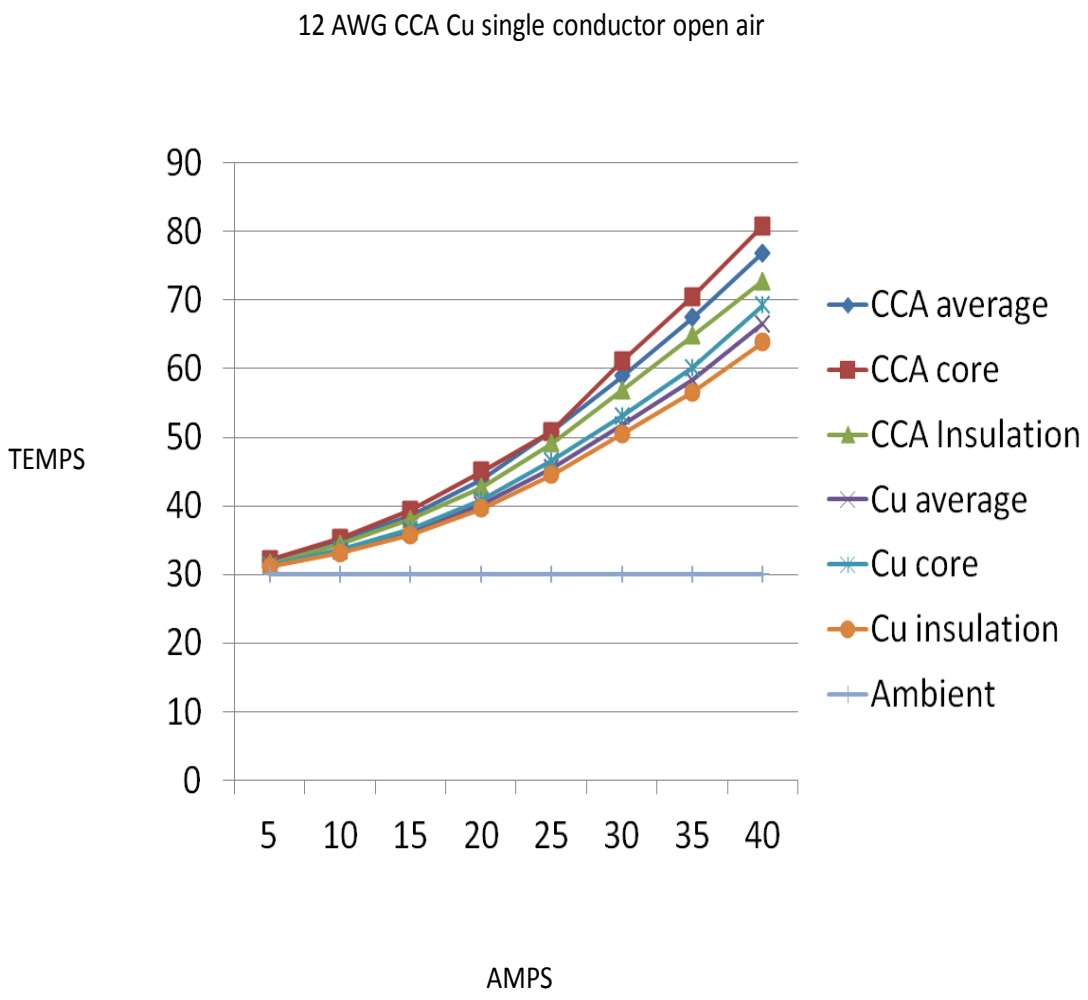

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Test Set- Up/ Layout
12 AWG in non-metallic cable (2 Conductor) in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 12 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 12 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 12 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG In (2 conductor) non-metallic cable

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	NM Cable	5	30
12	NM Cable	10	30
12	NM Cable	15	30
12	NM Cable	20	30
12	NM Cable	25	30
12	NM Cable	30	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 1 of 3)

Scan	Time	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	208 CU-AL Black Cable#2 Core	205 CU-AL Black Cable#2 Insulation
	5 AMPS					
30	**8/17/2017 10:29**	**22.67**	**22.926**	**23.13**	**23.256**	**23.015**
	Corrected Ambient	31.08	31.335	31.539	31.665	31.424
	Average	31.68				
	Average Core	31.73				
	Average Insulation	31.63				
	10 AMPS					
61	8/17/2017 11:00	25.93	26.059	26.92	26.863	26.217
	Corrected Ambient	34.32	34.443	35.304	35.247	34.601
	Average	34.88				
	Average Core	35.09				
	Average Insulation	34.68				
	15 AMPS					
91	8/17/2017 11:30	30.31	30.408	32.809	32.228	31.062
	Corrected Ambient	38.40	38.497	40.898	40.317	39.151
	Average	39.36				
	Average Core	39.90				
	Average Insulation	38.87				
	20 AMPS					
121	8/17/2017 12:00	35.95	36.03	40.071	39.839	36.86
	Corrected Ambient	44.35	44.426	48.467	48.235	45.256

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	Average	45.56				
	Average core	46.67				
	Average Insulation	44.54				
	25 AMPS					
152	8/17/2017 12:31	41.34	41.083	45.352	45.612	42.454
	Corrected Ambient	49.85	49.598	53.867	54.127	50.969
	Average	51.67				
	Average Core	53.50				
	Average Insulation	50.00				
	30 AMPS					
182	8/17/2017 13:01	47.44	47.015	53.341	52.596	50.518
	Corrected Ambient	55.74	55.316	61.642	60.897	58.819
	Average	59.54				
	Average Core	62.19				
	Average Insulation	57.11				

12 AWG CCA In non-metallic cable(2 conductor)
(Page 2 of 3)

211 CU-AL White Cable# 2 Insulation	102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #3 Insulation
23.196	**23.139**	**23.493**	**23.536**
31.605	31.548	31.902	31.945
26.208	26.16	26.433	26.599
34.592	34.544	34.817	34.983

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30.375	30.414	30.425	31.929
38.464	38.503	38.514	40.018
35.556	35.329	35.55	36.683
43.952	43.725	43.946	45.079
41.089	40.342	41.332	41.256
49.604	48.857	49.847	49.771
48.436	46.618	48.28	47.403
56.737	54.919	56.581	55.704

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 3of 3)

116 CU-AL Black Cable#4 Insulation	113 CU-AL White Cable #4 Core	114 CU-AL White Cable#4 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#5 Insulation
23.222	**23.2**	**23.399**	**23.443**	**23.14**
31.631	31.609	31.808	31.852	31.549
25.734	26.056	26.523	26.702	25.713
34.118	34.44	34.907	35.086	34.097
28.997	31.638	30.56	30.878	29.977
37.086	39.727	38.649	38.967	38.066
33.062	37.403	35.681	36.471	35.027
41.458	45.799	44.077	44.867	43.423

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37.425	44.796	40.903	42.529	40.103
45.94	53.311	49.418	51.044	48.618
43.655	55.384	48.43	51.204	48.229
51.956	63.685	56.731	59.505	56.53

12 AWG Cu In non-metallic cable(2 Conductor)
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30	**8/17/2017 10:29**	**22.614**	**22.554**	**22.891**	**22.59**	**22.796**	**22.882**
	Corrected Ambient	31.023	30.963	31.3	30.999	31.205	31.291
	Average	31.22208					
	Average Core	31.295					
	Average Insulation	31.14917					
	10 AMPS						
61	8/17/2017 11:00	25.114	24.271	25.231	24.387	24.977	24.9
	Corrected Ambient	33.498	32.655	33.615	32.771	33.361	33.284
	Average	33.271					

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	Average Core	33.58917					
	Average Insulation	32.95283					
	15 AMPS						
91	8/17/2017 11:30	28.333	27.255	28.517	27.065	28.032	28.006
	Corrected Ambient	36.422	35.344	36.606	35.154	36.121	36.095
	Average	36.00508					
	Average Core	36.45233					
	Average Insulation	35.55783					
	20 AMPS						
121	8/17/2017 12:00	32.461	30.737	32.806	30.378	32.047	31.754
	Corrected Ambient	40.857	39.133	41.202	38.774	40.443	40.15
	Average	40.02075					
	Average core	40.70133					
	Average Insulation	39.34017					
	25 AMPS						
152	8/17/2017 12:31	37.317	35.362	38.138	34.253	36.101	35.718
	Corrected Ambient	45.832	43.877	46.653	42.768	44.616	44.233
	Average	44.385					
	Average Core	45.3695					
	Average Insulation	43.4005					
	30 AMPS						
182	8/17/2017 13:01	43.719	41.111	44.969	39.04	42.173	41.491
	Corrected Ambient	52.02	49.412	53.27	47.341	50.474	49.792
	Average	49.96617					
	Average Core	51.36633					
	Average Insulation	48.566					

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 2 of 2)

305 CU White Cable#3 Insulation	309 CU Black Cable#2 Core	310 CU Black Cable#2 Insulation	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.726	**23.1**	**22.833**	**22.872**	**22.856**
31.135	31.509	31.242	31.281	31.265
24.487	25.693	24.642	24.877	24.726
32.871	34.077	33.026	33.261	33.11
27.237	29.01	27.541	27.932	27.709
35.326	37.099	35.63	36.021	35.798
30.746	33.217	31.041	31.343	31.009
39.142	41.613	39.437	39.739	39.405

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34.482	37.831	34.853	35.499	34.645
42.997	46.346	43.368	44.014	43.16
39.792	44.397	39.901	41.125	40.255
48.093	52.698	48.202	49.426	48.556

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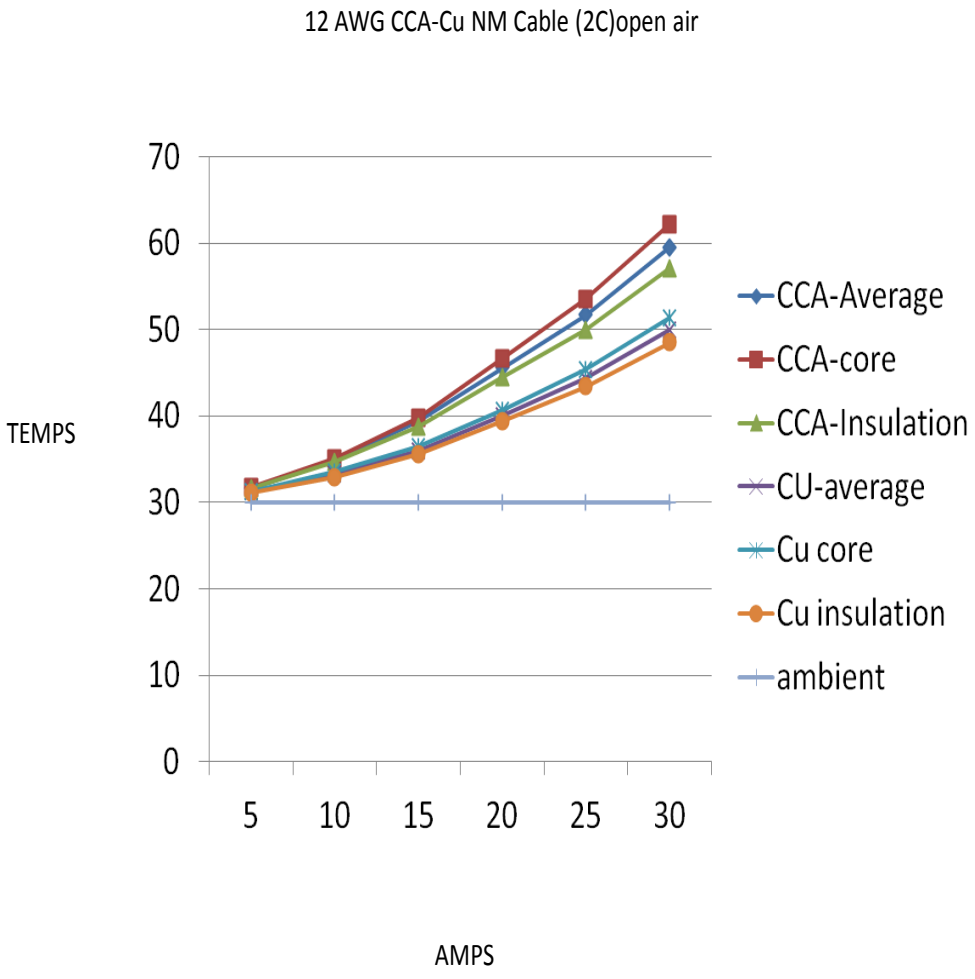

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Test Set- Up/ Layout
12 AWG in Conduit (2 conductors)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 12 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 12 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 12 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG In conduit (2 conductors)

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	Conduit	5	30
12	Conduit	10	30
12	Conduit	15	30
12	Conduit	20	30
12	Conduit	25	30
12	Conduit	30	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG CCA In conduit (2 conductors)
(Page 1 of 3)

Scan	Time	101- CU-AL White Cable-Core	103 CU-AL White Cable Insulation	104 CU-AL Black Cable Core	105 CU-AL Black Cable Insulation	106 CU-AL Black Cable Core	107 CU-AL Black Cable Insulation
	5 AMPS						
34.00	42,963.45	24.80	24.55	24.92	24.52	25.20	24.98
	Corrected Ambient	33.20	32.95	33.32	32.92	33.60	33.38
	Average	32.92					
	Average core	33.12					
	Average Insulation	32.75					
	10 Amps						
66.00	42,963.47	30.79	29.98	30.50	29.05	31.64	30.86
	Corrected Ambient	39.24	38.43	38.95	37.50	40.09	39.30
	Average	38.30					
	Average core	38.54					
	Average Insulation	38.71					
	15 Amps						
98.00	42,963.49	39.83	38.14	39.13	35.99	41.35	39.89
	Corrected Ambient	48.24	46.54	47.54	44.40	49.75	48.30
	Average	46.26					
	Average core	47.36					
	Average Insulation	45.34					
	20 AMPS						
130.00	42,963.51	53.93	51.10	52.57	46.42	56.43	53.62
	Corrected Ambient	62.34	59.51	60.98	54.83	64.84	62.03
	Average	58.48					

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	Average core	60.33					
	Average Insulation	56.95					
	25 AMPS						
162.00	42,963.54	71.01	66.92	68.93	58.87	75.38	70.30
	Corrected Ambient	79.37	75.29	77.29	67.23	83.74	78.66
	Average	73.37					
	Average core	76.31					
	Average Insulation	70.92					
	30 AMPS						
208.00	42,963.57	95.27	88.98	92.19	76.76	102.19	93.33
	Corrected Ambient	103.67	97.37	100.58	85.15	110.58	101.72
	Average	94.77					
	Average core	99.22					
	Average Insulation	91.05					

12 AWG CCA in Conduit (2 Conductors)
Page (2 of 3)

109 CU-AL White Cable Core	112 CU-AL White Cable Insulation	113 CU-AL Black Cable Core	114 CU-AL Black Cable Insulation	116 CU-AL White Cable Insulation	320 CU-AL White Cable Core
25.06	24.79	24.97	24.89	24.38	24.57
33.46	33.19	33.36	33.29	32.78	32.97
30.95	29.96	30.85	30.45	28.75	29.93
39.40	38.41	39.30	38.89	37.19	38.38

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39.93	38.02	39.99	39.25	35.66	38.12
48.34	46.43	48.40	47.65	44.07	46.53
53.56	50.15	53.76	52.46	45.78	50.35
61.97	58.57	62.17	60.87	54.19	58.76
70.65	65.52	71.23	69.04	58.58	65.18
79.02	73.88	79.59	77.40	66.95	73.54
94.77	86.67	95.96	92.55	76.17	86.50
103.16	95.06	104.35	100.95	84.56	94.89

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12 AWG CCA in Conduit (2 Conductors)
(Page 3 of 3)

315 CU-AL Black Cable Core	118 CU-AL Black Cable Insulation	102 CU-AL White Cable Insulation	110 CU-AL White Cable Core	211 CU-AL Black Cable Insulation	205CU-AL White Cable Insulation
24.41	24.04	24.69	25.09	24.46	24.15
32.81	32.44	33.08	33.49	32.86	32.55
29.90	27.86	30.58	31.01	30.08	29.09
38.35	36.31	39.03	39.46	38.52	37.54
38.26	34.03	39.40	40.19	38.41	36.46
46.67	42.44	47.80	48.60	46.82	44.87
50.81	45.67	52.82	53.77	51.24	47.67
59.23	54.08	61.23	62.19	59.65	56.08

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66.35	55.12	68.87	70.60	68.22	62.30
74.72	63.48	77.23	78.97	76.58	70.66
88.26	70.54	92.61	94.54	93.37	83.09
96.65	78.93	101.00	102.93	101.76	91.48

12 AWG Cu In conduit (2 Conductors)
(Page 1 of 2)

Scan	Time	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core	302 CU Black Cable#3 Insulation
	5 AMPS						
34.00	42,963.45	23.58	23.40	23.92	23.37	23.59	23.54
	Corrected Ambient	31.98	31.79	32.32	31.77	31.99	31.93
	Average	32.04					
	Average core	32.16					
	Average Insulation	31.92					
	10 Amps						
66.00	42,963.47	27.28	26.39	28.16	26.32	27.09	25.98
	Corrected Ambient	35.73	34.84	36.61	34.77	35.54	34.43
	Average	35.49					
	Average core	35.99					
	Average Insulation	34.99					
	15 Amps						

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98.00	42,963.49	32.59	30.64	34.57	30.92	32.40	30.16
	Corrected Ambient	40.99	39.05	42.98	39.32	40.81	38.57
	Average	40.68					
	Average core	41.67					
	Average Insulation	39.68					
	20 AMPS						
130.00	42,963.51	41.24	37.72	44.71	38.16	40.68	36.33
	Corrected Ambient	49.66	46.14	53.12	46.58	49.10	44.74
	Average	48.81					
	Average core	50.65					
	Average Insulation	46.96					
	25 AMPS						
162.00	42,963.54	52.09	46.85	57.21	46.77	50.75	44.10
	Corrected Ambient	60.45	55.21	65.57	55.14	59.11	52.46
	Average	58.67					
	Average core	61.52					
	Average Insulation	55.81					
	30 AMPS						
208.00	42,963.57	67.48	59.62	74.44	58.61	64.15	54.26
	Corrected Ambient	75.87	68.01	82.83	67.01	72.54	62.65
	Average	72.19					
	Average core	76.53					
	Average Insulation	67.86					

12 AWG Cu In conduit (2 Conductors)
(Page 2 of 2)

304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
23.91	23.65	23.81	23.67	23.76	23.55

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32.30	32.04	32.20	32.07	32.15	31.94
27.70	26.94	27.55	27.04	27.49	26.59
36.15	35.39	36.00	35.48	35.94	35.04
33.58	32.18	33.20	32.27	33.25	31.45
41.99	40.59	41.60	40.68	41.66	39.85
42.62	40.10	42.09	40.23	42.11	38.73
51.03	48.52	50.50	48.65	50.53	47.14
53.25	49.79	52.80	49.90	52.88	47.31
61.61	58.15	61.16	58.26	61.24	55.67
67.84	62.54	67.31	62.93	67.59	58.86
76.24	70.93	75.70	71.33	75.98	67.25

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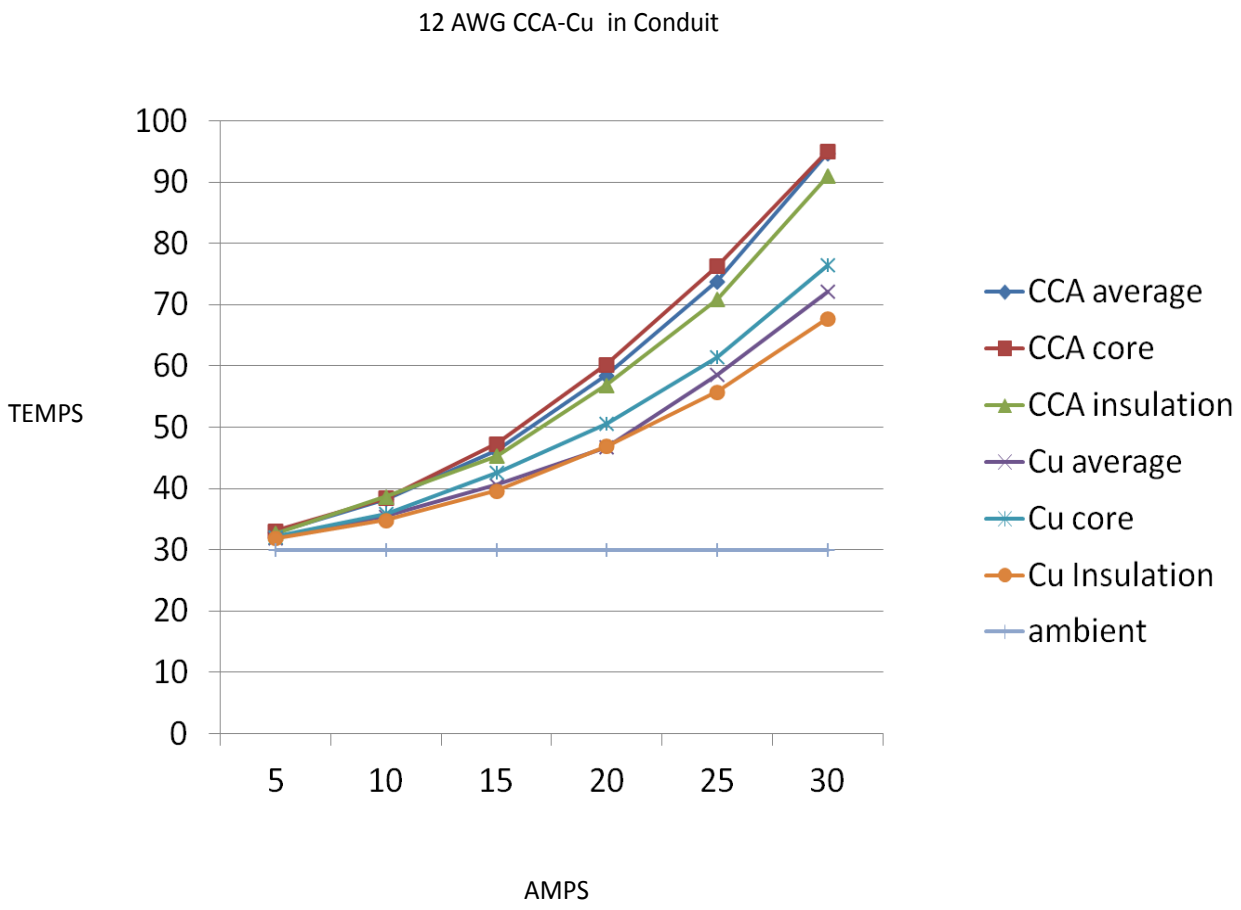

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Test Set- Up/ Layout
10 AWG single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 10 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 10 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 10 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG Single conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	Open air	5	30
10	Open air	10	30
10	Open air	15	30
10	Open air	20	30
10	Open air	25	30
10	Open air	30	30
10	Open air	35	30
10	Open air	40	30
10	Open air	45	30
10	Open air	50	30
10	Open air	55	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA Single conductor Open Air
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Scan	Time	Elapsed	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	208 CU-AL Black Cable#1 Core	205 CU-AL Black Cable#2 Insulation	120 CU-AL White Cable#2 Core	211 CU-AL White Cable#2 Insulation
	5 AMPS							
30.00	42965.59	00:00:28:59	22.27	22.95	22.82	22.50	23.18	22.75
	Corrected Ambient		30.81	31.49	31.36	31.04	31.72	31.28
	Average		31.47					
	Average core		31.47					
	Average Insulation		31.47					
	10 AMPS							
60.00	42965.62	00:00:58:59	24.20	25.01	24.70	24.41	25.11	24.60
	Corrected Ambient		32.71	33.52	33.20	32.91	33.61	33.10
	Average		33.30					
	Average core		33.34					
	Average Insulation		33.25					
	15 AMPS							
94.00	42965.64	00:01:32:59	27.20	28.61	27.87	27.26	28.29	27.43
94.00	Corrected Ambient		35.60	37.01	36.27	35.66	36.69	35.83
	Average		36.09					
	Average core		36.22					
	Average Insulation		35.94					
	20 AMPS							
121.00	42965.66	00:01:59:59	30.94	33.08	31.72	30.92	32.64	31.08
	Corrected Ambient		39.39	41.52	40.17	39.36	41.08	39.52
	Average		39.81					
	Average core		40.07					
	Average Insulation		39.52					

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	25 AMPS							
152.00	42965.68	00:02:30:59	35.76	39.24	36.76	34.98	37.75	35.59
	Corrected Ambient		44.20	47.67	45.20	43.41	46.19	44.03
	Average		44.24					
	Average core		44.68					
	Average Insulation		43.78					
	30 AMPS							
182.00	42965.70	00:03:00:59	39.98	43.90	41.39	39.49	42.72	39.71
	Corrected Ambient		48.45	52.37	49.85	47.96	51.19	48.18
	Average		48.75					
	Average core		49.39					
	Average Insulation		48.05					
	36 AMPS							
214.00	42965.72	00:03:32:59	47.04	48.39	48.73	46.42	50.45	46.40
	Corrected Ambient		55.61	56.97	57.30	54.99	59.03	54.97
	Average		55.57					
	Average core		56.61					
	Average Insulation		54.48					
	40 AMPS							
243.00	42965.74	00:04:01:59	52.41	53.30	54.36	51.59	56.81	51.39
	Corrected Ambient		60.70	61.59	62.65	59.88	65.10	59.68
	Average		60.64					
	Average core		62.02					
	Average Insulation		59.17					
	45 AMPS							
273.00	42965.76	00:04:31:59	59.93	60.57	61.45	59.16	64.82	58.73
	Corrected Ambient		68.43	69.07	69.94	67.66	73.32	67.23
	Average		68.02					
	Average core		69.86					

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	Average Insulation		66.10					
	50 AMPS							
304.00	42965.78	00:05:02:59	68.58	66.89	70.98	67.58	75.68	67.24
	Corrected Ambient		76.79	75.10	79.19	75.80	83.89	75.45
	Average		76.51					
	Average core		78.99					
	Average Insulation		73.93					
	55 AMPS							
334.00	42965.81	00:05:32:59	77.66	75.32	80.26	77.00	85.13	75.41
	Corrected Ambient		86.08	83.74	88.68	85.42	93.54	83.83
	Average		85.54					
	Average core		88.62					
	Average Insulation		82.30					

10 AWG CCA Single conductor Open Air
(Page 2 of 3)

102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #3 Insulation	315 CU-AL White Cable#4 Core	320 CU-AL Black Cable#4 Core	116 CU-AL Black Cable#4 Insulation
22.98	23.06	23.06	22.84	23.14	23.11
31.51	31.60	31.60	31.37	31.67	31.64
24.95	24.87	24.76	24.78	25.11	24.95

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33.46	33.37	33.27	33.29	33.61	33.46
27.94	27.66	27.49	28.04	28.49	27.92
36.34	36.06	35.89	36.45	36.89	36.32
31.97	31.21	31.04	32.09	32.60	31.53
40.41	39.65	39.48	40.54	41.04	39.98
36.86	35.52	34.62	36.88	37.56	35.94
45.30	43.96	43.05	45.32	46.00	44.38
41.65	40.19	38.87	41.54	42.71	40.19
50.12	48.66	47.34	50.00	51.18	48.66
49.26	47.09	45.20	48.99	50.60	47.06
57.83	55.66	53.78	57.57	59.17	55.63

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55.51	52.71	50.13	54.95	56.69	52.01
63.79	60.99	58.42	63.24	64.98	60.29
63.32	59.97	55.29	63.12	65.06	58.74
71.81	68.47	63.79	71.61	73.55	67.23
74.74	68.93	64.75	72.42	74.12	66.84
82.95	77.14	72.96	80.63	82.34	75.05
84.59	77.87	73.40	82.41	84.78	75.05
93.00	86.29	81.82	90.83	93.19	83.47

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10 AWG CCA Single conductor Open Air
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113 CU-AL White Cable #5 Core	114 CU-AL White Cable#5 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#6 Insulation	107 CU-AL White Cable#6 Insulation	106 CU-AL White Cable#6 Core
23.07	22.99	23.03	23.10	22.96	23.24
31.60	31.52	31.57	31.64	31.49	31.78
24.79	24.58	24.88	24.94	24.88	25.30
33.30	33.08	33.38	33.45	33.38	33.80
27.39	27.03	27.64	27.62	27.50	28.42
35.79	35.43	36.04	36.03	35.90	36.82
30.90	30.18	31.18	31.06	30.77	32.25
39.34	38.62	39.62	39.51	39.22	40.70

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34.92	33.57	35.29	35.22	34.83	37.20
43.36	42.01	43.73	43.65	43.27	45.64
39.04	37.63	40.14	39.22	39.04	42.06
47.51	46.10	48.60	47.69	47.50	50.53
45.69	43.45	46.83	45.74	45.25	49.22
54.26	52.02	55.40	54.32	53.83	57.79
50.91	48.17	52.61	50.82	50.25	55.22
59.19	56.46	60.90	59.10	58.54	63.51
58.10	54.41	60.26	57.35	56.69	63.45
66.59	62.90	68.75	65.85	65.18	71.95

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66.27	61.46	69.66	65.42	64.96	73.26
74.48	69.67	77.87	73.64	73.17	81.47
74.81	69.25	79.65	72.63	73.00	82.89
83.23	77.67	88.07	81.04	81.42	91.30

10 AWG Cu Single conductor Open Air
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30.00	42965.59	22.07	22.56	22.62	22.55	22.48	22.67
	Corrected Ambient	30.60	31.10	31.16	31.09	31.01	31.20
	Average	31.02					
	Average core	30.96					
	Average Insulation	31.08					
	10 AMPS						
60.00	42965.62	23.25	23.92	23.69	23.51	23.81	23.90
	Corrected Ambient	31.76	32.42	32.19	32.01	32.31	32.41
	Average	32.23					
	Average core	32.20					

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	Average Insulation	32.27					
	15 AMPS						
94.00	42965.64	25.17	26.29	25.70	25.23	26.09	25.97
94.00	Corrected Ambient	33.57	34.69	34.11	33.63	34.49	34.38
	Average	34.26					
	Average core	34.25					
	Average Insulation	34.28					
	20 AMPS						
121.00	42965.66	27.66	29.10	28.12	27.45	28.84	28.45
	Corrected Ambient	36.11	37.54	36.57	35.90	37.28	36.90
	Average	36.90					
	Average core	36.93					
	Average Insulation	36.86					
	25 AMPS						
152.00	42965.68	30.70	32.92	31.23	30.03	32.55	31.95
	Corrected Ambient	39.14	41.36	39.67	38.47	40.99	40.39
	Average	40.29					
	Average core	40.41					
	Average Insulation	40.18					
	30 AMPS						
182.00	42965.70	33.65	36.60	34.35	32.85	36.08	35.22
	Corrected Ambient	42.12	45.07	42.82	41.32	44.55	43.69
	Average	43.76					
	Average core	43.89					
	Average Insulation	43.63					
	36 AMPS						
214.00	42965.72	38.55	42.08	39.00	36.69	41.07	39.69
	Corrected Ambient	47.12	50.65	47.57	45.26	49.64	48.26
	Average	48.80					
	Average core	49.09					
	Average Insulation	48.51					

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	40 AMPS						
243.00	42965.74	41.71	46.30	42.78	40.04	45.42	43.45
	Corrected Ambient	50.00	54.59	51.07	48.33	53.71	51.74
	Average	52.54					
	Average core	52.83					
	Average Insulation	52.24					
	45 AMPS						
273.00	42965.76	47.71	51.95	47.60	43.96	50.47	48.26
	Corrected Ambient	56.20	60.44	56.09	52.45	58.97	56.75
	Average	58.05					
	Average core	58.61					
	Average Insulation	57.49					
	50 AMPS						
304.00	42965.78	53.84	59.41	54.11	49.30	57.74	54.24
	Corrected Ambient	62.05	67.62	62.32	57.52	65.96	62.45
	Average	64.37					
	Average core	65.11					
	Average Insulation	63.63					
	55 AMPS						
334.00	42965.81	60.19	63.55	59.83	53.97	58.77	58.08
	Corrected Ambient	68.60	71.96	68.24	62.39	67.18	66.50
	Average	69.97					
	Average core	70.96					
	Average Insulation	68.98					

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10 AWG Cu Single conductor Open Air
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304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Insulation	310 CU Black Cable#2 Core	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.23	22.47	22.49	22.70	22.46	22.50
30.77	31.01	31.03	31.24	30.99	31.04
23.53	23.74	23.77	24.13	23.77	23.74
32.03	32.25	32.28	32.64	32.28	32.24
25.65	25.95	26.07	26.49	25.96	25.75
34.05	34.35	34.47	34.89	34.37	34.16
28.23	28.61	28.70	29.55	28.52	28.20
36.68	37.05	37.14	38.00	36.97	36.64

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31.72	32.05	32.16	33.52	32.13	31.34
40.15	40.49	40.59	41.96	40.57	39.78
35.53	35.86	35.80	37.45	35.48	34.67
44.00	44.33	44.27	45.91	43.95	43.14
40.84	41.40	40.65	43.30	40.35	39.11
49.41	49.97	49.23	51.87	48.92	47.68
44.87	45.96	44.94	48.11	44.39	43.05
53.16	54.25	53.23	56.40	52.68	51.33
51.56	51.64	50.42	53.97	49.37	47.77
60.06	60.14	58.92	62.46	57.87	56.26

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57.88	58.65	56.87	61.91	55.93	54.05
66.10	66.86	65.08	70.12	64.14	62.26
64.75	65.59	62.39	70.14	61.61	59.85
73.17	74.00	70.80	78.55	70.03	68.26

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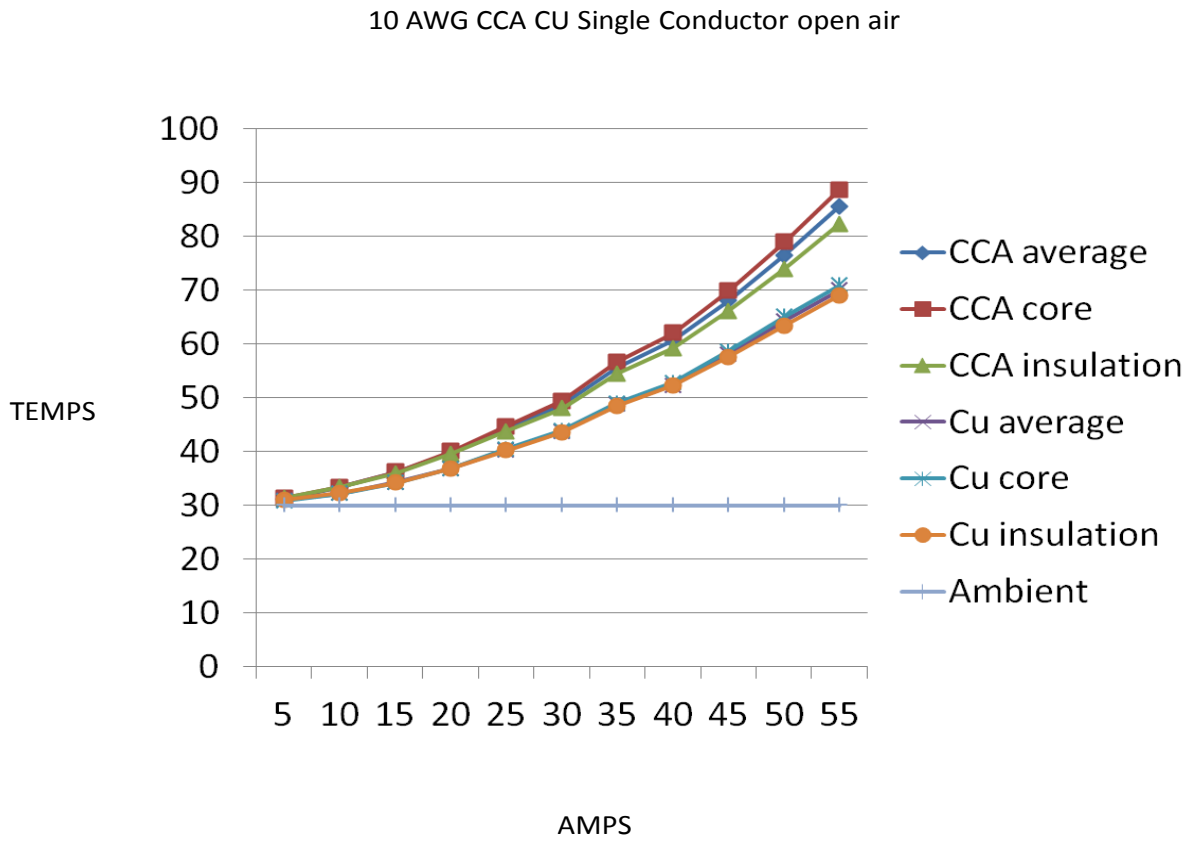

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Test Set- Up/ Layout
10 AWG in non-metallic cable in open air (2 Conductor)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 10 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 10 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 10 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG in Non-Metallic Cable (2 Conductors)

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	NM Cable	5	30
10	NM Cable	10	30
10	NM Cable	15	30
10	NM Cable	20	30
10	NM Cable	25	30
10	NM Cable	30	30
10	NM Cable	35	30
10	NM Cable	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA Non-Metallic Open Air (2 Conductor)

Page 1 of 3

Scan	Time	203 CU-AL White Cable#1-Core	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	208 CU-AL Black Cable#2 Core	120 CU-AL White Cable#2 Core	211 CU-AL White Cable# 2 Insulation
	5 AMPS						
29.00	42965.31	22.56	22.00	22.22	22.70	22.86	22.80
	Corrected Ambient	31.01	30.45	30.67	31.15	31.31	31.25
	Average	31.22					
	Average Core	31.25					
	Average Insulation	31.18					
	10 AMPS						
59.00	42965.34	24.64	24.13	24.46	24.90	25.31	25.33
	Corrected Ambient	33.21	32.70	33.02	33.47	33.88	33.90
	Average	33.48					
	Average Core	33.59					
	Average Insulation	33.34					
	15 AMPS						
90.00	42965.36	27.20	26.74	27.08	27.30	28.47	28.45
	Corrected Ambient	35.98	35.52	35.86	36.09	37.25	37.24
	Average	36.34					
	Average Core	36.53					
	Average Insulation	36.10					
	20 AMPS						
120.00	42965.38	30.31	29.56	30.82	31.04	32.46	31.76
120.00	Corrected Ambient	38.92	38.18	39.43	39.65	41.08	40.38
	Average	39.47					
	Average Core	39.91					
	Average Insulation	38.94					

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	25 AMPS						
151.00	42965.40	34.17	34.26	34.09	33.82	36.82	36.81
	Corrected Ambient	42.70	42.79	42.62	42.35	45.35	45.34
	Average	43.20					
	Average Core	43.67					
	Average Insulation	42.63					
	30 AMPS						
181.00	8/18/2017	40.14	40.25	39.61	39.67	44.07	43.95
	Corrected Ambient	48.87	48.97	48.34	48.40	52.80	52.68
	Average	49.73					
	Average Core	50.27					
	Average Insulation	49.07					
	35 AMPS						
211.00	8/18/2017	45.43	45.21	44.93	45.04	50.87	50.51
	Corrected Ambient	53.94	53.71	53.44	53.55	59.38	59.01
	Average	55.39					
	Average Core	56.18					
	Average Insulation	54.43					
	40 AMPS						
242.00	8/18/2017	50.84	50.96	50.37	51.04	58.24	57.38
	Corrected Ambient	59.52	59.63	59.04	59.71	66.92	66.05
	Average	61.97					
	Average Core	62.84					
	Average Insulation	60.91					

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10 AWG CCA Non-Metallic Open Air (2 Conductor)
(Page 2 of 3)

102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #4 Insulation	315 CU-AL White Cable#3 Core	320 CU-AL Black Cable#4 Core	116 CU-AL Black Cable#4 Insulation
22.96	22.92	22.95	22.83	22.89	22.68
31.41	31.37	31.40	31.29	31.35	31.13
25.39	24.90	25.21	25.08	25.02	24.41
33.96	33.47	33.77	33.65	33.59	32.98
28.53	27.32	28.01	27.79	27.59	26.58
37.31	36.10	36.79	36.58	36.37	35.36
32.18	30.26	31.60	31.28	30.79	29.22
40.80	38.87	40.21	39.89	39.40	37.83

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36.38	33.53	35.13	35.47	34.88	32.40
44.91	42.06	43.65	43.99	43.41	40.93
43.55	39.91	41.12	41.92	41.13	37.92
52.27	48.64	49.85	50.64	49.85	46.65
50.62	45.49	46.83	48.46	47.36	42.93
59.13	53.99	55.34	56.97	55.87	51.43
56.97	51.48	52.58	55.03	54.43	49.04
65.65	60.15	61.26	63.70	63.10	57.71

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10 AWG CCA Non-Metallic Open Air (2 Conductor)
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114 CU-AL White Cable#6 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#5 Insulation	107 CU-AL White Cable#6 Insulation	106 CU-AL White Cable#5 Core	103 CU-AL Black Cable#6 Core
22.86	23.16	22.83	22.75	23.01	22.61
31.31	31.62	31.28	31.21	31.46	31.06
24.90	25.52	24.59	24.68	25.19	24.49
33.46	34.08	33.16	33.25	33.76	33.06
27.45	28.59	26.81	26.95	27.86	26.80
36.23	37.37	35.59	35.73	36.64	35.58
30.62	32.31	29.51	29.96	31.51	29.93
39.23	40.93	38.12	38.57	40.12	38.54

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34.23	36.96	32.84	33.64	35.02	33.09
42.76	45.49	41.37	42.17	43.55	41.62
40.58	44.15	38.29	40.01	41.40	38.66
49.31	52.87	47.02	48.74	50.13	47.39
46.42	51.15	43.40	45.61	47.21	43.99
54.93	59.66	51.91	54.12	55.71	52.50
53.18	58.34	49.24	52.19	53.82	49.96
61.86	67.01	57.92	60.86	62.49	58.63

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10 AWG Cu in non-metallic cable (2 Conductor) in open air
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
29.00	42965.31	22.35	22.15	22.22	22.08	22.35	22.41
	Corrected Ambient	30.80	30.60	30.67	30.53	30.80	30.86
	Average	30.77					
	Average Core	30.79					
	Average Insulation	30.75					
	10 AMPS						
59.00	42965.34	23.86	23.34	23.35	23.28	23.64	23.74
	Corrected Ambient	32.42	31.91	31.92	31.85	32.21	32.31
	Average	32.18					
	Average Core	32.25					
	Average Insulation	32.12					
	15 AMPS						
90.00	42965.36	25.78	24.85	24.84	24.85	25.28	25.45
	Corrected Ambient	34.56	33.63	33.62	33.64	34.06	34.23
	Average	34.05					
	Average Core	34.14					
	Average Insulation	33.97					
	20 AMPS						
120.00	42965.38	28.46	26.70	26.84	26.63	27.38	27.39
120.00	Corrected Ambient	37.07	35.32	35.45	35.24	35.99	36.01
	Average	35.93					
	Average Core	36.20					
	Average Insulation	35.65					

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	25 AMPS						
151.00	42965.40	31.70	29.22	29.24	29.04	30.00	29.99
	Corrected Ambient	40.23	37.75	37.77	37.57	38.53	38.52
	Average	38.40					
	Average Core	38.78					
	Average Insulation	38.03					
	30 AMPS						
181.00	8/18/2017	36.74	33.05	33.55	33.39	33.88	34.40
	Corrected Ambient	45.47	41.78	42.28	42.12	42.61	43.13
	Average	42.80					
	Average Core	43.21					
	Average Insulation	42.39					
	35 AMPS						
211.00	8/18/2017	41.63	36.87	37.11	36.85	37.80	38.22
	Corrected Ambient	50.14	45.37	45.61	45.36	46.30	46.73
	Average	46.58					
	Average Core	47.13					
	Average Insulation	46.03					
	40 AMPS						
242.00	8/18/2017	47.11	41.04	41.32	40.92	42.28	42.42
	Corrected Ambient	55.78	49.71	50.00	49.59	50.96	51.10
	Average	51.05					
	Average Core	51.88					
	Average Insulation	50.21					

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10 AWG Cu in non-metallic cable (2 Conductor) in open air

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304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Core	310 CU Black Cable#2 Insulation	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.46	22.17	22.34	22.44	22.34	22.52
30.91	30.62	30.79	30.89	30.80	30.97
23.89	23.29	23.74	23.72	23.64	23.93
32.46	31.86	32.31	32.28	32.20	32.50
25.78	24.68	25.27	25.47	25.21	25.82
34.56	33.46	34.05	34.25	33.99	34.60
27.95	26.31	27.57	27.28	27.34	27.92
36.56	34.92	36.18	35.89	35.95	36.54

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30.76	28.50	30.31	29.75	29.47	30.49
39.29	37.03	38.84	38.28	38.00	39.02
35.55	32.13	34.15	34.05	33.00	34.97
44.28	40.86	42.88	42.77	41.73	43.70
40.14	35.60	38.38	38.05	36.70	39.58
48.65	44.11	46.89	46.56	45.21	48.08
44.88	38.92	43.18	42.00	40.48	43.95
53.55	47.60	51.85	50.67	49.16	52.62

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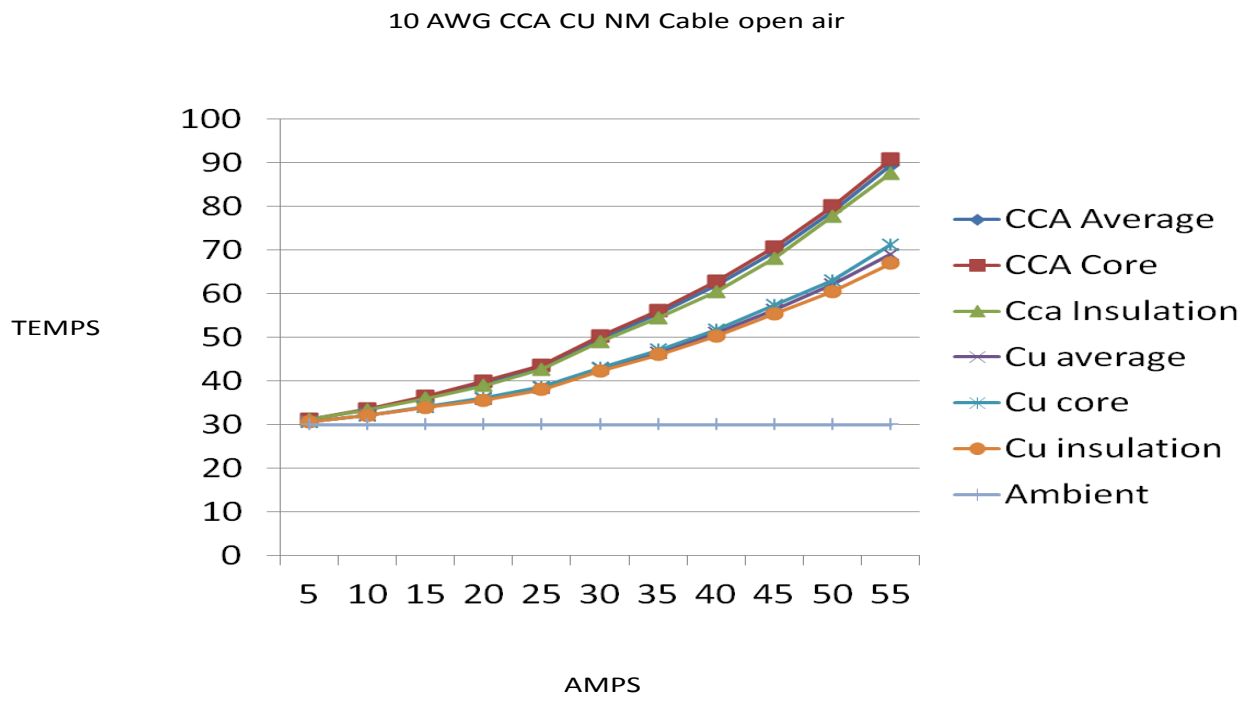

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Test Set- Up/ Layout
10 AWG in Conduit (2 Conductor)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 10 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 10 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 10 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG Conduit

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	Conduit	5	30
10	Conduit	10	30
10	Conduit	15	30
10	Conduit	20	30
10	Conduit	25	30
10	Conduit	30	30
10	Conduit	35	30
10	Conduit	40	30

Equilibrium: With reference to the test, test was continued until constant temperatures were attained. Thermal equilibrium is considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicate no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA in Conduit (2 Conductor)

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Scan	Time	203 CU-AL White Cable#1-Core	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	205 CU-AL Black Cable#2 Insulation	120 CU-AL White Cable#2 Core
	5 AMPS						
30.00	42966.40	23.32	22.63	22.90	23.15	23.26	23.40
	Corrected Ambient	31.77	31.08	31.35	31.59	31.70	31.85
	Average	31.85					
	Average core	31.89					
	Average insulation	31.80					
	10 AMPS						
64.00	42966.42	26.59	25.43	26.27	25.92	26.52	26.56
	Corrected Ambient	34.93	33.76	34.60	34.25	34.85	34.90
	Average	34.75					
	Average core	34.84					
	Average insulation	34.66					
	15 AMPS						
95.00	42966.44	31.92	29.65	31.74	30.41	31.65	31.89
	Corrected Ambient	40.23	37.96	40.05	38.72	39.97	40.21
	Average	39.72					
	Average core	39.93					
	Average insulation	39.49					
	20 AMPS						
132.00	42966.47	38.70	35.07	38.69	36.15	38.16	38.61
	Corrected Ambient	46.73	43.10	46.72	44.18	46.19	46.64
	Average	45.82					
	Average core	46.15					

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	Average insulation	45.45					
	26 AMPS						
162.00	42966.49	47.38	42.40	47.49	43.29	46.07	46.97
	Corrected Ambient	55.50	50.51	55.61	51.40	54.18	55.09
	Average	53.85					
	Average core	54.35					
	Average insulation	53.30					
	30 AMPS						
192.00	42966.51	57.44	50.50	57.79	51.44	55.09	56.93
	Corrected Ambient	65.41	58.46	65.75	59.40	63.05	64.90
	Average	62.99					
	Average core	63.71					
	Average insulation	62.17					
	35 AMPS						
222.00	42966.53	70.55	60.57	71.31	61.86	66.91	69.78
	Corrected Ambient	78.66	68.68	79.42	69.97	75.02	77.89
	Average	75.21					
	Average core	76.27					
	Average insulation	74.01					
	40 AMPS						
260.00	42966.56	86.35	74.81	87.61	74.53	81.18	86.55
	Corrected Ambient	94.33	82.80	95.59	82.51	89.16	94.53
	Average	89.94					
	Average core	91.36					
	Average insulation	88.34					

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10 AWG CCA in Conduit (2 Conductor)
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211 CU-AL White Cable# 3 Insulation	102 CU-AL Black Cable#3 Core	320 CU-AL Black Cable#4 Core	113 CU-AL White Cable #4 Core	114 CU-AL White Cable#4 Insulation	109 CU-AL Black Cable#5 Core
23.26	23.49	23.53	23.64	23.57	23.74
31.70	31.94	31.98	32.08	32.01	32.18
26.21	26.62	26.66	26.73	26.46	26.83
34.54	34.96	35.00	35.07	34.80	35.17
30.86	31.75	31.93	32.02	31.42	32.03
39.17	40.06	40.24	40.33	39.73	40.34
36.72	38.39	38.61	38.74	37.61	38.57
44.75	46.42	46.64	46.77	45.64	46.60

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43.72	46.74	46.85	47.03	45.17	46.62
51.83	54.86	54.96	55.14	53.28	54.74
51.86	56.42	56.62	56.89	54.04	56.27
59.83	64.38	64.58	64.86	62.00	64.23
62.45	69.09	69.33	69.71	65.42	68.98
70.56	77.20	77.43	77.81	73.53	77.09
74.86	84.65	84.99	85.42	79.26	84.28
82.84	92.63	92.97	93.40	87.25	92.26

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10 AWG CCA in Conduit (2 Conductor)
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107 CU-AL White Cable#5 Insulation	103 CU-AL Black Cable#5 Core	101 CU-AL Black Cbale#6 Insulation	104 CU-AL White Cable#6 Core	105 CU-AL White Cable#6 Insulation
23.63	23.30	23.62	23.65	23.71
32.08	31.75	32.07	32.09	32.16
26.63	25.87	26.80	26.40	26.61
8.34	8.34	8.34	8.34	8.34
34.97	34.21	35.14	34.73	34.94
31.70	30.22	32.18	31.08	31.53
8.31	8.31	8.31	8.31	8.31
40.01	38.53	40.49	39.39	39.85
38.35	35.78	39.22	37.02	38.08
8.03	8.03	8.03	8.03	8.03
46.38	43.81	47.25	45.05	46.11

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46.57	42.58	48.00	44.44	46.26
54.68	50.69	56.12	52.55	54.38
56.53	50.33	58.28	53.07	55.91
64.50	58.29	66.24	61.04	63.87
69.86	60.42	71.69	64.34	68.46
77.97	68.52	79.80	72.44	76.57
86.55	72.57	88.22	77.95	83.47
94.53	80.55	96.20	85.93	91.45

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10 AWG Cu in Conduit (2 Conductor)

(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30.00	42966.40	22.82	22.91	22.98	22.94	22.84	23.12
	Corrected Ambient	31.26	31.36	31.43	31.39	31.28	31.57
	Average	31.43					
	Average core	31.41					
	Average insulation	31.46					
	10 AMPS						
64.00	42966.42	24.81	24.98	24.84	24.87	24.60	24.72
	Corrected Ambient	33.14	33.32	33.18	33.21	32.94	33.06
	Average	33.21					
	Average core	33.19					
	Average insulation	33.23					
	15 AMPS						
95.00	42966.44	28.18	28.33	28.05	28.18	27.66	27.71
	Corrected Ambient	36.49	36.64	36.36	36.49	35.97	36.02
	Average	36.47					
	Average core	36.46					
	Average insulation	36.49					
	20 AMPS						
132.00	42966.47	32.50	32.63	32.33	32.54	31.64	31.58
	Corrected Ambient	40.53	40.66	40.36	40.57	39.67	39.61
	Average	40.49					
	Average core	40.48					
	Average insulation	40.50					
	26 AMPS						

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162.00	42966.49	37.65	37.76	37.74	37.82	36.46	36.24
	Corrected Ambient	45.76	45.87	45.85	45.93	44.58	44.35
	Average	45.73					
	Average core	45.75					
	Average insulation	45.72					
	30 AMPS						
192.00	42966.51	43.85	43.86	43.85	44.09	42.10	41.80
	Corrected Ambient	51.81	51.83	51.82	52.05	50.06	49.76
	Average	51.69					
	Average core	51.72					
	Average insulation	51.67					
	35 AMPS						
222.00	42966.53	51.88	51.82	51.54	52.18	49.45	48.85
	Corrected Ambient	59.99	59.93	59.65	60.29	57.56	56.95
	Average	59.66					
	Average core	59.67					
	Average insulation	59.65					
	40 AMPS						
260.00	42966.56	61.89	61.68	59.87	62.27	58.36	57.45
	Corrected Ambient	69.87	69.66	67.86	70.25	66.34	65.43
	Average	69.09					
	Average core	68.99					
	Average insulation	69.19					

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10 AWG Cu in Conduit (2 Conductor)

(Page 2 of 2)

304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Insulation	310 CU Black Cable#2 Core	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
23.07	22.92	23.07	23.03	23.07	23.10
31.52	31.37	31.51	31.48	31.51	31.54
24.81	24.45	25.07	24.82	25.23	25.25
33.15	32.79	33.41	33.16	33.56	33.58
27.97	27.26	28.60	28.02	29.02	28.99
36.28	35.57	36.91	36.33	37.33	37.30
32.12	30.89	33.22	32.16	33.93	33.93
40.15	38.92	41.25	40.19	41.96	41.96

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37.07	35.14	38.79	37.10	39.78	39.86
45.19	43.26	46.90	45.22	47.90	47.98
43.01	40.14	45.40	42.95	46.77	46.95
50.97	48.10	53.36	50.92	54.73	54.92
50.52	46.53	53.82	50.33	55.67	56.04
58.62	54.64	61.93	58.43	63.78	64.14
60.04	54.32	64.29	59.29	66.58	67.26
68.02	62.30	72.28	67.27	74.57	75.24

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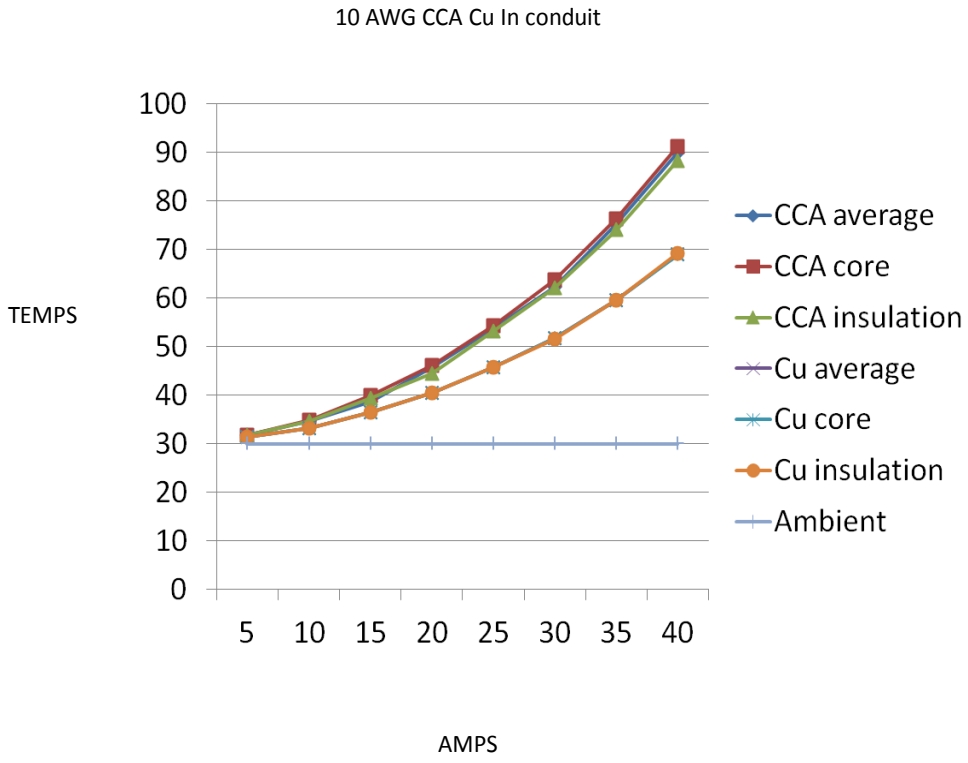

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Summary

14 AWG						
Max Temps	Single conductor@35A		NM cable@25A		Conduit@25A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	89.81	67.08	68.95	53.14	117.69	79.54
Average Core	92.67	67.91	69.61	53.05	124.41	82.77
Average Insulation	86.68	66.25	71.60	53.23	111.52	76.31

12 AWG						
Max Temps	Single conductor@40A		NM cable@30A		Conduit@30A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	76.85605	66.52817	59.54	49.96617	94.77	72.19
Average Core	80.71511	69.18933	62.19	51.36633	99.22	76.53
Average Insulation	72.72958	63.867	57.11	48.566	91.05	67.86

10 AWG						
Max Temps	Single conductor@55		NM cable@40A		Conduit@40 A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	85.54	69.97	61.97	51.05	89.94	69.09
Average Core	88.62	70.96	62.84	51.88	91.36	68.99
Average Insulation	82.30	68.98	60.91	50.21	88.34	69.19

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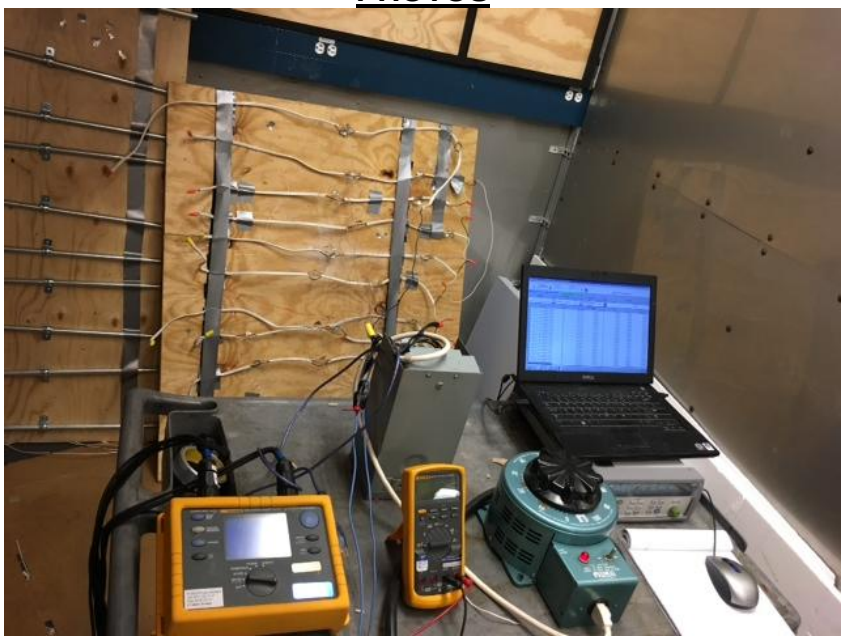
APPENDIX A
PHOTOS



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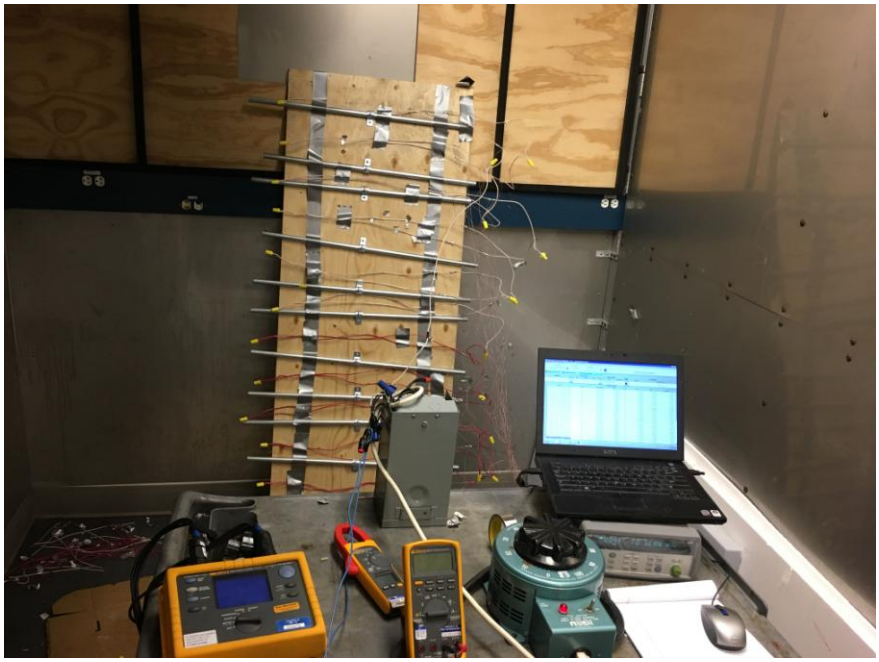

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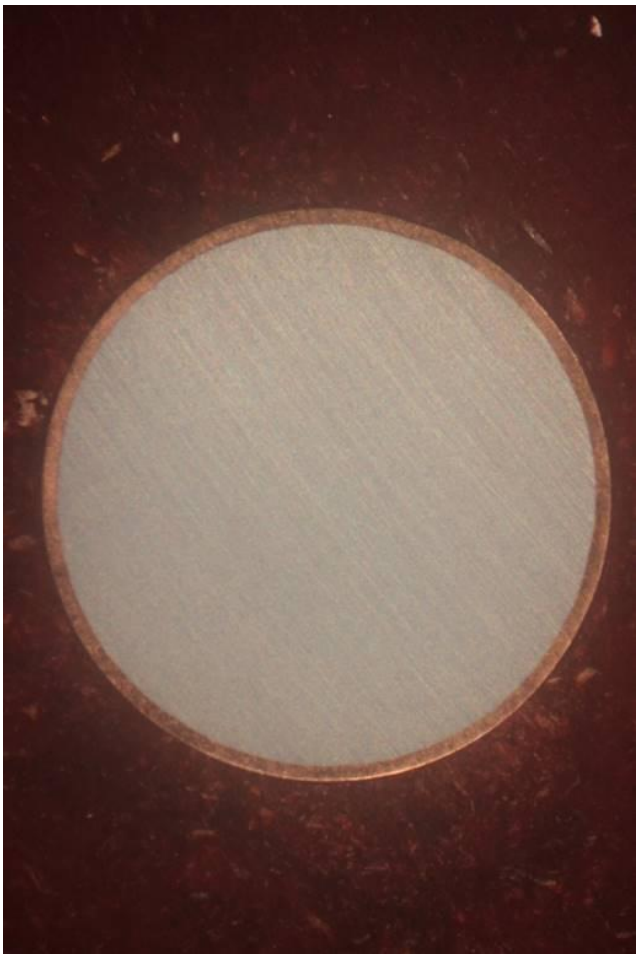

Cross Sectional view of the CCA

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APPENDIX B
EQUIPMENT LIST

Equipment	PL Code	Calibration
Transformer	PL004985	N/A
Agilent Temperature Data Acquisition system	PL005628	N/A
Thermocouples Cartridge, Type J	PL004988 PL003269 PL003268	Calibrated Daily or before each usage.
Simpson Model 06713100 Current shunt	PL002161	See Certificate Below Appendix C
Fluke multi meter, model 87V	PL004935	See Certificate Below Appendix C
Fluke Digital Clamp Meter, model 374FC	PL005812	See Certificate Below Appendix C
Thermocouples	Same as above	Conducted Daily
Power Logger	PL003379	See Certificate Below Appendix C

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APPENDIX C
CALIBRATION

Trescal

Certificate #: *3869120002 e* *W*

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	374FC
Description:	Clamp Meter
Serial Number:	37421743WS
Asset Number:	PL005812
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	05/01/2017
Due Date:	05/01/2018
Temperature:	73.00 **deg. F**
Humidity:	40.00 **%**
Baro. Press.:	
Procedure:	DCN 50442
Reference:	TO 33K1-4-853-1 Rev. 30 Jun 2008
Dept:	

Incoming Remarks:
w/case

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390482	Fluke	5522A	Multifunction Calibrator	11/22/2016	11/22/2017

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Trescal

Certificate #: *3765740001 e* *W*

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	87V
Description:	DMM
Serial Number:	26270081
Asset Number:	PL004935
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	01/31/2017
Due Date:	01/31/2018
Temperature:	74.00 **deg. F**
Humidity:	20.00 **%**
Baro. Press.:	
Procedure:	DCN 07074
Reference:	manufacturer's manual
Dept:	

Incoming Remarks:
w/case/leads/holster

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390169	Fluke	5500A	Multifunction Calibrator	04/26/2016	04/26/2017

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Trescal

Certificate #: *3869120002 e* *W*

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	374FC
Description:	Clamp Meter
Serial Number:	37421743WS
Asset Number:	PL005812
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	05/01/2017
Due Date:	05/01/2018
Temperature:	73.00 deg. F
Humidity:	40.00 %
Baro. Press.:	
Procedure:	DCN 50442
Reference:	TO 33K1-4-853-1 Rev. 30 Jun 2008
Dept:	

Incoming Remarks:
w/case

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390482	Fluke	5522A	Multifunction Calibrator	11/22/2016	11/22/2017

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ACCREDITED
Calibration Cert# 2165.01

FLUKE

Certificate of Calibration

Everett Service Center

Certificate Number:	322693		
Data Type:	As-Left	**Calibration Date:**	27-Feb-2017
Result Summary:	Measurement Results < Limits		
Manufacturer:	Fluke	**Certificate Date:**	28-Feb-2017
Model:	1735	**Temperature:**	23.6 °C
Serial Number:	S090503258B6	**Humidity:**	28.1 %
Description:	Power Quality Logger		
Procedure:	Fluke 1735:(2 year) ACAL VER RS-232/5520	**Revision:**	2.1
Customer:	NSF INTERNATIONAL		
City:	ANN ARBOR	**Country:**	US
State:	MI		
Purchase Order:	CCS CALIBRATION LAB - NSF INTERNATIONAL	**RMA:**	31194022
Asset ID:	PL003379		

This calibration is traceable to the International System of Units (SI), through National Metrology Institutes (NIST, PTB, NRC, NPL, etc.), ratiometric techniques, or natural physical constants. This certificate applies only to the item identified and shall not be reproduced either than in full, without the specific written approval by Fluke Corporation. Calibration certificates without signature are not valid. The calibration has been completed in accordance with Fluke Electronics Corporation Quality System Document 111.0 Revision 11B 8/2014 and/or Fluke 17025 Quality Manual QSD 111.41 Revision 005 8/2014.

The Data Type found in this certificate must be interpreted as:

- As - Found Calibration data collected before the unit is adjusted and / or repaired.
- As - Left Calibration data collected after the unit has been adjusted and / or repaired.
- Found-Left Calibration data collected without any adjustment and / or repair performed.

This calibration conforms to the requirements of ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994 (R2002).

In the attached measurement results, deviation may be expressed with units, Measured Value (MV) - Nominal Value (NV) or as a proportion of the nominal value ((MV-NV)/NV), expressed without units with a scalar multiplier such as % (0.01), or as a ratio of the units (mA/A, µ/V, etc.) Descriptions such as µA/A, µV/V, and others, where used to annotate results or column headings are the preferred replacements for what was historically labeled as "ppm" or parts-per-million and described the results in that column, unless otherwise noted by units symbols.

Where applicable, the expanded uncertainty of measurement at the time of test is given in the following pages. They are calculated in accordance with the method described in the ISO Guide to the Expression of Uncertainty in Measurement (GUM). The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k, such that the confidence level approximates 95%.

This calibration certificate may contain data that is not covered by the A2LA Scope of Accreditation. Unaccredited material, where applicable is indicated by an asterisk (*), or confined to clearly marked sections. Functional (Pass / Fail) tests are not accredited.

No statement of compliance with specifications is made or implied on this certificate. However, measurement results are reviewed, where applicable, to establish where any measurement result exceeded the manufacturer's specifications.

Measurement results greater than limits of error are indicated by '!'.

Accredited FLUKE

Cert # 322693
Cal Date 27-Feb-2017
S/N S090503258B6
www.fluke.com

Cert # 322693
Date 27/2/2017
www.fluke.com

Rolly Sherwood
Calibration Technician

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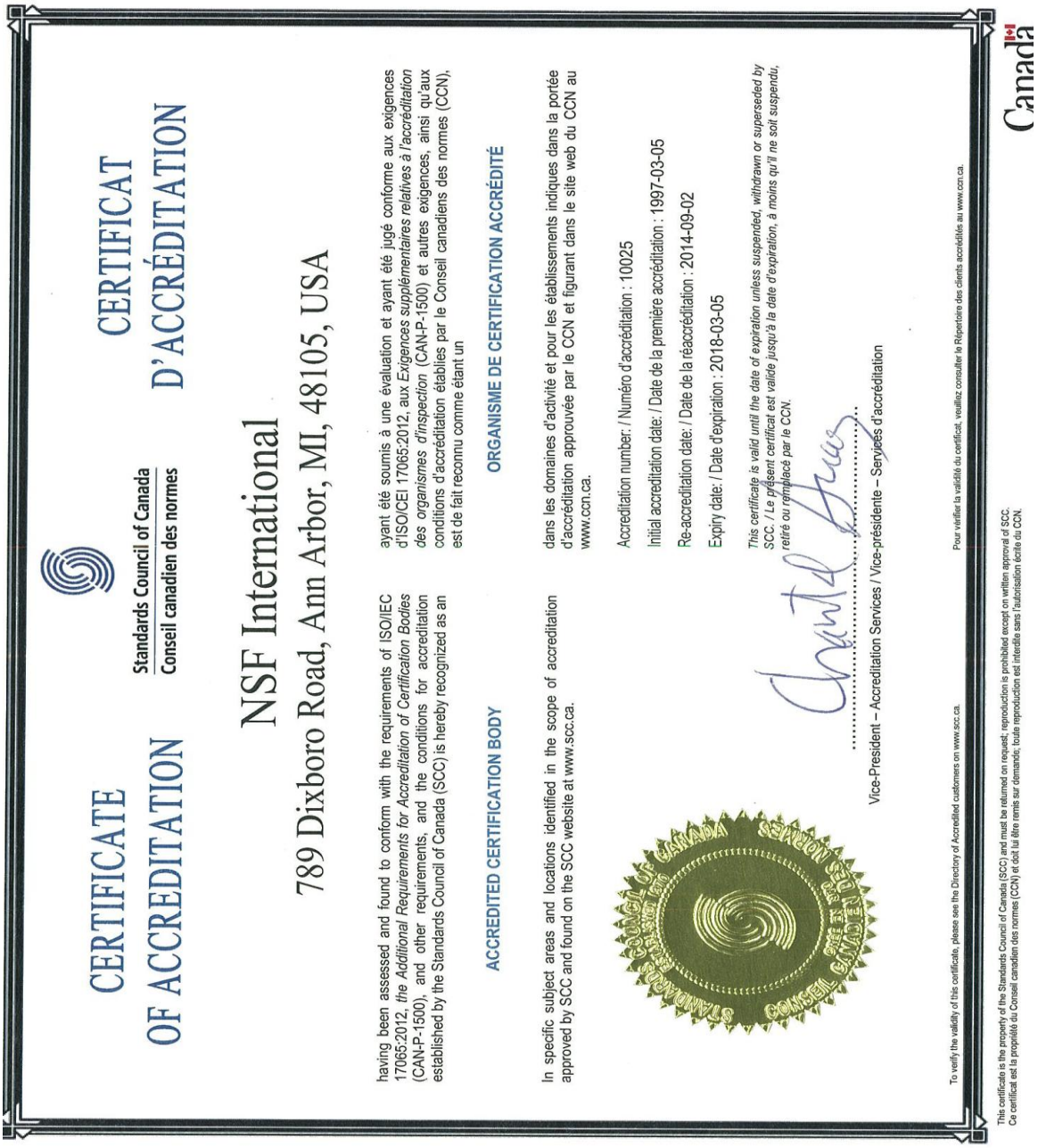
APPENDIX D
LABORATORY CERTIFICATIONS



CERTIFICATE OF ACCREDITATION

Standards Council of Canada
Conseil canadien des normes

CERTIFICAT D'ACCRÉDITATION

NSF International
789 Dixboro Road, Ann Arbor, MI, 48105, USA

having been assessed and found to conform with the requirements of ISO/IEC 17065:2012, *the Additional Requirements for Accreditation of Certification Bodies* (CAN-P-1500), and other requirements, and the conditions for accreditation established by the Standards Council of Canada (SCC) is hereby recognized as an

ayant été soumis à une évaluation et ayant été jugé conforme aux exigences d'ISO/CEI 17065:2012, aux *Exigences supplémentaires relatives à l'accréditation des organismes d'inspection* (CAN-P-1500) et autres exigences, ainsi qu'aux conditions d'accréditation établies par le Conseil canadiens des normes (CCN), est de fait reconnu comme étant un

ACCREDITED CERTIFICATION BODY

ORGANISME DE CERTIFICATION ACCRÉDITÉ

In specific subject areas and locations identified in the scope of accreditation approved by SCC and found on the SCC website at www.scc.ca.

dans les domaines d'activité et pour les établissements indiques dans la portée d'accréditation approuvée par le CCN et figurant dans le site web du CCN au www.ccn.ca.

Accreditation number: / Numéro d'accréditation : 10025

Initial accreditation date: / Date de la première accréditation : 1997-03-05

Re-accreditation date: / Date de la réaccréditation : 2014-09-02

Expiry date: / Date d'expiration : 2018-03-05

This certificate is valid until the date of expiration unless suspended, withdrawn or superseded by SCC. / Le présent certificat est valide jusqu'à la date d'expiration, à moins qu'il ne soit suspendu, retiré ou remplacé par le CCN.

STANDARDS COUNCIL OF CANADA
CONSEIL CANADIEN DES NORMES

Vice-President – Accreditation Services / Vice-présidente – Services d'accréditation

To verify the validity of this certificate, please see the Directory of Accredited customers on www.scc.ca.

Pour vérifier la validité du certificat, veuillez consulter le Répertoire des clients accrédités au www.ccn.ca.

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Canada

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CERTIFICATE

Certificate Number: 140920.00

The Environmental Management System and implementation of:

NSF International
789 N. Dixboro Road
Ann Arbor, MI 48105
United States

meets the requirements of the standard:

ISO 14001:2015

Scope:
Laboratory testing, product certification, and domestic (U.S.) auditing associated with the facility located at 789 N. Dixboro Road, Ann Arbor, Michigan. NSF-ISR operations are excluded from the scope of registration.

Certificate Expires:	July 04, 2018
Re-issued:	August 08, 2017
Certificate Issued:	July 05, 2015
Certified Since:	July 05, 2006

Dr. Cem O. Onus
Managing Director, Business Assurance
DEKRA Certification, Inc.
1120 Welsh Road, Suite 210
North Wales, PA 19454 USA
(215) 997-4519
dekra-certification.us

ANAB ACCREDITED ISO/IEC 17021 MANAGEMENT SYSTEMS CERTIFICATION BODY

MEMBER OF MULTILATERAL RECOGNITION ARRANGEMENT IAF

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Occupational Safety and Health Administration

Nationally Recognized Testing Laboratory Program

NRTLP

Certificate of Recognition

NSF International

with headquarters at:

789 Dixboro Road
Ann Arbor, Michigan 48105
United States

is recognized by the Occupational Safety and Health Administration (OSHA) as meeting the requirements for a Nationally Recognized Testing Laboratory (NRTL) established under Section 1910.7 of *Title 29, Code of Federal Regulations.* This recognition is limited to testing and certification only within the current scope of recognition and is subject to all other terms set forth in the letter of recognition and in applicable *Federal Register* notices and as summarized on OSHA's website. This recognition continues in force beyond the "*Effective through*" date below provided the NRTL has filed a timely request for renewal with OSHA. For current recognition status and other recognition information, contact the OSHA NRTL Program or visit *https://www.osha.gov/dts/otpca/nrtl/*

July 14, 2019
Effective Through

David Michaels, PhD, MPH
Assistant Secretary of Labor for
Occupational Safety and Health Administration

UNITED STATES OF AMERICA · DEPARTMENT OF LABOR

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intertek
Total Quality. Assured.

COPPERWELD BIMETALLICS
TEST REPORT

SCOPE OF WORK
ASTM E228 LINEAR THERMAL EXPANSION EVALUATION OF 14 AWG GAGE COPPER CLAD ALUMINUM (CCA) WIRE

REPORT NUMBER
I6049.04-106-31 R0

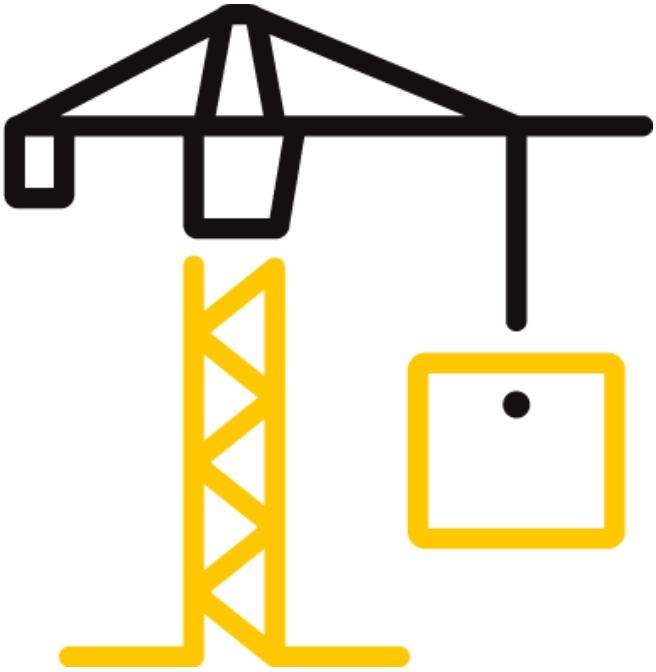
TEST DATES
07/12/18 - 07/19/18

ISSUE DATE
08/15/18

RECORD RETENTION END DATE
07/26/22

PAGES
8

DOCUMENT CONTROL NUMBER
ATI 00231 (09/05/17)
RT-R-AMER-Test-2827
© 2017 INTERTEK



130 Derry Court
York, Pennsylvania 17406

Telephone: 717-764-7700
Facsimile: 717-764-4129
www.intertek.com/building

TEST REPORT FOR COPPERWELD BIMETALLICS

Report No.: I6049.04-106-31 R0
Date: 08/15/18

REPORT ISSUED TO

COPPERWELD BIMETALLICS
254 Cotton Mill Road
Fayetteville, Tennessee 37334

SECTION 1

SCOPE

Products: 14 AWG gage Copper Clad Aluminum (CCA) Wire

Intertek Building & Construction (B&C) was contracted by Copperweld Bimetallics to evaluate 14 AWG gage Copper Clad Aluminum (CCA) Wire in accordance with ASTM E228 for Linear Thermal Expansion properties. Results obtained are tested values and were secured by using the designated test methods. Testing was conducted at the Intertek B&C test facility in York, Pennsylvania.

This report does not constitute certification of this product nor an opinion or endorsement by this laboratory.

SECTION 2

SUMMARY OF TEST RESULTS

COPPER CLAD ALUMINUM (CCA) WIRE AWG GAGE	CLTE (mm/mm/°C) 25°C to 90°C TEMPERATURE RANGE
14	8.89E-06

For INTERTEK B&C:

COMPLETED BY:	Joseph M. Brickner	**REVIEWED BY:**	Dawn M. Chaney
TITLE:	Laboratory Supervisor Materials Laboratory	**TITLE:**	Technician Team Lead Materials laboratory
SIGNATURE:		**SIGNATURE:**	
DATE:	08/15/18	**DATE:**	08/15/18

JMB:dmc/jp

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130 Derry Court
York, Pennsylvania 17406

Telephone: 717-764-7700
Facsimile: 717-764-4129
www.intertek.com/building

SECTION 3
TEST METHOD

The specimens were evaluated in accordance with the following:

> **ASTM E228-17**, *Standard Test Method for Linear Thermal Expansion of Solid Materials with a Push-Rod Dilatometer*

SECTION 4
MATERIAL SOURCE

The test materials were provided by Copperweld Bimetallics. The following was received: One (1), nominally 76 mm copper clad aluminum wire specimens in 14 AWG gage. Refer to the product description photo in Section 10. The material was tested as received except for smoothing the cut ends of each specimen. Representative test specimens will be retained by Intertek B&C for a minimum of four years from the test completion date.

SECTION 5
LIST OF OFFICIAL OBSERVERS

NAME	COMPANY
Joseph M. Brickner	Intertek B&C
Dawn M. Chaney	Intertek B&C

SECTION 6
TEST PROCEDURE

All conditioning of test specimens and test conditions were at standard laboratory conditions unless otherwise reported. Refer to the test related photos in Section 10.

ASTM E228 - Linear Thermal Expansion
One specimen for each wire gage was measured for initial length using a 6" digital caliper (ICN: 65688) and placed in the bottom of an outer glass dilatometer tube with an inner glass tube resting on it. An aluminum support cylinder was utilized to keep the wire oriented in a vertical position. The dilatometer tube was suspended in a heated environment utilizing a muffle furnace (ICN: Y002864) and subjected to exposure conditions of nominally 25°C and 90°C. At the equilibrium of each temperature condition, specimen temperature was measured using a thermocouple reader (ICN: 62101) and a measurement was recorded from a digital indicator (ICN: INT00193) resting on top of the inner tube. The Linear Thermal Expansion between the temperature range was calculated.

DRAFT

130 Derry Court
York, Pennsylvania 17406

Telephone: 717-764-7700
Facsimile: 717-764-4129
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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.04-106-31 R0
Date: 08/15/18

SECTION 7
TEST SPECIMEN DESCRIPTIONS

TEST PROCEDURE	NUMBER OF SPECIMENS	NOMINAL SPECIMEN DIMENSIONS	VISUAL CHARACTERISTICS
ASTM E228 Linear Thermal Expansion	1	75 mm x 14 gage wire thickness	Copper Clad Aluminum wire

SECTION 8
TEST RESULTS

ASTM E228 - Linear Thermal Expansion

Copper Clad Aluminum (CCA) Wire - 14 Gage

All Temperatures

LENGTH (mm)	75.56	
TARGET TEMPERATURE (°C)	25	90
ACTUAL TEMPERATURE (°C)	25.4	90.9
GAGE READING (mm)	6.6070	6.6510
ΔT (°C)		65.5
ΔL (mm)		0.0440
ΔL/ΔT (mm/°C)		6.72E-04
CLTE (mm/mm/°C)		**8.89E-06**

SECTION 9
CONCLUSION

The requested test method did not contain specific performance requirements.

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130 Derry Court
York, Pennsylvania 17406

Telephone: 717-764-7700
Facsimile: 717-764-4129
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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.04-106-31 R0
Date: 08/15/18

SECTION 10
PHOTOGRAPHS

Photo No. 1
Copper Clad Aluminum - Specimen Detail

Photo No. 2
ASTM E228 - Equipment Detail

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Facsimile: 717-764-4129
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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.04-106-31 R0
Date: 08/15/18

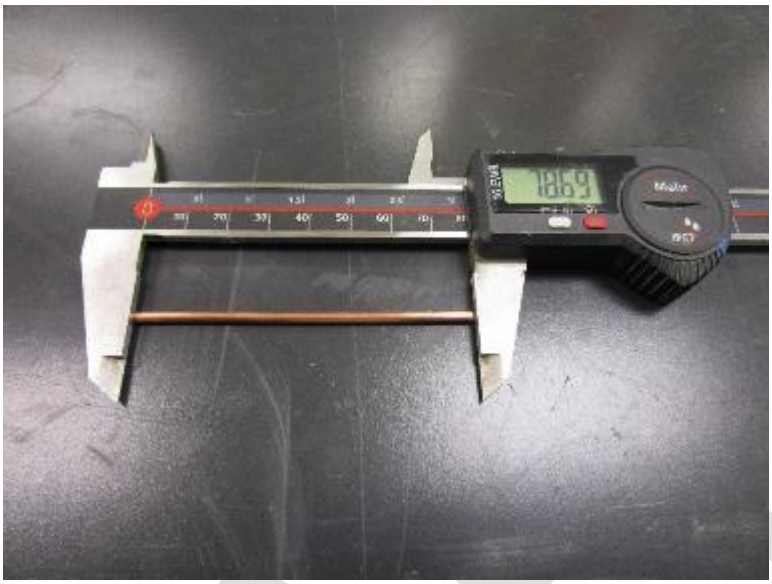

Photo No. 3
ASTM E228 - Length Measurement Equipment Detail

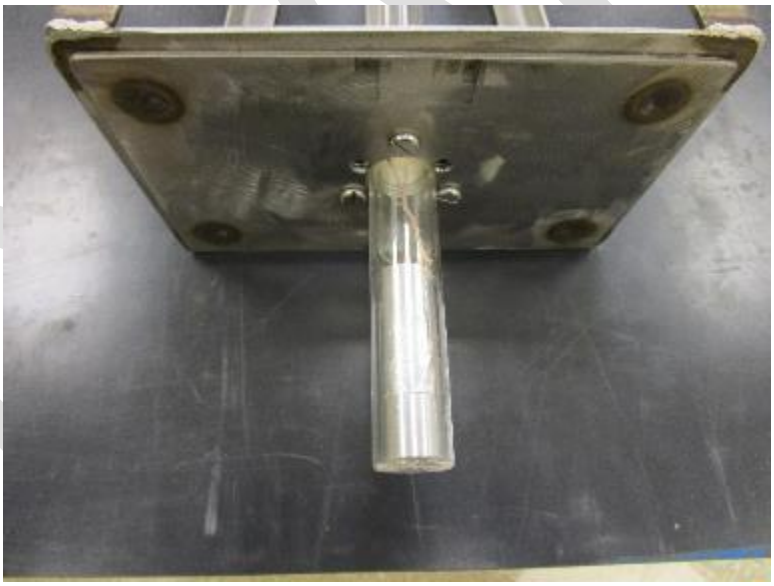

Photo No. 4
ASTM E228 - Specimen Support Detail

130 Derry Court
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TEST REPORT FOR COPPERWELD BIMETALLICS
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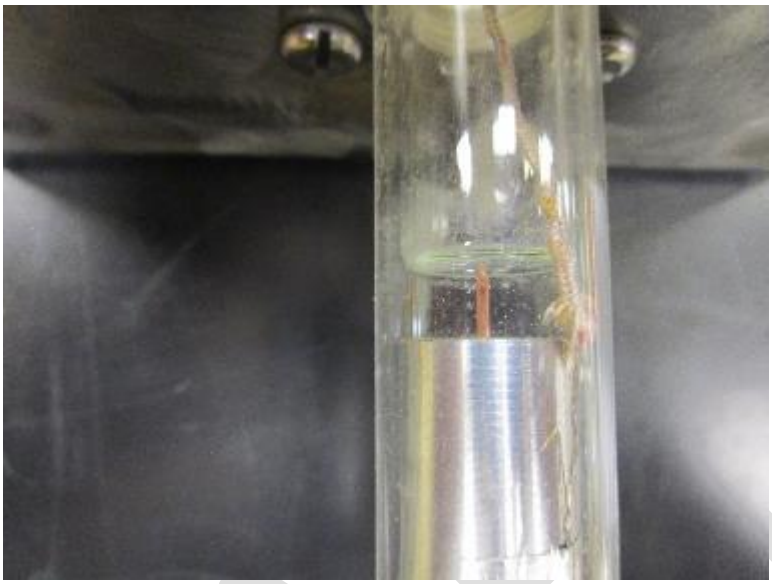

Photo No. 5
ASTM E228 - Specimen Temperature Measurement Detail

Photo No. 6
ASTM E228 - Linear Expansion Measurement Equipment Detail

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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.04-106-31 R0
Date: 08/15/18

SECTION 11
REVISION LOG

REVISION #	DATE	PAGES	REVISION
0	08/15/18	N/A	Original Report Issue

DRAFT

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COPPERWELD BIMETALLICS
TEST REPORT

SCOPE OF WORK
ASTM E228 LINEAR THERMAL EXPANSION EVALUATION OF 14 AWG GAGE ELECTROLYTIC TOUGH PITCH (ETP) COPPER WIRE

REPORT NUMBER
I6049.03-106-31 R0

TEST DATES
07/19/18 - 07/26/18

ISSUE DATE
08/15/18

RECORD RETENTION END DATE
07/26/22

PAGES
8

DOCUMENT CONTROL NUMBER
ATI 00231 (09/05/17)
RT-R-AMER-Test-2827
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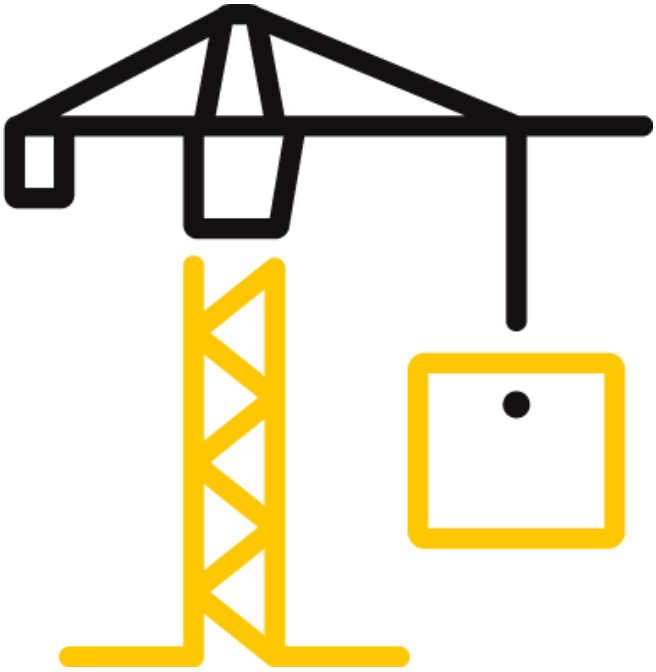

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TEST REPORT FOR COPPERWELD BIMETALLICS

Report No.: I6049.03-106-31 R0
Date: 08/15/18

REPORT ISSUED TO

COPPERWELD BIMETALLICS
254 Cotton Mill Road
Fayetteville, Tennessee 37334

SECTION 1

SCOPE

Products: 14 AWG gage Electrolytic Tough Pitch (ETP) Wire

Intertek Building & Construction (B&C) was contracted by Copperweld Bimetallics to evaluate 14 AWG gage Electrolytic Tough Pitch (ETP) Wire in accordance with ASTM E228 for Linear Thermal Expansion properties. Results obtained are tested values and were secured by using the designated test methods. Testing was conducted at the Intertek B&C test facility in York, Pennsylvania.

This report does not constitute certification of this product nor an opinion or endorsement by this laboratory.

SECTION 2

SUMMARY OF TEST RESULTS

ELECTROLYTIC TOUGH PITCH (ETP) COPPER WIRE AWG GAGE	CLTE (mm/mm/°C) 25°C to 90°C TEMPERATURE RANGE
14	1.57E-05

For INTERTEK B&C:

COMPLETED BY:	Joseph M. Brickner	**REVIEWED BY:**	Dawn M. Chaney
TITLE:	Laboratory Supervisor Materials Laboratory	**TITLE:**	Technician Team Lead Materials laboratory
SIGNATURE:		**SIGNATURE:**	
DATE:	08/15/18	**DATE:**	08/15/18

JMB:dmc/jlp

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130 Derry Court
York, Pennsylvania 17406

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SECTION 3
TEST METHOD

The specimens were evaluated in accordance with the following:

> **ASTM E228-17**, *Standard Test Method for Linear Thermal Expansion of Solid Materials with a Push-Rod Dilatometer*

SECTION 4
MATERIAL SOURCE

The test materials were provided by Copperweld Bimetallics. The following were received: One (1), nominally 76 mm electrolytic tough pitch copper wire specimen in 14 AWG gage. Refer to the product description photo in Section 10. The material was tested as received except for smoothing the cut ends of each specimen. Representative test specimens will be retained by Intertek B&C for a minimum of four years from the test completion date.

SECTION 5
LIST OF OFFICIAL OBSERVERS

NAME	COMPANY
Joseph M. Brickner	Intertek B&C
Dawn M. Chaney	Intertek B&C

SECTION 6
TEST PROCEDURE

All conditioning of test specimens and test conditions were at standard laboratory conditions unless otherwise reported. Refer to the test related photos in Section 10.

ASTM E228 - Linear Thermal Expansion
One specimen for each wire gage was measured for initial length using a 6" digital caliper (ICN: 65688) and placed in the bottom of an outer glass dilatometer tube with an inner glass tube resting on it. An aluminum support cylinder was utilized to keep the wire oriented in a vertical position. The dilatometer tube was suspended in a heated environment utilizing a muffle furnace (ICN: Y002864) and subjected to exposure conditions of nominally 25°C and 90°C. At the equilibrium of each temperature condition, specimen temperature was measured using a thermocouple reader (ICN: 62101) and a measurement was recorded from a digital indicator (ICN: INT00193) resting on top of the inner tube. The Linear Thermal Expansion between the temperature range was calculated.

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SECTION 7
TEST SPECIMEN DESCRIPTIONS

TEST PROCEDURE	NUMBER OF SPECIMENS	NOMINAL SPECIMEN DIMENSIONS	VISUAL CHARACTERISTICS
ASTM E228 Linear Thermal Expansion	1 each	75 mm x 14 gage wire thickness	Electrolytic Tough Pitch Copper wire

SECTION 8
TEST RESULTS

ASTM E228 - Linear Thermal Expansion

Electrolytic Tough Pitch (ETP) Copper Wire - 14 Gage

All Temperatures

LENGTH (mm)	75.60	
TARGET TEMPERATURE (°C)	25	90
ACTUAL TEMPERATURE (°C)	28.7	91.3
GAGE READING (mm)	5.6440	5.7220
ΔT (°C)		62.6
ΔL (mm)		0.0780
ΔL/ΔT (mm/°C)		1.25E-03
CLTE (mm/mm/°C)		**1.57E-05**

SECTION 9
CONCLUSION

The requested test method did not contain specific performance requirements.

DRAFT

130 Derry Court
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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.03-106-31 R0
Date: 08/15/18

SECTION 10
PHOTOGRAPHS

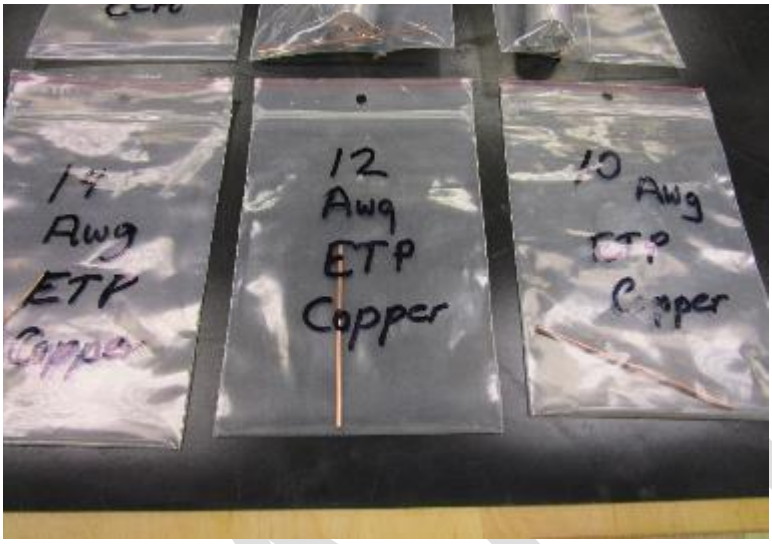

Photo No. 1
Electrolytic Tough Pitch - Specimen Detail

Photo No. 2
ASTM E228 - Equipment Detail

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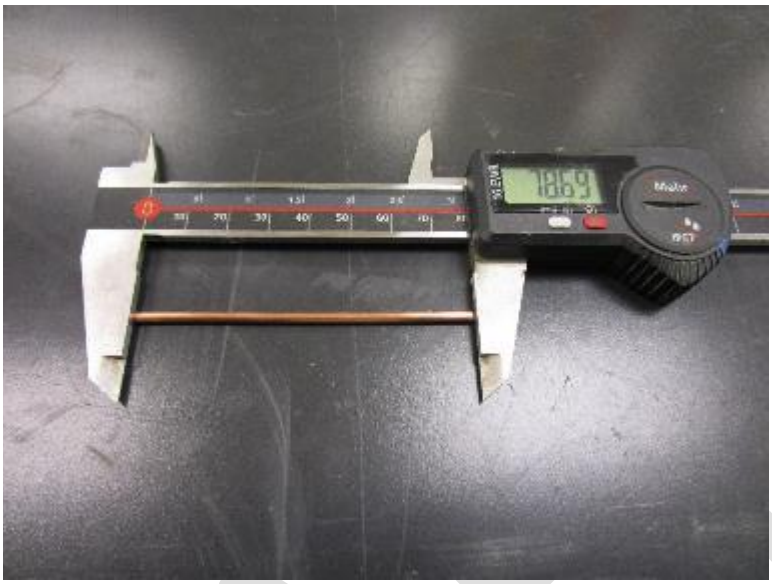

Photo No. 3
ASTM E228 - Length Measurement Equipment Detail

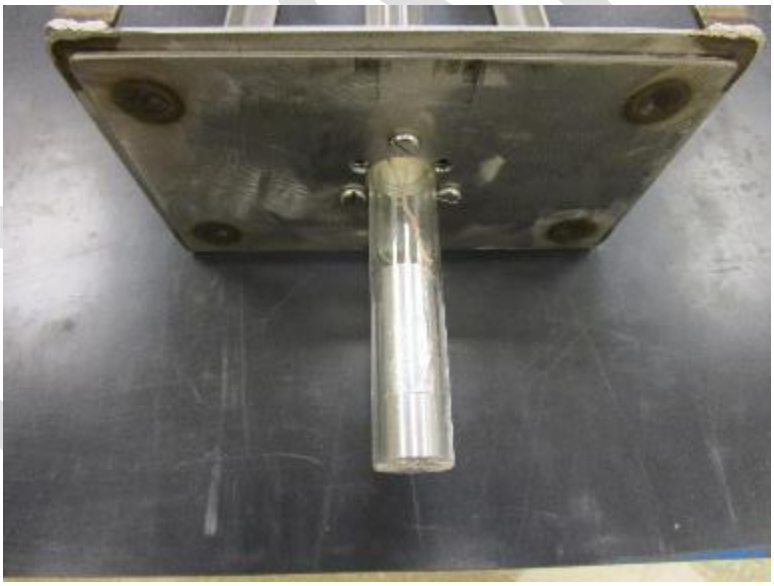

Photo No. 4
ASTM E228 - Specimen Support Detail

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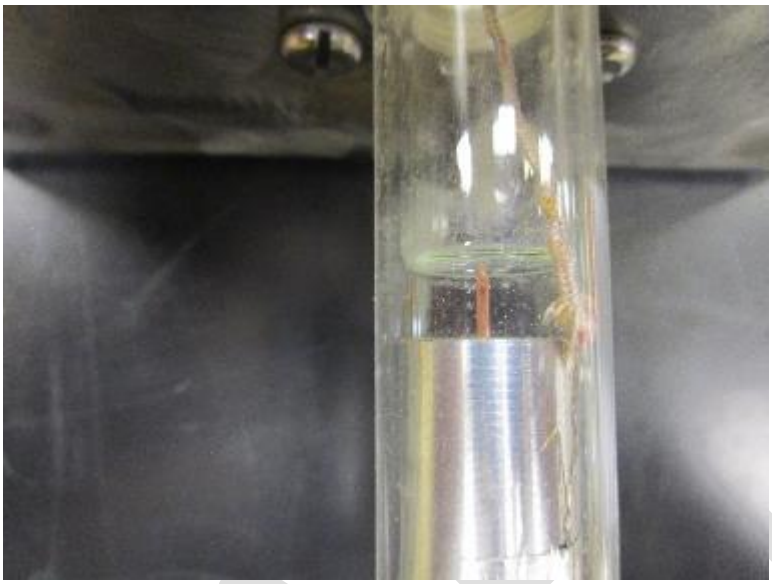

Photo No. 5
ASTM E228 - Specimen Temperature Measurement Detail

Photo No. 6
ASTM E228 - Linear Expansion Measurement Equipment Detail

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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.03-106-31 R0
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SECTION 11
REVISION LOG

REVISION #	DATE	PAGES	REVISION
0	08/15/18	N/A	Original Report Issue

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NOTICE OF COMPLETION
AND
AUTHORIZATION TO APPLY THE UL MARK

2017.10.06

Peter Graser
Copperweld Bimetallics LLC
254 Cotton Mill Rd
Fayetteville, TN, 37334, US

Our Reference:	File E492024, Vol 1	Order:	11882073
		Project:	4788086098
Your Reference:	Peter Graser 7/24/2017		
Project Scope:	Testing to add NM-B wire to NEW Copperweld Nonmetallic Sheathed-Cable File Construction will employ recognized CCA, and Listed Type THHN & PVC jacket		

Dear Peter Graser:

Congratulations! UL's investigation of your product(s) has been completed under the above Reference Number and the product was determined to comply with the applicable requirements. This letter temporarily supplements the UL Follow-Up Services Procedure and serves as authorization to apply the UL Mark at authorized factories under UL's Follow-Up Service Program. To provide your manufacturer(s) with the intended authorization to use the UL Mark, you must send a copy of this notice to each manufacturing location currently authorized under File e492024, Vol 1.

Records in the Follow-Up Services Procedure covering the product are now being prepared and will be sent in the near future. Until then, this letter authorizes application of the UL Mark for 90 days from the date indicated above.

Additional requirements related to your responsibilities as the Applicant can be found in the document "Applicant responsibilities related to Early Authorizations" that can be found at the following web-site: http://www.ul.com/EAResponsibilities

Any information and documentation provided to you involving UL Mark services are provided on behalf of UL LLC (UL) or any authorized licensee of UL.

We are excited you are now able to apply the UL Mark to your products and appreciate your business. Feel free to contact me or any of our Customer Service representatives if you have any questions.

Very truly yours,

Brian Cavalli
Engineering Associate
Brian.Cavalli@ul.com

Reviewed by:

Bruce A. Mahrenholz
CPO Director
Bruce.A.Mahrenholz@ul.com

d1ee6431-b01c-4fdc-ac75-c9d5fae7e357

SHIPPING FORM FOR SENDING SAMPLES TO UL

To

UL LLC
1285 Walt Whitman Rd.
Melville NY 11747-3081 USA

Order #: 11882073
Service Request #: N/A
Industry Group:
Requestor: BRIAN CAVALLI

Barcode for Project: 1000306419
1000306419

Samples Requested:

1080076	*1080076*	(Quantity: 1) 250 feet of 2/C, No. 14 AWG FLAT Type NM-B, employing THHN copper-clad aluminium conductors, bare grounding conductor, and overall PVC jacket with thickness in accordance with the Standard. (designation tbd)
1080077	*1080077*	(Quantity: 1) 250 feet of 3/C, No. 14 AWG ROUND Type NM-B, employing THHN copper-clad aluminium conductors, bare grounding conductor, and overall PVC jacket with thickness in accordance with the Standard. (designation tbd)

Completed by Customer

Note: Samples should be sent to the address location shown above with a copy of this form provided with each shipping container. To ensure prompt processing of your sample upon arrival, the information requested on this form MUST be included with the shipment. Incomplete or missing information will result in a delay of processing your sample, and possible return or disposal of the sample prematurely.

Samples included with this shipment (Please list in the box below):

What would you like UL to do with your sample(s) when work is complete? (Choose one)
Please Note: It is a UL policy that we return all hazardous materials unless prohibited by applicable laws.

☐ **Destroy** - UL will destroy the samples when work is complete and dispose of them in accordance with local disposal guidelines.

☐ **Customer to Pick Up at UL** - You will arrange for the samples to be picked up from the UL office. If samples are not picked up within 30 days, UL will arrange for the samples to be returned to you. Please provide the name of a shipping company, shipping account number, insurance value and confirm the return shipping information below.

☐ **Ship/Return at your expense** - UL will arrange for the samples to be returned to you. Please provide the name of a shipping company, shipping account number, insurance value, and confirm the return shipping information below. If you do not provide your shipping account number, the shipping charges will be added to your UL project invoice.

Sample Being Shipped to UL From:		**UL Should Return Sample to (complete if sample to be returned and address different than at left):**
Company Name:	Copperweld Bimetallics LLC	Company Name:
Company Address:	254 Cotton Mill Rd Fayetteville TN 37334	Company Address:
Contact Person:	Peter Graser	Contact Person:
Contact Phone:		Contact Phone:
Contact Email:	petergraser@intexpco.com	Contact Email:
		Shipping Company:
		Shipping Account Number:

Public Comment No. 1410-NFPA 70-2018 [Section No. 334.104]

334.104 Conductors.

The 600-volt

~~insulated power conductors~~

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

Additional Proposed Changes

File Name	Description	Approved
SampleReqForm_-_MEL.pdf	For Listing Purposes of Cu-Clad NM Cable, UL tested 14 AWG CCA	
Notice_of_Authorization-2017-10-06-4788086098.pdf	Notice of Authorization of UL Listing based upon 14 AWG CCA Testing for NM Cable	
Prop_Table_310.16_310.15_B_16_.pdf	Proposed Table 310.16 Allowing for 14 AWG CCA	
Proposed_Table_310.17_310.15_B_17_.pdf	Proposed Table 310.17 Allowing for 14 AWG CCA	
14_AWG_CCA_Summary.NSFvETL.pdf	Summary Heat Data ETL and NSF	
14_AWG_Thermal_Expansion_Summary.1535458407587_2_.pdf	Summary of Thermal Expansion per ASTM E228 14 AWG CCA vs. 14 AWG Cu at 90C	
CONCLUSIONS_FROM_UL_486C_SPRING.pdf	14 AWG CCA: Summary of UL 486C Spring Action Sequence TEST with "Copper Only" Wago, Ideal, Pushin Connectors	
Intetek.UL486C.SAS.103589128CRT-001A_003_.pdf	Test Report, Intertek: UL 486C Spring Action Sequence, Copper ONLY push-in Idea, Wago	
J-00265162_FINAL_Copperweld_FFR-_CCA-Cu_Final_Report_Revised_10-27-17.pdf	Test Report: NSF Fact Finding Heat Data.	
ETL.14awgCCA.Thermalstablei6049.04-106-31-r0.pdf	14 AWG CCA. INTERTEK Report. ASTM E228 Linear Thermal Expansion	
ETL.14awgCu.Thermalstablei6049.03-106-31-r0.pdf	14 AWG ETP Copper, INTERTEK Report. ASTM E228 Linear Thermal Expansion.	

Statement of Problem and Substantiation for Public Comment

PUBLIC COMMENT RESPONSE:

- Based upon Fact Finding reports provided to this Code Making Panel, 14 AWG CCA for use with NMB Cables at the Ampacity proposed in Public Comment 1382 is ideal for a future of energy-efficient branch circuits utilizing LEDs and Energy Saving Equipment. Such an allowance would not only be safe for the consumer, but also, it would provide a substantial savings in the cost of installation of such circuits. Public inputs 3174, 2123 and 2128 were submitted to provide for 14 AWG copper-clad aluminum as a recognized conductor in Articles 310 and 334. It

is agreed that the product standard does not recognize 14 AWG copper-clad aluminum but product standards follow what is allowed in the NEC. Therefore, this Public Comment requests that 14 AWG copper-clad aluminum be allowed into Code, as the Fact Finding solidly supports it. Using the lack of product safety standard recognition as reasoning to not allow 14 AWG copper-clad aluminum is creating an untenable catch 22.

- New Technology and Energy Efficiency have Ideal Uses for 14 AWG Copper-clad Aluminum. With the evolution of LED Lighting and Energy Efficient Equipment, the industry substantiates a need for 14 AWG copper-clad aluminum, even at an ampacity of 10 Amps, and it should be recognized by article 334. For copper-clad aluminum in general, there is no documented instances of failures that would cause a belief that there is a safety issue. With the ampacity limitations proposed for use of 14 AWG copper-clad aluminum and the testing data that backs it up, there is no technical reason for CMP-6 to not allow for 14 AWG copper-clad aluminum as a suitable conductor.
- History of Safe Use. 14 AWG and “smaller” ASTM B566 copper-clad aluminum wires have been safely used for decades in applications (as the individual strands of stranded conductors forming THHN, SEU, PV, Battery Cable, Large Appliance Cord, Jumper Cable, among others) and Data applications (coaxial and trunk cables). ASTM B566 copper-clad aluminum wire is routinely drawn to 22 AWG for applications in power, and 34 AWG for applications in data. There has been no technical substantiation given by CMP6 as to why 14 AWG ASTM B566 copper-clad aluminum wire made with an AA-8000 series aluminum core is unsuitable to be recognized by article 334. 14 AWG could be included in the UL standard for MC cable if it were recognized by article 310. Thermal Stability, Mechanical Integrity and Electrical Performance have never been questioned.

- Old History Should Not Impede with New Data as Provided. When the initial ampacities for copper-clad aluminum were introduced into the 1971 NEC, copper-clad aluminum and aluminum were grouped together right, wrong or indifferent. To not recognize 14 AWG ASTM B566 copper-clad aluminum wire in article 334 appears to be a clear case of CMP6 confusing it with single-metal aluminum wire, which carries historical baggage. ASTM B566 copper-clad aluminum wire’s safety record is spotless in the electrical field, evidenced by CMP6’s lack of ability to site instances of failure. Today’s fact finding has documented that 14 AWG copper-clad aluminum is safe for use at the ampacities proposed. CCA NM Cable currently carries a UL Listing, which presupposes electrical and mechanical suitability for the intended use.

Related Item

- 2128

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 28 09:20:44 EDT 2018
Committee: NEC-P06

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

SHIPPING FORM FOR SENDING SAMPLES TO UL

To

UL LLC
1285 Walt Whitman Rd.
Melville NY 11747-3081 USA

Order #: 11882073
Service Request #: N/A
Industry Group:
Requestor: BRIAN CAVALLI

Barcode for Project: 1000306419
1000306419

Samples Requested:

1080076	*1080076*	(Quantity: 1) 250 feet of 2/C, No. 14 AWG FLAT Type NM-B, employing THHN copper-clad aluminium conductors, bare grounding conductor, and overall PVC jacket with thickness in accordance with the Standard. (designation tbd)
1080077	*1080077*	(Quantity: 1) 250 feet of 3/C, No. 14 AWG ROUND Type NM-B, employing THHN copper-clad aluminium conductors, bare grounding conductor, and overall PVC jacket with thickness in accordance with the Standard. (designation tbd)

Completed by Customer

Note: Samples should be sent to the address location shown above with a copy of this form provided with each shipping container. To ensure prompt processing of your sample upon arrival, the information requested on this form MUST be included with the shipment. Incomplete or missing information will result in a delay of processing your sample, and possible return or disposal of the sample prematurely.

Samples included with this shipment (Please list in the box below):

What would you like UL to do with your sample(s) when work is complete? (Choose one)
Please Note: It is a UL policy that we return all hazardous materials unless prohibited by applicable laws.

☐ **Destroy** - UL will destroy the samples when work is complete and dispose of them in accordance with local disposal guidelines.

☐ **Customer to Pick Up at UL** - You will arrange for the samples to be picked up from the UL office. If samples are not picked up within 30 days, UL will arrange for the samples to be returned to you. Please provide the name of a shipping company, shipping account number, insurance value and confirm the return shipping information below.

☐ **Ship/Return at your expense** - UL will arrange for the samples to be returned to you. Please provide the name of a shipping company, shipping account number, insurance value, and confirm the return shipping information below. If you do not provide your shipping account number, the shipping charges will be added to your UL project invoice.

Sample Being Shipped to UL From:		**UL Should Return Sample to (complete if sample to be returned and address different than at left):**
Company Name:	Copperweld Bimetallics LLC	Company Name:
Company Address:	254 Cotton Mill Rd Fayetteville TN 37334	Company Address:
Contact Person:	Peter Graser	Contact Person:
Contact Phone:		Contact Phone:
Contact Email:	petergraser@intexpco.com	Contact Email:
		Shipping Company:
		Shipping Account Number:

NOTICE OF COMPLETION
AND
AUTHORIZATION TO APPLY THE UL MARK

2017.10.06

Peter Graser
Copperweld Bimetallics LLC
254 Cotton Mill Rd
Fayetteville, TN, 37334, US

Our Reference:	File E492024, Vol 1	Order:	11882073
		Project:	4788086098
Your Reference:	Peter Graser 7/24/2017		
Project Scope:	Testing to add NM-B wire to NEW Copperweld Nonmetallic Sheathed-Cable File Construction will employ recognized CCA, and Listed Type THHN & PVC jacket		

Dear Peter Graser:

Congratulations! UL's investigation of your product(s) has been completed under the above Reference Number and the product was determined to comply with the applicable requirements. This letter temporarily supplements the UL Follow-Up Services Procedure and serves as authorization to apply the UL Mark at authorized factories under UL's Follow-Up Service Program. To provide your manufacturer(s) with the intended authorization to use the UL Mark, you must send a copy of this notice to each manufacturing location currently authorized under File e492024, Vol 1.

Records in the Follow-Up Services Procedure covering the product are now being prepared and will be sent in the near future. Until then, this letter authorizes application of the UL Mark for 90 days from the date indicated above.

Additional requirements related to your responsibilities as the Applicant can be found in the document "Applicant responsibilities related to Early Authorizations" that can be found at the following web-site: http://www.ul.com/EAResponsibilities

Any information and documentation provided to you involving UL Mark services are provided on behalf of UL LLC (UL) or any authorized licensee of UL.

We are excited you are now able to apply the UL Mark to your products and appreciate your business. Feel free to contact me or any of our Customer Service representatives if you have any questions.

Very truly yours,

Brian Cavalli
Engineering Associate
Brian.Cavalli@ul.com

Reviewed by:

Bruce A. Mahrenholz
CPO Director
Bruce.A.Mahrenholz@ul.com

d1ee6431-b01c-4fdc-ac75-c9d5fae7e357

Table 310.15(B)(16) (formerly Table 310.16) Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)*

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.104(A).]									Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	COPPER			COPPER-CLAD ALUMINUM			ALUMINUM ~~OR COPPERCLAD ALUMINUM~~			
18**	-	-	14	-	-	-	-	-	-	-
16**	-	-	18	-	-	-	-	-	-	-
14**	15	20	25	10	15	20	-	-	-	-
12**	20	25	30	15	20	25	15	20	25	12**
10**	30	35	40	25	30	35	25	30	35	10**
8	40	50	55	35	40	45	35	40	45	8
6	55	65	75	40	50	55	40	50	55	6
4	70	85	95	55	65	75	55	65	75	4
3	85	100	115	65	75	85	65	75	85	3
2	95	115	130	75	90	100	75	90	100	2
1	110	130	145	85	100	115	85	100	115	1
1/0	125	150	170	100	120	135	100	120	135	1/0
2/0	145	175	195	115	135	150	115	135	150	2/0
3/0	165	200	225	130	155	175	130	155	175	3/0
4/0	195	230	260	150	180	205	150	180	205	4/0
250	215	255	290	170	205	230	170	205	230	250
300	240	285	320	195	230	260	195	230	260	300
350	260	310	350	210	250	280	210	250	280	350
400	280	335	380	225	270	305	225	270	305	400
500	320	380	430	260	310	350	260	310	350	500
600	350	420	475	285	340	385	285	340	385	600
700	385	460	520	315	375	425	315	375	425	700
750	400	475	535	320	385	435	320	385	435	750
800	410	490	555	330	395	445	330	395	445	800
900	435	520	585	355	425	480	355	425	480	900
1000	455	545	615	375	445	500	375	445	500	1000
1250	495	590	665	405	485	545	405	485	545	1250
1500	525	625	705	435	520	585	435	520	585	1500
1750	545	650	735	455	545	615	455	545	615	1750
2000	555	665	750	470	560	630	470	560	630	2000

*Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F). Refer to 310.15(B)(3)(a) for more than three current-carrying conductors.

**Refer to 240.4(D) for conductor overcurrent protection limitations.

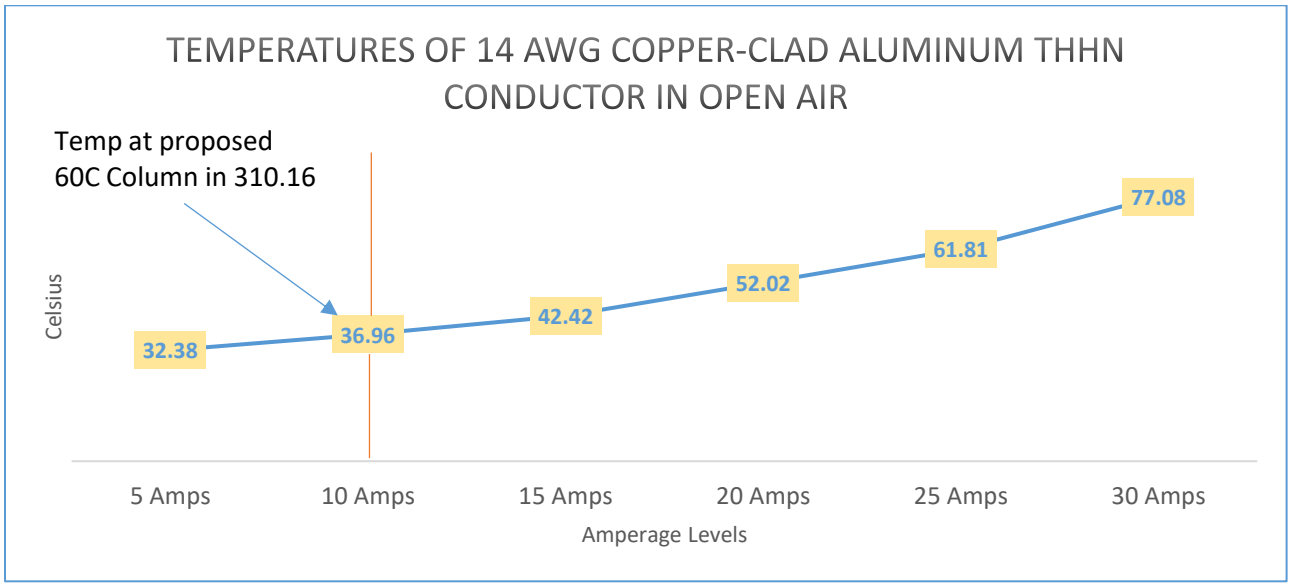
Table 310.15(B)(17) (formerly Table 310.17) Allowable Ampacities of Single-Insulated Conductors Rated Up to and Including2000 Volts in Free Air, Based on Ambient Temperature of 30°C (86°F)*

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.104(A).]									Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW,	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	COPPER			COPPER-CLAD ALUMINUM			ALUMINUM ~~OR COPPERCLAD ALUMINUM~~			
18**	-	-	18	-	-	-	-	-	-	-
16**	-	-	24	-	-	-	-	-	-	-
14**	25	30	35	20	25	30	-	-	-	-
12**	30	35	40	25	35	40	25	30	35	12**
10**	40	50	55	35	40	50	35	40	45	10**
8	60	70	80	45	55	60	45	55	60	8
6	80	95	105	60	75	85	60	75	85	6
4	105	125	140	80	100	115	80	100	115	4
3	120	145	165	95	115	130	95	115	130	3
2	140	170	190	110	135	150	110	135	150	2
1	165	195	220	130	155	175	130	155	175	1
1/0	195	230	260	150	180	205	150	180	205	1/0
2/0	225	265	300	175	210	235	175	210	235	2/0
3/0	260	310	350	200	240	270	200	240	270	3/0
4/0	300	360	405	235	280	315	235	280	315	4/0
250	340	405	455	265	315	355	265	315	355	250
300	375	445	500	290	350	395	290	350	395	300
350	420	505	570	330	395	445	330	395	445	350
400	455	545	615	355	425	480	355	425	480	400
500	515	620	700	405	485	545	405	485	545	500
600	575	690	780	455	545	615	455	545	615	600
700	630	755	850	500	595	670	500	595	670	700
750	655	785	885	515	620	700	515	620	700	750
800	680	815	920	535	645	725	535	645	725	800
900	730	870	980	580	700	790	580	700	790	900
1000	780	935	1055	625	750	845	625	750	845	1000
1250	890	1065	1200	710	855	965	710	855	965	1250
1500	980	1175	1325	795	950	1070	795	950	1070	1500
1750	1070	1280	1445	875	1050	1185	875	1050	1185	1750
2000	1155	1385	1560	960	1150	1295	960	1150	1295	2000

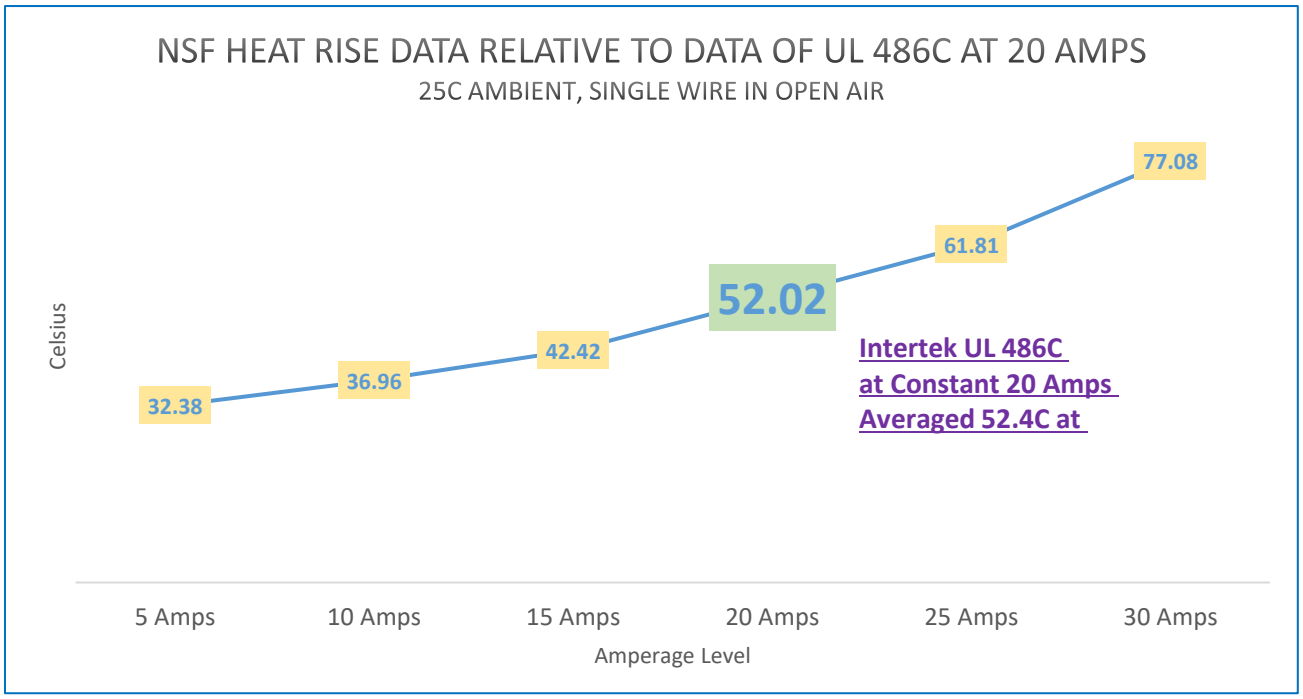
*Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F).
**Refer to 240.4(D) for conductor overcurrent protection limitations.

14 AWG CCA SAFE AT PROPOSED AMPERAGE OF TABLE 310.16:

UL 486C Testing Confirms NSF Data



Data Results of Fact Finding from NRTL Certified Electrical Lab, NSF. Orange Line Indicates Proposed Amperage of 14 AWG Copper-Clad Aluminum (ASTM B566) at 60C in Table 310.16



Average Heat Generated at 20 Amps by 14 AWG Copper-Clad Aluminum (ASTM B-566) is practically the same when comparing the testing done by NSF Electrical and that done by Intertek. Both labs are NRTL's with OSHA certified electrical labs. For 14 AWG CCA, NSF averaged 52.02C at 20 Amps, whereas Intertek Averaged 52.4C at 20 Amps.

14 AWG CCA SAFE AT PROPOSED AMPERAGE OF TABLE 310.16:

UL 486C Testing Confirms NSF Data

CONCLUSION:

At a temperature of 36.96 C° at Full Circuit of 10 Amps in the 60C column of proposed table 310.16, 14 AWG Copper-Clad Aluminum (ASTM B-566) is SAFE even considering elevated ambient temperatures. 75°C is the minimum temperature rating of insulation for the vast majority of general wiring applications, with the most utilized insulation types (THHN, XHHW, for example) rated at 90°C. All modern branch circuit components (switches, connectors, equipment and receptacles) are rated at a minimum of 75°C, most at 90°C. Even in severe overcurrent conditions, heat rise temperatures of 14 AWG Copper-Clad Aluminum (ASTM B-566) are well below the rating of the wire insulation and circuit components. OCPD's exist today for 10 Amp circuits, thus making 14 AWG Copper-Clad Aluminum wire a viable option. LED and Energy Star Equipment are driving the trend for more efficient circuits.

NRTL Credentials for NSF

Occupational Safety and Health Administration

Nationally Recognized Testing Laboratory Program

NRTLP

Certificate of Recognition

NSF International

with headquarters at:

789 Dixboro Road
Ann Arbor, Michigan 48105
United States

is recognized by the Occupational Safety and Health Administration (OSHA) as meeting the requirements for a Nationally Recognized Testing Laboratory (NRTL) established under Section 1910.7 of *Title 29, Code of Federal Regulations.* This recognition is limited to testing and certification only within the current scope of recognition and is subject to all other terms set forth in the letter of recognition and in applicable *Federal Register* notices and as summarized on OSHA's website. This recognition continues in force beyond the "*Effective through*" date below provided the NRTL has filed a timely request for renewal with OSHA. For current recognition status and other recognition information, contact the OSHA NRTL Program or visit *https://www.osha.gov/dts/otpca/nrtl/*

July 14, 2019
Effective Through

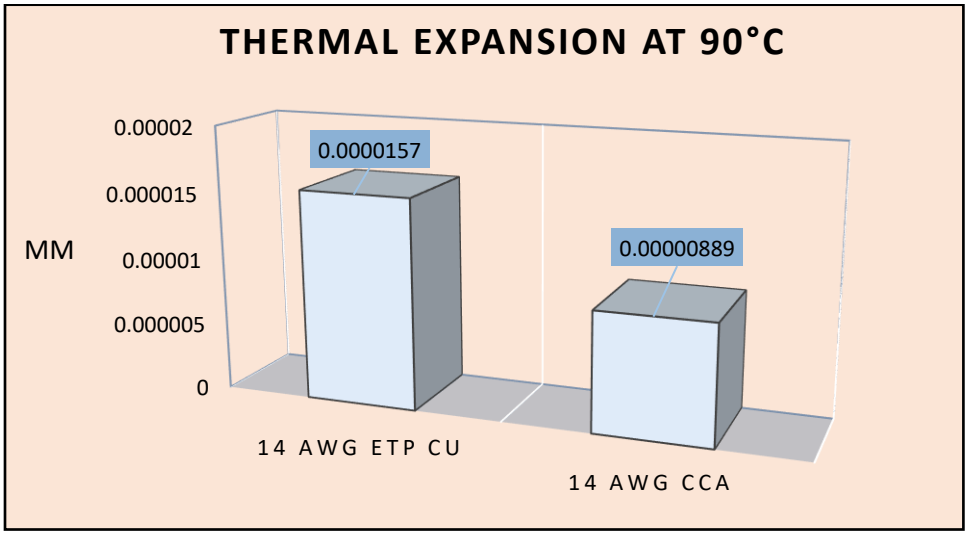
David Michaels, PhD, MPH
Assistant Secretary of Labor for
Occupational Safety and Health Administration

OSHA Scope of Recognition for NSF Electrical: https://www.osha.gov/dts/otpca/nrtl/nsf.html

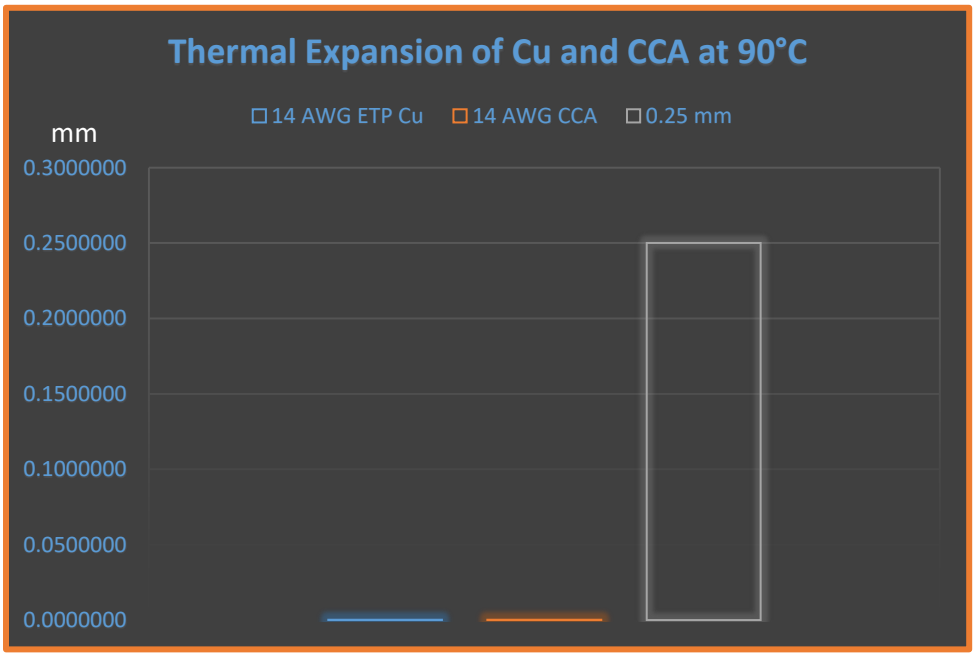
Among other electrical equipment and circuit components, the NSF Scope of Recognition Includes Small Electrical Appliances, Wired Cabinets, Luminaires, Washers, Driers, Residential Water Heaters, Electric Ranges and Temperature Measuring Equipment. Heat Rise Testing is Routine at NSF.

At 90°C, 14 AWG Copper-Clad Aluminum is nearly Twice as Thermally Stable as 14 AWG ETP Copper

Testing By Intertek B&C Labs per ASTM 228 Linear Thermal Expansion



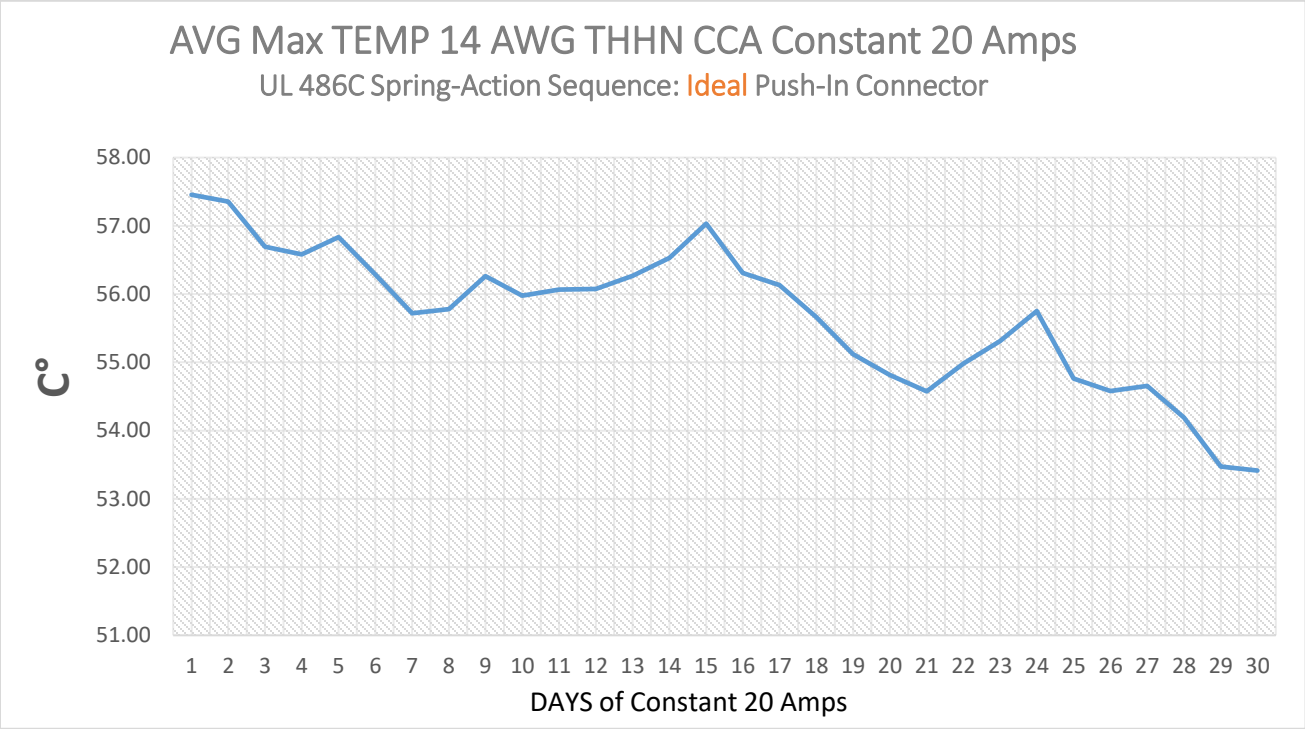
At 90C, ETP 14 AWG Cu expands nearly twice that of Copper Clad Aluminum 14 AWG

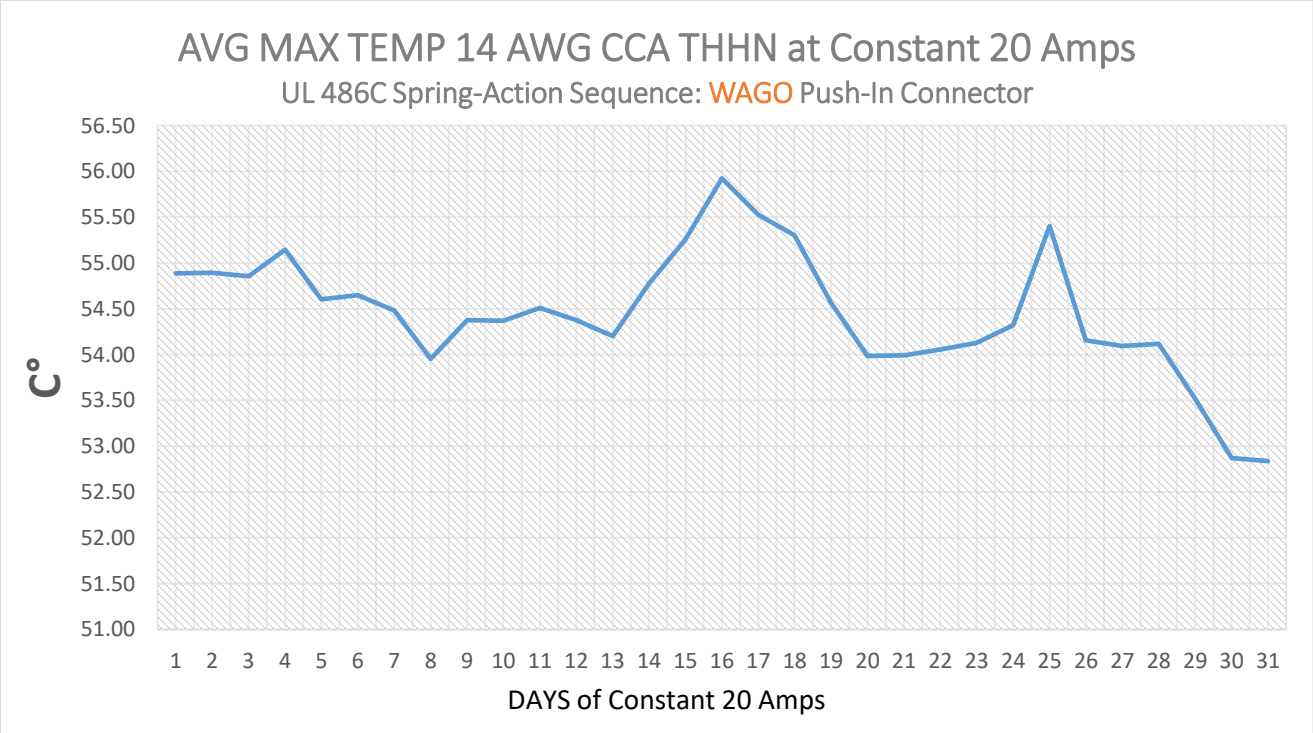


At 90°C, Both Copper Clad Aluminum and Copper are Extremely Thermally Stable

Performance of
14 AWG CCA THHN Under EXTREME OVERCURRENT CONDITION

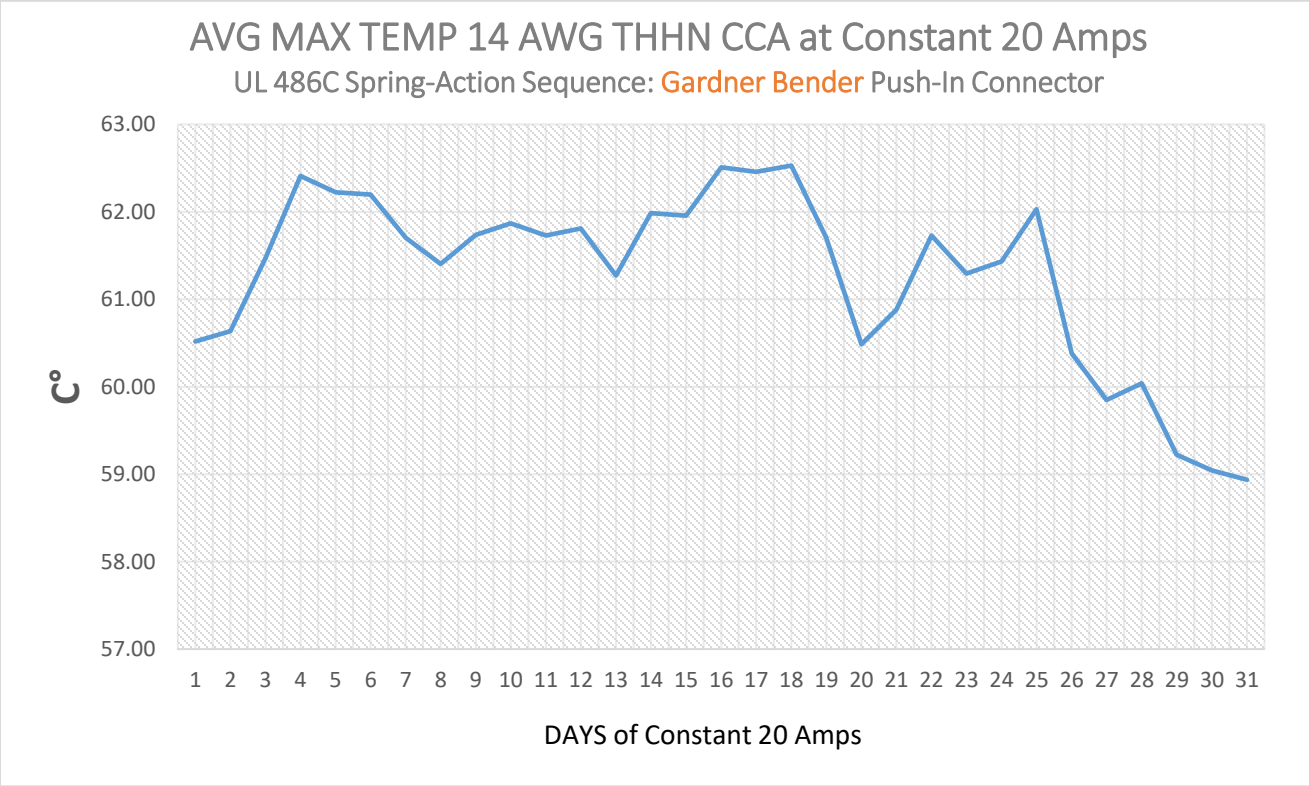
Three Push-In Connectors Tested By Intertek (NRTL with Wire & Cable in Scope of Recognition) to UL 486C Spring-Action Sequence





Performance of
14 AWG CCA THHN Under EXTREME OVERCURRENT CONDITION

Three Push-In Connectors Tested By Intertek (NRTL with Wire & Cable in Scope of Recognition) to UL 486C Spring-Action Sequence



CONCLUSIONS FROM UL 486C SPRING-Action SEQUENCE TESTING REG 14 AWG THHN MADE WITH ASTM B566 COPPER-CLAD ALUMINUM WIRE:

- The THHN Insulation (Rated at 90°C) Remained in Good Condition Throughout the Test
- Over 30 Days at Constant 20 Amps (twice the amperage of the proposed amperage at 60°C column requested by Public Comment 1402), the highest temperature registered by 14 AWG CCA was under 63°C. Over Current Protection Devices (OCPD's) are in place in a circuit to keep wire from over-heating. OCPD's will open the circuit when the amperage limit (10 amps in case of 14 AWG CCA) is reached.
- Ambient Temperature of 23°C Over 30 Days, Standard Deviation of ½ °C
- Average Max Temperatures decreased by 3°C over the month when connected to the three brands of push-in connectors
- The Gardner Bender Connector created more heat (+/- 6°C) within the wire than the other two test subjects
- Of the nine push-in connectors tested (three different brands), not one saw degradation or damage due to excessive heat, despite the constant over-current condition applied to the wire
- The wire remained thermally stable at the points of termination over all nine push-in connectors, and no arc-faulting was observed due to thermal expansion of the wire

3933 Route 11
Cortland, NY 13045
Telephone: 1-607-753-6711
Facsimile: 1-607-758-6595
www.intertek.com

TEST LETTER REPORT

Copperweld Bimetallics, LLC
Test Report

SCOPE OF WORK
PERFORMANCE TESTING – PRODUCT TYPE PER STANDARD

REPORT NUMBER
103589128CRT-001A

ISSUE DATE	**[REVISED DATE]**
27-Aug-2018	28-Aug-2018

PAGES
14

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TEST LETTER REPORT

27-Aug-2018

Intertek Report No.: 103589128CRT-001A
Intertek Project No.: G103589128

Mr. Peter Graser
Copperweld Bimetallics, LLC
215 Centerview Drive
Suite 360
Brentwood, TN 37027

Ph: (770) 952-6445
email: pgraser@copperweld.com

Subject: Static Heating test of Push-in Wire Connectors on CCA Conductors in accordance with Claus 9.12 Spring-action sequence per UL 486C.

Dear Mr. Peter Graser,

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

> **UL 486C / CSA C22.2 No. 188-18 –** Splicing Wire Connectors, Seventh Edition, Dated January 26, 2018

SECTION 1
SUMMARY

This investigation was authorized by signed proposal number Qu-00894894, dated 29-June-2018. A production sample was received on 26-June-2018 and tested from 23-Jul-2018 to 27-Aug-2018 at the Intertek Cortland facility.

TEST LETTER REPORT

SECTION 2
TESTING

Below is a summary of the tests and results for the entire test period. The test data appears at the end of this report in the Appendix.

Performance testing was carried out in accordance with UL486C, Clause 9.12 Spring-action sequence.

Three test circuits were built in the sizes 14AWG, 12AWG, and 10AWG, each circuit containing Copperweld CCA THHN wire and 3 three specimens each of push-in
wire connectors manufactured by Ideal, Wago, and Gardner and Bender, as available. This setup is a deviation from the standard which requires connectors to be tested separately on individual circuits.

Test currents (20A for 14AWG, 30A for 12AWG and 50A for 10AWG) were selected in accordance with client request rather than per Table 6 static heating columns in UL486C, and additional setup criteria indicated in Clause 9.1 of UL486C will not be used. Test currents were monitored periodically with a clamp style meter.

Ambient thermocouples were placed at least two feet out from the connectors under test, and approximately 3 feet apart, the number of ambient thermocouples is reduced due to the size of the apparatus.

Connector thermocouples are placed on the input and output side of each connector with a reference conductor between each set of three connectors.

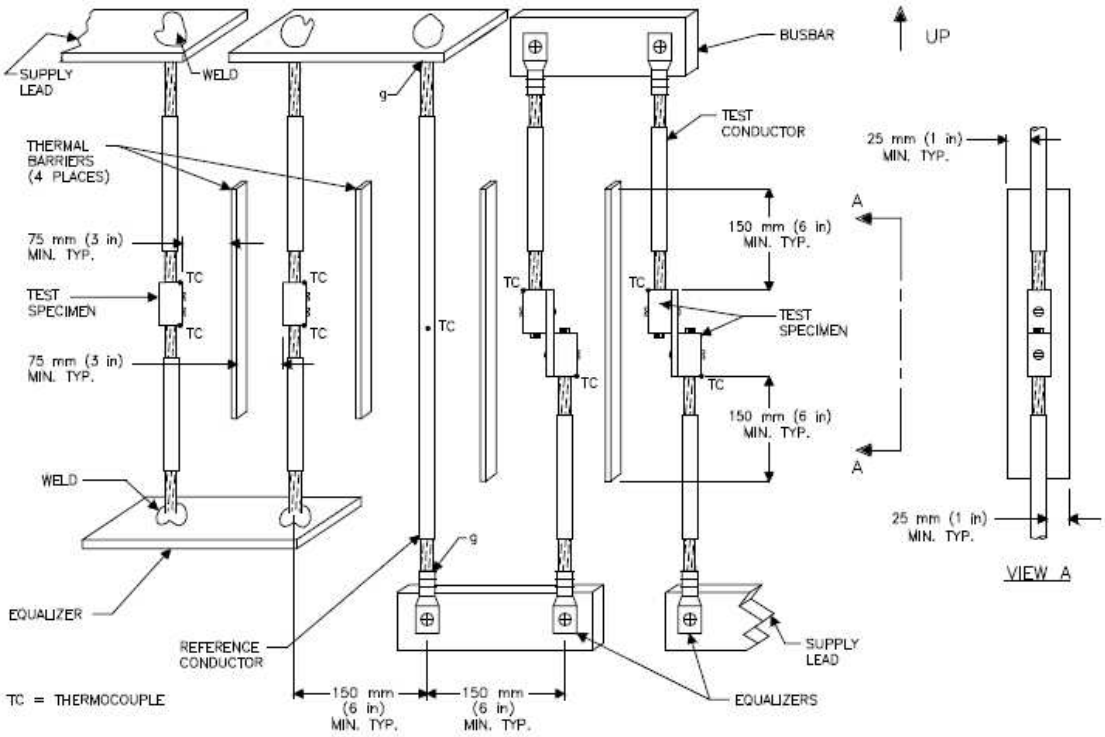
The apparatus is set up in complete compliance with Figure 2 on the next page, no other deviations from the standard were made.

Calibration Information:

Item #	Equipment Type	Asset #	Calibration Due
1	Fluke 365 True RMS Clamp Meter	M262	04/06/2019
2	Fluke Hydra Temperature Recorder	T1152	04/20/2019
3	Fluke Hydra Temperature Recorder	U080	07/16/2019
4	Fluke Hydra Temperature Recorder	T834S	02/13/2019
5	Fluke Hydra Temperature Recorder	T1565	09/27/2018

TEST LETTER REPORT

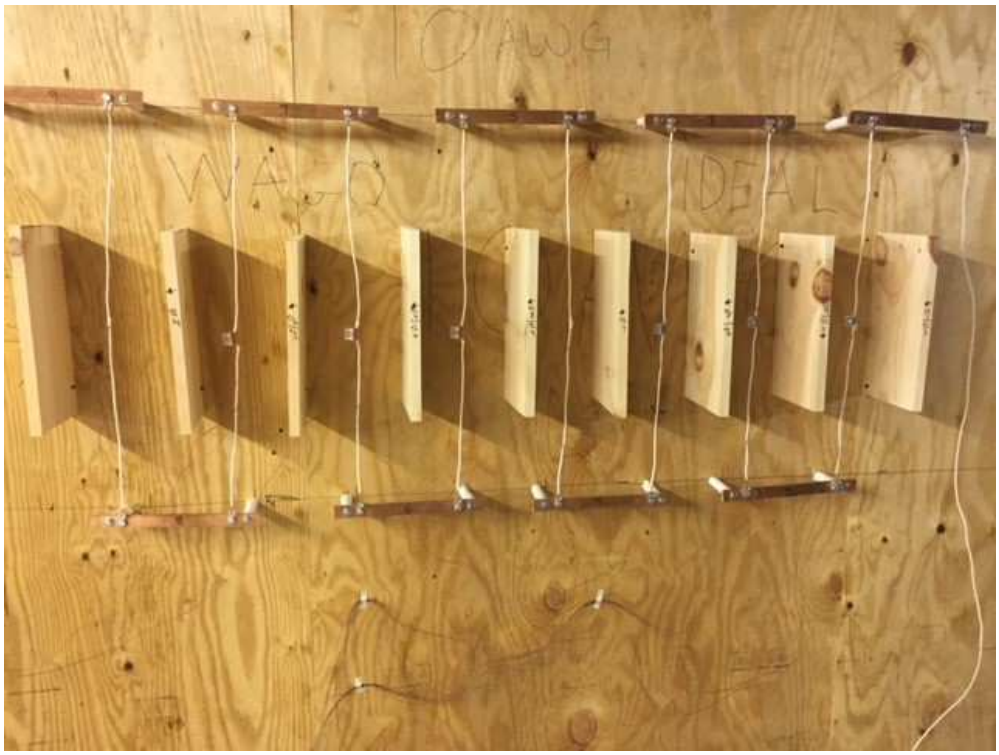
Figure 2
Vertical arrangement of specimen for current-cycling test
(Clause 9.1.10.7)



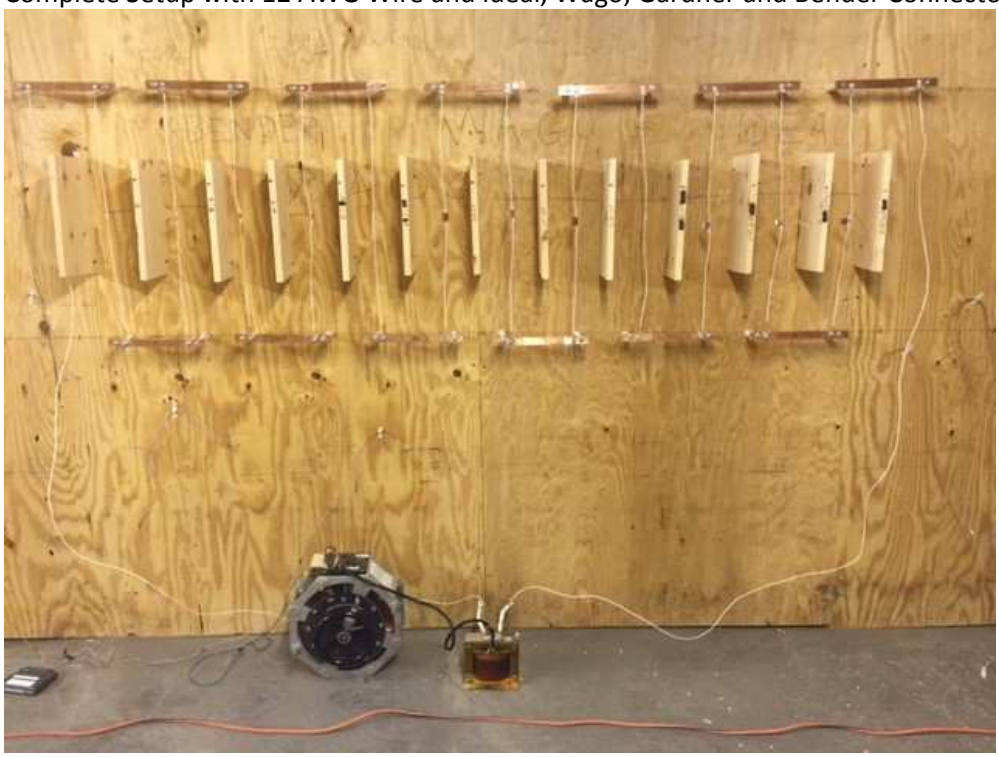
TEST LETTER REPORT

SECTION 3
PHOTOGRAPHS

10AWG Wire with IDEAL and WAGO connectors

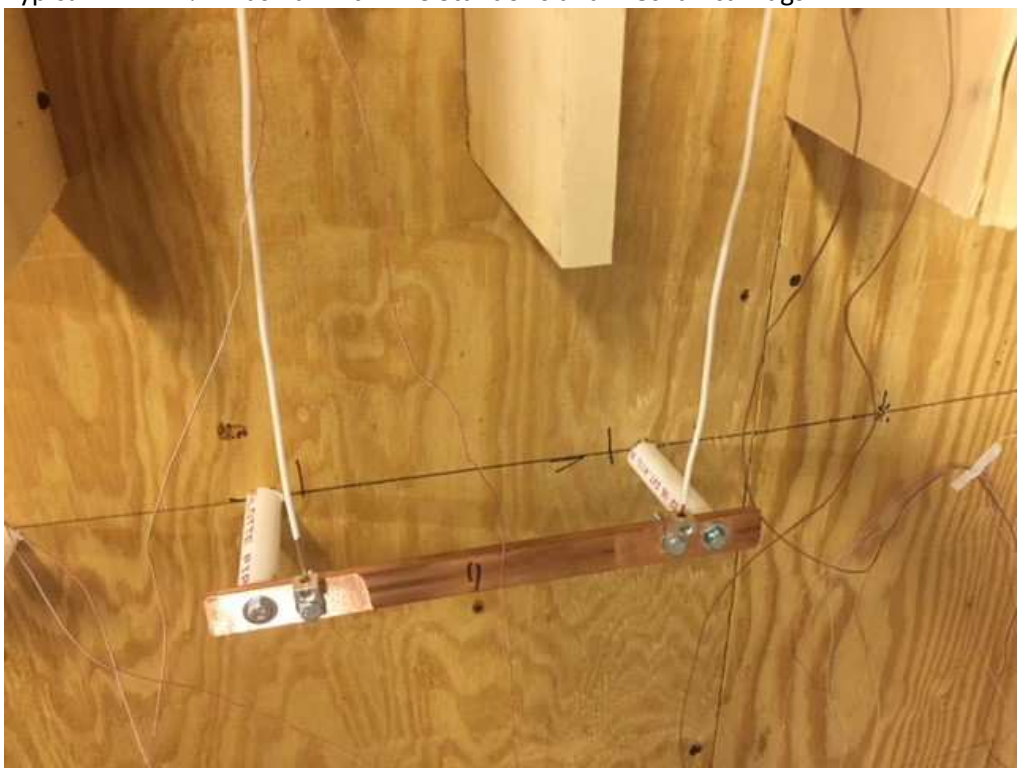


Complete Setup with 12 AWG Wire and Ideal, Wago, Gardner and Bender Connectors

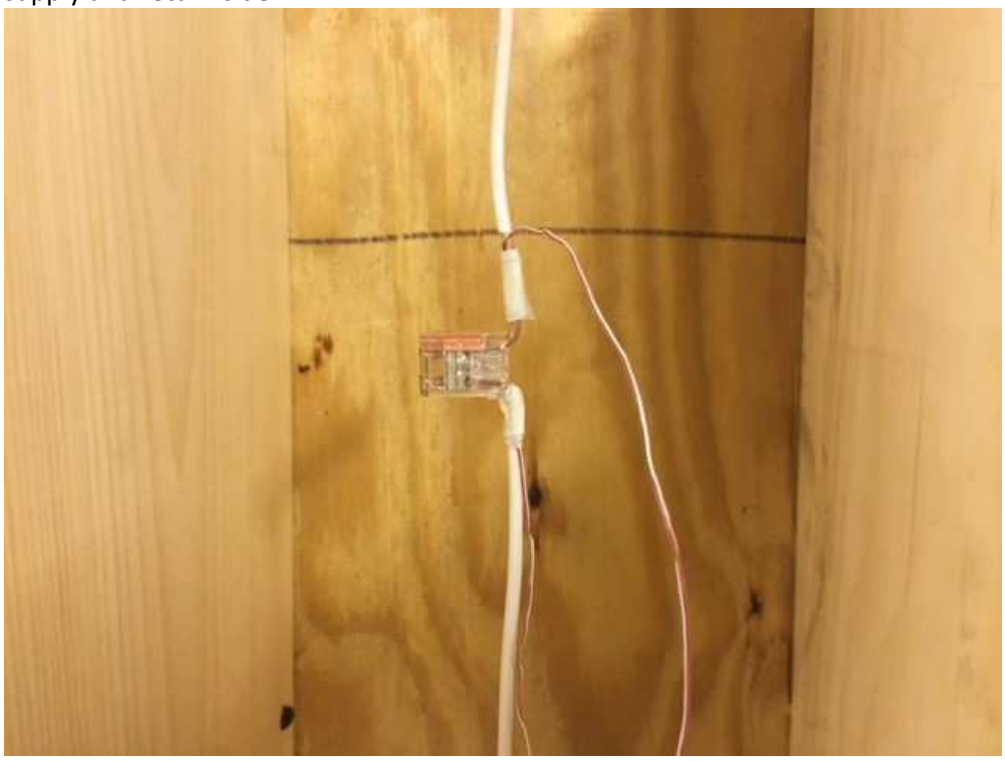


TEST LETTER REPORT

Typical 12 x 1 x ¼" Bus Bar with PVC Standoffs and Mechanical Lugs



Typical Connector, Gardner and Bender Shown, TC attached within 1/2" of the connector on supply and return side



TEST LETTER REPORT

SECTION 4
PROJECT STATUS & ACTION

One set of thermocouples did not record results on the first day of testing on one of the data recorders in use. Intertek performed a full 31 days of testing to capture a minimum of 30 days these thermocouples in question, at the request of the client.

One ambient thermocouple stopped recording at the end of the last day of testing, on the Ideal connectors for the 20A test setup. Data is recorded as “No Data” due to this malfunction. The seven remaining thermocouples reading ambient temperature show normal results.

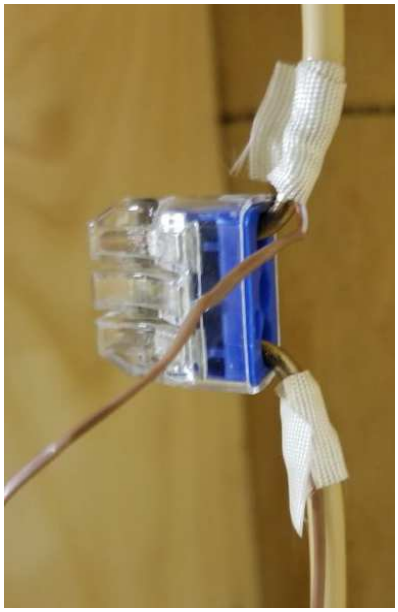
All testing is now complete.

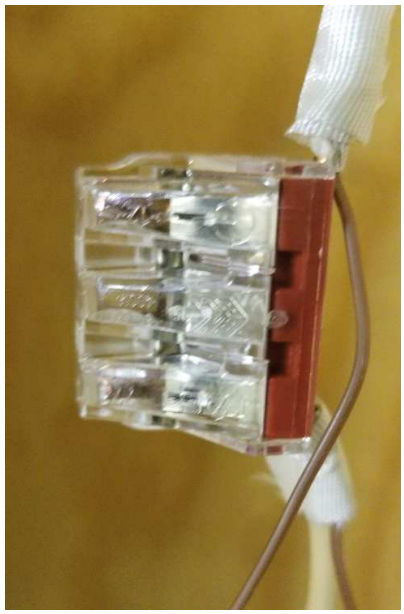
SECTION 5
CONCLUSION

The results contained in this report are to be evaluated by the client. This data is not to be used for certification of these products.

Upon completion of the test, there was no visible damage to any of the connectors contained within this report. There was however a visible change to the coloration of the insulation on the conductors involved in the 50A test on the 10 AWG conductors; no other conductors involved in the test exhibited this discoloration. The consistent temperatures recorded during the test, indicate that there is no evidence of arcing at the connectors.

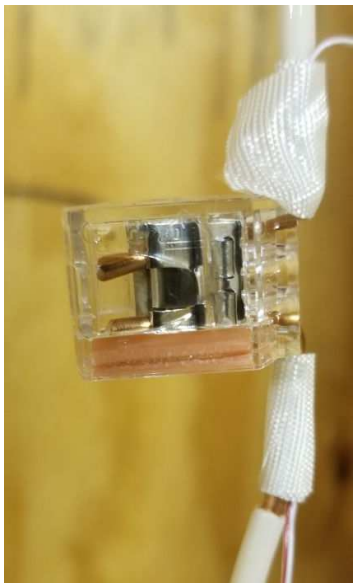
10 AWG Connectors (Left to Right: Ideal, Wago):



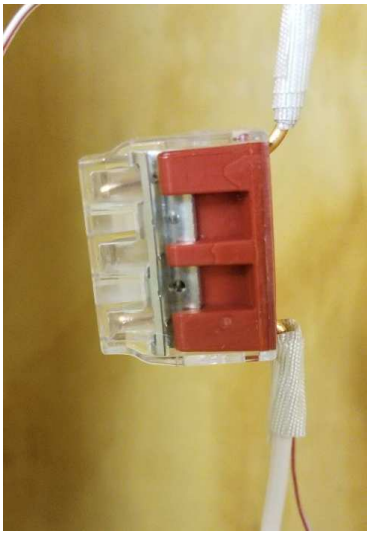
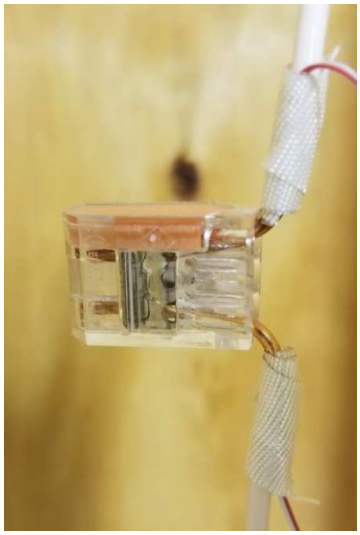


TEST LETTER REPORT

12 AWG Connectors (Left to right: Ideal, Wago, Gardner and Bender):



14 AWG Connectors (Left to right: Ideal, Wago, Gardner and Bender):

TEST LETTER REPORT

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

Completed by:	Joshua O'Connor	Reviewed by:	James Diescher
Title:	Engineering Team Lead	Title:	Technical Lead
Signature:		Signature	
Date	08/28/2018	Date:	08/28/2018

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

Revision History

08/28/2018: Added information in the conclusions about the condition of the connectors and conductors at the end of the test. Added example pictures of each connector for each test setup at the completion of the test.

TEST LETTER REPORT

APPENDIX

MAX TEMP (50A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		1	104.82	101.00	100.66	99.70	98.60	98.79	98.82	98.52	97.64	98.16	97.79	97.82	97.16	97.85	97.85	98.06	97.49	97.63	97.64	97.06	96.68	97.02	96.45	96.65	97.49	Power Outage			98.90	96.25	97.02	96.45	96.40	96.40
	1	2	83.92	81.32	81.26	80.73	80.09	80.76	80.48	80.18	79.64	80.31	79.79	79.55	79.49	80.47	79.93	80.34	80.07	79.59	79.50	79.27	79.02	78.94	78.79	78.94	79.93				80.77	78.35	78.70	78.40	78.30	78.26
		3	90.28	90.79	91.78	90.78	90.16	91.16	91.82	90.89	91.38	91.08	91.32	91.26	90.70	90.75	92.09	92.63	92.46	92.58	91.78	91.17	91.46	91.99	91.87	91.58	92.43				92.03	91.35	91.57	91.57	91.17	91.48
	2	4	77.14	77.62	78.16	77.92	77.83	78.34	77.99	77.93	78.12	78.28	78.10	78.06	77.93	77.76	79.17	79.25	79.16	79.14	78.74	78.29	78.55	78.53	78.67	78.38	79.24				78.86	78.68	78.79	78.53	78.25	78.37
		5	89.40	88.00	88.06	87.39	87.14	87.66	87.95	87.41	87.60	87.22	87.75	87.22	86.90	86.69	87.59	88.87	88.31	88.06	87.62	87.42	87.39	87.85	87.47	87.94	88.26				87.35	87.09	86.96	87.18	86.77	86.46
	3	6	92.73	91.58	92.06	91.46	91.54	91.75	92.33	92.00	92.01	91.28	91.62	91.88	90.90	90.83	92.07	93.37	92.96	92.68	92.04	91.75	92.20	92.29	92.00	92.57	92.69				92.26	91.65	91.54	92.05	91.31	91.72
	Ref	7	86.70	86.98	87.33	87.63	87.71	87.57	88.23	88.32	88.19	87.94	88.14	88.45	88.04	88.34	88.47	90.28	89.05	89.39	89.32	88.39	89.12	89.10	88.61	88.89	88.95				88.30	88.79	88.18	88.82	87.86	87.96
WAGO		8	81.37	80.88	80.74	80.56	80.08	79.93	79.18	79.02	78.45	79.39	79.33	79.00	79.07	79.55	79.65	79.63	79.81	79.52	78.93	77.99	78.56	78.44	78.10	78.43	78.26				79.39	77.75	77.91	77.48	76.92	77.02
	4	9	87.95	87.91	88.06	88.05	87.56	87.44	87.70	87.40	86.31	87.10	87.04	86.49	86.47	86.60	87.34	86.86	87.23	87.05	86.03	84.97	85.43	85.51	84.84	84.26	83.99				87.60	82.66	82.59	83.04	82.02	81.62
		10	87.19	87.84	87.90	88.43	87.66	87.34	86.86	86.11	86.57	87.48	87.70	87.54	87.20	87.45	87.88	87.92	88.00	86.61	86.52	85.52	85.46	85.47	85.73	86.22	86.18				87.75	85.60	85.48	85.31	85.87	85.36
	5	11	82.99	83.08	82.87	82.89	82.67	82.08	81.59	80.97	81.03	81.96	82.48	81.96	81.56	81.82	82.39	82.34	82.33	81.56	80.99	80.17	80.20	80.27	80.35	80.94	80.77				81.80	79.82	79.83	79.33	79.68	79.62
		12	85.43	85.05	85.09	85.12	84.61	84.80	84.10	83.59	83.47	84.12	84.26	84.58	84.16	84.36	84.31	84.97	84.57	84.23	83.86	83.73	83.34	83.49	83.12	84.01	83.75				84.34	83.84	83.04	83.06	83.41	83.41
	6	13	89.14	88.21	88.76	88.48	88.17	88.23	87.82	87.01	87.15	87.56	87.82	88.05	88.09	87.89	88.53	88.38	88.30	88.18	87.92	88.06	87.42	87.56	87.31	87.99	87.42				88.68	87.93	86.71	86.83	88.01	87.86
	Ref	14	88.72	89.64	91.45	90.71	91.45	91.75	91.57	91.95	91.31	90.84	92.18	92.33	92.35	91.99	92.78	92.10	93.57	93.63	92.06	91.81	92.52	93.07	92.84	94.56	92.34				91.83	91.48	91.76	90.88	91.75	92.01

MIN TEMP (50A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		1	22.29	95.90	95.73	93.01	91.23	93.56	92.72	93.94	92.48	90.88	92.40	92.03	91.11	91.39	90.62	91.45	91.51	91.06	89.73	93.36	91.73	91.20	89.59	91.80	90.50	Power Outage			88.57	89.43	88.66	87.20	89.04	88.91
	1	2	22.78	75.58	76.48	74.61	74.09	74.86	73.01	75.43	74.83	73.38	74.29	74.35	73.76	73.98	73.51	74.34	73.20	72.76	72.79	75.75	73.99	71.52	71.85	73.85	73.60				70.57	71.15	71.60	70.77	72.03	72.00
		3	22.32	86.68	86.59	86.16	86.30	86.08	83.75	86.01	85.92	86.01	86.10	86.12	86.44	86.39	86.00	87.18	85.73	86.73	84.95	86.06	85.97	85.69	84.59	86.34	86.40				86.41	84.28	82.96	83.55	86.01	86.60
	2	4	23.01	73.41	74.53	73.82	73.74	73.90	71.63	74.62	74.23	73.44	74.07	74.11	74.11	74.10	73.74	74.07	73.55	74.16	73.04	75.59	74.45	72.99	72.67	75.16	74.60				73.70	71.28	72.09	72.66	74.55	74.63
		5	22.81	82.43	83.23	81.87	81.43	81.93	82.40	83.10	83.04	81.18	81.53	82.37	82.07	81.62	80.99	81.31	82.41	83.19	83.08	83.34	83.08	83.36	82.56	82.89	81.89				83.00	80.76	80.45	78.26	82.23	82.20
	3	6	22.78	88.40	88.90	87.84	87.42	88.03	87.74	88.31	88.04	87.25	87.44	88.02	87.65	87.71	87.08	87.91	88.31	88.13	88.39	87.65	87.47	88.14	87.58	88.05	88.04				87.82	87.69	86.02	85.31	86.77	86.95
	Ref	7	22.80	81.99	82.99	82.63	83.18	82.18	83.80	84.81	83.61	82.84	83.48	83.28	83.82	83.52	82.89	82.37	84.23	85.36	85.18	85.16	84.67	85.61	84.25	85.09	83.40				85.03	84.55	82.60	82.30	84.22	84.61
WAGO		8	22.80	76.69	76.90	75.55	75.53	75.70	76.45	76.09	75.90	74.84	75.21	75.08	75.48	74.30	73.94	74.72	75.67	75.74	76.09	75.53	75.31	75.63	75.48	75.29	73.59				75.39	75.23	74.02	73.67	74.40	74.30
	4	9	22.75	83.28	83.55	82.80	83.07	82.84	83.59	82.50	82.47	81.84	82.09	81.47	81.66	81.43	80.58	81.16	81.56	81.90	81.02	81.21	80.95	80.60	80.67	79.89	78.46				78.59	78.57	76.50	76.81	77.42	78.12
		10	22.75	82.20	82.69	81.78	82.24	82.32	82.49	81.70	82.03	81.84	81.99	81.63	81.98	81.22	81.81	81.26	82.31	82.46	82.27	82.11	82.40	82.79	82.36	81.77	81.11				81.76	81.86	80.13	80.89	82.58	82.28
	5	11	22.70	78.01	77.83	76.59	77.48	77.09	77.56	77.03	77.05	76.60	76.94	76.43	76.92	75.85	76.32	75.92	77.07	77.78	77.22	77.46	77.68	77.94	77.27	76.76	75.78				76.67	77.06	75.06	74.97	77.20	77.02
		12	22.73	79.80	79.49	79.39	79.38	79.26	79.13	78.50	78.95	78.66	78.39	78.53	78.81	77.70	78.11	78.08	78.59	79.55	79.11	79.58	80.09	80.23	79.47	79.04	78.20				80.03	80.00	77.96	78.62	80.09	80.09
	6	13	22.70	83.65	83.07	83.06	82.47	82.70	81.87	82.49	82.24	82.41	82.51	82.69	82.38	82.30	82.45	82.67	82.99	83.63	82.82	83.27	83.53	82.79	82.66	83.04	82.52				83.28	82.88	81.04	81.24	83.12	83.10
	Ref	14	22.75	83.42	83.49	83.33	83.15	83.16	84.08	83.31	83.25	83.72	83.44	84.10	83.54	83.30	83.76	83.49	84.07	85.48	84.55	84.60	84.76	86.01	86.22	84.12	83.95				85.18	86.83	84.58	85.39	86.90	86.05

AVE TEMP (50A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		1	99.09	97.98	98.38	96.49	96.29	96.22	96.29	96.62	95.90	94.68	94.80	95.19	94.67	94.22	93.82	94.56	95.24	94.85	95.27	95.51	94.83	95.38	94.79	94.84	93.99	Power Outage			94.89	94.26	94.24	94.20	94.00	93.87
	1	2	78.62	77.88	78.84	77.46	77.72	77.86	77.92	78.29	77.87	76.79	76.90	77.39	76.91	76.46	76.14	76.80	77.45	77.10	77.47	77.66	76.99	77.46	76.86	77.13	76.46				77.03	76.21	76.26	76.30	76.08	75.89
		3	87.84	88.16	88.53	88.23	88.08	88.11	88.28	89.15	88.37	87.83	87.96	88.17	88.13	88.01	88.27	88.92	88.91	88.76	89.17	89.46	89.14	89.83	89.40	88.87	88.33				89.35	89.23	89.23	89.66	89.13	89.13
	2	4	74.75	75.56	76.47	75.77	76.01	76.19	76.27	76.75	76.46	75.81	76.07	76.44	76.22	76.03	75.91	76.52	77.05	76.92	77.14	77.29	76.93	77.37	76.97	76.95	76.55				77.40	77.13	77.02	77.23	76.91	76.87
		5	85.18	85.31	86.02	84.86	84.92	85.09	85.23	85.58	85.08	84.29	84.65	84.97	84.72	84.37	84.00	84.77	85.68	85.51	85.55	85.51	85.35	85.90	85.44	85.27	84.63				85.15	85.01	84.98	85.35	84.70	84.57
	3	6	89.99	89.95	90.10	89.68	89.52	89.54	89.60	89.92	89.43	89.14	89.38	89.37	89.34	89.25	89.24	89.79	90.18	90.00	90.00	89.89	89.87	90.32	89.99	89.55	89.44				89.70	89.75	89.67	90.16	89.29	89.23
	Ref	7	83.50	85.01	86.15	85.57	85.88	86.06	86.26	86.37	86.24	85.89	86.32	86.57	86.42	86.21	85.84	86.43	87.54	87.24	87.07	86.83	86.84	87.13	86.83	86.82	86.54				86.65	86.66	86.39	86.75	86.16	86.09
WAGO		8	78.35	79.13	79.27	78.39	78.35	78.06	77.90	77.38	77.23	77.29	77.47	77.56	77.44	77.45	77.14	77.46	78.23	77.77	77.39	76.77	76.84	76.80	76.83	76.98	76.73				76.63	76.32	76.04	75.97	75.51	75.42
	4	9	84.58	85.48	86.36	85.50	85.75	85.54	85.61	85.08	84.72	84.50	84.67	84.86	84.45	84.21	83.69	84.00	84.92	84.05	83.52	82.87	82.82	82.80	82.74	82.61	81.91				80.89	80.74	80.41	80.61	79.86	79.65
		10	83.91	85.12	86.05	85.11	85.40	85.17	85.01	84.69	84.79	84.74	85.01	85.30	85.06	84.91	84.51	84.81	85.78	84.94	84.53	84.03	84.08	84.17	84.11	84.43	84.03				84.44	84.26	83.59	83.64	83.85	83.81
	5	11	80.26	80.70	81.22	80.18	80.42	80.17	79.78	79.44	79.60	79.51	79.76	80.01	79.81	79.68	79.25	79.58	80.47	79.72	79.44	79.06	78.99	79.14	78.99	79.44	78.90				78.97	78.61	77.87	77.75	78.20	78.18
		12	82.32	82.81	83.38	82.23	82.52	82.39	81.93	81.68	81.73	81.45	81.71	82.35	82.02	81.68	81.38	81.71	82.58	82.39	81.91	81.77	81.72	81.78	81.45	81.81	80.94				82.08	81.76	80.74	80.37	81.44	81.64
	6	13	85.70	86.01	86.62	85.59	85.98	85.86	85.30	84.99	85.27	85.14	85.34	85.96	85.64	85.40	85.22	85.48	86.23	86.10	85.59	85.45	85.37	85.27	85.02	85.68	85.04				85.73	85.16	83.85	83.47	84.99	85.23
	Ref	14	84.72	85.98	87.39	86.49	86.92	87.91	88.34	89.19	88.00	86.86	87.38	88.68	88.21	87.26	87.03	87.49	88.69	89.53	89.36	89.39	89.47	90.37	89.71	89.12	87.38				88.84	89.23	88.46	87.94	88.82	89.13

MAX TEMP (30A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		15	68.57	62.14	61.07	60.48	60.15	59.65	59.37	58.88	59.40	59.21	59.03	59.59	59.52	59.65	59.99	60.38	60.45	59.45	59.20	58.92	58.77	58.79	58.81	58.92	59.54	Power Outage			59.22	59.20	59.03	57.81	58.09	58.50
	7	16	70.43	68.41	67.93	68.09	68.43	67.89	67.69	67.60	68.16	68.53	68.28	68.40	68.92	69.05	69.48	69.99	69.51	68.90	68.62	68.40	68.22	68.39	68.44	68.78	69.62				69.42	69.18	69.09	67.95	68.09	68.48
		17	80.39	65.87	64.23	64.36	64.12	64.12	63.84	63.72	63.63	63.62	63.27	63.19	63.31	63.70	64.09	64.17	63.63	62.92	62.82	62.44	62.19	62.22	61.94	62.91	62.70				61.81	61.15	61.09	59.86	59.84	60.07
	8	18	85.75	73.23	72.38	72.61	72.10	71.52	71.15	70.74	71.21	71.51	70.95	71.21	71.18	71.59	71.92	71.56	71.49	70.52	70.30	69.77	69.93	70.05	70.06	70.05	70.87				69.84	69.72	69.64	68.99	68.71	68.62
		19	65.78	64.66	64.04	64.77	64.75	63.82	63.62	63.56	63.54	63.56	63.63	63.38	63.44	63.94	64.33	64.51	64.62	63.36	63.50	63.00	63.26	63.48	63.70	63.34	63.57				63.36	63.25	62.99	62.38	62.04	61.95
	9	20	66.27	65.63	64.73	65.12	65.13	64.40	63.75	63.91	63.97	64.18	64.01	63.92	63.94	64.15	64.53	64.88	64.45	63.56	63.36	63.26	63.32	63.22	63.41	63.25	63.63				63.27	63.16	63.19	62.11	61.91	62.00
	Ref	21	67.20	67.35	66.97	67.88	67.89	67.24	67.55	67.53	67.24	66.93	67.88	67.56	67.55	67.87	68.14	68.77	68.16	68.30	68.23	67.37	68.14	67.45	68.48	67.70	67.67				68.10	68.36	67.75	67.62	67.07	67.07
WAGO		22	65.17	64.36	64.07	64.63	64.25	63.61	63.37	63.14	62.95	62.40	63.08	63.02	63.03	63.12	63.70	63.99	63.60	63.24	63.14	62.71	62.44	62.43	62.68	62.38	62.81				62.04	61.98	61.88	61.51	61.12	61.12
	10	23	68.15	67.25	66.94	67.10	66.98	66.28	65.89	65.83	65.73	65.47	65.73	65.81	65.53	65.73	66.41	66.67	66.20	65.39	65.46	64.95	64.75	64.86	64.97	64.77	65.26				64.25	64.38	64.25	63.67	63.45	63.45
		24	65.42	64.44	64.92	64.86	64.90	64.75	64.43	64.46	64.20	64.16	64.51	64.42	64.44	64.71	65.24	65.05	64.99	64.41	64.53	64.13	63.94	63.86	63.69	63.81	64.36				63.36	63.76	63.50	63.13	63.11	63.11
	11	25	64.28	61.42	61.21	61.24	61.13	60.69	60.29	60.28	60.01	60.01	60.27	60.29	60.44	59.64	59.79	59.84	59.96	59.49	59.24	58.74	58.55	58.60	58.17	58.42	58.97				57.57	57.58	57.45	57.45	56.89	56.89
		26	64.38	63.89	64.46	64.34	64.05	63.46	63.45	63.50	63.01	62.61	63.23	63.18	63.08	63.01	63.75	63.17	63.81	62.80	63.06	62.42	61.96	62.39	61.92	62.32	62.88				61.77	61.14	60.99	60.83	60.72	60.72
	12	27	67.34	67.23	67.54	67.26	67.17	67.19	66.53	66.41	65.93	65.99	66.46	66.16	66.28	66.03	66.53	66.53	66.88	66.02	65.95	65.53	65.04	65.08	65.23	65.31	66.17				64.83	64.29	64.23	64.03	63.79	63.79
	Ref	28	60.36	60.63	61.31	61.58	61.70	61.36	60.77	60.95	60.41	60.41	61.25	61.03	61.14	60.78	61.20	61.14	61.63	60.92	61.26	60.79	60.38	60.18	60.48	60.56	60.90				60.27	60.70	60.18	59.65	59.69	59.69
Gardner Bender		29	62.68	62.96	63.23	62.97	63.25	62.90	62.67	62.94	62.30	62.38	62.95	62.66	63.07	62.67	63.11	62.55	63.57	63.03	62.65	62.57	62.16	62.00	62.31	62.55	62.56				61.79	61.47	61.62	61.09	60.97	60.97
	13	30	64.06	64.02	64.43	64.32	64.44	64.32	64.04	64.15	63.91	63.98	64.28	64.22	64.51	64.26	64.75	64.44	65.41	64.22	64.25	64.16	63.74	63.55	64.06	64.11	64.33				63.81	63.81	63.91	63.13	63.08	63.08
		31	67.09	66.75	67.66	67.43	67.57	67.25	67.46	67.18	66.81	66.98	67.50	67.36	67.36	67.46	67.60	67.32	68.12	67.12	67.60	67.16	66.68	66.65	67.04	67.10	67.15				67.34	66.88	67.05	66.51	66.23	66.23
	14	32	No Data	67.16	67.72	67.56	67.82	67.27	67.57	67.43	66.98	67.55	67.95	67.50	67.50	67.33	67.63	67.41	68.28	67.21	67.96	67.42	66.89	66.79	67.33	67.49	67.43				67.86	66.79	66.94	66.31	66.25	66.25
		33	No Data	68.57	68.92	68.71	68.94	68.61	68.47	68.64	68.06	68.67	68.83	68.89	68.52	68.42	68.78	68.61	68.92	67.98	68.57	68.39	67.78	67.47	68.01	68.15	67.96				68.29	67.33	67.37	66.91	66.81	66.81
	15	34	No Data	65.91	65.94	65.52	65.62	65.33	65.00	64.92	64.42	64.83	65.17	65.19	64.34	64.53	64.76	64.51	64.68	63.67	64.28	64.26	63.49	63.09	63.76	63.87	63.44				63.23	62.80	62.35	61.87	61.92	61.92
	Ref	35	No Data	65.03	65.01	64.45	64.81	64.77	64.45	64.50	64.22	64.68	64.79	64.49	64.74	64.36	64.70	64.42	65.08	64.28	64.36	64.39	64.27	63.92	63.98	64.55	64.63				64.18	64.33	64.26	63.69	63.50	63.50

MIN TEMP (30A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		15	22.77	57.58	56.18	55.47	56.17	56.05	54.30	56.03	54.67	55.31	54.34	54.49	56.15	55.24	55.12	54.89	55.83	55.52	53.60	56.59	55.37	54.74	56.06	54.83	54.52	Power Outage			56.05	55.18	53.01	53.28	55.20	55.76
	7	16	22.75	64.48	64.38	63.99	64.72	64.79	63.90	65.26	64.38	65.44	64.65	64.53	66.23	65.24	65.00	64.95	65.76	66.08	64.69	65.90	66.02	65.34	65.89	65.79	65.72				66.20	66.45	63.80	64.49	66.06	66.17
		17	22.72	60.87	60.38	60.22	60.35	60.73	60.20	60.58	59.82	60.60	59.59	60.37	60.44	59.53	59.53	59.51	59.88	59.76	59.66	59.65	59.09	59.07	59.20	59.21	58.97				58.75	58.51	56.75	56.91	57.43	57.44
	8	18	22.73	69.00	69.03	68.30	68.23	68.70	68.06	68.73	67.88	68.03	67.70	67.69	68.59	67.68	67.31	66.96	67.95	67.89	67.32	68.39	68.31	67.35	68.10	67.69	66.99				67.27	67.55	64.94	65.56	67.07	67.37
		19	22.73	59.98	60.15	59.82	59.93	60.23	60.98	60.99	59.94	59.98	59.26	60.02	59.92	59.93	60.20	59.29	60.47	59.96	60.62	61.18	60.87	60.36	60.73	60.00	59.11				60.39	60.55	58.06	58.78	60.52	60.37
	9	20	22.70	61.16	61.38	61.20	61.55	61.51	61.68	61.04	60.78	60.90	60.68	61.06	60.54	61.25	60.92	60.34	61.25	61.27	61.53	61.29	61.40	60.79	61.06	60.77	60.38				60.64	60.93	59.00	59.81	60.22	60.27
	Ref	21	23.00	62.21	62.84	62.36	63.25	63.69	64.05	64.89	63.00	62.62	63.53	62.58	64.50	63.99	63.41	63.48	63.79	64.67	64.44	65.95	65.58	64.06	64.49	63.65	62.50				64.62	64.74	61.88	62.35	63.63	63.63
WAGO		22	23.02	59.21	59.42	58.74	58.99	59.38	59.33	60.21	58.13	57.78	58.80	57.64	59.60	58.67	57.99	58.01	58.48	58.96	58.93	60.69	60.04	57.83	58.84	58.02	56.75				58.68	58.52	56.02	56.86	57.95	57.95
	10	23	23.00	62.52	62.21	61.72	61.82	61.94	62.50	63.04	60.80	60.67	61.60	60.52	62.47	61.55	60.96	60.80	61.47	61.81	61.33	63.19	62.51	60.66	61.53	60.82	59.77				61.51	61.43	59.00	59.92	60.68	60.68
		24	23.02	60.65	60.80	60.62	60.81	61.46	60.99	61.87	60.15	60.26	60.59	59.96	61.62	60.89	60.49	60.46	60.95	61.58	61.47	62.36	61.67	60.51	60.98	60.13	59.75				60.48	60.99	58.22	59.69	59.84	59.84
	11	25	23.07	57.07	56.58	56.68	56.69	56.88	56.66	57.07	56.35	55.85	56.35	55.84	56.70	55.53	54.59	54.30	55.11	55.45	55.37	56.38	55.05	54.50	53.48	53.09	52.24				52.13	53.09	50.44	50.89	51.40	51.40
		26	23.05	58.73	58.77	58.40	59.00	58.48	58.52	59.16	57.75	57.96	57.86	57.39	58.41	58.42	57.88	57.79	58.09	58.42	58.22	60.13	58.57	57.41	57.14	57.18	57.05				57.66	57.98	55.59	56.70	56.63	56.63
	12	27	23.02	62.05	62.29	61.74	62.48	62.06	62.35	62.57	61.59	61.31	61.82	61.22	61.92	61.95	61.74	61.41	61.80	62.12	61.41	63.02	62.21	61.25	61.29	60.89	60.91				61.45	61.74	59.33	60.39	60.26	60.26
	Ref	28	23.05	55.09	54.46	54.76	56.16	55.22	55.92	56.42	55.98	55.79	56.10	55.70	56.37	55.77	56.14	56.02	55.91	56.25	56.33	57.81	56.53	55.96	55.80	55.62	55.48				56.30	57.54	55.38	55.88	56.27	56.27
Gardner Bender		29	23.03	56.09	55.54	55.72	56.34	55.68	56.74	56.71	56.14	55.32	56.25	56.46	57.26	57.41	56.92	56.71	56.27	56.76	55.89	59.38	58.23	56.04	55.97	55.91	56.04				56.30	57.15	55.72	56.01	56.10	56.10
	13	30	23.00	58.88	58.14	58.57	58.60	58.83	59.15	59.75	58.92	57.87	59.21	59.46	60.23	60.13	59.37	59.43	58.80	59.60	59.40	61.86	60.54	59.05	59.15	58.59	58.51				59.47	60.48	58.94	59.36	59.27	59.27
		31	22.91	60.43	59.64	59.94	60.71	60.63	61.05	62.26	59.81	59.70	60.51	60.80	62.60	60.70	61.36	60.98	59.79	61.30	60.67	63.95	62.40	60.33	60.62	60.06	60.39				61.77	62.93	61.23	62.62	62.11	62.11
	14	32	No Data	59.91	59.38	59.83	60.02	59.62	60.37	61.40	59.30	59.39	60.35	60.12	61.55	60.39	60.74	60.75	59.19	60.49	59.97	63.98	61.42	59.87	59.67	59.61	60.27				60.89	62.15	60.49	61.70	61.62	61.62
		33	No Data	63.35	62.04	61.80	61.88	61.90	61.99	62.92	61.26	61.57	61.88	62.11	62.91	61.98	62.67	62.15	60.99	61.71	61.53	64.55	62.26	61.06	60.82	60.58	61.22				61.39	62.68	61.00	62.39	61.60	61.60
	15	34	No Data	60.13	58.82	58.25	58.86	58.51	58.42	59.14	57.44	57.34	57.62	58.39	59.05	57.74	57.98	58.19	56.76	57.66	56.81	60.03	58.20	56.55	56.50	55.56	55.44				56.14	57.06	55.99	56.96	55.70	55.70
	Ref	35	No Data	60.01	59.16	59.60	59.57	59.61	59.71	60.18	58.88	59.50	59.28	59.95	59.52	59.73	59.97	60.38	59.10	58.74	59.26	60.50	60.06	58.98	58.66	58.36	58.92				59.41	60.12	59.63	59.35	58.66	58.66

AVE TEMP (30A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		15	62.96	60.51	59.09	58.64	58.55	58.25	57.68	57.73	57.72	57.76	57.63	57.85	57.93	58.04	58.29	58.21	58.34	58.07	57.93	57.80	57.58	57.76	57.69	57.76	57.73	Power Outage			59.22	57.62	56.55	56.00	56.89	57.06
	7	16	67.80	67.05	66.52	66.72	67.00	66.93	66.45	66.53	66.95	67.25	67.21	67.42	67.59	67.88	68.24	68.24	68.21	67.75	67.55	67.36	67.19	67.48	67.42	67.79	67.99				69.42	67.95	66.93	66.42	66.93	67.03
		17	65.55	63.34	62.66	62.44	62.62	62.72	62.34	62.15	62.25	62.03	62.00	62.05	61.92	62.11	62.30	62.10	62.14	61.56	61.34	61.00	60.65	60.79	60.65	60.82	61.01				61.81	59.87	59.11	58.38	58.57	58.64
	8	18	72.98	71.28	70.57	70.55	70.48	70.28	70.02	69.91	70.01	69.88	69.74	69.80	69.82	69.95	70.20	70.00	69.97	69.67	69.44	69.16	69.10	69.11	69.09	69.06	69.14				69.84	69.06	68.06	67.76	68.03	67.95
		19	63.36	62.65	62.53	62.52	62.73	62.50	62.45	62.39	62.30	61.91	61.96	62.23	62.15	62.32	62.58	62.54	62.77	62.48	62.45	62.21	62.22	62.17	62.22	61.94	61.95				63.36	62.22	61.24	61.17	61.36	61.25
	9	20	64.35	63.60	63.29	63.26	63.34	63.07	62.88	62.78	62.81	62.52	62.54	62.70	62.65	62.83	63.13	63.09	63.19	62.76	62.60	62.31	62.28	62.29	62.31	62.13	62.27				63.27	62.29	61.49	61.17	61.22	61.14
	Ref	21	65.33	65.41	65.85	65.71	66.26	66.08	66.19	66.19	66.07	65.58	65.93	66.17	66.12	66.26	66.37	66.42	66.89	66.77	66.78	66.63	66.65	66.55	66.71	66.31	66.16				66.59	66.86	65.65	65.71	65.95	65.95
WAGO		22	62.58	62.44	62.80	61.98	62.48	62.15	62.07	62.04	61.67	61.03	61.45	61.71	61.48	61.61	61.48	61.32	62.01	61.72	61.86	61.82	61.52	61.28	61.37	60.96	60.86				60.90	60.92	59.73	59.76	60.04	60.04
	10	23	65.64	65.47	65.60	64.63	65.20	64.92	64.80	64.78	64.42	63.80	64.13	64.42	64.17	64.35	64.27	64.02	64.64	64.24	64.35	64.21	63.92	63.69	63.75	63.36	63.34				63.25	63.32	62.29	62.28	62.38	62.38
		24	62.85	62.98	63.65	62.98	63.64	63.54	63.40	63.47	63.15	62.78	63.10	63.34	63.28	63.35	63.31	63.07	63.61	63.34	63.55	63.38	63.05	62.88	62.86	62.53	62.58				62.49	62.61	61.70	61.80	62.13	62.13
	11	25	60.31	59.35	59.79	58.99	59.56	59.36	59.24	59.28	58.79	58.22	58.79	59.04	58.79	58.17	57.52	57.30	58.21	57.78	57.87	57.78	57.34	57.14	56.83	56.32	56.22				55.87	55.74	54.77	54.79	55.06	55.06
		26	61.30	61.24	62.45	61.23	62.06	61.91	61.71	61.85	61.09	60.53	61.16	61.49	61.14	61.05	60.66	60.49	61.54	60.94	61.26	61.34	60.62	60.45	60.37	60.09	60.02				59.91	59.63	58.84	58.80	59.08	59.08
	12	27	64.19	64.20	65.46	64.30	65.14	65.04	64.94	65.02	64.40	63.79	64.39	64.74	64.38	64.37	64.07	63.95	64.87	64.32	64.61	64.56	63.94	63.78	63.81	63.45	63.48				63.25	63.17	62.48	62.41	62.46	62.46
	Ref	28	57.47	57.72	59.09	58.44	59.26	59.15	59.27	59.36	58.80	58.33	58.93	59.20	58.99	58.84	58.73	58.77	59.52	59.09	59.48	59.57	59.11	58.86	59.06	58.71	58.72				58.86	59.03	58.42	58.40	58.24	58.24
Gardner Bender		29	59.04	59.48	60.89	59.71	60.70	60.60	60.86	61.05	60.32	59.90	60.47	60.80	60.67	60.35	59.91	59.73	60.83	60.31	60.81	61.18	60.45	60.09	60.32	59.77	59.83				60.09	60.18	59.40	59.29	59.51	59.51
	13	30	61.18	61.58	62.66	61.75	62.61	62.55	62.75	62.87	62.33	62.03	62.47	62.80	62.70	62.55	62.34	62.20	63.04	62.60	62.93	63.07	62.49	62.26	62.41	61.99	62.09				62.39	62.52	62.00	61.85	61.81	61.81
		31	63.63	63.96	65.26	64.15	65.12	65.04	65.34	65.44	64.75	64.54	65.02	65.35	65.21	65.00	64.67	64.27	65.35	64.76	65.45	65.88	65.13	64.65	64.98	64.41	64.43				65.27	65.47	64.84	64.91	64.89	64.89
	14	32	No Data	63.57	65.09	63.76	64.90	64.80	65.09	65.19	64.44	64.24	64.79	65.13	64.99	64.75	64.32	63.82	65.05	64.37	65.16	65.82	64.91	64.39	64.71	64.11	64.22				64.99	65.13	64.34	64.41	64.70	64.70
		33	No Data	65.59	66.72	65.43	66.31	66.22	66.48	66.49	65.93	65.90	66.23	66.44	66.42	66.17	65.90	65.39	66.31	65.78	66.30	66.80	65.80	65.37	65.62	65.14	65.21				65.49	65.58	64.95	64.84	65.21	65.21
	15	34	No Data	62.85	63.73	62.23	62.91	62.69	62.89	62.83	62.23	62.07	62.30	62.46	62.31	61.95	61.63	61.10	62.03	61.39	61.86	62.18	61.33	60.82	61.15	60.53	60.50				60.27	60.41	59.78	59.66	59.80	59.80
	Ref	35	No Data	62.16	63.09	62.21	62.62	62.54	62.89	62.73	62.44	62.48	62.65	62.65	62.71	62.43	62.40	62.23	62.79	62.57	62.68	62.86	62.34	61.95	62.30	61.97	62.19				62.37	62.49	62.19	61.90	61.74	61.74

MAX TEMP (20A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		36	No Data	62.13	61.46	60.56	60.29	60.59	59.48	59.07	58.70	58.95	58.83	58.72	58.61	58.78	58.97	59.81	58.95	58.60	57.88	57.27	57.12	57.72	57.02	57.49	58.02	Power Outage			55.94	56.39	55.77	54.77	54.71	54.52
	16	37	No Data	61.55	61.48	60.69	60.29	60.42	59.33	58.77	58.49	59.20	58.83	58.91	58.80	58.85	59.36	60.28	58.72	58.39	57.21	57.18	56.89	56.21	56.79	57.72	57.67				56.06	55.89	55.26	55.12	54.70	54.71
		38	No Data	53.15	53.64	52.80	52.67	53.02	52.45	52.11	52.09	52.60	52.50	52.54	52.74	52.96	53.10	53.16	52.74	53.18	52.53	51.91	51.67	51.18	51.62	52.10	52.53				52.03	51.42	52.15	51.49	50.43	50.66
	17	39	No Data	53.55	53.88	53.02	53.33	53.47	52.88	52.47	52.77	53.33	53.18	53.27	53.13	53.11	53.64	53.92	53.68	53.27	53.14	52.67	52.14	51.76	52.10	52.54	53.11				52.15	51.65	52.10	51.53	50.89	51.19
		40	No Data	58.52	58.37	57.97	57.89	58.17	58.29	57.23	57.63	57.96	57.56	57.85	57.78	58.40	58.14	58.80	58.13	58.01	57.80	57.28	56.80	56.33	57.45	57.09	57.96				57.14	56.87	57.52	57.04	56.10	55.62
	18	41	56.13	55.83	55.29	55.13	55.00	55.35	55.29	54.68	54.99	55.53	54.95	55.10	55.40	55.49	55.95	56.23	55.65	55.32	55.43	54.40	54.26	54.25	54.91	54.95	55.22				55.24	55.27	55.11	55.20	54.01	53.78
	Ref	42	56.42	56.74	56.50	56.62	56.33	56.28	56.37	56.22	55.96	56.23	56.48	56.54	56.60	56.96	57.50	58.27	57.01	56.53	56.28	55.38	55.46	55.50	55.62	56.07	57.18				56.25	56.25	55.48	55.38	54.02	53.94
WAGO		43	53.75	53.87	53.82	54.10	53.50	53.57	53.50	52.85	53.41	53.48	53.44	53.31	53.17	53.72	54.38	54.62	54.30	54.03	53.64	53.09	52.91	52.87	53.25	53.21	54.05				53.32	53.22	53.29	52.33	51.90	51.89
	19	44	55.89	55.65	55.78	55.82	55.25	55.40	55.26	54.84	55.04	55.27	55.32	54.92	54.82	55.36	56.26	56.63	56.03	55.85	54.97	54.46	54.50	54.34	54.62	54.71	56.00				54.68	54.77	54.47	53.68	53.04	53.04
		45	52.99	52.56	52.37	52.78	52.28	52.39	51.91	51.41	52.14	51.95	52.12	51.92	51.77	52.32	52.70	53.38	53.05	52.99	52.06	51.45	51.56	51.28	51.61	52.00	52.99				51.71	51.64	51.68	51.02	50.29	50.59
	20	46	57.96	57.96	58.00	58.20	57.49	57.50	57.34	56.82	56.96	56.99	57.24	57.16	56.95	57.64	57.95	58.84	58.49	58.11	57.46	56.50	56.58	56.79	56.97	56.85	58.01				56.80	56.91	56.95	56.39	55.60	55.52
		47	53.18	53.28	53.38	53.69	53.55	53.35	53.31	52.74	53.21	53.00	53.30	53.27	52.91	53.47	53.94	54.55	54.36	54.40	53.55	53.10	53.19	53.37	53.15	53.33	54.35				53.02	52.94	52.99	52.49	52.10	51.88
	21	48	55.56	56.03	55.79	56.28	55.54	55.68	55.56	55.06	55.50	55.52	55.63	55.69	55.57	56.12	56.31	57.52	56.93	56.43	55.72	55.31	55.22	55.68	55.18	55.82	57.01				55.40	55.08	55.32	55.19	54.29	54.10
	Ref	49	59.88	59.48	59.52	59.78	59.74	59.54	59.32	58.76	59.02	59.55	59.43	59.60	59.70	60.14	60.29	61.11	60.15	60.55	59.73	58.64	59.01	59.14	58.71	59.67	60.63				59.49	57.94	57.98	57.35	57.49	57.67
Gardner Bender		50	59.35	59.42	59.95	60.32	60.10	59.65	59.22	59.17	59.70	59.58	59.53	59.91	59.58	60.30	60.72	61.01	61.32	61.23	60.14	59.45	59.70	60.72	60.05	60.38	61.19				59.47	59.21	59.74	58.66	58.40	58.24
	22	51	61.96	61.58	61.77	62.22	61.85	61.58	60.92	60.99	61.25	61.51	61.27	61.81	61.27	62.80	62.52	63.28	62.56	62.82	61.88	61.01	60.90	62.66	62.00	62.71	63.59				61.36	60.54	61.33	59.95	59.91	59.67
		52	66.06	66.79	68.72	70.24	70.50	70.99	70.27	69.62	69.82	69.78	69.56	69.39	68.80	69.02	68.78	69.45	69.11	69.08	68.03	66.70	66.93	68.02	67.48	67.56	67.48				65.92	65.69	65.37	64.75	64.53	64.40
	23	53	64.35	65.25	66.55	68.23	68.67	68.51	67.96	67.56	67.49	67.69	67.29	67.03	66.68	66.49	66.51	66.98	66.88	66.84	65.76	64.83	64.73	65.30	65.00	65.00	65.02				63.50	63.06	63.04	62.42	62.02	61.88
		54	55.36	54.87	55.50	56.30	55.60	55.79	55.48	55.15	55.71	55.81	55.94	55.96	55.13	56.22	56.19	56.60	57.05	57.12	56.81	54.97	56.06	56.35	56.19	56.09	56.92				55.52	54.86	54.79	54.18	54.23	54.17
	24	55	56.03	55.91	56.35	57.15	56.61	56.65	56.36	55.93	56.44	56.83	56.78	56.76	56.16	57.08	57.02	57.72	57.82	58.08	57.58	55.95	56.97	57.32	57.03	56.86	57.98				56.51	55.73	55.96	55.38	55.18	55.26
	Ref	56	57.85	57.34	58.14	58.45	58.11	58.29	57.80	57.79	58.00	58.26	58.49	58.19	57.91	58.52	58.96	59.31	59.46	59.75	58.73	58.07	58.74	58.89	58.86	58.61	59.32				58.52	58.03	57.79	57.42	57.41	57.28

MIN TEMP (20A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		36	No Data	59.35	58.63	57.86	57.56	57.20	56.72	56.52	55.94	56.36	56.49	56.26	56.20	56.30	56.63	56.66	56.30	55.87	55.43	54.74	54.82	54.93	54.79	55.20	55.26	Power Outage			54.14	53.70	52.99	52.13	52.45	52.29
	16	37	No Data	57.79	57.06	56.48	56.14	55.91	55.38	55.24	55.21	55.24	55.15	55.20	55.05	55.24	55.58	55.58	55.34	54.86	54.43	53.72	53.84	53.79	53.38	54.02	54.44				53.12	52.87	52.22	51.82	51.65	51.61
		38	No Data	49.75	49.98	49.67	49.75	49.31	49.02	48.63	49.23	49.38	49.51	49.41	49.51	50.28	50.34	50.40	50.06	49.63	49.53	49.25	48.51	48.91	48.37	49.05	49.95				48.12	48.34	48.27	47.40	47.43	47.71
	17	39	No Data	50.82	50.92	50.31	49.90	49.96	49.24	49.84	50.10	50.56	49.98	50.29	50.27	50.79	51.28	50.99	50.57	49.91	49.81	49.54	48.94	49.36	48.70	49.30	50.66				48.65	48.64	48.11	47.65	47.82	48.16
		40	No Data	55.18	55.29	54.75	54.41	54.78	53.98	54.16	53.99	54.52	54.21	54.25	54.66	54.96	55.24	55.12	53.62	54.03	53.64	53.63	52.40	53.14	52.87	52.99	54.58				53.13	52.93	53.08	52.44	52.17	52.41
	18	41	22.86	52.29	52.65	52.48	52.14	52.15	51.89	51.58	52.03	51.88	52.19	52.23	52.31	52.52	53.15	53.36	52.73	51.94	52.08	51.26	51.32	51.46	50.98	51.87	52.47				51.54	51.62	50.85	51.01	50.33	50.86
	Ref	42	22.88	52.07	53.43	52.73	52.59	52.26	52.30	52.58	52.32	52.32	53.09	53.11	52.81	51.80	52.71	51.32	53.41	52.17	52.87	51.55	52.17	51.97	52.11	52.48	52.22				52.56	51.63	51.30	51.25	50.30	50.80
WAGO		43	22.90	50.19	51.07	49.83	50.72	51.22	50.90	51.03	51.03	51.32	50.99	51.53	51.32	50.32	50.18	49.22	50.40	51.92	51.73	51.02	51.08	51.13	51.25	51.43	50.34				51.31	50.96	50.69	50.04	49.93	50.16
	19	44	22.88	51.23	52.25	50.87	51.42	52.09	52.41	52.35	51.81	52.44	51.92	52.60	52.11	51.11	50.86	49.83	50.85	53.18	52.77	51.85	52.01	51.90	52.07	52.15	51.13				52.07	51.60	51.56	50.79	50.53	50.61
		45	22.88	48.73	49.44	48.31	48.85	49.19	48.74	49.27	49.56	49.69	49.07	49.80	49.36	47.50	47.44	47.56	48.58	50.38	49.96	49.51	49.51	49.52	49.61	49.98	48.48				49.70	49.40	49.33	48.42	48.46	48.58
	20	46	22.90	53.18	54.28	53.41	54.27	54.09	53.31	54.01	54.41	54.55	53.91	54.38	54.23	52.66	52.79	52.77	53.34	55.14	54.94	54.69	54.80	54.11	54.50	54.71	53.17				54.70	54.38	54.57	53.62	53.36	53.76
		47	22.86	48.90	49.92	49.34	49.38	49.73	49.55	49.88	50.21	50.20	48.87	50.15	50.08	48.36	48.97	48.64	49.93	51.04	50.75	50.99	50.82	51.28	51.08	51.13	49.94				50.66	51.01	51.08	50.49	49.96	50.68
	21	48	22.85	50.05	50.83	50.24	50.67	50.80	50.55	51.55	52.03	51.66	49.48	51.39	51.07	49.69	50.11	49.68	50.86	52.18	51.95	52.44	52.70	52.49	52.07	52.61	51.19				52.51	52.75	52.82	52.29	51.15	51.94
	Ref	49	22.85	52.31	53.12	52.11	52.79	53.02	53.25	53.67	54.19	53.43	51.96	53.91	53.11	51.78	51.67	52.72	53.34	54.64	53.62	54.57	54.76	54.82	55.01	54.57	53.48				54.76	54.54	54.22	53.79	53.82	54.81
Gardner Bender		50	22.82	53.04	53.91	53.59	54.27	54.49	54.33	54.51	54.63	54.22	54.16	54.86	54.70	53.55	53.28	53.89	54.27	55.96	55.18	55.14	55.77	55.23	56.24	55.22	55.05				56.33	55.73	55.79	56.51	55.47	56.24
	22	51	22.69	53.66	54.11	53.97	54.71	55.02	54.91	55.14	55.52	54.80	54.58	55.20	55.27	53.57	52.89	54.15	54.33	56.56	55.70	55.37	56.50	56.21	56.91	55.79	55.09				56.40	56.89	56.66	57.25	56.09	56.53
		52	22.70	59.15	60.30	61.39	63.00	63.46	63.42	63.63	63.43	62.55	62.30	62.46	62.06	60.52	60.60	60.90	60.69	62.22	61.00	61.81	61.94	61.57	61.16	60.35	59.99				61.06	60.99	60.05	61.57	60.52	61.33
	23	53	22.70	57.96	59.48	60.06	61.63	61.74	60.48	61.87	61.59	61.08	60.51	60.61	59.86	59.36	59.35	59.25	59.30	59.88	59.48	59.78	59.81	59.47	59.70	58.40	58.65				58.92	58.37	58.28	59.16	58.30	59.14
		54	22.69	48.53	48.73	48.85	49.31	49.08	49.33	49.87	49.51	49.40	49.07	49.17	49.49	48.35	48.21	49.38	49.25	50.09	49.37	50.31	50.26	50.98	50.13	50.68	49.76				50.34	50.89	50.78	50.81	50.87	50.56
	24	55	22.67	48.93	49.19	49.36	49.47	49.69	49.29	50.17	49.76	49.93	49.61	49.42	50.01	48.98	48.83	49.55	49.62	51.01	50.24	50.57	50.60	51.09	50.52	50.91	50.31				50.62	51.03	51.01	52.23	51.43	51.51
	Ref	56	22.67	50.30	50.45	50.53	50.97	50.51	50.98	51.60	50.90	51.36	51.00	51.29	51.42	50.75	51.16	51.15	51.30	52.26	51.60	51.74	51.74	52.88	52.04	52.03	51.84				52.01	53.03	53.29	52.89	52.51	53.01

AVE TEMP (20A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		36	No Data	60.77	59.99	59.24	58.80	58.40	58.00	57.49	57.52	57.76	57.57	57.30	57.23	57.33	57.76	57.80	57.64	57.23	56.62	55.92	55.94	55.93	55.88	56.18	56.41	Power Outage			55.04	54.76	54.33	53.61	53.61	53.38
	16	37	No Data	59.73	59.15	58.20	57.97	57.61	57.21	56.61	56.80	57.16	56.97	56.73	56.67	56.83	57.26	57.16	56.99	56.29	55.69	55.13	54.96	54.78	54.74	55.25	55.77				54.45	53.99	53.52	52.73	52.79	52.83
		38	No Data	51.64	51.53	51.16	51.23	51.05	50.88	50.46	50.78	51.23	51.13	51.05	51.16	51.32	51.72	51.89	51.78	51.21	50.92	50.47	50.25	50.03	50.05	50.54	51.13				50.27	50.05	50.06	49.36	48.98	49.14
	17	39	No Data	52.36	52.28	51.85	51.98	51.84	51.62	51.21	51.53	51.98	51.88	51.79	51.87	52.06	52.56	52.70	52.44	51.80	51.50	51.02	50.73	50.55	50.45	51.19	51.86				50.82	50.31	50.14	49.41	49.31	49.63
		40	No Data	57.10	56.83	56.46	56.37	56.22	56.18	55.59	55.98	56.44	56.20	56.06	56.21	56.40	56.80	56.96	56.68	56.18	55.89	55.15	55.04	54.84	54.94	55.52	56.13				55.55	55.12	55.25	54.72	53.96	54.04
	18	41	54.35	54.35	54.11	53.73	53.66	53.51	53.53	53.04	53.48	53.89	53.63	53.60	53.69	53.85	54.28	54.42	54.35	53.89	53.64	52.95	52.89	52.64	52.80	53.23	53.72				53.56	53.41	53.53	53.05	52.25	52.22
	Ref	42	54.46	54.97	54.95	54.71	54.71	54.56	54.52	53.98	54.20	54.69	54.53	54.54	54.65	54.74	55.27	55.60	55.45	55.02	54.56	53.63	53.65	53.55	53.64	54.24	54.82				54.09	53.61	53.64	53.01	52.33	52.35
WAGO		43	52.34	52.86	52.83	52.65	52.62	52.60	52.50	52.13	52.17	52.55	52.49	52.40	52.46	52.56	52.85	53.12	53.35	53.18	52.71	52.00	51.96	51.99	52.03	52.35	52.75				52.16	51.89	51.76	51.15	50.90	50.94
	19	44	53.85	54.41	54.30	54.00	53.94	53.89	53.83	53.35	53.46	53.91	53.75	53.66	53.72	53.80	54.13	54.38	54.58	54.37	53.78	53.02	52.99	52.96	52.95	53.43	53.89				53.19	52.78	52.71	52.01	51.65	51.73
		45	50.72	51.29	51.32	51.11	51.09	51.09	50.95	50.66	50.76	51.10	51.02	50.93	50.92	51.04	51.30	51.57	51.85	51.73	51.16	50.53	50.46	50.43	50.40	50.82	51.21				50.58	50.27	50.16	49.44	49.33	49.44
	20	46	55.98	56.52	56.48	56.35	56.23	56.22	56.14	55.79	55.84	56.15	56.05	55.95	55.94	56.04	56.30	56.56	56.87	56.79	56.22	55.57	55.55	55.52	55.52	55.84	56.16				55.66	55.47	55.45	54.85	54.58	54.61
		47	51.11	51.74	51.95	51.89	51.88	52.04	51.95	51.98	52.00	52.08	52.09	52.14	52.02	52.10	52.29	52.67	52.98	53.07	52.61	52.25	52.21	52.28	52.28	52.43	52.63				52.20	52.09	52.00	51.41	51.24	51.27
	21	48	52.89	53.69	53.92	53.82	53.79	54.02	53.95	53.96	54.15	54.19	54.09	54.18	54.06	54.11	54.26	54.64	54.97	55.03	54.55	54.19	54.18	54.16	54.18	54.41	54.71				54.26	54.06	54.03	53.42	53.12	53.16
	Ref	49	55.39	56.19	56.54	56.47	56.49	56.91	56.47	56.79	56.93	57.03	56.85	56.95	56.66	56.83	57.08	57.66	57.59	57.74	57.32	56.91	56.86	57.09	56.76	57.41	57.60				57.35	56.52	56.08	55.30	55.86	56.14
Gardner Bender		50	55.71	56.39	56.97	57.15	57.15	57.46	57.23	57.60	57.66	57.54	57.44	57.62	57.34	57.48	57.84	58.33	58.40	58.63	58.28	58.15	58.10	58.30	58.26	58.34	58.49				58.28	58.09	58.02	57.49	57.48	57.52
	22	51	57.01	57.72	58.08	58.21	58.23	58.63	58.29	58.74	58.92	58.77	58.59	58.80	58.43	58.63	59.01	59.53	59.52	59.77	59.39	59.19	59.16	59.37	59.28	59.54	59.74				59.43	59.11	58.93	58.28	58.38	58.45
		52	61.13	62.84	64.45	65.90	67.06	67.63	66.98	67.63	67.46	66.66	66.23	66.31	65.41	65.37	65.53	65.90	65.57	65.67	65.29	65.24	64.97	65.14	64.86	64.73	64.52				64.38	64.15	63.84	63.18	63.10	63.09
	23	53	60.07	61.53	62.97	64.21	65.24	65.72	65.02	65.67	65.39	64.69	64.29	64.34	63.48	63.40	63.57	63.87	63.60	63.66	63.37	63.36	63.05	63.27	62.97	62.78	62.55				62.09	61.88	61.63	61.02	60.93	60.90
		54	51.35	51.69	51.99	52.22	52.26	52.59	52.15	53.04	52.90	52.57	52.45	52.70	52.18	52.40	52.98	53.66	53.45	53.67	53.44	53.40	53.28	53.83	53.66	53.82	53.81				53.51	53.33	52.99	52.50	52.79	52.86
	24	55	51.67	52.13	52.52	52.75	52.78	53.22	52.76	53.77	53.72	53.26	53.14	53.43	52.83	53.04	53.59	54.30	54.07	54.37	54.23	54.30	54.19	54.70	54.52	54.63	54.56				54.52	54.43	54.18	53.65	53.87	53.96
	Ref	56	52.96	53.47	54.00	54.16	54.27	54.76	54.18	55.51	55.43	54.79	54.68	55.02	54.35	54.51	55.12	55.81	55.56	55.92	55.88	56.09	55.95	56.60	56.32	56.32	56.07				56.26	56.30	56.11	55.67	56.01	56.06

MAX TEMP (Ambient, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
50A																																				
IDEAL	1-3	1	23.37	23.48	23.45	23.95	23.75	23.61	23.47	23.24	23.33	23.51	23.61	23.55	23.58	23.74	24.22	24.47	24.45	24.44	24.16	23.67	23.68	23.65	23.62	23.84	24.15	24.10	23.45	23.10	23.61	23.43	23.42	22.93	22.84	22.87
WAGO	4-6	2	23.80	23.31	23.32	23.82	23.57	23.47	23.33	23.14	23.19	23.30	23.42	23.41	23.42	23.61	24.07	24.32	24.36	24.36	24.03	23.64	23.56	23.52	23.50	23.66	23.99	24.00	23.43	23.05	23.52	23.34	23.39	22.80	22.77	22.74
30A																																				
IDEAL	7-9	3	23.43	23.19	23.10	23.47	23.40	23.23	23.13	22.93	22.95	23.15	23.23	23.24	23.21	23.43	23.92	24.16	24.20	24.11	23.85	23.38	23.36	23.37	23.31	23.44	23.79	23.77	23.39	22.97	23.29	23.26	23.31	22.77	22.49	22.50
WAGO	10-12	4	23.59	23.19	23.13	23.49	23.41	23.26	23.11	22.92	22.96	23.18	23.27	23.24	23.25	23.51	23.98	24.25	24.16	24.08	23.84	23.38	23.33	23.33	23.28	23.40	23.85	23.80	23.38	22.97	23.23	23.22	23.28	22.75	22.51	22.49
Gardner Bender	13-15	5	23.66	23.21	23.15	23.67	23.49	23.31	23.12	22.92	23.06	23.21	23.30	23.28	23.25	23.56	24.04	24.38	24.19	24.08	23.84	23.37	23.28	23.35	23.27	23.44	24.01	23.82	23.43	23.12	23.21	23.18	23.24	22.73	22.47	22.46
20A																																				
IDEAL	16-18	6	23.58	23.28	23.22	23.76	23.53	23.36	23.16	23.03	23.10	23.31	23.37	23.38	23.38	23.65	24.11	24.30	24.28	24.21	23.93	23.48	23.35	23.44	23.36	23.54	23.97	23.92	23.43	23.10	23.28	23.17	23.23	22.72	22.55	No Data
WAGO	19-21	7	23.66	23.28	23.24	23.61	23.50	23.35	23.17	22.99	23.05	23.27	23.35	23.36	23.37	23.62	24.10	24.25	24.24	24.13	23.89	23.46	23.37	23.44	23.33	23.49	23.83	23.94	23.42	23.02	23.27	23.18	23.22	22.68	22.60	22.59
Gardner Bender	22-24	8	23.70	23.23	23.22	23.55	23.46	23.32	23.15	22.95	23.02	23.26	23.34	23.33	23.36	23.59	24.06	24.22	24.22	24.12	23.85	23.43	23.33	23.41	23.30	23.43	23.83	23.91	23.41	22.98	23.26	23.15	23.17	22.64	22.55	22.54

MIN TEMP (Ambient, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
50A																																				
IDEAL	1-3	1	22.86	23.21	23.18	23.24	23.38	23.21	23.09	23.04	22.91	23.06	23.28	23.23	23.27	23.39	23.69	24.13	24.13	23.99	23.67	23.31	23.28	23.39	23.31	23.36	23.63	23.42	22.87	22.71	22.65	23.16	22.61	22.37	22.37	22.49
WAGO	4-6	2	23.07	23.11	23.07	23.12	23.27	23.11	22.98	22.90	22.81	22.96	23.17	23.13	23.14	23.30	23.58	23.99	24.05	23.89	23.62	23.26	23.19	23.31	23.18	23.21	23.47	23.40	22.81	22.66	22.60	23.09	22.58	22.32	22.29	22.40
30A																																				
IDEAL	7-9	3	22.96	22.95	22.88	22.94	23.12	22.92	22.78	22.74	22.64	22.77	23.00	22.95	22.96	23.12	23.43	23.87	23.89	23.66	23.35	23.07	23.06	23.05	23.00	23.06	23.27	23.34	22.77	22.60	22.55	22.90	22.58	22.28	22.18	22.28
WAGO	10-12	4	22.96	22.99	22.92	22.97	23.15	22.94	22.78	22.71	22.66	22.82	23.03	22.98	22.99	23.13	23.47	23.91	23.92	23.68	23.32	23.06	23.07	23.05	23.01	23.03	23.27	23.35	22.79	22.63	22.55	22.89	22.61	22.26	22.21	22.28
Gardner Bender	13-15	5	22.98	22.99	22.91	22.99	23.15	22.94	22.78	22.71	22.64	22.84	23.01	22.98	22.99	23.13	23.50	23.95	23.90	23.66	23.34	23.06	23.06	23.03	22.98	23.03	23.30	23.37	22.82	22.70	22.57	22.87	22.58	22.21	22.19	22.27
20A																																				
IDEAL	16-18	6	23.06	23.04	23.00	23.05	23.24	23.03	22.82	22.79	22.71	22.95	23.11	23.05	23.07	23.21	23.61	24.07	24.02	23.74	23.44	23.15	23.10	23.16	23.05	23.09	23.37	23.39	22.83	22.70	22.54	22.95	22.55	22.20	22.22	No Data
WAGO	19-21	7	23.07	23.04	22.96	23.03	23.23	23.00	22.81	22.75	22.66	22.92	23.08	23.02	23.04	23.18	23.59	24.04	24.00	23.72	23.42	23.06	23.03	23.16	23.04	23.07	23.35	23.39	22.82	22.67	22.52	22.91	22.54	22.20	22.16	22.26
Gardner Bender	22-24	8	23.06	23.04	22.93	22.98	23.21	22.96	22.79	22.73	22.64	22.89	23.04	23.01	23.01	23.16	23.56	24.00	24.00	23.72	23.36	23.03	23.01	23.11	23.00	23.03	23.30	23.36	22.79	22.65	22.51	22.89	22.50	22.15	22.11	22.22

AVE TEMP (Ambient, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
50A																																				
IDEAL	1-3	1	23.23	23.31	23.29	23.44	23.51	23.41	23.26	23.16	23.07	23.28	23.41	23.40	23.42	23.58	23.99	24.28	24.29	24.18	23.92	23.57	23.47	23.51	23.43	23.58	23.86	23.69	23.24	22.92	23.29	23.28	23.14	22.73	22.68	22.69
WAGO	4-6	2	23.19	23.22	23.17	23.33	23.39	23.29	23.17	23.04	22.95	23.16	23.28	23.27	23.30	23.48	23.90	24.17	24.19	24.09	23.84	23.51	23.39	23.40	23.34	23.45	23.73	23.64	23.22	22.89	23.20	23.20	23.06	22.64	22.59	22.60
30A																																				
IDEAL	7-9	3	23.04	23.05	22.99	23.15	23.23	23.09	22.95	22.82	22.76	22.99	23.10	23.09	23.11	23.30	23.75	24.00	23.99	23.84	23.60	23.26	23.17	23.16	23.10	23.22	23.53	23.55	23.16	22.83	22.99	23.03	22.89	22.51	22.41	22.40
WAGO	10-12	4	23.06	23.07	23.02	23.18	23.26	23.11	22.96	22.83	22.78	23.02	23.13	23.11	23.13	23.33	23.78	24.04	24.01	23.83	23.60	23.27	23.18	23.17	23.10	23.24	23.56	23.56	23.16	22.84	23.00	23.01	22.88	22.50	22.40	22.40
Gardner Bender	13-15	5	23.07	23.08	23.02	23.20	23.26	23.12	22.96	22.82	22.78	23.03	23.14	23.11	23.13	23.34	23.80	24.07	24.02	23.84	23.59	23.24	23.16	23.15	23.08	23.25	23.59	23.59	23.22	22.91	23.00	22.98	22.85	22.46	22.37	22.37
20A																																				
IDEAL	16-18	6	23.18	23.17	23.09	23.26	23.35	23.23	23.04	22.92	22.86	23.13	23.23	23.22	23.24	23.46	23.94	24.20	24.17	23.95	23.71	23.34	23.23	23.25	23.16	23.36	23.68	23.65	23.20	22.90	23.06	23.04	22.89	22.47	22.43	No Data
WAGO	19-21	7	23.20	23.18	23.09	23.26	23.35	23.21	23.03	22.90	22.83	23.11	23.22	23.19	23.22	23.44	23.92	24.18	24.14	23.93	23.68	23.33	23.21	23.25	23.17	23.32	23.65	23.64	23.20	22.88	23.03	23.03	22.91	22.49	22.45	22.45
Gardner Bender	22-24	8	23.18	23.17	23.08	23.25	23.33	23.18	23.01	22.86	22.81	23.10	23.20	23.17	23.20	23.42	23.89	24.14	24.11	23.90	23.64	23.29	23.18	23.21	23.13	23.29	23.61	23.62	23.19	22.87	23.00	23.00	22.88	22.46	22.41	22.40

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Copperweld Bimetallic
215 Centerview Dr
Brentwood TN 37027

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Copperweld Bimetallic
215 Centerview Dr
Brentwood TN 37027

Report Date: October 27, 2017

Description:	CCA –Cu Ampacity Comparison
Type of Evaluation	Fact Finding Investigation
Job Number	J-00265162
Project Number	0225-104
Project Manager	Don Tottingham
Location	789 Dixboro Road, Ann Arbor
Inspection Dates	August 7- August 18, 2017
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Evaluated By: _____

Anas Alaghazali- Engineer

Reviewed By: Steve Fabian

Steve Fabian- Senior Technical Manager

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Purpose: The purpose of this testing was to evaluate copper clad aluminum wire (CCA) and copper wire (Cu) as a single conductor, non- -metallic 2 hot conductors, and two conductor in conduit, under the same current condition, and to determine their equivalence in performance

Credentials: NSF International, an accredited Nationally Recognized Testing Laboratory (NRTL), an Accredited Standards Council of Canada (SCC) laboratory, and accredited by the International Standards Organization (ISO) to ISO 14001.

Executive Summary: This Fact-Finding Investigation was conducted to develop a comparative temperature – heat rise database for Copper and Copper-Clad Aluminum Conductors in Sizes No. 14 -10 AWG.

The details of the test procedure for each conductor size, 14-10 AWG, is outlined in the report.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 14 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 18, 29, and 38.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 12 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 50, 61, and 71.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 10 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 87, 100, and 113.

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Test Set- Up/ Layout
14 AWG single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 14AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 14AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 14 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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FIGURE 1
Circuit Layout

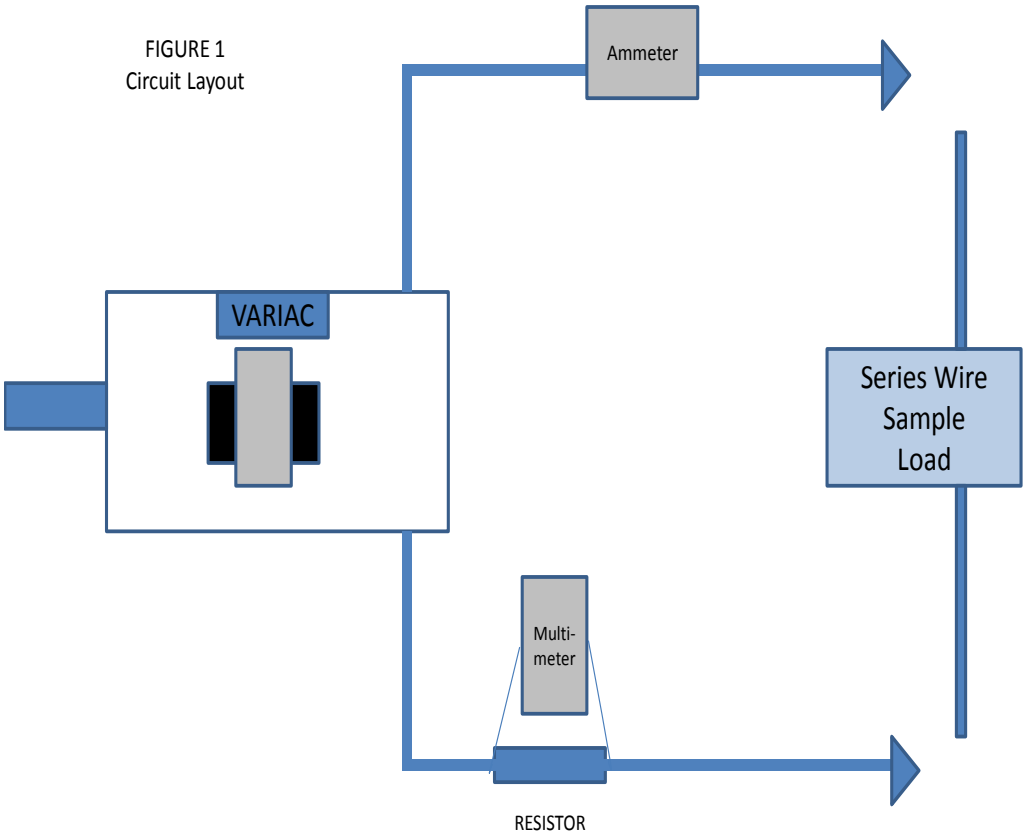

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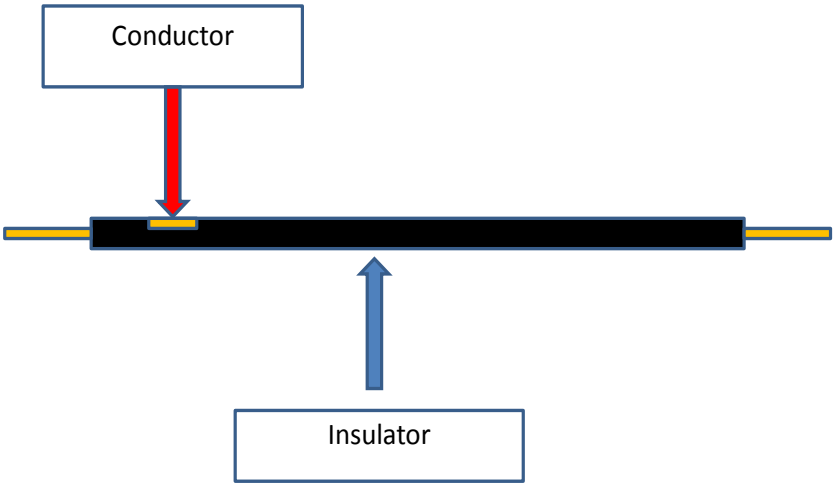
FIGURE 2
Single conductor



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Test Procedure
14 AWG Single Conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	Open air	5	30
14	Open air	10	30
14	Open air	15	30
14	Open air	20	30
14	Open air	25	30
14	Open air	30	30
14	Open air	35	30
14	Open air	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA Single Conductor open Air (Page 1/3))

Scan	Time	Elapsed	212 CU-AL #1 Core	213 CU-AL #1 Insu	203 CU-AL#2 Core	204 CU-AL#2 Insu	205 CU-AL#3 Insu
	5 AMPS						
32.00	42956.43	00:00:30:59	23.66	23.26	23.60	23.45	23.89
		Corrected Ambient	32.38	31.98	32.32	32.17	32.61
		Average	32.31				
		Average Core	32.40				
		Average Insulation	32.20				
	10 AMPS						
62.00	42956.45	00:01:00:59	28.37	28.10	27.74	28.35	28.81
		Corrected Ambient	36.96	36.69	36.33	36.94	37.40
		Average	36.38				
		Average Core	36.52				
		Average Insulation	36.22				
	15 AMPS						
92.00	42956.47	00:01:30:59	33.80	33.78	32.88	33.88	34.50
		Corrected Ambient	42.42	42.40	41.50	42.50	43.12
		Average	41.70				
		Average Core	42.16				
		Average Insulation	41.20				
	20 AMPS						
122.00	42956.49	00:02:00:59	43.82	43.54	42.12	43.28	44.61
		Corrected Ambient	52.04	51.76	50.34	51.50	52.83

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		Average	50.79				
		Average Core	51.77				
		Average Insulation	49.71				
	25 AMPS						
154.00	42956.52	00:02:32:59	53.50	53.49	51.23	52.53	54.61
		Corrected Ambient	61.81	61.80	59.54	60.84	62.92
		Average	60.07				
		Average Core	61.51				
		Average Insulation	58.50				
	30 AMPS						
183.00	42956.54	00:03:01:59	69.00	67.27	65.45	65.49	69.18
		Corrected Ambient	77.08	75.35	73.53	73.57	77.26
		Average	73.57				
		Average Core	75.91				
		Average Insulation	71.02				
	35 AMPS						
216.00	42956.56	00:03:34:59	85.83	83.73	80.52	81.75	86.71
		Corrected Ambient	93.96	91.86	88.65	89.88	94.84
		Average	89.81				
		Average Core	92.67				
		Average Insulation	86.68				

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14 AWG CCA Single Conductor open Air (Page 2/3))

208 CU-AL#3 Core	120 CU-AL #4 Core	211 CU-AL#4 Insu	102 CU-AL#5 Core	110 CU-AL#5 Insu	117 CU-AL#6 Core	116 CU-AL#7 Insul	320 CU-AL#7 Core	113 CU-AL#8 Core
23.51	23.63	23.37	23.62	23.47	23.86	23.44	23.36	23.79
32.23	32.35	32.09	32.34	32.19	32.58	32.16	32.08	32.51
27.61	27.35	26.86	27.79	27.18	27.93	27.43	27.16	27.92
36.20	35.94	35.45	36.38	35.77	36.52	36.02	35.75	36.51
32.59	32.02	31.20	33.01	31.82	33.24	31.93	32.18	33.99
41.21	40.64	39.82	41.63	40.44	41.86	40.55	40.80	42.61
41.25	41.32	38.66	42.34	39.53	43.15	40.71	41.44	44.59
49.47	49.54	46.88	50.56	47.75	51.37	48.93	49.66	52.81

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49.39	49.93	45.71	51.18	46.84	52.51	48.79	50.05	53.67
57.70	58.24	54.02	59.49	55.15	60.82	57.10	58.36	61.98
62.25	62.46	56.14	64.18	58.21	68.21	60.49	63.39	67.06
70.33	70.54	64.22	72.26	66.29	76.29	68.57	71.47	75.14
76.43	76.02	68.71	79.20	71.51	84.64	74.08	77.84	82.07
84.56	84.15	76.84	87.33	79.64	92.77	82.21	85.97	90.20

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14 AWG CCA Single Conductor open Air (Page 3/3))

114 CU-AL#8 Insul	109 CU-AL#9 Core	112 CU-AL#9 Insul	106 CU-AL#10 Core	107 CU-AL#10 Insul	101 CU-AL#11 Core	103 CU-AL#11 Insul	104 CU-AL#12 Core	105 CU-AL#12 Insul
23.65	23.82	23.63	23.82	23.54	23.54	23.19	23.97	23.43
32.37	32.54	32.35	32.54	32.26	32.26	31.91	32.69	32.15
27.87	27.44	27.22	27.77	27.44	28.29	26.84	29.82	27.86
36.46	36.03	35.81	36.36	36.03	36.88	35.43	38.41	36.45
32.54	33.29	31.49	33.60	32.07	34.85	31.62	37.00	33.55
41.16	41.91	40.11	42.22	40.69	43.47	40.24	45.62	42.17
42.59	42.44	39.88	44.38	40.51	46.65	40.27	49.14	42.83

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50.81	50.66	48.10	52.60	48.73	54.87	48.49	57.36	51.05
51.66	51.50	47.77	54.91	48.80	58.73	49.17	61.74	52.68
59.97	59.81	56.08	63.22	57.11	67.04	57.48	70.05	60.99
64.87	64.44	60.00	70.51	61.42	75.50	62.17	81.54	67.10
72.95	72.52	68.08	78.59	69.50	83.58	70.25	89.62	75.18
81.21	80.84	74.81	88.65	76.44	96.72	79.11	105.73	86.00
89.34	88.97	82.94	96.78	84.57	104.85	87.24	113.86	94.13

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14 AWG Cu Single conductor open air (Page 1/2))

Scan	Time	Elapsed	313 CU#1 Insul	312 CU#1 Core	309 CU#2 Core	310 CU#2 Insul	304 CU#3 Core	305 CU#3 Insul
	5 AMPS							
32.00	42956.43	00:00:30:59	22.94	22.76	23.27	22.75	23.19	22.87
		Corrected Ambient	31.66	31.48	31.99	31.47	31.91	31.59
		Average	31.76					
		Average Core	31.82					
		Average Insulation	31.70					
	10 AMPS							
62.00	42956.45	00:01:00:59	26.12	25.30	26.88	25.64	25.98	25.79
		Corrected Ambient	34.71	33.89	35.47	34.23	34.57	34.38
		Average	34.71					
		Average Core	34.68					
		Average Insulation	34.75					
	15 AMPS							
92.00	42956.47	00:01:30:59	29.59	28.15	30.84	28.94	29.08	29.21
		Corrected Ambient	38.21	36.77	39.46	37.56	37.70	37.83
		Average	38.20					
		Average Core	38.06					
		Average Insulation	38.34					

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	20 AMPS							
122.00	42956.49	00:02:00:59	35.06	33.50	38.22	34.03	34.76	34.30
		Corrected Ambient	43.28	41.72	46.44	42.25	42.98	42.52
		Average	43.85					
		Average Core	44.07					
		Average Insulation	43.64					
	25 AMPS							
154.00	42956.52	00:02:32:59	41.11	39.21	44.97	39.53	39.76	39.48
		Corrected Ambient	49.42	47.52	53.28	47.84	48.07	47.79
		Average	49.79					
		Average Core	49.98					
		Average Insulation	49.60					
	30 AMPS							
183.00	42956.54	00:03:01:59	50.05	48.57	55.19	47.04	46.81	46.68
		Corrected Ambient	58.13	56.65	63.27	55.12	54.89	54.76
		Average	58.05					
		Average Core	58.69					
		Average Insulation	57.42					
	35 AMPS							
216.00	42956.56	00:03:34:59	58.77	56.46	67.22	55.89	54.87	54.95
		Corrected Ambient	66.90	64.59	75.35	64.02	63.00	63.08
		Average	67.08					
		Average Core	67.91					
		Average Insulation	66.25					

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14 AWG Cu Single Conductor open Air (Page 2/2))

206 CU#4 Core	302 CU#4 Insul	218 CU#5 Core	220 CU#5 Insul	209 CU#6 Core	214 CU#6 Insul
23.07	23.20	23.11	22.85	23.21	23.30
31.79	31.92	31.83	31.57	31.93	32.02
26.07	26.44	26.00	26.11	26.30	26.84
34.66	35.03	34.59	34.70	34.89	35.43
29.44	30.07	29.34	29.78	29.81	30.74
38.06	38.69	37.96	38.40	38.43	39.36
35.82	35.84	35.94	35.90	36.83	37.36

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44.04	44.06	44.16	44.12	45.05	45.58
41.32	41.65	41.70	41.84	43.06	44.11
49.63	49.96	50.01	50.15	51.37	52.42
50.11	49.91	50.16	49.62	52.82	52.73
58.19	57.99	58.24	57.70	60.90	60.81
59.11	58.81	59.35	57.77	61.68	62.52
67.24	66.94	67.48	65.90	69.81	70.65

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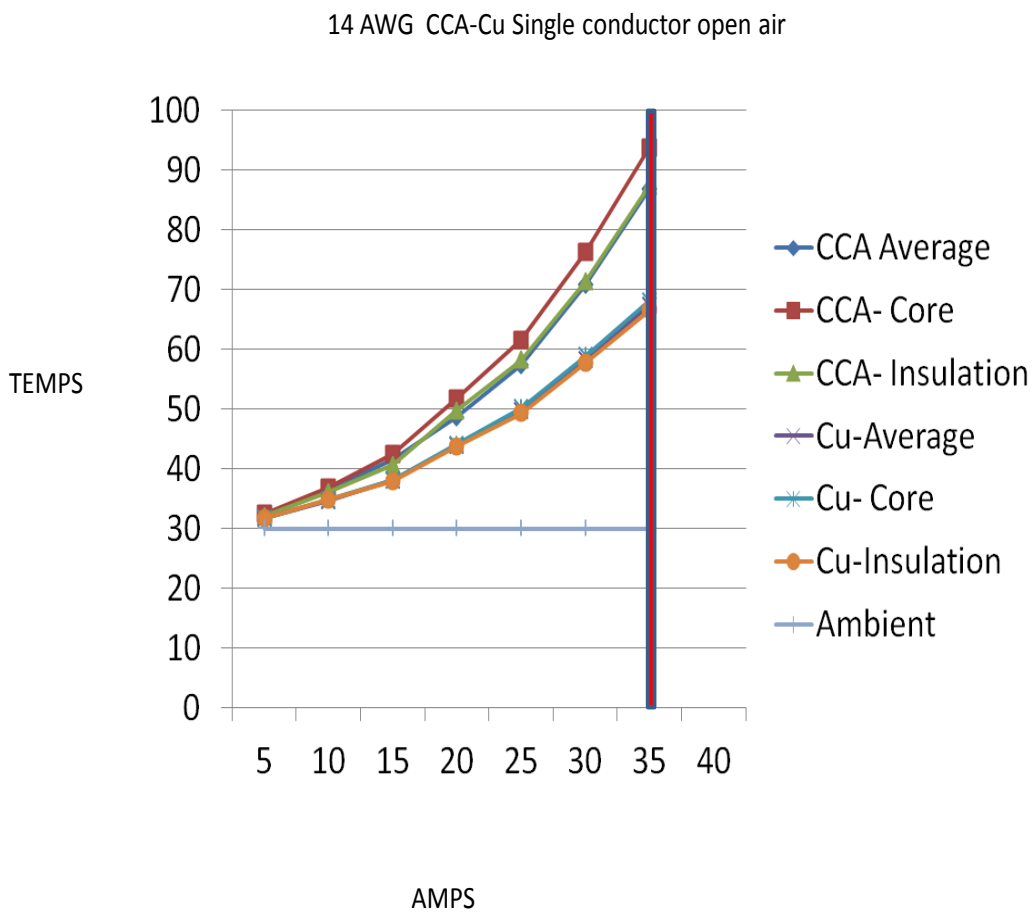

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Test Set- Up/ Layout
14 AWG in non-metallic cable in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 14 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 14 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 14 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used is calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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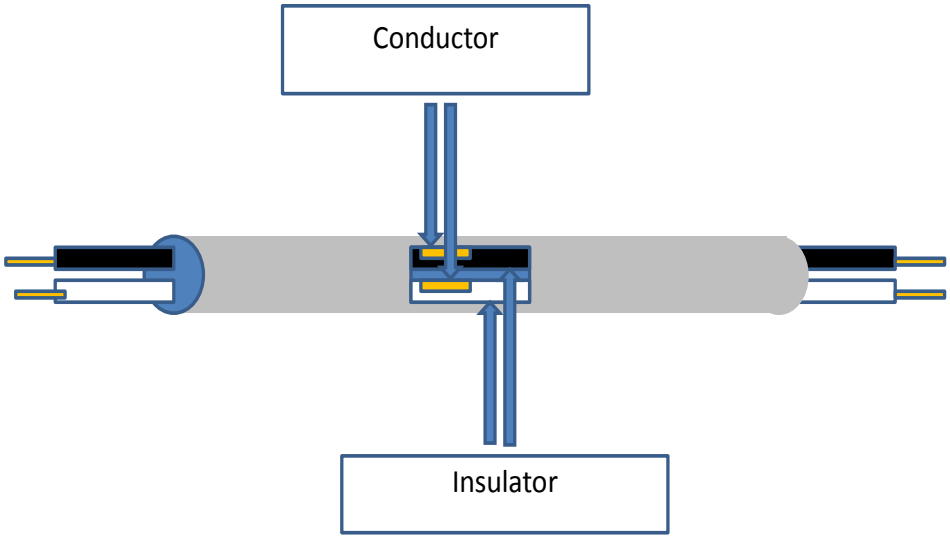
FIGURE 3
Two Line Conductor/ Ground(not connected) Non- metallic Cable



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Test Procedure
14 AWG in Non-metallic cable

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.
.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	NM Cable	5	30
14	NM Cable	10	30
14	NM Cable	15	30
14	NM Cable	20	30
14	NM Cable	25	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA Non Metallic (2 Conductor) open air (Page 1/3)

Scan	Time	Elapsed	101-CU-AL White Cable-Core	103 CU-AL White Cable Insulation	104 CU-AL Black Cable Core	105 CU-AL Black Cable Insulation	106 CU-AL Black Cable Core
29	5 AMPS	00:00:27:59					
30	8/15/2017 12:13	00:00:28:59	24.592	24.57	24.179	24.336	24.308
		Corrected Ambient	32.96	32.94	32.55	32.71	32.68
		Average	32.80				
		Average Core	32.92				
		Average Insulation	32.86				
60	10 AMPS	00:00:58:59	29.924	30.049	28.525	28.47	28.704
61	8/15/2017 12:44	00:00:59:59	29.497	30.014	28.308	28.427	28.595
		Corrected Ambient	37.95	38.46	36.76	36.88	37.04
		Average	37.53				
		Average Core	38.05				
		Average Insulation	38.13				
88	15 AMPS	00:01:26:59					
89	8/15/2017 13:12	00:01:27:59	37.658	38.549	35.166	34.525	34.751
		Corrected Ambient	45.92	46.81	43.43	42.79	43.02
		Average	44.46				
		Average Core	45.13				
		Average Insulation	45.22				
120	20 AMPS	00:01:58:59					
121	8/15/2017 13:44	00:01:59:59	48.404	50.441	43.994	43.521	43.462
		Corrected Ambient	56.61	58.65	52.20	51.73	51.67

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		Average	54.26				
		Average Core	54.78				
		Average Insulation	55.89				
151	25 AMPS	00:02:29:59					
152	8/15/2017 14:15	00:02:30:59	64.72	68.548	57.572	55.957	56.371
		Corrected Ambient	73.02	76.85	65.87	64.26	64.67
		Average	68.95				
		Average Core	69.61				
		Average Insulation	71.60				

14 AWG CCA Non Metallic (2 Conductor) open air (Page 2/3)

107 CU-AL Black Cable Insulation	109 CU-AL White Cable Core	112 CU-AL White Cable# 2 Insulation	113 CU-AL Black Cable#3 Core	114 CU-AL Black Cable #3 Insulation	116 CU-AL White Cable #3 Insulation	320 CU-AL White Cable#3 Core	315 CU-AL Black Cable#4 Core	118 CU-AL Black Cable#4 Insulation	102 CU-AL White Cable #4 Core
24.3	24.745	24.436	24.638	24.609	24.972	25.105	24.416	23.739	24.551
32.67	33.12	32.81	33.01	32.98	33.34	33.48	32.79	32.11	32.92
28.89	29.97	29.341	29.59	29.289	30.546	31.225	29.545	29.786	29.823
28.741	29.96	29.233	29.734	29.38	30.642	31.368	29.462	29.627	29.73
37.19	38.41	37.68	38.18	37.83	39.09	39.82	37.91	38.08	38.18

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35.244	37.473	35.97	36.069	36.113	38.561	39.712	36.608	35.975	37.473
43.51	45.74	44.23	44.33	44.38	46.83	47.98	44.87	44.24	45.74
44.923	47.618	47.015	45.275	46.599	50.61	51.411	46.52	44.202	47.657
53.13	55.83	55.22	53.48	54.81	58.82	59.62	54.73	52.41	55.86
58.491	62.893	62.242	58.51	61.014	67.133	69.89	61.364	57.959	63.192
66.79	71.19	70.54	66.81	69.32	75.43	78.19	69.67	66.26	71.49

14 AWG CCA Non Metallic (2 Conductor) open air (Page 3/3)

110 CU-AL White Cable#4 Insulation	120 CU-AL Black Cable#5 Core	211 CU-AL Black Cable#5 Insulation	205CU-AL White Cable#5 Insulation	208 CU-AL White Cable#5 Core	203 CU-AL Black Cable#6 Core	204 CU-AL Black Cbale#6 Insulation	212 CU-AL White Cable#6 Core	213 CU-AL White Cable#6 Insulation
25.194	24.66	25.029	24.923	24.407	24.321	24.045	24.677	23.717
33.56	33.03	33.40	33.29	32.78	32.69	32.42	33.05	32.09

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31.019	29.933	30.894	30.803	29.33	29.022	29.051	30.233	28.558
31.019	29.959	30.909	30.863	29.348	29.055	28.806	30.238	28.543
39.47	38.41	39.36	39.31	37.80	37.50	37.26	38.69	36.99
39.162	37.293	38.859	38.947	35.984	35.982	36.311	38.22	35.275
47.43	45.56	47.12	47.21	44.25	44.25	44.58	46.48	43.54
51.486	47.619	50.771	50.602	44.739	43.968	46.287	48.202	45.682
59.69	55.83	58.98	58.81	52.95	52.18	54.49	56.41	53.89
69.419	62.641	68.43	68.105	58.395	56.519	61.868	63.671	60.471
77.72	70.94	76.73	76.41	66.70	64.82	70.17	71.97	68.77

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14 AWG Cu Non Metallic (2 Conductor) open air
Page (1/2)

Scan	Time	Elapsed	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core
29	5 AMPS	00:00:27:59					
30	8/15/2017 12:13	00:00:28:59	23.451	23.326	22.977	23.042	22.899
		Corrected Ambient	31.82	31.70	31.35	31.41	31.27
		Average	31.63				
		Average Core	31.61				
		Average Insulation	31.66				
60	10 AMPS	00:00:58:59					
61	8/15/2017 12:44	00:00:59:59	27.177	26.623	25.544	25.678	25.495
		Corrected Ambient	35.63	35.07	33.99	34.13	33.94
		Average	34.60				
		Average Core	34.58				
		Average Insulation	34.62				
88	15 AMPS	00:01:26:59					
89	8/15/2017 13:12	00:01:27:59	32.586	31.152	29.253	29.605	29.106
		Corrected Ambient	40.85	39.42	37.52	37.87	37.37
		Average	38.69				
		Average Core	38.68				
		Average Insulation	38.70				
120	20 AMPS	00:01:58:59					
121	8/15/2017 13:44	00:01:59:59	40.601	37.689	35.231	35.538	35.083
		Corrected Ambient	48.81	45.90	43.44	43.75	43.29

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		Average	44.60				
		Average Core	44.79				
		Average Insulation	44.41				
151	25 AMPS	00:02:29:59					
152	8/15/2017 14:15	00:02:30:59	51.287	47.245	42.544	43.699	41.81
		Corrected Ambient	59.59	55.55	50.85	52.00	50.11
		Average	53.14				
		Average Core	53.05				
		Average Insulation	53.23				

14 AWG Cu Non Metallic (2 Conductor) open air Page (2/2)

302 CU Black Cable#3 Insulation	304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
23.44	23.503	23.264	23.458	23.245	23.126	23.416
31.81	31.87	31.63	31.83	31.62	31.50	31.79
26.374	26.371	26.051	26.426	25.928	25.744	26.369
34.82	34.82	34.50	34.88	34.38	34.19	34.82

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31.135	30.734	30.046	30.955	29.706	29.884	30.947
39.40	39.00	38.31	39.22	37.97	38.15	39.21
37.502	36.586	35.021	37.138	34.631	34.872	36.818
45.71	44.79	43.23	45.35	42.84	43.08	45.03
47.427	44.327	43.744	45.605	42.023	42.908	45.452
55.73	52.63	52.05	53.91	50.32	51.21	53.75

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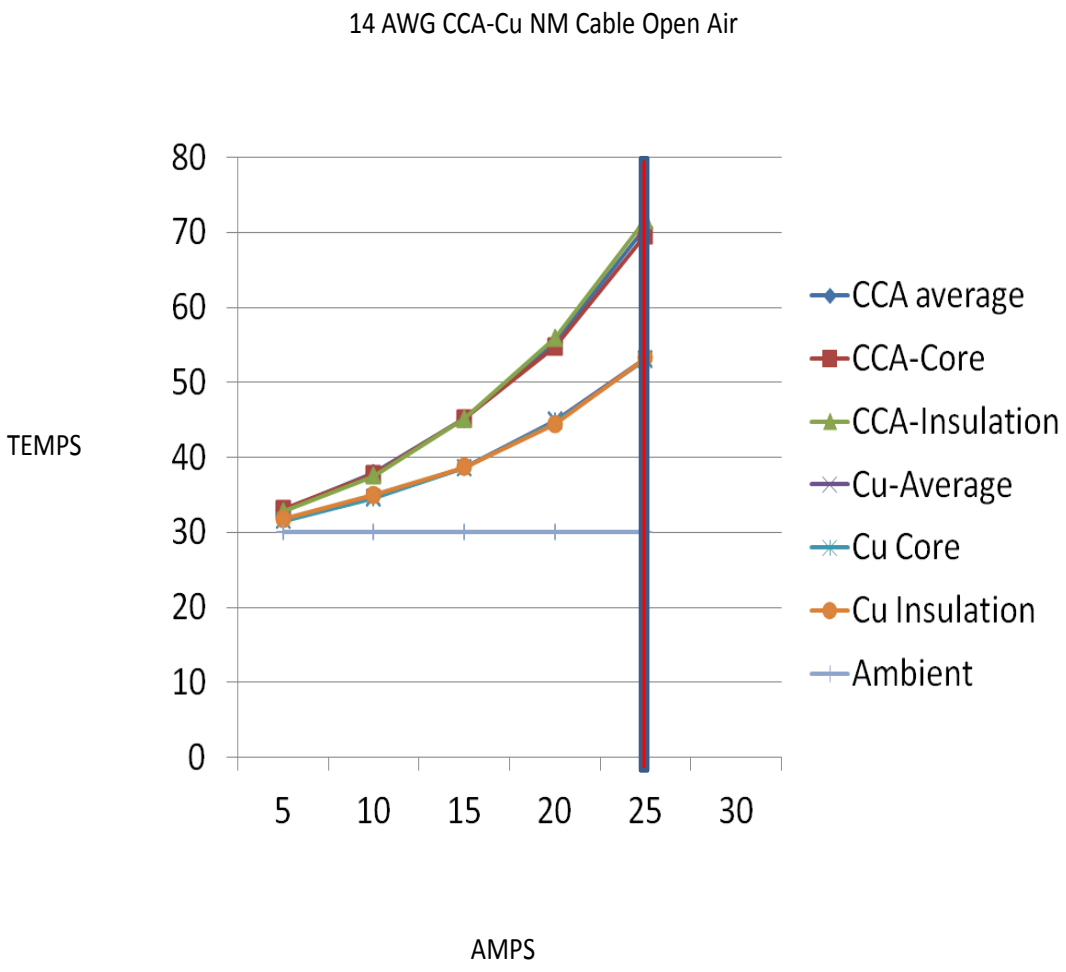

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Test Set- Up/ Layout
14 AWG (2 conductors) in Conduit

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 14 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 14 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 14 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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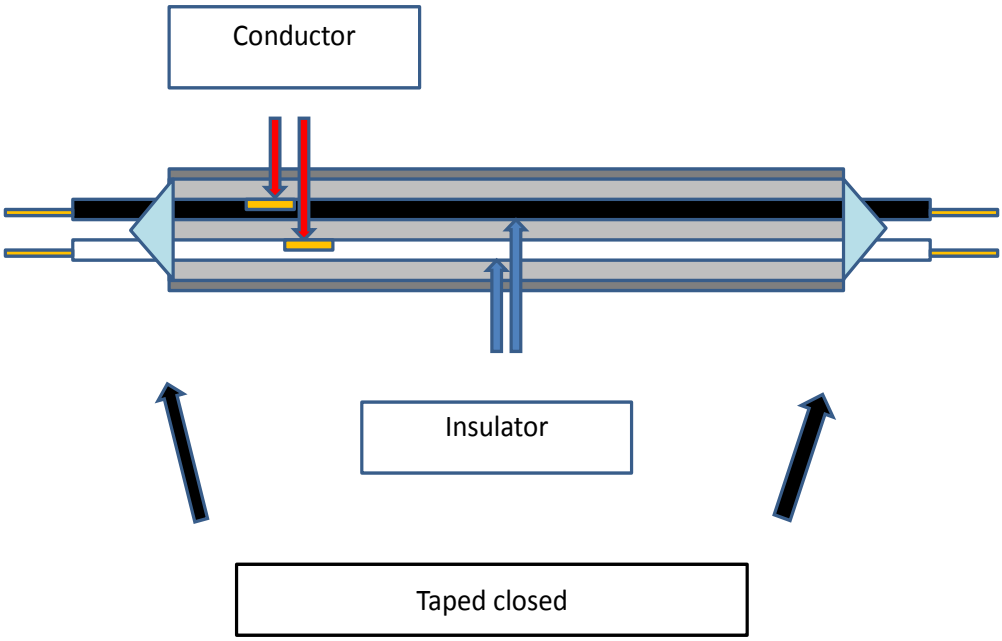
FIGURE 4
Two Conductors in ½ Inch Conduit



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Test Procedure
14 AWG(2 conductors) in Conduit

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 Amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	Conduit	5	30
14	Conduit	10	30
14	Conduit	15	30
14	Conduit	20	30
14	Conduit	25	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA (2 Conductor) in Conduit
Page(1/3)

	101-CCA#1 Core	106 CCA#1 Insulation	107 CCA#2 Core	105 CCA#2 Insulation	112 CCA#3 Core	109 CCA#3 Insulation	113 CCA#4 Core	104 CCA#4 Insulaiton
5 AMPS								
00:00:51:59	24.79	24.61	24.66	24.03	24.04	23.58	23.96	23.72
Corrected Ambient	34.83	34.65	34.70	34.07	34.08	33.62	34.00	33.76
Average	34.19							
Core Average	34.55							
Insulation Average	33.86							
10 AMPS								
00:02:01:59	34.64	34.94	34.84	32.81	32.64	31.25	32.51	31.30
Corrected Ambient	44.83	45.13	45.03	42.99	42.83	41.44	42.70	41.49
Average	43.35							
Core Average	44.12							
Insulation Average	42.64							
15 AMPS								
00:02:52:59	51.48	52.20	52.36	47.74	46.95	43.79	46.60	43.97
Corrected Ambient	61.07	61.78	61.94	57.32	56.53	53.37	56.18	53.55
Average	58.13							
Core Average	59.84							
Insulation Average	56.57							
20 AMPS								
00:03:43:59	72.68	74.44	73.96	66.89	66.02	59.92	64.39	60.07
Corrected Ambient	82.07	83.84	83.35	76.28	75.41	69.31	73.78	69.47
Average	77.26							
Core Average	80.16							
Insulation Average	74.60							
25 AMPS								
00:04:33:59	117.65	117.35	119.71	105.33	107.61	92.87	101.25	92.53
Corrected Ambient	127.06	126.76	129.12	114.74	117.02	102.28	110.66	101.94
Average	117.69							
Core Average	124.41							

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Insulation Average	111.52							

14 AWG CCA (2 Conductor) in Conduit Page(2/3)

120 CCA#5 Core	116 CCA#5 Insulation	110 CCA#6 Core	102 CCA#6 Insulation	118 CCA#7 Insulation	117 CCA#8 Core	103 CCA#8 Insulation	114 CCA#9 Core
24.64	23.92	25.11	24.39	23.42	24.81	23.37	24.43
34.69	33.97	35.15	34.43	33.47	34.85	33.42	34.48
34.64	32.33	35.84	34.63	30.90	33.95	31.16	32.84
44.82	42.52	46.03	44.82	41.09	44.13	41.35	43.03
51.59	46.53	54.59	52.00	43.29	50.64	44.39	47.81
61.17	56.11	64.17	61.58	52.88	60.22	53.97	57.39
73.42	64.63	78.42	73.82	58.67	71.14	60.84	67.02
82.81	74.02	87.81	83.21	68.06	80.53	70.23	76.41
119.35	101.08	128.37	117.64	88.72	117.29	94.74	110.37
128.76	110.49	137.78	127.05	98.13	126.70	104.15	119.78

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14 AWG CCA (2 Conductor) in Conduit Page(3/3)

211 CCA#9 Insulation	212 CCA#10 Core	204 CCA#10 Insulation	220 CCA#11 Core	203 CCA#11 Insulaiton	218 CCA#12 Core	214 CCA#12 Insulation
23.42	24.44	23.75	24.58	24.03	24.15	23.59
33.46	34.48	33.80	34.62	34.07	34.20	33.63
31.17	34.07	33.65	34.69	33.24	32.61	32.04
41.36	44.26	43.84	44.88	43.43	42.80	42.22
45.01	50.94	50.44	52.39	48.40	47.47	46.07
54.59	60.52	60.02	61.97	57.98	57.05	55.65
61.56	71.91	71.23	73.72	67.11	65.73	63.36
70.95	81.30	80.62	83.11	76.50	75.12	72.75
97.96	118.18	113.21	118.54	104.99	106.66	98.95
107.37	127.59	122.62	127.95	114.40	116.07	108.36

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14 AWG Cu (2 Conductor) in Conduit Page 1/2)

	206 CU#1 Core	209 CU#1 Insulation	213 CU#3 Core	208 CU#3 Insualtion	205 CU#5 Core	305 CU#5 Insulation
5 AMPS						
00:00:51:59	22.48	21.97	22.25	22.56	22.77	22.70
Corrected Ambient	32.52	32.02	32.30	32.60	32.81	32.74
Average	32.67					
Core Average	32.81					
Insulation Average	32.53					
10 AMPS						
00:02:01:59	27.37	26.44	27.92	28.45	28.47	28.16
Corrected Ambient	37.56	36.63	38.11	38.63	38.65	38.35
Average	38.29					
Core Average	38.65					
Insulation Average	37.92					
15 AMPS						
00:02:52:59	36.14	34.08	37.61	38.51	38.48	37.28
Corrected Ambient	45.72	43.67	47.19	48.09	48.07	46.86
Average	47.09					
Core Average	47.98					
Insulation Average	46.20					
20 AMPS						
00:03:43:59	45.98	42.87	49.09	50.19	50.16	47.55
Corrected Ambient	55.37	52.26	58.48	59.58	59.56	56.94
Average	57.97					
Core Average	59.56					
Insulation Average	56.39					
25 AMPS						
00:04:33:59	65.98	59.49	71.81	72.52	73.11	68.34
Corrected Ambient	75.39	68.90	81.22	81.93	82.52	77.75
Average	79.54					
Core Average	82.77					
Insulation Average	76.31					

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14 AWG Cu (2 Conductor) in Conduit
Page (2/2)

318 CU#7 Core	315 CU#7 Insulation	310 CU#9 Core	313 CU#9 Insulaiton	304 CU#11 Core	312 CU#11 Insulation
23.00	22.44	23.28	22.62	22.81	22.62
33.04	32.48	33.33	32.66	32.85	32.66
29.12	27.38	29.95	27.92	27.95	28.05
39.31	37.57	40.14	38.11	38.14	38.24
39.72	36.00	41.63	36.70	36.82	37.14
49.30	45.58	51.21	46.28	46.40	46.73
52.56	46.16	55.35	47.13	47.86	48.12
61.95	55.55	64.74	56.52	57.25	57.51
78.19	65.80	82.60	66.20	68.46	69.08
87.60	75.21	92.01	75.61	77.87	78.49

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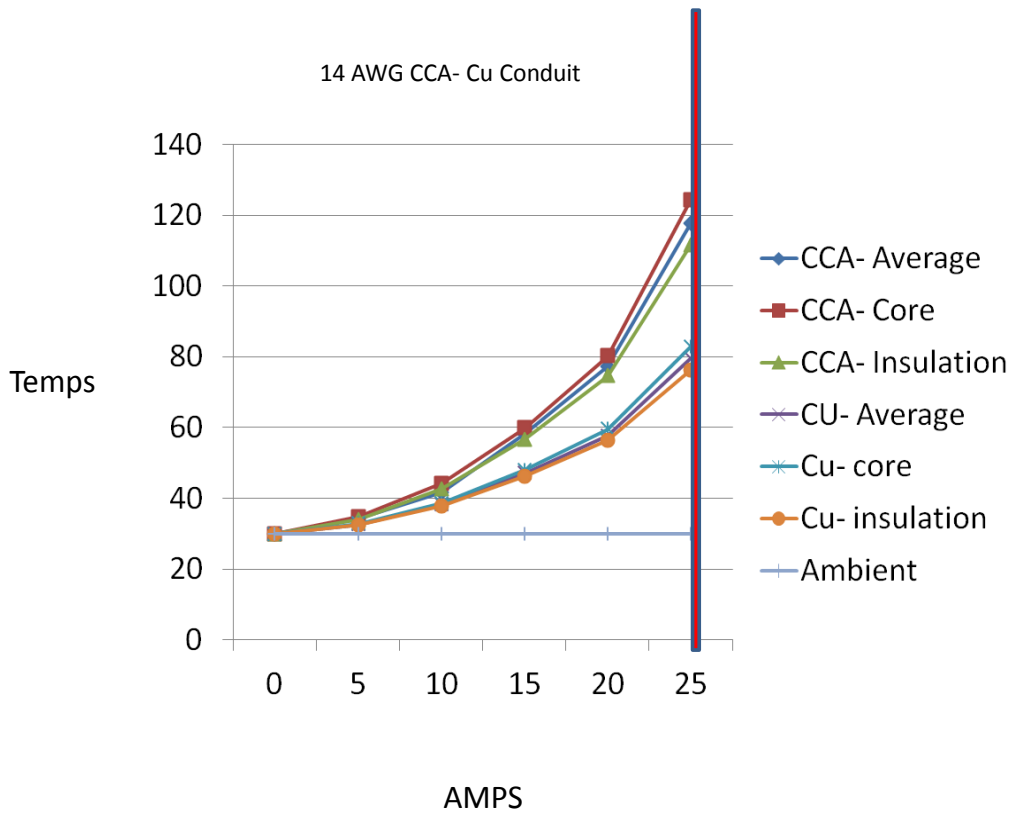

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Test Set- Up/ Layout
12 AWG Single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 12 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 12 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 12 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG single conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	Open air	5	30
12	Open air	10	30
12	Open air	15	30
12	Open air	20	30
12	Open air	25	30
12	Open air	30	30
12	Open air	35	30
12	Open air	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG single conductors
(Page 1 of 3)

Scan	Time	101- CU-AL White Cable#1- Insulation	104 CU-AL Black Cable#1 Core	105 CU-AL Black Cable#1 Insulation	106 CU-AL Black Cable#2 Core	107 CU-AL Black Cable#2 Insulation	109 CU-AL White Cable#2 Core
	5 AMPS						
30	8/16/2017 14:54	23.5	23.719	23.597	24.101	23.626	23.882
	Corrected Ambient	31.925	32.144	32.022	32.526	32.051	32.307
	Average	31.86845					
	Average Core	32.1068					
	Average Insulation	31.66983					
	10 AMPS						
60	8/16/2017 15:24	26.487	26.702	26.788	27.393	26.714	26.989
	Corrected Ambient	35	35.215	35.301	35.906	35.227	35.502
	Average	34.92791					
	Average Core	35.3563					
	Average Insulation	34.57092					
	15 AMPS						
91	8/16/2017 15:55	30.559	30.658	30.656	32.374	30.779	31.249
	Corrected Ambient	38.79	38.889	38.887	40.605	39.01	39.48
	Average	38.64927					
	Average Core	39.4042					
	Average Insulation	38.02017					
	20 AMPS						
121	8/16/2017 16:25	35.826	35.837	35.678	38.337	35.742	36.622
	Corrected Ambient	44.421	44.432	44.273	46.932	44.337	45.217
	Average	43.80986					
	Average Core	45.065					
	Average Insulation	42.76392					

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	25 AMPS						
152	8/16/2017 16:56	42.958	43.207	43.137	48.117	43.123	44.441
	Corrected Ambient	51.22	51.469	51.399	56.379	51.385	52.703
	Average	50.82832					
	Average Core	52.8027					
	Average Insulation	49.183					
	30 AMPS						
182	8/16/2017 17:26	50.663	51.573	51.558	58.75	51.353	52.748
	Corrected Ambient	59.164	60.074	60.059	67.251	59.854	61.249
	Average	58.849					
	Average Core	61.1368					
	Average Insulation	56.9425					
	35 AMPS						
213	8/16/2017 17:57	59.241	60.489	60.736	70.389	59.671	62.631
	Corrected Ambient	67.397	68.645	68.892	78.545	67.827	70.787
	Average	67.43436					
	Average Core	70.5558					
	Average Insulation	64.83317					
	40 AMPS						
244	8/16/2017 18:28	67.579	70.938	69.371	84.754	68.417	73.658
	Corrected Ambient	75.86	79.219	77.652	93.035	76.698	81.939
	Average	76.85605					
	Average Core	80.71511					
	Average Insulation	72.72958					

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12 AWG Single conductor
(Page 2 of 3)

112 CU-AL White Cable# 2 Insulation	113 CU-AL Black Cable#3 Core	114 CU-AL Black Cable #3 Insulation	116 CU-AL White Cable #3 Insulation	320 CU-AL White Cable#4 Core	118 CU-AL Black Cable#4 Insulation
23.57	23.62	23.4	23.285	23.776	23.093
31.995	32.045	31.825	31.71	32.201	31.518
26.464	26.507	26.264	25.822	26.845	25.692
34.977	35.02	34.777	34.335	35.358	34.205
30.073	30.291	29.915	29.382	31.533	29.206
38.304	38.522	38.146	37.613	39.764	37.437
34.775	34.982	34.305	33.662	37.097	32.398
43.37	43.577	42.9	42.257	45.692	40.993
41.606	42.027	41.564	40.681	46.895	35.318

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49.868	50.289	49.826	48.943	55.157	43.58
49.167	49.465	49.303	47.244	55.947	45.015
57.668	57.966	57.804	55.745	64.448	53.516
57.152	57.789	57.623	54.861	67.265	52.7
65.308	65.945	65.779	63.017	75.421	60.856
66.056	67.263	67.276	63.756	81.93	48.048
74.337	75.544	75.557	72.037	90.211	56.329

12 AWG Single conductor
(Page 3 of 3)

110 CU-AL White Cable#4 Core	120 CU-AL Black Cable#5 Core	211 CU-AL Black Cable#5 Insulation	205CU-AL White Cable#5 Insulation	208 CU-AL White Cable#6 Core	203 CU-AL Black Cable#6 Core	204 CU-AL Black Cbale#6 Insulation
23.509	23.482	23.149	23.038	23.485	23.786	22.755
31.934	31.907	31.574	31.463	31.91	32.211	31.18

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26.402	26.539	25.762	25.861	26.673	27.668	25.409
34.915	35.052	34.275	34.374	35.186	36.181	33.922
30.025	30.717	29.685	29.704	31.023	32.791	28.963
38.256	38.948	37.916	37.935	39.254	41.022	37.194
34.209	35.835	33.848	34.108	36.344	39.108	32.692
42.804	44.43	42.443	42.703	44.939	47.703	41.287
40.855	43.7	41.307	41.654	44.03	48.851	39.803
49.117	51.962	49.569	49.916	52.292	57.113	48.065
47.49	51.417	48.521	49.376	51.659	58.336	46.401
55.991	59.918	57.022	57.877	60.16	66.837	54.902

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55.696	61.164	57.106	58.492	61.252	69.982	53.979
63.852	69.32	65.262	66.648	69.408	78.138	62.135
63.039	72.843	66.826	67.72	70.828	83.361	63.75
71.32	81.124	75.107	76.001	79.109	91.642	72.031

12 AWG Cu Single conductors
(Page 1 of 2)

Scan	Time	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core
	5 AMPS					
30	8/16/2017 14:54	22.678	22.601	23.084	22.862	23.1
	Corrected Ambient	31.103	31.026	31.509	31.287	31.525
	Average	31.28				
	Average Core	31.346				
	Average Insulation	31.214				
	10 AMPS					
60	8/16/2017 15:24	24.574	24.195	25.492	24.984	25.629
	Corrected Ambient	33.087	32.708	34.005	33.497	34.142
	Average	33.44408				
	Average Core	33.63167				
	Average Insulation	33.2565				
	15 AMPS					

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91	8/16/2017 15:55	27.938	27.51	29.234	28.369	29.346
	Corrected Ambient	36.169	35.741	37.465	36.6	37.577
	Average	36.27708				
	Average Core	36.65483				
	Average Insulation	35.89933				
	20 AMPS					
121	8/16/2017 16:25	31.89	31.073	33.381	32.19	33.634
	Corrected Ambient	40.485	39.668	41.976	40.785	42.229
	Average	40.2505				
	Average Core	40.86083				
	Average Insulation	39.64017				
	25 AMPS					
152	8/16/2017 16:56	37.908	36.251	39.895	37.963	40.79
	Corrected Ambient	46.17	44.513	48.157	46.225	49.052
	Average	45.57908				
	Average Core	46.602				
	Average Insulation	44.55617				
	30 AMPS					
182	8/16/2017 17:26	45.629	44.793	46.939	43.77	47.443
	Corrected Ambient	54.13	53.294	55.44	52.271	55.944
	Average	51.87658				
	Average Core	53.18617				
	Average Insulation	50.567				
	35 AMPS					
213	8/16/2017 17:57	53.356	52.266	54.603	50.492	54.888
	Corrected Ambient	61.512	60.422	62.759	58.648	63.044
	Average	58.39692				
	Average Core	60.13967				
	Average Insulation	56.65417				
	40 AMPS					
244	8/16/2017 18:28	62.217	61.357	63.891	59.265	64.258
	Corrected Ambient	70.498	69.638	72.172	67.546	72.539

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	Average	66.52817				
	Average Core	69.18933				
	Average Insulation	63.867				

12 AWG Cu Single conductors
(Page 1 of 2)

	Time	304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
	5 AMPS						
30	8/16/2017 14:54	22.672	22.586	23.069	22.909	22.923	22.74
	Corrected Ambient	31.097	31.011	31.494	31.334	31.348	31.165
	10 AMPS						
60	8/16/2017 15:24	24.713	24.647	25.355	24.993	24.949	24.515
	Corrected Ambient	33.226	33.16	33.868	33.506	33.462	33.028
	15 AMPS						
91	8/16/2017 15:55	27.693	27.514	28.674	27.745	27.658	26.826
	Corrected Ambient	35.924	35.745	36.905	35.976	35.889	35.057
	20 AMPS						
121	8/16/2017 16:25	31.304	30.91	32.491	31.202	30.895	29.56
	Corrected Ambient	39.899	39.505	41.086	39.797	39.49	38.155

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	25 AMPS						
152	8/16/2017 16:56	36.656	36.446	39.125	36.545	35.666	33.819
	Corrected Ambient	44.918	44.708	47.387	44.807	43.928	42.081
	30 AMPS						
182	8/16/2017 17:26	42.269	41.429	45.709	41.914	40.122	38.201
	Corrected Ambient	50.77	49.93	54.21	50.415	48.623	46.702
	35 AMPS						
213	8/16/2017 17:57	50.113	48.676	53.39	48.317	45.552	43.055
	Corrected Ambient	58.269	56.832	61.546	56.473	53.708	51.211
	40 AMPS						
244	8/16/2017 18:28	55.495	53.591	66.664	55.887	52.925	47.744
	Corrected Ambient	63.776	61.872	74.945	64.168	61.206	56.025

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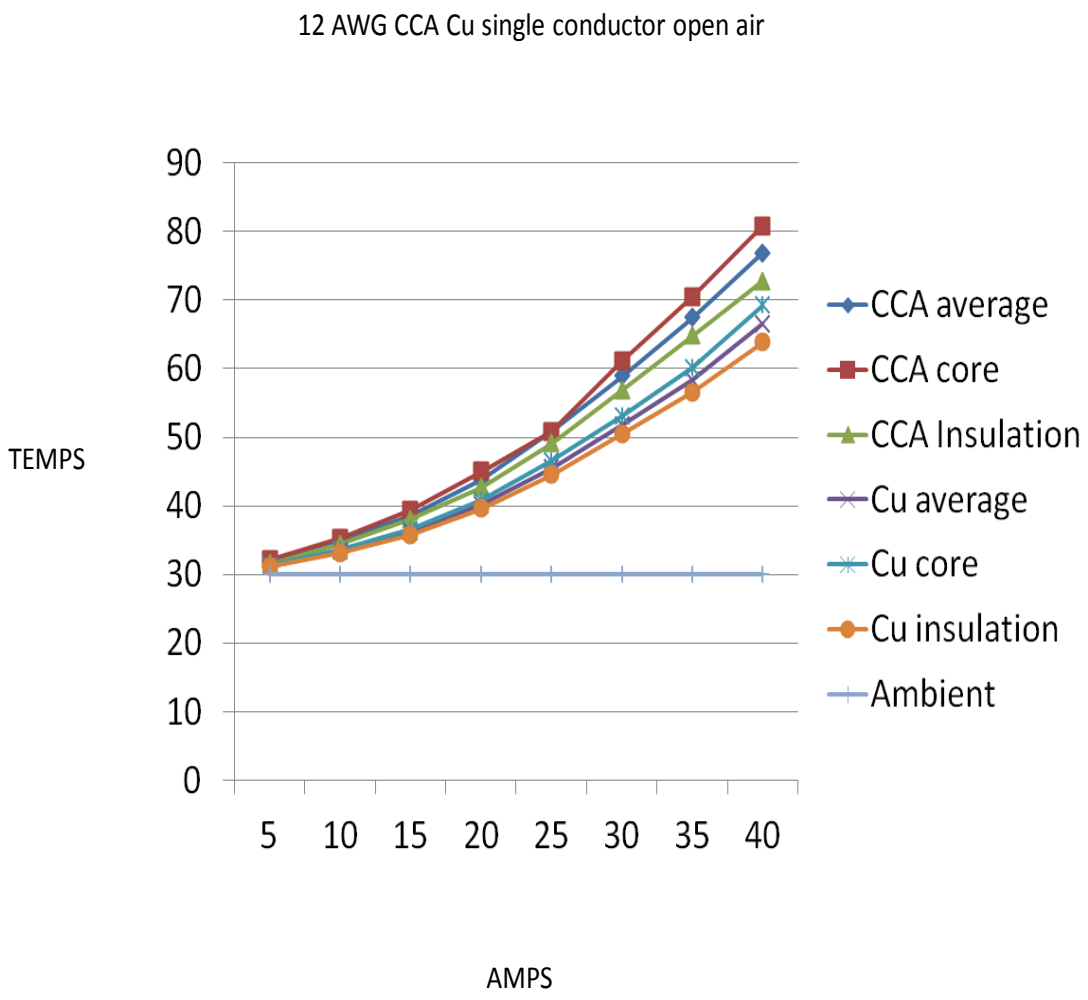

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Test Set- Up/ Layout
12 AWG in non-metallic cable (2 Conductor) in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 12 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 12 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 12 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG In (2 conductor) non-metallic cable

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	NM Cable	5	30
12	NM Cable	10	30
12	NM Cable	15	30
12	NM Cable	20	30
12	NM Cable	25	30
12	NM Cable	30	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 1 of 3)

Scan	Time	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	208 CU-AL Black Cable#2 Core	205 CU-AL Black Cable#2 Insulation
	5 AMPS					
30	**8/17/2017 10:29**	**22.67**	**22.926**	**23.13**	**23.256**	**23.015**
	Corrected Ambient	31.08	31.335	31.539	31.665	31.424
	Average	31.68				
	Average Core	31.73				
	Average Insulation	31.63				
	10 AMPS					
61	8/17/2017 11:00	25.93	26.059	26.92	26.863	26.217
	Corrected Ambient	34.32	34.443	35.304	35.247	34.601
	Average	34.88				
	Average Core	35.09				
	Average Insulation	34.68				
	15 AMPS					
91	8/17/2017 11:30	30.31	30.408	32.809	32.228	31.062
	Corrected Ambient	38.40	38.497	40.898	40.317	39.151
	Average	39.36				
	Average Core	39.90				
	Average Insulation	38.87				
	20 AMPS					
121	8/17/2017 12:00	35.95	36.03	40.071	39.839	36.86
	Corrected Ambient	44.35	44.426	48.467	48.235	45.256

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	Average	45.56				
	Average core	46.67				
	Average Insulation	44.54				
	25 AMPS					
152	8/17/2017 12:31	41.34	41.083	45.352	45.612	42.454
	Corrected Ambient	49.85	49.598	53.867	54.127	50.969
	Average	51.67				
	Average Core	53.50				
	Average Insulation	50.00				
	30 AMPS					
182	8/17/2017 13:01	47.44	47.015	53.341	52.596	50.518
	Corrected Ambient	55.74	55.316	61.642	60.897	58.819
	Average	59.54				
	Average Core	62.19				
	Average Insulation	57.11				

12 AWG CCA In non-metallic cable(2 conductor)
(Page 2 of 3)

211 CU-AL White Cable# 2 Insulation	102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #3 Insulation
23.196	**23.139**	**23.493**	**23.536**
31.605	31.548	31.902	31.945
26.208	26.16	26.433	26.599
34.592	34.544	34.817	34.983

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30.375	30.414	30.425	31.929
38.464	38.503	38.514	40.018
35.556	35.329	35.55	36.683
43.952	43.725	43.946	45.079
41.089	40.342	41.332	41.256
49.604	48.857	49.847	49.771
48.436	46.618	48.28	47.403
56.737	54.919	56.581	55.704

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 3of 3)

116 CU-AL Black Cable#4 Insulation	113 CU-AL White Cable #4 Core	114 CU-AL White Cable#4 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#5 Insulation
23.222	**23.2**	**23.399**	**23.443**	**23.14**
31.631	31.609	31.808	31.852	31.549
25.734	26.056	26.523	26.702	25.713
34.118	34.44	34.907	35.086	34.097
28.997	31.638	30.56	30.878	29.977
37.086	39.727	38.649	38.967	38.066
33.062	37.403	35.681	36.471	35.027
41.458	45.799	44.077	44.867	43.423

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37.425	44.796	40.903	42.529	40.103
45.94	53.311	49.418	51.044	48.618
43.655	55.384	48.43	51.204	48.229
51.956	63.685	56.731	59.505	56.53

12 AWG Cu In non-metallic cable(2 Conductor)
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30	**8/17/2017 10:29**	**22.614**	**22.554**	**22.891**	**22.59**	**22.796**	**22.882**
	Corrected Ambient	31.023	30.963	31.3	30.999	31.205	31.291
	Average	31.22208					
	Average Core	31.295					
	Average Insulation	31.14917					
	10 AMPS						
61	8/17/2017 11:00	25.114	24.271	25.231	24.387	24.977	24.9
	Corrected Ambient	33.498	32.655	33.615	32.771	33.361	33.284
	Average	33.271					

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	Average Core	33.58917					
	Average Insulation	32.95283					
	15 AMPS						
91	8/17/2017 11:30	28.333	27.255	28.517	27.065	28.032	28.006
	Corrected Ambient	36.422	35.344	36.606	35.154	36.121	36.095
	Average	36.00508					
	Average Core	36.45233					
	Average Insulation	35.55783					
	20 AMPS						
121	8/17/2017 12:00	32.461	30.737	32.806	30.378	32.047	31.754
	Corrected Ambient	40.857	39.133	41.202	38.774	40.443	40.15
	Average	40.02075					
	Average core	40.70133					
	Average Insulation	39.34017					
	25 AMPS						
152	8/17/2017 12:31	37.317	35.362	38.138	34.253	36.101	35.718
	Corrected Ambient	45.832	43.877	46.653	42.768	44.616	44.233
	Average	44.385					
	Average Core	45.3695					
	Average Insulation	43.4005					
	30 AMPS						
182	8/17/2017 13:01	43.719	41.111	44.969	39.04	42.173	41.491
	Corrected Ambient	52.02	49.412	53.27	47.341	50.474	49.792
	Average	49.96617					
	Average Core	51.36633					
	Average Insulation	48.566					

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 2 of 2)

305 CU White Cable#3 Insulation	309 CU Black Cable#2 Core	310 CU Black Cable#2 Insulation	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.726	**23.1**	**22.833**	**22.872**	**22.856**
31.135	31.509	31.242	31.281	31.265
24.487	25.693	24.642	24.877	24.726
32.871	34.077	33.026	33.261	33.11
27.237	29.01	27.541	27.932	27.709
35.326	37.099	35.63	36.021	35.798
30.746	33.217	31.041	31.343	31.009
39.142	41.613	39.437	39.739	39.405

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34.482	37.831	34.853	35.499	34.645
42.997	46.346	43.368	44.014	43.16
39.792	44.397	39.901	41.125	40.255
48.093	52.698	48.202	49.426	48.556

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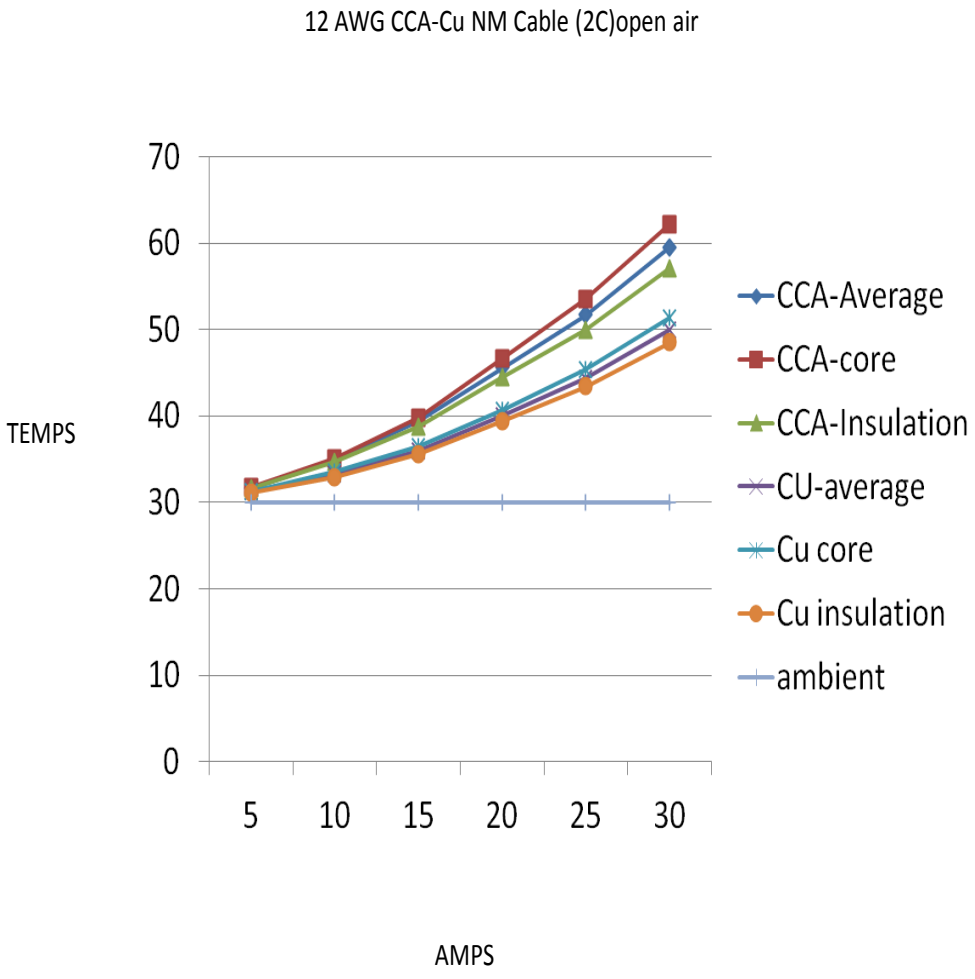

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Test Set- Up/ Layout
12 AWG in Conduit (2 conductors)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 12 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 12 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 12 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG In conduit (2 conductors)

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	Conduit	5	30
12	Conduit	10	30
12	Conduit	15	30
12	Conduit	20	30
12	Conduit	25	30
12	Conduit	30	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG CCA In conduit (2 conductors)
(Page 1 of 3)

Scan	Time	101- CU-AL White Cable-Core	103 CU-AL White Cable Insulation	104 CU-AL Black Cable Core	105 CU-AL Black Cable Insulation	106 CU-AL Black Cable Core	107 CU-AL Black Cable Insulation
	5 AMPS						
34.00	42,963.45	24.80	24.55	24.92	24.52	25.20	24.98
	Corrected Ambient	33.20	32.95	33.32	32.92	33.60	33.38
	Average	32.92					
	Average core	33.12					
	Average Insulation	32.75					
	10 Amps						
66.00	42,963.47	30.79	29.98	30.50	29.05	31.64	30.86
	Corrected Ambient	39.24	38.43	38.95	37.50	40.09	39.30
	Average	38.30					
	Average core	38.54					
	Average Insulation	38.71					
	15 Amps						
98.00	42,963.49	39.83	38.14	39.13	35.99	41.35	39.89
	Corrected Ambient	48.24	46.54	47.54	44.40	49.75	48.30
	Average	46.26					
	Average core	47.36					
	Average Insulation	45.34					
	20 AMPS						
130.00	42,963.51	53.93	51.10	52.57	46.42	56.43	53.62
	Corrected Ambient	62.34	59.51	60.98	54.83	64.84	62.03
	Average	58.48					

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	Average core	60.33					
	Average Insulation	56.95					
	25 AMPS						
162.00	42,963.54	71.01	66.92	68.93	58.87	75.38	70.30
	Corrected Ambient	79.37	75.29	77.29	67.23	83.74	78.66
	Average	73.37					
	Average core	76.31					
	Average Insulation	70.92					
	30 AMPS						
208.00	42,963.57	95.27	88.98	92.19	76.76	102.19	93.33
	Corrected Ambient	103.67	97.37	100.58	85.15	110.58	101.72
	Average	94.77					
	Average core	99.22					
	Average Insulation	91.05					

12 AWG CCA in Conduit (2 Conductors)
Page (2 of 3)

109 CU-AL White Cable Core	112 CU-AL White Cable Insulation	113 CU-AL Black Cable Core	114 CU-AL Black Cable Insulation	116 CU-AL White Cable Insulation	320 CU-AL White Cable Core
25.06	24.79	24.97	24.89	24.38	24.57
33.46	33.19	33.36	33.29	32.78	32.97
30.95	29.96	30.85	30.45	28.75	29.93
39.40	38.41	39.30	38.89	37.19	38.38

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39.93	38.02	39.99	39.25	35.66	38.12
48.34	46.43	48.40	47.65	44.07	46.53
53.56	50.15	53.76	52.46	45.78	50.35
61.97	58.57	62.17	60.87	54.19	58.76
70.65	65.52	71.23	69.04	58.58	65.18
79.02	73.88	79.59	77.40	66.95	73.54
94.77	86.67	95.96	92.55	76.17	86.50
103.16	95.06	104.35	100.95	84.56	94.89

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12 AWG CCA in Conduit (2 Conductors)
(Page 3 of 3)

315 CU-AL Black Cable Core	118 CU-AL Black Cable Insulation	102 CU-AL White Cable Insulation	110 CU-AL White Cable Core	211 CU-AL Black Cable Insulation	205CU-AL White Cable Insulation
24.41	24.04	24.69	25.09	24.46	24.15
32.81	32.44	33.08	33.49	32.86	32.55
29.90	27.86	30.58	31.01	30.08	29.09
38.35	36.31	39.03	39.46	38.52	37.54
38.26	34.03	39.40	40.19	38.41	36.46
46.67	42.44	47.80	48.60	46.82	44.87
50.81	45.67	52.82	53.77	51.24	47.67
59.23	54.08	61.23	62.19	59.65	56.08

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66.35	55.12	68.87	70.60	68.22	62.30
74.72	63.48	77.23	78.97	76.58	70.66
88.26	70.54	92.61	94.54	93.37	83.09
96.65	78.93	101.00	102.93	101.76	91.48

12 AWG Cu In conduit (2 Conductors)
(Page 1 of 2)

Scan	Time	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core	302 CU Black Cable#3 Insulation
	5 AMPS						
34.00	42,963.45	23.58	23.40	23.92	23.37	23.59	23.54
	Corrected Ambient	31.98	31.79	32.32	31.77	31.99	31.93
	Average	32.04					
	Average core	32.16					
	Average Insulation	31.92					
	10 Amps						
66.00	42,963.47	27.28	26.39	28.16	26.32	27.09	25.98
	Corrected Ambient	35.73	34.84	36.61	34.77	35.54	34.43
	Average	35.49					
	Average core	35.99					
	Average Insulation	34.99					
	15 Amps						

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98.00	42,963.49	32.59	30.64	34.57	30.92	32.40	30.16
	Corrected Ambient	40.99	39.05	42.98	39.32	40.81	38.57
	Average	40.68					
	Average core	41.67					
	Average Insulation	39.68					
	20 AMPS						
130.00	42,963.51	41.24	37.72	44.71	38.16	40.68	36.33
	Corrected Ambient	49.66	46.14	53.12	46.58	49.10	44.74
	Average	48.81					
	Average core	50.65					
	Average Insulation	46.96					
	25 AMPS						
162.00	42,963.54	52.09	46.85	57.21	46.77	50.75	44.10
	Corrected Ambient	60.45	55.21	65.57	55.14	59.11	52.46
	Average	58.67					
	Average core	61.52					
	Average Insulation	55.81					
	30 AMPS						
208.00	42,963.57	67.48	59.62	74.44	58.61	64.15	54.26
	Corrected Ambient	75.87	68.01	82.83	67.01	72.54	62.65
	Average	72.19					
	Average core	76.53					
	Average Insulation	67.86					

12 AWG Cu In conduit (2 Conductors)
(Page 2 of 2)

304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
23.91	23.65	23.81	23.67	23.76	23.55

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32.30	32.04	32.20	32.07	32.15	31.94
27.70	26.94	27.55	27.04	27.49	26.59
36.15	35.39	36.00	35.48	35.94	35.04
33.58	32.18	33.20	32.27	33.25	31.45
41.99	40.59	41.60	40.68	41.66	39.85
42.62	40.10	42.09	40.23	42.11	38.73
51.03	48.52	50.50	48.65	50.53	47.14
53.25	49.79	52.80	49.90	52.88	47.31
61.61	58.15	61.16	58.26	61.24	55.67
67.84	62.54	67.31	62.93	67.59	58.86
76.24	70.93	75.70	71.33	75.98	67.25

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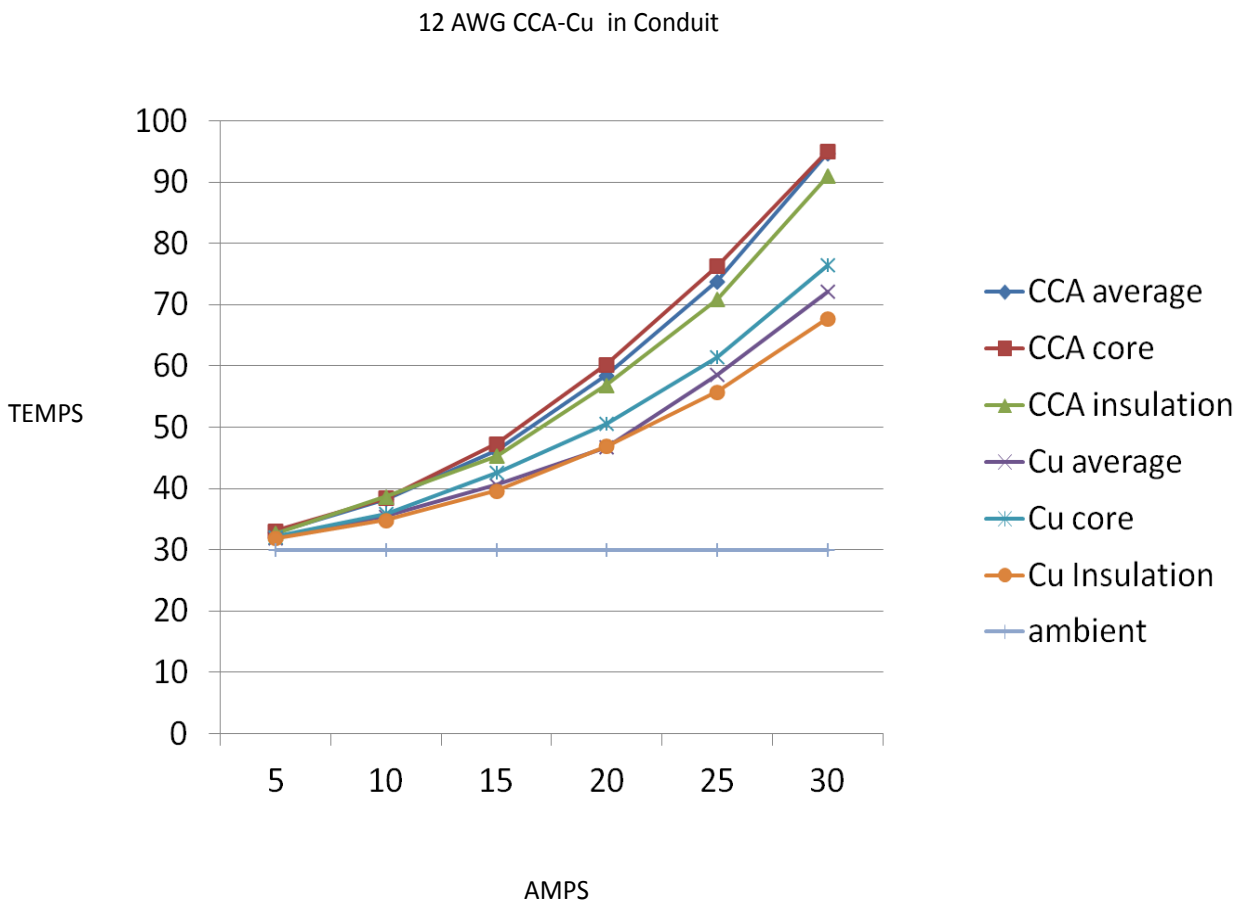

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Test Set- Up/ Layout
10 AWG single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 10 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 10 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 10 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG Single conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	Open air	5	30
10	Open air	10	30
10	Open air	15	30
10	Open air	20	30
10	Open air	25	30
10	Open air	30	30
10	Open air	35	30
10	Open air	40	30
10	Open air	45	30
10	Open air	50	30
10	Open air	55	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA Single conductor Open Air
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Scan	Time	Elapsed	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	208 CU-AL Black Cable#1 Core	205 CU-AL Black Cable#2 Insulation	120 CU-AL White Cable#2 Core	211 CU-AL White Cable#2 Insulation
	5 AMPS							
30.00	42965.59	00:00:28:59	22.27	22.95	22.82	22.50	23.18	22.75
	Corrected Ambient		30.81	31.49	31.36	31.04	31.72	31.28
	Average		31.47					
	Average core		31.47					
	Average Insulation		31.47					
	10 AMPS							
60.00	42965.62	00:00:58:59	24.20	25.01	24.70	24.41	25.11	24.60
	Corrected Ambient		32.71	33.52	33.20	32.91	33.61	33.10
	Average		33.30					
	Average core		33.34					
	Average Insulation		33.25					
	15 AMPS							
94.00	42965.64	00:01:32:59	27.20	28.61	27.87	27.26	28.29	27.43
94.00	Corrected Ambient		35.60	37.01	36.27	35.66	36.69	35.83
	Average		36.09					
	Average core		36.22					
	Average Insulation		35.94					
	20 AMPS							
121.00	42965.66	00:01:59:59	30.94	33.08	31.72	30.92	32.64	31.08
	Corrected Ambient		39.39	41.52	40.17	39.36	41.08	39.52
	Average		39.81					
	Average core		40.07					
	Average Insulation		39.52					

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	25 AMPS							
152.00	42965.68	00:02:30:59	35.76	39.24	36.76	34.98	37.75	35.59
	Corrected Ambient		44.20	47.67	45.20	43.41	46.19	44.03
	Average		44.24					
	Average core		44.68					
	Average Insulation		43.78					
	30 AMPS							
182.00	42965.70	00:03:00:59	39.98	43.90	41.39	39.49	42.72	39.71
	Corrected Ambient		48.45	52.37	49.85	47.96	51.19	48.18
	Average		48.75					
	Average core		49.39					
	Average Insulation		48.05					
	36 AMPS							
214.00	42965.72	00:03:32:59	47.04	48.39	48.73	46.42	50.45	46.40
	Corrected Ambient		55.61	56.97	57.30	54.99	59.03	54.97
	Average		55.57					
	Average core		56.61					
	Average Insulation		54.48					
	40 AMPS							
243.00	42965.74	00:04:01:59	52.41	53.30	54.36	51.59	56.81	51.39
	Corrected Ambient		60.70	61.59	62.65	59.88	65.10	59.68
	Average		60.64					
	Average core		62.02					
	Average Insulation		59.17					
	45 AMPS							
273.00	42965.76	00:04:31:59	59.93	60.57	61.45	59.16	64.82	58.73
	Corrected Ambient		68.43	69.07	69.94	67.66	73.32	67.23
	Average		68.02					
	Average core		69.86					

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	Average Insulation		66.10					
	50 AMPS							
304.00	42965.78	00:05:02:59	68.58	66.89	70.98	67.58	75.68	67.24
	Corrected Ambient		76.79	75.10	79.19	75.80	83.89	75.45
	Average		76.51					
	Average core		78.99					
	Average Insulation		73.93					
	55 AMPS							
334.00	42965.81	00:05:32:59	77.66	75.32	80.26	77.00	85.13	75.41
	Corrected Ambient		86.08	83.74	88.68	85.42	93.54	83.83
	Average		85.54					
	Average core		88.62					
	Average Insulation		82.30					

10 AWG CCA Single conductor Open Air
(Page 2 of 3)

102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #3 Insulation	315 CU-AL White Cable#4 Core	320 CU-AL Black Cable#4 Core	116 CU-AL Black Cable#4 Insulation
22.98	23.06	23.06	22.84	23.14	23.11
31.51	31.60	31.60	31.37	31.67	31.64
24.95	24.87	24.76	24.78	25.11	24.95

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33.46	33.37	33.27	33.29	33.61	33.46
27.94	27.66	27.49	28.04	28.49	27.92
36.34	36.06	35.89	36.45	36.89	36.32
31.97	31.21	31.04	32.09	32.60	31.53
40.41	39.65	39.48	40.54	41.04	39.98
36.86	35.52	34.62	36.88	37.56	35.94
45.30	43.96	43.05	45.32	46.00	44.38
41.65	40.19	38.87	41.54	42.71	40.19
50.12	48.66	47.34	50.00	51.18	48.66
49.26	47.09	45.20	48.99	50.60	47.06
57.83	55.66	53.78	57.57	59.17	55.63

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55.51	52.71	50.13	54.95	56.69	52.01
63.79	60.99	58.42	63.24	64.98	60.29
63.32	59.97	55.29	63.12	65.06	58.74
71.81	68.47	63.79	71.61	73.55	67.23
74.74	68.93	64.75	72.42	74.12	66.84
82.95	77.14	72.96	80.63	82.34	75.05
84.59	77.87	73.40	82.41	84.78	75.05
93.00	86.29	81.82	90.83	93.19	83.47

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10 AWG CCA Single conductor Open Air
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113 CU-AL White Cable #5 Core	114 CU-AL White Cable#5 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#6 Insulation	107 CU-AL White Cable#6 Insulation	106 CU-AL White Cable#6 Core
23.07	22.99	23.03	23.10	22.96	23.24
31.60	31.52	31.57	31.64	31.49	31.78
24.79	24.58	24.88	24.94	24.88	25.30
33.30	33.08	33.38	33.45	33.38	33.80
27.39	27.03	27.64	27.62	27.50	28.42
35.79	35.43	36.04	36.03	35.90	36.82
30.90	30.18	31.18	31.06	30.77	32.25
39.34	38.62	39.62	39.51	39.22	40.70

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34.92	33.57	35.29	35.22	34.83	37.20
43.36	42.01	43.73	43.65	43.27	45.64
39.04	37.63	40.14	39.22	39.04	42.06
47.51	46.10	48.60	47.69	47.50	50.53
45.69	43.45	46.83	45.74	45.25	49.22
54.26	52.02	55.40	54.32	53.83	57.79
50.91	48.17	52.61	50.82	50.25	55.22
59.19	56.46	60.90	59.10	58.54	63.51
58.10	54.41	60.26	57.35	56.69	63.45
66.59	62.90	68.75	65.85	65.18	71.95

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66.27	61.46	69.66	65.42	64.96	73.26
74.48	69.67	77.87	73.64	73.17	81.47
74.81	69.25	79.65	72.63	73.00	82.89
83.23	77.67	88.07	81.04	81.42	91.30

10 AWG Cu Single conductor Open Air
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30.00	42965.59	22.07	22.56	22.62	22.55	22.48	22.67
	Corrected Ambient	30.60	31.10	31.16	31.09	31.01	31.20
	Average	31.02					
	Average core	30.96					
	Average Insulation	31.08					
	10 AMPS						
60.00	42965.62	23.25	23.92	23.69	23.51	23.81	23.90
	Corrected Ambient	31.76	32.42	32.19	32.01	32.31	32.41
	Average	32.23					
	Average core	32.20					

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	Average Insulation	32.27					
	15 AMPS						
94.00	42965.64	25.17	26.29	25.70	25.23	26.09	25.97
94.00	Corrected Ambient	33.57	34.69	34.11	33.63	34.49	34.38
	Average	34.26					
	Average core	34.25					
	Average Insulation	34.28					
	20 AMPS						
121.00	42965.66	27.66	29.10	28.12	27.45	28.84	28.45
	Corrected Ambient	36.11	37.54	36.57	35.90	37.28	36.90
	Average	36.90					
	Average core	36.93					
	Average Insulation	36.86					
	25 AMPS						
152.00	42965.68	30.70	32.92	31.23	30.03	32.55	31.95
	Corrected Ambient	39.14	41.36	39.67	38.47	40.99	40.39
	Average	40.29					
	Average core	40.41					
	Average Insulation	40.18					
	30 AMPS						
182.00	42965.70	33.65	36.60	34.35	32.85	36.08	35.22
	Corrected Ambient	42.12	45.07	42.82	41.32	44.55	43.69
	Average	43.76					
	Average core	43.89					
	Average Insulation	43.63					
	36 AMPS						
214.00	42965.72	38.55	42.08	39.00	36.69	41.07	39.69
	Corrected Ambient	47.12	50.65	47.57	45.26	49.64	48.26
	Average	48.80					
	Average core	49.09					
	Average Insulation	48.51					

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	40 AMPS						
243.00	42965.74	41.71	46.30	42.78	40.04	45.42	43.45
	Corrected Ambient	50.00	54.59	51.07	48.33	53.71	51.74
	Average	52.54					
	Average core	52.83					
	Average Insulation	52.24					
	45 AMPS						
273.00	42965.76	47.71	51.95	47.60	43.96	50.47	48.26
	Corrected Ambient	56.20	60.44	56.09	52.45	58.97	56.75
	Average	58.05					
	Average core	58.61					
	Average Insulation	57.49					
	50 AMPS						
304.00	42965.78	53.84	59.41	54.11	49.30	57.74	54.24
	Corrected Ambient	62.05	67.62	62.32	57.52	65.96	62.45
	Average	64.37					
	Average core	65.11					
	Average Insulation	63.63					
	55 AMPS						
334.00	42965.81	60.19	63.55	59.83	53.97	58.77	58.08
	Corrected Ambient	68.60	71.96	68.24	62.39	67.18	66.50
	Average	69.97					
	Average core	70.96					
	Average Insulation	68.98					

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10 AWG Cu Single conductor Open Air
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304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Insulation	310 CU Black Cable#2 Core	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.23	22.47	22.49	22.70	22.46	22.50
30.77	31.01	31.03	31.24	30.99	31.04
23.53	23.74	23.77	24.13	23.77	23.74
32.03	32.25	32.28	32.64	32.28	32.24
25.65	25.95	26.07	26.49	25.96	25.75
34.05	34.35	34.47	34.89	34.37	34.16
28.23	28.61	28.70	29.55	28.52	28.20
36.68	37.05	37.14	38.00	36.97	36.64

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31.72	32.05	32.16	33.52	32.13	31.34
40.15	40.49	40.59	41.96	40.57	39.78
35.53	35.86	35.80	37.45	35.48	34.67
44.00	44.33	44.27	45.91	43.95	43.14
40.84	41.40	40.65	43.30	40.35	39.11
49.41	49.97	49.23	51.87	48.92	47.68
44.87	45.96	44.94	48.11	44.39	43.05
53.16	54.25	53.23	56.40	52.68	51.33
51.56	51.64	50.42	53.97	49.37	47.77
60.06	60.14	58.92	62.46	57.87	56.26

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57.88	58.65	56.87	61.91	55.93	54.05
66.10	66.86	65.08	70.12	64.14	62.26
64.75	65.59	62.39	70.14	61.61	59.85
73.17	74.00	70.80	78.55	70.03	68.26

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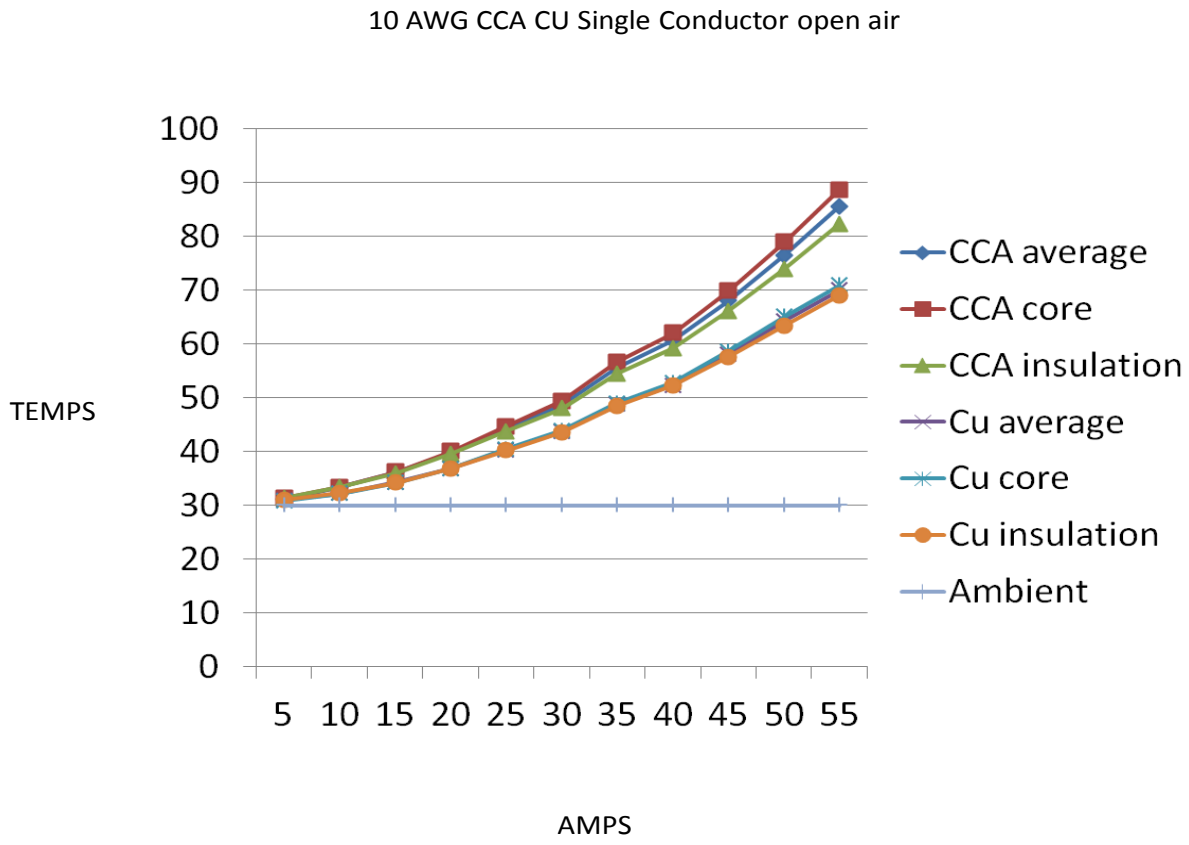

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Test Set- Up/ Layout
10 AWG in non-metallic cable in open air (2 Conductor)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 10 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 10 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 10 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG in Non-Metallic Cable (2 Conductors)

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	NM Cable	5	30
10	NM Cable	10	30
10	NM Cable	15	30
10	NM Cable	20	30
10	NM Cable	25	30
10	NM Cable	30	30
10	NM Cable	35	30
10	NM Cable	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA Non-Metallic Open Air (2 Conductor)

Page 1 of 3

Scan	Time	203 CU-AL White Cable#1-Core	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	208 CU-AL Black Cable#2 Core	120 CU-AL White Cable#2 Core	211 CU-AL White Cable# 2 Insulation
	5 AMPS						
29.00	42965.31	22.56	22.00	22.22	22.70	22.86	22.80
	Corrected Ambient	31.01	30.45	30.67	31.15	31.31	31.25
	Average	31.22					
	Average Core	31.25					
	Average Insulation	31.18					
	10 AMPS						
59.00	42965.34	24.64	24.13	24.46	24.90	25.31	25.33
	Corrected Ambient	33.21	32.70	33.02	33.47	33.88	33.90
	Average	33.48					
	Average Core	33.59					
	Average Insulation	33.34					
	15 AMPS						
90.00	42965.36	27.20	26.74	27.08	27.30	28.47	28.45
	Corrected Ambient	35.98	35.52	35.86	36.09	37.25	37.24
	Average	36.34					
	Average Core	36.53					
	Average Insulation	36.10					
	20 AMPS						
120.00	42965.38	30.31	29.56	30.82	31.04	32.46	31.76
120.00	Corrected Ambient	38.92	38.18	39.43	39.65	41.08	40.38
	Average	39.47					
	Average Core	39.91					
	Average Insulation	38.94					

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	25 AMPS						
151.00	42965.40	34.17	34.26	34.09	33.82	36.82	36.81
	Corrected Ambient	42.70	42.79	42.62	42.35	45.35	45.34
	Average	43.20					
	Average Core	43.67					
	Average Insulation	42.63					
	30 AMPS						
181.00	8/18/2017	40.14	40.25	39.61	39.67	44.07	43.95
	Corrected Ambient	48.87	48.97	48.34	48.40	52.80	52.68
	Average	49.73					
	Average Core	50.27					
	Average Insulation	49.07					
	35 AMPS						
211.00	8/18/2017	45.43	45.21	44.93	45.04	50.87	50.51
	Corrected Ambient	53.94	53.71	53.44	53.55	59.38	59.01
	Average	55.39					
	Average Core	56.18					
	Average Insulation	54.43					
	40 AMPS						
242.00	8/18/2017	50.84	50.96	50.37	51.04	58.24	57.38
	Corrected Ambient	59.52	59.63	59.04	59.71	66.92	66.05
	Average	61.97					
	Average Core	62.84					
	Average Insulation	60.91					

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10 AWG CCA Non-Metallic Open Air (2 Conductor)
(Page 2 of 3)

102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #4 Insulation	315 CU-AL White Cable#3 Core	320 CU-AL Black Cable#4 Core	116 CU-AL Black Cable#4 Insulation
22.96	22.92	22.95	22.83	22.89	22.68
31.41	31.37	31.40	31.29	31.35	31.13
25.39	24.90	25.21	25.08	25.02	24.41
33.96	33.47	33.77	33.65	33.59	32.98
28.53	27.32	28.01	27.79	27.59	26.58
37.31	36.10	36.79	36.58	36.37	35.36
32.18	30.26	31.60	31.28	30.79	29.22
40.80	38.87	40.21	39.89	39.40	37.83

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36.38	33.53	35.13	35.47	34.88	32.40
44.91	42.06	43.65	43.99	43.41	40.93
43.55	39.91	41.12	41.92	41.13	37.92
52.27	48.64	49.85	50.64	49.85	46.65
50.62	45.49	46.83	48.46	47.36	42.93
59.13	53.99	55.34	56.97	55.87	51.43
56.97	51.48	52.58	55.03	54.43	49.04
65.65	60.15	61.26	63.70	63.10	57.71

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10 AWG CCA Non-Metallic Open Air (2 Conductor)
(Page 3 of 3)

114 CU-AL White Cable#6 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#5 Insulation	107 CU-AL White Cable#6 Insulation	106 CU-AL White Cable#5 Core	103 CU-AL Black Cable#6 Core
22.86	23.16	22.83	22.75	23.01	22.61
31.31	31.62	31.28	31.21	31.46	31.06
24.90	25.52	24.59	24.68	25.19	24.49
33.46	34.08	33.16	33.25	33.76	33.06
27.45	28.59	26.81	26.95	27.86	26.80
36.23	37.37	35.59	35.73	36.64	35.58
30.62	32.31	29.51	29.96	31.51	29.93
39.23	40.93	38.12	38.57	40.12	38.54

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34.23	36.96	32.84	33.64	35.02	33.09
42.76	45.49	41.37	42.17	43.55	41.62
40.58	44.15	38.29	40.01	41.40	38.66
49.31	52.87	47.02	48.74	50.13	47.39
46.42	51.15	43.40	45.61	47.21	43.99
54.93	59.66	51.91	54.12	55.71	52.50
53.18	58.34	49.24	52.19	53.82	49.96
61.86	67.01	57.92	60.86	62.49	58.63

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10 AWG Cu in non-metallic cable (2 Conductor) in open air
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
29.00	42965.31	22.35	22.15	22.22	22.08	22.35	22.41
	Corrected Ambient	30.80	30.60	30.67	30.53	30.80	30.86
	Average	30.77					
	Average Core	30.79					
	Average Insulation	30.75					
	10 AMPS						
59.00	42965.34	23.86	23.34	23.35	23.28	23.64	23.74
	Corrected Ambient	32.42	31.91	31.92	31.85	32.21	32.31
	Average	32.18					
	Average Core	32.25					
	Average Insulation	32.12					
	15 AMPS						
90.00	42965.36	25.78	24.85	24.84	24.85	25.28	25.45
	Corrected Ambient	34.56	33.63	33.62	33.64	34.06	34.23
	Average	34.05					
	Average Core	34.14					
	Average Insulation	33.97					
	20 AMPS						
120.00	42965.38	28.46	26.70	26.84	26.63	27.38	27.39
120.00	Corrected Ambient	37.07	35.32	35.45	35.24	35.99	36.01
	Average	35.93					
	Average Core	36.20					
	Average Insulation	35.65					

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	25 AMPS						
151.00	42965.40	31.70	29.22	29.24	29.04	30.00	29.99
	Corrected Ambient	40.23	37.75	37.77	37.57	38.53	38.52
	Average	38.40					
	Average Core	38.78					
	Average Insulation	38.03					
	30 AMPS						
181.00	8/18/2017	36.74	33.05	33.55	33.39	33.88	34.40
	Corrected Ambient	45.47	41.78	42.28	42.12	42.61	43.13
	Average	42.80					
	Average Core	43.21					
	Average Insulation	42.39					
	35 AMPS						
211.00	8/18/2017	41.63	36.87	37.11	36.85	37.80	38.22
	Corrected Ambient	50.14	45.37	45.61	45.36	46.30	46.73
	Average	46.58					
	Average Core	47.13					
	Average Insulation	46.03					
	40 AMPS						
242.00	8/18/2017	47.11	41.04	41.32	40.92	42.28	42.42
	Corrected Ambient	55.78	49.71	50.00	49.59	50.96	51.10
	Average	51.05					
	Average Core	51.88					
	Average Insulation	50.21					

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10 AWG Cu in non-metallic cable (2 Conductor) in open air

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304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Core	310 CU Black Cable#2 Insulation	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.46	22.17	22.34	22.44	22.34	22.52
30.91	30.62	30.79	30.89	30.80	30.97
23.89	23.29	23.74	23.72	23.64	23.93
32.46	31.86	32.31	32.28	32.20	32.50
25.78	24.68	25.27	25.47	25.21	25.82
34.56	33.46	34.05	34.25	33.99	34.60
27.95	26.31	27.57	27.28	27.34	27.92
36.56	34.92	36.18	35.89	35.95	36.54

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30.76	28.50	30.31	29.75	29.47	30.49
39.29	37.03	38.84	38.28	38.00	39.02
35.55	32.13	34.15	34.05	33.00	34.97
44.28	40.86	42.88	42.77	41.73	43.70
40.14	35.60	38.38	38.05	36.70	39.58
48.65	44.11	46.89	46.56	45.21	48.08
44.88	38.92	43.18	42.00	40.48	43.95
53.55	47.60	51.85	50.67	49.16	52.62

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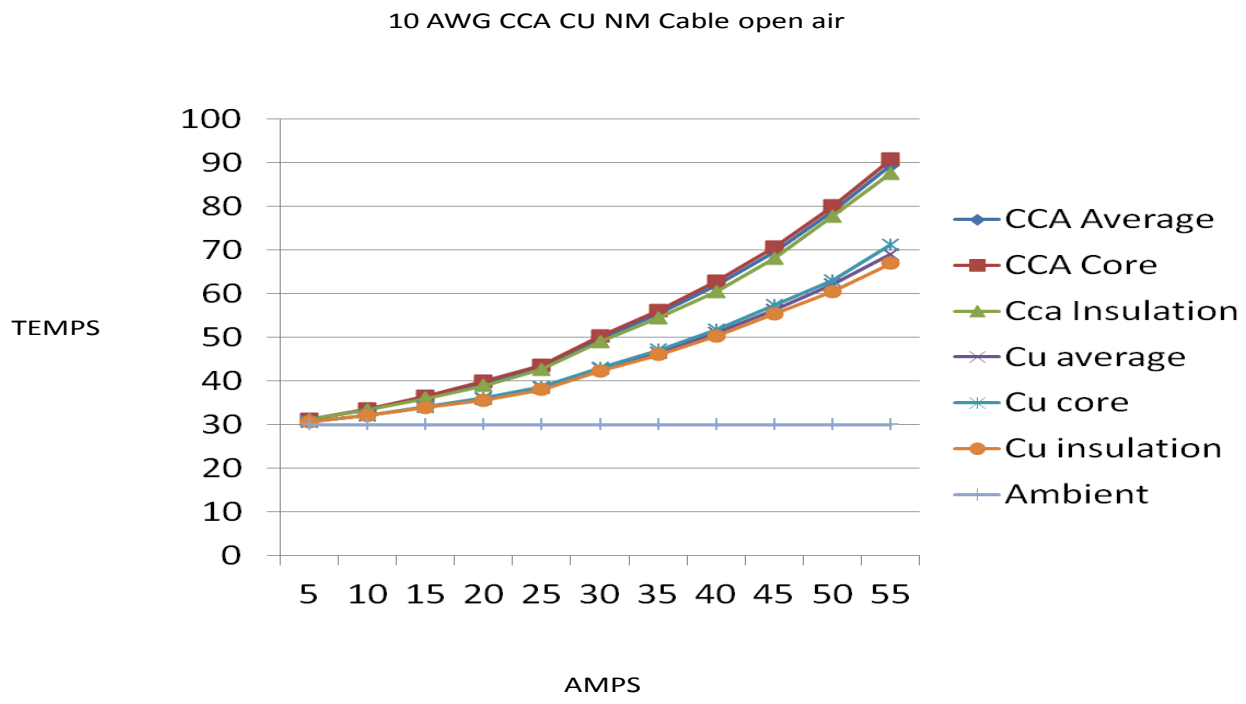

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Test Set- Up/ Layout
10 AWG in Conduit (2 Conductor)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 10 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 10 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 10 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG Conduit

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	Conduit	5	30
10	Conduit	10	30
10	Conduit	15	30
10	Conduit	20	30
10	Conduit	25	30
10	Conduit	30	30
10	Conduit	35	30
10	Conduit	40	30

Equilibrium: With reference to the test, test was continued until constant temperatures were attained. Thermal equilibrium is considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicate no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA in Conduit (2 Conductor)

(Page 1 of 3)

Scan	Time	203 CU-AL White Cable#1-Core	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	205 CU-AL Black Cable#2 Insulation	120 CU-AL White Cable#2 Core
	5 AMPS						
30.00	42966.40	23.32	22.63	22.90	23.15	23.26	23.40
	Corrected Ambient	31.77	31.08	31.35	31.59	31.70	31.85
	Average	31.85					
	Average core	31.89					
	Average insulation	31.80					
	10 AMPS						
64.00	42966.42	26.59	25.43	26.27	25.92	26.52	26.56
	Corrected Ambient	34.93	33.76	34.60	34.25	34.85	34.90
	Average	34.75					
	Average core	34.84					
	Average insulation	34.66					
	15 AMPS						
95.00	42966.44	31.92	29.65	31.74	30.41	31.65	31.89
	Corrected Ambient	40.23	37.96	40.05	38.72	39.97	40.21
	Average	39.72					
	Average core	39.93					
	Average insulation	39.49					
	20 AMPS						
132.00	42966.47	38.70	35.07	38.69	36.15	38.16	38.61
	Corrected Ambient	46.73	43.10	46.72	44.18	46.19	46.64
	Average	45.82					
	Average core	46.15					

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	Average insulation	45.45					
	26 AMPS						
162.00	42966.49	47.38	42.40	47.49	43.29	46.07	46.97
	Corrected Ambient	55.50	50.51	55.61	51.40	54.18	55.09
	Average	53.85					
	Average core	54.35					
	Average insulation	53.30					
	30 AMPS						
192.00	42966.51	57.44	50.50	57.79	51.44	55.09	56.93
	Corrected Ambient	65.41	58.46	65.75	59.40	63.05	64.90
	Average	62.99					
	Average core	63.71					
	Average insulation	62.17					
	35 AMPS						
222.00	42966.53	70.55	60.57	71.31	61.86	66.91	69.78
	Corrected Ambient	78.66	68.68	79.42	69.97	75.02	77.89
	Average	75.21					
	Average core	76.27					
	Average insulation	74.01					
	40 AMPS						
260.00	42966.56	86.35	74.81	87.61	74.53	81.18	86.55
	Corrected Ambient	94.33	82.80	95.59	82.51	89.16	94.53
	Average	89.94					
	Average core	91.36					
	Average insulation	88.34					

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10 AWG CCA in Conduit (2 Conductor)
(Page 2 of 3)

211 CU-AL White Cable# 3 Insulation	102 CU-AL Black Cable#3 Core	320 CU-AL Black Cable#4 Core	113 CU-AL White Cable #4 Core	114 CU-AL White Cable#4 Insulation	109 CU-AL Black Cable#5 Core
23.26	23.49	23.53	23.64	23.57	23.74
31.70	31.94	31.98	32.08	32.01	32.18
26.21	26.62	26.66	26.73	26.46	26.83
34.54	34.96	35.00	35.07	34.80	35.17
30.86	31.75	31.93	32.02	31.42	32.03
39.17	40.06	40.24	40.33	39.73	40.34
36.72	38.39	38.61	38.74	37.61	38.57
44.75	46.42	46.64	46.77	45.64	46.60

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43.72	46.74	46.85	47.03	45.17	46.62
51.83	54.86	54.96	55.14	53.28	54.74
51.86	56.42	56.62	56.89	54.04	56.27
59.83	64.38	64.58	64.86	62.00	64.23
62.45	69.09	69.33	69.71	65.42	68.98
70.56	77.20	77.43	77.81	73.53	77.09
74.86	84.65	84.99	85.42	79.26	84.28
82.84	92.63	92.97	93.40	87.25	92.26

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10 AWG CCA in Conduit (2 Conductor)
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107 CU-AL White Cable#5 Insulation	103 CU-AL Black Cable#5 Core	101 CU-AL Black Cbale#6 Insulation	104 CU-AL White Cable#6 Core	105 CU-AL White Cable#6 Insulation
23.63	23.30	23.62	23.65	23.71
32.08	31.75	32.07	32.09	32.16
26.63	25.87	26.80	26.40	26.61
8.34	8.34	8.34	8.34	8.34
34.97	34.21	35.14	34.73	34.94
31.70	30.22	32.18	31.08	31.53
8.31	8.31	8.31	8.31	8.31
40.01	38.53	40.49	39.39	39.85
38.35	35.78	39.22	37.02	38.08
8.03	8.03	8.03	8.03	8.03
46.38	43.81	47.25	45.05	46.11

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46.57	42.58	48.00	44.44	46.26
54.68	50.69	56.12	52.55	54.38
56.53	50.33	58.28	53.07	55.91
64.50	58.29	66.24	61.04	63.87
69.86	60.42	71.69	64.34	68.46
77.97	68.52	79.80	72.44	76.57
86.55	72.57	88.22	77.95	83.47
94.53	80.55	96.20	85.93	91.45

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10 AWG Cu in Conduit (2 Conductor)

(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30.00	42966.40	22.82	22.91	22.98	22.94	22.84	23.12
	Corrected Ambient	31.26	31.36	31.43	31.39	31.28	31.57
	Average	31.43					
	Average core	31.41					
	Average insulation	31.46					
	10 AMPS						
64.00	42966.42	24.81	24.98	24.84	24.87	24.60	24.72
	Corrected Ambient	33.14	33.32	33.18	33.21	32.94	33.06
	Average	33.21					
	Average core	33.19					
	Average insulation	33.23					
	15 AMPS						
95.00	42966.44	28.18	28.33	28.05	28.18	27.66	27.71
	Corrected Ambient	36.49	36.64	36.36	36.49	35.97	36.02
	Average	36.47					
	Average core	36.46					
	Average insulation	36.49					
	20 AMPS						
132.00	42966.47	32.50	32.63	32.33	32.54	31.64	31.58
	Corrected Ambient	40.53	40.66	40.36	40.57	39.67	39.61
	Average	40.49					
	Average core	40.48					
	Average insulation	40.50					
	26 AMPS						

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162.00	42966.49	37.65	37.76	37.74	37.82	36.46	36.24
	Corrected Ambient	45.76	45.87	45.85	45.93	44.58	44.35
	Average	45.73					
	Average core	45.75					
	Average insulation	45.72					
	30 AMPS						
192.00	42966.51	43.85	43.86	43.85	44.09	42.10	41.80
	Corrected Ambient	51.81	51.83	51.82	52.05	50.06	49.76
	Average	51.69					
	Average core	51.72					
	Average insulation	51.67					
	35 AMPS						
222.00	42966.53	51.88	51.82	51.54	52.18	49.45	48.85
	Corrected Ambient	59.99	59.93	59.65	60.29	57.56	56.95
	Average	59.66					
	Average core	59.67					
	Average insulation	59.65					
	40 AMPS						
260.00	42966.56	61.89	61.68	59.87	62.27	58.36	57.45
	Corrected Ambient	69.87	69.66	67.86	70.25	66.34	65.43
	Average	69.09					
	Average core	68.99					
	Average insulation	69.19					

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10 AWG Cu in Conduit (2 Conductor)

(Page 2 of 2)

304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Insulation	310 CU Black Cable#2 Core	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
23.07	22.92	23.07	23.03	23.07	23.10
31.52	31.37	31.51	31.48	31.51	31.54
24.81	24.45	25.07	24.82	25.23	25.25
33.15	32.79	33.41	33.16	33.56	33.58
27.97	27.26	28.60	28.02	29.02	28.99
36.28	35.57	36.91	36.33	37.33	37.30
32.12	30.89	33.22	32.16	33.93	33.93
40.15	38.92	41.25	40.19	41.96	41.96

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37.07	35.14	38.79	37.10	39.78	39.86
45.19	43.26	46.90	45.22	47.90	47.98
43.01	40.14	45.40	42.95	46.77	46.95
50.97	48.10	53.36	50.92	54.73	54.92
50.52	46.53	53.82	50.33	55.67	56.04
58.62	54.64	61.93	58.43	63.78	64.14
60.04	54.32	64.29	59.29	66.58	67.26
68.02	62.30	72.28	67.27	74.57	75.24

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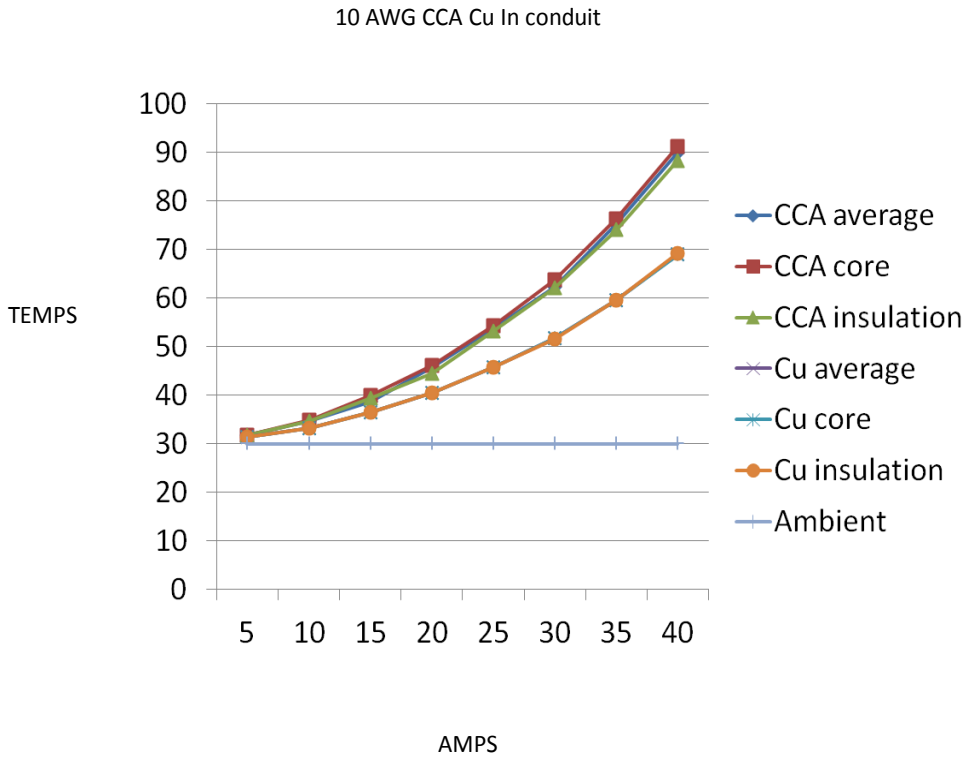

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Summary

14 AWG						
Max Temps	Single conductor@35A		NM cable@25A		Conduit@25A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	89.81	67.08	68.95	53.14	117.69	79.54
Average Core	92.67	67.91	69.61	53.05	124.41	82.77
Average Insulation	86.68	66.25	71.60	53.23	111.52	76.31

12 AWG						
Max Temps	Single conductor@40A		NM cable@30A		Conduit@30A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	76.85605	66.52817	59.54	49.96617	94.77	72.19
Average Core	80.71511	69.18933	62.19	51.36633	99.22	76.53
Average Insulation	72.72958	63.867	57.11	48.566	91.05	67.86

10 AWG						
Max Temps	Single conductor@55		NM cable@40A		Conduit@40 A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	85.54	69.97	61.97	51.05	89.94	69.09
Average Core	88.62	70.96	62.84	51.88	91.36	68.99
Average Insulation	82.30	68.98	60.91	50.21	88.34	69.19

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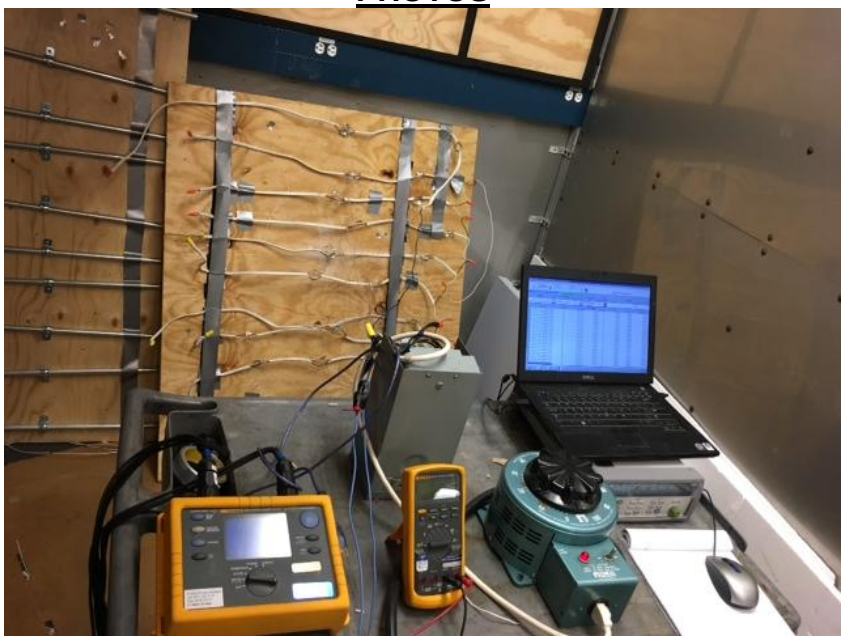
APPENDIX A
PHOTOS



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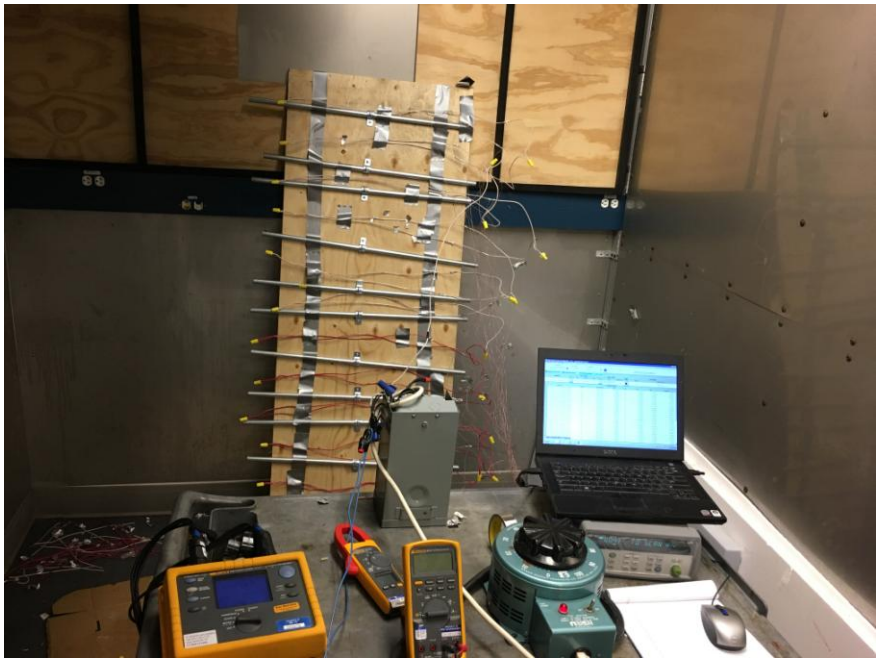

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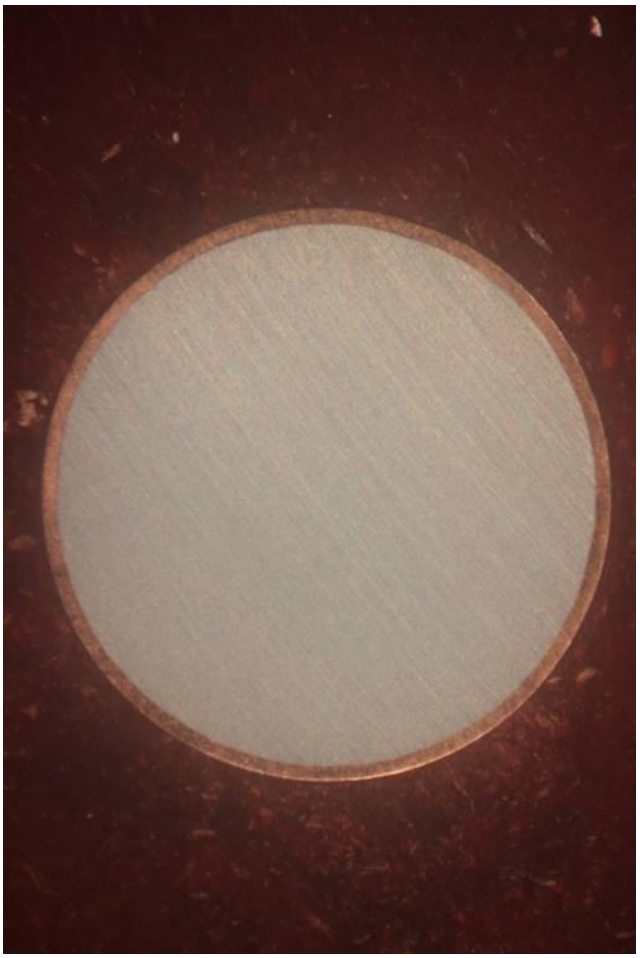

Cross Sectional view of the CCA

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APPENDIX B
EQUIPMENT LIST

Equipment	PL Code	Calibration
Transformer	PL004985	N/A
Agilent Temperature Data Acquisition system	PL005628	N/A
Thermocouples Cartridge, Type J	PL004988 PL003269 PL003268	Calibrated Daily or before each usage.
Simpson Model 06713100 Current shunt	PL002161	See Certificate Below Appendix C
Fluke multi meter, model 87V	PL004935	See Certificate Below Appendix C
Fluke Digital Clamp Meter, model 374FC	PL005812	See Certificate Below Appendix C
Thermocouples	Same as above	Conducted Daily
Power Logger	PL003379	See Certificate Below Appendix C

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APPENDIX C
CALIBRATION

Trescal

Certificate #: *3869120002 e* *W*

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	374FC
Description:	Clamp Meter
Serial Number:	37421743WS
Asset Number:	PL005812
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	05/01/2017
Due Date:	05/01/2018
Temperature:	73.00 **deg. F**
Humidity:	40.00 **%**
Baro. Press.:	
Procedure:	DCN 50442
Reference:	TO 33K1-4-853-1 Rev. 30 Jun 2008
Dept:	

Incoming Remarks:
w/case

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390482	Fluke	5522A	Multifunction Calibrator	11/22/2016	11/22/2017

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Trescal

Certificate #: *3765740001 e* *W*

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	87V
Description:	DMM
Serial Number:	26270081
Asset Number:	PL004935
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	01/31/2017
Due Date:	01/31/2018
Temperature:	74.00 **deg. F**
Humidity:	20.00 **%**
Baro. Press.:	
Procedure:	DCN 07074
Reference:	manufacturer's manual
Dept:	

Incoming Remarks:
w/case/leads/holster

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390169	Fluke	5500A	Multifunction Calibrator	04/26/2016	04/26/2017

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Trescal

Certificate #: *3869120002 e* *W*

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	374FC
Description:	Clamp Meter
Serial Number:	37421743WS
Asset Number:	PL005812
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	05/01/2017
Due Date:	05/01/2018
Temperature:	73.00 deg. F
Humidity:	40.00 %
Baro. Press.:	
Procedure:	DCN 50442
Reference:	TO 33K1-4-853-1 Rev. 30 Jun 2008
Dept:	

Incoming Remarks:
w/case

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390482	Fluke	5522A	Multifunction Calibrator	11/22/2016	11/22/2017

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ACCREDITED
Calibration Cert# 2165.01

FLUKE

Certificate of Calibration

Everett Service Center

Certificate Number:	322693		
Data Type:	As-Left	**Calibration Date:**	27-Feb-2017
Result Summary:	Measurement Results < Limits		
Manufacturer:	Fluke	**Certificate Date:**	28-Feb-2017
Model:	1735	**Temperature:**	23.6 °C
Serial Number:	S090503258B6	**Humidity:**	28.1 %
Description:	Power Quality Logger		
Procedure:	Fluke 1735:(2 year) ACAL VER RS-232/5520	**Revision:**	2.1
Customer:	NSF INTERNATIONAL		
City:	ANN ARBOR	**Country:**	US
State:	MI		
Purchase Order:	CCS CALIBRATION LAB - NSF INTERNATIONAL	**RMA:**	31194022
Asset ID:	PL003379		

This calibration is traceable to the International System of Units (SI), through National Metrology Institutes (NIST, PTB, NRC, NPL, etc.), ratiometric techniques, or natural physical constants. This certificate applies only to the item identified and shall not be reproduced either than in full, without the specific written approval by Fluke Corporation. Calibration certificates without signature are not valid. The calibration has been completed in accordance with Fluke Electronics Corporation Quality System Document 111.0 Revision 11B 8/2014 and/or Fluke 17025 Quality Manual QSD 111.41 Revision 005 8/2014.

The Data Type found in this certificate must be interpreted as:

- As - Found Calibration data collected before the unit is adjusted and / or repaired.
- As - Left Calibration data collected after the unit has been adjusted and / or repaired.
- Found-Left Calibration data collected without any adjustment and / or repair performed.

This calibration conforms to the requirements of ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994 (R2002).

In the attached measurement results, deviation may be expressed with units, Measured Value (MV) - Nominal Value (NV) or as a proportion of the nominal value ((MV-NV)/NV), expressed without units with a scalar multiplier such as % (0.01), or as a ratio of the units (mA/A, µ/V, etc.) Descriptions such as µA/A, µV/V, and others, where used to annotate results or column headings are the preferred replacements for what was historically labeled as "ppm" or parts-per-million and described the results in that column, unless otherwise noted by units symbols.

Where applicable, the expanded uncertainty of measurement at the time of test is given in the following pages. They are calculated in accordance with the method described in the ISO Guide to the Expression of Uncertainty in Measurement (GUM). The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k, such that the confidence level approximates 95%.

This calibration certificate may contain data that is not covered by the A2LA Scope of Accreditation. Unaccredited material, where applicable is indicated by an asterisk (*), or confined to clearly marked sections. Functional (Pass / Fail) tests are not accredited.

No statement of compliance with specifications is made or implied on this certificate. However, measurement results are reviewed, where applicable, to establish where any measurement result exceeded the manufacturer's specifications.

Measurement results greater than limits of error are indicated by '!'.

Accredited FLUKE

Cert # 322693
Cal Date 27-Feb-2017
S/N S090503258B6
www.fluke.com

Cert # 322693
Date 27/2/2017
www.fluke.com

Rolly Sherwood
Calibration Technician

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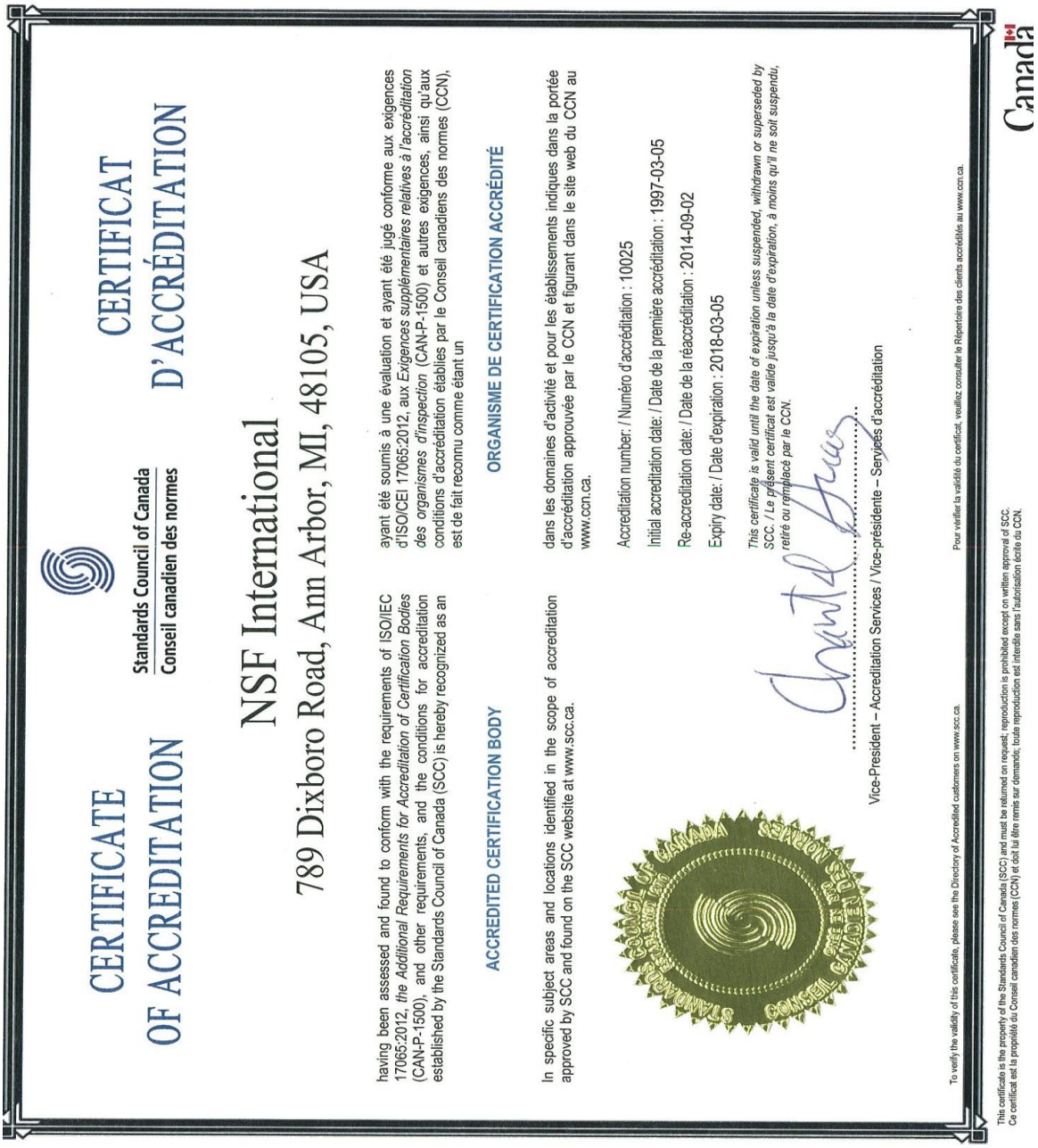
APPENDIX D
LABORATORY CERTIFICATIONS



CERTIFICATE OF ACCREDITATION

Standards Council of Canada
Conseil canadien des normes

CERTIFICAT D'ACCRÉDITATION

NSF International
789 Dixboro Road, Ann Arbor, MI, 48105, USA

having been assessed and found to conform with the requirements of ISO/IEC 17065:2012, *the Additional Requirements for Accreditation of Certification Bodies* (CAN-P-1500), and other requirements, and the conditions for accreditation established by the Standards Council of Canada (SCC) is hereby recognized as an

ayant été soumis à une évaluation et ayant été jugé conforme aux exigences d'ISO/CEI 17065:2012, aux *Exigences supplémentaires relatives à l'accréditation des organismes d'inspection* (CAN-P-1500) et autres exigences, ainsi qu'aux conditions d'accréditation établies par le Conseil canadiens des normes (CCN), est de fait reconnu comme étant un

ACCREDITED CERTIFICATION BODY

ORGANISME DE CERTIFICATION ACCRÉDITÉ

In specific subject areas and locations identified in the scope of accreditation approved by SCC and found on the SCC website at www.scc.ca.

dans les domaines d'activité et pour les établissements indiques dans la portée d'accréditation approuvée par le CCN et figurant dans le site web du CCN au www.ccn.ca.

Accreditation number: / Numéro d'accréditation : 10025

Initial accreditation date: / Date de la première accréditation : 1997-03-05

Re-accreditation date: / Date de la réaccréditation : 2014-09-02

Expiry date: / Date d'expiration : 2018-03-05

This certificate is valid until the date of expiration unless suspended, withdrawn or superseded by SCC. / Le présent certificat est valide jusqu'à la date d'expiration, à moins qu'il ne soit suspendu, retiré ou remplacé par le CCN.

STANDARDS COUNCIL OF CANADA
CONSEIL CANADIEN DES NORMES

Vice-President – Accreditation Services / Vice-présidente – Services d'accréditation

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Pour vérifier la validité du certificat, veuillez consulter le Répertoire des clients accrédités au www.ccn.ca.

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CERTIFICATE

Certificate Number: 140920.00

The Environmental Management System and implementation of:

NSF International
789 N. Dixboro Road
Ann Arbor, MI 48105
United States

meets the requirements of the standard:

ISO 14001:2015

Scope:
Laboratory testing, product certification, and domestic (U.S.) auditing associated with the facility located at 789 N. Dixboro Road, Ann Arbor, Michigan. NSF-ISR operations are excluded from the scope of registration.

Certificate Expires:	July 04, 2018
Re-issued:	August 08, 2017
Certificate Issued:	July 05, 2015
Certified Since:	July 05, 2006

Dr. Cem O. Onus
Managing Director, Business Assurance
DEKRA Certification, Inc.
1120 Welsh Road, Suite 210
North Wales, PA 19454 USA
(215) 997-4519
dekra-certification.us

ANAB ACCREDITED ISO/IEC 17021 MANAGEMENT SYSTEMS CERTIFICATION BODY

MEMBER OF MULTILATERAL RECOGNITION ARRANGEMENT IAF

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Occupational Safety and Health Administration

Nationally Recognized Testing Laboratory Program

NRTLP

Certificate of Recognition

NSF International

with headquarters at:

789 Dixboro Road
Ann Arbor, Michigan 48105
United States

is recognized by the Occupational Safety and Health Administration (OSHA) as meeting the requirements for a Nationally Recognized Testing Laboratory (NRTL) established under Section 1910.7 of *Title 29, Code of Federal Regulations.* This recognition is limited to testing and certification only within the current scope of recognition and is subject to all other terms set forth in the letter of recognition and in applicable *Federal Register* notices and as summarized on OSHA's website. This recognition continues in force beyond the "*Effective through*" date below provided the NRTL has filed a timely request for renewal with OSHA. For current recognition status and other recognition information, contact the OSHA NRTL Program or visit *https://www.osha.gov/dts/otpca/nrtl/*

July 14, 2019
Effective Through

David Michaels, PhD, MPH
Assistant Secretary of Labor for
Occupational Safety and Health Administration

UNITED STATES OF AMERICA · DEPARTMENT OF LABOR

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intertek
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COPPERWELD BIMETALLICS
TEST REPORT

SCOPE OF WORK
ASTM E228 LINEAR THERMAL EXPANSION EVALUATION OF 14 AWG GAGE COPPER CLAD ALUMINUM (CCA) WIRE

REPORT NUMBER
I6049.04-106-31 R0

TEST DATES
07/12/18 - 07/19/18

ISSUE DATE
08/15/18

RECORD RETENTION END DATE
07/26/22

PAGES
8

DOCUMENT CONTROL NUMBER
ATI 00231 (09/05/17)
RT-R-AMER-Test-2827
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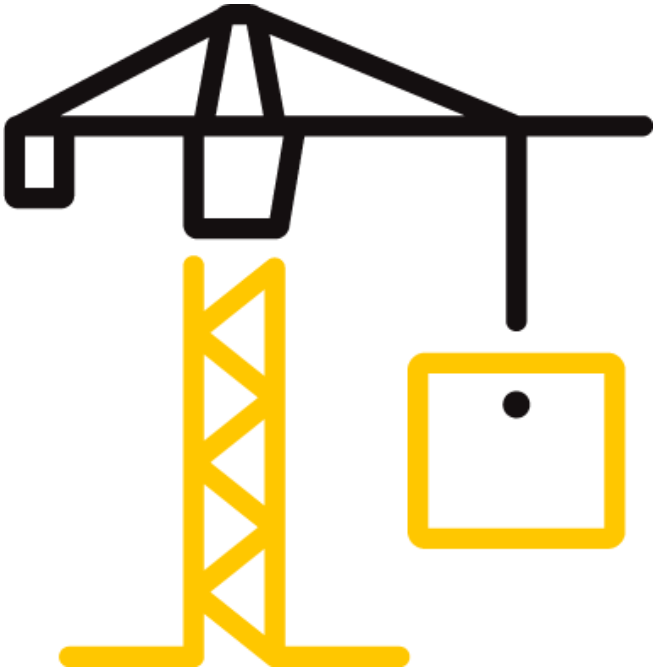

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TEST REPORT FOR COPPERWELD BIMETALLICS

Report No.: I6049.04-106-31 R0
Date: 08/15/18

REPORT ISSUED TO

COPPERWELD BIMETALLICS
254 Cotton Mill Road
Fayetteville, Tennessee 37334

SECTION 1

SCOPE

Products: 14 AWG gage Copper Clad Aluminum (CCA) Wire

Intertek Building & Construction (B&C) was contracted by Copperweld Bimetallics to evaluate 14 AWG gage Copper Clad Aluminum (CCA) Wire in accordance with ASTM E228 for Linear Thermal Expansion properties. Results obtained are tested values and were secured by using the designated test methods. Testing was conducted at the Intertek B&C test facility in York, Pennsylvania.

This report does not constitute certification of this product nor an opinion or endorsement by this laboratory.

SECTION 2

SUMMARY OF TEST RESULTS

COPPER CLAD ALUMINUM (CCA) WIRE AWG GAGE	CLTE (mm/mm/°C) 25°C to 90°C TEMPERATURE RANGE
14	8.89E-06

For INTERTEK B&C:

COMPLETED BY:	Joseph M. Brickner	**REVIEWED BY:**	Dawn M. Chaney
TITLE:	Laboratory Supervisor Materials Laboratory	**TITLE:**	Technician Team Lead Materials laboratory
SIGNATURE:		**SIGNATURE:**	
DATE:	08/15/18	**DATE:**	08/15/18

JMB:dmc/jp

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SECTION 3
TEST METHOD

The specimens were evaluated in accordance with the following:

> **ASTM E228-17**, *Standard Test Method for Linear Thermal Expansion of Solid Materials with a Push-Rod Dilatometer*

SECTION 4
MATERIAL SOURCE

The test materials were provided by Copperweld Bimetallics. The following was received: One (1), nominally 76 mm copper clad aluminum wire specimens in 14 AWG gage. Refer to the product description photo in Section 10. The material was tested as received except for smoothing the cut ends of each specimen. Representative test specimens will be retained by Intertek B&C for a minimum of four years from the test completion date.

SECTION 5
LIST OF OFFICIAL OBSERVERS

NAME	COMPANY
Joseph M. Brickner	Intertek B&C
Dawn M. Chaney	Intertek B&C

SECTION 6
TEST PROCEDURE

All conditioning of test specimens and test conditions were at standard laboratory conditions unless otherwise reported. Refer to the test related photos in Section 10.

ASTM E228 - Linear Thermal Expansion
One specimen for each wire gage was measured for initial length using a 6" digital caliper (ICN: 65688) and placed in the bottom of an outer glass dilatometer tube with an inner glass tube resting on it. An aluminum support cylinder was utilized to keep the wire oriented in a vertical position. The dilatometer tube was suspended in a heated environment utilizing a muffle furnace (ICN: Y002864) and subjected to exposure conditions of nominally 25°C and 90°C. At the equilibrium of each temperature condition, specimen temperature was measured using a thermocouple reader (ICN: 62101) and a measurement was recorded from a digital indicator (ICN: INT00193) resting on top of the inner tube. The Linear Thermal Expansion between the temperature range was calculated.

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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.04-106-31 R0
Date: 08/15/18

SECTION 7
TEST SPECIMEN DESCRIPTIONS

TEST PROCEDURE	NUMBER OF SPECIMENS	NOMINAL SPECIMEN DIMENSIONS	VISUAL CHARACTERISTICS
ASTM E228 Linear Thermal Expansion	1	75 mm x 14 gage wire thickness	Copper Clad Aluminum wire

SECTION 8
TEST RESULTS

ASTM E228 - Linear Thermal Expansion

Copper Clad Aluminum (CCA) Wire - 14 Gage

All Temperatures

LENGTH (mm)	75.56	
TARGET TEMPERATURE (°C)	25	90
ACTUAL TEMPERATURE (°C)	25.4	90.9
GAGE READING (mm)	6.6070	6.6510
ΔT (°C)		65.5
ΔL (mm)		0.0440
ΔL/ΔT (mm/°C)		6.72E-04
CLTE (mm/mm/°C)		**8.89E-06**

SECTION 9
CONCLUSION

The requested test method did not contain specific performance requirements.

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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.04-106-31 R0
Date: 08/15/18

SECTION 10
PHOTOGRAPHS

Photo No. 1
Copper Clad Aluminum - Specimen Detail

Photo No. 2
ASTM E228 - Equipment Detail

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Report No.: I6049.04-106-31 R0
Date: 08/15/18

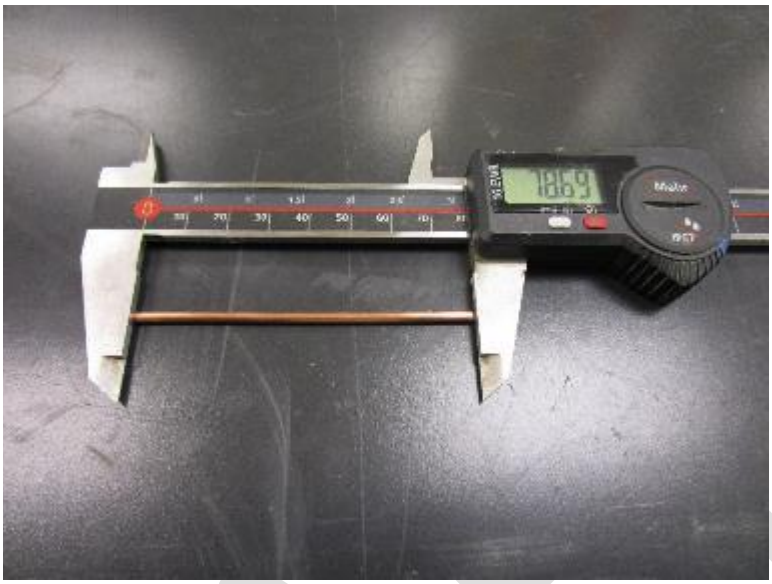

Photo No. 3
ASTM E228 - Length Measurement Equipment Detail

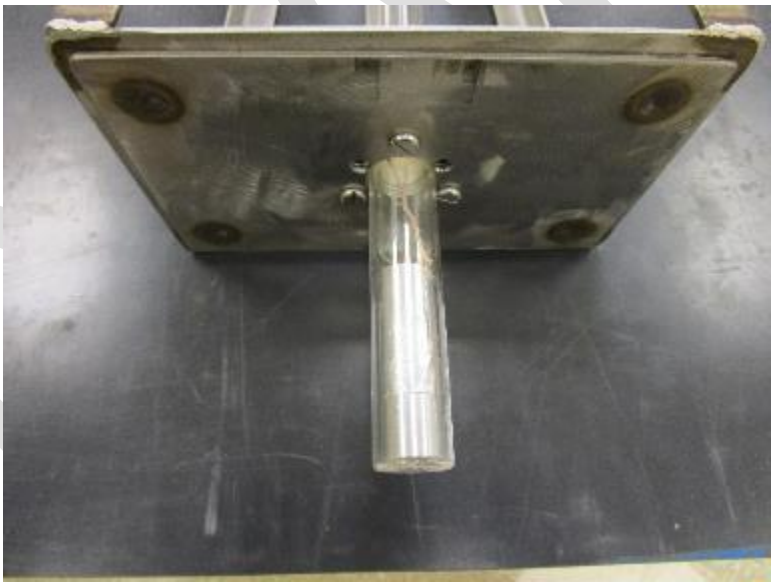

Photo No. 4
ASTM E228 - Specimen Support Detail

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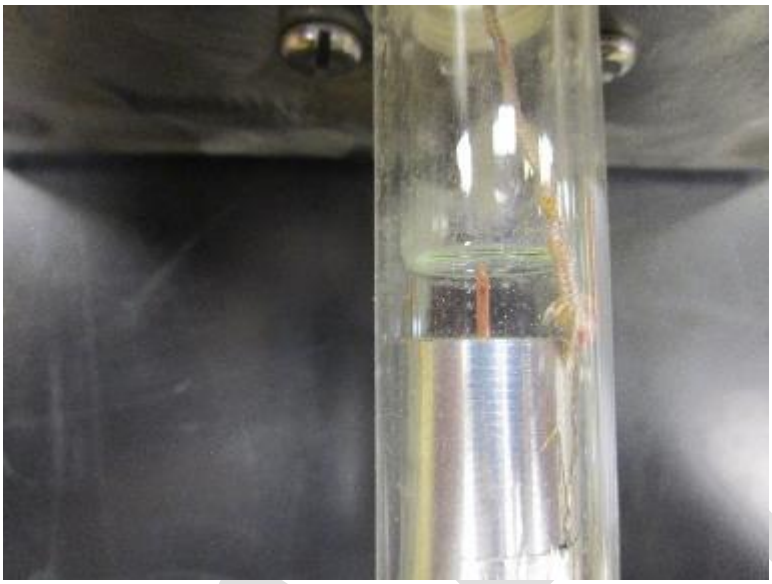

Photo No. 5
ASTM E228 - Specimen Temperature Measurement Detail

Photo No. 6
ASTM E228 - Linear Expansion Measurement Equipment Detail

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Report No.: I6049.04-106-31 R0
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SECTION 11
REVISION LOG

REVISION #	DATE	PAGES	REVISION
0	08/15/18	N/A	Original Report Issue

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COPPERWELD BIMETALLICS
TEST REPORT

SCOPE OF WORK
ASTM E228 LINEAR THERMAL EXPANSION EVALUATION OF 14 AWG GAGE ELECTROLYTIC TOUGH PITCH (ETP) COPPER WIRE

REPORT NUMBER
I6049.03-106-31 R0

TEST DATES
07/19/18 - 07/26/18

ISSUE DATE
08/15/18

RECORD RETENTION END DATE
07/26/22

PAGES
8

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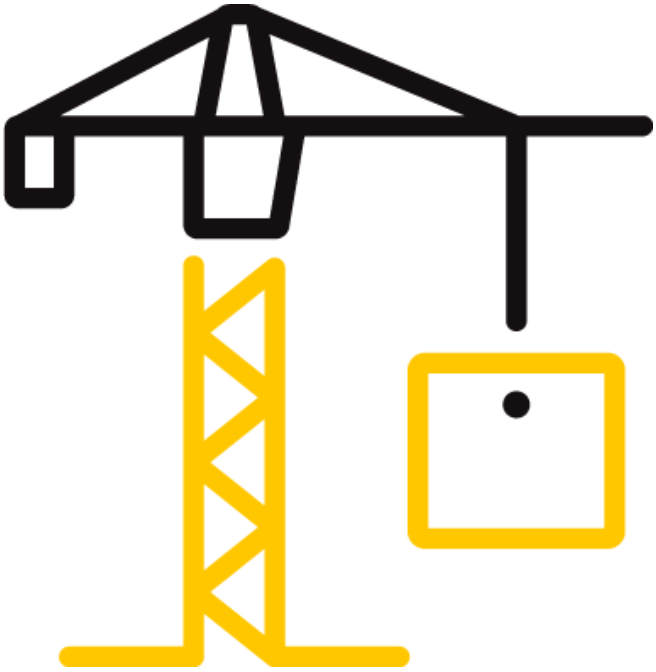

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TEST REPORT FOR COPPERWELD BIMETALLICS

Report No.: I6049.03-106-31 R0
Date: 08/15/18

REPORT ISSUED TO

COPPERWELD BIMETALLICS
254 Cotton Mill Road
Fayetteville, Tennessee 37334

SECTION 1

SCOPE

Products: 14 AWG gage Electrolytic Tough Pitch (ETP) Wire

Intertek Building & Construction (B&C) was contracted by Copperweld Bimetallics to evaluate 14 AWG gage Electrolytic Tough Pitch (ETP) Wire in accordance with ASTM E228 for Linear Thermal Expansion properties. Results obtained are tested values and were secured by using the designated test methods. Testing was conducted at the Intertek B&C test facility in York, Pennsylvania.

This report does not constitute certification of this product nor an opinion or endorsement by this laboratory.

SECTION 2

SUMMARY OF TEST RESULTS

ELECTROLYTIC TOUGH PITCH (ETP) COPPER WIRE AWG GAGE	CLTE (mm/mm/°C) 25°C to 90°C TEMPERATURE RANGE
14	1.57E-05

For INTERTEK B&C:

COMPLETED BY:	Joseph M. Brickner	**REVIEWED BY:**	Dawn M. Chaney
TITLE:	Laboratory Supervisor Materials Laboratory	**TITLE:**	Technician Team Lead Materials laboratory
SIGNATURE:		**SIGNATURE:**	
DATE:	08/15/18	**DATE:**	08/15/18

JMB:dmc/jlp

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SECTION 3
TEST METHOD

The specimens were evaluated in accordance with the following:

> **ASTM E228-17**, *Standard Test Method for Linear Thermal Expansion of Solid Materials with a Push-Rod Dilatometer*

SECTION 4
MATERIAL SOURCE

The test materials were provided by Copperweld Bimetallics. The following were received: One (1), nominally 76 mm electrolytic tough pitch copper wire specimen in 14 AWG gage. Refer to the product description photo in Section 10. The material was tested as received except for smoothing the cut ends of each specimen. Representative test specimens will be retained by Intertek B&C for a minimum of four years from the test completion date.

SECTION 5
LIST OF OFFICIAL OBSERVERS

NAME	COMPANY
Joseph M. Brickner	Intertek B&C
Dawn M. Chaney	Intertek B&C

SECTION 6
TEST PROCEDURE

All conditioning of test specimens and test conditions were at standard laboratory conditions unless otherwise reported. Refer to the test related photos in Section 10.

ASTM E228 - Linear Thermal Expansion
One specimen for each wire gage was measured for initial length using a 6" digital caliper (ICN: 65688) and placed in the bottom of an outer glass dilatometer tube with an inner glass tube resting on it. An aluminum support cylinder was utilized to keep the wire oriented in a vertical position. The dilatometer tube was suspended in a heated environment utilizing a muffle furnace (ICN: Y002864) and subjected to exposure conditions of nominally 25°C and 90°C. At the equilibrium of each temperature condition, specimen temperature was measured using a thermocouple reader (ICN: 62101) and a measurement was recorded from a digital indicator (ICN: INT00193) resting on top of the inner tube. The Linear Thermal Expansion between the temperature range was calculated.

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SECTION 7
TEST SPECIMEN DESCRIPTIONS

TEST PROCEDURE	NUMBER OF SPECIMENS	NOMINAL SPECIMEN DIMENSIONS	VISUAL CHARACTERISTICS
ASTM E228 Linear Thermal Expansion	1 each	75 mm x 14 gage wire thickness	Electrolytic Tough Pitch Copper wire

SECTION 8
TEST RESULTS

ASTM E228 - Linear Thermal Expansion

Electrolytic Tough Pitch (ETP) Copper Wire - 14 Gage

All Temperatures

LENGTH (mm)	75.60	
TARGET TEMPERATURE (°C)	25	90
ACTUAL TEMPERATURE (°C)	28.7	91.3
GAGE READING (mm)	5.6440	5.7220
ΔT (°C)		62.6
ΔL (mm)		0.0780
ΔL/ΔT (mm/°C)		1.25E-03
CLTE (mm/mm/°C)		**1.57E-05**

SECTION 9
CONCLUSION

The requested test method did not contain specific performance requirements.

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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.03-106-31 R0
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SECTION 10
PHOTOGRAPHS

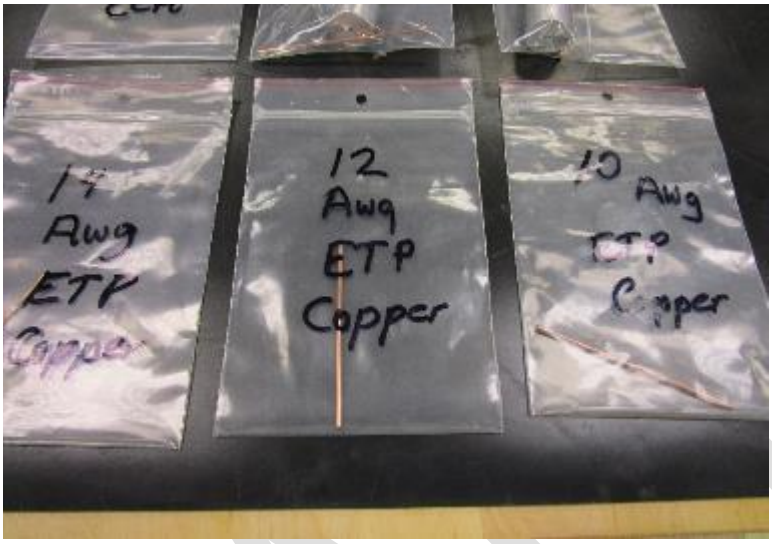

Photo No. 1
Electrolytic Tough Pitch - Specimen Detail

Photo No. 2
ASTM E228 - Equipment Detail

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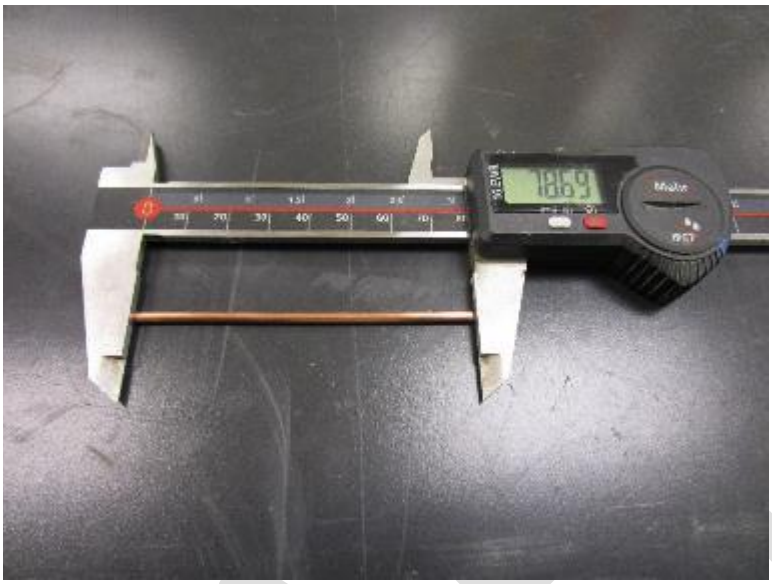

Photo No. 3
ASTM E228 - Length Measurement Equipment Detail

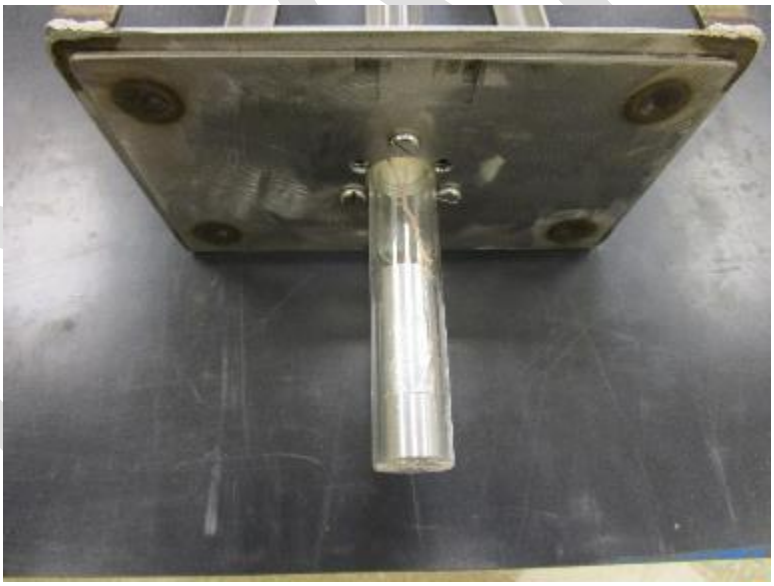

Photo No. 4
ASTM E228 - Specimen Support Detail

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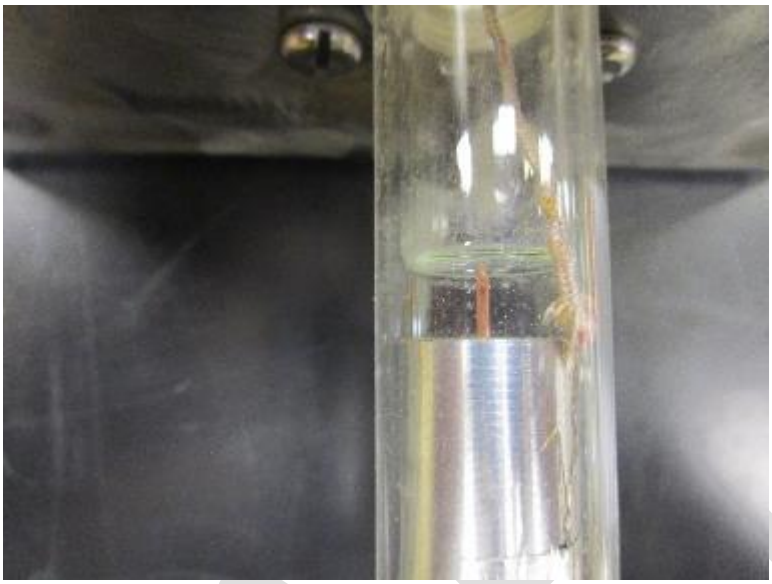

Photo No. 5
ASTM E228 - Specimen Temperature Measurement Detail

Photo No. 6
ASTM E228 - Linear Expansion Measurement Equipment Detail

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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.03-106-31 R0
Date: 08/15/18

SECTION 11
REVISION LOG

REVISION #	DATE	PAGES	REVISION
0	08/15/18	N/A	Original Report Issue

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Public Comment No. 1265-NFPA 70-2018 [Section No. 336.10]

336.10 Uses Permitted.

Type TC cable shall be permitted to be used as follows:

(1) For power, lighting, control, and signal circuits.

(2) In cable trays, including those with mechanically discontinuous segments up to 300 mm (1 ft).

(3) In raceways.

(4) In outdoor locations supported by a messenger wire.

(5) For Class 1 circuits as permitted in Parts II and III of Article 725.

(6) For non–power-limited fire alarm circuits if conductors comply with the requirements of 760.49.

(7) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(8) The cable is Type TC-ER.

(9) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(10) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(11) The cable complies with the crush and impact requirements of Type MC cable and is identified with the marking "TC–ER."

(12) The cable is secured at intervals not exceeding 1.8 m (6 ft).

(13) Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor must be provided within the cable or, at the time of installation, one or more insulated conductors must be permanently identified as an equipment grounding conductor in accordance with 250.119(B) .

Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and utilization equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

(14) Where installed in wet locations, Type TC cable shall also be resistant to moisture and corrosive agents.

(15) In one- and two-family dwelling units, Type TC-ER cable containing ~~both~~ power ~~and~~ conductors or control conductors or a combination of both that is identified for pulling through structural members shall be permitted for branch circuits and feeders. Type TC-ER cable used as interior wiring shall be installed per the requirements of Part II of Article 334 and where installed as exterior wiring shall be installed per the requirements of Part II of Article 340.

Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by 334.80 or 340.80.

Informational Note No. 1: TC-ER cable that is suitable for pulling through structural members is marked "JP."

Informational Note No. 2: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.

(16) Direct buried, where identified for such use.

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

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

Statement of Problem and Substantiation for Public Comment

If the cable is suitable where it contains a combination of power and control conductors, it is also suitable where it only contains power or control conductors. The construction of the cable is identical. If the product is permitted to be used suitable fittings will become available.

Related Item

• Public Input No. 13-NFPA 70-2017

Submitter Information Verification

Submitter Full Name: Don Ganiere
Organization: [Not Specified]
Street Address:
City:
State:
Zip:
Submittal Date: Sat Aug 25 00:04:01 EDT 2018
Committee: NEC-P06

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Public Comment No. 1625-NFPA 70-2018 [Section No. 336.10]

336.10 Uses Permitted.

Type TC cable shall be permitted to be used as follows:

(1) For power, lighting, control, and signal circuits.

(2) In cable trays, including those with mechanically discontinuous segments up to 300 mm (1 ft).

(3) In raceways.

(4) In outdoor locations supported by a messenger wire.

(5) For Class 1 circuits as permitted in Parts II and III of Article 725.

(6) For non–power-limited fire alarm circuits if conductors comply with the requirements of 760.49.

(7) Between a cable tray and ~~the utilization equipment~~ the equipment or device(s), provided all of the following apply:

(8) The cable is Type TC-ER.

(9) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(10) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(11) The cable complies with the crush and impact requirements of Type MC cable and is identified with the marking "TC–ER."

(12) The cable is secured at intervals not exceeding 1.8 m (6 ft).

(13) Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor must be provided within the cable or, at the time of installation, one or more insulated conductors must be permanently identified as an equipment grounding conductor in accordance with 250.119(B) .

Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and ~~utilization~~ equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

(14) Where installed in wet locations, Type TC cable shall also be resistant to moisture and corrosive agents.

(15) In one- and two-family dwelling units, Type TC-ER cable containing both power and control conductors that is identified for pulling through structural members shall be permitted for branch circuits and feeders. Type TC-ER cable used as interior wiring shall be installed per the requirements of Part II of Article 334 and where installed as exterior wiring shall be installed per the requirements of Part II of Article 340.

Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by 334.80 or 340.80.

Informational Note No. 1: TC-ER cable that is suitable for pulling through structural members is marked "JP."

Informational Note No. 2: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.

(16) Direct buried, where identified for such use.

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

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

Statement of Problem and Substantiation for Public Comment

The panel statement resolving PI 2851 did not provide a technical reason why connection to utilization equipment, as allowed by this section, has a lower hazard to the type TC-ER cables than allowing a span of type TC-ER cable between the cable tray and the distribution equipment. The utilization equipment is most often at floor level and would subject to much more possible physical contact from moving equipment and personnel than a type TC-ER cable installed above a MCC with the top at 90 or more inches above the finish floor. Installing cable tray drops to each section of a multi-section switchboard, switchgear or MCC is not necessarily practical nor does it increase the protection from physical damage the cable at this elevation may be subject to. The cable is specifically listed to be more robust, similar to MC cable, to protect from the physical hazards and as could be done with MC cable installed in cable tray, a span of up to 6 feet unsupported should be allowed.

Related Item

• PI 2851

Submitter Information Verification

Submitter Full Name: Charles Mello
Organization: Cdcmello Consulting Llc
Affiliation: Self
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 29 13:34:38 EDT 2018
Committee: NEC-P06

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Public Comment No. 180-NFPA 70-2018 [Section No. 336.10]

336.10 Uses Permitted.

Type TC cable shall be permitted to be used as follows:

(1) For power, lighting, control, and signal circuits.

(2) In cable trays, including those with mechanically discontinuous segments up to 300 mm (1 ft).

(3) In raceways.

(4) In outdoor locations supported by a messenger wire.

(5) For Class 1 circuits as permitted in Parts II and III of Article 725.

(6) For non–power-limited fire alarm circuits if conductors comply with the requirements of 760.49.

(7) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(8) The cable is Type TC-ER.

(9) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(10) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(11) The cable complies with the crush and impact requirements of Type MC cable and is identified with the marking "TC–ER."

(12) The cable is secured at intervals not exceeding 1.8 m (6 ft).

(13) Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor must be provided within the cable or, at the time of installation, one or more insulated conductors must be permanently identified as an equipment grounding conductor in accordance with 250.119(B) .

Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and utilization equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

(14) Where installed in wet locations, Type TC cable shall also be resistant to moisture and corrosive agents.

(15) In one- and two-family dwelling units, Type TC-ER-JP cable containing both power and control conductors ~~that is identified for pulling through structural members~~ shall be permitted for branch circuits and feeders. Type TC-ER-JP cable used as interior wiring shall be installed per the requirements of Part II of Article 334 and where installed as exterior wiring shall be installed per the requirements of Part II of Article 340.

Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by 334.80 or 340.80.

Informational Note

~~No. 1~~

:

~~TC-ER cable that is suitable for pulling through structural members is marked "JP." Informational Note No. 2:~~

See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.

(16) Direct buried, where identified for such use.

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

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

Additional Proposed Changes

File Name	Description	Approved
336.10_9_PC.DOCX	Legislative test of proposal	

Statement of Problem and Substantiation for Public Comment

Substantiation;
Currently, the 2017 NEC as well as the first draft of the 2020 states TC-ER cable that is identified for pulling through structural members shall be permitted, but falls short of how the cable is to be identified. Informational Note No. 1 identifies that TC-ER cable that is suitable for pulling through structural members is marked “JP.” Unfortunately, per the NEC Style manual, information notes are not enforceable language.
The term identified as defined in Article 100; Recognizable as suitable for the specific purpose, function, use, environment, application, and so forth, where described in a particular Code requirement. This language makes it difficult for AHJ’s to determine how TC-ER cable is to be marked to specifically identify that it is suitable for pulling through structural members.
NEC Section 336.6 requires Type TC cable to be listed. UL 1277 (Standard For Safety For Electrical Power and Control Tray Cables with Optional Optical-Fiber Members) states that the supplementary letters ″-JP″ shall be added after the type letters TC-ER for cable that complies with the test requirements in Pulling-Through-Joists Test. Additionally, UL Product Category QPOR (Power and Control Tray Cable), under the heading “Product Marking” states that “Cable suitable for pulling through structural members in accordance with NEC 336.10(9) is surface marked with the suffix "-JP" after the type designation "TC-ER." Therefore, if 336.10(9) required the cable to be marked “TC-ER-JP” that would eliminate any confusion between AHJ’s and installers as well as fall in line with the marking requirements of applicable product standard.

Related Item

• FR8032

Submitter Information Verification

Submitter Full Name: Susan Stene
Organization: UL LLC
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jul 09 08:35:46 EDT 2018
Committee: NEC-P06

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336.10(9)

In one- and two-family dwelling units, Type TC-ER-JP cable containing both power and control conductors ~~that is identified for pulling through structural members~~ shall be permitted for branch circuits and feeders. Type TC-ER-JP cable used as interior wiring shall be installed per the requirements of Part II of Article 334 and where installed as exterior wiring shall be installed per the requirements of Part II of Article 340.

Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by 334.80 or 340.80.

~~Informational Note No. 1: TC-ER cable that is suitable for pulling through structural members is marked "JP."~~

Informational Note ~~No. 2~~: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.

Public Comment No. 1887-NFPA 70-2018 [Section No. 336.10]

336.10 Uses Permitted.

Type TC cable shall be permitted to be used as follows:

(1) For power, lighting, control, and signal circuits.

(2) In cable trays, including those with mechanically discontinuous segments up to 300 mm (1 ft).

(3) In raceways.

(4) In outdoor locations supported by a messenger wire.

(5) For Class 1 circuits as permitted in Parts II and III of Article 725.

(6) For non–power-limited fire alarm circuits if conductors comply with the requirements of 760.49.

(7) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(8) The cable is Type TC-ER.

(9) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(10) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(11) The cable complies with the crush and impact requirements of Type MC cable and is identified with the marking "TC–ER."

(12) The cable is secured at intervals not exceeding 1.8 m (6 ft).

(13) Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor must be provided within the cable or, at the time of installation, one or more insulated conductors must be permanently identified as an equipment grounding conductor in accordance with 250.119(B) .

Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and utilization equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

(14) Where installed in wet locations, Type TC cable shall also be resistant to moisture and corrosive agents.

(15) In one- and two-family dwelling units, Type TC-ER cable containing ~~both power and control~~ conductors that is identified for pulling through structural members shall be permitted for branch circuits and feeders. Type TC-ER cable used as interior wiring shall be installed per the requirements of Part II of Article 334 and where installed as exterior wiring shall be installed per the requirements of Part II of Article 340.

Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by 334.80 or 340.80.

Informational Note No. 1: TC-ER cable that is suitable for pulling through structural members is marked "JP."

Informational Note No. 2: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.

(16) Direct buried, where identified for such use.

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

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

Statement of Problem and Substantiation for Public Comment

Greetings Code Panel Members,

This PC shows extensive underlined items. However, my only change to this FR is the removal of the "Power and Control" in item 9 of this section. There has been no substantiation as to the need for both power and control in the TC cable for this use. The insulation on the power and the control would be at the same insulation ratings. It seems that this panel has some "personal" interest in not seeing the expanded use type TC Cable in such a benign environment. Ironically some of the members of this panel believe type TC Cable is made for the harsh industrial environment yet fail to see the less harsh and rather subtle environment of a single family or two family dwelling where we already permit other nonmetallic type wiring methods to be used. Arguing that Type TC cable is not as robust as type SE-R is misleading or foolish at best even if type TC cable is not tested to the same UL standard as type SE cable. In fact, when the type TC cable is rated for direct burial it would be acceptable in locations that type SE can't go yet there seems to be some fear that it is constructed differently, other than the fiberglass binder the inners are identical and the extruded covering is thicker and well suited for the expanded use.

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 1894-NFPA 70-2018 [Section No. 230.30(B)]	

Related Item

• PI 200 • PI 210 • PI 220

Submitter Information Verification

Submitter Full Name: Paul Abernathy
Organization: Encore Wire Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 30 11:07:07 EDT 2018
Committee: NEC-P06

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Public Comment No. 1888-NFPA 70-2018 [Section No. 336.10]

336.10 Uses Permitted.

Type TC cable shall be permitted to be used as follows:

(1) For power, lighting, control, and signal circuits.

(2) In cable trays, including those with mechanically discontinuous segments up to 300 mm (1 ft).

(3) In raceways.

(4) In outdoor locations supported by a messenger wire.

(5) For Class 1 circuits as permitted in Parts II and III of Article 725.

(6) For non–power-limited fire alarm circuits if conductors comply with the requirements of 760.49.

(7) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(8) The cable is Type TC-ER.

(9) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(10) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(11) The cable complies with the crush and impact requirements of Type MC cable and is identified with the marking "TC–ER."

(12) The cable is secured at intervals not exceeding 1.8 m (6 ft).

(13) Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor must be provided within the cable or, at the time of installation, one or more insulated conductors must be permanently identified as an equipment grounding conductor in accordance with 250.119(B) .

Exception to (7): Where not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and utilization equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

(14) Where installed in wet locations, Type TC cable shall also be resistant to moisture and corrosive agents.

(15) ~~In one- and two-family dwelling units, Type TC-ER cable containing both power and control conductors that is identified for pulling through structural members shall be permitted for branch circuits and feeders.~~ For Service, Feeders and Branch Circuits (a) Interior Installations. In addition to the provisions of this article, Type TC-ER cable used ~~as~~ for interior wiring shall ~~be installed per~~ comply with the installation requirements of ~~Part II~~ Part II of Article 334 , excluding 334.80. For Type TC-ER cable with ungrounded conductor sizes 10 AWG and smaller, where installed ~~as exterior wiring shall be installed per the requirements of Part II of Article 340.~~

~~*Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by 334.80 or 340.80 .*~~

~~Informational Note No. 1:~~ in thermal insulation, the ampacity shall be in accordance with 60°C (140°F) conductor temperature rating. The maximum conductor temperature rating shall be permitted to be used for ampacity adjustment and correction purposes, if the final derated ampacity does not exceed that for a 60°C (140°F) rated conductor.

Informational Note No. 1: See 310.15(A)(3) for temperature limitation of conductors.

Informational Note No. 2: For the installation of main power feeder conductors in dwelling units refer to 310.15(B)(7).

Informational Note No. 3: TC-ER cable that is suitable for pulling through structural members is marked "JP."

~~Informational Note No. 2: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.~~
(b) Exterior Installations. In addition to the provisions of this article, Type TC-ER cable used for feeders or branch circuits, where installed as exterior wiring, shall be installed in accordance with

Part I of Article 225. The cable shall be installed per the requirements of Part II of Article 340.

(16) Direct buried, where identified for such use.

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

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

Statement of Problem and Substantiation for Public Comment

Greetings Panel Members,

In the refusal statement of the PI 210 the committee stated their reason for not expanding the use of type TC cable, even if the inners are exactly the same as those of Type SE-R was due to the lack of fittings available. However, there are a vast array of fittings available on the market for Type TC Cable. I believe that is also evident in the push to expand type TC in hazardous locations as well. The fact is there are plenty of manufacturers on the market who make fittings for use with type TC cable. Do we really think that a wiring method that has been around for decades, used in both commercial and industrial installations for decades would lack fittings? Again, some individuals would tend to point out that type TC cable is designed for commercial and industrial installations get it is not ok for a residential installation? Also the ability for the cable to contain both power and control is not an issue with the safe operation of the cable assembly since all insulation would have to be at the same temperature ratings. Not expanding the use of type TC cable is because some folks who do not have an interest in it to see it expand to create a competing product plain and simple.

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 1894-NFPA 70-2018 [Section No. 230.30(B)]	

Related Item

• PI 210 • PI 207 • PI 209

Submitter Information Verification

Submitter Full Name: Paul Abernathy
Organization: Encore Wire Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 30 11:18:00 EDT 2018
Committee: NEC-P06

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Public Comment No. 72-NFPA 70-2018 [Section No. 336.10]

336.10 Uses Permitted.

Type TC cable shall be permitted to be used as follows:

(1) For power, lighting, control, and signal circuits.

(2) In cable trays, including those with mechanically discontinuous segments up to ~~300 mm (1 ft)~~ 6 ft .

(3) In raceways.

(4) In outdoor locations supported by a messenger wire.

(5) For Class 1 circuits as permitted in Parts II and III of Article 725.

(6) For non–power-limited fire alarm circuits if conductors comply with the requirements of 760.49.

(7) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(8) The cable is

~~Type TC-ER.The cable is~~

a. installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

b. The cable

~~is continuously supported and protected~~

a. is protected against physical damage using mechanical protection such as struts, angles, or channels.

b. The cable

~~complies with the crush and impact requirements of Type MC cable and~~

a. is

~~identified with the marking "TC–ER."The cable is~~

a. secured at intervals not exceeding 1.8 m (6 ft).

b. Equipment grounding for the utilization equipment is provided by an equipment grounding conductor within the cable. In cables containing conductors sized 6 AWG or smaller, the equipment grounding conductor must be provided within the cable or, at the time of installation, one or more insulated conductors must be permanently identified as an equipment grounding conductor in accordance with 250.119(B) .

~~Exception to (7):~~

(9) Where

~~not subject to physical damage, Type TC-ER shall be permitted to transition between cable trays and between cable trays and utilization equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.~~

(10) ~~Where~~ installed in wet locations, Type TC cable shall also be resistant to moisture and corrosive agents.

(11) In one- and two-family dwelling units, Type TC-ER cable containing both power and control conductors that is identified for pulling through structural members shall be permitted for branch circuits and feeders. Type TC-ER cable used as interior wiring shall be installed per the requirements of Part II of Article 334 and where installed as exterior wiring shall be installed per the requirements of Part II of Article 340.

Exception: Where used to connect a generator and associated equipment having terminals rated 75°C (140°F) or higher, the cable shall not be limited in ampacity by 334.80 or 340.80.

Informational Note No. 1: TC-ER cable that is suitable for pulling through structural members is marked "JP."

Informational Note No. 2: See 725.136 for limitations on Class 2 or 3 circuits contained within the same cable with conductors of electric light, power, or Class 1 circuits.

(12) Direct buried, where identified for such use.

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

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

Statement of Problem and Substantiation for Public Comment

PI 8010 allows multi-conductor cables to be outside of tray for 6 feet. Aligning.

Now, the only thing offered in TC-ER over TC is the ability to run passed 6 ft with continuous support. This makes me further question the real differences between TC-ER and MC.

1. Required to have the same crush rating as MC.
2. If you allow 6 feet between trays, what is the difference between an intervals of supporting every 6 feet?
3. Continuous support is not referenced anywhere in the code, and it seems impracticable. Vertical runs cannot be considered continuous support. Neither can cable tray be considered “continuous”: there is no requirement for rung spacing for multiconductors. (12” rung spacing seems to be the typical from NEMA VE-1)
4. No maximum run for TC-ER outside of tray. (Several articles show this as 50 ft, but I don’t see this in the Code. UL standard?)

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 69-NFPA 70-2018 [Section No. 392.30(B)]	

Related Item

• First Revision No. 8010-NFPA 70-2018

Submitter Information Verification

Submitter Full Name: Evan Zaker
Organization: Intel Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Wed Jun 27 19:24:49 EDT 2018
Committee: NEC-P06

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Public Comment No. 412-NFPA 70-2018 [Section No. 336.80]

336.80 Ampacity.

~~The~~ (A) Installed in Cable Tray. Where installed in a cable tray, the ampacity of Type TC tray cable shall be determined in accordance with 392.80(A) for 14 AWG and larger conductors, in accordance with 402.5 for 18 AWG through 16 AWG conductors ~~where~~ .

(B) Installed in Other than Cable Trays. Where installed in other than cable trays, ~~and~~ the ampacity of Type TC tray cable shall be determined in accordance ~~with~~ with 310. ~~14 where installed outside of cable trays, where permitted~~ 15 .

Statement of Problem and Substantiation for Public Comment

I revised the text into a list and corrected the reference of 310.14 to 310.15. But I'm wondering if it was the intent to reference 310.14.

Related Item

• FR-8032

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 05 14:18:53 EDT 2018
Committee: NEC-P06

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Public Comment No. 1411-NFPA 70-2018 [Section No. 336.104 [Excluding any Sub-Sections]]

The insulated conductors of Type TC cables shall be in sizes 18 AWG to 1000 kcmil copper, nickel, or nickel-coated copper, 14 AWG copper-clad aluminum , and sizes 12 AWG through 1000 kcmil aluminum

~~or~~

~~or copper-clad aluminum~~ . Insulated conductors of sizes 14 AWG, and larger copper, copper-clad aluminum, nickel, or nickel-coated copper, and sizes 12 AWG through 1000 kcmil

~~aluminum~~

aluminum ~~or copper-clad~~

~~aluminum~~

~~aluminum~~ shall be one of the types listed

~~in Table~~

in Table 310.

4

104 (A)

~~or Table~~

or Table 310.

4

104 (B)

~~that~~

that is suitable for branch circuit and feeder circuits or one that is identified for such use.

Additional Proposed Changes

File Name	Description	Approved
Prop_Table_310.16_310.15_B_16_.pdf	Proposed 310.16 Table Which Will Include 14 AWG Copper Clad Aluminum	
Proposed_Table_310.17_310.15_B_17_.pdf	Proposed 310.17 Table	
14_AWG_CCA_Summary.NSFvETL.pdf	NSF and Intertek Heat Data Statistically Similar	
CONCLUSIONS_FROM_UL_486C_SPRING.pdf	Summary of UL 486C Spring Action Sequence by Intertek	
14_AWG_Thermal_Expansion_Summary.1535458407587_2_.pdf	Summary of 14 AWG CCA Lack of Thermal Expansion vs. 14 AWG ETP Copper	
J-00265162_FINAL_Copperweld_FFR-_CCA-Cu_Final_Report_Revised_10-27-17.pdf	NSF Fact Finding Report on Copper Clad Aluminum 10, 12 and 14 AWG	
Intetek.UL486C.SAS.103589128CRT-001A_003_.pdf	UL 486C Test Report Intertek, CCA 14 AWG Copper-Only Push-In Connectors. Extreme Over-current.	
ETL.14awgCCA.Thermalstablei6049.04-106-31-r0.pdf	14 AWG Copper Clad Aluminum: Report: ASTM E228 Lineal Thermal Expansion, INTERTEK NRTL	
ETL.14awgCu.Thermalstablei6049.03-106-31-r0.pdf	14 AWG ETP Copper: Report ASTM E228 Lineal Thermal Expansion, INTERTEK NRTL	

Statement of Problem and Substantiation for Public Comment

PUBLIC COMMENT RESPONSE:

- NEC Needs to Change First. Public inputs 3174, 2123 and 2131 were submitted to provide for 14 AWG copper-clad aluminum as a recognized conductor in Article 310 and 336. It is agreed that the product standard does not recognize 14 AWG copper-clad aluminum but product standards follow what is allowed in the NEC and the standard would not be changed to allow something that is not allowed by the NEC. Therefore, the NEC needs to make the change first deeming 14 AWG copper-clad aluminum suitable for use. Using the lack of product safety standard recognition as reasoning to not allow is creating an untenable catch 22.
- New Technology and Energy Efficiency have Ideal Uses for 14 AWG Copper-clad Aluminum. With the evolution of LED Lighting and Energy Efficient Equipment, the industry substantiates a need for 14 AWG copper-clad aluminum, even at an ampacity of 10 Amps, and it should be recognized by article 336. For copper-clad aluminum in general, there is no documented instances of failures that would cause a belief that there is a safety issue. With the ampacity limitations proposed for use of 14 AWG copper-clad aluminum and the testing data that backs it up, there is no technical reason for CMP-6 to not allow for 14 AWG copper-clad aluminum as a suitable conductor.
- 14 AWG and “smaller” ASTM B566 copper-clad aluminum wires have been safely used for decades in applications (as the individual strands of stranded conductors forming THHN, SEU, PV, Battery Cable, Large Appliance Cord, Jumper Cable, among others) and Data applications (coaxial and trunk cables). ASTM B566 copper-clad aluminum wire is routinely drawn to 22 AWG for applications in power, and 34 AWG for applications in data. There has been no technical substantiation given by CMP6 as to why 14 AWG ASTM B566 copper-clad aluminum wire made with an AA-8000 series aluminum core is unsuitable to be recognized by article 336. 14 AWG could be included in the UL standard for MC cable if it were recognized by article 310. Thermal Stability, Mechanical Integrity and Electrical Performance have never been questioned.

- Old History Should Not Imped with New Data as Provided. When the initial ampacities for copper-clad aluminum were introduced into the 1971 NEC, copper-clad aluminum and aluminum were grouped together right wrong or indifferent. To not recognize 14 AWG ASTM B566 copper-clad aluminum wire in article 336 appears to be a clear case of CMP6 confusing it with single-metal aluminum wire, which carries historical baggage with single metal aluminum. ASTM B566 copper-clad aluminum wire’s safety record is spotless in the electrical field, evidenced by CMP6’s lack of ability to site instances of failure. Today’s fact finding has documented that 14 AWG copper-clad aluminum is safe for use at the ampacities proposed and has had testing for terminals, corrosion elongation and other aspects conducted for existing UL listings.

Related Item

- 2131

Submitter Information Verification

Submitter Full Name: Peter Graser
Organization: Copperweld
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 28 09:23:12 EDT 2018
Committee: NEC-P06

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Table 310.15(B)(16) (formerly Table 310.16) Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)*

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.104(A).]									Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	COPPER			COPPER-CLAD ALUMINUM			ALUMINUM ~~OR COPPERCLAD ALUMINUM~~			
18**	-	-	14	-	-	-	-	-	-	-
16**	-	-	18	-	-	-	-	-	-	-
14**	15	20	25	10	15	20	-	-	-	-
12**	20	25	30	15	20	25	15	20	25	12**
10**	30	35	40	25	30	35	25	30	35	10**
8	40	50	55	35	40	45	35	40	45	8
6	55	65	75	40	50	55	40	50	55	6
4	70	85	95	55	65	75	55	65	75	4
3	85	100	115	65	75	85	65	75	85	3
2	95	115	130	75	90	100	75	90	100	2
1	110	130	145	85	100	115	85	100	115	1
1/0	125	150	170	100	120	135	100	120	135	1/0
2/0	145	175	195	115	135	150	115	135	150	2/0
3/0	165	200	225	130	155	175	130	155	175	3/0
4/0	195	230	260	150	180	205	150	180	205	4/0
250	215	255	290	170	205	230	170	205	230	250
300	240	285	320	195	230	260	195	230	260	300
350	260	310	350	210	250	280	210	250	280	350
400	280	335	380	225	270	305	225	270	305	400
500	320	380	430	260	310	350	260	310	350	500
600	350	420	475	285	340	385	285	340	385	600
700	385	460	520	315	375	425	315	375	425	700
750	400	475	535	320	385	435	320	385	435	750
800	410	490	555	330	395	445	330	395	445	800
900	435	520	585	355	425	480	355	425	480	900
1000	455	545	615	375	445	500	375	445	500	1000
1250	495	590	665	405	485	545	405	485	545	1250
1500	525	625	705	435	520	585	435	520	585	1500
1750	545	650	735	455	545	615	455	545	615	1750
2000	555	665	750	470	560	630	470	560	630	2000

*Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F). Refer to 310.15(B)(3)(a) for more than three current-carrying conductors.

**Refer to 240.4(D) for conductor overcurrent protection limitations.

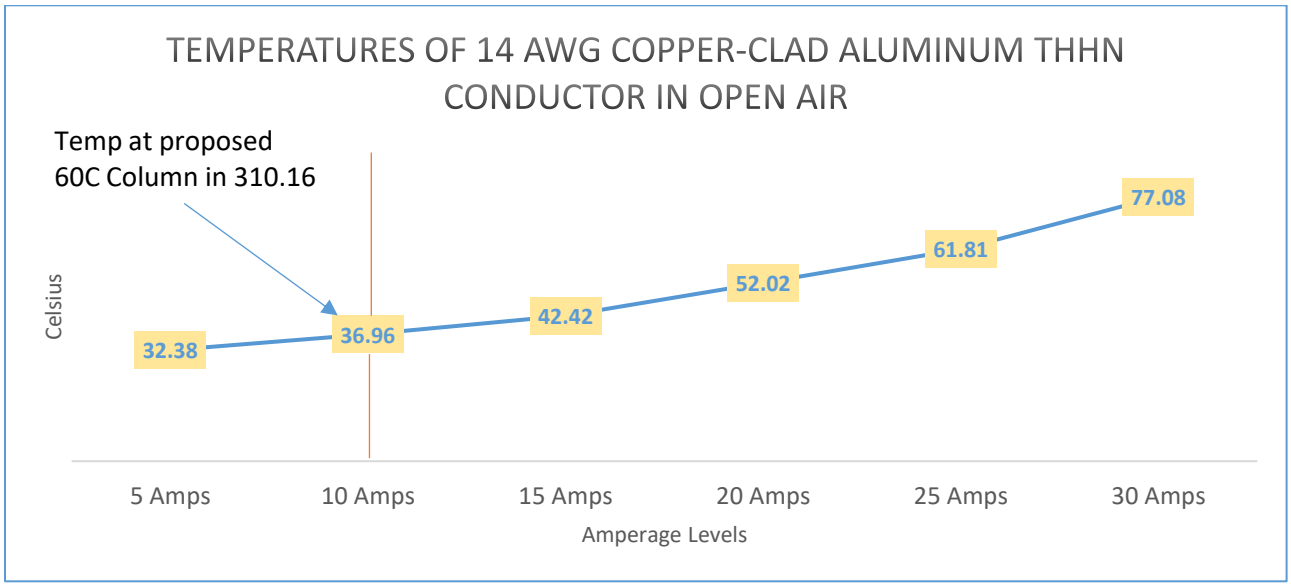
Table 310.15(B)(17) (formerly Table 310.17) Allowable Ampacities of Single-Insulated Conductors Rated Up to and Including2000 Volts in Free Air, Based on Ambient Temperature of 30°C (86°F)*

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.104(A).]									Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW,	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	COPPER			COPPER-CLAD ALUMINUM			ALUMINUM ~~OR COPPERCLAD ALUMINUM~~			
18**	-	-	18	-	-	-	-	-	-	-
16**	-	-	24	-	-	-	-	-	-	-
14**	25	30	35	20	25	30	-	-	-	-
12**	30	35	40	25	35	40	25	30	35	12**
10**	40	50	55	35	40	50	35	40	45	10**
8	60	70	80	45	55	60	45	55	60	8
6	80	95	105	60	75	85	60	75	85	6
4	105	125	140	80	100	115	80	100	115	4
3	120	145	165	95	115	130	95	115	130	3
2	140	170	190	110	135	150	110	135	150	2
1	165	195	220	130	155	175	130	155	175	1
1/0	195	230	260	150	180	205	150	180	205	1/0
2/0	225	265	300	175	210	235	175	210	235	2/0
3/0	260	310	350	200	240	270	200	240	270	3/0
4/0	300	360	405	235	280	315	235	280	315	4/0
250	340	405	455	265	315	355	265	315	355	250
300	375	445	500	290	350	395	290	350	395	300
350	420	505	570	330	395	445	330	395	445	350
400	455	545	615	355	425	480	355	425	480	400
500	515	620	700	405	485	545	405	485	545	500
600	575	690	780	455	545	615	455	545	615	600
700	630	755	850	500	595	670	500	595	670	700
750	655	785	885	515	620	700	515	620	700	750
800	680	815	920	535	645	725	535	645	725	800
900	730	870	980	580	700	790	580	700	790	900
1000	780	935	1055	625	750	845	625	750	845	1000
1250	890	1065	1200	710	855	965	710	855	965	1250
1500	980	1175	1325	795	950	1070	795	950	1070	1500
1750	1070	1280	1445	875	1050	1185	875	1050	1185	1750
2000	1155	1385	1560	960	1150	1295	960	1150	1295	2000

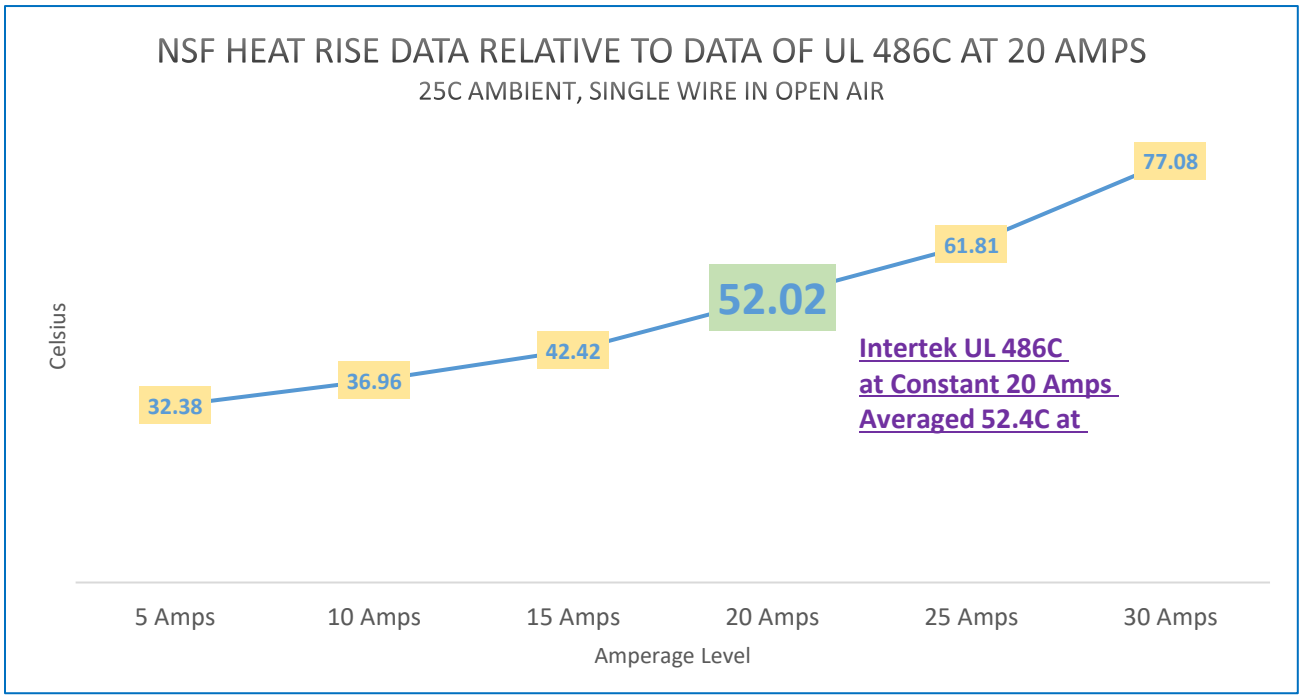
*Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F).
**Refer to 240.4(D) for conductor overcurrent protection limitations.

14 AWG CCA SAFE AT PROPOSED AMPERAGE OF TABLE 310.16:

UL 486C Testing Confirms NSF Data



Data Results of Fact Finding from NRTL Certified Electrical Lab, NSF. Orange Line Indicates Proposed Amperage of 14 AWG Copper-Clad Aluminum (ASTM B566) at 60C in Table 310.16



Average Heat Generated at 20 Amps by 14 AWG Copper-Clad Aluminum (ASTM B-566) is practically the same when comparing the testing done by NSF Electrical and that done by Intertek. Both labs are NRTL's with OSHA certified electrical labs. For 14 AWG CCA, NSF averaged 52.02C at 20 Amps, whereas Intertek Averaged 52.4C at 20 Amps.

14 AWG CCA SAFE AT PROPOSED AMPERAGE OF TABLE 310.16:

UL 486C Testing Confirms NSF Data

CONCLUSION:

At a temperature of 36.96 C° at Full Circuit of 10 Amps in the 60C column of proposed table 310.16, 14 AWG Copper-Clad Aluminum (ASTM B-566) is SAFE even considering elevated ambient temperatures. 75°C is the minimum temperature rating of insulation for the vast majority of general wiring applications, with the most utilized insulation types (THHN, XHHW, for example) rated at 90°C. All modern branch circuit components (switches, connectors, equipment and receptacles) are rated at a minimum of 75°C, most at 90°C. Even in severe overcurrent conditions, heat rise temperatures of 14 AWG Copper-Clad Aluminum (ASTM B-566) are well below the rating of the wire insulation and circuit components. OCPD's exist today for 10 Amp circuits, thus making 14 AWG Copper-Clad Aluminum wire a viable option. LED and Energy Star Equipment are driving the trend for more efficient circuits.

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July 14, 2019
Effective Through

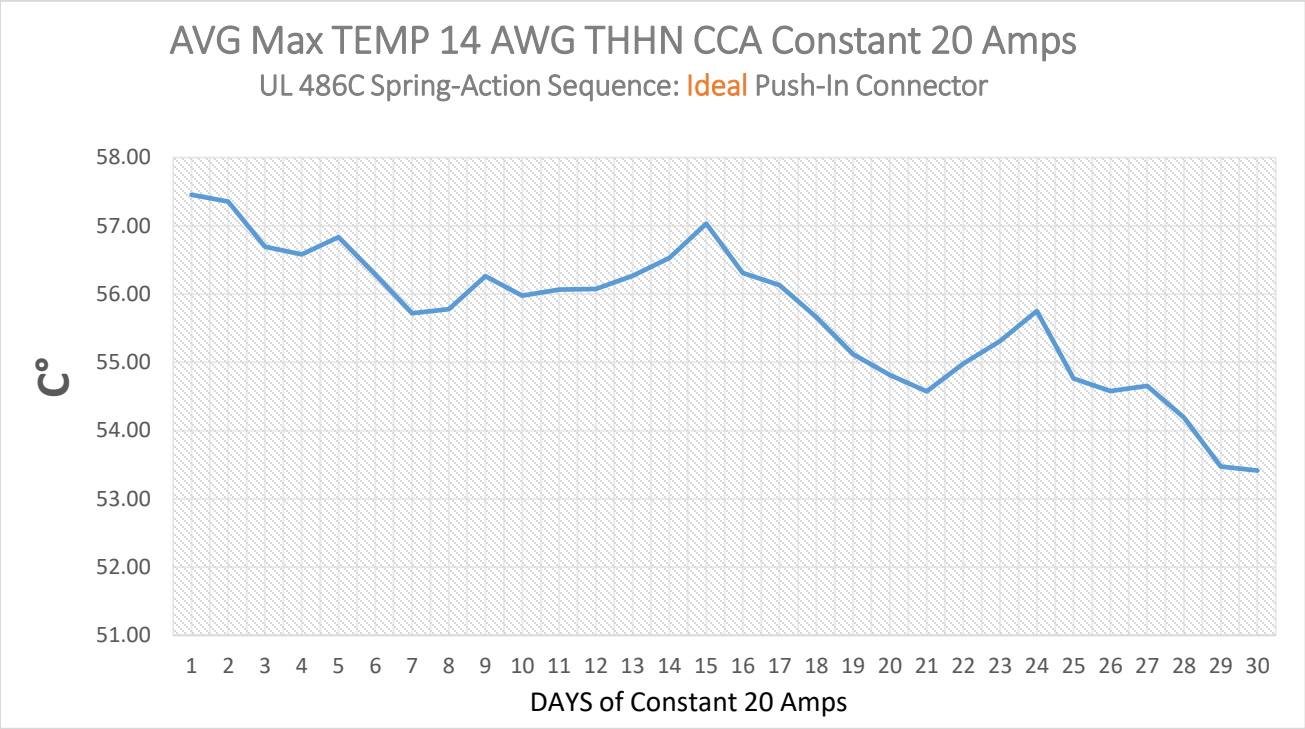
David Michaels, PhD, MPH
Assistant Secretary of Labor for
Occupational Safety and Health Administration

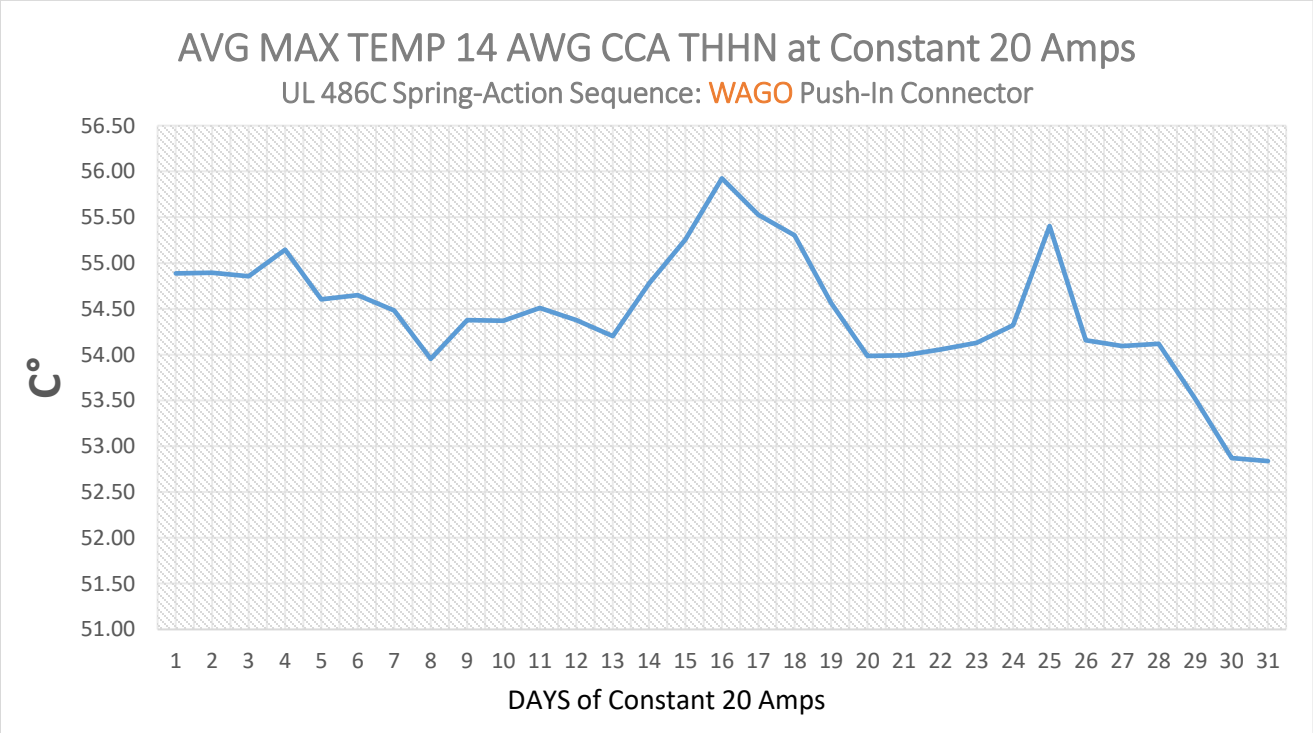
OSHA Scope of Recognition for NSF Electrical: https://www.osha.gov/dts/otpca/nrtl/nsf.html

Among other electrical equipment and circuit components, the NSF Scope of Recognition Includes Small Electrical Appliances, Wired Cabinets, Luminaires, Washers, Driers, Residential Water Heaters, Electric Ranges and Temperature Measuring Equipment. Heat Rise Testing is Routine at NSF.

Performance of
14 AWG CCA THHN Under EXTREME OVERCURRENT CONDITION

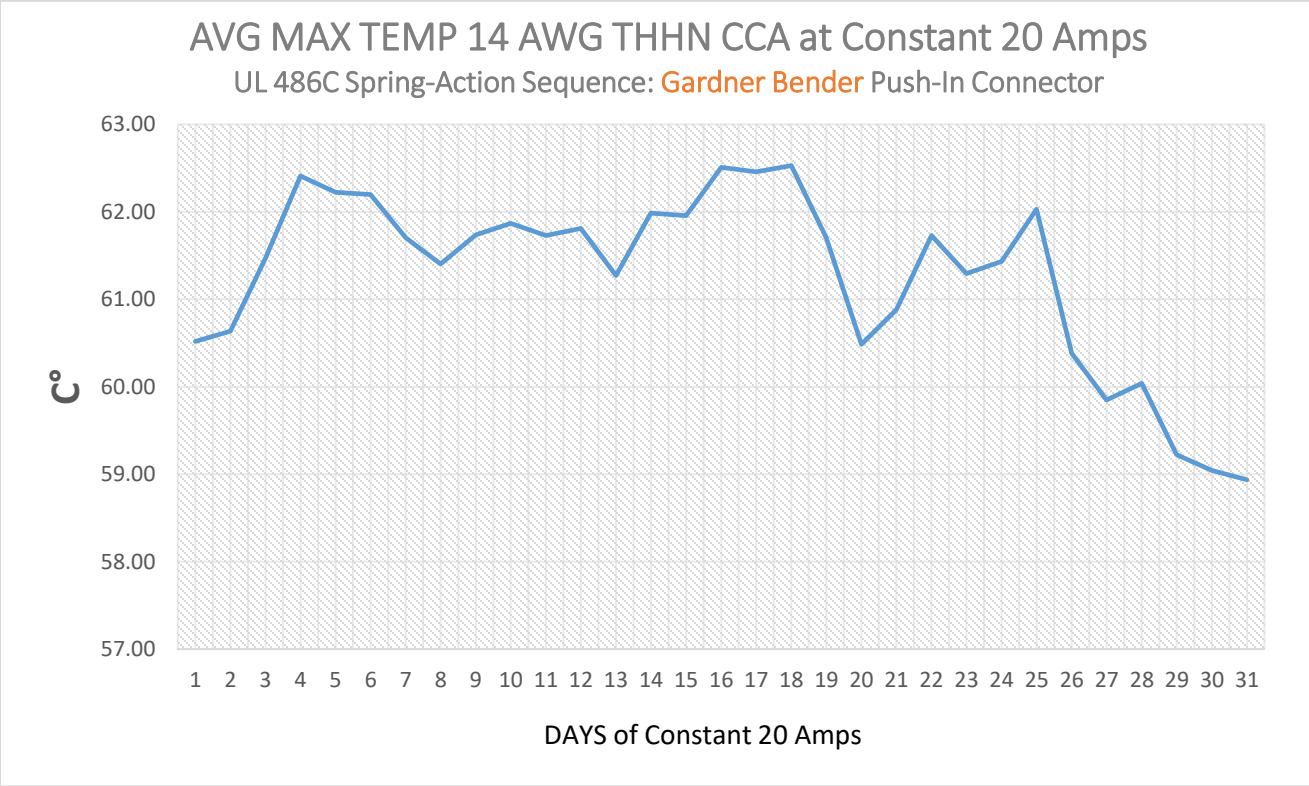
Three Push-In Connectors Tested By Intertek (NRTL with Wire & Cable in Scope of Recognition) to UL 486C Spring-Action Sequence





Performance of
14 AWG CCA THHN Under EXTREME OVERCURRENT CONDITION

Three Push-In Connectors Tested By Intertek (NRTL with Wire & Cable in Scope of Recognition) to UL 486C Spring-Action Sequence

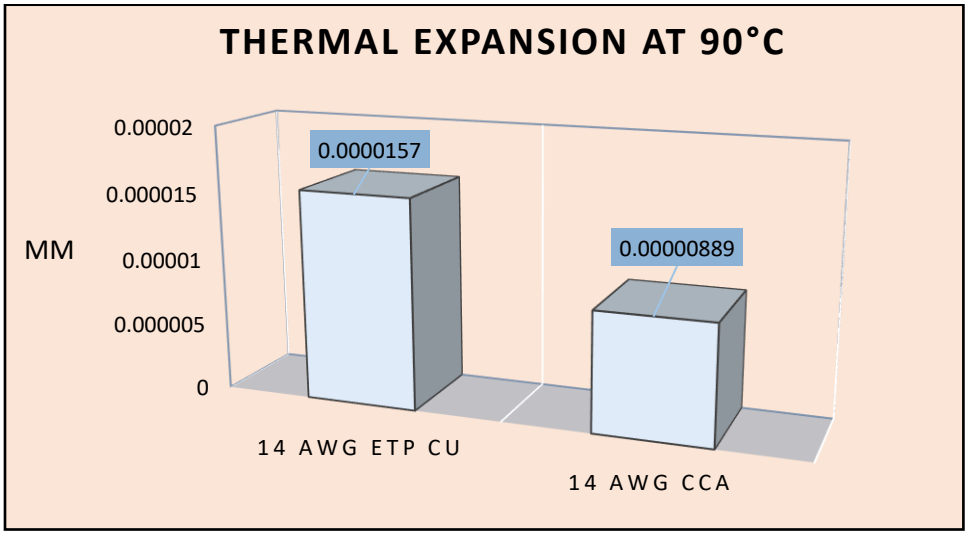


CONCLUSIONS FROM UL 486C SPRING-Action SEQUENCE TESTING REG 14 AWG THHN MADE WITH ASTM B566 COPPER-CLAD ALUMINUM WIRE:

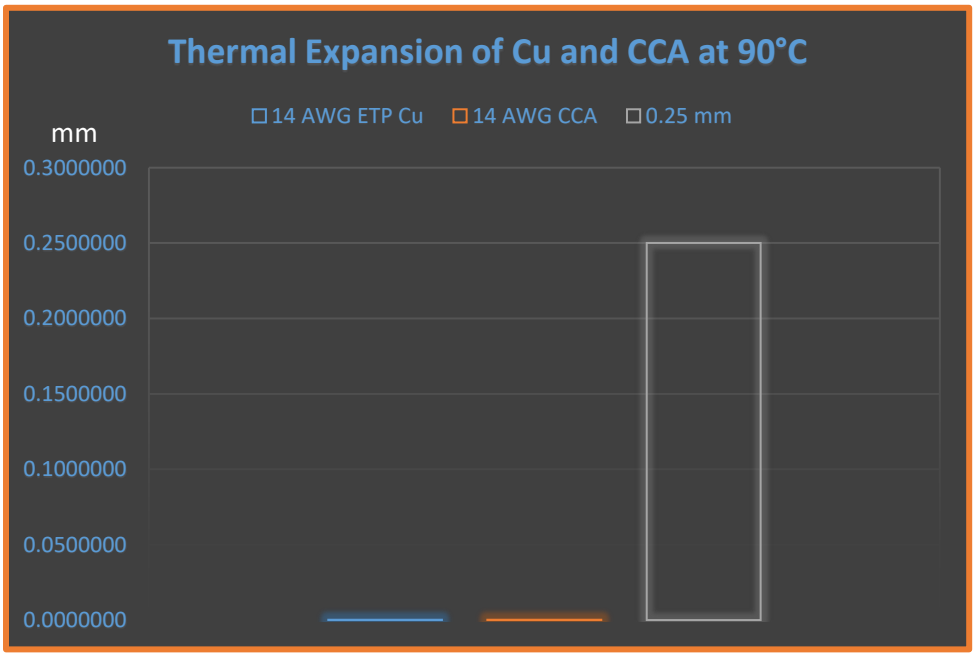
- The THHN Insulation (Rated at 90°C) Remained in Good Condition Throughout the Test
- Over 30 Days at Constant 20 Amps (twice the amperage of the proposed amperage at 60°C column requested by Public Comment 1402), the highest temperature registered by 14 AWG CCA was under 63°C. Over Current Protection Devices (OCPD's) are in place in a circuit to keep wire from over-heating. OCPD's will open the circuit when the amperage limit (10 amps in case of 14 AWG CCA) is reached.
- Ambient Temperature of 23°C Over 30 Days, Standard Deviation of ½ °C
- Average Max Temperatures decreased by 3°C over the month when connected to the three brands of push-in connectors
- The Gardner Bender Connector created more heat (+/- 6°C) within the wire than the other two test subjects
- Of the nine push-in connectors tested (three different brands), not one saw degradation or damage due to excessive heat, despite the constant over-current condition applied to the wire
- The wire remained thermally stable at the points of termination over all nine push-in connectors, and no arc-faulting was observed due to thermal expansion of the wire

At 90°C, 14 AWG Copper-Clad Aluminum is nearly Twice as Thermally Stable as 14 AWG ETP Copper

Testing By Intertek B&C Labs per ASTM 228 Linear Thermal Expansion



At 90C, ETP 14 AWG Cu expands nearly twice that of Copper Clad Aluminum 14 AWG



At 90°C, Both Copper Clad Aluminum and Copper are Extremely Thermally Stable

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789 N. Dixboro Rd. Ann Arbor, MI 48015, USA
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TEST REPORT

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Peter Graser
Copperweld Bimetallic
215 Centerview Dr
Brentwood TN 37027

Facility: C0352008
Copperweld Bimetallic
215 Centerview Dr
Brentwood TN 37027

Report Date: October 27, 2017

Description:	CCA –Cu Ampacity Comparison
Type of Evaluation	Fact Finding Investigation
Job Number	J-00265162
Project Number	0225-104
Project Manager	Don Tottingham
Location	789 Dixboro Road, Ann Arbor
Inspection Dates	August 7- August 18, 2017
Total # of Pages	125 Pages

Evaluated By: _____

Anas Alaghazali- Engineer

Reviewed By: Steve Fabian

Steve Fabian- Senior Technical Manager

Thank you for having your product tested by NSF International.

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Purpose: The purpose of this testing was to evaluate copper clad aluminum wire (CCA) and copper wire (Cu) as a single conductor, non- -metallic 2 hot conductors, and two conductor in conduit, under the same current condition, and to determine their equivalence in performance

Credentials: NSF International, an accredited Nationally Recognized Testing Laboratory (NRTL), an Accredited Standards Council of Canada (SCC) laboratory, and accredited by the International Standards Organization (ISO) to ISO 14001.

Executive Summary: This Fact-Finding Investigation was conducted to develop a comparative temperature – heat rise database for Copper and Copper-Clad Aluminum Conductors in Sizes No. 14 -10 AWG.

The details of the test procedure for each conductor size, 14-10 AWG, is outlined in the report.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 14 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 18, 29, and 38.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 12 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 50, 61, and 71.

The comparative CCA - Cu temperature – heat rise data for the conductor sizes, 10 AWG for Single Conductor Open Air, NM Cable Open Air, and Conductors in a Conduit is summarized and shown in the graphs on pages 87, 100, and 113.

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Test Set- Up/ Layout
14 AWG single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 14AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 14AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 14 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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FIGURE 1
Circuit Layout

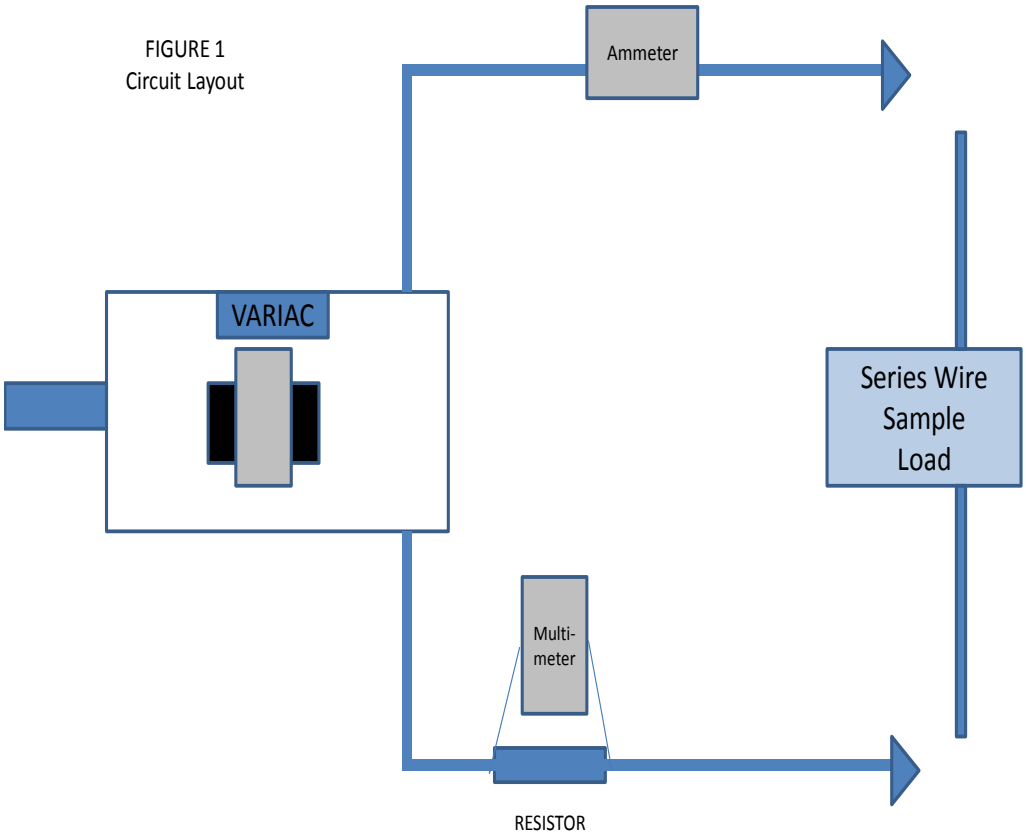

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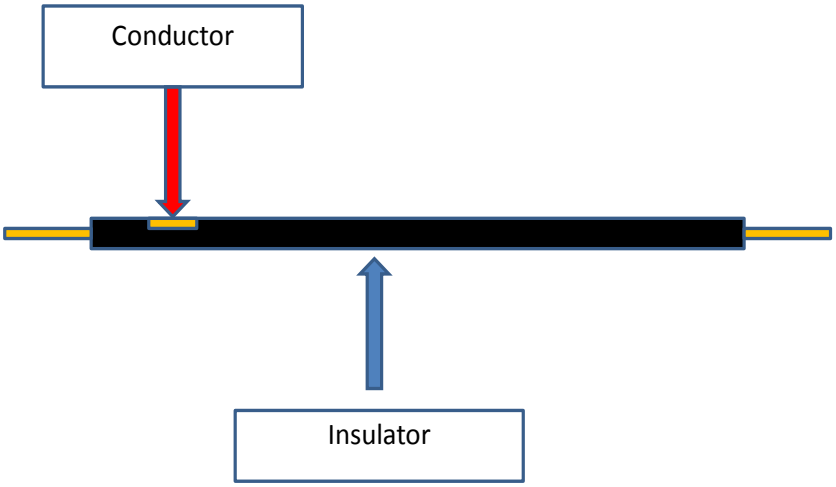
FIGURE 2
Single conductor



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Test Procedure
14 AWG Single Conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	Open air	5	30
14	Open air	10	30
14	Open air	15	30
14	Open air	20	30
14	Open air	25	30
14	Open air	30	30
14	Open air	35	30
14	Open air	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA Single Conductor open Air (Page 1/3))

Scan	Time	Elapsed	212 CU-AL #1 Core	213 CU-AL #1 Insu	203 CU-AL#2 Core	204 CU-AL#2 Insu	205 CU-AL#3 Insu
	5 AMPS						
32.00	42956.43	00:00:30:59	23.66	23.26	23.60	23.45	23.89
		Corrected Ambient	32.38	31.98	32.32	32.17	32.61
		Average	32.31				
		Average Core	32.40				
		Average Insulation	32.20				
	10 AMPS						
62.00	42956.45	00:01:00:59	28.37	28.10	27.74	28.35	28.81
		Corrected Ambient	36.96	36.69	36.33	36.94	37.40
		Average	36.38				
		Average Core	36.52				
		Average Insulation	36.22				
	15 AMPS						
92.00	42956.47	00:01:30:59	33.80	33.78	32.88	33.88	34.50
		Corrected Ambient	42.42	42.40	41.50	42.50	43.12
		Average	41.70				
		Average Core	42.16				
		Average Insulation	41.20				
	20 AMPS						
122.00	42956.49	00:02:00:59	43.82	43.54	42.12	43.28	44.61
		Corrected Ambient	52.04	51.76	50.34	51.50	52.83

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		Average	50.79				
		Average Core	51.77				
		Average Insulation	49.71				
	25 AMPS						
154.00	42956.52	00:02:32:59	53.50	53.49	51.23	52.53	54.61
		Corrected Ambient	61.81	61.80	59.54	60.84	62.92
		Average	60.07				
		Average Core	61.51				
		Average Insulation	58.50				
	30 AMPS						
183.00	42956.54	00:03:01:59	69.00	67.27	65.45	65.49	69.18
		Corrected Ambient	77.08	75.35	73.53	73.57	77.26
		Average	73.57				
		Average Core	75.91				
		Average Insulation	71.02				
	35 AMPS						
216.00	42956.56	00:03:34:59	85.83	83.73	80.52	81.75	86.71
		Corrected Ambient	93.96	91.86	88.65	89.88	94.84
		Average	89.81				
		Average Core	92.67				
		Average Insulation	86.68				

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14 AWG CCA Single Conductor open Air (Page 2/3))

208 CU-AL#3 Core	120 CU-AL #4 Core	211 CU-AL#4 Insu	102 CU-AL#5 Core	110 CU-AL#5 Insu	117 CU-AL#6 Core	116 CU-AL#7 Insul	320 CU-AL#7 Core	113 CU-AL#8 Core
23.51	23.63	23.37	23.62	23.47	23.86	23.44	23.36	23.79
32.23	32.35	32.09	32.34	32.19	32.58	32.16	32.08	32.51
27.61	27.35	26.86	27.79	27.18	27.93	27.43	27.16	27.92
36.20	35.94	35.45	36.38	35.77	36.52	36.02	35.75	36.51
32.59	32.02	31.20	33.01	31.82	33.24	31.93	32.18	33.99
41.21	40.64	39.82	41.63	40.44	41.86	40.55	40.80	42.61
41.25	41.32	38.66	42.34	39.53	43.15	40.71	41.44	44.59
49.47	49.54	46.88	50.56	47.75	51.37	48.93	49.66	52.81

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49.39	49.93	45.71	51.18	46.84	52.51	48.79	50.05	53.67
57.70	58.24	54.02	59.49	55.15	60.82	57.10	58.36	61.98
62.25	62.46	56.14	64.18	58.21	68.21	60.49	63.39	67.06
70.33	70.54	64.22	72.26	66.29	76.29	68.57	71.47	75.14
76.43	76.02	68.71	79.20	71.51	84.64	74.08	77.84	82.07
84.56	84.15	76.84	87.33	79.64	92.77	82.21	85.97	90.20

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14 AWG CCA Single Conductor open Air (Page 3/3))

114 CU-AL#8 Insul	109 CU-AL#9 Core	112 CU-AL#9 Insul	106 CU-AL#10 Core	107 CU-AL#10 Insul	101 CU-AL#11 Core	103 CU-AL#11 Insul	104 CU-AL#12 Core	105 CU-AL#12 Insul
23.65	23.82	23.63	23.82	23.54	23.54	23.19	23.97	23.43
32.37	32.54	32.35	32.54	32.26	32.26	31.91	32.69	32.15
27.87	27.44	27.22	27.77	27.44	28.29	26.84	29.82	27.86
36.46	36.03	35.81	36.36	36.03	36.88	35.43	38.41	36.45
32.54	33.29	31.49	33.60	32.07	34.85	31.62	37.00	33.55
41.16	41.91	40.11	42.22	40.69	43.47	40.24	45.62	42.17
42.59	42.44	39.88	44.38	40.51	46.65	40.27	49.14	42.83

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50.81	50.66	48.10	52.60	48.73	54.87	48.49	57.36	51.05
51.66	51.50	47.77	54.91	48.80	58.73	49.17	61.74	52.68
59.97	59.81	56.08	63.22	57.11	67.04	57.48	70.05	60.99
64.87	64.44	60.00	70.51	61.42	75.50	62.17	81.54	67.10
72.95	72.52	68.08	78.59	69.50	83.58	70.25	89.62	75.18
81.21	80.84	74.81	88.65	76.44	96.72	79.11	105.73	86.00
89.34	88.97	82.94	96.78	84.57	104.85	87.24	113.86	94.13

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14 AWG Cu Single conductor open air (Page 1/2))

Scan	Time	Elapsed	313 CU#1 Insul	312 CU#1 Core	309 CU#2 Core	310 CU#2 Insul	304 CU#3 Core	305 CU#3 Insul
	5 AMPS							
32.00	42956.43	00:00:30:59	22.94	22.76	23.27	22.75	23.19	22.87
		Corrected Ambient	31.66	31.48	31.99	31.47	31.91	31.59
		Average	31.76					
		Average Core	31.82					
		Average Insulation	31.70					
	10 AMPS							
62.00	42956.45	00:01:00:59	26.12	25.30	26.88	25.64	25.98	25.79
		Corrected Ambient	34.71	33.89	35.47	34.23	34.57	34.38
		Average	34.71					
		Average Core	34.68					
		Average Insulation	34.75					
	15 AMPS							
92.00	42956.47	00:01:30:59	29.59	28.15	30.84	28.94	29.08	29.21
		Corrected Ambient	38.21	36.77	39.46	37.56	37.70	37.83
		Average	38.20					
		Average Core	38.06					
		Average Insulation	38.34					

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	20 AMPS							
122.00	42956.49	00:02:00:59	35.06	33.50	38.22	34.03	34.76	34.30
		Corrected Ambient	43.28	41.72	46.44	42.25	42.98	42.52
		Average	43.85					
		Average Core	44.07					
		Average Insulation	43.64					
	25 AMPS							
154.00	42956.52	00:02:32:59	41.11	39.21	44.97	39.53	39.76	39.48
		Corrected Ambient	49.42	47.52	53.28	47.84	48.07	47.79
		Average	49.79					
		Average Core	49.98					
		Average Insulation	49.60					
	30 AMPS							
183.00	42956.54	00:03:01:59	50.05	48.57	55.19	47.04	46.81	46.68
		Corrected Ambient	58.13	56.65	63.27	55.12	54.89	54.76
		Average	58.05					
		Average Core	58.69					
		Average Insulation	57.42					
	35 AMPS							
216.00	42956.56	00:03:34:59	58.77	56.46	67.22	55.89	54.87	54.95
		Corrected Ambient	66.90	64.59	75.35	64.02	63.00	63.08
		Average	67.08					
		Average Core	67.91					
		Average Insulation	66.25					

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14 AWG Cu Single Conductor open Air (Page 2/2))

206 CU#4 Core	302 CU#4 Insul	218 CU#5 Core	220 CU#5 Insul	209 CU#6 Core	214 CU#6 Insul
23.07	23.20	23.11	22.85	23.21	23.30
31.79	31.92	31.83	31.57	31.93	32.02
26.07	26.44	26.00	26.11	26.30	26.84
34.66	35.03	34.59	34.70	34.89	35.43
29.44	30.07	29.34	29.78	29.81	30.74
38.06	38.69	37.96	38.40	38.43	39.36
35.82	35.84	35.94	35.90	36.83	37.36

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44.04	44.06	44.16	44.12	45.05	45.58
41.32	41.65	41.70	41.84	43.06	44.11
49.63	49.96	50.01	50.15	51.37	52.42
50.11	49.91	50.16	49.62	52.82	52.73
58.19	57.99	58.24	57.70	60.90	60.81
59.11	58.81	59.35	57.77	61.68	62.52
67.24	66.94	67.48	65.90	69.81	70.65

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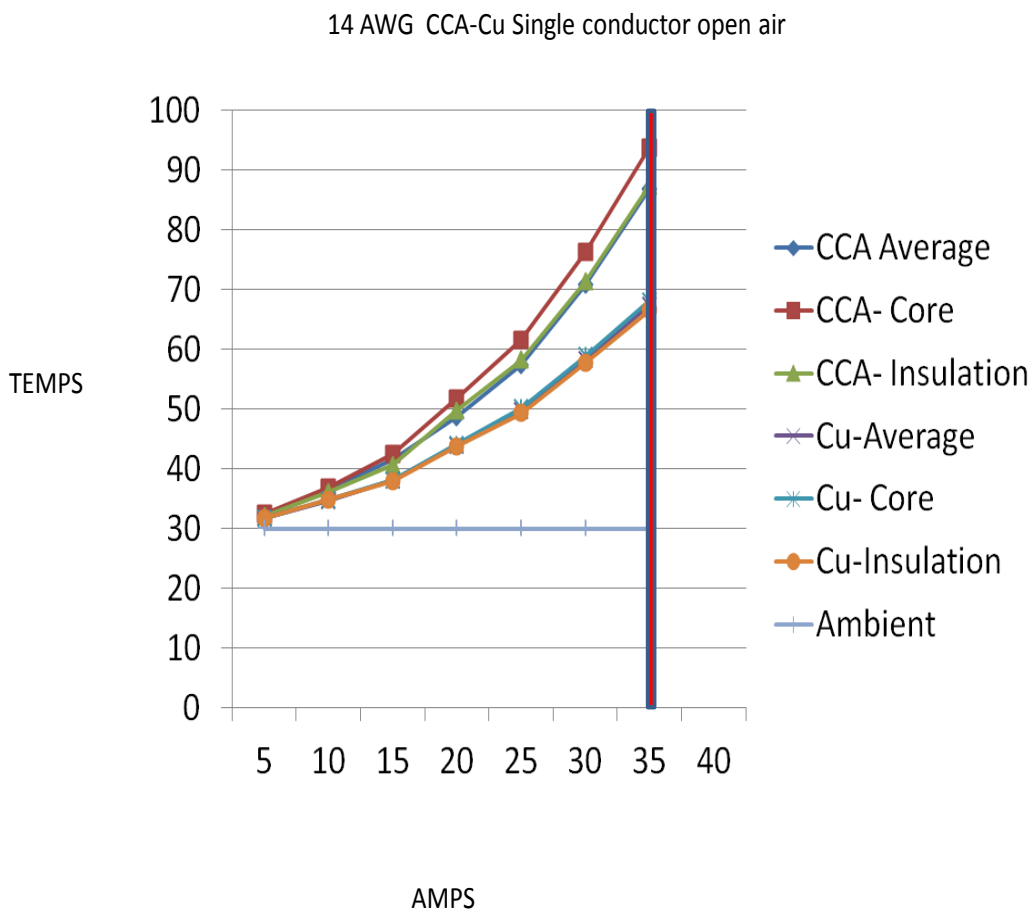

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Test Set- Up/ Layout
14 AWG in non-metallic cable in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 14 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 14 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 14 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used is calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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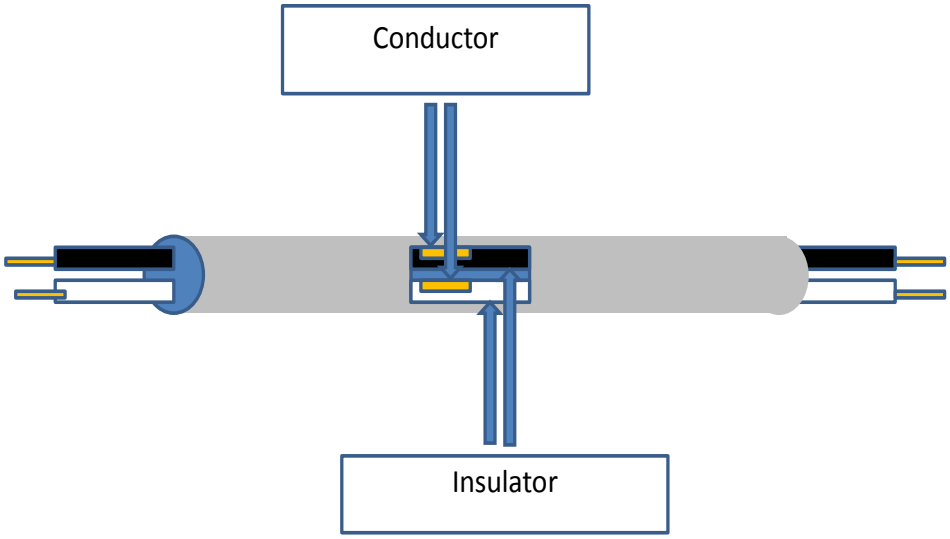
FIGURE 3
Two Line Conductor/ Ground(not connected) Non- metallic Cable



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Test Procedure
14 AWG in Non-metallic cable

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.
.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	NM Cable	5	30
14	NM Cable	10	30
14	NM Cable	15	30
14	NM Cable	20	30
14	NM Cable	25	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA Non Metallic (2 Conductor) open air (Page 1/3)

Scan	Time	Elapsed	101-CU-AL White Cable-Core	103 CU-AL White Cable Insulation	104 CU-AL Black Cable Core	105 CU-AL Black Cable Insulation	106 CU-AL Black Cable Core
29	5 AMPS	00:00:27:59					
30	8/15/2017 12:13	00:00:28:59	24.592	24.57	24.179	24.336	24.308
		Corrected Ambient	32.96	32.94	32.55	32.71	32.68
		Average	32.80				
		Average Core	32.92				
		Average Insulation	32.86				
60	10 AMPS	00:00:58:59	29.924	30.049	28.525	28.47	28.704
61	8/15/2017 12:44	00:00:59:59	29.497	30.014	28.308	28.427	28.595
		Corrected Ambient	37.95	38.46	36.76	36.88	37.04
		Average	37.53				
		Average Core	38.05				
		Average Insulation	38.13				
88	15 AMPS	00:01:26:59					
89	8/15/2017 13:12	00:01:27:59	37.658	38.549	35.166	34.525	34.751
		Corrected Ambient	45.92	46.81	43.43	42.79	43.02
		Average	44.46				
		Average Core	45.13				
		Average Insulation	45.22				
120	20 AMPS	00:01:58:59					
121	8/15/2017 13:44	00:01:59:59	48.404	50.441	43.994	43.521	43.462
		Corrected Ambient	56.61	58.65	52.20	51.73	51.67

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		Average	54.26				
		Average Core	54.78				
		Average Insulation	55.89				
151	25 AMPS	00:02:29:59					
152	8/15/2017 14:15	00:02:30:59	64.72	68.548	57.572	55.957	56.371
		Corrected Ambient	73.02	76.85	65.87	64.26	64.67
		Average	68.95				
		Average Core	69.61				
		Average Insulation	71.60				

14 AWG CCA Non Metallic (2 Conductor) open air (Page 2/3)

107 CU-AL Black Cable Insulation	109 CU-AL White Cable Core	112 CU-AL White Cable# 2 Insulation	113 CU-AL Black Cable#3 Core	114 CU-AL Black Cable #3 Insulation	116 CU-AL White Cable #3 Insulation	320 CU-AL White Cable#3 Core	315 CU-AL Black Cable#4 Core	118 CU-AL Black Cable#4 Insulation	102 CU-AL White Cable #4 Core
24.3	24.745	24.436	24.638	24.609	24.972	25.105	24.416	23.739	24.551
32.67	33.12	32.81	33.01	32.98	33.34	33.48	32.79	32.11	32.92
28.89	29.97	29.341	29.59	29.289	30.546	31.225	29.545	29.786	29.823
28.741	29.96	29.233	29.734	29.38	30.642	31.368	29.462	29.627	29.73
37.19	38.41	37.68	38.18	37.83	39.09	39.82	37.91	38.08	38.18

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35.244	37.473	35.97	36.069	36.113	38.561	39.712	36.608	35.975	37.473
43.51	45.74	44.23	44.33	44.38	46.83	47.98	44.87	44.24	45.74
44.923	47.618	47.015	45.275	46.599	50.61	51.411	46.52	44.202	47.657
53.13	55.83	55.22	53.48	54.81	58.82	59.62	54.73	52.41	55.86
58.491	62.893	62.242	58.51	61.014	67.133	69.89	61.364	57.959	63.192
66.79	71.19	70.54	66.81	69.32	75.43	78.19	69.67	66.26	71.49

14 AWG CCA Non Metallic (2 Conductor) open air (Page 3/3)

110 CU-AL White Cable#4 Insulation	120 CU-AL Black Cable#5 Core	211 CU-AL Black Cable#5 Insulation	205CU-AL White Cable#5 Insulation	208 CU-AL White Cable#5 Core	203 CU-AL Black Cable#6 Core	204 CU-AL Black Cbale#6 Insulation	212 CU-AL White Cable#6 Core	213 CU-AL White Cable#6 Insulation
25.194	24.66	25.029	24.923	24.407	24.321	24.045	24.677	23.717
33.56	33.03	33.40	33.29	32.78	32.69	32.42	33.05	32.09

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31.019	29.933	30.894	30.803	29.33	29.022	29.051	30.233	28.558
31.019	29.959	30.909	30.863	29.348	29.055	28.806	30.238	28.543
39.47	38.41	39.36	39.31	37.80	37.50	37.26	38.69	36.99
39.162	37.293	38.859	38.947	35.984	35.982	36.311	38.22	35.275
47.43	45.56	47.12	47.21	44.25	44.25	44.58	46.48	43.54
51.486	47.619	50.771	50.602	44.739	43.968	46.287	48.202	45.682
59.69	55.83	58.98	58.81	52.95	52.18	54.49	56.41	53.89
69.419	62.641	68.43	68.105	58.395	56.519	61.868	63.671	60.471
77.72	70.94	76.73	76.41	66.70	64.82	70.17	71.97	68.77

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14 AWG Cu Non Metallic (2 Conductor) open air
Page (1/2)

Scan	Time	Elapsed	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core
29	5 AMPS	00:00:27:59					
30	8/15/2017 12:13	00:00:28:59	23.451	23.326	22.977	23.042	22.899
		Corrected Ambient	31.82	31.70	31.35	31.41	31.27
		Average	31.63				
		Average Core	31.61				
		Average Insulation	31.66				
60	10 AMPS	00:00:58:59					
61	8/15/2017 12:44	00:00:59:59	27.177	26.623	25.544	25.678	25.495
		Corrected Ambient	35.63	35.07	33.99	34.13	33.94
		Average	34.60				
		Average Core	34.58				
		Average Insulation	34.62				
88	15 AMPS	00:01:26:59					
89	8/15/2017 13:12	00:01:27:59	32.586	31.152	29.253	29.605	29.106
		Corrected Ambient	40.85	39.42	37.52	37.87	37.37
		Average	38.69				
		Average Core	38.68				
		Average Insulation	38.70				
120	20 AMPS	00:01:58:59					
121	8/15/2017 13:44	00:01:59:59	40.601	37.689	35.231	35.538	35.083
		Corrected Ambient	48.81	45.90	43.44	43.75	43.29

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		Average	44.60				
		Average Core	44.79				
		Average Insulation	44.41				
151	25 AMPS	00:02:29:59					
152	8/15/2017 14:15	00:02:30:59	51.287	47.245	42.544	43.699	41.81
		Corrected Ambient	59.59	55.55	50.85	52.00	50.11
		Average	53.14				
		Average Core	53.05				
		Average Insulation	53.23				

14 AWG Cu Non Metallic (2 Conductor) open air Page (2/2)

302 CU Black Cable#3 Insulation	304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
23.44	23.503	23.264	23.458	23.245	23.126	23.416
31.81	31.87	31.63	31.83	31.62	31.50	31.79
26.374	26.371	26.051	26.426	25.928	25.744	26.369
34.82	34.82	34.50	34.88	34.38	34.19	34.82

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31.135	30.734	30.046	30.955	29.706	29.884	30.947
39.40	39.00	38.31	39.22	37.97	38.15	39.21
37.502	36.586	35.021	37.138	34.631	34.872	36.818
45.71	44.79	43.23	45.35	42.84	43.08	45.03
47.427	44.327	43.744	45.605	42.023	42.908	45.452
55.73	52.63	52.05	53.91	50.32	51.21	53.75

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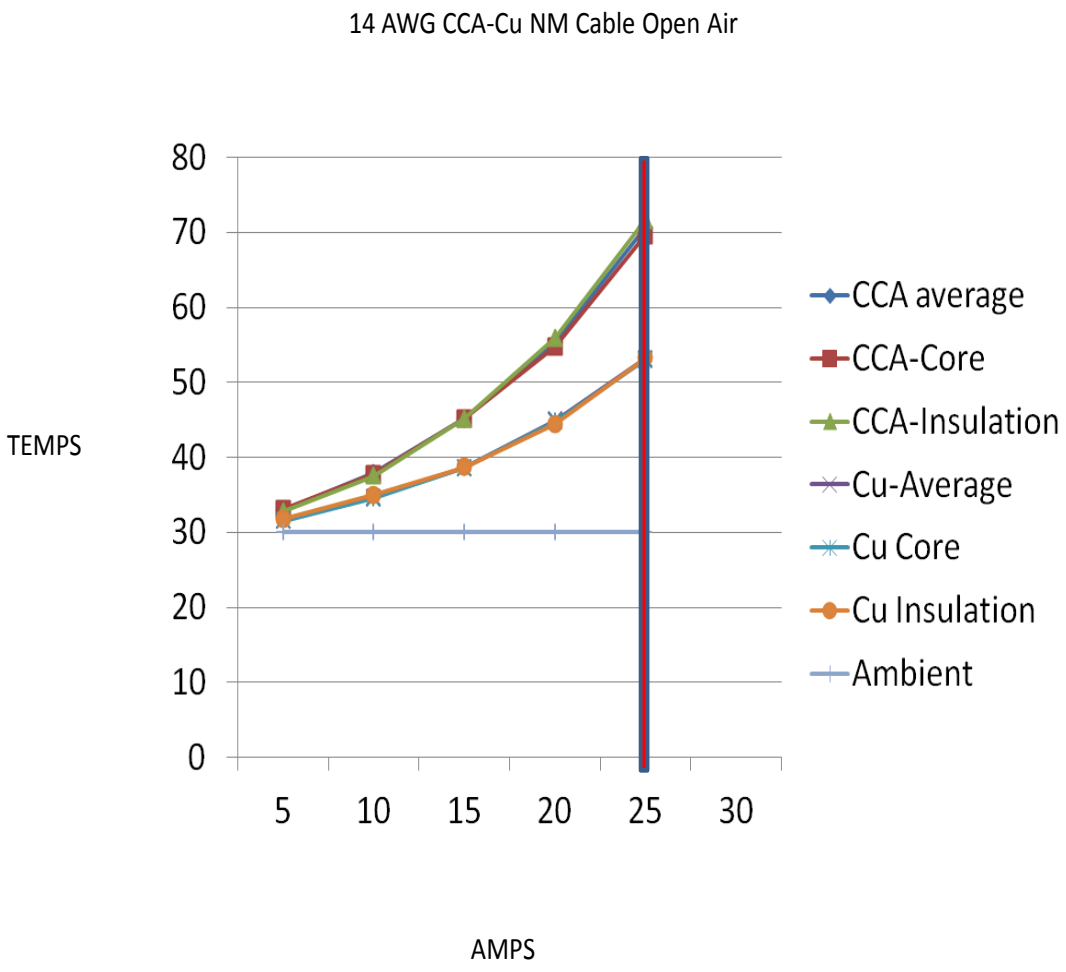

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Test Set- Up/ Layout
14 AWG (2 conductors) in Conduit

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 14 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 14 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 14 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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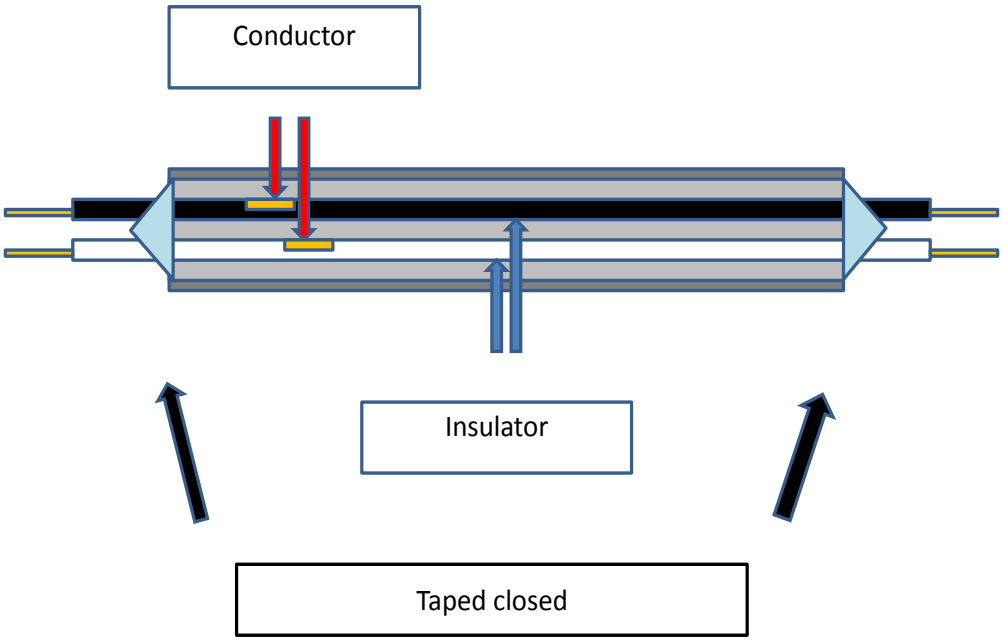
FIGURE 4
Two Conductors in ½ Inch Conduit



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Test Procedure
14 AWG(2 conductors) in Conduit

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 Amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
14	Conduit	5	30
14	Conduit	10	30
14	Conduit	15	30
14	Conduit	20	30
14	Conduit	25	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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14 AWG CCA (2 Conductor) in Conduit
Page(1/3)

	101-CCA#1 Core	106 CCA#1 Insulation	107 CCA#2 Core	105 CCA#2 Insulation	112 CCA#3 Core	109 CCA#3 Insulation	113 CCA#4 Core	104 CCA#4 Insulaiton
5 AMPS								
00:00:51:59	24.79	24.61	24.66	24.03	24.04	23.58	23.96	23.72
Corrected Ambient	34.83	34.65	34.70	34.07	34.08	33.62	34.00	33.76
Average	34.19							
Core Average	34.55							
Insulation Average	33.86							
10 AMPS								
00:02:01:59	34.64	34.94	34.84	32.81	32.64	31.25	32.51	31.30
Corrected Ambient	44.83	45.13	45.03	42.99	42.83	41.44	42.70	41.49
Average	43.35							
Core Average	44.12							
Insulation Average	42.64							
15 AMPS								
00:02:52:59	51.48	52.20	52.36	47.74	46.95	43.79	46.60	43.97
Corrected Ambient	61.07	61.78	61.94	57.32	56.53	53.37	56.18	53.55
Average	58.13							
Core Average	59.84							
Insulation Average	56.57							
20 AMPS								
00:03:43:59	72.68	74.44	73.96	66.89	66.02	59.92	64.39	60.07
Corrected Ambient	82.07	83.84	83.35	76.28	75.41	69.31	73.78	69.47
Average	77.26							
Core Average	80.16							
Insulation Average	74.60							
25 AMPS								
00:04:33:59	117.65	117.35	119.71	105.33	107.61	92.87	101.25	92.53
Corrected Ambient	127.06	126.76	129.12	114.74	117.02	102.28	110.66	101.94
Average	117.69							
Core Average	124.41							

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Insulation Average	111.52							

14 AWG CCA (2 Conductor) in Conduit Page(2/3)

120 CCA#5 Core	116 CCA#5 Insulation	110 CCA#6 Core	102 CCA#6 Insulation	118 CCA#7 Insulation	117 CCA#8 Core	103 CCA#8 Insulation	114 CCA#9 Core
24.64	23.92	25.11	24.39	23.42	24.81	23.37	24.43
34.69	33.97	35.15	34.43	33.47	34.85	33.42	34.48
34.64	32.33	35.84	34.63	30.90	33.95	31.16	32.84
44.82	42.52	46.03	44.82	41.09	44.13	41.35	43.03
51.59	46.53	54.59	52.00	43.29	50.64	44.39	47.81
61.17	56.11	64.17	61.58	52.88	60.22	53.97	57.39
73.42	64.63	78.42	73.82	58.67	71.14	60.84	67.02
82.81	74.02	87.81	83.21	68.06	80.53	70.23	76.41
119.35	101.08	128.37	117.64	88.72	117.29	94.74	110.37
128.76	110.49	137.78	127.05	98.13	126.70	104.15	119.78

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14 AWG CCA (2 Conductor) in Conduit Page(3/3)

211 CCA#9 Insulation	212 CCA#10 Core	204 CCA#10 Insulation	220 CCA#11 Core	203 CCA#11 Insulaiton	218 CCA#12 Core	214 CCA#12 Insulation
23.42	24.44	23.75	24.58	24.03	24.15	23.59
33.46	34.48	33.80	34.62	34.07	34.20	33.63
31.17	34.07	33.65	34.69	33.24	32.61	32.04
41.36	44.26	43.84	44.88	43.43	42.80	42.22
45.01	50.94	50.44	52.39	48.40	47.47	46.07
54.59	60.52	60.02	61.97	57.98	57.05	55.65
61.56	71.91	71.23	73.72	67.11	65.73	63.36
70.95	81.30	80.62	83.11	76.50	75.12	72.75
97.96	118.18	113.21	118.54	104.99	106.66	98.95
107.37	127.59	122.62	127.95	114.40	116.07	108.36

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14 AWG Cu (2 Conductor) in Conduit Page 1/2)

	206 CU#1 Core	209 CU#1 Insulation	213 CU#3 Core	208 CU#3 Insualtion	205 CU#5 Core	305 CU#5 Insulation
5 AMPS						
00:00:51:59	22.48	21.97	22.25	22.56	22.77	22.70
Corrected Ambient	32.52	32.02	32.30	32.60	32.81	32.74
Average	32.67					
Core Average	32.81					
Insulation Average	32.53					
10 AMPS						
00:02:01:59	27.37	26.44	27.92	28.45	28.47	28.16
Corrected Ambient	37.56	36.63	38.11	38.63	38.65	38.35
Average	38.29					
Core Average	38.65					
Insulation Average	37.92					
15 AMPS						
00:02:52:59	36.14	34.08	37.61	38.51	38.48	37.28
Corrected Ambient	45.72	43.67	47.19	48.09	48.07	46.86
Average	47.09					
Core Average	47.98					
Insulation Average	46.20					
20 AMPS						
00:03:43:59	45.98	42.87	49.09	50.19	50.16	47.55
Corrected Ambient	55.37	52.26	58.48	59.58	59.56	56.94
Average	57.97					
Core Average	59.56					
Insulation Average	56.39					
25 AMPS						
00:04:33:59	65.98	59.49	71.81	72.52	73.11	68.34
Corrected Ambient	75.39	68.90	81.22	81.93	82.52	77.75
Average	79.54					
Core Average	82.77					
Insulation Average	76.31					

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14 AWG Cu (2 Conductor) in Conduit
Page (2/2)

318 CU#7 Core	315 CU#7 Insulation	310 CU#9 Core	313 CU#9 Insulaiton	304 CU#11 Core	312 CU#11 Insulation
23.00	22.44	23.28	22.62	22.81	22.62
33.04	32.48	33.33	32.66	32.85	32.66
29.12	27.38	29.95	27.92	27.95	28.05
39.31	37.57	40.14	38.11	38.14	38.24
39.72	36.00	41.63	36.70	36.82	37.14
49.30	45.58	51.21	46.28	46.40	46.73
52.56	46.16	55.35	47.13	47.86	48.12
61.95	55.55	64.74	56.52	57.25	57.51
78.19	65.80	82.60	66.20	68.46	69.08
87.60	75.21	92.01	75.61	77.87	78.49

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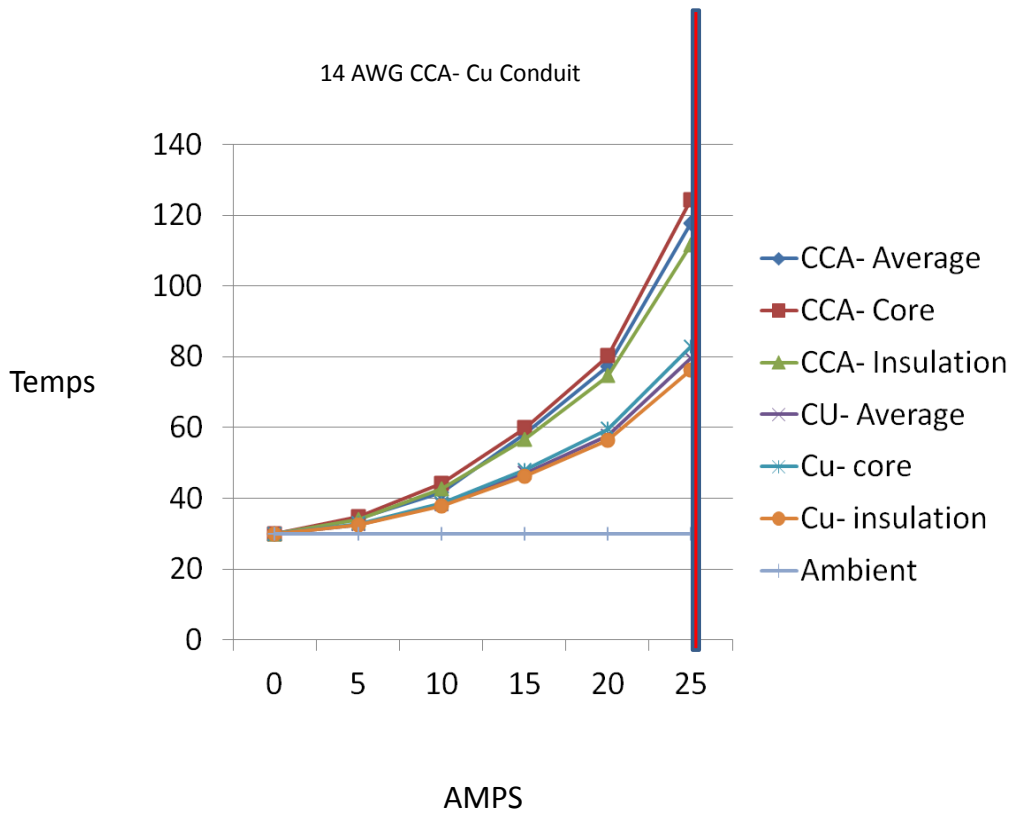

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Test Set- Up/ Layout
12 AWG Single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 12 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 12 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 12 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG single conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time an additional 5 amps was drawn through the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	Open air	5	30
12	Open air	10	30
12	Open air	15	30
12	Open air	20	30
12	Open air	25	30
12	Open air	30	30
12	Open air	35	30
12	Open air	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG single conductors
(Page 1 of 3)

Scan	Time	101- CU-AL White Cable#1- Insulation	104 CU-AL Black Cable#1 Core	105 CU-AL Black Cable#1 Insulation	106 CU-AL Black Cable#2 Core	107 CU-AL Black Cable#2 Insulation	109 CU-AL White Cable#2 Core
	5 AMPS						
30	8/16/2017 14:54	23.5	23.719	23.597	24.101	23.626	23.882
	Corrected Ambient	31.925	32.144	32.022	32.526	32.051	32.307
	Average	31.86845					
	Average Core	32.1068					
	Average Insulation	31.66983					
	10 AMPS						
60	8/16/2017 15:24	26.487	26.702	26.788	27.393	26.714	26.989
	Corrected Ambient	35	35.215	35.301	35.906	35.227	35.502
	Average	34.92791					
	Average Core	35.3563					
	Average Insulation	34.57092					
	15 AMPS						
91	8/16/2017 15:55	30.559	30.658	30.656	32.374	30.779	31.249
	Corrected Ambient	38.79	38.889	38.887	40.605	39.01	39.48
	Average	38.64927					
	Average Core	39.4042					
	Average Insulation	38.02017					
	20 AMPS						
121	8/16/2017 16:25	35.826	35.837	35.678	38.337	35.742	36.622
	Corrected Ambient	44.421	44.432	44.273	46.932	44.337	45.217
	Average	43.80986					
	Average Core	45.065					
	Average Insulation	42.76392					

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	25 AMPS						
152	8/16/2017 16:56	42.958	43.207	43.137	48.117	43.123	44.441
	Corrected Ambient	51.22	51.469	51.399	56.379	51.385	52.703
	Average	50.82832					
	Average Core	52.8027					
	Average Insulation	49.183					
	30 AMPS						
182	8/16/2017 17:26	50.663	51.573	51.558	58.75	51.353	52.748
	Corrected Ambient	59.164	60.074	60.059	67.251	59.854	61.249
	Average	58.849					
	Average Core	61.1368					
	Average Insulation	56.9425					
	35 AMPS						
213	8/16/2017 17:57	59.241	60.489	60.736	70.389	59.671	62.631
	Corrected Ambient	67.397	68.645	68.892	78.545	67.827	70.787
	Average	67.43436					
	Average Core	70.5558					
	Average Insulation	64.83317					
	40 AMPS						
244	8/16/2017 18:28	67.579	70.938	69.371	84.754	68.417	73.658
	Corrected Ambient	75.86	79.219	77.652	93.035	76.698	81.939
	Average	76.85605					
	Average Core	80.71511					
	Average Insulation	72.72958					

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12 AWG Single conductor
(Page 2 of 3)

112 CU-AL White Cable# 2 Insulation	113 CU-AL Black Cable#3 Core	114 CU-AL Black Cable #3 Insulation	116 CU-AL White Cable #3 Insulation	320 CU-AL White Cable#4 Core	118 CU-AL Black Cable#4 Insulation
23.57	23.62	23.4	23.285	23.776	23.093
31.995	32.045	31.825	31.71	32.201	31.518
26.464	26.507	26.264	25.822	26.845	25.692
34.977	35.02	34.777	34.335	35.358	34.205
30.073	30.291	29.915	29.382	31.533	29.206
38.304	38.522	38.146	37.613	39.764	37.437
34.775	34.982	34.305	33.662	37.097	32.398
43.37	43.577	42.9	42.257	45.692	40.993
41.606	42.027	41.564	40.681	46.895	35.318

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49.868	50.289	49.826	48.943	55.157	43.58
49.167	49.465	49.303	47.244	55.947	45.015
57.668	57.966	57.804	55.745	64.448	53.516
57.152	57.789	57.623	54.861	67.265	52.7
65.308	65.945	65.779	63.017	75.421	60.856
66.056	67.263	67.276	63.756	81.93	48.048
74.337	75.544	75.557	72.037	90.211	56.329

12 AWG Single conductor
(Page 3 of 3)

110 CU-AL White Cable#4 Core	120 CU-AL Black Cable#5 Core	211 CU-AL Black Cable#5 Insulation	205CU-AL White Cable#5 Insulation	208 CU-AL White Cable#6 Core	203 CU-AL Black Cable#6 Core	204 CU-AL Black Cbale#6 Insulation
23.509	23.482	23.149	23.038	23.485	23.786	22.755
31.934	31.907	31.574	31.463	31.91	32.211	31.18

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26.402	26.539	25.762	25.861	26.673	27.668	25.409
34.915	35.052	34.275	34.374	35.186	36.181	33.922
30.025	30.717	29.685	29.704	31.023	32.791	28.963
38.256	38.948	37.916	37.935	39.254	41.022	37.194
34.209	35.835	33.848	34.108	36.344	39.108	32.692
42.804	44.43	42.443	42.703	44.939	47.703	41.287
40.855	43.7	41.307	41.654	44.03	48.851	39.803
49.117	51.962	49.569	49.916	52.292	57.113	48.065
47.49	51.417	48.521	49.376	51.659	58.336	46.401
55.991	59.918	57.022	57.877	60.16	66.837	54.902

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55.696	61.164	57.106	58.492	61.252	69.982	53.979
63.852	69.32	65.262	66.648	69.408	78.138	62.135
63.039	72.843	66.826	67.72	70.828	83.361	63.75
71.32	81.124	75.107	76.001	79.109	91.642	72.031

12 AWG Cu Single conductors
(Page 1 of 2)

Scan	Time	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core
	5 AMPS					
30	8/16/2017 14:54	22.678	22.601	23.084	22.862	23.1
	Corrected Ambient	31.103	31.026	31.509	31.287	31.525
	Average	31.28				
	Average Core	31.346				
	Average Insulation	31.214				
	10 AMPS					
60	8/16/2017 15:24	24.574	24.195	25.492	24.984	25.629
	Corrected Ambient	33.087	32.708	34.005	33.497	34.142
	Average	33.44408				
	Average Core	33.63167				
	Average Insulation	33.2565				
	15 AMPS					

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91	8/16/2017 15:55	27.938	27.51	29.234	28.369	29.346
	Corrected Ambient	36.169	35.741	37.465	36.6	37.577
	Average	36.27708				
	Average Core	36.65483				
	Average Insulation	35.89933				
	20 AMPS					
121	8/16/2017 16:25	31.89	31.073	33.381	32.19	33.634
	Corrected Ambient	40.485	39.668	41.976	40.785	42.229
	Average	40.2505				
	Average Core	40.86083				
	Average Insulation	39.64017				
	25 AMPS					
152	8/16/2017 16:56	37.908	36.251	39.895	37.963	40.79
	Corrected Ambient	46.17	44.513	48.157	46.225	49.052
	Average	45.57908				
	Average Core	46.602				
	Average Insulation	44.55617				
	30 AMPS					
182	8/16/2017 17:26	45.629	44.793	46.939	43.77	47.443
	Corrected Ambient	54.13	53.294	55.44	52.271	55.944
	Average	51.87658				
	Average Core	53.18617				
	Average Insulation	50.567				
	35 AMPS					
213	8/16/2017 17:57	53.356	52.266	54.603	50.492	54.888
	Corrected Ambient	61.512	60.422	62.759	58.648	63.044
	Average	58.39692				
	Average Core	60.13967				
	Average Insulation	56.65417				
	40 AMPS					
244	8/16/2017 18:28	62.217	61.357	63.891	59.265	64.258
	Corrected Ambient	70.498	69.638	72.172	67.546	72.539

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	Average	66.52817				
	Average Core	69.18933				
	Average Insulation	63.867				

12 AWG Cu Single conductors
(Page 1 of 2)

	Time	304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
	5 AMPS						
30	8/16/2017 14:54	22.672	22.586	23.069	22.909	22.923	22.74
	Corrected Ambient	31.097	31.011	31.494	31.334	31.348	31.165
	10 AMPS						
60	8/16/2017 15:24	24.713	24.647	25.355	24.993	24.949	24.515
	Corrected Ambient	33.226	33.16	33.868	33.506	33.462	33.028
	15 AMPS						
91	8/16/2017 15:55	27.693	27.514	28.674	27.745	27.658	26.826
	Corrected Ambient	35.924	35.745	36.905	35.976	35.889	35.057
	20 AMPS						
121	8/16/2017 16:25	31.304	30.91	32.491	31.202	30.895	29.56
	Corrected Ambient	39.899	39.505	41.086	39.797	39.49	38.155

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	25 AMPS						
152	8/16/2017 16:56	36.656	36.446	39.125	36.545	35.666	33.819
	Corrected Ambient	44.918	44.708	47.387	44.807	43.928	42.081
	30 AMPS						
182	8/16/2017 17:26	42.269	41.429	45.709	41.914	40.122	38.201
	Corrected Ambient	50.77	49.93	54.21	50.415	48.623	46.702
	35 AMPS						
213	8/16/2017 17:57	50.113	48.676	53.39	48.317	45.552	43.055
	Corrected Ambient	58.269	56.832	61.546	56.473	53.708	51.211
	40 AMPS						
244	8/16/2017 18:28	55.495	53.591	66.664	55.887	52.925	47.744
	Corrected Ambient	63.776	61.872	74.945	64.168	61.206	56.025

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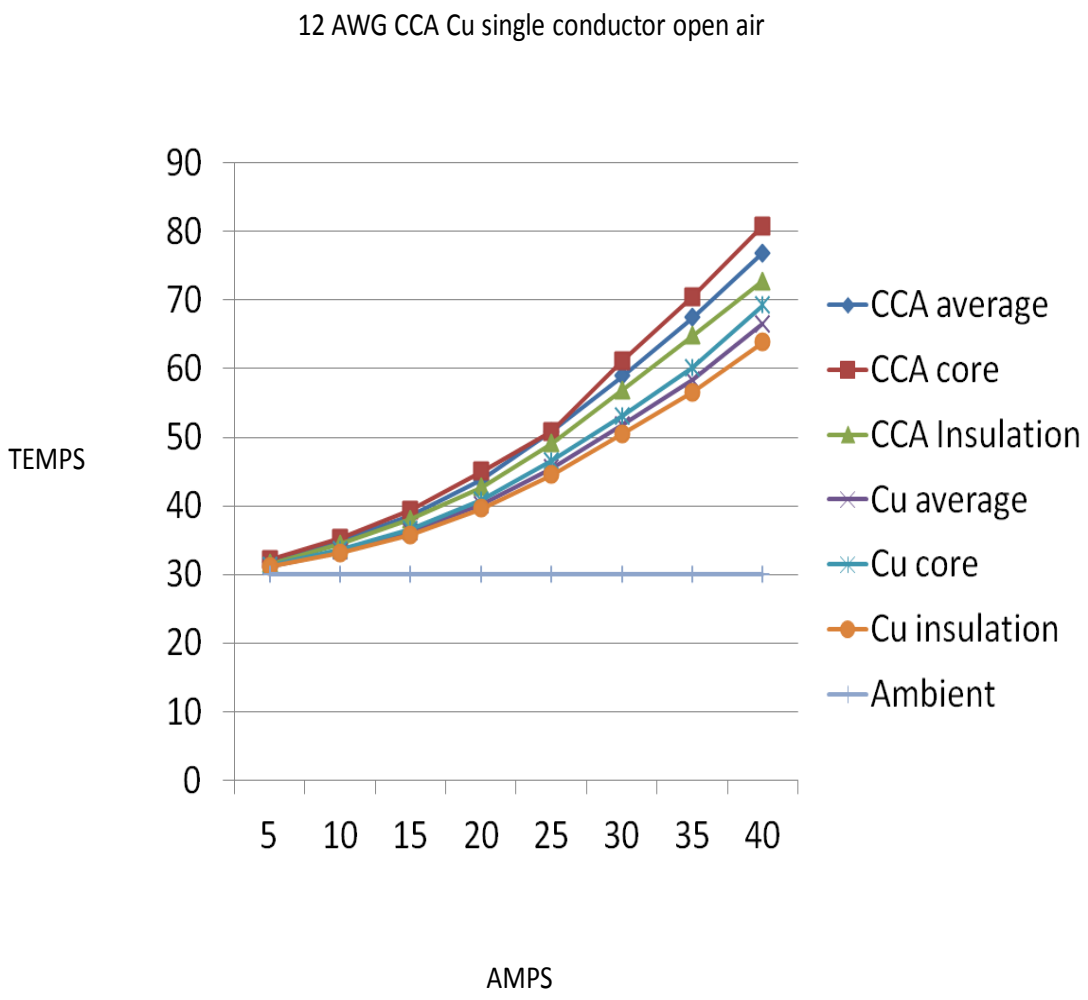

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Test Set- Up/ Layout
12 AWG in non-metallic cable (2 Conductor) in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 12 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 12 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 12 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG In (2 conductor) non-metallic cable

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	NM Cable	5	30
12	NM Cable	10	30
12	NM Cable	15	30
12	NM Cable	20	30
12	NM Cable	25	30
12	NM Cable	30	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 1 of 3)

Scan	Time	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	208 CU-AL Black Cable#2 Core	205 CU-AL Black Cable#2 Insulation
	5 AMPS					
30	**8/17/2017 10:29**	**22.67**	**22.926**	**23.13**	**23.256**	**23.015**
	Corrected Ambient	31.08	31.335	31.539	31.665	31.424
	Average	31.68				
	Average Core	31.73				
	Average Insulation	31.63				
	10 AMPS					
61	8/17/2017 11:00	25.93	26.059	26.92	26.863	26.217
	Corrected Ambient	34.32	34.443	35.304	35.247	34.601
	Average	34.88				
	Average Core	35.09				
	Average Insulation	34.68				
	15 AMPS					
91	8/17/2017 11:30	30.31	30.408	32.809	32.228	31.062
	Corrected Ambient	38.40	38.497	40.898	40.317	39.151
	Average	39.36				
	Average Core	39.90				
	Average Insulation	38.87				
	20 AMPS					
121	8/17/2017 12:00	35.95	36.03	40.071	39.839	36.86
	Corrected Ambient	44.35	44.426	48.467	48.235	45.256

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	Average	45.56				
	Average core	46.67				
	Average Insulation	44.54				
	25 AMPS					
152	8/17/2017 12:31	41.34	41.083	45.352	45.612	42.454
	Corrected Ambient	49.85	49.598	53.867	54.127	50.969
	Average	51.67				
	Average Core	53.50				
	Average Insulation	50.00				
	30 AMPS					
182	8/17/2017 13:01	47.44	47.015	53.341	52.596	50.518
	Corrected Ambient	55.74	55.316	61.642	60.897	58.819
	Average	59.54				
	Average Core	62.19				
	Average Insulation	57.11				

12 AWG CCA In non-metallic cable(2 conductor)
(Page 2 of 3)

211 CU-AL White Cable# 2 Insulation	102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #3 Insulation
23.196	**23.139**	**23.493**	**23.536**
31.605	31.548	31.902	31.945
26.208	26.16	26.433	26.599
34.592	34.544	34.817	34.983

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30.375	30.414	30.425	31.929
38.464	38.503	38.514	40.018
35.556	35.329	35.55	36.683
43.952	43.725	43.946	45.079
41.089	40.342	41.332	41.256
49.604	48.857	49.847	49.771
48.436	46.618	48.28	47.403
56.737	54.919	56.581	55.704

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 3of 3)

116 CU-AL Black Cable#4 Insulation	113 CU-AL White Cable #4 Core	114 CU-AL White Cable#4 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#5 Insulation
23.222	**23.2**	**23.399**	**23.443**	**23.14**
31.631	31.609	31.808	31.852	31.549
25.734	26.056	26.523	26.702	25.713
34.118	34.44	34.907	35.086	34.097
28.997	31.638	30.56	30.878	29.977
37.086	39.727	38.649	38.967	38.066
33.062	37.403	35.681	36.471	35.027
41.458	45.799	44.077	44.867	43.423

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37.425	44.796	40.903	42.529	40.103
45.94	53.311	49.418	51.044	48.618
43.655	55.384	48.43	51.204	48.229
51.956	63.685	56.731	59.505	56.53

12 AWG Cu In non-metallic cable(2 Conductor)
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30	**8/17/2017 10:29**	**22.614**	**22.554**	**22.891**	**22.59**	**22.796**	**22.882**
	Corrected Ambient	31.023	30.963	31.3	30.999	31.205	31.291
	Average	31.22208					
	Average Core	31.295					
	Average Insulation	31.14917					
	10 AMPS						
61	8/17/2017 11:00	25.114	24.271	25.231	24.387	24.977	24.9
	Corrected Ambient	33.498	32.655	33.615	32.771	33.361	33.284
	Average	33.271					

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	Average Core	33.58917					
	Average Insulation	32.95283					
	15 AMPS						
91	8/17/2017 11:30	28.333	27.255	28.517	27.065	28.032	28.006
	Corrected Ambient	36.422	35.344	36.606	35.154	36.121	36.095
	Average	36.00508					
	Average Core	36.45233					
	Average Insulation	35.55783					
	20 AMPS						
121	8/17/2017 12:00	32.461	30.737	32.806	30.378	32.047	31.754
	Corrected Ambient	40.857	39.133	41.202	38.774	40.443	40.15
	Average	40.02075					
	Average core	40.70133					
	Average Insulation	39.34017					
	25 AMPS						
152	8/17/2017 12:31	37.317	35.362	38.138	34.253	36.101	35.718
	Corrected Ambient	45.832	43.877	46.653	42.768	44.616	44.233
	Average	44.385					
	Average Core	45.3695					
	Average Insulation	43.4005					
	30 AMPS						
182	8/17/2017 13:01	43.719	41.111	44.969	39.04	42.173	41.491
	Corrected Ambient	52.02	49.412	53.27	47.341	50.474	49.792
	Average	49.96617					
	Average Core	51.36633					
	Average Insulation	48.566					

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12 AWG CCA In non-metallic cable(2 conductor)
(Page 2 of 2)

305 CU White Cable#3 Insulation	309 CU Black Cable#2 Core	310 CU Black Cable#2 Insulation	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.726	**23.1**	**22.833**	**22.872**	**22.856**
31.135	31.509	31.242	31.281	31.265
24.487	25.693	24.642	24.877	24.726
32.871	34.077	33.026	33.261	33.11
27.237	29.01	27.541	27.932	27.709
35.326	37.099	35.63	36.021	35.798
30.746	33.217	31.041	31.343	31.009
39.142	41.613	39.437	39.739	39.405

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34.482	37.831	34.853	35.499	34.645
42.997	46.346	43.368	44.014	43.16
39.792	44.397	39.901	41.125	40.255
48.093	52.698	48.202	49.426	48.556

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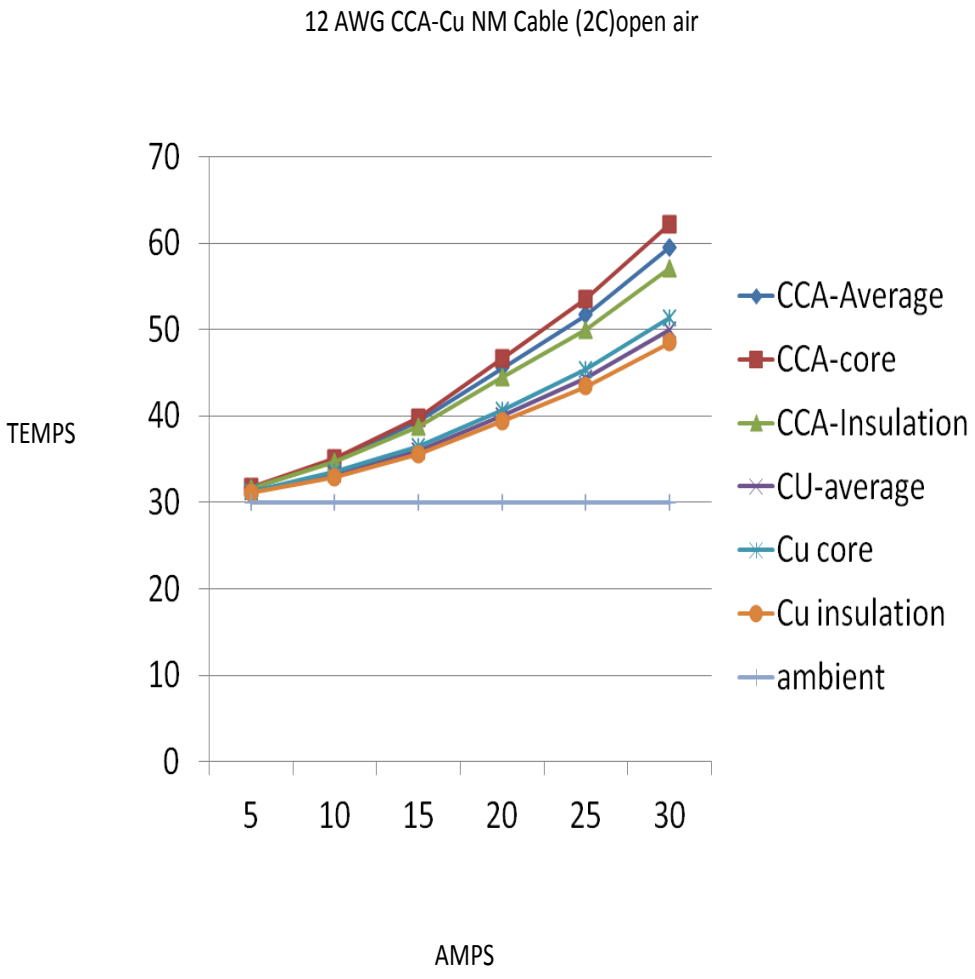

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Test Set- Up/ Layout
12 AWG in Conduit (2 conductors)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 12 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 12 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 12 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
12 AWG In conduit (2 conductors)

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
12	Conduit	5	30
12	Conduit	10	30
12	Conduit	15	30
12	Conduit	20	30
12	Conduit	25	30
12	Conduit	30	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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12 AWG CCA In conduit (2 conductors)
(Page 1 of 3)

Scan	Time	101- CU-AL White Cable-Core	103 CU-AL White Cable Insulation	104 CU-AL Black Cable Core	105 CU-AL Black Cable Insulation	106 CU-AL Black Cable Core	107 CU-AL Black Cable Insulation
	5 AMPS						
34.00	42,963.45	24.80	24.55	24.92	24.52	25.20	24.98
	Corrected Ambient	33.20	32.95	33.32	32.92	33.60	33.38
	Average	32.92					
	Average core	33.12					
	Average Insulation	32.75					
	10 Amps						
66.00	42,963.47	30.79	29.98	30.50	29.05	31.64	30.86
	Corrected Ambient	39.24	38.43	38.95	37.50	40.09	39.30
	Average	38.30					
	Average core	38.54					
	Average Insulation	38.71					
	15 Amps						
98.00	42,963.49	39.83	38.14	39.13	35.99	41.35	39.89
	Corrected Ambient	48.24	46.54	47.54	44.40	49.75	48.30
	Average	46.26					
	Average core	47.36					
	Average Insulation	45.34					
	20 AMPS						
130.00	42,963.51	53.93	51.10	52.57	46.42	56.43	53.62
	Corrected Ambient	62.34	59.51	60.98	54.83	64.84	62.03
	Average	58.48					

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	Average core	60.33					
	Average Insulation	56.95					
	25 AMPS						
162.00	42,963.54	71.01	66.92	68.93	58.87	75.38	70.30
	Corrected Ambient	79.37	75.29	77.29	67.23	83.74	78.66
	Average	73.37					
	Average core	76.31					
	Average Insulation	70.92					
	30 AMPS						
208.00	42,963.57	95.27	88.98	92.19	76.76	102.19	93.33
	Corrected Ambient	103.67	97.37	100.58	85.15	110.58	101.72
	Average	94.77					
	Average core	99.22					
	Average Insulation	91.05					

12 AWG CCA in Conduit (2 Conductors)
Page (2 of 3)

109 CU-AL White Cable Core	112 CU-AL White Cable Insulation	113 CU-AL Black Cable Core	114 CU-AL Black Cable Insulation	116 CU-AL White Cable Insulation	320 CU-AL White Cable Core
25.06	24.79	24.97	24.89	24.38	24.57
33.46	33.19	33.36	33.29	32.78	32.97
30.95	29.96	30.85	30.45	28.75	29.93
39.40	38.41	39.30	38.89	37.19	38.38

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39.93	38.02	39.99	39.25	35.66	38.12
48.34	46.43	48.40	47.65	44.07	46.53
53.56	50.15	53.76	52.46	45.78	50.35
61.97	58.57	62.17	60.87	54.19	58.76
70.65	65.52	71.23	69.04	58.58	65.18
79.02	73.88	79.59	77.40	66.95	73.54
94.77	86.67	95.96	92.55	76.17	86.50
103.16	95.06	104.35	100.95	84.56	94.89

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12 AWG CCA in Conduit (2 Conductors)
(Page 3 of 3)

315 CU-AL Black Cable Core	118 CU-AL Black Cable Insulation	102 CU-AL White Cable Insulation	110 CU-AL White Cable Core	211 CU-AL Black Cable Insulation	205CU-AL White Cable Insulation
24.41	24.04	24.69	25.09	24.46	24.15
32.81	32.44	33.08	33.49	32.86	32.55
29.90	27.86	30.58	31.01	30.08	29.09
38.35	36.31	39.03	39.46	38.52	37.54
38.26	34.03	39.40	40.19	38.41	36.46
46.67	42.44	47.80	48.60	46.82	44.87
50.81	45.67	52.82	53.77	51.24	47.67
59.23	54.08	61.23	62.19	59.65	56.08

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66.35	55.12	68.87	70.60	68.22	62.30
74.72	63.48	77.23	78.97	76.58	70.66
88.26	70.54	92.61	94.54	93.37	83.09
96.65	78.93	101.00	102.93	101.76	91.48

12 AWG Cu In conduit (2 Conductors)
(Page 1 of 2)

Scan	Time	209 CU Black Cable#1 Core	214 CU Black Cable#1 Insulation	218 CU White Cable#2 Core	220 CU White Cable#2 Insulation	206 CU Black Cable#3 Core	302 CU Black Cable#3 Insulation
	5 AMPS						
34.00	42,963.45	23.58	23.40	23.92	23.37	23.59	23.54
	Corrected Ambient	31.98	31.79	32.32	31.77	31.99	31.93
	Average	32.04					
	Average core	32.16					
	Average Insulation	31.92					
	10 Amps						
66.00	42,963.47	27.28	26.39	28.16	26.32	27.09	25.98
	Corrected Ambient	35.73	34.84	36.61	34.77	35.54	34.43
	Average	35.49					
	Average core	35.99					
	Average Insulation	34.99					
	15 Amps						

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98.00	42,963.49	32.59	30.64	34.57	30.92	32.40	30.16
	Corrected Ambient	40.99	39.05	42.98	39.32	40.81	38.57
	Average	40.68					
	Average core	41.67					
	Average Insulation	39.68					
	20 AMPS						
130.00	42,963.51	41.24	37.72	44.71	38.16	40.68	36.33
	Corrected Ambient	49.66	46.14	53.12	46.58	49.10	44.74
	Average	48.81					
	Average core	50.65					
	Average Insulation	46.96					
	25 AMPS						
162.00	42,963.54	52.09	46.85	57.21	46.77	50.75	44.10
	Corrected Ambient	60.45	55.21	65.57	55.14	59.11	52.46
	Average	58.67					
	Average core	61.52					
	Average Insulation	55.81					
	30 AMPS						
208.00	42,963.57	67.48	59.62	74.44	58.61	64.15	54.26
	Corrected Ambient	75.87	68.01	82.83	67.01	72.54	62.65
	Average	72.19					
	Average core	76.53					
	Average Insulation	67.86					

12 AWG Cu In conduit (2 Conductors)
(Page 2 of 2)

304 CU White Cable#4 Core	305 CU White Cable#4 Insulation	309 CU Black Cable#5 Core	310 CU Black Cable#5 Insulation	312 CU White Cable#6 Core	313 CU White Cable#6 Insulation
23.91	23.65	23.81	23.67	23.76	23.55

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32.30	32.04	32.20	32.07	32.15	31.94
27.70	26.94	27.55	27.04	27.49	26.59
36.15	35.39	36.00	35.48	35.94	35.04
33.58	32.18	33.20	32.27	33.25	31.45
41.99	40.59	41.60	40.68	41.66	39.85
42.62	40.10	42.09	40.23	42.11	38.73
51.03	48.52	50.50	48.65	50.53	47.14
53.25	49.79	52.80	49.90	52.88	47.31
61.61	58.15	61.16	58.26	61.24	55.67
67.84	62.54	67.31	62.93	67.59	58.86
76.24	70.93	75.70	71.33	75.98	67.25

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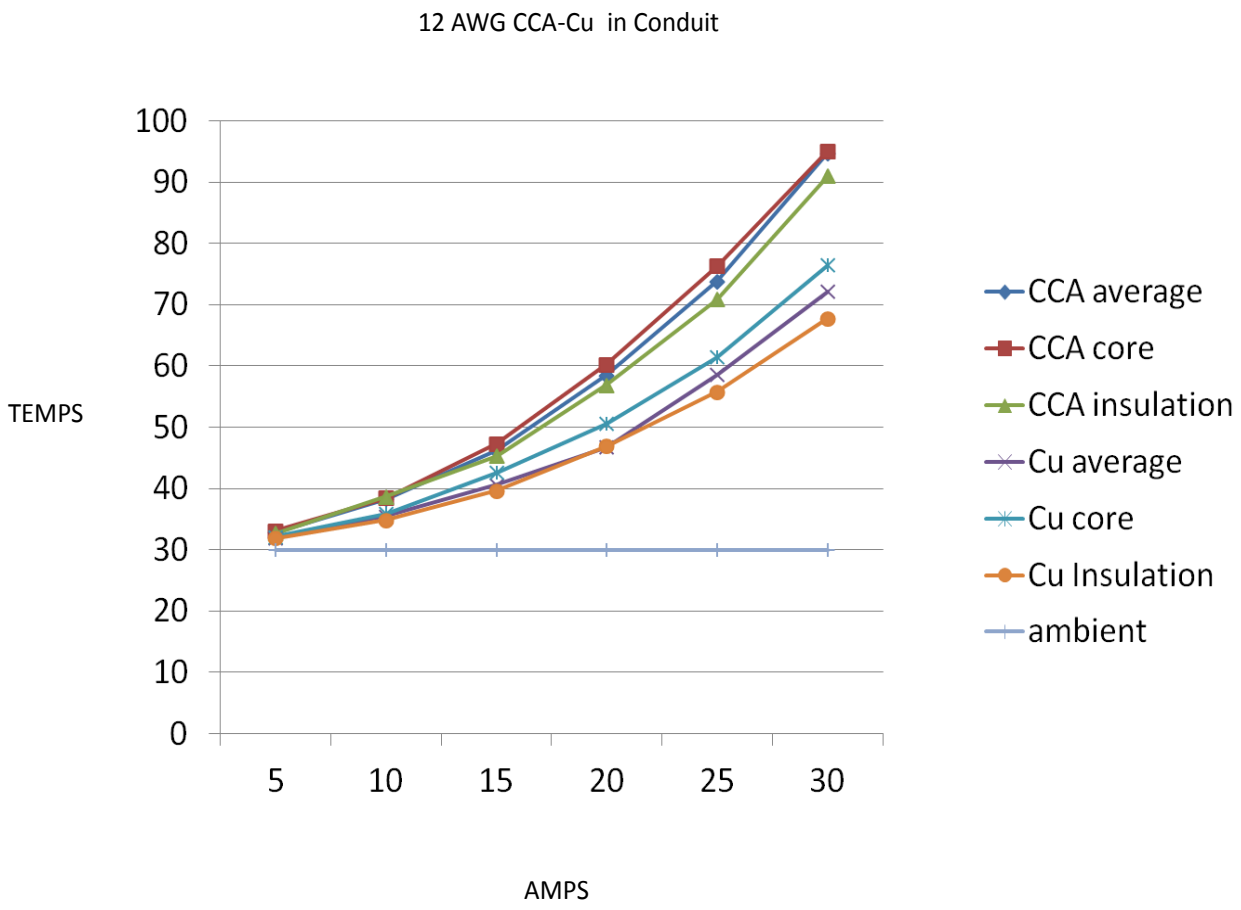

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Test Set- Up/ Layout
10 AWG single conductor in open air

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 10 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 10 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 2.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 10 AWG. Each sample was located in free open air, and laid out straight, with separation between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG Single conductor Open Air

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	Open air	5	30
10	Open air	10	30
10	Open air	15	30
10	Open air	20	30
10	Open air	25	30
10	Open air	30	30
10	Open air	35	30
10	Open air	40	30
10	Open air	45	30
10	Open air	50	30
10	Open air	55	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA Single conductor Open Air
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Scan	Time	Elapsed	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	208 CU-AL Black Cable#1 Core	205 CU-AL Black Cable#2 Insulation	120 CU-AL White Cable#2 Core	211 CU-AL White Cable#2 Insulation
	5 AMPS							
30.00	42965.59	00:00:28:59	22.27	22.95	22.82	22.50	23.18	22.75
	Corrected Ambient		30.81	31.49	31.36	31.04	31.72	31.28
	Average		31.47					
	Average core		31.47					
	Average Insulation		31.47					
	10 AMPS							
60.00	42965.62	00:00:58:59	24.20	25.01	24.70	24.41	25.11	24.60
	Corrected Ambient		32.71	33.52	33.20	32.91	33.61	33.10
	Average		33.30					
	Average core		33.34					
	Average Insulation		33.25					
	15 AMPS							
94.00	42965.64	00:01:32:59	27.20	28.61	27.87	27.26	28.29	27.43
94.00	Corrected Ambient		35.60	37.01	36.27	35.66	36.69	35.83
	Average		36.09					
	Average core		36.22					
	Average Insulation		35.94					
	20 AMPS							
121.00	42965.66	00:01:59:59	30.94	33.08	31.72	30.92	32.64	31.08
	Corrected Ambient		39.39	41.52	40.17	39.36	41.08	39.52
	Average		39.81					
	Average core		40.07					
	Average Insulation		39.52					

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	25 AMPS							
152.00	42965.68	00:02:30:59	35.76	39.24	36.76	34.98	37.75	35.59
	Corrected Ambient		44.20	47.67	45.20	43.41	46.19	44.03
	Average		44.24					
	Average core		44.68					
	Average Insulation		43.78					
	30 AMPS							
182.00	42965.70	00:03:00:59	39.98	43.90	41.39	39.49	42.72	39.71
	Corrected Ambient		48.45	52.37	49.85	47.96	51.19	48.18
	Average		48.75					
	Average core		49.39					
	Average Insulation		48.05					
	36 AMPS							
214.00	42965.72	00:03:32:59	47.04	48.39	48.73	46.42	50.45	46.40
	Corrected Ambient		55.61	56.97	57.30	54.99	59.03	54.97
	Average		55.57					
	Average core		56.61					
	Average Insulation		54.48					
	40 AMPS							
243.00	42965.74	00:04:01:59	52.41	53.30	54.36	51.59	56.81	51.39
	Corrected Ambient		60.70	61.59	62.65	59.88	65.10	59.68
	Average		60.64					
	Average core		62.02					
	Average Insulation		59.17					
	45 AMPS							
273.00	42965.76	00:04:31:59	59.93	60.57	61.45	59.16	64.82	58.73
	Corrected Ambient		68.43	69.07	69.94	67.66	73.32	67.23
	Average		68.02					
	Average core		69.86					

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	Average Insulation		66.10					
	50 AMPS							
304.00	42965.78	00:05:02:59	68.58	66.89	70.98	67.58	75.68	67.24
	Corrected Ambient		76.79	75.10	79.19	75.80	83.89	75.45
	Average		76.51					
	Average core		78.99					
	Average Insulation		73.93					
	55 AMPS							
334.00	42965.81	00:05:32:59	77.66	75.32	80.26	77.00	85.13	75.41
	Corrected Ambient		86.08	83.74	88.68	85.42	93.54	83.83
	Average		85.54					
	Average core		88.62					
	Average Insulation		82.30					

10 AWG CCA Single conductor Open Air
(Page 2 of 3)

102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #3 Insulation	315 CU-AL White Cable#4 Core	320 CU-AL Black Cable#4 Core	116 CU-AL Black Cable#4 Insulation
22.98	23.06	23.06	22.84	23.14	23.11
31.51	31.60	31.60	31.37	31.67	31.64
24.95	24.87	24.76	24.78	25.11	24.95

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33.46	33.37	33.27	33.29	33.61	33.46
27.94	27.66	27.49	28.04	28.49	27.92
36.34	36.06	35.89	36.45	36.89	36.32
31.97	31.21	31.04	32.09	32.60	31.53
40.41	39.65	39.48	40.54	41.04	39.98
36.86	35.52	34.62	36.88	37.56	35.94
45.30	43.96	43.05	45.32	46.00	44.38
41.65	40.19	38.87	41.54	42.71	40.19
50.12	48.66	47.34	50.00	51.18	48.66
49.26	47.09	45.20	48.99	50.60	47.06
57.83	55.66	53.78	57.57	59.17	55.63

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55.51	52.71	50.13	54.95	56.69	52.01
63.79	60.99	58.42	63.24	64.98	60.29
63.32	59.97	55.29	63.12	65.06	58.74
71.81	68.47	63.79	71.61	73.55	67.23
74.74	68.93	64.75	72.42	74.12	66.84
82.95	77.14	72.96	80.63	82.34	75.05
84.59	77.87	73.40	82.41	84.78	75.05
93.00	86.29	81.82	90.83	93.19	83.47

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10 AWG CCA Single conductor Open Air
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113 CU-AL White Cable #5 Core	114 CU-AL White Cable#5 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#6 Insulation	107 CU-AL White Cable#6 Insulation	106 CU-AL White Cable#6 Core
23.07	22.99	23.03	23.10	22.96	23.24
31.60	31.52	31.57	31.64	31.49	31.78
24.79	24.58	24.88	24.94	24.88	25.30
33.30	33.08	33.38	33.45	33.38	33.80
27.39	27.03	27.64	27.62	27.50	28.42
35.79	35.43	36.04	36.03	35.90	36.82
30.90	30.18	31.18	31.06	30.77	32.25
39.34	38.62	39.62	39.51	39.22	40.70

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34.92	33.57	35.29	35.22	34.83	37.20
43.36	42.01	43.73	43.65	43.27	45.64
39.04	37.63	40.14	39.22	39.04	42.06
47.51	46.10	48.60	47.69	47.50	50.53
45.69	43.45	46.83	45.74	45.25	49.22
54.26	52.02	55.40	54.32	53.83	57.79
50.91	48.17	52.61	50.82	50.25	55.22
59.19	56.46	60.90	59.10	58.54	63.51
58.10	54.41	60.26	57.35	56.69	63.45
66.59	62.90	68.75	65.85	65.18	71.95

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66.27	61.46	69.66	65.42	64.96	73.26
74.48	69.67	77.87	73.64	73.17	81.47
74.81	69.25	79.65	72.63	73.00	82.89
83.23	77.67	88.07	81.04	81.42	91.30

10 AWG Cu Single conductor Open Air
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30.00	42965.59	22.07	22.56	22.62	22.55	22.48	22.67
	Corrected Ambient	30.60	31.10	31.16	31.09	31.01	31.20
	Average	31.02					
	Average core	30.96					
	Average Insulation	31.08					
	10 AMPS						
60.00	42965.62	23.25	23.92	23.69	23.51	23.81	23.90
	Corrected Ambient	31.76	32.42	32.19	32.01	32.31	32.41
	Average	32.23					
	Average core	32.20					

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	Average Insulation	32.27					
	15 AMPS						
94.00	42965.64	25.17	26.29	25.70	25.23	26.09	25.97
94.00	Corrected Ambient	33.57	34.69	34.11	33.63	34.49	34.38
	Average	34.26					
	Average core	34.25					
	Average Insulation	34.28					
	20 AMPS						
121.00	42965.66	27.66	29.10	28.12	27.45	28.84	28.45
	Corrected Ambient	36.11	37.54	36.57	35.90	37.28	36.90
	Average	36.90					
	Average core	36.93					
	Average Insulation	36.86					
	25 AMPS						
152.00	42965.68	30.70	32.92	31.23	30.03	32.55	31.95
	Corrected Ambient	39.14	41.36	39.67	38.47	40.99	40.39
	Average	40.29					
	Average core	40.41					
	Average Insulation	40.18					
	30 AMPS						
182.00	42965.70	33.65	36.60	34.35	32.85	36.08	35.22
	Corrected Ambient	42.12	45.07	42.82	41.32	44.55	43.69
	Average	43.76					
	Average core	43.89					
	Average Insulation	43.63					
	36 AMPS						
214.00	42965.72	38.55	42.08	39.00	36.69	41.07	39.69
	Corrected Ambient	47.12	50.65	47.57	45.26	49.64	48.26
	Average	48.80					
	Average core	49.09					
	Average Insulation	48.51					

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	40 AMPS						
243.00	42965.74	41.71	46.30	42.78	40.04	45.42	43.45
	Corrected Ambient	50.00	54.59	51.07	48.33	53.71	51.74
	Average	52.54					
	Average core	52.83					
	Average Insulation	52.24					
	45 AMPS						
273.00	42965.76	47.71	51.95	47.60	43.96	50.47	48.26
	Corrected Ambient	56.20	60.44	56.09	52.45	58.97	56.75
	Average	58.05					
	Average core	58.61					
	Average Insulation	57.49					
	50 AMPS						
304.00	42965.78	53.84	59.41	54.11	49.30	57.74	54.24
	Corrected Ambient	62.05	67.62	62.32	57.52	65.96	62.45
	Average	64.37					
	Average core	65.11					
	Average Insulation	63.63					
	55 AMPS						
334.00	42965.81	60.19	63.55	59.83	53.97	58.77	58.08
	Corrected Ambient	68.60	71.96	68.24	62.39	67.18	66.50
	Average	69.97					
	Average core	70.96					
	Average Insulation	68.98					

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10 AWG Cu Single conductor Open Air
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304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Insulation	310 CU Black Cable#2 Core	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.23	22.47	22.49	22.70	22.46	22.50
30.77	31.01	31.03	31.24	30.99	31.04
23.53	23.74	23.77	24.13	23.77	23.74
32.03	32.25	32.28	32.64	32.28	32.24
25.65	25.95	26.07	26.49	25.96	25.75
34.05	34.35	34.47	34.89	34.37	34.16
28.23	28.61	28.70	29.55	28.52	28.20
36.68	37.05	37.14	38.00	36.97	36.64

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31.72	32.05	32.16	33.52	32.13	31.34
40.15	40.49	40.59	41.96	40.57	39.78
35.53	35.86	35.80	37.45	35.48	34.67
44.00	44.33	44.27	45.91	43.95	43.14
40.84	41.40	40.65	43.30	40.35	39.11
49.41	49.97	49.23	51.87	48.92	47.68
44.87	45.96	44.94	48.11	44.39	43.05
53.16	54.25	53.23	56.40	52.68	51.33
51.56	51.64	50.42	53.97	49.37	47.77
60.06	60.14	58.92	62.46	57.87	56.26

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57.88	58.65	56.87	61.91	55.93	54.05
66.10	66.86	65.08	70.12	64.14	62.26
64.75	65.59	62.39	70.14	61.61	59.85
73.17	74.00	70.80	78.55	70.03	68.26

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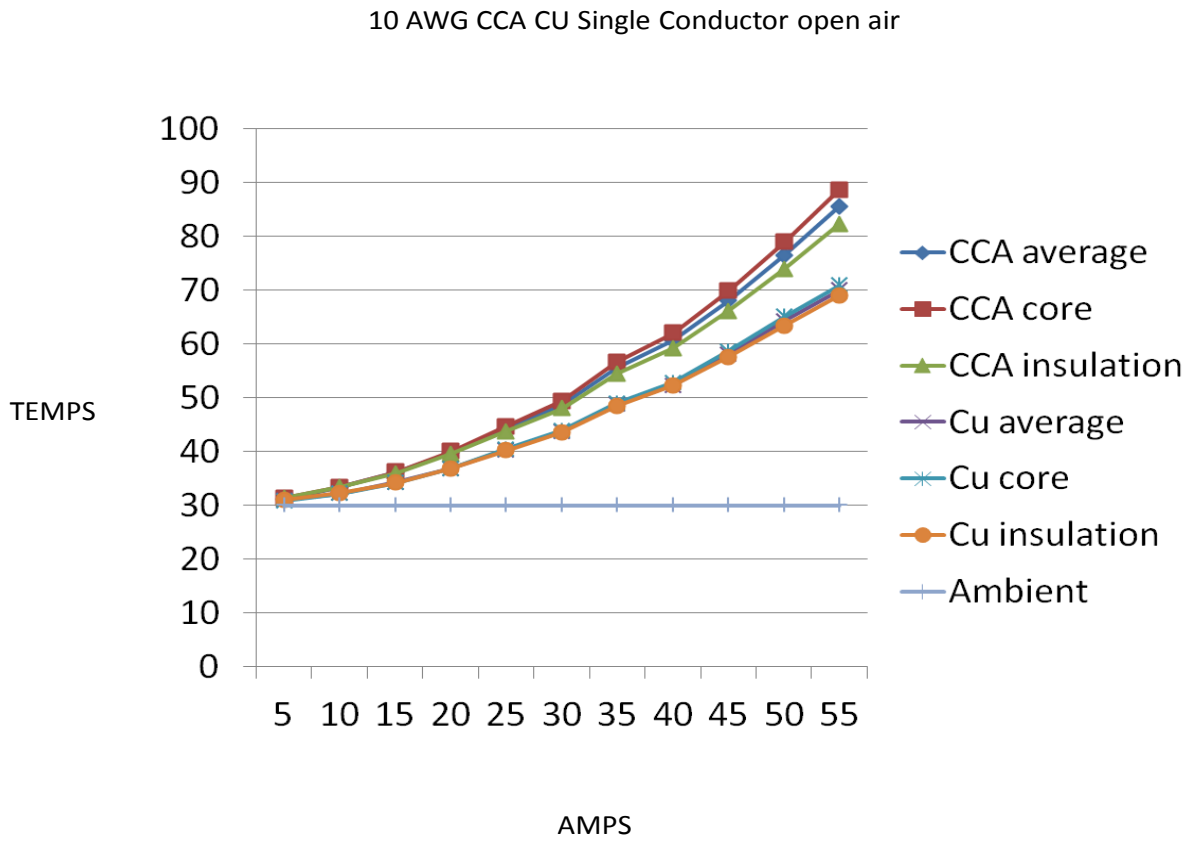

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Test Set- Up/ Layout
10 AWG in non-metallic cable in open air (2 Conductor)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the sample. Samples of 10 AWG solid three conductor (two line/ one PE) non-metallic Copper Clad Aluminum Cable (CCA wire), and samples of 10 AWG solid three conductor (Two Line/ one PE) Copper (Cu) cable were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were placed on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to Figure 3.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Each conductor sample was approximately 4 feet in length, with THHN insulation, 10 AWG. Each sample was located in free open air, and laid out straight, with approximately 3-4 inches between samples.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples were necessary, thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG in Non-Metallic Cable (2 Conductors)

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	NM Cable	5	30
10	NM Cable	10	30
10	NM Cable	15	30
10	NM Cable	20	30
10	NM Cable	25	30
10	NM Cable	30	30
10	NM Cable	35	30
10	NM Cable	40	30

Equilibrium: With reference to the test, the test was continued until constant temperatures were attained. Thermal equilibrium was considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicated no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA Non-Metallic Open Air (2 Conductor)

Page 1 of 3

Scan	Time	203 CU-AL White Cable#1-Core	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	208 CU-AL Black Cable#2 Core	120 CU-AL White Cable#2 Core	211 CU-AL White Cable# 2 Insulation
	5 AMPS						
29.00	42965.31	22.56	22.00	22.22	22.70	22.86	22.80
	Corrected Ambient	31.01	30.45	30.67	31.15	31.31	31.25
	Average	31.22					
	Average Core	31.25					
	Average Insulation	31.18					
	10 AMPS						
59.00	42965.34	24.64	24.13	24.46	24.90	25.31	25.33
	Corrected Ambient	33.21	32.70	33.02	33.47	33.88	33.90
	Average	33.48					
	Average Core	33.59					
	Average Insulation	33.34					
	15 AMPS						
90.00	42965.36	27.20	26.74	27.08	27.30	28.47	28.45
	Corrected Ambient	35.98	35.52	35.86	36.09	37.25	37.24
	Average	36.34					
	Average Core	36.53					
	Average Insulation	36.10					
	20 AMPS						
120.00	42965.38	30.31	29.56	30.82	31.04	32.46	31.76
120.00	Corrected Ambient	38.92	38.18	39.43	39.65	41.08	40.38
	Average	39.47					
	Average Core	39.91					
	Average Insulation	38.94					

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	25 AMPS						
151.00	42965.40	34.17	34.26	34.09	33.82	36.82	36.81
	Corrected Ambient	42.70	42.79	42.62	42.35	45.35	45.34
	Average	43.20					
	Average Core	43.67					
	Average Insulation	42.63					
	30 AMPS						
181.00	8/18/2017	40.14	40.25	39.61	39.67	44.07	43.95
	Corrected Ambient	48.87	48.97	48.34	48.40	52.80	52.68
	Average	49.73					
	Average Core	50.27					
	Average Insulation	49.07					
	35 AMPS						
211.00	8/18/2017	45.43	45.21	44.93	45.04	50.87	50.51
	Corrected Ambient	53.94	53.71	53.44	53.55	59.38	59.01
	Average	55.39					
	Average Core	56.18					
	Average Insulation	54.43					
	40 AMPS						
242.00	8/18/2017	50.84	50.96	50.37	51.04	58.24	57.38
	Corrected Ambient	59.52	59.63	59.04	59.71	66.92	66.05
	Average	61.97					
	Average Core	62.84					
	Average Insulation	60.91					

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10 AWG CCA Non-Metallic Open Air (2 Conductor)
(Page 2 of 3)

102 CU-AL Black Cable#3 Core	110 CU-AL Black Cable #3 Insulation	118 CU-AL White Cable #4 Insulation	315 CU-AL White Cable#3 Core	320 CU-AL Black Cable#4 Core	116 CU-AL Black Cable#4 Insulation
22.96	22.92	22.95	22.83	22.89	22.68
31.41	31.37	31.40	31.29	31.35	31.13
25.39	24.90	25.21	25.08	25.02	24.41
33.96	33.47	33.77	33.65	33.59	32.98
28.53	27.32	28.01	27.79	27.59	26.58
37.31	36.10	36.79	36.58	36.37	35.36
32.18	30.26	31.60	31.28	30.79	29.22
40.80	38.87	40.21	39.89	39.40	37.83

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36.38	33.53	35.13	35.47	34.88	32.40
44.91	42.06	43.65	43.99	43.41	40.93
43.55	39.91	41.12	41.92	41.13	37.92
52.27	48.64	49.85	50.64	49.85	46.65
50.62	45.49	46.83	48.46	47.36	42.93
59.13	53.99	55.34	56.97	55.87	51.43
56.97	51.48	52.58	55.03	54.43	49.04
65.65	60.15	61.26	63.70	63.10	57.71

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10 AWG CCA Non-Metallic Open Air (2 Conductor)
(Page 3 of 3)

114 CU-AL White Cable#6 Insulation	109 CU-AL Black Cable#5 Core	112 CU-AL Black Cable#5 Insulation	107 CU-AL White Cable#6 Insulation	106 CU-AL White Cable#5 Core	103 CU-AL Black Cable#6 Core
22.86	23.16	22.83	22.75	23.01	22.61
31.31	31.62	31.28	31.21	31.46	31.06
24.90	25.52	24.59	24.68	25.19	24.49
33.46	34.08	33.16	33.25	33.76	33.06
27.45	28.59	26.81	26.95	27.86	26.80
36.23	37.37	35.59	35.73	36.64	35.58
30.62	32.31	29.51	29.96	31.51	29.93
39.23	40.93	38.12	38.57	40.12	38.54

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34.23	36.96	32.84	33.64	35.02	33.09
42.76	45.49	41.37	42.17	43.55	41.62
40.58	44.15	38.29	40.01	41.40	38.66
49.31	52.87	47.02	48.74	50.13	47.39
46.42	51.15	43.40	45.61	47.21	43.99
54.93	59.66	51.91	54.12	55.71	52.50
53.18	58.34	49.24	52.19	53.82	49.96
61.86	67.01	57.92	60.86	62.49	58.63

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10 AWG Cu in non-metallic cable (2 Conductor) in open air
(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
29.00	42965.31	22.35	22.15	22.22	22.08	22.35	22.41
	Corrected Ambient	30.80	30.60	30.67	30.53	30.80	30.86
	Average	30.77					
	Average Core	30.79					
	Average Insulation	30.75					
	10 AMPS						
59.00	42965.34	23.86	23.34	23.35	23.28	23.64	23.74
	Corrected Ambient	32.42	31.91	31.92	31.85	32.21	32.31
	Average	32.18					
	Average Core	32.25					
	Average Insulation	32.12					
	15 AMPS						
90.00	42965.36	25.78	24.85	24.84	24.85	25.28	25.45
	Corrected Ambient	34.56	33.63	33.62	33.64	34.06	34.23
	Average	34.05					
	Average Core	34.14					
	Average Insulation	33.97					
	20 AMPS						
120.00	42965.38	28.46	26.70	26.84	26.63	27.38	27.39
120.00	Corrected Ambient	37.07	35.32	35.45	35.24	35.99	36.01
	Average	35.93					
	Average Core	36.20					
	Average Insulation	35.65					

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	25 AMPS						
151.00	42965.40	31.70	29.22	29.24	29.04	30.00	29.99
	Corrected Ambient	40.23	37.75	37.77	37.57	38.53	38.52
	Average	38.40					
	Average Core	38.78					
	Average Insulation	38.03					
	30 AMPS						
181.00	8/18/2017	36.74	33.05	33.55	33.39	33.88	34.40
	Corrected Ambient	45.47	41.78	42.28	42.12	42.61	43.13
	Average	42.80					
	Average Core	43.21					
	Average Insulation	42.39					
	35 AMPS						
211.00	8/18/2017	41.63	36.87	37.11	36.85	37.80	38.22
	Corrected Ambient	50.14	45.37	45.61	45.36	46.30	46.73
	Average	46.58					
	Average Core	47.13					
	Average Insulation	46.03					
	40 AMPS						
242.00	8/18/2017	47.11	41.04	41.32	40.92	42.28	42.42
	Corrected Ambient	55.78	49.71	50.00	49.59	50.96	51.10
	Average	51.05					
	Average Core	51.88					
	Average Insulation	50.21					

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10 AWG Cu in non-metallic cable (2 Conductor) in open air

Page 2 of 2

304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Core	310 CU Black Cable#2 Insulation	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
22.46	22.17	22.34	22.44	22.34	22.52
30.91	30.62	30.79	30.89	30.80	30.97
23.89	23.29	23.74	23.72	23.64	23.93
32.46	31.86	32.31	32.28	32.20	32.50
25.78	24.68	25.27	25.47	25.21	25.82
34.56	33.46	34.05	34.25	33.99	34.60
27.95	26.31	27.57	27.28	27.34	27.92
36.56	34.92	36.18	35.89	35.95	36.54

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30.76	28.50	30.31	29.75	29.47	30.49
39.29	37.03	38.84	38.28	38.00	39.02
35.55	32.13	34.15	34.05	33.00	34.97
44.28	40.86	42.88	42.77	41.73	43.70
40.14	35.60	38.38	38.05	36.70	39.58
48.65	44.11	46.89	46.56	45.21	48.08
44.88	38.92	43.18	42.00	40.48	43.95
53.55	47.60	51.85	50.67	49.16	52.62

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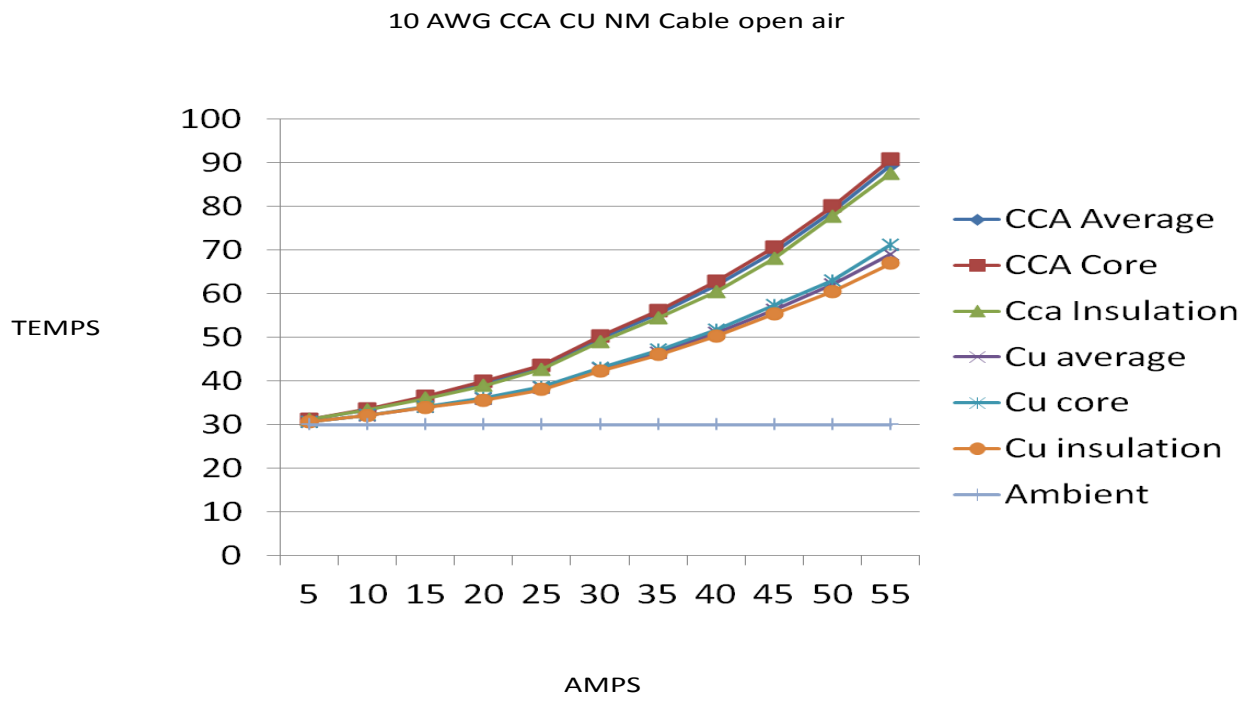

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Test Set- Up/ Layout
10 AWG in Conduit (2 Conductor)

Circuit layout is shown in figure 1. A Variac, which was supplied by a 120V source, was connected to a step-down transformer. One side of the secondary coil was connected to the samples. Samples of conduit were filled each with two wires of 10 AWG solid Copper Clad Aluminum (CCA wire) with THHN insulation, and samples of 10 AWG solid Copper (Cu) wire with THHN insulation were all connected in series. The other side of the series connected wires was connected to a resistor, which in return was connected to the other side of the coil winding on the transformer, and completed the series circuit. The current was monitored by an ammeter, and the voltage across the resistor was also monitored using a voltmeter.

Thermocouples were places on both the conductor and insulator of the individual wires. The wires were connected using standard wire nuts, suitable for the wire gauge and number of wires. Refer to figure 4.

Data: Total average, core average and insulation average were taken for both CCA and CU wire. Data was adjusted to 30C ambient

Samples: Consisted of a ½ inch conduit, approximately 3 feet in length. Each conduit was wired with two separate single solid conductor wires. Each wire sample was 4 feet in length, with THHN insulation, 10 AWG. There were three feet of wire in the conduit, and approximately 6.0 inches of length on wire on each side. Each conduit was located approximately 3-4 inches between samples. The conduit was sealed with duck tap on both sides to prevent air flow. The position of each wire sample within the conduit is unknown. Wire insulation had the ability to come into close proximity of each other and the conduit surface.

Test Equipment: All equipment used was calibrated, and is listed in appendix B

Thermocouples: Thermocouples was consisted of wire not larger than 24AWG and not smaller than 30AWG. Whenever referee temperature measurements by thermocouples was necessary. Thermocouples consisting of 30AWG iron constantan wire and a potentiometer type instrument were used. The thermocouple wire conformed to the requirements for Special Tolerances Standards Specification and Temperature Electromotive Force (emf) Tables for Standardized Thermocouple ANSI/ ASTM E320M.

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Test Procedure
10 AWG Conduit

The sample was configured as shown in figure 1. Initially, 5 Amps was drawn through the sample. Temperature and current data was recorded every minute. The current was maintained for 30 minutes, at which time, data was reviewed for equilibrium. Once equilibrium was reach, final data was recorded for the amperage rating. At which time, an additional 5 amps was drawn though the sample. This procedure to incrementally increase the amperage was continued until failure or a max current was reached for the applicable wire gauge and application.

Gauge (AWG)	Condition	Amperage(A)	Approx. Time(mins)
10	Conduit	5	30
10	Conduit	10	30
10	Conduit	15	30
10	Conduit	20	30
10	Conduit	25	30
10	Conduit	30	30
10	Conduit	35	30
10	Conduit	40	30

Equilibrium: With reference to the test, test was continued until constant temperatures were attained. Thermal equilibrium is considered to exist when three successive readings taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 5 minutes intervals, indicate no change.

Environment: 25C ambient in a 25-45% humidity

Temperatures: All temperatures are in Celsius

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10 AWG CCA in Conduit (2 Conductor)

(Page 1 of 3)

Scan	Time	203 CU-AL White Cable#1-Core	213 CU-AL White Cable#1 Insulation	204 CU-AL Black Cable#1 Core	212 CU-AL Black Cable#1 Insulation	205 CU-AL Black Cable#2 Insulation	120 CU-AL White Cable#2 Core
	5 AMPS						
30.00	42966.40	23.32	22.63	22.90	23.15	23.26	23.40
	Corrected Ambient	31.77	31.08	31.35	31.59	31.70	31.85
	Average	31.85					
	Average core	31.89					
	Average insulation	31.80					
	10 AMPS						
64.00	42966.42	26.59	25.43	26.27	25.92	26.52	26.56
	Corrected Ambient	34.93	33.76	34.60	34.25	34.85	34.90
	Average	34.75					
	Average core	34.84					
	Average insulation	34.66					
	15 AMPS						
95.00	42966.44	31.92	29.65	31.74	30.41	31.65	31.89
	Corrected Ambient	40.23	37.96	40.05	38.72	39.97	40.21
	Average	39.72					
	Average core	39.93					
	Average insulation	39.49					
	20 AMPS						
132.00	42966.47	38.70	35.07	38.69	36.15	38.16	38.61
	Corrected Ambient	46.73	43.10	46.72	44.18	46.19	46.64
	Average	45.82					
	Average core	46.15					

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	Average insulation	45.45					
	26 AMPS						
162.00	42966.49	47.38	42.40	47.49	43.29	46.07	46.97
	Corrected Ambient	55.50	50.51	55.61	51.40	54.18	55.09
	Average	53.85					
	Average core	54.35					
	Average insulation	53.30					
	30 AMPS						
192.00	42966.51	57.44	50.50	57.79	51.44	55.09	56.93
	Corrected Ambient	65.41	58.46	65.75	59.40	63.05	64.90
	Average	62.99					
	Average core	63.71					
	Average insulation	62.17					
	35 AMPS						
222.00	42966.53	70.55	60.57	71.31	61.86	66.91	69.78
	Corrected Ambient	78.66	68.68	79.42	69.97	75.02	77.89
	Average	75.21					
	Average core	76.27					
	Average insulation	74.01					
	40 AMPS						
260.00	42966.56	86.35	74.81	87.61	74.53	81.18	86.55
	Corrected Ambient	94.33	82.80	95.59	82.51	89.16	94.53
	Average	89.94					
	Average core	91.36					
	Average insulation	88.34					

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10 AWG CCA in Conduit (2 Conductor)
(Page 2 of 3)

211 CU-AL White Cable# 3 Insulation	102 CU-AL Black Cable#3 Core	320 CU-AL Black Cable#4 Core	113 CU-AL White Cable #4 Core	114 CU-AL White Cable#4 Insulation	109 CU-AL Black Cable#5 Core
23.26	23.49	23.53	23.64	23.57	23.74
31.70	31.94	31.98	32.08	32.01	32.18
26.21	26.62	26.66	26.73	26.46	26.83
34.54	34.96	35.00	35.07	34.80	35.17
30.86	31.75	31.93	32.02	31.42	32.03
39.17	40.06	40.24	40.33	39.73	40.34
36.72	38.39	38.61	38.74	37.61	38.57
44.75	46.42	46.64	46.77	45.64	46.60

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43.72	46.74	46.85	47.03	45.17	46.62
51.83	54.86	54.96	55.14	53.28	54.74
51.86	56.42	56.62	56.89	54.04	56.27
59.83	64.38	64.58	64.86	62.00	64.23
62.45	69.09	69.33	69.71	65.42	68.98
70.56	77.20	77.43	77.81	73.53	77.09
74.86	84.65	84.99	85.42	79.26	84.28
82.84	92.63	92.97	93.40	87.25	92.26

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10 AWG CCA in Conduit (2 Conductor)
(Page 3 of 3)

107 CU-AL White Cable#5 Insulation	103 CU-AL Black Cable#5 Core	101 CU-AL Black Cbale#6 Insulation	104 CU-AL White Cable#6 Core	105 CU-AL White Cable#6 Insulation
23.63	23.30	23.62	23.65	23.71
32.08	31.75	32.07	32.09	32.16
26.63	25.87	26.80	26.40	26.61
8.34	8.34	8.34	8.34	8.34
34.97	34.21	35.14	34.73	34.94
31.70	30.22	32.18	31.08	31.53
8.31	8.31	8.31	8.31	8.31
40.01	38.53	40.49	39.39	39.85
38.35	35.78	39.22	37.02	38.08
8.03	8.03	8.03	8.03	8.03
46.38	43.81	47.25	45.05	46.11

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46.57	42.58	48.00	44.44	46.26
54.68	50.69	56.12	52.55	54.38
56.53	50.33	58.28	53.07	55.91
64.50	58.29	66.24	61.04	63.87
69.86	60.42	71.69	64.34	68.46
77.97	68.52	79.80	72.44	76.57
86.55	72.57	88.22	77.95	83.47
94.53	80.55	96.20	85.93	91.45

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10 AWG Cu in Conduit (2 Conductor)

(Page 1 of 2)

Scan	Time	209 CU Black Cable#6 Core	214 CU Black Cable#6 Insulation	218 CU White Cable#5 Core	220 CU White Cable#5 Insulation	206 CU Black Cable#4 Core	302 CU Black Cable#4 Insulation
	5 AMPS						
30.00	42966.40	22.82	22.91	22.98	22.94	22.84	23.12
	Corrected Ambient	31.26	31.36	31.43	31.39	31.28	31.57
	Average	31.43					
	Average core	31.41					
	Average insulation	31.46					
	10 AMPS						
64.00	42966.42	24.81	24.98	24.84	24.87	24.60	24.72
	Corrected Ambient	33.14	33.32	33.18	33.21	32.94	33.06
	Average	33.21					
	Average core	33.19					
	Average insulation	33.23					
	15 AMPS						
95.00	42966.44	28.18	28.33	28.05	28.18	27.66	27.71
	Corrected Ambient	36.49	36.64	36.36	36.49	35.97	36.02
	Average	36.47					
	Average core	36.46					
	Average insulation	36.49					
	20 AMPS						
132.00	42966.47	32.50	32.63	32.33	32.54	31.64	31.58
	Corrected Ambient	40.53	40.66	40.36	40.57	39.67	39.61
	Average	40.49					
	Average core	40.48					
	Average insulation	40.50					
	26 AMPS						

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162.00	42966.49	37.65	37.76	37.74	37.82	36.46	36.24
	Corrected Ambient	45.76	45.87	45.85	45.93	44.58	44.35
	Average	45.73					
	Average core	45.75					
	Average insulation	45.72					
	30 AMPS						
192.00	42966.51	43.85	43.86	43.85	44.09	42.10	41.80
	Corrected Ambient	51.81	51.83	51.82	52.05	50.06	49.76
	Average	51.69					
	Average core	51.72					
	Average insulation	51.67					
	35 AMPS						
222.00	42966.53	51.88	51.82	51.54	52.18	49.45	48.85
	Corrected Ambient	59.99	59.93	59.65	60.29	57.56	56.95
	Average	59.66					
	Average core	59.67					
	Average insulation	59.65					
	40 AMPS						
260.00	42966.56	61.89	61.68	59.87	62.27	58.36	57.45
	Corrected Ambient	69.87	69.66	67.86	70.25	66.34	65.43
	Average	69.09					
	Average core	68.99					
	Average insulation	69.19					

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10 AWG Cu in Conduit (2 Conductor)

(Page 2 of 2)

304 CU White Cable#3 Core	305 CU White Cable#3 Insulation	309 CU Black Cable#2 Insulation	310 CU Black Cable#2 Core	312 CU White Cable#1 Core	313 CU White Cable#1 Insulation
23.07	22.92	23.07	23.03	23.07	23.10
31.52	31.37	31.51	31.48	31.51	31.54
24.81	24.45	25.07	24.82	25.23	25.25
33.15	32.79	33.41	33.16	33.56	33.58
27.97	27.26	28.60	28.02	29.02	28.99
36.28	35.57	36.91	36.33	37.33	37.30
32.12	30.89	33.22	32.16	33.93	33.93
40.15	38.92	41.25	40.19	41.96	41.96

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37.07	35.14	38.79	37.10	39.78	39.86
45.19	43.26	46.90	45.22	47.90	47.98
43.01	40.14	45.40	42.95	46.77	46.95
50.97	48.10	53.36	50.92	54.73	54.92
50.52	46.53	53.82	50.33	55.67	56.04
58.62	54.64	61.93	58.43	63.78	64.14
60.04	54.32	64.29	59.29	66.58	67.26
68.02	62.30	72.28	67.27	74.57	75.24

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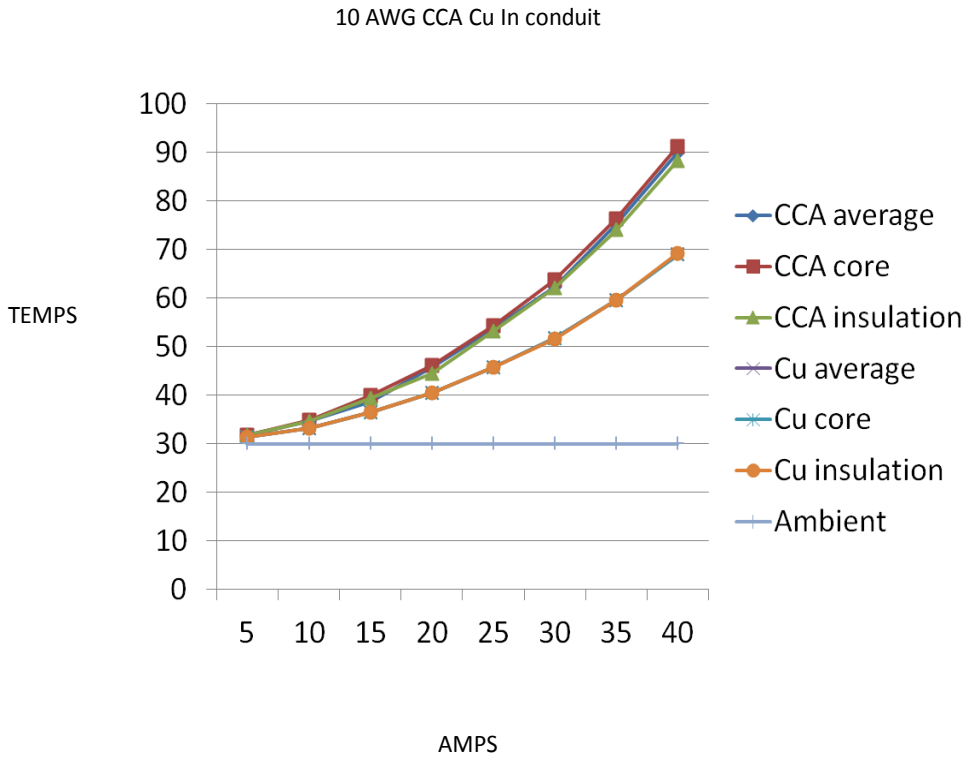

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Summary

14 AWG						
Max Temps	Single conductor@35A		NM cable@25A		Conduit@25A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	89.81	67.08	68.95	53.14	117.69	79.54
Average Core	92.67	67.91	69.61	53.05	124.41	82.77
Average Insulation	86.68	66.25	71.60	53.23	111.52	76.31

12 AWG						
Max Temps	Single conductor@40A		NM cable@30A		Conduit@30A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	76.85605	66.52817	59.54	49.96617	94.77	72.19
Average Core	80.71511	69.18933	62.19	51.36633	99.22	76.53
Average Insulation	72.72958	63.867	57.11	48.566	91.05	67.86

10 AWG						
Max Temps	Single conductor@55		NM cable@40A		Conduit@40 A	
	CCA	Cu	CCA	Cu	CCA	Cu
Average	85.54	69.97	61.97	51.05	89.94	69.09
Average Core	88.62	70.96	62.84	51.88	91.36	68.99
Average Insulation	82.30	68.98	60.91	50.21	88.34	69.19

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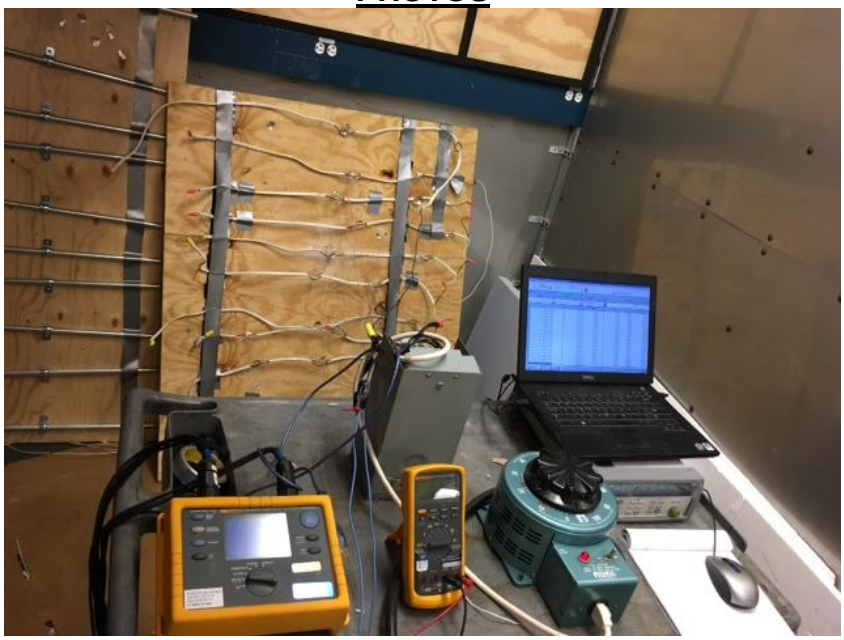
APPENDIX A
PHOTOS



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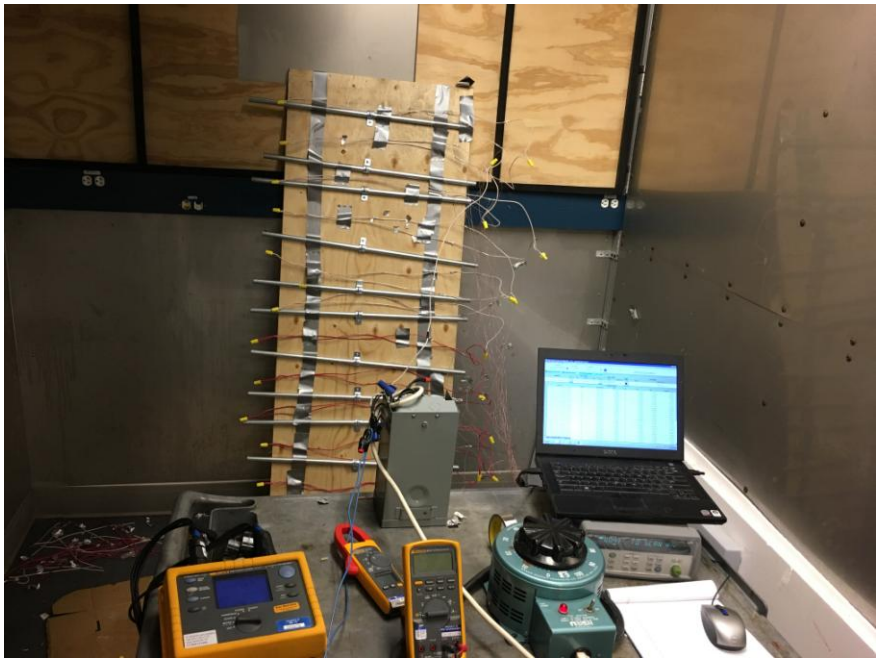

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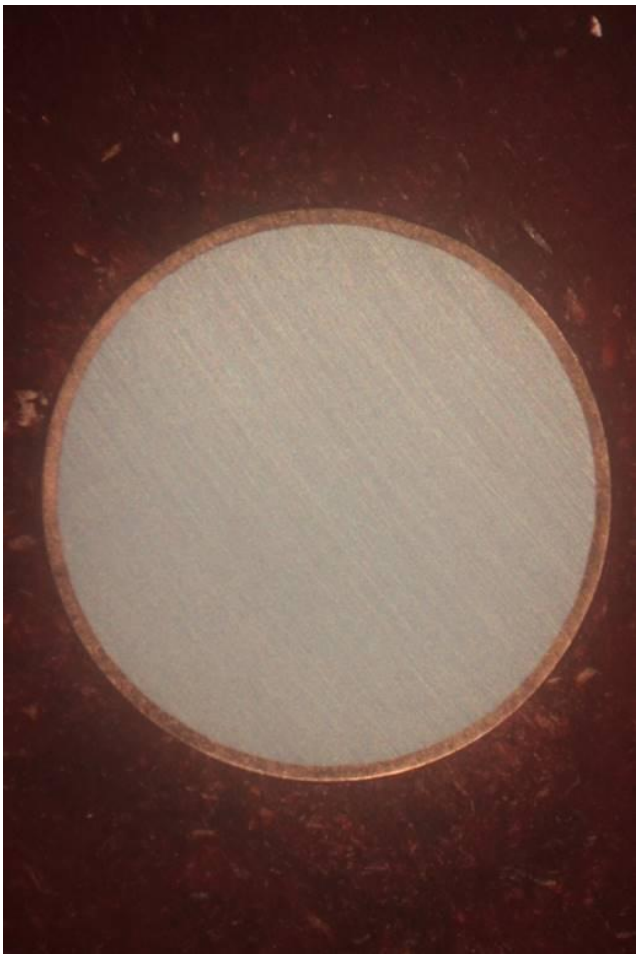

Cross Sectional view of the CCA

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APPENDIX B
EQUIPMENT LIST

Equipment	PL Code	Calibration
Transformer	PL004985	N/A
Agilent Temperature Data Acquisition system	PL005628	N/A
Thermocouples Cartridge, Type J	PL004988 PL003269 PL003268	Calibrated Daily or before each usage.
Simpson Model 06713100 Current shunt	PL002161	See Certificate Below Appendix C
Fluke multi meter, model 87V	PL004935	See Certificate Below Appendix C
Fluke Digital Clamp Meter, model 374FC	PL005812	See Certificate Below Appendix C
Thermocouples	Same as above	Conducted Daily
Power Logger	PL003379	See Certificate Below Appendix C

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APPENDIX C
CALIBRATION

Trescal

Certificate #: *3869120002 e* *W*

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	374FC
Description:	Clamp Meter
Serial Number:	37421743WS
Asset Number:	PL005812
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	05/01/2017
Due Date:	05/01/2018
Temperature:	73.00 **deg. F**
Humidity:	40.00 **%**
Baro. Press.:	
Procedure:	DCN 50442
Reference:	TO 33K1-4-853-1 Rev. 30 Jun 2008
Dept:	

Incoming Remarks:
w/case

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390482	Fluke	5522A	Multifunction Calibrator	11/22/2016	11/22/2017

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Trescal

Certificate #: *3765740001 e* *W*

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	87V
Description:	DMM
Serial Number:	26270081
Asset Number:	PL004935
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	01/31/2017
Due Date:	01/31/2018
Temperature:	74.00 **deg. F**
Humidity:	20.00 **%**
Baro. Press.:	
Procedure:	DCN 07074
Reference:	manufacturer's manual
Dept:	

Incoming Remarks:
w/case/leads/holster

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390169	Fluke	5500A	Multifunction Calibrator	04/26/2016	04/26/2017

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Trescal

Certificate #: *3869120002 e* *W*

17025 Accredited Certificate of Calibration

Calibration Laboratory
Certificate #: 1022.01

Acct #:	047070
Customer:	NSF International
Shipper #:	
Address:	789 N. Dixboro Road Ann Arbor, MI, 48105-9723
Contact:	Heather Wade
PO #:	Credit Card

Manufacturer:	Fluke
Model:	374FC
Description:	Clamp Meter
Serial Number:	37421743WS
Asset Number:	PL005812
Barcode:	

As Received		As Returned		Action Taken	
In Tolerance	X	In Tolerance	X	Full Calibration	X
Out of Tolerance		Out of Tolerance		Special Calibration	
Malfunctioning		Malfunctioning		Oper. Verification	
Operational		Operational		Adjusted	
Damaged		N/A		Repaired	
N/A				Charted	
				Returned As Is	

Cal Date:	05/01/2017
Due Date:	05/01/2018
Temperature:	73.00 deg. F
Humidity:	40.00 %
Baro. Press.:	
Procedure:	DCN 50442
Reference:	TO 33K1-4-853-1 Rev. 30 Jun 2008
Dept:	

Incoming Remarks:
w/case

Technical Remarks:

Calibration Standards Utilized

Cert. #	Manufacturer	Model #	Description	Cal Date	Due Date
3369390482	Fluke	5522A	Multifunction Calibrator	11/22/2016	11/22/2017

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ACCREDITED
Calibration Cert# 2165.01

FLUKE

Certificate of Calibration

Everett Service Center

Certificate Number:	322693		
Data Type:	As-Left	**Calibration Date:**	27-Feb-2017
Result Summary:	Measurement Results < Limits		
Manufacturer:	Fluke	**Certificate Date:**	28-Feb-2017
Model:	1735	**Temperature:**	23.6 °C
Serial Number:	S090503258B6	**Humidity:**	28.1 %
Description:	Power Quality Logger		
Procedure:	Fluke 1735:(2 year) ACAL VER RS-232/5520	**Revision:**	2.1
Customer:	NSF INTERNATIONAL		
City:	ANN ARBOR	**Country:**	US
State:	MI		
Purchase Order:	CCS CALIBRATION LAB - NSF INTERNATIONAL	**RMA:**	31194022
Asset ID:	PL003379		

This calibration is traceable to the International System of Units (SI), through National Metrology Institutes (NIST, PTB, NRC, NPL, etc.), ratiometric techniques, or natural physical constants. This certificate applies only to the item identified and shall not be reproduced either than in full, without the specific written approval by Fluke Corporation. Calibration certificates without signature are not valid. The calibration has been completed in accordance with Fluke Electronics Corporation Quality System Document 111.0 Revision 11B 8/2014 and/or Fluke 17025 Quality Manual QSD 111.41 Revision 005 8/2014.

The Data Type found in this certificate must be interpreted as:

- As - Found Calibration data collected before the unit is adjusted and / or repaired.
- As - Left Calibration data collected after the unit has been adjusted and / or repaired.
- Found-Left Calibration data collected without any adjustment and / or repair performed.

This calibration conforms to the requirements of ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994 (R2002).

In the attached measurement results, deviation may be expressed with units, Measured Value (MV) - Nominal Value (NV) or as a proportion of the nominal value ((MV-NV)/NV), expressed without units with a scalar multiplier such as % (0.01), or as a ratio of the units (mA/A, µ/V, etc.) Descriptions such as µA/A, µV/V, and others, where used to annotate results or column headings are the preferred replacements for what was historically labeled as "ppm" or parts-per-million and described the results in that column, unless otherwise noted by units symbols.

Where applicable, the expanded uncertainty of measurement at the time of test is given in the following pages. They are calculated in accordance with the method described in the ISO Guide to the Expression of Uncertainty in Measurement (GUM). The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k, such that the confidence level approximates 95%.

This calibration certificate may contain data that is not covered by the A2LA Scope of Accreditation. Unaccredited material, where applicable is indicated by an asterisk (*), or confined to clearly marked sections. Functional (Pass / Fail) tests are not accredited.

No statement of compliance with specifications is made or implied on this certificate. However, measurement results are reviewed, where applicable, to establish where any measurement result exceeded the manufacturer's specifications.

Measurement results greater than limits of error are indicated by '!'.

Accredited FLUKE

Cert # 322693
Cal Date 27-Feb-2017
S/N S090503258B6
www.fluke.com

Cert # 322693
Date 27/2/2017
www.fluke.com

Rolly Sherwood
Calibration Technician

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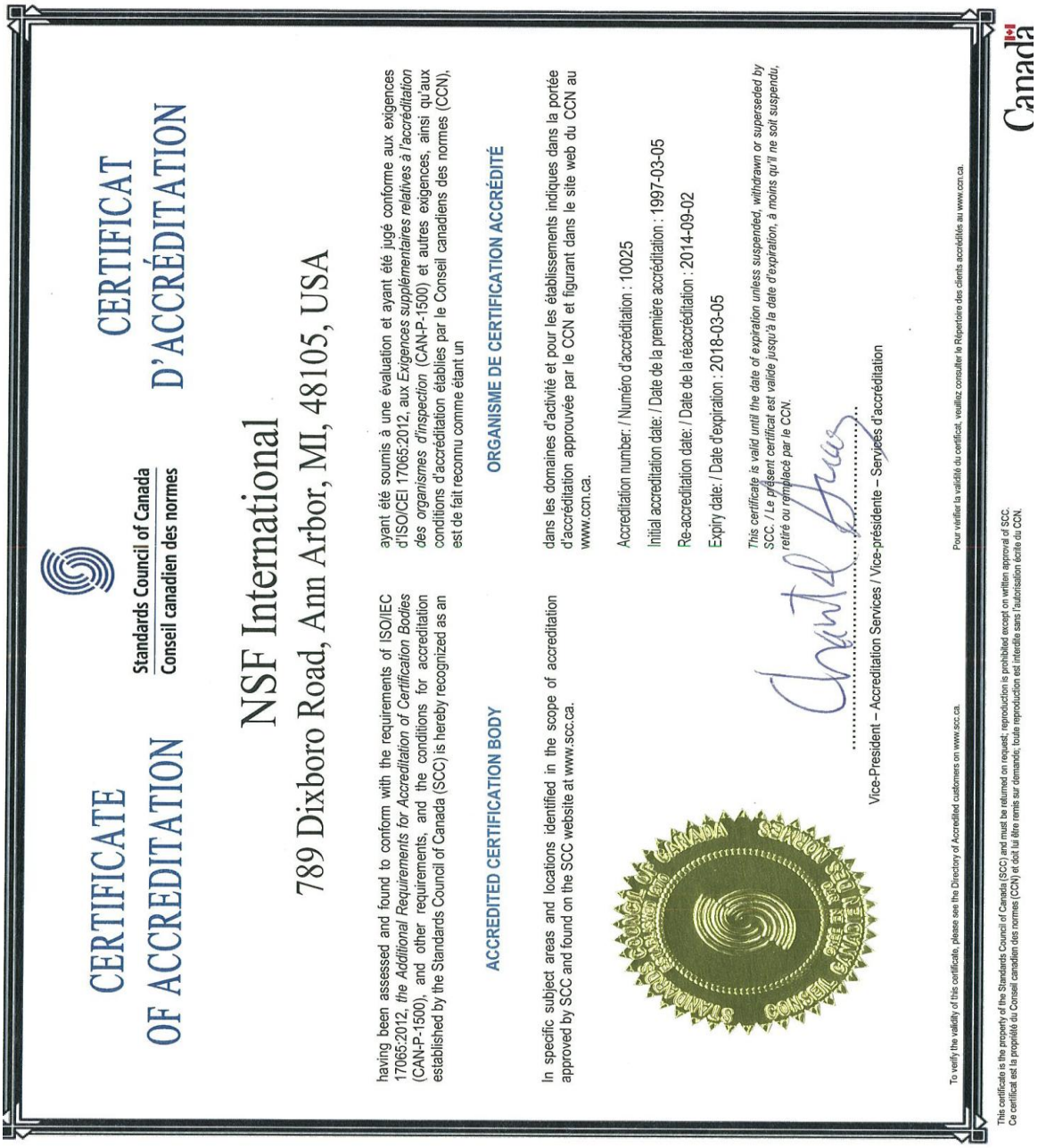
APPENDIX D
LABORATORY CERTIFICATIONS



CERTIFICATE OF ACCREDITATION

Standards Council of Canada
Conseil canadien des normes

CERTIFICAT D'ACCRÉDITATION

NSF International
789 Dixboro Road, Ann Arbor, MI, 48105, USA

having been assessed and found to conform with the requirements of ISO/IEC 17065:2012, *the Additional Requirements for Accreditation of Certification Bodies* (CAN-P-1500), and other requirements, and the conditions for accreditation established by the Standards Council of Canada (SCC) is hereby recognized as an

ayant été soumis à une évaluation et ayant été jugé conforme aux exigences d'ISO/CEI 17065:2012, aux *Exigences supplémentaires relatives à l'accréditation des organismes d'inspection* (CAN-P-1500) et autres exigences, ainsi qu'aux conditions d'accréditation établies par le Conseil canadiens des normes (CCN), est de fait reconnu comme étant un

ACCREDITED CERTIFICATION BODY

ORGANISME DE CERTIFICATION ACCRÉDITÉ

In specific subject areas and locations identified in the scope of accreditation approved by SCC and found on the SCC website at www.scc.ca.

dans les domaines d'activité et pour les établissements indiques dans la portée d'accréditation approuvée par le CCN et figurant dans le site web du CCN au www.ccn.ca.

Accreditation number: / Numéro d'accréditation : 10025

Initial accreditation date: / Date de la première accréditation : 1997-03-05

Re-accreditation date: / Date de la réaccréditation : 2014-09-02

Expiry date: / Date d'expiration : 2018-03-05

This certificate is valid until the date of expiration unless suspended, withdrawn or superseded by SCC. / Le présent certificat est valide jusqu'à la date d'expiration, à moins qu'il ne soit suspendu, retiré ou remplacé par le CCN.

STANDARDS COUNCIL OF CANADA
CONSEIL CANADIEN DES NORMES

Vice-President – Accreditation Services / Vice-présidente – Services d'accréditation

To verify the validity of this certificate, please see the Directory of Accredited customers on www.scc.ca.

Pour vérifier la validité du certificat, veuillez consulter le Répertoire des clients accrédités au www.ccn.ca.

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Canada

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CERTIFICATE

Certificate Number: 140920.00

The Environmental Management System and implementation of:

NSF International
789 N. Dixboro Road
Ann Arbor, MI 48105
United States

meets the requirements of the standard:

ISO 14001:2015

Scope:
Laboratory testing, product certification, and domestic (U.S.) auditing associated with the facility located at 789 N. Dixboro Road, Ann Arbor, Michigan. NSF-ISR operations are excluded from the scope of registration.

Certificate Expires:	July 04, 2018
Re-issued:	August 08, 2017
Certificate Issued:	July 05, 2015
Certified Since:	July 05, 2006

Dr. Cem O. Onus
Managing Director, Business Assurance
DEKRA Certification, Inc.
1120 Welsh Road, Suite 210
North Wales, PA 19454 USA
(215) 997-4519
dekra-certification.us

ANAB ACCREDITED ISO/IEC 17021 MANAGEMENT SYSTEMS CERTIFICATION BODY

MEMBER OF MULTILATERAL RECOGNITION ARRANGEMENT IAF

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Occupational Safety and Health Administration

Nationally Recognized Testing Laboratory Program

NRTLP

Certificate of Recognition

NSF International

with headquarters at:

789 Dixboro Road
Ann Arbor, Michigan 48105
United States

is recognized by the Occupational Safety and Health Administration (OSHA) as meeting the requirements for a Nationally Recognized Testing Laboratory (NRTL) established under Section 1910.7 of *Title 29, Code of Federal Regulations.* This recognition is limited to testing and certification only within the current scope of recognition and is subject to all other terms set forth in the letter of recognition and in applicable *Federal Register* notices and as summarized on OSHA's website. This recognition continues in force beyond the "*Effective through*" date below provided the NRTL has filed a timely request for renewal with OSHA. For current recognition status and other recognition information, contact the OSHA NRTL Program or visit *https://www.osha.gov/dts/otpca/nrtl/*

July 14, 2019
Effective Through

David Michaels, PhD, MPH
Assistant Secretary of Labor for
Occupational Safety and Health Administration

UNITED STATES OF AMERICA · DEPARTMENT OF LABOR

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3933 Route 11
Cortland, NY 13045
Telephone: 1-607-753-6711
Facsimile: 1-607-758-6595
www.intertek.com

TEST LETTER REPORT

Copperweld Bimetallics, LLC
Test Report

SCOPE OF WORK
PERFORMANCE TESTING – PRODUCT TYPE PER STANDARD

REPORT NUMBER
103589128CRT-001A

ISSUE DATE	**[REVISED DATE]**
27-Aug-2018	28-Aug-2018

PAGES
14

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TEST LETTER REPORT

27-Aug-2018

Intertek Report No.: 103589128CRT-001A
Intertek Project No.: G103589128

Mr. Peter Graser
Copperweld Bimetallics, LLC
215 Centerview Drive
Suite 360
Brentwood, TN 37027

Ph: (770) 952-6445
email: pgraser@copperweld.com

Subject: Static Heating test of Push-in Wire Connectors on CCA Conductors in accordance with Claus 9.12 Spring-action sequence per UL 486C.

Dear Mr. Peter Graser,

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

> **UL 486C / CSA C22.2 No. 188-18 –** Splicing Wire Connectors, Seventh Edition, Dated January 26, 2018

SECTION 1
SUMMARY

This investigation was authorized by signed proposal number Qu-00894894, dated 29-June-2018. A production sample was received on 26-June-2018 and tested from 23-Jul-2018 to 27-Aug-2018 at the Intertek Cortland facility.

TEST LETTER REPORT

SECTION 2
TESTING

Below is a summary of the tests and results for the entire test period. The test data appears at the end of this report in the Appendix.

Performance testing was carried out in accordance with UL486C, Clause 9.12 Spring-action sequence.

Three test circuits were built in the sizes 14AWG, 12AWG, and 10AWG, each circuit containing Copperweld CCA THHN wire and 3 three specimens each of push-in
wire connectors manufactured by Ideal, Wago, and Gardner and Bender, as available. This setup is a deviation from the standard which requires connectors to be tested separately on individual circuits.

Test currents (20A for 14AWG, 30A for 12AWG and 50A for 10AWG) were selected in accordance with client request rather than per Table 6 static heating columns in UL486C, and additional setup criteria indicated in Clause 9.1 of UL486C will not be used. Test currents were monitored periodically with a clamp style meter.

Ambient thermocouples were placed at least two feet out from the connectors under test, and approximately 3 feet apart, the number of ambient thermocouples is reduced due to the size of the apparatus.

Connector thermocouples are placed on the input and output side of each connector with a reference conductor between each set of three connectors.

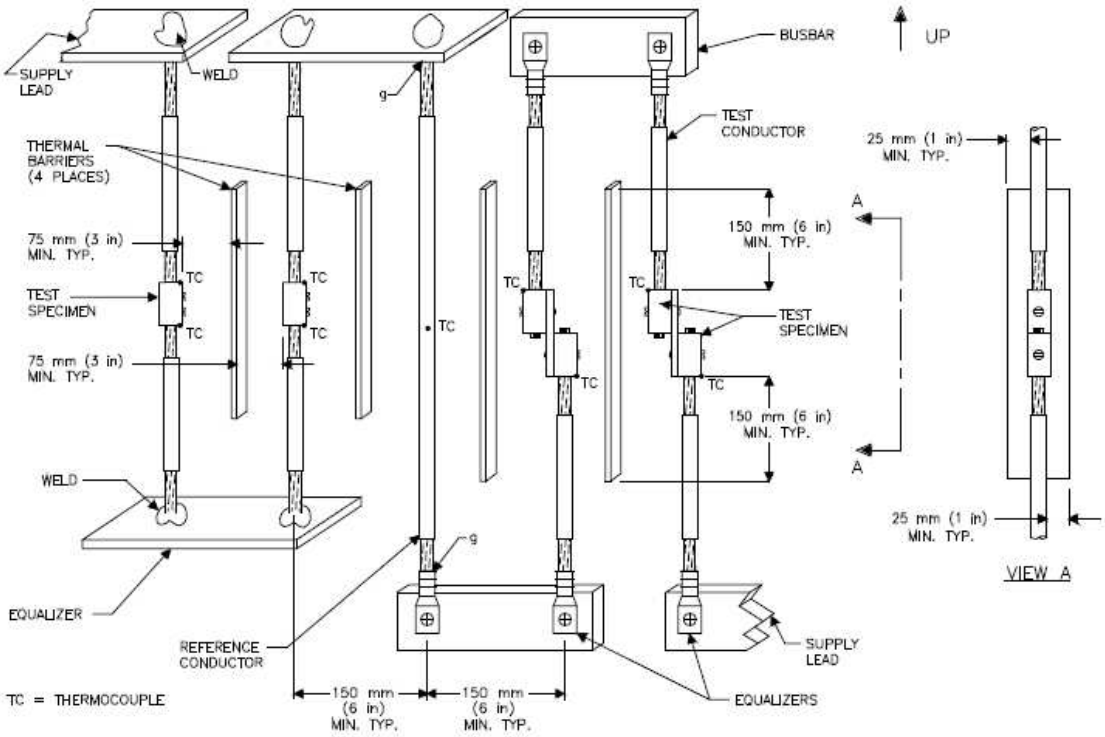
The apparatus is set up in complete compliance with Figure 2 on the next page, no other deviations from the standard were made.

Calibration Information:

Item #	Equipment Type	Asset #	Calibration Due
1	Fluke 365 True RMS Clamp Meter	M262	04/06/2019
2	Fluke Hydra Temperature Recorder	T1152	04/20/2019
3	Fluke Hydra Temperature Recorder	U080	07/16/2019
4	Fluke Hydra Temperature Recorder	T834S	02/13/2019
5	Fluke Hydra Temperature Recorder	T1565	09/27/2018

TEST LETTER REPORT

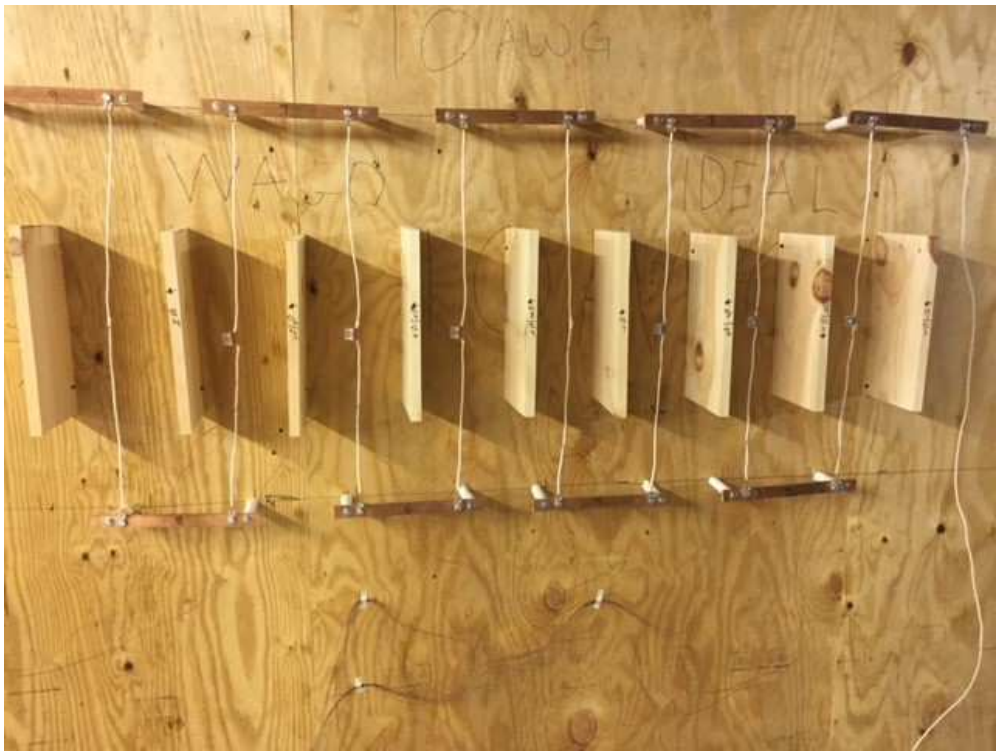
Figure 2
Vertical arrangement of specimen for current-cycling test
(Clause 9.1.10.7)



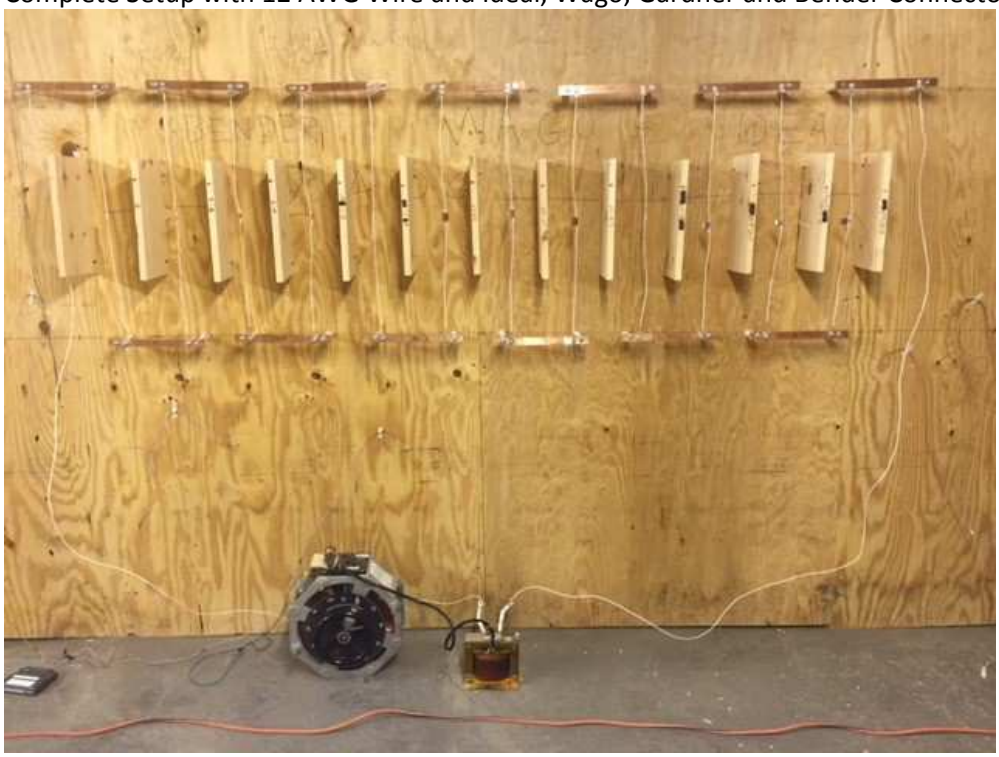
TEST LETTER REPORT

SECTION 3
PHOTOGRAPHS

10AWG Wire with IDEAL and WAGO connectors

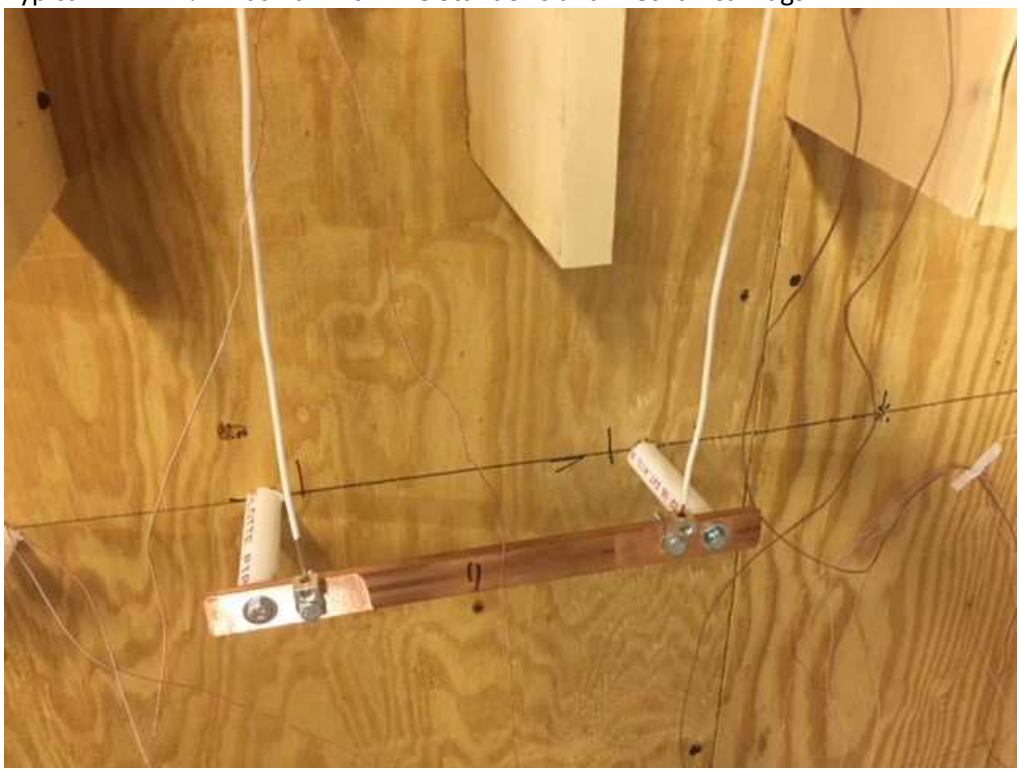


Complete Setup with 12 AWG Wire and Ideal, Wago, Gardner and Bender Connectors

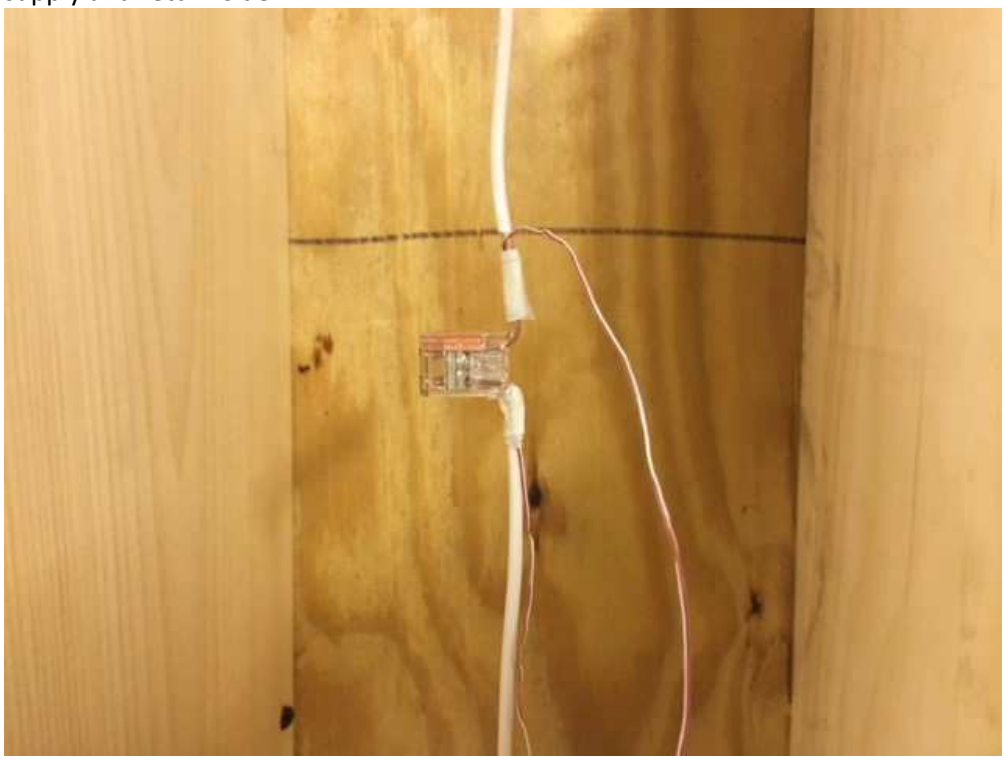


TEST LETTER REPORT

Typical 12 x 1 x ¼" Bus Bar with PVC Standoffs and Mechanical Lugs



Typical Connector, Gardner and Bender Shown, TC attached within 1/2" of the connector on supply and return side



TEST LETTER REPORT

SECTION 4
PROJECT STATUS & ACTION

One set of thermocouples did not record results on the first day of testing on one of the data recorders in use. Intertek performed a full 31 days of testing to capture a minimum of 30 days these thermocouples in question, at the request of the client.

One ambient thermocouple stopped recording at the end of the last day of testing, on the Ideal connectors for the 20A test setup. Data is recorded as “No Data” due to this malfunction. The seven remaining thermocouples reading ambient temperature show normal results.

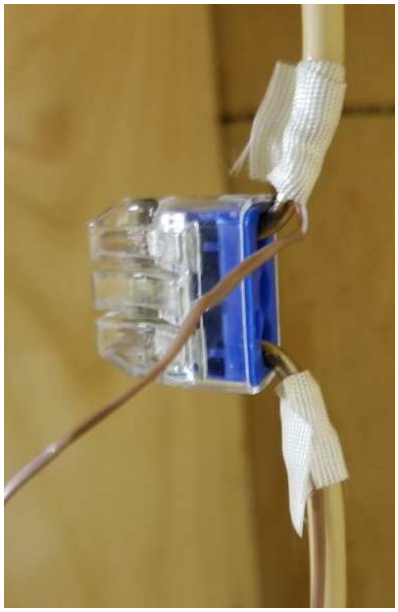
All testing is now complete.

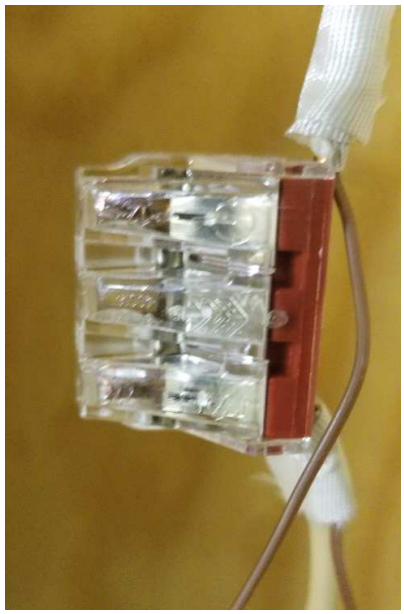
SECTION 5
CONCLUSION

The results contained in this report are to be evaluated by the client. This data is not to be used for certification of these products.

Upon completion of the test, there was no visible damage to any of the connectors contained within this report. There was however a visible change to the coloration of the insulation on the conductors involved in the 50A test on the 10 AWG conductors; no other conductors involved in the test exhibited this discoloration. The consistent temperatures recorded during the test, indicate that there is no evidence of arcing at the connectors.

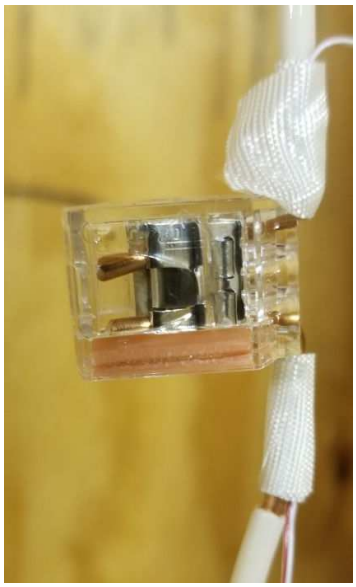
10 AWG Connectors (Left to Right: Ideal, Wago):



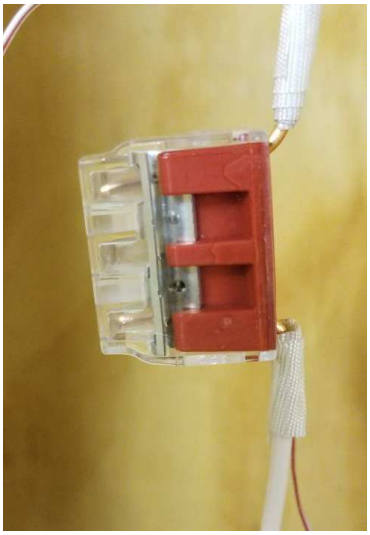
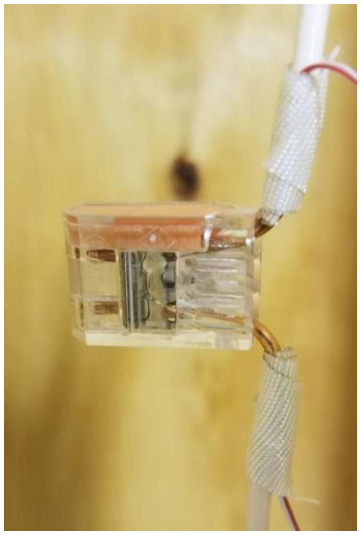


TEST LETTER REPORT

12 AWG Connectors (Left to right: Ideal, Wago, Gardner and Bender):



14 AWG Connectors (Left to right: Ideal, Wago, Gardner and Bender):

TEST LETTER REPORT

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

Completed by:	Joshua O'Connor	Reviewed by:	James Diescher
Title:	Engineering Team Lead	Title:	Technical Lead
Signature:		Signature	
Date	08/28/2018	Date:	08/28/2018

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

Revision History

08/28/2018: Added information in the conclusions about the condition of the connectors and conductors at the end of the test. Added example pictures of each connector for each test setup at the completion of the test.

TEST LETTER REPORT

APPENDIX

MAX TEMP (50A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		1	104.82	101.00	100.66	99.70	98.60	98.79	98.82	98.52	97.64	98.16	97.79	97.82	97.16	97.85	97.85	98.06	97.49	97.63	97.64	97.06	96.68	97.02	96.45	96.65	97.49	Power Outage			98.90	96.25	97.02	96.45	96.40	96.40
	1	2	83.92	81.32	81.26	80.73	80.09	80.76	80.48	80.18	79.64	80.31	79.79	79.55	79.49	80.47	79.93	80.34	80.07	79.59	79.50	79.27	79.02	78.94	78.79	78.94	79.93				80.77	78.35	78.70	78.40	78.30	78.26
		3	90.28	90.79	91.78	90.78	90.16	91.16	91.82	90.89	91.38	91.08	91.32	91.26	90.70	90.75	92.09	92.63	92.46	92.58	91.78	91.17	91.46	91.99	91.87	91.58	92.43				92.03	91.35	91.57	91.57	91.17	91.48
	2	4	77.14	77.62	78.16	77.92	77.83	78.34	77.99	77.93	78.12	78.28	78.10	78.06	77.93	77.76	79.17	79.25	79.16	79.14	78.74	78.29	78.55	78.53	78.67	78.38	79.24				78.86	78.68	78.79	78.53	78.25	78.37
		5	89.40	88.00	88.06	87.39	87.14	87.66	87.95	87.41	87.60	87.22	87.75	87.22	86.90	86.69	87.59	88.87	88.31	88.06	87.62	87.42	87.39	87.85	87.47	87.94	88.26				87.35	87.09	86.96	87.18	86.77	86.46
	3	6	92.73	91.58	92.06	91.46	91.54	91.75	92.33	92.00	92.01	91.28	91.62	91.88	90.90	90.83	92.07	93.37	92.96	92.68	92.04	91.75	92.20	92.29	92.00	92.57	92.69				92.26	91.65	91.54	92.05	91.31	91.72
	Ref	7	86.70	86.98	87.33	87.63	87.71	87.57	88.23	88.32	88.19	87.94	88.14	88.45	88.04	88.34	88.47	90.28	89.05	89.39	89.32	88.39	89.12	89.10	88.61	88.89	88.95				88.30	88.79	88.18	88.82	87.86	87.96
WAGO		8	81.37	80.88	80.74	80.56	80.08	79.93	79.18	79.02	78.45	79.39	79.33	79.00	79.07	79.55	79.65	79.63	79.81	79.52	78.93	77.99	78.56	78.44	78.10	78.43	78.26				79.39	77.75	77.91	77.48	76.92	77.02
	4	9	87.95	87.91	88.06	88.05	87.56	87.44	87.70	87.40	86.31	87.10	87.04	86.49	86.47	86.60	87.34	86.86	87.23	87.05	86.03	84.97	85.43	85.51	84.84	84.26	83.99				87.60	82.66	82.59	83.04	82.02	81.62
		10	87.19	87.84	87.90	88.43	87.66	87.34	86.86	86.11	86.57	87.48	87.70	87.54	87.20	87.45	87.88	87.92	88.00	86.61	86.52	85.52	85.46	85.47	85.73	86.22	86.18				87.75	85.60	85.48	85.31	85.87	85.36
	5	11	82.99	83.08	82.87	82.89	82.67	82.08	81.59	80.97	81.03	81.96	82.48	81.96	81.56	81.82	82.39	82.34	82.33	81.56	80.99	80.17	80.20	80.27	80.35	80.94	80.77				81.80	79.82	79.83	79.33	79.68	79.62
		12	85.43	85.05	85.09	85.12	84.61	84.80	84.10	83.59	83.47	84.12	84.26	84.58	84.16	84.36	84.31	84.97	84.57	84.23	83.86	83.73	83.34	83.49	83.12	84.01	83.75				84.34	83.84	83.04	83.06	83.41	83.41
	6	13	89.14	88.21	88.76	88.48	88.17	88.23	87.82	87.01	87.15	87.56	87.82	88.05	88.09	87.89	88.53	88.38	88.30	88.18	87.92	88.06	87.42	87.56	87.31	87.99	87.42				88.68	87.93	86.71	86.83	88.01	87.86
	Ref	14	88.72	89.64	91.45	90.71	91.45	91.75	91.57	91.95	91.31	90.84	92.18	92.33	92.35	91.99	92.78	92.10	93.57	93.63	92.06	91.81	92.52	93.07	92.84	94.56	92.34				91.83	91.48	91.76	90.88	91.75	92.01

MIN TEMP (50A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		1	22.29	95.90	95.73	93.01	91.23	93.56	92.72	93.94	92.48	90.88	92.40	92.03	91.11	91.39	90.62	91.45	91.51	91.06	89.73	93.36	91.73	91.20	89.59	91.80	90.50	Power Outage			88.57	89.43	88.66	87.20	89.04	88.91
	1	2	22.78	75.58	76.48	74.61	74.09	74.86	73.01	75.43	74.83	73.38	74.29	74.35	73.76	73.98	73.51	74.34	73.20	72.76	72.79	75.75	73.99	71.52	71.85	73.85	73.60				70.57	71.15	71.60	70.77	72.03	72.00
		3	22.32	86.68	86.59	86.16	86.30	86.08	83.75	86.01	85.92	86.01	86.10	86.12	86.44	86.39	86.00	87.18	85.73	86.73	84.95	86.06	85.97	85.69	84.59	86.34	86.40				86.41	84.28	82.96	83.55	86.01	86.60
	2	4	23.01	73.41	74.53	73.82	73.74	73.90	71.63	74.62	74.23	73.44	74.07	74.11	74.11	74.10	73.74	74.07	73.55	74.16	73.04	75.59	74.45	72.99	72.67	75.16	74.60				73.70	71.28	72.09	72.66	74.55	74.63
		5	22.81	82.43	83.23	81.87	81.43	81.93	82.40	83.10	83.04	81.18	81.53	82.37	82.07	81.62	80.99	81.31	82.41	83.19	83.08	83.34	83.08	83.36	82.56	82.89	81.89				83.00	80.76	80.45	78.26	82.23	82.20
	3	6	22.78	88.40	88.90	87.84	87.42	88.03	87.74	88.31	88.04	87.25	87.44	88.02	87.65	87.71	87.08	87.91	88.31	88.13	88.39	87.65	87.47	88.14	87.58	88.05	88.04				87.82	87.69	86.02	85.31	86.77	86.95
	Ref	7	22.80	81.99	82.99	82.63	83.18	82.18	83.80	84.81	83.61	82.84	83.48	83.28	83.82	83.52	82.89	82.37	84.23	85.36	85.18	85.16	84.67	85.61	84.25	85.09	83.40				85.03	84.55	82.60	82.30	84.22	84.61
WAGO		8	22.80	76.69	76.90	75.55	75.53	75.70	76.45	76.09	75.90	74.84	75.21	75.08	75.48	74.30	73.94	74.72	75.67	75.74	76.09	75.53	75.31	75.63	75.48	75.29	73.59				75.39	75.23	74.02	73.67	74.40	74.30
	4	9	22.75	83.28	83.55	82.80	83.07	82.84	83.59	82.50	82.47	81.84	82.09	81.47	81.66	81.43	80.58	81.16	81.56	81.90	81.02	81.21	80.95	80.60	80.67	79.89	78.46				78.59	78.57	76.50	76.81	77.42	78.12
		10	22.75	82.20	82.69	81.78	82.24	82.32	82.49	81.70	82.03	81.84	81.99	81.63	81.98	81.22	81.81	81.26	82.31	82.46	82.27	82.11	82.40	82.79	82.36	81.77	81.11				81.76	81.86	80.13	80.89	82.58	82.28
	5	11	22.70	78.01	77.83	76.59	77.48	77.09	77.56	77.03	77.05	76.60	76.94	76.43	76.92	75.85	76.32	75.92	77.07	77.78	77.22	77.46	77.68	77.94	77.27	76.76	75.78				76.67	77.06	75.06	74.97	77.20	77.02
		12	22.73	79.80	79.49	79.39	79.38	79.26	79.13	78.50	78.95	78.66	78.39	78.53	78.81	77.70	78.11	78.08	78.59	79.55	79.11	79.58	80.09	80.23	79.47	79.04	78.20				80.03	80.00	77.96	78.62	80.09	80.09
	6	13	22.70	83.65	83.07	83.06	82.47	82.70	81.87	82.49	82.24	82.41	82.51	82.69	82.38	82.30	82.45	82.67	82.99	83.63	82.82	83.27	83.53	82.79	82.66	83.04	82.52				83.28	82.88	81.04	81.24	83.12	83.10
	Ref	14	22.75	83.42	83.49	83.33	83.15	83.16	84.08	83.31	83.25	83.72	83.44	84.10	83.54	83.30	83.76	83.49	84.07	85.48	84.55	84.60	84.76	86.01	86.22	84.12	83.95				85.18	86.83	84.58	85.39	86.90	86.05

AVE TEMP (50A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		1	99.09	97.98	98.38	96.49	96.29	96.22	96.29	96.62	95.90	94.68	94.80	95.19	94.67	94.22	93.82	94.56	95.24	94.85	95.27	95.51	94.83	95.38	94.79	94.84	93.99	Power Outage			94.89	94.26	94.24	94.20	94.00	93.87
	1	2	78.62	77.88	78.84	77.46	77.72	77.86	77.92	78.29	77.87	76.79	76.90	77.39	76.91	76.46	76.14	76.80	77.45	77.10	77.47	77.66	76.99	77.46	76.86	77.13	76.46				77.03	76.21	76.26	76.30	76.08	75.89
		3	87.84	88.16	88.53	88.23	88.08	88.11	88.28	89.15	88.37	87.83	87.96	88.17	88.13	88.01	88.27	88.92	88.91	88.76	89.17	89.46	89.14	89.83	89.40	88.87	88.33				89.35	89.23	89.23	89.66	89.13	89.13
	2	4	74.75	75.56	76.47	75.77	76.01	76.19	76.27	76.75	76.46	75.81	76.07	76.44	76.22	76.03	75.91	76.52	77.05	76.92	77.14	77.29	76.93	77.37	76.97	76.95	76.55				77.40	77.13	77.02	77.23	76.91	76.87
		5	85.18	85.31	86.02	84.86	84.92	85.09	85.23	85.58	85.08	84.29	84.65	84.97	84.72	84.37	84.00	84.77	85.68	85.51	85.55	85.51	85.35	85.90	85.44	85.27	84.63				85.15	85.01	84.98	85.35	84.70	84.57
	3	6	89.99	89.95	90.10	89.68	89.52	89.54	89.60	89.92	89.43	89.14	89.38	89.37	89.34	89.25	89.24	89.79	90.18	90.00	90.00	89.89	89.87	90.32	89.99	89.55	89.44				89.70	89.75	89.67	90.16	89.29	89.23
	Ref	7	83.50	85.01	86.15	85.57	85.88	86.06	86.26	86.37	86.24	85.89	86.32	86.57	86.42	86.21	85.84	86.43	87.54	87.24	87.07	86.83	86.84	87.13	86.83	86.82	86.54				86.65	86.66	86.39	86.75	86.16	86.09
WAGO		8	78.35	79.13	79.27	78.39	78.35	78.06	77.90	77.38	77.23	77.29	77.47	77.56	77.44	77.45	77.14	77.46	78.23	77.77	77.39	76.77	76.84	76.80	76.83	76.98	76.73				76.63	76.32	76.04	75.97	75.51	75.42
	4	9	84.58	85.48	86.36	85.50	85.75	85.54	85.61	85.08	84.72	84.50	84.67	84.86	84.45	84.21	83.69	84.00	84.92	84.05	83.52	82.87	82.82	82.80	82.74	82.61	81.91				80.89	80.74	80.41	80.61	79.86	79.65
		10	83.91	85.12	86.05	85.11	85.40	85.17	85.01	84.69	84.79	84.74	85.01	85.30	85.06	84.91	84.51	84.81	85.78	84.94	84.53	84.03	84.08	84.17	84.11	84.43	84.03				84.44	84.26	83.59	83.64	83.85	83.81
	5	11	80.26	80.70	81.22	80.18	80.42	80.17	79.78	79.44	79.60	79.51	79.76	80.01	79.81	79.68	79.25	79.58	80.47	79.72	79.44	79.06	78.99	79.14	78.99	79.44	78.90				78.97	78.61	77.87	77.75	78.20	78.18
		12	82.32	82.81	83.38	82.23	82.52	82.39	81.93	81.68	81.73	81.45	81.71	82.35	82.02	81.68	81.38	81.71	82.58	82.39	81.91	81.77	81.72	81.78	81.45	81.81	80.94				82.08	81.76	80.74	80.37	81.44	81.64
	6	13	85.70	86.01	86.62	85.59	85.98	85.86	85.30	84.99	85.27	85.14	85.34	85.96	85.64	85.40	85.22	85.48	86.23	86.10	85.59	85.45	85.37	85.27	85.02	85.68	85.04				85.73	85.16	83.85	83.47	84.99	85.23
	Ref	14	84.72	85.98	87.39	86.49	86.92	87.91	88.34	89.19	88.00	86.86	87.38	88.68	88.21	87.26	87.03	87.49	88.69	89.53	89.36	89.39	89.47	90.37	89.71	89.12	87.38				88.84	89.23	88.46	87.94	88.82	89.13

MAX TEMP (30A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		15	68.57	62.14	61.07	60.48	60.15	59.65	59.37	58.88	59.40	59.21	59.03	59.59	59.52	59.65	59.99	60.38	60.45	59.45	59.20	58.92	58.77	58.79	58.81	58.92	59.54	Power Outage			59.22	59.20	59.03	57.81	58.09	58.50
	7	16	70.43	68.41	67.93	68.09	68.43	67.89	67.69	67.60	68.16	68.53	68.28	68.40	68.92	69.05	69.48	69.99	69.51	68.90	68.62	68.40	68.22	68.39	68.44	68.78	69.62				69.42	69.18	69.09	67.95	68.09	68.48
		17	80.39	65.87	64.23	64.36	64.12	64.12	63.84	63.72	63.63	63.62	63.27	63.19	63.31	63.70	64.09	64.17	63.63	62.92	62.82	62.44	62.19	62.22	61.94	62.91	62.70				61.81	61.15	61.09	59.86	59.84	60.07
	8	18	85.75	73.23	72.38	72.61	72.10	71.52	71.15	70.74	71.21	71.51	70.95	71.21	71.18	71.59	71.92	71.56	71.49	70.52	70.30	69.77	69.93	70.05	70.06	70.05	70.87				69.84	69.72	69.64	68.99	68.71	68.62
		19	65.78	64.66	64.04	64.77	64.75	63.82	63.62	63.56	63.54	63.56	63.63	63.38	63.44	63.94	64.33	64.51	64.62	63.36	63.50	63.00	63.26	63.48	63.70	63.34	63.57				63.36	63.25	62.99	62.38	62.04	61.95
	9	20	66.27	65.63	64.73	65.12	65.13	64.40	63.75	63.91	63.97	64.18	64.01	63.92	63.94	64.15	64.53	64.88	64.45	63.56	63.36	63.26	63.32	63.22	63.41	63.25	63.63				63.27	63.16	63.19	62.11	61.91	62.00
	Ref	21	67.20	67.35	66.97	67.88	67.89	67.24	67.55	67.53	67.24	66.93	67.88	67.56	67.55	67.87	68.14	68.77	68.16	68.30	68.23	67.37	68.14	67.45	68.48	67.70	67.67				68.10	68.36	67.75	67.62	67.07	67.07
WAGO		22	65.17	64.36	64.07	64.63	64.25	63.61	63.37	63.14	62.95	62.40	63.08	63.02	63.03	63.12	63.70	63.99	63.60	63.24	63.14	62.71	62.44	62.43	62.68	62.38	62.81				62.04	61.98	61.88	61.51	61.12	61.12
	10	23	68.15	67.25	66.94	67.10	66.98	66.28	65.89	65.83	65.73	65.47	65.73	65.81	65.53	65.73	66.41	66.67	66.20	65.39	65.46	64.95	64.75	64.86	64.97	64.77	65.26				64.25	64.38	64.25	63.67	63.45	63.45
		24	65.42	64.44	64.92	64.86	64.90	64.75	64.43	64.46	64.20	64.16	64.51	64.42	64.44	64.71	65.24	65.05	64.99	64.41	64.53	64.13	63.94	63.86	63.69	63.81	64.36				63.36	63.76	63.50	63.13	63.11	63.11
	11	25	64.28	61.42	61.21	61.24	61.13	60.69	60.29	60.28	60.01	60.01	60.27	60.29	60.44	59.64	59.79	59.84	59.96	59.49	59.24	58.74	58.55	58.60	58.17	58.42	58.97				57.57	57.58	57.45	57.45	56.89	56.89
		26	64.38	63.89	64.46	64.34	64.05	63.46	63.45	63.50	63.01	62.61	63.23	63.18	63.08	63.01	63.75	63.17	63.81	62.80	63.06	62.42	61.96	62.39	61.92	62.32	62.88				61.77	61.14	60.99	60.83	60.72	60.72
	12	27	67.34	67.23	67.54	67.26	67.17	67.19	66.53	66.41	65.93	65.99	66.46	66.16	66.28	66.03	66.53	66.53	66.88	66.02	65.95	65.53	65.04	65.08	65.23	65.31	66.17				64.83	64.29	64.23	64.03	63.79	63.79
	Ref	28	60.36	60.63	61.31	61.58	61.70	61.36	60.77	60.95	60.41	60.41	61.25	61.03	61.14	60.78	61.20	61.14	61.63	60.92	61.26	60.79	60.38	60.18	60.48	60.56	60.90				60.27	60.70	60.18	59.65	59.69	59.69
Gardner Bender		29	62.68	62.96	63.23	62.97	63.25	62.90	62.67	62.94	62.30	62.38	62.95	62.66	63.07	62.67	63.11	62.55	63.57	63.03	62.65	62.57	62.16	62.00	62.31	62.55	62.56				61.79	61.47	61.62	61.09	60.97	60.97
	13	30	64.06	64.02	64.43	64.32	64.44	64.32	64.04	64.15	63.91	63.98	64.28	64.22	64.51	64.26	64.75	64.44	65.41	64.22	64.25	64.16	63.74	63.55	64.06	64.11	64.33				63.81	63.81	63.91	63.13	63.08	63.08
		31	67.09	66.75	67.66	67.43	67.57	67.25	67.46	67.18	66.81	66.98	67.50	67.36	67.36	67.46	67.60	67.32	68.12	67.12	67.60	67.16	66.68	66.65	67.04	67.10	67.15				67.34	66.88	67.05	66.51	66.23	66.23
	14	32	No Data	67.16	67.72	67.56	67.82	67.27	67.57	67.43	66.98	67.55	67.95	67.50	67.50	67.33	67.63	67.41	68.28	67.21	67.96	67.42	66.89	66.79	67.33	67.49	67.43				67.86	66.79	66.94	66.31	66.25	66.25
		33	No Data	68.57	68.92	68.71	68.94	68.61	68.47	68.64	68.06	68.67	68.83	68.89	68.52	68.42	68.78	68.61	68.92	67.98	68.57	68.39	67.78	67.47	68.01	68.15	67.96				68.29	67.33	67.37	66.91	66.81	66.81
	15	34	No Data	65.91	65.94	65.52	65.62	65.33	65.00	64.92	64.42	64.83	65.17	65.19	64.34	64.53	64.76	64.51	64.68	63.67	64.28	64.26	63.49	63.09	63.76	63.87	63.44				63.23	62.80	62.35	61.87	61.92	61.92
	Ref	35	No Data	65.03	65.01	64.45	64.81	64.77	64.45	64.50	64.22	64.68	64.79	64.49	64.74	64.36	64.70	64.42	65.08	64.28	64.36	64.39	64.27	63.92	63.98	64.55	64.63				64.18	64.33	64.26	63.69	63.50	63.50

MIN TEMP (30A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		15	22.77	57.58	56.18	55.47	56.17	56.05	54.30	56.03	54.67	55.31	54.34	54.49	56.15	55.24	55.12	54.89	55.83	55.52	53.60	56.59	55.37	54.74	56.06	54.83	54.52	Power Outage			56.05	55.18	53.01	53.28	55.20	55.76
	7	16	22.75	64.48	64.38	63.99	64.72	64.79	63.90	65.26	64.38	65.44	64.65	64.53	66.23	65.24	65.00	64.95	65.76	66.08	64.69	65.90	66.02	65.34	65.89	65.79	65.72				66.20	66.45	63.80	64.49	66.06	66.17
		17	22.72	60.87	60.38	60.22	60.35	60.73	60.20	60.58	59.82	60.60	59.59	60.37	60.44	59.53	59.53	59.51	59.88	59.76	59.66	59.65	59.09	59.07	59.20	59.21	58.97				58.75	58.51	56.75	56.91	57.43	57.44
	8	18	22.73	69.00	69.03	68.30	68.23	68.70	68.06	68.73	67.88	68.03	67.70	67.69	68.59	67.68	67.31	66.96	67.95	67.89	67.32	68.39	68.31	67.35	68.10	67.69	66.99				67.27	67.55	64.94	65.56	67.07	67.37
		19	22.73	59.98	60.15	59.82	59.93	60.23	60.98	60.99	59.94	59.98	59.26	60.02	59.92	59.93	60.20	59.29	60.47	59.96	60.62	61.18	60.87	60.36	60.73	60.00	59.11				60.39	60.55	58.06	58.78	60.52	60.37
	9	20	22.70	61.16	61.38	61.20	61.55	61.51	61.68	61.04	60.78	60.90	60.68	61.06	60.54	61.25	60.92	60.34	61.25	61.27	61.53	61.29	61.40	60.79	61.06	60.77	60.38				60.64	60.93	59.00	59.81	60.22	60.27
	Ref	21	23.00	62.21	62.84	62.36	63.25	63.69	64.05	64.89	63.00	62.62	63.53	62.58	64.50	63.99	63.41	63.48	63.79	64.67	64.44	65.95	65.58	64.06	64.49	63.65	62.50				64.62	64.74	61.88	62.35	63.63	63.63
WAGO		22	23.02	59.21	59.42	58.74	58.99	59.38	59.33	60.21	58.13	57.78	58.80	57.64	59.60	58.67	57.99	58.01	58.48	58.96	58.93	60.69	60.04	57.83	58.84	58.02	56.75				58.68	58.52	56.02	56.86	57.95	57.95
	10	23	23.00	62.52	62.21	61.72	61.82	61.94	62.50	63.04	60.80	60.67	61.60	60.52	62.47	61.55	60.96	60.80	61.47	61.81	61.33	63.19	62.51	60.66	61.53	60.82	59.77				61.51	61.43	59.00	59.92	60.68	60.68
		24	23.02	60.65	60.80	60.62	60.81	61.46	60.99	61.87	60.15	60.26	60.59	59.96	61.62	60.89	60.49	60.46	60.95	61.58	61.47	62.36	61.67	60.51	60.98	60.13	59.75				60.48	60.99	58.22	59.69	59.84	59.84
	11	25	23.07	57.07	56.58	56.68	56.69	56.88	56.66	57.07	56.35	55.85	56.35	55.84	56.70	55.53	54.59	54.30	55.11	55.45	55.37	56.38	55.05	54.50	53.48	53.09	52.24				52.13	53.09	50.44	50.89	51.40	51.40
		26	23.05	58.73	58.77	58.40	59.00	58.48	58.52	59.16	57.75	57.96	57.86	57.39	58.41	58.42	57.88	57.79	58.09	58.42	58.22	60.13	58.57	57.41	57.14	57.18	57.05				57.66	57.98	55.59	56.70	56.63	56.63
	12	27	23.02	62.05	62.29	61.74	62.48	62.06	62.35	62.57	61.59	61.31	61.82	61.22	61.92	61.95	61.74	61.41	61.80	62.12	61.41	63.02	62.21	61.25	61.29	60.89	60.91				61.45	61.74	59.33	60.39	60.26	60.26
	Ref	28	23.05	55.09	54.46	54.76	56.16	55.22	55.92	56.42	55.98	55.79	56.10	55.70	56.37	55.77	56.14	56.02	55.91	56.25	56.33	57.81	56.53	55.96	55.80	55.62	55.48				56.30	57.54	55.38	55.88	56.27	56.27
Gardner Bender		29	23.03	56.09	55.54	55.72	56.34	55.68	56.74	56.71	56.14	55.32	56.25	56.46	57.26	57.41	56.92	56.71	56.27	56.76	55.89	59.38	58.23	56.04	55.97	55.91	56.04				56.30	57.15	55.72	56.01	56.10	56.10
	13	30	23.00	58.88	58.14	58.57	58.60	58.83	59.15	59.75	58.92	57.87	59.21	59.46	60.23	60.13	59.37	59.43	58.80	59.60	59.40	61.86	60.54	59.05	59.15	58.59	58.51				59.47	60.48	58.94	59.36	59.27	59.27
		31	22.91	60.43	59.64	59.94	60.71	60.63	61.05	62.26	59.81	59.70	60.51	60.80	62.60	60.70	61.36	60.98	59.79	61.30	60.67	63.95	62.40	60.33	60.62	60.06	60.39				61.77	62.93	61.23	62.62	62.11	62.11
	14	32	No Data	59.91	59.38	59.83	60.02	59.62	60.37	61.40	59.30	59.39	60.35	60.12	61.55	60.39	60.74	60.75	59.19	60.49	59.97	63.98	61.42	59.87	59.67	59.61	60.27				60.89	62.15	60.49	61.70	61.62	61.62
		33	No Data	63.35	62.04	61.80	61.88	61.90	61.99	62.92	61.26	61.57	61.88	62.11	62.91	61.98	62.67	62.15	60.99	61.71	61.53	64.55	62.26	61.06	60.82	60.58	61.22				61.39	62.68	61.00	62.39	61.60	61.60
	15	34	No Data	60.13	58.82	58.25	58.86	58.51	58.42	59.14	57.44	57.34	57.62	58.39	59.05	57.74	57.98	58.19	56.76	57.66	56.81	60.03	58.20	56.55	56.50	55.56	55.44				56.14	57.06	55.99	56.96	55.70	55.70
	Ref	35	No Data	60.01	59.16	59.60	59.57	59.61	59.71	60.18	58.88	59.50	59.28	59.95	59.52	59.73	59.97	60.38	59.10	58.74	59.26	60.50	60.06	58.98	58.66	58.36	58.92				59.41	60.12	59.63	59.35	58.66	58.66

AVE TEMP (30A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		15	62.96	60.51	59.09	58.64	58.55	58.25	57.68	57.73	57.72	57.76	57.63	57.85	57.93	58.04	58.29	58.21	58.34	58.07	57.93	57.80	57.58	57.76	57.69	57.76	57.73	Power Outage			59.22	57.62	56.55	56.00	56.89	57.06
	7	16	67.80	67.05	66.52	66.72	67.00	66.93	66.45	66.53	66.95	67.25	67.21	67.42	67.59	67.88	68.24	68.24	68.21	67.75	67.55	67.36	67.19	67.48	67.42	67.79	67.99				69.42	67.95	66.93	66.42	66.93	67.03
		17	65.55	63.34	62.66	62.44	62.62	62.72	62.34	62.15	62.25	62.03	62.00	62.05	61.92	62.11	62.30	62.10	62.14	61.56	61.34	61.00	60.65	60.79	60.65	60.82	61.01				61.81	59.87	59.11	58.38	58.57	58.64
	8	18	72.98	71.28	70.57	70.55	70.48	70.28	70.02	69.91	70.01	69.88	69.74	69.80	69.82	69.95	70.20	70.00	69.97	69.67	69.44	69.16	69.10	69.11	69.09	69.06	69.14				69.84	69.06	68.06	67.76	68.03	67.95
		19	63.36	62.65	62.53	62.52	62.73	62.50	62.45	62.39	62.30	61.91	61.96	62.23	62.15	62.32	62.58	62.54	62.77	62.48	62.45	62.21	62.22	62.17	62.22	61.94	61.95				63.36	62.22	61.24	61.17	61.36	61.25
	9	20	64.35	63.60	63.29	63.26	63.34	63.07	62.88	62.78	62.81	62.52	62.54	62.70	62.65	62.83	63.13	63.09	63.19	62.76	62.60	62.31	62.28	62.29	62.31	62.13	62.27				63.27	62.29	61.49	61.17	61.22	61.14
	Ref	21	65.33	65.41	65.85	65.71	66.26	66.08	66.19	66.19	66.07	65.58	65.93	66.17	66.12	66.26	66.37	66.42	66.89	66.77	66.78	66.63	66.65	66.55	66.71	66.31	66.16				66.59	66.86	65.65	65.71	65.95	65.95
WAGO		22	62.58	62.44	62.80	61.98	62.48	62.15	62.07	62.04	61.67	61.03	61.45	61.71	61.48	61.61	61.48	61.32	62.01	61.72	61.86	61.82	61.52	61.28	61.37	60.96	60.86				60.90	60.92	59.73	59.76	60.04	60.04
	10	23	65.64	65.47	65.60	64.63	65.20	64.92	64.80	64.78	64.42	63.80	64.13	64.42	64.17	64.35	64.27	64.02	64.64	64.24	64.35	64.21	63.92	63.69	63.75	63.36	63.34				63.25	63.32	62.29	62.28	62.38	62.38
		24	62.85	62.98	63.65	62.98	63.64	63.54	63.40	63.47	63.15	62.78	63.10	63.34	63.28	63.35	63.31	63.07	63.61	63.34	63.55	63.38	63.05	62.88	62.86	62.53	62.58				62.49	62.61	61.70	61.80	62.13	62.13
	11	25	60.31	59.35	59.79	58.99	59.56	59.36	59.24	59.28	58.79	58.22	58.79	59.04	58.79	58.17	57.52	57.30	58.21	57.78	57.87	57.78	57.34	57.14	56.83	56.32	56.22				55.87	55.74	54.77	54.79	55.06	55.06
		26	61.30	61.24	62.45	61.23	62.06	61.91	61.71	61.85	61.09	60.53	61.16	61.49	61.14	61.05	60.66	60.49	61.54	60.94	61.26	61.34	60.62	60.45	60.37	60.09	60.02				59.91	59.63	58.84	58.80	59.08	59.08
	12	27	64.19	64.20	65.46	64.30	65.14	65.04	64.94	65.02	64.40	63.79	64.39	64.74	64.38	64.37	64.07	63.95	64.87	64.32	64.61	64.56	63.94	63.78	63.81	63.45	63.48				63.25	63.17	62.48	62.41	62.46	62.46
	Ref	28	57.47	57.72	59.09	58.44	59.26	59.15	59.27	59.36	58.80	58.33	58.93	59.20	58.99	58.84	58.73	58.77	59.52	59.09	59.48	59.57	59.11	58.86	59.06	58.71	58.72				58.86	59.03	58.42	58.40	58.24	58.24
Gardner Bender		29	59.04	59.48	60.89	59.71	60.70	60.60	60.86	61.05	60.32	59.90	60.47	60.80	60.67	60.35	59.91	59.73	60.83	60.31	60.81	61.18	60.45	60.09	60.32	59.77	59.83				60.09	60.18	59.40	59.29	59.51	59.51
	13	30	61.18	61.58	62.66	61.75	62.61	62.55	62.75	62.87	62.33	62.03	62.47	62.80	62.70	62.55	62.34	62.20	63.04	62.60	62.93	63.07	62.49	62.26	62.41	61.99	62.09				62.39	62.52	62.00	61.85	61.81	61.81
		31	63.63	63.96	65.26	64.15	65.12	65.04	65.34	65.44	64.75	64.54	65.02	65.35	65.21	65.00	64.67	64.27	65.35	64.76	65.45	65.88	65.13	64.65	64.98	64.41	64.43				65.27	65.47	64.84	64.91	64.89	64.89
	14	32	No Data	63.57	65.09	63.76	64.90	64.80	65.09	65.19	64.44	64.24	64.79	65.13	64.99	64.75	64.32	63.82	65.05	64.37	65.16	65.82	64.91	64.39	64.71	64.11	64.22				64.99	65.13	64.34	64.41	64.70	64.70
		33	No Data	65.59	66.72	65.43	66.31	66.22	66.48	66.49	65.93	65.90	66.23	66.44	66.42	66.17	65.90	65.39	66.31	65.78	66.30	66.80	65.80	65.37	65.62	65.14	65.21				65.49	65.58	64.95	64.84	65.21	65.21
	15	34	No Data	62.85	63.73	62.23	62.91	62.69	62.89	62.83	62.23	62.07	62.30	62.46	62.31	61.95	61.63	61.10	62.03	61.39	61.86	62.18	61.33	60.82	61.15	60.53	60.50				60.27	60.41	59.78	59.66	59.80	59.80
	Ref	35	No Data	62.16	63.09	62.21	62.62	62.54	62.89	62.73	62.44	62.48	62.65	62.65	62.71	62.43	62.40	62.23	62.79	62.57	62.68	62.86	62.34	61.95	62.30	61.97	62.19				62.37	62.49	62.19	61.90	61.74	61.74

MAX TEMP (20A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		36	No Data	62.13	61.46	60.56	60.29	60.59	59.48	59.07	58.70	58.95	58.83	58.72	58.61	58.78	58.97	59.81	58.95	58.60	57.88	57.27	57.12	57.72	57.02	57.49	58.02	Power Outage			55.94	56.39	55.77	54.77	54.71	54.52
	16	37	No Data	61.55	61.48	60.69	60.29	60.42	59.33	58.77	58.49	59.20	58.83	58.91	58.80	58.85	59.36	60.28	58.72	58.39	57.21	57.18	56.89	56.21	56.79	57.72	57.67				56.06	55.89	55.26	55.12	54.70	54.71
		38	No Data	53.15	53.64	52.80	52.67	53.02	52.45	52.11	52.09	52.60	52.50	52.54	52.74	52.96	53.10	53.16	52.74	53.18	52.53	51.91	51.67	51.18	51.62	52.10	52.53				52.03	51.42	52.15	51.49	50.43	50.66
	17	39	No Data	53.55	53.88	53.02	53.33	53.47	52.88	52.47	52.77	53.33	53.18	53.27	53.13	53.11	53.64	53.92	53.68	53.27	53.14	52.67	52.14	51.76	52.10	52.54	53.11				52.15	51.65	52.10	51.53	50.89	51.19
		40	No Data	58.52	58.37	57.97	57.89	58.17	58.29	57.23	57.63	57.96	57.56	57.85	57.78	58.40	58.14	58.80	58.13	58.01	57.80	57.28	56.80	56.33	57.45	57.09	57.96				57.14	56.87	57.52	57.04	56.10	55.62
	18	41	56.13	55.83	55.29	55.13	55.00	55.35	55.29	54.68	54.99	55.53	54.95	55.10	55.40	55.49	55.95	56.23	55.65	55.32	55.43	54.40	54.26	54.25	54.91	54.95	55.22				55.24	55.27	55.11	55.20	54.01	53.78
	Ref	42	56.42	56.74	56.50	56.62	56.33	56.28	56.37	56.22	55.96	56.23	56.48	56.54	56.60	56.96	57.50	58.27	57.01	56.53	56.28	55.38	55.46	55.50	55.62	56.07	57.18				56.25	56.25	55.48	55.38	54.02	53.94
WAGO		43	53.75	53.87	53.82	54.10	53.50	53.57	53.50	52.85	53.41	53.48	53.44	53.31	53.17	53.72	54.38	54.62	54.30	54.03	53.64	53.09	52.91	52.87	53.25	53.21	54.05				53.32	53.22	53.29	52.33	51.90	51.89
	19	44	55.89	55.65	55.78	55.82	55.25	55.40	55.26	54.84	55.04	55.27	55.32	54.92	54.82	55.36	56.26	56.63	56.03	55.85	54.97	54.46	54.50	54.34	54.62	54.71	56.00				54.68	54.77	54.47	53.68	53.04	53.04
		45	52.99	52.56	52.37	52.78	52.28	52.39	51.91	51.41	52.14	51.95	52.12	51.92	51.77	52.32	52.70	53.38	53.05	52.99	52.06	51.45	51.56	51.28	51.61	52.00	52.99				51.71	51.64	51.68	51.02	50.29	50.59
	20	46	57.96	57.96	58.00	58.20	57.49	57.50	57.34	56.82	56.96	56.99	57.24	57.16	56.95	57.64	57.95	58.84	58.49	58.11	57.46	56.50	56.58	56.79	56.97	56.85	58.01				56.80	56.91	56.95	56.39	55.60	55.52
		47	53.18	53.28	53.38	53.69	53.55	53.35	53.31	52.74	53.21	53.00	53.30	53.27	52.91	53.47	53.94	54.55	54.36	54.40	53.55	53.10	53.19	53.37	53.15	53.33	54.35				53.02	52.94	52.99	52.49	52.10	51.88
	21	48	55.56	56.03	55.79	56.28	55.54	55.68	55.56	55.06	55.50	55.52	55.63	55.69	55.57	56.12	56.31	57.52	56.93	56.43	55.72	55.31	55.22	55.68	55.18	55.82	57.01				55.40	55.08	55.32	55.19	54.29	54.10
	Ref	49	59.88	59.48	59.52	59.78	59.74	59.54	59.32	58.76	59.02	59.55	59.43	59.60	59.70	60.14	60.29	61.11	60.15	60.55	59.73	58.64	59.01	59.14	58.71	59.67	60.63				59.49	57.94	57.98	57.35	57.49	57.67
Gardner Bender		50	59.35	59.42	59.95	60.32	60.10	59.65	59.22	59.17	59.70	59.58	59.53	59.91	59.58	60.30	60.72	61.01	61.32	61.23	60.14	59.45	59.70	60.72	60.05	60.38	61.19				59.47	59.21	59.74	58.66	58.40	58.24
	22	51	61.96	61.58	61.77	62.22	61.85	61.58	60.92	60.99	61.25	61.51	61.27	61.81	61.27	62.80	62.52	63.28	62.56	62.82	61.88	61.01	60.90	62.66	62.00	62.71	63.59				61.36	60.54	61.33	59.95	59.91	59.67
		52	66.06	66.79	68.72	70.24	70.50	70.99	70.27	69.62	69.82	69.78	69.56	69.39	68.80	69.02	68.78	69.45	69.11	69.08	68.03	66.70	66.93	68.02	67.48	67.56	67.48				65.92	65.69	65.37	64.75	64.53	64.40
	23	53	64.35	65.25	66.55	68.23	68.67	68.51	67.96	67.56	67.49	67.69	67.29	67.03	66.68	66.49	66.51	66.98	66.88	66.84	65.76	64.83	64.73	65.30	65.00	65.00	65.02				63.50	63.06	63.04	62.42	62.02	61.88
		54	55.36	54.87	55.50	56.30	55.60	55.79	55.48	55.15	55.71	55.81	55.94	55.96	55.13	56.22	56.19	56.60	57.05	57.12	56.81	54.97	56.06	56.35	56.19	56.09	56.92				55.52	54.86	54.79	54.18	54.23	54.17
	24	55	56.03	55.91	56.35	57.15	56.61	56.65	56.36	55.93	56.44	56.83	56.78	56.76	56.16	57.08	57.02	57.72	57.82	58.08	57.58	55.95	56.97	57.32	57.03	56.86	57.98				56.51	55.73	55.96	55.38	55.18	55.26
	Ref	56	57.85	57.34	58.14	58.45	58.11	58.29	57.80	57.79	58.00	58.26	58.49	58.19	57.91	58.52	58.96	59.31	59.46	59.75	58.73	58.07	58.74	58.89	58.86	58.61	59.32				58.52	58.03	57.79	57.42	57.41	57.28

MIN TEMP (20A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		36	No Data	59.35	58.63	57.86	57.56	57.20	56.72	56.52	55.94	56.36	56.49	56.26	56.20	56.30	56.63	56.66	56.30	55.87	55.43	54.74	54.82	54.93	54.79	55.20	55.26	Power Outage			54.14	53.70	52.99	52.13	52.45	52.29
	16	37	No Data	57.79	57.06	56.48	56.14	55.91	55.38	55.24	55.21	55.24	55.15	55.20	55.05	55.24	55.58	55.58	55.34	54.86	54.43	53.72	53.84	53.79	53.38	54.02	54.44				53.12	52.87	52.22	51.82	51.65	51.61
		38	No Data	49.75	49.98	49.67	49.75	49.31	49.02	48.63	49.23	49.38	49.51	49.41	49.51	50.28	50.34	50.40	50.06	49.63	49.53	49.25	48.51	48.91	48.37	49.05	49.95				48.12	48.34	48.27	47.40	47.43	47.71
	17	39	No Data	50.82	50.92	50.31	49.90	49.96	49.24	49.84	50.10	50.56	49.98	50.29	50.27	50.79	51.28	50.99	50.57	49.91	49.81	49.54	48.94	49.36	48.70	49.30	50.66				48.65	48.64	48.11	47.65	47.82	48.16
		40	No Data	55.18	55.29	54.75	54.41	54.78	53.98	54.16	53.99	54.52	54.21	54.25	54.66	54.96	55.24	55.12	53.62	54.03	53.64	53.63	52.40	53.14	52.87	52.99	54.58				53.13	52.93	53.08	52.44	52.17	52.41
	18	41	22.86	52.29	52.65	52.48	52.14	52.15	51.89	51.58	52.03	51.88	52.19	52.23	52.31	52.52	53.15	53.36	52.73	51.94	52.08	51.26	51.32	51.46	50.98	51.87	52.47				51.54	51.62	50.85	51.01	50.33	50.86
	Ref	42	22.88	52.07	53.43	52.73	52.59	52.26	52.30	52.58	52.32	52.32	53.09	53.11	52.81	51.80	52.71	51.32	53.41	52.17	52.87	51.55	52.17	51.97	52.11	52.48	52.22				52.56	51.63	51.30	51.25	50.30	50.80
WAGO		43	22.90	50.19	51.07	49.83	50.72	51.22	50.90	51.03	51.03	51.32	50.99	51.53	51.32	50.32	50.18	49.22	50.40	51.92	51.73	51.02	51.08	51.13	51.25	51.43	50.34				51.31	50.96	50.69	50.04	49.93	50.16
	19	44	22.88	51.23	52.25	50.87	51.42	52.09	52.41	52.35	51.81	52.44	51.92	52.60	52.11	51.11	50.86	49.83	50.85	53.18	52.77	51.85	52.01	51.90	52.07	52.15	51.13				52.07	51.60	51.56	50.79	50.53	50.61
		45	22.88	48.73	49.44	48.31	48.85	49.19	48.74	49.27	49.56	49.69	49.07	49.80	49.36	47.50	47.44	47.56	48.58	50.38	49.96	49.51	49.51	49.52	49.61	49.98	48.48				49.70	49.40	49.33	48.42	48.46	48.58
	20	46	22.90	53.18	54.28	53.41	54.27	54.09	53.31	54.01	54.41	54.55	53.91	54.38	54.23	52.66	52.79	52.77	53.34	55.14	54.94	54.69	54.80	54.11	54.50	54.71	53.17				54.70	54.38	54.57	53.62	53.36	53.76
		47	22.86	48.90	49.92	49.34	49.38	49.73	49.55	49.88	50.21	50.20	48.87	50.15	50.08	48.36	48.97	48.64	49.93	51.04	50.75	50.99	50.82	51.28	51.08	51.13	49.94				50.66	51.01	51.08	50.49	49.96	50.68
	21	48	22.85	50.05	50.83	50.24	50.67	50.80	50.55	51.55	52.03	51.66	49.48	51.39	51.07	49.69	50.11	49.68	50.86	52.18	51.95	52.44	52.70	52.49	52.07	52.61	51.19				52.51	52.75	52.82	52.29	51.15	51.94
	Ref	49	22.85	52.31	53.12	52.11	52.79	53.02	53.25	53.67	54.19	53.43	51.96	53.91	53.11	51.78	51.67	52.72	53.34	54.64	53.62	54.57	54.76	54.82	55.01	54.57	53.48				54.76	54.54	54.22	53.79	53.82	54.81
Gardner Bender		50	22.82	53.04	53.91	53.59	54.27	54.49	54.33	54.51	54.63	54.22	54.16	54.86	54.70	53.55	53.28	53.89	54.27	55.96	55.18	55.14	55.77	55.23	56.24	55.22	55.05				56.33	55.73	55.79	56.51	55.47	56.24
	22	51	22.69	53.66	54.11	53.97	54.71	55.02	54.91	55.14	55.52	54.80	54.58	55.20	55.27	53.57	52.89	54.15	54.33	56.56	55.70	55.37	56.50	56.21	56.91	55.79	55.09				56.40	56.89	56.66	57.25	56.09	56.53
		52	22.70	59.15	60.30	61.39	63.00	63.46	63.42	63.63	63.43	62.55	62.30	62.46	62.06	60.52	60.60	60.90	60.69	62.22	61.00	61.81	61.94	61.57	61.16	60.35	59.99				61.06	60.99	60.05	61.57	60.52	61.33
	23	53	22.70	57.96	59.48	60.06	61.63	61.74	60.48	61.87	61.59	61.08	60.51	60.61	59.86	59.36	59.35	59.25	59.30	59.88	59.48	59.78	59.81	59.47	59.70	58.40	58.65				58.92	58.37	58.28	59.16	58.30	59.14
		54	22.69	48.53	48.73	48.85	49.31	49.08	49.33	49.87	49.51	49.40	49.07	49.17	49.49	48.35	48.21	49.38	49.25	50.09	49.37	50.31	50.26	50.98	50.13	50.68	49.76				50.34	50.89	50.78	50.81	50.87	50.56
	24	55	22.67	48.93	49.19	49.36	49.47	49.69	49.29	50.17	49.76	49.93	49.61	49.42	50.01	48.98	48.83	49.55	49.62	51.01	50.24	50.57	50.60	51.09	50.52	50.91	50.31				50.62	51.03	51.01	52.23	51.43	51.51
	Ref	56	22.67	50.30	50.45	50.53	50.97	50.51	50.98	51.60	50.90	51.36	51.00	51.29	51.42	50.75	51.16	51.15	51.30	52.26	51.60	51.74	51.74	52.88	52.04	52.03	51.84				52.01	53.03	53.29	52.89	52.51	53.01

AVE TEMP (20A, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
IDEAL		36	No Data	60.77	59.99	59.24	58.80	58.40	58.00	57.49	57.52	57.76	57.57	57.30	57.23	57.33	57.76	57.80	57.64	57.23	56.62	55.92	55.94	55.93	55.88	56.18	56.41	Power Outage			55.04	54.76	54.33	53.61	53.61	53.38
	16	37	No Data	59.73	59.15	58.20	57.97	57.61	57.21	56.61	56.80	57.16	56.97	56.73	56.67	56.83	57.26	57.16	56.99	56.29	55.69	55.13	54.96	54.78	54.74	55.25	55.77				54.45	53.99	53.52	52.73	52.79	52.83
		38	No Data	51.64	51.53	51.16	51.23	51.05	50.88	50.46	50.78	51.23	51.13	51.05	51.16	51.32	51.72	51.89	51.78	51.21	50.92	50.47	50.25	50.03	50.05	50.54	51.13				50.27	50.05	50.06	49.36	48.98	49.14
	17	39	No Data	52.36	52.28	51.85	51.98	51.84	51.62	51.21	51.53	51.98	51.88	51.79	51.87	52.06	52.56	52.70	52.44	51.80	51.50	51.02	50.73	50.55	50.45	51.19	51.86				50.82	50.31	50.14	49.41	49.31	49.63
		40	No Data	57.10	56.83	56.46	56.37	56.22	56.18	55.59	55.98	56.44	56.20	56.06	56.21	56.40	56.80	56.96	56.68	56.18	55.89	55.15	55.04	54.84	54.94	55.52	56.13				55.55	55.12	55.25	54.72	53.96	54.04
	18	41	54.35	54.35	54.11	53.73	53.66	53.51	53.53	53.04	53.48	53.89	53.63	53.60	53.69	53.85	54.28	54.42	54.35	53.89	53.64	52.95	52.89	52.64	52.80	53.23	53.72				53.56	53.41	53.53	53.05	52.25	52.22
	Ref	42	54.46	54.97	54.95	54.71	54.71	54.56	54.52	53.98	54.20	54.69	54.53	54.54	54.65	54.74	55.27	55.60	55.45	55.02	54.56	53.63	53.65	53.55	53.64	54.24	54.82				54.09	53.61	53.64	53.01	52.33	52.35
WAGO		43	52.34	52.86	52.83	52.65	52.62	52.60	52.50	52.13	52.17	52.55	52.49	52.40	52.46	52.56	52.85	53.12	53.35	53.18	52.71	52.00	51.96	51.99	52.03	52.35	52.75				52.16	51.89	51.76	51.15	50.90	50.94
	19	44	53.85	54.41	54.30	54.00	53.94	53.89	53.83	53.35	53.46	53.91	53.75	53.66	53.72	53.80	54.13	54.38	54.58	54.37	53.78	53.02	52.99	52.96	52.95	53.43	53.89				53.19	52.78	52.71	52.01	51.65	51.73
		45	50.72	51.29	51.32	51.11	51.09	51.09	50.95	50.66	50.76	51.10	51.02	50.93	50.92	51.04	51.30	51.57	51.85	51.73	51.16	50.53	50.46	50.43	50.40	50.82	51.21				50.58	50.27	50.16	49.44	49.33	49.44
	20	46	55.98	56.52	56.48	56.35	56.23	56.22	56.14	55.79	55.84	56.15	56.05	55.95	55.94	56.04	56.30	56.56	56.87	56.79	56.22	55.57	55.55	55.52	55.52	55.84	56.16				55.66	55.47	55.45	54.85	54.58	54.61
		47	51.11	51.74	51.95	51.89	51.88	52.04	51.95	51.98	52.00	52.08	52.09	52.14	52.02	52.10	52.29	52.67	52.98	53.07	52.61	52.25	52.21	52.28	52.28	52.43	52.63				52.20	52.09	52.00	51.41	51.24	51.27
	21	48	52.89	53.69	53.92	53.82	53.79	54.02	53.95	53.96	54.15	54.19	54.09	54.18	54.06	54.11	54.26	54.64	54.97	55.03	54.55	54.19	54.18	54.16	54.18	54.41	54.71				54.26	54.06	54.03	53.42	53.12	53.16
	Ref	49	55.39	56.19	56.54	56.47	56.49	56.91	56.47	56.79	56.93	57.03	56.85	56.95	56.66	56.83	57.08	57.66	57.59	57.74	57.32	56.91	56.86	57.09	56.76	57.41	57.60				57.35	56.52	56.08	55.30	55.86	56.14
Gardner Bender		50	55.71	56.39	56.97	57.15	57.15	57.46	57.23	57.60	57.66	57.54	57.44	57.62	57.34	57.48	57.84	58.33	58.40	58.63	58.28	58.15	58.10	58.30	58.26	58.34	58.49				58.28	58.09	58.02	57.49	57.48	57.52
	22	51	57.01	57.72	58.08	58.21	58.23	58.63	58.29	58.74	58.92	58.77	58.59	58.80	58.43	58.63	59.01	59.53	59.52	59.77	59.39	59.19	59.16	59.37	59.28	59.54	59.74				59.43	59.11	58.93	58.28	58.38	58.45
		52	61.13	62.84	64.45	65.90	67.06	67.63	66.98	67.63	67.46	66.66	66.23	66.31	65.41	65.37	65.53	65.90	65.57	65.67	65.29	65.24	64.97	65.14	64.86	64.73	64.52				64.38	64.15	63.84	63.18	63.10	63.09
	23	53	60.07	61.53	62.97	64.21	65.24	65.72	65.02	65.67	65.39	64.69	64.29	64.34	63.48	63.40	63.57	63.87	63.60	63.66	63.37	63.36	63.05	63.27	62.97	62.78	62.55				62.09	61.88	61.63	61.02	60.93	60.90
		54	51.35	51.69	51.99	52.22	52.26	52.59	52.15	53.04	52.90	52.57	52.45	52.70	52.18	52.40	52.98	53.66	53.45	53.67	53.44	53.40	53.28	53.83	53.66	53.82	53.81				53.51	53.33	52.99	52.50	52.79	52.86
	24	55	51.67	52.13	52.52	52.75	52.78	53.22	52.76	53.77	53.72	53.26	53.14	53.43	52.83	53.04	53.59	54.30	54.07	54.37	54.23	54.30	54.19	54.70	54.52	54.63	54.56				54.52	54.43	54.18	53.65	53.87	53.96
	Ref	56	52.96	53.47	54.00	54.16	54.27	54.76	54.18	55.51	55.43	54.79	54.68	55.02	54.35	54.51	55.12	55.81	55.56	55.92	55.88	56.09	55.95	56.60	56.32	56.32	56.07				56.26	56.30	56.11	55.67	56.01	56.06

MAX TEMP (Ambient, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
50A																																				
IDEAL	1-3	1	23.37	23.48	23.45	23.95	23.75	23.61	23.47	23.24	23.33	23.51	23.61	23.55	23.58	23.74	24.22	24.47	24.45	24.44	24.16	23.67	23.68	23.65	23.62	23.84	24.15	24.10	23.45	23.10	23.61	23.43	23.42	22.93	22.84	22.87
WAGO	4-6	2	23.80	23.31	23.32	23.82	23.57	23.47	23.33	23.14	23.19	23.30	23.42	23.41	23.42	23.61	24.07	24.32	24.36	24.36	24.03	23.64	23.56	23.52	23.50	23.66	23.99	24.00	23.43	23.05	23.52	23.34	23.39	22.80	22.77	22.74
30A																																				
IDEAL	7-9	3	23.43	23.19	23.10	23.47	23.40	23.23	23.13	22.93	22.95	23.15	23.23	23.24	23.21	23.43	23.92	24.16	24.20	24.11	23.85	23.38	23.36	23.37	23.31	23.44	23.79	23.77	23.39	22.97	23.29	23.26	23.31	22.77	22.49	22.50
WAGO	10-12	4	23.59	23.19	23.13	23.49	23.41	23.26	23.11	22.92	22.96	23.18	23.27	23.24	23.25	23.51	23.98	24.25	24.16	24.08	23.84	23.38	23.33	23.33	23.28	23.40	23.85	23.80	23.38	22.97	23.23	23.22	23.28	22.75	22.51	22.49
Gardner Bender	13-15	5	23.66	23.21	23.15	23.67	23.49	23.31	23.12	22.92	23.06	23.21	23.30	23.28	23.25	23.56	24.04	24.38	24.19	24.08	23.84	23.37	23.28	23.35	23.27	23.44	24.01	23.82	23.43	23.12	23.21	23.18	23.24	22.73	22.47	22.46
20A																																				
IDEAL	16-18	6	23.58	23.28	23.22	23.76	23.53	23.36	23.16	23.03	23.10	23.31	23.37	23.38	23.38	23.65	24.11	24.30	24.28	24.21	23.93	23.48	23.35	23.44	23.36	23.54	23.97	23.92	23.43	23.10	23.28	23.17	23.23	22.72	22.55	No Data
WAGO	19-21	7	23.66	23.28	23.24	23.61	23.50	23.35	23.17	22.99	23.05	23.27	23.35	23.36	23.37	23.62	24.10	24.25	24.24	24.13	23.89	23.46	23.37	23.44	23.33	23.49	23.83	23.94	23.42	23.02	23.27	23.18	23.22	22.68	22.60	22.59
Gardner Bender	22-24	8	23.70	23.23	23.22	23.55	23.46	23.32	23.15	22.95	23.02	23.26	23.34	23.33	23.36	23.59	24.06	24.22	24.22	24.12	23.85	23.43	23.33	23.41	23.30	23.43	23.83	23.91	23.41	22.98	23.26	23.15	23.17	22.64	22.55	22.54

MIN TEMP (Ambient, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
50A																																				
IDEAL	1-3	1	22.86	23.21	23.18	23.24	23.38	23.21	23.09	23.04	22.91	23.06	23.28	23.23	23.27	23.39	23.69	24.13	24.13	23.99	23.67	23.31	23.28	23.39	23.31	23.36	23.63	23.42	22.87	22.71	22.65	23.16	22.61	22.37	22.37	22.49
WAGO	4-6	2	23.07	23.11	23.07	23.12	23.27	23.11	22.98	22.90	22.81	22.96	23.17	23.13	23.14	23.30	23.58	23.99	24.05	23.89	23.62	23.26	23.19	23.31	23.18	23.21	23.47	23.40	22.81	22.66	22.60	23.09	22.58	22.32	22.29	22.40
30A																																				
IDEAL	7-9	3	22.96	22.95	22.88	22.94	23.12	22.92	22.78	22.74	22.64	22.77	23.00	22.95	22.96	23.12	23.43	23.87	23.89	23.66	23.35	23.07	23.06	23.05	23.00	23.06	23.27	23.34	22.77	22.60	22.55	22.90	22.58	22.28	22.18	22.28
WAGO	10-12	4	22.96	22.99	22.92	22.97	23.15	22.94	22.78	22.71	22.66	22.82	23.03	22.98	22.99	23.13	23.47	23.91	23.92	23.68	23.32	23.06	23.07	23.05	23.01	23.03	23.27	23.35	22.79	22.63	22.55	22.89	22.61	22.26	22.21	22.28
Gardner Bender	13-15	5	22.98	22.99	22.91	22.99	23.15	22.94	22.78	22.71	22.64	22.84	23.01	22.98	22.99	23.13	23.50	23.95	23.90	23.66	23.34	23.06	23.06	23.03	22.98	23.03	23.30	23.37	22.82	22.70	22.57	22.87	22.58	22.21	22.19	22.27
20A																																				
IDEAL	16-18	6	23.06	23.04	23.00	23.05	23.24	23.03	22.82	22.79	22.71	22.95	23.11	23.05	23.07	23.21	23.61	24.07	24.02	23.74	23.44	23.15	23.10	23.16	23.05	23.09	23.37	23.39	22.83	22.70	22.54	22.95	22.55	22.20	22.22	No Data
WAGO	19-21	7	23.07	23.04	22.96	23.03	23.23	23.00	22.81	22.75	22.66	22.92	23.08	23.02	23.04	23.18	23.59	24.04	24.00	23.72	23.42	23.06	23.03	23.16	23.04	23.07	23.35	23.39	22.82	22.67	22.52	22.91	22.54	22.20	22.16	22.26
Gardner Bender	22-24	8	23.06	23.04	22.93	22.98	23.21	22.96	22.79	22.73	22.64	22.89	23.04	23.01	23.01	23.16	23.56	24.00	24.00	23.72	23.36	23.03	23.01	23.11	23.00	23.03	23.30	23.36	22.79	22.65	22.51	22.89	22.50	22.15	22.11	22.22

AVE TEMP (Ambient, °C)

Manu.	Conn.	TC #	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug
50A																																				
IDEAL	1-3	1	23.23	23.31	23.29	23.44	23.51	23.41	23.26	23.16	23.07	23.28	23.41	23.40	23.42	23.58	23.99	24.28	24.29	24.18	23.92	23.57	23.47	23.51	23.43	23.58	23.86	23.69	23.24	22.92	23.29	23.28	23.14	22.73	22.68	22.69
WAGO	4-6	2	23.19	23.22	23.17	23.33	23.39	23.29	23.17	23.04	22.95	23.16	23.28	23.27	23.30	23.48	23.90	24.17	24.19	24.09	23.84	23.51	23.39	23.40	23.34	23.45	23.73	23.64	23.22	22.89	23.20	23.20	23.06	22.64	22.59	22.60
30A																																				
IDEAL	7-9	3	23.04	23.05	22.99	23.15	23.23	23.09	22.95	22.82	22.76	22.99	23.10	23.09	23.11	23.30	23.75	24.00	23.99	23.84	23.60	23.26	23.17	23.16	23.10	23.22	23.53	23.55	23.16	22.83	22.99	23.03	22.89	22.51	22.41	22.40
WAGO	10-12	4	23.06	23.07	23.02	23.18	23.26	23.11	22.96	22.83	22.78	23.02	23.13	23.11	23.13	23.33	23.78	24.04	24.01	23.83	23.60	23.27	23.18	23.17	23.10	23.24	23.56	23.56	23.16	22.84	23.00	23.01	22.88	22.50	22.40	22.40
Gardner Bender	13-15	5	23.07	23.08	23.02	23.20	23.26	23.12	22.96	22.82	22.78	23.03	23.14	23.11	23.13	23.34	23.80	24.07	24.02	23.84	23.59	23.24	23.16	23.15	23.08	23.25	23.59	23.59	23.22	22.91	23.00	22.98	22.85	22.46	22.37	22.37
20A																																				
IDEAL	16-18	6	23.18	23.17	23.09	23.26	23.35	23.23	23.04	22.92	22.86	23.13	23.23	23.22	23.24	23.46	23.94	24.20	24.17	23.95	23.71	23.34	23.23	23.25	23.16	23.36	23.68	23.65	23.20	22.90	23.06	23.04	22.89	22.47	22.43	No Data
WAGO	19-21	7	23.20	23.18	23.09	23.26	23.35	23.21	23.03	22.90	22.83	23.11	23.22	23.19	23.22	23.44	23.92	24.18	24.14	23.93	23.68	23.33	23.21	23.25	23.17	23.32	23.65	23.64	23.20	22.88	23.03	23.03	22.91	22.49	22.45	22.45
Gardner Bender	22-24	8	23.18	23.17	23.08	23.25	23.33	23.18	23.01	22.86	22.81	23.10	23.20	23.17	23.20	23.42	23.89	24.14	24.11	23.90	23.64	23.29	23.18	23.21	23.13	23.29	23.61	23.62	23.19	22.87	23.00	23.00	22.88	22.46	22.41	22.40

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COPPERWELD BIMETALLICS
TEST REPORT

SCOPE OF WORK
ASTM E228 LINEAR THERMAL EXPANSION EVALUATION OF 14 AWG GAGE COPPER CLAD ALUMINUM (CCA) WIRE

REPORT NUMBER
I6049.04-106-31 R0

TEST DATES
07/12/18 - 07/19/18

ISSUE DATE
08/15/18

RECORD RETENTION END DATE
07/26/22

PAGES
8

DOCUMENT CONTROL NUMBER
ATI 00231 (09/05/17)
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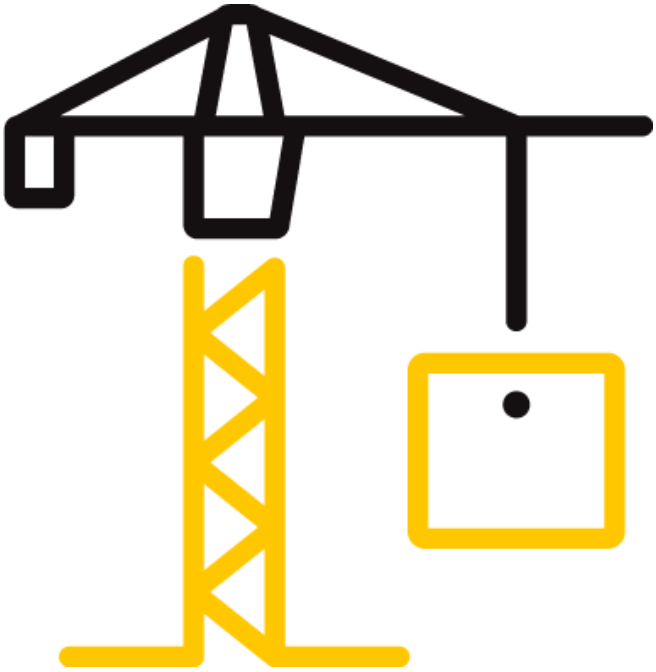

130 Derry Court
York, Pennsylvania 17406

Telephone: 717-764-7700
Facsimile: 717-764-4129
www.intertek.com/building

TEST REPORT FOR COPPERWELD BIMETALLICS

Report No.: I6049.04-106-31 R0
Date: 08/15/18

REPORT ISSUED TO

COPPERWELD BIMETALLICS
254 Cotton Mill Road
Fayetteville, Tennessee 37334

SECTION 1

SCOPE

Products: 14 AWG gage Copper Clad Aluminum (CCA) Wire

Intertek Building & Construction (B&C) was contracted by Copperweld Bimetallics to evaluate 14 AWG gage Copper Clad Aluminum (CCA) Wire in accordance with ASTM E228 for Linear Thermal Expansion properties. Results obtained are tested values and were secured by using the designated test methods. Testing was conducted at the Intertek B&C test facility in York, Pennsylvania.

This report does not constitute certification of this product nor an opinion or endorsement by this laboratory.

SECTION 2

SUMMARY OF TEST RESULTS

COPPER CLAD ALUMINUM (CCA) WIRE AWG GAGE	CLTE (mm/mm/°C) 25°C to 90°C TEMPERATURE RANGE
14	8.89E-06

For INTERTEK B&C:

COMPLETED BY:	Joseph M. Brickner	**REVIEWED BY:**	Dawn M. Chaney
TITLE:	Laboratory Supervisor Materials Laboratory	**TITLE:**	Technician Team Lead Materials laboratory
SIGNATURE:		**SIGNATURE:**	
DATE:	08/15/18	**DATE:**	08/15/18

JMB:dmc/jp

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York, Pennsylvania 17406

Telephone: 717-764-7700
Facsimile: 717-764-4129
www.intertek.com/building

SECTION 3
TEST METHOD

The specimens were evaluated in accordance with the following:

> **ASTM E228-17**, *Standard Test Method for Linear Thermal Expansion of Solid Materials with a Push-Rod Dilatometer*

SECTION 4
MATERIAL SOURCE

The test materials were provided by Copperweld Bimetallics. The following was received: One (1), nominally 76 mm copper clad aluminum wire specimens in 14 AWG gage. Refer to the product description photo in Section 10. The material was tested as received except for smoothing the cut ends of each specimen. Representative test specimens will be retained by Intertek B&C for a minimum of four years from the test completion date.

SECTION 5
LIST OF OFFICIAL OBSERVERS

NAME	COMPANY
Joseph M. Brickner	Intertek B&C
Dawn M. Chaney	Intertek B&C

SECTION 6
TEST PROCEDURE

All conditioning of test specimens and test conditions were at standard laboratory conditions unless otherwise reported. Refer to the test related photos in Section 10.

ASTM E228 - Linear Thermal Expansion
One specimen for each wire gage was measured for initial length using a 6" digital caliper (ICN: 65688) and placed in the bottom of an outer glass dilatometer tube with an inner glass tube resting on it. An aluminum support cylinder was utilized to keep the wire oriented in a vertical position. The dilatometer tube was suspended in a heated environment utilizing a muffle furnace (ICN: Y002864) and subjected to exposure conditions of nominally 25°C and 90°C. At the equilibrium of each temperature condition, specimen temperature was measured using a thermocouple reader (ICN: 62101) and a measurement was recorded from a digital indicator (ICN: INT00193) resting on top of the inner tube. The Linear Thermal Expansion between the temperature range was calculated.

DRAFT

130 Derry Court
York, Pennsylvania 17406

Telephone: 717-764-7700
Facsimile: 717-764-4129
www.intertek.com/building

TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.04-106-31 R0
Date: 08/15/18

SECTION 7
TEST SPECIMEN DESCRIPTIONS

TEST PROCEDURE	NUMBER OF SPECIMENS	NOMINAL SPECIMEN DIMENSIONS	VISUAL CHARACTERISTICS
ASTM E228 Linear Thermal Expansion	1	75 mm x 14 gage wire thickness	Copper Clad Aluminum wire

SECTION 8
TEST RESULTS

ASTM E228 - Linear Thermal Expansion

Copper Clad Aluminum (CCA) Wire - 14 Gage

All Temperatures

LENGTH (mm)	75.56	
TARGET TEMPERATURE (°C)	25	90
ACTUAL TEMPERATURE (°C)	25.4	90.9
GAGE READING (mm)	6.6070	6.6510
ΔT (°C)		65.5
ΔL (mm)		0.0440
ΔL/ΔT (mm/°C)		6.72E-04
CLTE (mm/mm/°C)		**8.89E-06**

SECTION 9
CONCLUSION

The requested test method did not contain specific performance requirements.

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130 Derry Court
York, Pennsylvania 17406

Telephone: 717-764-7700
Facsimile: 717-764-4129
www.intertek.com/building

TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.04-106-31 R0
Date: 08/15/18

SECTION 10
PHOTOGRAPHS

Photo No. 1
Copper Clad Aluminum - Specimen Detail

Photo No. 2
ASTM E228 - Equipment Detail

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York, Pennsylvania 17406

Telephone: 717-764-7700
Facsimile: 717-764-4129
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Date: 08/15/18

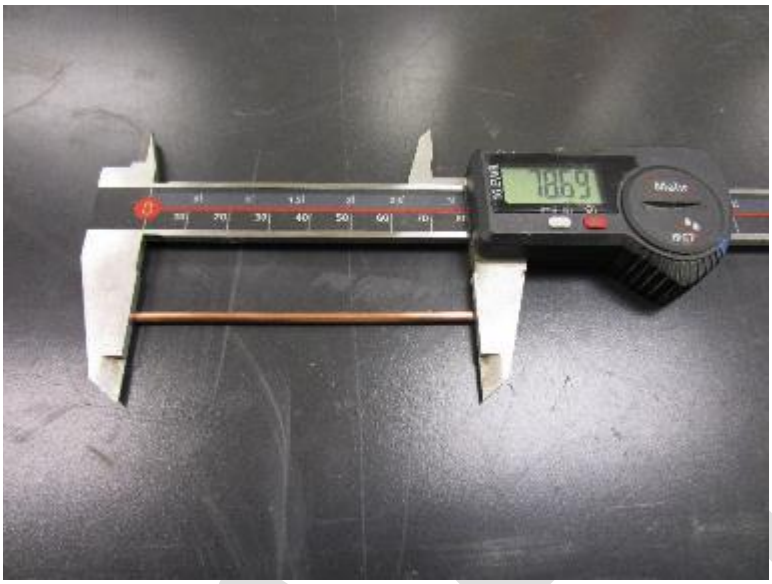

Photo No. 3
ASTM E228 - Length Measurement Equipment Detail

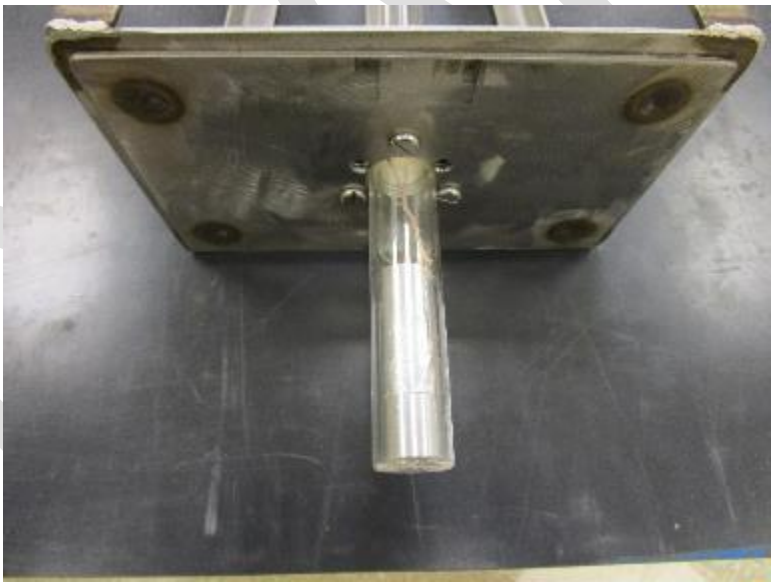

Photo No. 4
ASTM E228 - Specimen Support Detail

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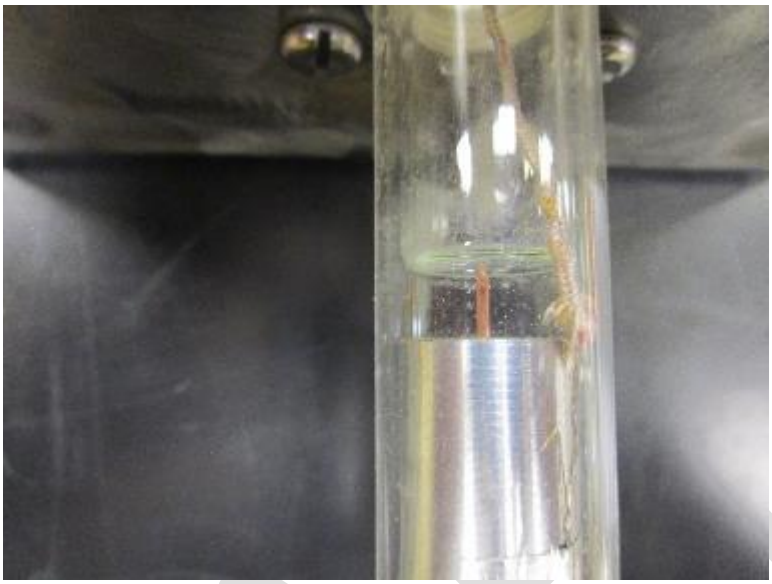

Photo No. 5
ASTM E228 - Specimen Temperature Measurement Detail

Photo No. 6
ASTM E228 - Linear Expansion Measurement Equipment Detail

130 Derry Court
York, Pennsylvania 17406

Telephone: 717-764-7700
Facsimile: 717-764-4129
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Report No.: I6049.04-106-31 R0
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SECTION 11
REVISION LOG

REVISION #	DATE	PAGES	REVISION
0	08/15/18	N/A	Original Report Issue

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COPPERWELD BIMETALLICS
TEST REPORT

SCOPE OF WORK
ASTM E228 LINEAR THERMAL EXPANSION EVALUATION OF 14 AWG GAGE ELECTROLYTIC TOUGH PITCH (ETP) COPPER WIRE

REPORT NUMBER
I6049.03-106-31 R0

TEST DATES
07/19/18 - 07/26/18

ISSUE DATE
08/15/18

RECORD RETENTION END DATE
07/26/22

PAGES
8

DOCUMENT CONTROL NUMBER
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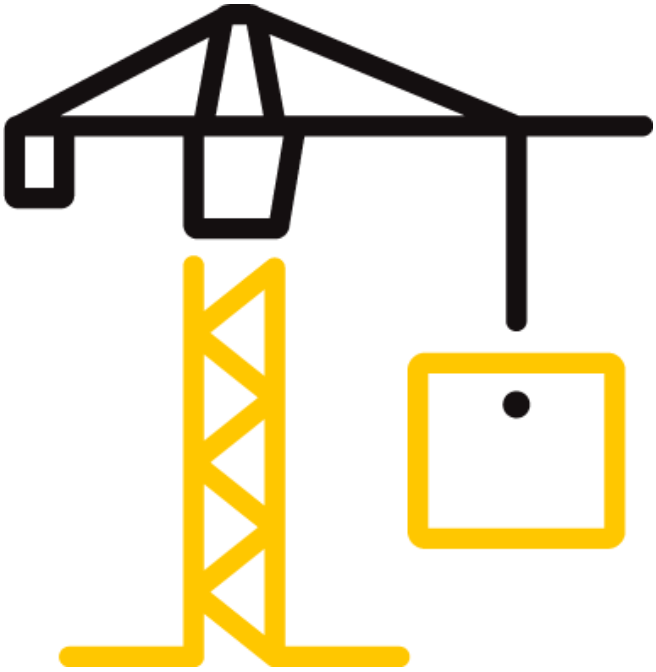

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TEST REPORT FOR COPPERWELD BIMETALLICS

Report No.: I6049.03-106-31 R0
Date: 08/15/18

REPORT ISSUED TO

COPPERWELD BIMETALLICS
254 Cotton Mill Road
Fayetteville, Tennessee 37334

SECTION 1

SCOPE

Products: 14 AWG gage Electrolytic Tough Pitch (ETP) Wire

Intertek Building & Construction (B&C) was contracted by Copperweld Bimetallics to evaluate 14 AWG gage Electrolytic Tough Pitch (ETP) Wire in accordance with ASTM E228 for Linear Thermal Expansion properties. Results obtained are tested values and were secured by using the designated test methods. Testing was conducted at the Intertek B&C test facility in York, Pennsylvania.

This report does not constitute certification of this product nor an opinion or endorsement by this laboratory.

SECTION 2

SUMMARY OF TEST RESULTS

ELECTROLYTIC TOUGH PITCH (ETP) COPPER WIRE AWG GAGE	CLTE (mm/mm/°C) 25°C to 90°C TEMPERATURE RANGE
14	1.57E-05

For INTERTEK B&C:

COMPLETED BY:	Joseph M. Brickner	**REVIEWED BY:**	Dawn M. Chaney
TITLE:	Laboratory Supervisor Materials Laboratory	**TITLE:**	Technician Team Lead Materials laboratory
SIGNATURE:		**SIGNATURE:**	
DATE:	08/15/18	**DATE:**	08/15/18

JMB:dmc/jlp

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130 Derry Court
York, Pennsylvania 17406

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SECTION 3
TEST METHOD

The specimens were evaluated in accordance with the following:

> **ASTM E228-17**, *Standard Test Method for Linear Thermal Expansion of Solid Materials with a Push-Rod Dilatometer*

SECTION 4
MATERIAL SOURCE

The test materials were provided by Copperweld Bimetallics. The following were received: One (1), nominally 76 mm electrolytic tough pitch copper wire specimen in 14 AWG gage. Refer to the product description photo in Section 10. The material was tested as received except for smoothing the cut ends of each specimen. Representative test specimens will be retained by Intertek B&C for a minimum of four years from the test completion date.

SECTION 5
LIST OF OFFICIAL OBSERVERS

NAME	COMPANY
Joseph M. Brickner	Intertek B&C
Dawn M. Chaney	Intertek B&C

SECTION 6
TEST PROCEDURE

All conditioning of test specimens and test conditions were at standard laboratory conditions unless otherwise reported. Refer to the test related photos in Section 10.

ASTM E228 - Linear Thermal Expansion
One specimen for each wire gage was measured for initial length using a 6" digital caliper (ICN: 65688) and placed in the bottom of an outer glass dilatometer tube with an inner glass tube resting on it. An aluminum support cylinder was utilized to keep the wire oriented in a vertical position. The dilatometer tube was suspended in a heated environment utilizing a muffle furnace (ICN: Y002864) and subjected to exposure conditions of nominally 25°C and 90°C. At the equilibrium of each temperature condition, specimen temperature was measured using a thermocouple reader (ICN: 62101) and a measurement was recorded from a digital indicator (ICN: INT00193) resting on top of the inner tube. The Linear Thermal Expansion between the temperature range was calculated.

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130 Derry Court
York, Pennsylvania 17406

Telephone: 717-764-7700
Facsimile: 717-764-4129
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SECTION 7
TEST SPECIMEN DESCRIPTIONS

TEST PROCEDURE	NUMBER OF SPECIMENS	NOMINAL SPECIMEN DIMENSIONS	VISUAL CHARACTERISTICS
ASTM E228 Linear Thermal Expansion	1 each	75 mm x 14 gage wire thickness	Electrolytic Tough Pitch Copper wire

SECTION 8
TEST RESULTS

ASTM E228 - Linear Thermal Expansion

Electrolytic Tough Pitch (ETP) Copper Wire - 14 Gage

All Temperatures

LENGTH (mm)	75.60	
TARGET TEMPERATURE (°C)	25	90
ACTUAL TEMPERATURE (°C)	28.7	91.3
GAGE READING (mm)	5.6440	5.7220
ΔT (°C)		62.6
ΔL (mm)		0.0780
ΔL/ΔT (mm/°C)		1.25E-03
CLTE (mm/mm/°C)		**1.57E-05**

SECTION 9
CONCLUSION

The requested test method did not contain specific performance requirements.

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130 Derry Court
York, Pennsylvania 17406

Telephone: 717-764-7700
Facsimile: 717-764-4129
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TEST REPORT FOR COPPERWELD BIMETALLICS
Report No.: I6049.03-106-31 R0
Date: 08/15/18

SECTION 10
PHOTOGRAPHS

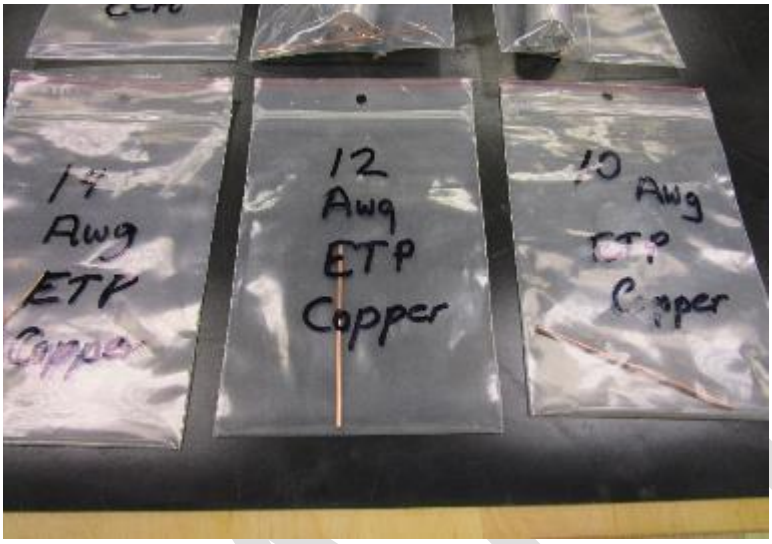

Photo No. 1
Electrolytic Tough Pitch - Specimen Detail

Photo No. 2
ASTM E228 - Equipment Detail

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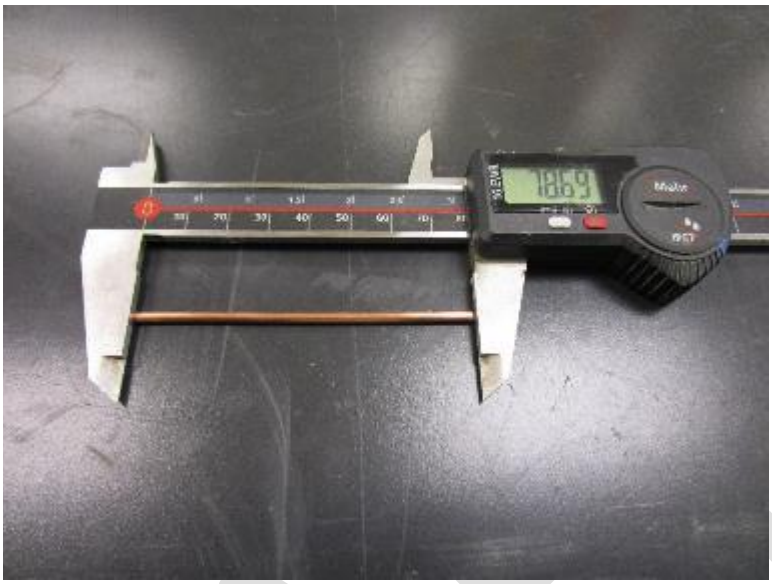

Photo No. 3
ASTM E228 - Length Measurement Equipment Detail

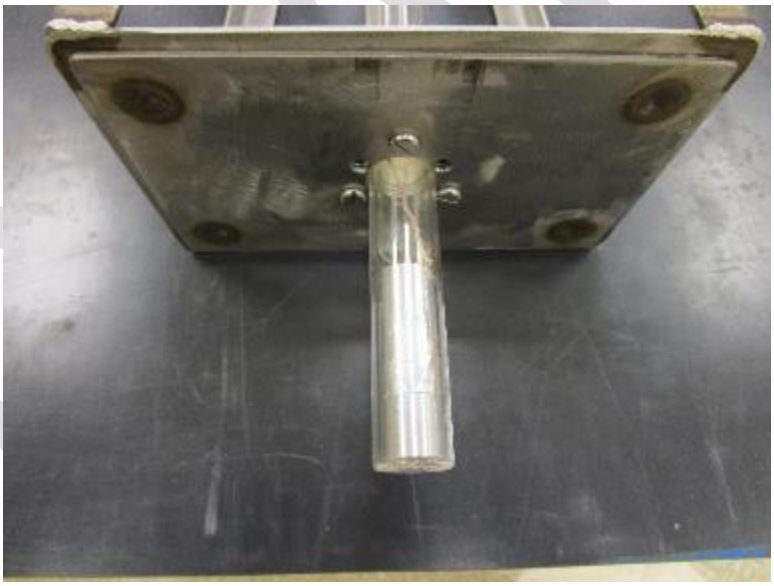

Photo No. 4
ASTM E228 - Specimen Support Detail

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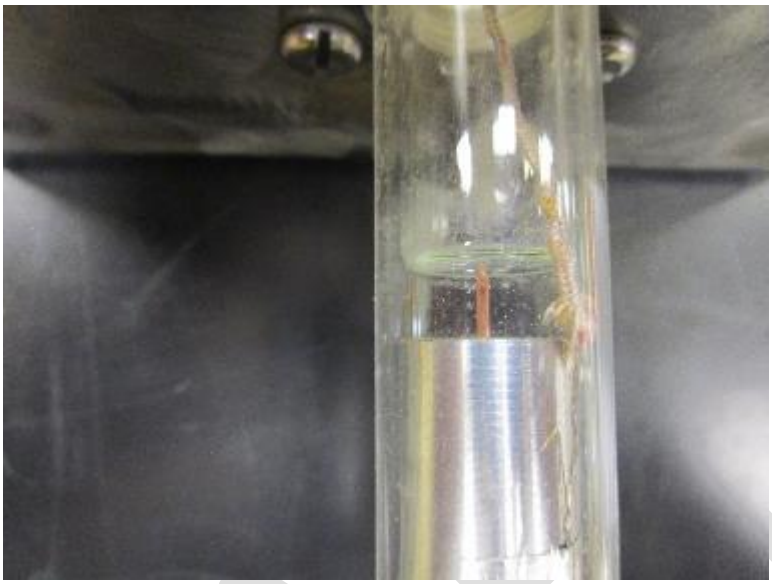

Photo No. 5
ASTM E228 - Specimen Temperature Measurement Detail

Photo No. 6
ASTM E228 - Linear Expansion Measurement Equipment Detail

130 Derry Court
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TEST REPORT FOR COPPERWELD BIMETALLICS
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Date: 08/15/18

SECTION 11
REVISION LOG

REVISION #	DATE	PAGES	REVISION
0	08/15/18	N/A	Original Report Issue

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Public Comment No. 916-NFPA 70-2018 [Section No. 336.120]

336.120 Marking.

There shall be no voltage marking on a Type TC cable employing thermocouple extension wire.

Additional Proposed Changes

File Name	Description	Approved
CN_7.pdf	70_CN 7	

Statement of Problem and Substantiation for Public Comment

NOTE: This Public Comment appeared as CC Note No. 7 in the First Draft Report on First Revision No. 7647.

The Correlating Committee directs that First Revision 7647 be rewritten to comply with the NEC Style Manual, Section 3.2.1, regarding List Item (2) relative to enforceability and the use of vague and unenforceable terms including “essentially”.

This action will be considered as a public comment.

Related Item

- FR 7647

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC
Organization: NEC Correlating Committee
Street Address:
City:
State:
Zip:
Submittal Date: Mon Aug 20 15:58:00 EDT 2018
Committee: NEC-P06

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Correlating Committee Note No. 7-NFPA 70-2018 [New Section after 336.120]

Submitter Information Verification

Submitter Full Name: Sarah Caldwell
Committee:
Submittal Date: Wed May 09 11:50:23 EDT 2018

Committee Statement and Meeting Notes

Committee Statement: The Correlating Committee directs that First Revision 7647 be rewritten to comply with the NEC Style Manual, Section 3.2.1, regarding List Item (2) relative to enforceability and the use of vague and unenforceable terms including “essentially”. This action will be considered as a public comment.

First Revision No. 7647-NFPA 70-2018 [New Section after 336.120]

Ballot Results

✔ **This item has passed ballot**

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

Affirmative All

Brunssen, James E.
Dressman, Kevin L.
Hickman, Palmer L.
Hittinger, David L.
Holub, Richard A.
Johnston, Michael J.
Kovacik, John R.
Manche, Alan
McDaniel, Roger D.
Pierce, James F.
Saporita, Vincent J.
Williams, David A.

Public Comment No. 1912-NFPA 70-2018 [Section No. 336.130]

336.130 Hazardous (Classified) Location Cable.

Cable listed and marked Type TC-ER-HL shall comply with the following:

(1) The overall nonmetallic jacket shall be suitable for the environment.

(2) The overall cable construction shall be ~~essentially~~ circular in cross-section.

(3) The overal nonmetallic jacket shall be continuous and gas/vapor tight.

(4) For construction greater than 25.4 mm (1 in.) in diameter, the following shall apply:

(5) The equipment grounding conductor shall be bare.

(6) A

~~metalic~~

a. metallic shield shall be included over all conductors under the

~~outter~~

a. outer jacket.

Statement of Problem and Substantiation for Public Comment

The word "essentially" could be considered unenforceable. Product standards can address the tolerance for determining the required tolerances of construction. Two words in the final list item were spelled incorrectly.

Related Item

• FR 7647

Submitter Information Verification

Submitter Full Name: Christel Hunter
Organization: Cerro Wire
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 30 12:08:41 EDT 2018
Committee: NEC-P06

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Public Comment No. 1987-NFPA 70-2018 [Section No. 336.130]

336.130 Hazardous (Classified) Location Cable.

Cable listed and marked Type TC-ER-HL shall comply with the following:

(1) The overall nonmetallic jacket shall be suitable for the environment.

(2) The overall cable construction shall be essentially circular in cross-section.

(3) The overal nonmetallic jacket shall be continuous and gas/vapor tight.

(4) For construction greater than 25.4 mm (1 in.) in diameter or the conductor ampacity is greater than 30 amperes , the following shall apply:

(5) The equipment grounding conductor shall be bare.

(6) A metalic shield shall be included over all conductors under the outter jacket.

Statement of Problem and Substantiation for Public Comment

This is to ensure the additional bare ground wire and metallic shielding is only required for power cables where significant amounts of ground fault energy are available. If these type faults are not detected and cleared immediately, they can result in an ignition of flammable materials in a hazardous (classified) location.

Related Item

• FR 7647

Submitter Information Verification

Submitter Full Name: Dave Burns
Organization: Shell P&T: Innovation/R&D
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 30 13:46:57 EDT 2018
Committee: NEC-P06

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Public Comment No. 1453-NFPA 70-2018 [Article 337]

Article 337 Type P

Part I. General

337.1 Scope.

This article covers the use, installation, and construction specifications for 600 volt Type P cable (armored and unarmored), for use in hazardous (classified) locations as permitted in this *Code* .

337.2 Definition.

The definition in this section shall apply within this article and throughout the *Code* .

Type P.

A factory assembly of two or more insulated flexible tinned copper conductors, with associated bare or covered grounding conductors, impervious sheath, braided metallic armored or unarmored cable. See Part III.

337.6 Listing Requirements.

Type P cables and associated fittings shall be listed.

Part II. Installation

337.10 Uses Permitted.

In industrial locations under engineering supervision where the conditions of maintenance and supervision ensure that only qualified persons service the installation, Type P cable shall be permitted for use in hazardous (classified) locations and to transition between a hazardous (classified) location and a non-hazardous (classified) location as follows:

(1) For services, feeders, and branch circuits

(2) For power, lighting, control, and signal circuits

(3) Indoors

(4) Outdoors where identified for such use

(5) Exposed or concealed

(6) For direct burial where identified for such use

(7) In cable tray where identified for such use

(8) In any raceway

(9) In wet locations

(10) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(11) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(12) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(13) The cable is secured at intervals not exceeding 1.4 m (4.5 ft).

(14) Equipment grounding for the utilization equipment is provided by a bare equipment grounding conductor within the cable.

Exception to (10): Where not subject to physical damage, Type P shall be permitted to transition between cable trays and between cable trays and utilization equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

337.12 Uses Not Permitted.

Type P cable shall not be installed or used where it will be exposed to physical damage.

337.24 Bending Radius.

Bends in Type P cable shall be made such that the cable will not be damaged. The radius of the curve of the inner edge of any bend shall not be less than required in 337.24(A) through (B).

(A) Unarmored Cable.

(1) Four times the overall diameter for cables 25 mm (1 in.) or less in diameter

(2) Five times the overall diameter for cables larger than 25 mm (1 in.) but not more than 50 mm (2 in.) in diameter

(3) Six times the overall diameter for cables larger than 50 mm (2 in.) in diameter

(B) Armored Cable.

(1) Ten times the external diameter of the metallic armor for cable not more than 19 mm ($^{3}/_{4}$ in.) in external diameter

(2) Twelve times the external diameter of the metallic armor for cable more than 19 mm ($^{3}/_{4}$ in.) in external diameter

337.30 Securing and Supporting.

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

(A) Securing.

Unless otherwise provided, cables shall be secured at intervals not exceeding 1.4 m (4.5 ft). Cables containing four or fewer conductors sized no larger than 10 AWG shall be secured within 300 mm (12 in.) of every box, cabinet, fitting, or other cable termination. In vertical installations, cables with ungrounded conductors 250 kcmil and larger shall be permitted to be secured at intervals not exceeding 3 m (10 ft.).

(B) Supporting.

Unless otherwise provided, cables shall be supported at intervals not exceeding 1.4 m (4.5 ft). Horizontal runs of Type P cable installed in wooden or metal framing members or similar supporting means shall be considered supported and secured where such support does not exceed 1.4 m (4.5 ft) intervals.

(C) Unsupported Cables.

Type P cable shall be permitted to be unsupported and unsecured where the cable complies with any of the following:

(1) Is fished between access points through concealed spaces in finished buildings or structures and supporting is impractical

(2) Is not more than 1.4 m (4.5 ft) in length from the last point of cable support to the point of connection to luminaires or other electrical equipment and the cable and point of connection are within an accessible ceiling

(3) Is in lengths not exceeding 900 mm (3 ft) from the last point where it is securely fastened and is used to connect equipment where flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation

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 cable shall be determined in accordance with 310.15 for 14 AWG and larger conductors and in accordance with Table 402.5 for 18 AWG and 16 AWG conductors. When installed in cable tray, the ampacities shall 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 the cable.~~

~~An uninsulated equipment grounding conductor shall be provided in cable marked Type P-HL.~~

~~**337.112** Insulation.~~

~~Insulated conductors shall comply with 337.112(A) or (B).~~

~~Insulated conductors in sizes 18 AWG and 16 AWG shall be Type FFHH-2 as listed in Table 402.3. Conductors larger than 16 AWG shall be Type XHHW or XHHW-2 as listed in Table 310.4(A).~~

~~**337.116** Sheath.~~

~~The sheath or outer covering shall comply with 337.116(A) or (B).~~

~~**(A)** Armored.~~

~~An overall nonmetallic jacket impervious to moisture and corrosion-resistant shall be provided over the armor. The armor or metallic covering shall be a braided basket weave type consisting of wire laid closely together, flat and parallel, and forming a basket weave that shall firmly grip the cable. The wire shall be commercial bronze. The armor shall not be used as a current-carrying conductor.~~

~~**(B)** Unarmored.~~

~~An overall flame-retardant, nonmetallic material impervious to moisture and corrosion-resistant shall be provided over the cable core. A metallic sheath or armor as defined in 337.116 shall not be permitted either under or over the nonmetallic jacket. Metallic shield(s) shall be permitted over groups of conductors, under the outer jacket, or both.~~

~~**337.120** Marking.~~

~~Type P cable shall be marked in accordance with 310.8. Armored cable shall be marked as Type P-HL.~~

Additional Proposed Changes

File Name	Description	Approved
Article_6XX-_GS_Proposal.docx	Proposed Article 6XX. to replace proposed Article 337	

Statement of Problem and Substantiation for Public Comment

The sole intended purpose of the recommendation to add type P cables to the Code by the PI Submittors was to accommodate thousands of existing and future land based drilling rigs operating in the U.S. For the past few decades, these facilities have not been operating in compliance with NFPA 70 out of necessity, as no cables within NFPA are adequate for this very severe service. Although CMP 6 made a valiant attempt to include Type P cables in new Article 337, it is now apparent that Type P cables do not fit well into the Tray Cable category and the proposed Article 337, as written, does not adequately define the cable construction, application, or installation of Type P cables for this special intended service. In fact, it would create a number of issues, limitations, and conflicts with the historical use of these cables in the intended application This would result in confusion among users and AHJs, as well as manufacturers, as well as potential legal issues. This public comment recommends the deletion of Article 337 in its entirety, and to replace it with a new Article in Chapter 6 to address this special service (proposed wording attached).

Related Item

• Proposed Article 6XX-

Submitter Information Verification

Submitter Full Name: Gary Savage
Organization: Prysmian Group
Street Address:
City:
State:
Zip:

Submittal Date: Tue Aug 28 16:58:02 EDT 2018
Committee: NEC-P06

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Proposed Article 6XX-
Type P Cables for Oil & Gas Land Rig Applications
G. Savage

Article 6XX

Type P Cables for Oil and Gas Well Drilling Land Rigs

6XX.1 Scope.
This article covers the installation of Type P cable in hazardous (classified) areas on Oil and Gas Well Drilling Land Rigs where permitted in this *Code*.

6XX.2 Definition.

Oil & Gas Well Drilling Land Rig. A collection of portable (not hand-portable) industrial equipment that are individually transported to a designated location (drill site), then positioned per a specific rig layout design and interconnected (rigged up) to implement a drilling program. Land rigs remain on the drill site from just a few days up to a number of months depending on the drilling program. Once drilling operations are complete, the land rig is disassembled (rigged down) and transported to the next drill site.

Type P Cable.
A factory assembly of one or more insulated, flexible, stranded, tinned-copper conductors, manufactured per IEEE-1580, rated 600/1000 volt or 2000 volt, with or without associated insulated grounding conductor(s), basket-weave type braid metallic armor with non-metallic impervious sheath, or unarmored.

Informational Note 1: The Oil and Gas Well Drilling Land Rig Industry require quick and easy mobility when rigging up, rigging down, and transporting the drilling rig overland between drill sites. In addition, the drilling rigs and the equipment on them are subjected to significant movement, shaking, and vibration while drilling. Therefore, these conditions require special consideration with regards to the selection and installation of electrical cables. The Oil and Gas Well Drilling Land Rig Industry has historically used IEEE-1580, Type P, cable to ***rig-up*** *and interconnect the various machines and equipment that make up the drilling rig. These cables may also be listed as UL-1309 cables. The flexible and rugged IEEE-1580, Type P, cable is highly suitable for the oil and gas well drilling land rig application because of its ability to resist drilling muds that contain various chemicals, abrasives, and petroleum-based additives as well as its ability to resist damage from vibration, shaking, and movement that occurs during the drilling process, and the rigors of rig-up and rig-down. They are also highly suited because of their ability to perform in extreme cold weather conditions in that they can pass a -40° C cold bend test and a -35° C cold impact test. In addition to their flexibility and mechanical ruggedness as just described, the IEEE-1580, Type P, cable is rated 600/1000 volts or 2000 volts which makes it suitable for use on both DC and AC powered drilling rigs including rigs with VFD powered drilling machines, has a maximum conductor temperature rating of 110° C, has a flexible tinned-copper stranded conductor that resists oxidation, and passes an IEEE 1202 vertical cable tray flame test. In addition, the flexible tinned-copper conductors are available in sizes such as 444 kcmil, 535 kcmil, 646 kcmil, and 777 kcmi; which are sizes commonly used on the drilling rigs. These cables are also available with a metallic basket-weave braided armor with non-metallic impervious sheath over the armor, which is used in certain areas of the rig, that effectively enhances their durability, provides crush, impact, and cut-through resistance, and is not prone to failure due to fatigue and cracking; properties that are very important in the drilling environment.*

Commented [SGU1]:

6XX.3 Grounding
When using Type P cable with a metallic basket-weave braided armor, the armor shall be electrically continuous throughout the entire length of the cable run and shall be effectively grounded using cable fittings listed for the application. However, the metallic basket-weave braided armor shall not be used as the equipment grounding path or conductor. Therefore, an appropriate sized **insulated** grounding conductor shall be included within both armored and unarmored Type P cable, or other adequate grounding means provided to comply with Article 250.

6XX.4 Installation.
Cables should be adequately protected where exposed to damage. Armored cables should be considered or

may be required depending on application or location. Type P cable installed on or between portable (not hand-portable) oil & gas well drilling land rig utilization equipment shall be routed to minimize the risk of mechanical damage and shall comply with the requirements of 6XX.4 (A) and (B).

(A) Bending Radius.
Bends in Type P cable shall be made such that the cable will not be damaged. The radius of the curve of the inner edge of any bend shall not be less than required in 6XX.4(A)(1) and 6XX.4(A)(2).

(1) Unarmored Cable.
(a) Four times the overall diameter for cables 25 mm (1 in) or less in diameter
(b) Six times the overall diameter for cables larger than 25 mm (1 in)

(2) Armored (Braided) Cable.
(a) Six times the overall diameter of the cable

(B) Securing and Supporting.
Type P cables shall be secured and supported in accordance with the manufacturer's installation instructions.

If cable supports are used, cables shall be individually secured to the supports at intervals to prevent excessive sag or strain on the cables so as not to damage the cable.

6XX.5 Ampacity.
The allowable ampacity of Type P cable shall be determined in accordance with Tables 6XX.5(A) through Table 6XX.5(C) or under engineering supervision.

Table 6XX.5(A) Ampacities for Type P Distribution, Control, and Signal Cables, 2000 Volts or Less, AC or DC, Copper Conductors, Single-banked (Single-Layered), Based on 45º C (113º F) Ambient Temperature.

			Maximum Conductor Insulation Temperature Ratings					
AWG or kcmil	mm^2	Circular Mils	Single-conductor Cable		Two-conductor Cable		Three-conductor Cable	
			100º C (212º F)	110º C (230º F)	100º C (212º F)	110º C (230º F)	100º C (212º F)	110º C (230º F)
22	0.355	700	9	10	8	9	7	8
20	0.52	1020	12	13	10	11	9	10
18	0.82	1620	16	17	14	15	12	13
16	1.31	2580	23	25	19	20	16	17
14	2.08	4110	37	40	31	33	25	27
12	3.31	6530	45	48	40	43	31	33
10	5.26	10,380	58	62	49	52	41	44
8	8.37	16,510	72	77	64	69	52	56
7	10.55	20,820	84	88	78	82	65	67
6	13.30	26,240	96	103	85	91	70	75

5	16.77	33,090	109	117	101	108	82	88
4	21.15	41,740	128	137	110	118	92	99
3	26.66	52,620	146	156	132	141	108	116
2	33.62	66,630	169	181	149	160	122	131
1	44.21	83,690	194	208	174	186	143	153
1/0	53.50	105,600	227	243	199	213	164	176
2/0	67.44	137,100	262	281	242	259	188	201
3/0	85.02	167,800	300	281	265	284	218	234
4/0	107.20	211,600	351	378	307	329	252	270
250	126.70	250,000	389	409	344	360	282	295
262	133.10	262,600	407	436	358	383	294	315
313	158.60	313,100	455	487	391	419	321	344
350	177.30	350,000	485	508	421	441	344	361
373	189.30	373,700	516	553	442	473	361	387
444	225.20	444,400	588	630	504	540	411	440
500	253.30	500,000	609	638	520	546	428	448
535	271.20	535,300	630	676	538	576	443	475
646	327.50	646,400	731	783	632	677	516	553
750	380.00	750,000	786	824	656	686	537	563
777	394.00	777,700	822	881	684	733	562	602
1000	506.70	1,000,000	939	988				
1111	563.10	1,111,000	1025	1098				
1250	633.30	1,250,000	1072	1128				
1500	760.00	1,500,000	1195	1254				
2000	1013.30	2,000,000	1400	1473				

Notes to Table 6XX.5(A):

1) The allowable ampacities are based on the conductor temperature rise in a given ambient. When selecting conductor sizes and insulation ratings, consideration shall be given to the following.

a) The actual conductor operating temperature shall be compatible with the connected equipment, especially at the connection points.

b) Conductor selection shall be permitted to be coordinated with circuit and system overcurrent and short-circuit protection to avoid cable damage during through-fault conditions.

2) Current-carrying capacity of four-conductor cables where one conductor is not a current-carrying phase conductor (e.g. neutral or grounding conductor) is the same as three-conductor cables.

3) Current ratings are for ac or dc. Exceptions are stated in Table 6XX.5(B)

4) The ampacities in the tables are based on various maximum conductor temperatures. If the ampacity at a different maximum conductor is required, then, under engineering supervision, the following equation, from IEEE 835, shall be permitted to be used to calculate the ampacity:

$$I' = \sqrt{\left(\frac{T_c' - T_a - \Delta T_d'}{T_c - T_a - \Delta T_d}\right) \times \left(\frac{\tau_c + T_c}{\tau_c + T_c'}\right)} \times I$$

$T_c -$ *is maximum conductor temperature used in tables*
$T_a -$ *is ambient temperature used in the tables*
$\Delta T_d -$ *is temperature rise due to dielectric loss*
$I -$ *is ampacity shown in tables for* T_c, T_a *, and* ΔT_d
$T_c' -$ *is new maximum conductor temperture*
$\Delta T_d' -$ *is new temperature rise due to dielectric loss*
$\tau_c -$ *is inferred temperature of zero electrical resistance* (234.5 *for copper conductors*)

5) The current-carrying capacities are for cable installations with cables arranged in a single bank per hanger and are 85% of the calculated free air values. For those instances where cables are double banked, the current-carrying capacities shall be decreased by multiplying the value shown by 0.8.

6) For cables with maintained spacing of at least 1 cable diameter apart, the ampacities shall be permitted to be increased by dividing the values shown by 0.85.

7) Single-conductor cables configured in triplex or triangular configuration shall be permitted to be conservatively treated as three conductor cables when determining ampacity. For detailed capacity for triplex or triangular calculations in IEEE 835 shall be permitted to be used.

8) Cable runs where segments with different thermal conditions exist will require separate derating considerations. The lowest ampacity calculated for any 10 ft (3 m) section in the cable run shall determine the cable size.

9) If ambient temperatures differ from 45º C (113º F), cable ampacities shall be permitted to be multiplied by the factors in Table 6XX.5(D)

10) If cables are installed in conduit, the free air values shall be derated by a factor of 0.8

Table 6XX.5(B) Ampacities for Type P, Single-Conductor, Distribution Cables, 2000 Volts or Less, DC Only, Copper Conductors, Single-banked (Single-Layered), Based on 45º C (113º F) Ambient Temperature.

		Single-conductor Cable	
kcmil	**mm²**	**100º C (212º F)**	**110º C (230º F)**
750	380.0	802	859
1000	506.7	964	1033
1250	633.3	1126	1206
1500	760.0	1276	1367
2000	1013.0	1557	1636

Table 6XX.5(C) Ampacities Adjustment Factors and Equations for Tables 6XX.5(A) and 6XX.5(B)

1) Use the following factors to calculate ampacity for cables with more than 3 conductors.

Number of Conductors	**Percent of Values for Three-conductor Cable as Adjusted for Ambient Temperature, if Necessary**
4 through 6	80
7 through 9	70
10 through 20	50
21 through 30	45
31 through 40	40
41 through 60	35

If ambient temperatures differ from 45º C (113º F), cable ampacities shall be permitted to be multiplied by the following factors:

Table 6XX.5(D)- Adjustment Factors for Ambient Temperatures

Ambient Temperature	**30º C (86º F)**	**40º C (104º F)**	**50º C (122º F)**	**55º C (131º F)**	**60º C (140º F)**	**70º C (158º F)**
100º C (212º F) Conductor Temperature	1.13	1.04	0.95	0.90	0.85	0.74
110º C (230º F) Conductor Temperature	1.11	1.04	0.96	0.92	0.88	0.78

The following equation from IEEE 835 shall be permitted to be used to calculate ampacity at an ambient temperature not listed in Note 4) above:

$$I' = \sqrt{\frac{T_c - T_a'}{T_c - T_a}} \times I$$

$$T_c - \text{ is maximum conductor temperature used in tables}$$
$$T_a - \text{is ambient temperature used in the tables}$$
$$T_a' - \text{is new ambient temperture}$$
$$I - \text{is ampacity shown in tables for } T_c \text{ and } T_a$$

6XX.6 Listing Requirements.
Type P cables shall be listed or classified to the requirements of IEEE 1580 or UL 1309. .

Informational Note 2: For further information on Type P cable see UL-1309, IEEE-1580, IEEE 45.8., API RP 14F, and API RP 14FZ

Public Comment No. 2082-NFPA 70-2018 [Article 337]

Article 337 Type P

Part I. General

337.1 Scope.

This article covers the use, installation, and construction specifications for 600 volt Type P cable (armored and unarmored), for use in hazardous (classified) locations as permitted in this *Code* .

337.2 Definition.

The definition in this section shall apply within this article and throughout the *Code* .

Type P.

A factory assembly of two or more insulated flexible tinned copper conductors, with associated bare or covered grounding conductors, impervious sheath, braided metallic armored or unarmored cable. See Part III.

337.6 Listing Requirements.

Type P cables and associated fittings shall be listed.

Part II. Installation

337.10 Uses Permitted.

In industrial locations under engineering supervision where the conditions of maintenance and supervision ensure that only qualified persons service the installation, Type P cable shall be permitted for use in hazardous (classified) locations and to transition between a hazardous (classified) location and a non-hazardous (classified) location as follows:

(1) For services, feeders, and branch circuits

(2) For power, lighting, control, and signal circuits

(3) Indoors

(4) Outdoors where identified for such use

(5) Exposed or concealed

(6) For direct burial where identified for such use

(7) In cable tray where identified for such use

(8) In any raceway

(9) In wet locations

(10) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(11) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(12) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(13) The cable is secured at intervals not exceeding 1.4 m (4.5 ft).

(14) Equipment grounding for the utilization equipment is provided by a bare equipment grounding conductor within the cable.

Exception to (10): Where not subject to physical damage, Type P shall be permitted to transition between cable trays and between cable trays and utilization equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

337.12 Uses Not Permitted.

Type P cable shall not be installed or used where it will be exposed to physical damage.

337.24 Bending Radius.

Bends in Type P cable shall be made such that the cable will not be damaged. The radius of the curve of the inner edge of any bend shall not be less than required in 337.24(A) through (B).

(A) Unarmored Cable.

(1) Four times the overall diameter for cables 25 mm (1 in.) or less in diameter

(2) Five times the overall diameter for cables larger than 25 mm (1 in.) but not more than 50 mm (2 in.) in diameter

(3) Six times the overall diameter for cables larger than 50 mm (2 in.) in diameter

(B) Armored Cable.

(1) Ten times the external diameter of the metallic armor for cable not more than 19 mm ($^{3}/_{4}$ in.) in external diameter

(2) Twelve times the external diameter of the metallic armor for cable more than 19 mm ($^{3}/_{4}$ in.) in external diameter

337.30 Securing and Supporting.

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

(A) Securing.

Unless otherwise provided, cables shall be secured at intervals not exceeding 1.4 m (4.5 ft). Cables containing four or fewer conductors sized no larger than 10 AWG shall be secured within 300 mm (12 in.) of every box, cabinet, fitting, or other cable termination. In vertical installations, cables with ungrounded conductors 250 kcmil and larger shall be permitted to be secured at intervals not exceeding 3 m (10 ft.).

(B) Supporting.

Unless otherwise provided, cables shall be supported at intervals not exceeding 1.4 m (4.5 ft). Horizontal runs of Type P cable installed in wooden or metal framing members or similar supporting means shall be considered supported and secured where such support does not exceed 1.4 m (4.5 ft) intervals.

(C) Unsupported Cables.

Type P cable shall be permitted to be unsupported and unsecured where the cable complies with any of the following:

(1) Is fished between access points through concealed spaces in finished buildings or structures and supporting is impractical

(2) Is not more than 1.4 m (4.5 ft) in length from the last point of cable support to the point of connection to luminaires or other electrical equipment and the cable and point of connection are within an accessible ceiling

(3) Is in lengths not exceeding 900 mm (3 ft) from the last point where it is securely fastened and is used to connect equipment where flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation

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 cable shall be determined in accordance with 310.15 for 14 AWG and larger conductors and in accordance with Table 402.5 for 18 AWG and 16 AWG conductors. When installed in cable tray, the ampacities shall 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 the cable.~~

~~An uninsulated equipment grounding conductor shall be provided in cable marked Type P-HL.~~

~~**337.112** Insulation.~~

~~Insulated conductors shall comply with 337.112(A) or (B).~~

~~Insulated conductors in sizes 18 AWG and 16 AWG shall be Type FFHH-2 as listed in Table 402.3. Conductors larger than 16 AWG shall be Type XHHW or XHHW-2 as listed in Table 310.4(A).~~

~~**337.116** Sheath.~~

~~The sheath or outer covering shall comply with 337.116(A) or (B).~~

~~**(A)** Armored.~~

~~An overall nonmetallic jacket impervious to moisture and corrosion-resistant shall be provided over the armor. The armor or metallic covering shall be a braided basket weave type consisting of wire laid closely together, flat and parallel, and forming a basket weave that shall firmly grip the cable. The wire shall be commercial bronze. The armor shall not be used as a current-carrying conductor.~~

~~**(B)** Unarmored.~~

~~An overall flame-retardant, nonmetallic material impervious to moisture and corrosion-resistant shall be provided over the cable core. A metallic sheath or armor as defined in 337.116 shall not be permitted either under or over the nonmetallic jacket. Metallic shield(s) shall be permitted over groups of conductors, under the outer jacket, or both.~~

~~**337.120** Marking.~~

~~Type P cable shall be marked in accordance with 310.8. Armored cable shall be marked as Type P-HL.~~

Additional Proposed Changes

File Name	Description	Approved
Type_P_-_Article_xXX_OG_Land_Rigs_-_rev-jc_8-30-18.docx		

Statement of Problem and Substantiation for Public Comment

Type P cables are unique cables that have flexible strands, higher ampacity rating than typical Chapter 3 wiring methods. This new article should not be in Chapter 3 and should be moved to either Chapter 5, 6 or 7. Please see my attached write-up since TerraView would not let me add the tables and complete mark-up

Related Item

- Type P cables used on oil land rigs

Submitter Information Verification

Submitter Full Name: James Conrad
Organization: RSCC Wire & Cable
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 30 16:32:30 EDT 2018
Committee: NEC-P06

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Article xxx
Cables used for Oil and Gas Drilling Land Rigs
Part 1. General

xxx.1 Scope.

This article covers the construction and installation of power, control and signal cables (Type P) in hazardous (classified) areas on Oil and Gas Well Drilling Land Rigs..

Informational Note: The Oil and Gas Well Drilling Land Rig Industry require quick and easy mobility when rigging up, rigging down, and transporting the drilling rig overland between drill sites. In addition, the drilling rigs and the equipment on them are subjected to significant movement, shaking, and vibration while drilling. Therefore, these conditions require special consideration with regards to the selection and installation of electrical cables

xxx.2 Definition.

Oil & Gas Well Drilling Land Rig. A collection of portable (not hand-portable) industrial equipment that are individually transported to a designated location (drill site), then positioned per a specific rig layout design and interconnected (rigged up) to implement a drilling program.

Type P Cable.
A factory assembly of one or more insulated, flexible, stranded, tinned-copper conductors, manufactured per IEEE-1580/UL 1309,

Part II. Installation

Information Note 1: See IEEE 45.8 Section 6 for additional information on cable installation.

xxx.3 Special Requirements for Particular Locations.

1) **Other Articles.** Wherever the requirements of other articles of this Code and Article xxx differ, the requirements of Article xxx shall apply to the wiring on land rigs.

2) Harardous Locations.

A) Class I Division 1 & Zone 1 Locations. Cables shall be listed as Type P with an overall metallic braid armor, an outer non-metallic jacket over the armor, and terminated with fittings suitable for the application.

Informational Note 2: Armored Type P cables with a non-metallic impervious sheath over the armor, have been used in hazardous areas on drilling rigs because of their enhanced durability,which provides crush, impact, and cut-through resistance, and is not prone to failure due to fatigue and cracking; properties that are very important in the drilling environment.

B) Class I Division 2 & Zone 2 Locations. Cables shall be listed as Type P and terminated with fittings suitablefor the application.

xxx.4 Grounding
When using Type P cable with a metallic basket-weave braided armor, the armor shall be electrically continuous throughout the entire length of the cable run and shall be effectively grounded using cable fittings listed for the application. However, the metallic basket-weave braided armor shall not be used as the equipment grounding path or conductor. Therefore, an appropriate

sized grounding conductor shall be included within both armored and unarmored Type P cable, or other adequate grounding means provided to comply with Article 250.

xxx.5 Installation.
Type P cable installed on or between portable (not hand-portable) oil & gas well drilling land rig utilization equipment shall be routed to minimize the risk of mechanical damage and shall comply with the requirements of xxx.5 (A)through (D).

(A) Bending Radius.
Bends in Type P cable shall be made such that the cable will not be damaged. The radius of the curve of the inner edge of any bend shall not be less than required in xxx.5(A)(1) and xxx.5(A)(2).

(1) Unarmored Cable.
(a) Four times the overall diameter for cables 25 mm (1 in) or less in diameter
(b) Six times the overall diameter for cables larger than 25 mm (1 in)

(2) Armored (Braided) Cable.
(a) Six times the overall diameter of the cable

(B) Securing and Supporting.
Type P cables shall be secured and supported in accordance with the manufacturer's installation instructions.

If cable supports are used, cables shall be individually secured to the supports at intervals to prevent excessive sag or strain on the cables so as not to damage the cable.

(C) Protection.
Cables shall be arranged to minimize the tripping hazard and shall be permitted to be covered with nonconductive matting. It shall be permitted to bury cables. The requirements of 300.5 shall not apply.

(**D) Electrical Connections**.
Type P cable have finely standed conductors therefore the connectors and terminals must be identified for the specific conductor class or classes.

xxx.6 Ampacity.
The allowable ampacity of Type P cable shall be determined in accordance with Tables xxx.6(A) through Table xxx.6(C) or under engineering supervision.

DRAFT

Table xxx.6(A) Ampacities for Type P Distribution, Control, and Signal Cables, 2000 Volts or Less, AC or DC, Copper Conductors, Single-banked (Single-Layered), Based on 45º C (113º F) Ambient Temperature.

			Maximum Conductor Insulation Temperature Ratings					
AWG or kcmil	mm²	Circular Mils	Single-conductor Cable		Two-conductor Cable		Three-conductor Cable	
			100º C (212º F)	110º C (230º F)	100º C (212º F)	110º C (230º F)	100º C (212º F)	110º C (230º F)
22	0.355	700	9	10	8	9	7	8
20	0.52	1020	12	13	10	11	9	10
18	0.82	1620	16	17	14	15	12	13
16	1.31	2580	23	25	19	20	16	17
14	2.08	4110	37	40	31	33	25	27
12	3.31	6530	45	48	40	43	31	33
10	5.26	10,380	58	62	49	52	41	44
8	8.37	16,510	72	77	64	69	52	56
7	10.55	20,820	84	88	78	82	65	67
6	13.30	26,240	96	103	85	91	70	75
5	16.77	33,090	109	117	101	108	82	88
4	21.15	41,740	128	137	110	118	92	99
3	26.66	52,620	146	156	132	141	108	116
2	33.62	66,630	169	181	149	160	122	131
1	44.21	83,690	194	208	174	186	143	153
1/0	53.50	105,600	227	243	199	213	164	176
2/0	67.44	137,100	262	281	242	259	188	201
3/0	85.02	167,800	300	281	265	284	218	234
4/0	107.20	211,600	351	378	307	329	252	270
250	126.70	250,000	389	409	344	360	282	295
262	133.10	262,600	407	436	358	383	294	315
313	158.60	313,100	455	487	391	419	321	344
350	177.30	350,000	485	508	421	441	344	361
373	189.30	373,700	516	553	442	473	361	387

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444	225.20	444,400	588	630	504	540	411	440
500	253.30	500,000	609	638	520	546	428	448
535	271.20	535,300	630	676	538	576	443	475
646	327.50	646,400	731	783	632	677	516	553
750	380.00	750,000	786	824	656	686	537	563
777	394.00	777,700	822	881	684	733	562	602
1000	506.70	1,000,000	939	988				
1111	563.10	1,111,000	1025	1098				
1250	633.30	1,250,000	1072	1128				
1500	760.00	1,500,000	1195	1254				
2000	1013.30	2,000,000	1400	1473				

Table xxx.6(B) Ampacities for Type P, Single-Conductor, Distribution Cables, 2000 Volts or Less, DC Only, Copper Conductors, Single-banked (Single-Layered), Based on 45° C (113° F) Ambient Temperature.

		Single-conductor Cable	
kcmil	**mm²**	**100° C (212° F)**	**110° C (230° F)**
750	380.0	802	859
1000	506.7	964	1033
1250	633.3	1126	1206
1500	760.0	1276	1367
2000	1013.0	1557	1636

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Table xxx.6(C) Ampacities Adjustment Factors and Equations for Tables xxx.6(A) and xxx.6(B)

1) Use the following factors to calculate ampacity for cables with more than 3 conductors.

Number of Conductors	Percent of Values for Three-conductor Cable as Adjusted for Ambient Temperature, if Necessary
4 through 6	80
7 through 9	70
10 through 20	50
21 through 30	45
31 through 40	40
41 through 60	35

2) The allowable ampacities are based on the conductor temperature rise in a given ambient. When selecting conductor sizes and insulation ratings, consideration shall be given to the following.

a) The actual conductor operating temperature shall be compatible with the connected equipment, especially at the connection points.

b) Conductor selection shall be permitted to be coordinated with circuit and system overcurrent and short-circuit protection to avoid cable damage during through-fault conditions.

3) Current-carrying capacity of four-conductor cables where one conductor is not a current-carrying phase conductor (e.g. neutral or grounding conductor) is the same as three-conductor cables.

4) If ambient temperatures differ from 45º C (113º F), cable ampacities shall be permitted to be multiplied by the following factors:

Ambient Temperature	30º C (86º F)	40º C (104º F)	50º C (122º F)	55º C (131º F)	60º C (140º F)	70º C (158º F)
100º C (212º F) Conductor Temperature	1.13	1.04	0.95	0.90	0.85	0.74
110º C (230º F) Conductor Temperature	1.11	1.04	0.96	0.92	0.88	0.78

5) The following equation from IEEE 835 shall be permitted to be used to calculate ampacity at an ambient temperature not listed in Note 4) above:

$$I' = \sqrt{\frac{T_c - T_a'}{T_c - T_a}} \times I$$

$T_c -$ *is maximum conductor temperature used in tables*
T_a *– is ambient temperature used in the tables*
T_a' *– is new ambient temperture*
$I -$ *is ampacity shown in tables for* T_c *and* T_a

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4) The ampacities in the tables are based on various maximum conductor temperatures. If the ampacity at a different maximum conductor is required, then the following equation from IEEE 835 shall be permitted to be used to calculate the ampacity:

$$I' = \sqrt{\left(\frac{T_c' - T_a - \Delta T_d'}{T_c - T_a - \Delta T_d}\right) \times \left(\frac{\tau_c + T_c}{\tau_c + T_c'}\right)} \times I$$

$T_c -$ is maximum conductor temperature used in tables
$T_a -$ is ambient temperature used in the tables
$\Delta T_d -$ is temperature rise due to dielectric loss
$I -$ is ampacity shown in tables for T_c, T_a, and ΔT_d
$T_c' -$ is new maximum conductor temperture
$\Delta T_d' -$ is new temperature rise due to dielectric loss
$\tau_c -$ is inferred temperature of zero electrical resistance (234.5 for copper conductors)

5) The current-carrying capacities are for cable installations with cables arranged in a single bank per hanger and are 85% of the calculated free air values. For those instances where cables are double banked, the current-carrying capacities shall be decreased by multiplying the value shown by 0.8.

6) For cables with maintained spacing of at least 1 cable diameter apart, the ampacities shall be permitted to be increased by dividing the values shown by 0.85.

7) Single-conductor cables configured in triplex or triangular configuration shall be permitted to be conservatively treated as three conductor cables when determining ampacity. For detailed capacity for triplex or triangular calculations in IEEE 835 shall be permitted to be used.

8) Cable runs where segments with different thermal conditions exist will require separate derating considerations. The lowest ampacity calculated for any 10 ft (3 m) section in the cable run shall determine the cable size.

9) Current ratings are for AC or DC. Exceptions are noted in Table xxx.6(B).

Informational Note3: The Oil and Gas Well Drilling Land Rig Industry has historically used IEEE-1580, Type P, cable to cable-up and interconnect the various machines and equipment that make up the drilling rig. These cables may also be listed as UL-1309 cables. The flexible and rugged IEEE-1580, Type P, cable is highly suitable for the oil and gas well drilling land rig application because of its ability to resist drilling muds that contain various chemicals, abrasives, and petroleum-based additives as well as its ability to resist damage from vibration, shaking, and movement that occurs during the drilling process, and the rigors of rig-up and rig-down. They are also highly suited because of their ability to perform in extreme cold weather conditions in that they can pass a -40° C cold bend test and a -35° C cold impact test. In addition to their flexibility and mechanical ruggedness as just described, the IEEE-1580, Type P, cable is rated 600/1000 volts or 2000 volts which makes it suitable for use on both DC and AC powered drilling rigs including rigs with VFD powered drilling machines, has a maximum conductor temperature rating of 110° C, has a flexible tinned-copper stranded conductor that resists oxidation, and passes an IEEE 1202 vertical cable tray flame test. In addition, the flexible tinned-copper conductors are available in sizes such as 444 Kcmil, 535 Kcmil, 646 Kcmil, and 777 Kcmil; which are sizes commonly used on the drilling rigs.

xxx.7 Listing Requirements.
Type P cables shall be listed to IEEE 1580/UL 1309

Informational Note: For further information on Type P cable see UL-1309, IEEE-1580, IEEE 45.8., API RP 14F, and API RP 14FZ

Part III. Construction Specifications

xxx.104 Conductors.

Conductors shall be flexible stranded tinned copper per Table 4.2 per UL 1309.

xxx.108 Equipment Grounding Conductor.
All equipmemt grounding conductors shall be insulated.

xxx.112 Insulation.

Insulated conductors in Type P cables shall be insulated with XLPO and comply with IEEE 1580 Table 14 and UL 1309 Table 5.2

xxx.116 Jacket.

The outer covering of both single conductor cables or multiconductor cable shall comply with IEEE 1580/1309. Cable jackets exposed to sunlight shall be sunlight resistant.

xxx.117 Armor (Opitional).

The armor or metallic covering shall be a braided basket weave type consisting of wire laid closely together, flat and parallel, and forming a basket weave that shall firmly grip the cable. The wire shall be commercial bronze. The armor shall not be used as a current-carrying conductor. An overall nonmetallic jacket impervious to moisture and corrosion-resistant shall be provided over the armor.

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Public Comment No. 2162-NFPA 70-2018 [Article 337]

Article 337 Type P

Part I. General

337.1 Scope.

This article covers the use, installation, and construction specifications for 600 volt Type P cable (armored and unarmored), for use in hazardous (classified) locations as permitted in this *Code* .

337.2 Definition.

The definition in this section shall apply within this article and throughout the *Code* .

Type P.

A factory assembly of two or more insulated flexible tinned copper conductors, with associated bare or covered grounding conductors, impervious sheath, braided metallic armored or unarmored cable. See Part III.

337.6 Listing Requirements.

Type P cables and associated fittings shall be listed.

Part II. Installation

337.10 Uses Permitted.

In industrial locations under engineering supervision where the conditions of maintenance and supervision ensure that only qualified persons service the installation, Type P cable shall be permitted for use in hazardous (classified) locations and to transition between a hazardous (classified) location and a non-hazardous (classified) location as follows:

(1) For services, feeders, and branch circuits

(2) For power, lighting, control, and signal circuits

(3) Indoors

(4) Outdoors where identified for such use

(5) Exposed or concealed

(6) For direct burial where identified for such use

(7) In cable tray where identified for such use

(8) In any raceway

(9) In wet locations

(10) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(11) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(12) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(13) The cable is secured at intervals not exceeding 1.4 m (4.5 ft).

(14) Equipment grounding for the utilization equipment is provided by a bare equipment grounding conductor within the cable.

Exception to (10): Where not subject to physical damage, Type P shall be permitted to transition between cable trays and between cable trays and utilization equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

337.12 Uses Not Permitted.

Type P cable shall not be installed or used where it will be exposed to physical damage.

337.24 Bending Radius.

Bends in Type P cable shall be made such that the cable will not be damaged. The radius of the curve of the inner edge of any bend shall not be less than required in 337.24(A) through (B).

(A) Unarmored Cable.

(1) Four times the overall diameter for cables 25 mm (1 in.) or less in diameter

(2) Five times the overall diameter for cables larger than 25 mm (1 in.) but not more than 50 mm (2 in.) in diameter

(3) Six times the overall diameter for cables larger than 50 mm (2 in.) in diameter

(B) Armored Cable.

(1) Ten times the external diameter of the metallic armor for cable not more than 19 mm ($^{3}/_{4}$ in.) in external diameter

(2) Twelve times the external diameter of the metallic armor for cable more than 19 mm ($^{3}/_{4}$ in.) in external diameter

337.30 Securing and Supporting.

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

(A) Securing.

Unless otherwise provided, cables shall be secured at intervals not exceeding 1.4 m (4.5 ft). Cables containing four or fewer conductors sized no larger than 10 AWG shall be secured within 300 mm (12 in.) of every box, cabinet, fitting, or other cable termination. In vertical installations, cables with ungrounded conductors 250 kcmil and larger shall be permitted to be secured at intervals not exceeding 3 m (10 ft.).

(B) Supporting.

Unless otherwise provided, cables shall be supported at intervals not exceeding 1.4 m (4.5 ft). Horizontal runs of Type P cable installed in wooden or metal framing members or similar supporting means shall be considered supported and secured where such support does not exceed 1.4 m (4.5 ft) intervals.

(C) Unsupported Cables.

Type P cable shall be permitted to be unsupported and unsecured where the cable complies with any of the following:

(1) Is fished between access points through concealed spaces in finished buildings or structures and supporting is impractical

(2) Is not more than 1.4 m (4.5 ft) in length from the last point of cable support to the point of connection to luminaires or other electrical equipment and the cable and point of connection are within an accessible ceiling

(3) Is in lengths not exceeding 900 mm (3 ft) from the last point where it is securely fastened and is used to connect equipment where flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation

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 cable shall be determined in accordance with 310.15 for 14 AWG and larger conductors and in accordance with Table 402.5 for 18 AWG and 16 AWG conductors. When installed in cable tray, the ampacities shall 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 the cable.~~

~~An uninsulated equipment grounding conductor shall be provided in cable marked Type P-HL.~~

~~337.112~~ ~~Insulation.~~

~~Insulated conductors shall comply with 337.112(A) or (B).~~

~~Insulated conductors in sizes 18 AWG and 16 AWG shall be Type FFHH-2 as listed in Table 402.3. Conductors larger than 16 AWG shall be Type XHHW or XHHW-2 as listed in Table 310.4(A).~~

~~337.116~~ ~~Sheath.~~

~~The sheath or outer covering shall comply with 337.116(A) or (B).~~

~~(A)~~ ~~Armored.~~

~~An overall nonmetallic jacket impervious to moisture and corrosion-resistant shall be provided over the armor. The armor or metallic covering shall be a braided basket weave type consisting of wire laid closely together, flat and parallel, and forming a basket weave that shall firmly grip the cable. The wire shall be commercial bronze. The armor shall not be used as a current-carrying conductor.~~

~~(B)~~ ~~Unarmored.~~

~~An overall flame-retardant, nonmetallic material impervious to moisture and corrosion-resistant shall be provided over the cable core. A metallic sheath or armor as defined in 337.116 shall not be permitted either under or over the nonmetallic jacket. Metallic shield(s) shall be permitted over groups of conductors, under the outer jacket, or both.~~

~~337.120~~ ~~Marking.~~

~~Type P cable shall be marked in accordance with 310.8. Armored cable shall be marked as Type P-HL.~~

Additional Proposed Changes

File Name	Description	Approved
Type_P_-_Article_XXX_OG_Land_Rigs_-_MJF_JC_8-30-18_.docx		

Statement of Problem and Substantiation for Public Comment

Article 337 needs to be deleted in its entirety. I appreciate the effort of Panel 6 to add Type P cable into the NEC, but unfortunately it was done so with the mindset that this product is being used in industrial building wire applications. This is not the case and Type P cable does not belong in chapter 3. While it is true that some Type P cables are used in building wire applications, they are dual rated as Type TC and in such cases are governed by Article 336. Type P cable is constructed and tested to the requirements in IEEE 1580 and installed in accordance with IEEE 45.8, API RP 14F, or API RP 14FZ. It is these applications that differentiate Type P cable from a typical Tray Cable. As discussed in IEEE-1242, when Type P cable is used in non-offshore applications, (such as land-based oil & gas well drilling rigs), it is used in very special applications where flexible stranded conductors are needed. It is also used in these applications where higher ampacities (up to 110°C) are needed and in VFD applications (typically 2 kV cables). These construction and performance criteria make this cable the preferred product in land-based oil & gas well drilling rigs, especially in Class I, Division 1 and Zone 1 hazardous (classified) locations where API RP 14F and API RP 14FZ allow armored and sheathed Type P cable to be used. Moving forward with publishing the NEC with this new Article will cause far more harm than good. Article 337, in its present form, does not accurately define Type P cables, their applications, or installation methods and, if allowed to stand, would create significant confusion and potential legal ramifications within the industry, as well as conflict with existing IEEE and API standards. In addition, the requirement for a bare equipment ground cable can cause a hazard with this type cable and its applications on the land rigs. I urge the panel to delete this Article and consider placing the Type P cable in a different chapter such as Chapter 6 using the document for Type P cable that I am submitting with this public input.

Related Item

• 4309-NFPA 70-2017

Submitter Information Verification

Submitter Full Name: Mark Fillip

Organization: National Oilwell Varco

Street Address:

City:

State:

Zip:

Submittal Date: Thu Aug 30 21:23:11 EDT 2018

Committee: NEC-P06

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Article xxx
Cables used for Oil and Gas Drilling Land Rigs
Part 1. General

xxx.1 Scope.

This article covers the construction and installation of power, control and signal cables (Type P) in hazardous (classified) areas on Oil and Gas Well Drilling Land Rigs..

Informational Note: The Oil and Gas Well Drilling Land Rig Industry require quick and easy mobility when rigging up, rigging down, and transporting the drilling rig overland between drill sites. In addition, the drilling rigs and the equipment on them are subjected to significant movement, shaking, and vibration while drilling. Therefore, these conditions require special consideration with regards to the selection and installation of electrical cables

xxx.2 Definition.

Oil & Gas Well Drilling Land Rig. A collection of portable (not hand-portable) industrial equipment that are individually transported to a designated location (drill site), then positioned per a specific rig layout design and interconnected (rigged up) to implement a drilling program.

Type P Cable.
A factory assembly of one or more insulated, flexible, stranded, tinned-copper conductors, manufactured per IEEE-1580/UL 1309,

Part II. Installation

Information Note 1: See IEEE 45.8 Section 6 for additional information on cable installation.

xxx.3 Special Requirements for Particular Locations.

1) **Other Articles.** Wherever the requirements of other articles of this Code and Article xxx differ, the requirements of Article xxx shall apply to the wiring on land rigs.

2) Harardous Locations.

A) Class I Division 1 & Zone 1 Locations. Cables shall be listed as Type P with an overall metallic braid armor, an outer non-metallic jacket over the armor, and terminated with fittings suitable for the application.

Informational Note 2: Armored Type P cables with a non-metallic impervious sheath over the armor, have been used in hazardous areas on drilling rigs because of their enhanced durability,which provides crush, impact, and cut-through resistance, and is not prone to failure due to fatigue and cracking; properties that are very important in the drilling environment.

B) Class I Division 2 & Zone 2 Locations. Cables shall be listed as Type P and terminated with fittings suitablefor the application.

xxx.4 Grounding
When using Type P cable with a metallic basket-weave braided armor, the armor shall be electrically continuous throughout the entire length of the cable run and shall be effectively grounded using cable fittings listed for the application. However, the metallic basket-weave braided armor shall not be used as the equipment grounding path or conductor. Therefore, an appropriate

sized grounding conductor shall be included within both armored and unarmored Type P cable, or other adequate grounding means provided to comply with Article 250.

xxx.5 Installation.
Type P cable installed on or between portable (not hand-portable) oil & gas well drilling land rig utilization equipment shall be routed to minimize the risk of mechanical damage and shall comply with the requirements of xxx.5 (A)through (D).

(A) Bending Radius.
Bends in Type P cable shall be made such that the cable will not be damaged. The radius of the curve of the inner edge of any bend shall not be less than required in xxx.5(A)(1) and xxx.5(A)(2).

(1) Unarmored Cable.
(a) Four times the overall diameter for cables 25 mm (1 in) or less in diameter
(b) Six times the overall diameter for cables larger than 25 mm (1 in)

(2) Armored (Braided) Cable.
(a) Six times the overall diameter of the cable

(B) Securing and Supporting.
Type P cables shall be secured and supported in accordance with the manufacturer's installation instructions.

If cable supports are used, cables shall be individually secured to the supports at intervals to prevent excessive sag or strain on the cables so as not to damage the cable.

(C) Protection.
Cables shall be arranged to minimize the tripping hazard and shall be permitted to be covered with nonconductive matting. It shall be permitted to bury cables. The requirements of 300.5 shall not apply.

(**D) Electrical Connections**.
Type P cable have finely standed conductors therefore the connectors and terminals must be identified for the specific conductor class or classes.

xxx.6 Ampacity.
The allowable ampacity of Type P cable shall be determined in accordance with Tables xxx.6(A) through Table xxx.6(C) or under engineering supervision.

Table xxx.6(A) Ampacities for Type P Distribution, Control, and Signal Cables, 2000 Volts or Less, AC or DC, Copper Conductors, Single-banked (Single-Layered), Based on 45º C (113º F) Ambient Temperature.

			Maximum Conductor Insulation Temperature Ratings					
AWG or kcmil	mm²	Circular Mils	Single-conductor Cable		Two-conductor Cable		Three-conductor Cable	
			100º C (212º F)	110º C (230º F)	100º C (212º F)	110º C (230º F)	100º C (212º F)	110º C (230º F)
22	0.355	700	9	10	8	9	7	8
20	0.52	1020	12	13	10	11	9	10
18	0.82	1620	16	17	14	15	12	13
16	1.31	2580	23	25	19	20	16	17
14	2.08	4110	37	40	31	33	25	27
12	3.31	6530	45	48	40	43	31	33
10	5.26	10,380	58	62	49	52	41	44
8	8.37	16,510	72	77	64	69	52	56
7	10.55	20,820	84	88	78	82	65	67
6	13.30	26,240	96	103	85	91	70	75
5	16.77	33,090	109	117	101	108	82	88
4	21.15	41,740	128	137	110	118	92	99
3	26.66	52,620	146	156	132	141	108	116
2	33.62	66,630	169	181	149	160	122	131
1	44.21	83,690	194	208	174	186	143	153
1/0	53.50	105,600	227	243	199	213	164	176
2/0	67.44	137,100	262	281	242	259	188	201
3/0	85.02	167,800	300	281	265	284	218	234
4/0	107.20	211,600	351	378	307	329	252	270
250	126.70	250,000	389	409	344	360	282	295
262	133.10	262,600	407	436	358	383	294	315
313	158.60	313,100	455	487	391	419	321	344
350	177.30	350,000	485	508	421	441	344	361
373	189.30	373,700	516	553	442	473	361	387

444	225.20	444,400	588	630	504	540	411	440
500	253.30	500,000	609	638	520	546	428	448
535	271.20	535,300	630	676	538	576	443	475
646	327.50	646,400	731	783	632	677	516	553
750	380.00	750,000	786	824	656	686	537	563
777	394.00	777,700	822	881	684	733	562	602
1000	506.70	1,000,000	939	988				
1111	563.10	1,111,000	1025	1098				
1250	633.30	1,250,000	1072	1128				
1500	760.00	1,500,000	1195	1254				
2000	1013.30	2,000,000	1400	1473				

Table xxx.6(B) Ampacities for Type P, Single-Conductor, Distribution Cables, 2000 Volts or Less, DC Only, Copper Conductors, Single-banked (Single-Layered), Based on 45° C (113° F) Ambient Temperature.

		Single-conductor Cable	
kcmil	**mm²**	**100° C (212° F)**	**110° C (230° F)**
750	380.0	802	859
1000	506.7	964	1033
1250	633.3	1126	1206
1500	760.0	1276	1367
2000	1013.0	1557	1636

Table xxx.6(C) Ampacities Adjustment Factors and Equations for Tables xxx.6(A) and xxx.6(B)

1) Use the following factors to calculate ampacity for cables with more than 3 conductors.

Number of Conductors	Percent of Values for Three-conductor Cable as Adjusted for Ambient Temperature, if Necessary
4 through 6	80
7 through 9	70
10 through 20	50
21 through 30	45
31 through 40	40
41 through 60	35

2) The allowable ampacities are based on the conductor temperature rise in a given ambient. When selecting conductor sizes and insulation ratings, consideration shall be given to the following.

a) The actual conductor operating temperature shall be compatible with the connected equipment, especially at the connection points.

b) Conductor selection shall be permitted to be coordinated with circuit and system overcurrent and short-circuit protection to avoid cable damage during through-fault conditions.

3) Current-carrying capacity of four-conductor cables where one conductor is not a current-carrying phase conductor (e.g. neutral or grounding conductor) is the same as three-conductor cables.

4) If ambient temperatures differ from 45º C (113º F), cable ampacities shall be permitted to be multiplied by the following factors:

Ambient Temperature	30º C (86º F)	40º C (104º F)	50º C (122º F)	55º C (131º F)	60º C (140º F)	70º C (158º F)
100º C (212º F) Conductor Temperature	1.13	1.04	0.95	0.90	0.85	0.74
110º C (230º F) Conductor Temperature	1.11	1.04	0.96	0.92	0.88	0.78

5) The following equation from IEEE 835 shall be permitted to be used to calculate ampacity at an ambient temperature not listed in Note 4) above:

$$I' = \sqrt{\frac{T_c - T_a'}{T_c - T_a}} \times I$$

$T_c -$ *is maximum conductor temperature used in tables*
T_a *– is ambient temperature used in the tables*
T_a' *– is new ambient temperture*
$I -$ *is ampacity shown in tables for* T_c *and* T_a

4) The ampacities in the tables are based on various maximum conductor temperatures. If the ampacity at a different maximum conductor is required, then the following equation from IEEE 835 shall be permitted to be used to calculate the ampacity:

$$I' = \sqrt{\left(\frac{T_c' - T_a - \Delta T_d'}{T_c - T_a - \Delta T_d}\right) \times \left(\frac{\tau_c + T_c}{\tau_c + T_c'}\right)} \times I$$

$T_c -$ is maximum conductor temperature used in tables
$T_a -$ is ambient temperature used in the tables
$\Delta T_d -$ is temperature rise due to dielectric loss
$I -$ is ampacity shown in tables for T_c, T_a, and ΔT_d
$T_c' -$ is new maximum conductor temperture
$\Delta T_d' -$ is new temperature rise due to dielectric loss
$\tau_c -$ is inferred temperature of zero electrical resistance (234.5 for copper conductors)

5) The current-carrying capacities are for cable installations with cables arranged in a single bank per hanger and are 85% of the calculated free air values. For those instances where cables are double banked, the current-carrying capacities shall be decreased by multiplying the value shown by 0.8.

6) For cables with maintained spacing of at least 1 cable diameter apart, the ampacities shall be permitted to be increased by dividing the values shown by 0.85.

7) Single-conductor cables configured in triplex or triangular configuration shall be permitted to be conservatively treated as three conductor cables when determining ampacity. For detailed capacity for triplex or triangular calculations in IEEE 835 shall be permitted to be used.

8) Cable runs where segments with different thermal conditions exist will require separate derating considerations. The lowest ampacity calculated for any 10 ft (3 m) section in the cable run shall determine the cable size.

9) Current ratings are for AC or DC. Exceptions are noted in Table xxx.6(B).

Informational Note3: The Oil and Gas Well Drilling Land Rig Industry has historically used IEEE-1580, Type P, cable to cable-up and interconnect the various machines and equipment that make up the drilling rig. These cables may also be listed as UL-1309 cables. The flexible and rugged IEEE-1580, Type P, cable is highly suitable for the oil and gas well drilling land rig application because of its ability to resist drilling muds that contain various chemicals, abrasives, and petroleum-based additives as well as its ability to resist damage from vibration, shaking, and movement that occurs during the drilling process, and the rigors of rig-up and rig-down. They are also highly suited because of their ability to perform in extreme cold weather conditions in that they can pass a -40° C cold bend test and a -35° C cold impact test. In addition to their flexibility and mechanical ruggedness as just described, the IEEE-1580, Type P, cable is rated 600/1000 volts or 2000 volts which makes it suitable for use on both DC and AC powered drilling rigs including rigs with VFD powered drilling machines, has a maximum conductor temperature rating of 110° C, has a flexible tinned-copper stranded conductor that resists oxidation, and passes an IEEE 1202 vertical cable tray flame test. In addition, the flexible tinned-copper conductors are available in sizes such as 444 Kcmil, 535 Kcmil, 646 Kcmil, and 777 Kcmil; which are sizes commonly used on the drilling rigs.

xxx.7 Listing Requirements.
Type P cables shall be listed to IEEE 1580/UL 1309

Informational Note: For further information on Type P cable see UL-1309, IEEE-1580, IEEE 45.8., API RP 14F, and API RP 14FZ

Part III. Construction Specifications

xxx.104 Conductors.

Conductors shall be flexible stranded tinned copper per Table 4.2 per UL 1309.

xxx.108 Equipment Grounding Conductor.
All equipmemt grounding conductors shall be insulated.

xxx.112 Insulation.

Insulated conductors in Type P cables shall be insulated with XLPO and comply with IEEE 1580 Table 14 and UL 1309 Table 5.2

xxx.116 Jacket.

The outer covering of both single conductor cables or multiconductor cable shall comply with IEEE 1580/1309. Cable jackets exposed to sunlight shall be sunlight resistant.

xxx.117 Armor (Opitional).

The armor or metallic covering shall be a braided basket weave type consisting of wire laid closely together, flat and parallel, and forming a basket weave that shall firmly grip the cable. The wire shall be commercial bronze. The armor shall not be used as a current-carrying conductor. An overall nonmetallic jacket impervious to moisture and corrosion-resistant shall be provided over the armor.

Public Comment No. 322-NFPA 70-2018 [Article 337]

Article 337 Type P

Part I. General

337.1 Scope.

This article covers the use, installation, and construction specifications for 600 volt Type P cable (armored and unarmored), for use in hazardous (classified) locations as permitted in this *Code* .

337.2 Definition.

The definition in this section shall apply within this article and throughout the *Code* .

Type P.

A factory assembly of two or more insulated flexible tinned copper conductors, with associated bare or covered grounding conductors, impervious sheath, braided metallic armored or unarmored cable. See Part III.

337.6 Listing Requirements.

Type P cables and associated fittings shall be listed.

Part II. Installation

337.10 Uses Permitted.

In industrial locations under engineering supervision where the conditions of maintenance and supervision ensure that only qualified persons service the installation, Type P cable shall be permitted for use in hazardous (classified) locations and to transition between a hazardous (classified) location and a non-hazardous (classified) location as follows:

(1) For services, feeders, and branch circuits

(2) For power, lighting, control, and signal circuits

(3) Indoors

(4) Outdoors where identified for such use

(5) Exposed or concealed

(6) For direct burial where identified for such use

(7) In cable tray where identified for such use

(8) In any raceway

(9) In wet locations

(10) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(11) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(12) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(13) The cable is secured at intervals not exceeding 1.4 m (4.5 ft).

(14) Equipment grounding for the utilization equipment is provided by a bare equipment grounding conductor within the cable.

Exception to (10): Where not subject to physical damage, Type P shall be permitted to transition between cable trays and between cable trays and utilization equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

337.12 Uses Not Permitted.

Type P cable shall not be installed or used where it will be exposed to physical damage.

337.24 Bending Radius.

Bends in Type P cable shall be made such that the cable will not be damaged. The radius of the curve of the inner edge of any bend shall not be less than required in 337.24(A) through (B).

(A) Unarmored Cable.

(1) Four times the overall diameter for cables 25 mm (1 in.) or less in diameter

(2) Five times the overall diameter for cables larger than 25 mm (1 in.) but not more than 50 mm (2 in.) in diameter

(3) Six times the overall diameter for cables larger than 50 mm (2 in.) in diameter

(B) Armored Cable.

(1) Ten times the external diameter of the metallic armor for cable not more than 19 mm ($^{3}/_{4}$ in.) in external diameter

(2) Twelve times the external diameter of the metallic armor for cable more than 19 mm ($^{3}/_{4}$ in.) in external diameter

337.30 Securing and Supporting.

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

(A) Securing.

Unless otherwise provided, cables shall be secured at intervals not exceeding 1.4 m (4.5 ft). Cables containing four or fewer conductors sized no larger than 10 AWG shall be secured within 300 mm (12 in.) of every box, cabinet, fitting, or other cable termination. In vertical installations, cables with ungrounded conductors 250 kcmil and larger shall be permitted to be secured at intervals not exceeding 3 m (10 ft.).

(B) Supporting.

Unless otherwise provided, cables shall be supported at intervals not exceeding 1.4 m (4.5 ft). Horizontal runs of Type P cable installed in wooden or metal framing members or similar supporting means shall be considered supported and secured where such support does not exceed 1.4 m (4.5 ft) intervals.

(C) Unsupported Cables.

Type P cable shall be permitted to be unsupported and unsecured where the cable complies with any of the following:

(1) Is fished between access points through concealed spaces in finished buildings or structures and supporting is impractical

(2) Is not more than 1.4 m (4.5 ft) in length from the last point of cable support to the point of connection to luminaires or other electrical equipment and the cable and point of connection are within an accessible ceiling

(3) Is in lengths not exceeding 900 mm (3 ft) from the last point where it is securely fastened and is used to connect equipment where flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation

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 cable shall be determined in accordance with 310.15 for 14 AWG and larger conductors and in accordance with Table 402.5 for 18 AWG and 16 AWG conductors. When installed in cable tray, the ampacities shall 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 the cable.~~

~~An uninsulated equipment grounding conductor shall be provided in cable marked Type P-HL.~~

~~**337.112** Insulation.~~

~~Insulated conductors shall comply with 337.112(A) or (B).~~

~~Insulated conductors in sizes 18 AWG and 16 AWG shall be Type FFHH-2 as listed in Table 402.3. Conductors larger than 16 AWG shall be Type XHHW or XHHW-2 as listed in Table 310.4(A).~~

~~**337.116** Sheath.~~

~~The sheath or outer covering shall comply with 337.116(A) or (B).~~

~~**(A)** Armored.~~

~~An overall nonmetallic jacket impervious to moisture and corrosion-resistant shall be provided over the armor. The armor or metallic covering shall be a braided basket weave type consisting of wire laid closely together, flat and parallel, and forming a basket weave that shall firmly grip the cable. The wire shall be commercial bronze. The armor shall not be used as a current-carrying conductor.~~

~~**(B)** Unarmored.~~

~~An overall flame-retardant, nonmetallic material impervious to moisture and corrosion-resistant shall be provided over the cable core. A metallic sheath or armor as defined in 337.116 shall not be permitted either under or over the nonmetallic jacket. Metallic shield(s) shall be permitted over groups of conductors, under the outer jacket, or both.~~

~~**337.120** Marking.~~

~~Type P cable shall be marked in accordance with 310.8. Armored cable shall be marked as Type P-HL.~~

Delete the whole article

Statement of Problem and Substantiation for Public Comment

Article 337 needs to be deleted in its entirety. We appreciate the effort of Panel 6 to add Type P cable into the NEC but, unfortunately, it was done so with the mindset that this product is being used in industrial building wire applications. This is not the case and Type P cable does not belong in chapter 3. While it is true that some Type P cables are used in building wire applications, they are dual rated as Type TC and in such cases are governed by Article 336. Type P cable is constructed and tested to the requirements in IEEE 1580 and installed in accordance with IEEE 45.8, API RP 14F, or API RP 14FZ. It is these applications that differentiate Type P cable from a typical Tray Cable. As discussed in IEEE-1242, when Type P cable is used in non-offshore applications, such as land-based oil & gas well drilling rigs, it is used in very special applications where flexible stranded conductors are needed. It is also used in these applications where higher ampacities (up to 110°C) are needed and in VFD applications (typically 2 kV cables). These construction and performance criteria make this cable the preferred product in land-based oil & gas well drilling rigs, especially in Class I, Division 1 and Zone 1 hazardous (classified) locations where API RP 14F and API RP 14FZ allow armored and sheathed Type P cable to be used. An IEEE Guide for installation of cables in hazardous (classified) locations on land-based oil & gas well drilling rigs is currently being written and will be published within 2 years. We believe that this guide will serve as the supporting documentation for Type P cable to be added to the NEC in the appropriate chapter, be it chapter 4 or chapter 6. Moving forward with publishing the NEC with this new Article will cause far more harm than good. Article 337, in its present form, does not accurately define Type P cables, their applications, or installation methods and, if allowed to stand, would create significant confusion and potential legal ramifications within the industry, as well as conflict with existing IEEE and API standards. We urge the panel to delete this Article.

Related Item

• Conflict with current industry practices • Conflic with current industry practices

Submitter Information Verification

Submitter Full Name: Altin Dabulla
Organization: RSCC Wire & Cable
Street Address:

City:

State:

Zip:

Submittal Date: Tue Jul 31 11:52:17 EDT 2018

Committee: NEC-P06

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Public Comment No. 326-NFPA 70-2018 [Article 337]

Article 337 Type P

Part I. General

337.1 Scope.

This article covers the use, installation, and construction specifications for 600 volt Type P cable (armored and unarmored), for use in hazardous (classified) locations as permitted in this *Code* .

337.2 Definition.

The definition in this section shall apply within this article and throughout the *Code* .

Type P.

A factory assembly of two or more insulated flexible tinned copper conductors, with associated bare or covered grounding conductors, impervious sheath, braided metallic armored or unarmored cable. See Part III.

337.6 Listing Requirements.

Type P cables and associated fittings shall be listed.

Part II. Installation

337.10 Uses Permitted.

In industrial locations under engineering supervision where the conditions of maintenance and supervision ensure that only qualified persons service the installation, Type P cable shall be permitted for use in hazardous (classified) locations and to transition between a hazardous (classified) location and a non-hazardous (classified) location as follows:

(1) For services, feeders, and branch circuits

(2) For power, lighting, control, and signal circuits

(3) Indoors

(4) Outdoors where identified for such use

(5) Exposed or concealed

(6) For direct burial where identified for such use

(7) In cable tray where identified for such use

(8) In any raceway

(9) In wet locations

(10) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(11) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(12) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(13) The cable is secured at intervals not exceeding 1.4 m (4.5 ft).

(14) Equipment grounding for the utilization equipment is provided by a bare equipment grounding conductor within the cable.

Exception to (10): Where not subject to physical damage, Type P shall be permitted to transition between cable trays and between cable trays and utilization equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

337.12 Uses Not Permitted.

Type P cable shall not be installed or used where it will be exposed to physical damage.

337.24 Bending Radius.

Bends in Type P cable shall be made such that the cable will not be damaged. The radius of the curve of the inner edge of any bend shall not be less than required in 337.24(A) through (B).

(A) Unarmored Cable.

(1) Four times the overall diameter for cables 25 mm (1 in.) or less in diameter

(2) Five times the overall diameter for cables larger than 25 mm (1 in.) but not more than 50 mm (2 in.) in diameter

(3) Six times the overall diameter for cables larger than 50 mm (2 in.) in diameter

(B) Armored Cable.

(1) Ten times the external diameter of the metallic armor for cable not more than 19 mm ($^{3}/_{4}$ in.) in external diameter

(2) Twelve times the external diameter of the metallic armor for cable more than 19 mm ($^{3}/_{4}$ in.) in external diameter

337.30 Securing and Supporting.

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

(A) Securing.

Unless otherwise provided, cables shall be secured at intervals not exceeding 1.4 m (4.5 ft). Cables containing four or fewer conductors sized no larger than 10 AWG shall be secured within 300 mm (12 in.) of every box, cabinet, fitting, or other cable termination. In vertical installations, cables with ungrounded conductors 250 kcmil and larger shall be permitted to be secured at intervals not exceeding 3 m (10 ft.).

(B) Supporting.

Unless otherwise provided, cables shall be supported at intervals not exceeding 1.4 m (4.5 ft). Horizontal runs of Type P cable installed in wooden or metal framing members or similar supporting means shall be considered supported and secured where such support does not exceed 1.4 m (4.5 ft) intervals.

(C) Unsupported Cables.

Type P cable shall be permitted to be unsupported and unsecured where the cable complies with any of the following:

(1) Is fished between access points through concealed spaces in finished buildings or structures and supporting is impractical

(2) Is not more than 1.4 m (4.5 ft) in length from the last point of cable support to the point of connection to luminaires or other electrical equipment and the cable and point of connection are within an accessible ceiling

(3) Is in lengths not exceeding 900 mm (3 ft) from the last point where it is securely fastened and is used to connect equipment where flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation

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 cable shall be determined in accordance with 310.15 for 14 AWG and larger conductors and in accordance with Table 402.5 for 18 AWG and 16 AWG conductors. When installed in cable tray, the ampacities shall 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 the cable.~~

~~An uninsulated equipment grounding conductor shall be provided in cable marked Type P-HL.~~

~~**337.112** Insulation.~~

~~Insulated conductors shall comply with 337.112(A) or (B).~~

~~Insulated conductors in sizes 18 AWG and 16 AWG shall be Type FFHH-2 as listed in Table 402.3. Conductors larger than 16 AWG shall be Type XHHW or XHHW-2 as listed in Table 310.4(A).~~

~~**337.116** Sheath.~~

~~The sheath or outer covering shall comply with 337.116(A) or (B).~~

~~**(A)** Armored.~~

~~An overall nonmetallic jacket impervious to moisture and corrosion-resistant shall be provided over the armor. The armor or metallic covering shall be a braided basket weave type consisting of wire laid closely together, flat and parallel, and forming a basket weave that shall firmly grip the cable. The wire shall be commercial bronze. The armor shall not be used as a current-carrying conductor.~~

~~**(B)** Unarmored.~~

~~An overall flame-retardant, nonmetallic material impervious to moisture and corrosion-resistant shall be provided over the cable core. A metallic sheath or armor as defined in 337.116 shall not be permitted either under or over the nonmetallic jacket. Metallic shield(s) shall be permitted over groups of conductors, under the outer jacket, or both.~~

~~**337.120** Marking.~~

~~Type P cable shall be marked in accordance with 310.8. Armored cable shall be marked as Type P-HL.~~

Statement of Problem and Substantiation for Public Comment

Article 337 needs to be deleted in its entirety. We appreciate the effort of Panel 6 to add Type P cable into the NEC but, unfortunately, it was done so with the mindset that this product is being used in industrial building wire applications. This is not the case and Type P cable does not belong in chapter 3. While it is true that some Type P cables are used in building wire applications, they are dual rated as Type TC and in such cases are governed by Article 336. Type P cable is constructed and tested to the requirements in IEEE 1580 and installed in accordance with IEEE 45.8, API RP 14F, or API RP 14FZ. It is these applications that differentiate Type P cable from a typical Tray Cable. As discussed in IEEE-1242, when Type P cable is used in non-offshore applications, (such as land-based oil & gas well drilling rigs), it is used in very special applications where flexible stranded conductors are needed. It is also used in these applications where higher ampacities (up to 110°C) are needed and in VFD applications (typically 2 kV cables). These construction and performance criteria make this cable the preferred product in land-based oil & gas well drilling rigs, especially in Class I, Division 1 and Zone 1 hazardous (classified) locations where API RP 14F and API RP 14FZ allow armored and sheathed Type P cable to be used. An IEEE Guide for installation of cables in hazardous (classified) locations on land-based oil & gas well drilling rigs is currently being written and will be published within 2 years. We believe that this guide will serve as the supporting documentation for Type P cable to be added to the NEC in the appropriate chapter, be it chapter 4 or chapter 6. Moving forward with publishing the NEC with this new Article will cause far more harm than good. Article 337, in its present form, does not accurately define Type P cables, their applications, or installation methods and, if allowed to stand, would create significant confusion and potential legal ramifications within the industry, as well as conflict with existing IEEE and API standards. We urge the panel to delete this Article.

Related Public Comments for This Document

Related Comment	Relationship
Public Comment No. 328-NFPA 70-2018 [Sections 501.10(A), 501.10(B)]	
Public Comment No. 330-NFPA 70-2018 [Section No. 505.15]	
Public Comment No. 368-NFPA 70-2018 [Section No. 501.10(A)(2)]	

Related Item

- None

Submitter Information Verification

Submitter Full Name: Philip Laudicina
Organization: Nexans AmerCable
Street Address:
City:
State:
Zip:
Submittal Date: Wed Aug 01 10:06:42 EDT 2018
Committee: NEC-P06

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Public Comment No. 1445-NFPA 70-2018 [Section No. 337.1]

337.1 Scope.

This article covers the use, installation, and construction specifications for 600 volt Type P cable (armored and unarmored), for use in hazardous (classified) locations and as permitted in this *Code*.

Statement of Problem and Substantiation for Public Comment

The use of Type P cable should not be restricted to Hazardous (Classified) locations. This very robust cable type has several other potential uses within the NEC such as for boat yards, and other "wet" locations. The addition of the word "and" would allow the use of this cable type where applicable and allowed in other parts of the NEC.

Related Item

- PI 3683

Submitter Information Verification

Submitter Full Name: Mark Goodman
Organization: Mark Goodman Electrical Consul
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 28 16:09:26 EDT 2018
Committee: NEC-P06

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Public Comment No. 1969-NFPA 70-2018 [Section No. 337.1]

337.1 Scope.

This article covers the use, installation, and construction specifications for 600 volt Type P cable (armored and unarmored), for use in hazardous (classified) locations ~~as permitted~~ and general purpose (unclassified) as permitted in this *Code*.

Statement of Problem and Substantiation for Public Comment

the use of type P cable should not be restricted to Hazardous Locations only and should be allowed to be used in other applications as well

Related Item

• FR 8036

Submitter Information Verification

Submitter Full Name: Dave Burns
Organization: Shell P&T: Innovation/R&D
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 30 13:16:20 EDT 2018
Committee: NEC-P06

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Public Comment No. 2043-NFPA 70-2018 [Definition: Type P.]

Type P.

A factory assembly ~~of two~~ of one or more insulated flexible tinned copper conductors, with associated bare or covered grounding conductors, impervious sheath, braided metallic armored or unarmored cable. See Part III.

Statement of Problem and Substantiation for Public Comment

In 337.31 single conductor cable of this type construction is described.

Related Item

• FR 8036

Submitter Information Verification

Submitter Full Name: Dave Burns
Organization: Shell P&T: Innovation/R&D
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 30 15:32:38 EDT 2018
Committee: NEC-P06

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Public Comment No. 1448-NFPA 70-2018 [Section No. 337.10]

337.10 Uses Permitted.

(A) In industrial locations under engineering supervision where the conditions of maintenance and supervision ensure that only qualified persons service the installation, Type P cable shall be permitted for use in hazardous (classified) locations and to transition between a hazardous (classified) location and a non-hazardous (classified) location as follows:

(1) For services, feeders, and branch circuits

(2) For power, lighting, control, and signal circuits

(3) Indoors

(4) Outdoors where identified for such use

(5) Exposed or concealed

(6) For direct burial where identified for such use

(7) In cable tray where identified for such use

(8) In any raceway

(9) In wet locations

(10) Between a cable tray and the utilization equipment or device(s), provided all of the following apply:

(11) The cable is installed in industrial establishments where the conditions of maintenance and supervision ensure that only qualified persons service the installation.

(12) The cable is continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

(13) The cable is secured at intervals not exceeding 1.4 m (4.5 ft).

(14) Equipment grounding for the utilization equipment is provided by a bare equipment grounding conductor within the cable.

Exception to (10): Where not subject to physical damage, Type P shall be permitted to transition between cable trays and between cable trays and utilization equipment or devices for a distance not to exceed 1.8 m (6 ft) without continuous support. The cable shall be mechanically supported where exiting the cable tray to ensure that the minimum bending radius is not exceeded.

(B) In Unclassified locations permitted by other sections of the Code.

Statement of Problem and Substantiation for Public Comment

The permitted use of Type P cable should not be limited to Hazardous (Classified) locations as this robust cable type could be utilized in other applications within the Code such as in boatyards or other wet locations..

Related Item

• New Section Article 337

Submitter Information Verification

Submitter Full Name: Mark Goodman
Organization: Mark Goodman Electrical Consul
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 28 16:33:48 EDT 2018

Committee: NEC-P06

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Public Comment No. 1460-NFPA 70-2018 [Section No. 337.108]

337.108 Equipment Grounding Conductor.

An equipment grounding conductor complying with 250.122 shall be provided within the cable.

~~An uninsulated equipment grounding conductor shall be provided in cable marked Type P-HL.~~

Statement of Problem and Substantiation for Public Comment

The grounding conductor meeting 250.122 should be required. The provision for an uninsulated grounding conductor was not included in the original Public Input nor is there justification for the grounding conductor to be uninsulated. There also appears to be some question as to whether cable Type P-HL actually exists. The more generic term referencing 250.122 should be used instead of Type P-HL.

Related Item

- New section Article 337

Submitter Information Verification

Submitter Full Name: Mark Goodman
Organization: Mark Goodman Electrical Consul
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 28 17:19:02 EDT 2018
Committee: NEC-P06

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Public Comment No. 2049-NFPA 70-2018 [Section No. 337.108]

337.108 Equipment Grounding Conductor.

An equipment grounding conductor complying with 250.122 shall be provided within the cable.~~An uninsulated equipment grounding conductor shall be provided in cable marked Type P-HL.~~ When using Type P cable with a metallic basket-weave braided armor, the armor shall be electrically continuous throughout the entire length of the cable run and shall be effectively grounded using cable fittings listed for the application. However, the metallic basket-weave braided armor shall not be used as the equipment grounding path or conductor.

Statement of Problem and Substantiation for Public Comment

The type P-HL cable definition nor standard exists and should be deleted from this section. Additional text was added for the case of armored Type P cable to required the basket weave sheath to be continuously grounded but not to be used as a grounding conductor or equipment grounding means.

Related Item

- FR 8036

Submitter Information Verification

Submitter Full Name: Dave Burns
Organization: Shell P&T: Innovation/R&D
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 30 15:39:08 EDT 2018
Committee: NEC-P06

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Public Comment No. 1457-NFPA 70-2018 [Section No. 337.112]

337.112 Insulation.

Insulated conductors

~~shall comply with 337.112(A) or (B).Insulated conductors~~

in sizes 18 AWG and 16 AWG shall be Type FFHH-2 as listed in Table 402.3. Conductors larger than 16 AWG shall be Type XHHW or XHHW-2 as listed in Table 310.4(A).

Statement of Problem and Substantiation for Public Comment

Delete the references to sections (A) and (B) that do not exist.

Related Item

- New Section Article 337

Submitter Information Verification

Submitter Full Name: Mark Goodman
Organization: Mark Goodman Electrical Consul
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 28 17:11:15 EDT 2018
Committee: NEC-P06

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Public Comment No. 2056-NFPA 70-2018 [Section No. 337.112]

337.112 Insulation.

Insulated conductors ~~shall comply with 337.112(A) or (B).Insulated conductors~~ in sizes 18 AWG and 16 AWG shall be Type FFHH-2 as listed in Table 402.3. Conductors larger than 16 AWG shall be Type XHHW or XHHW-2 as listed in Table 310.4(A).

Statement of Problem and Substantiation for Public Comment

There is no (A) or (B) parts in this section

Related Item

- FR 8036

Submitter Information Verification

Submitter Full Name: Dave Burns
Organization: Shell P&T: Innovation/R&D
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 30 15:47:04 EDT 2018
Committee: NEC-P06

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Public Comment No. 1481-NFPA 70-2018 [Section No. 337.120]

337.120 Marking.

Type P cable shall be marked in accordance with 310.8.- ~~Armored cable shall be marked as Type P-HL.~~

Statement of Problem and Substantiation for Public Comment

The referenced "Type P-HL" does not exist and shouldn't be a referenced requirement for marking.

Related Item

- New article 337

Submitter Information Verification

Submitter Full Name: Mark Goodman
Organization: Mark Goodman Electrical Consul
Street Address:
City:
State:
Zip:
Submittal Date: Tue Aug 28 19:25:24 EDT 2018
Committee: NEC-P06

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Public Comment No. 2058-NFPA 70-2018 [Section No. 337.120]

337.120 Marking.

Type P cable shall be marked in accordance with 310.8.- ~~Armored cable shall be marked as Type P-HL.~~

Statement of Problem and Substantiation for Public Comment

There is no definition of Type P-HL nor standard for that cable designation. Should be deleted from this section.

Related Item

- FR 8036

Submitter Information Verification

Submitter Full Name: Dave Burns
Organization: Shell P&T: Innovation/R&D
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 30 15:50:00 EDT 2018
Committee: NEC-P06

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Public Comment No. 407-NFPA 70-2018 [Section No. 338.10]

338.10 Uses Permitted.

(A) Service-Entrance Conductors.

Service-entrance cable shall be permitted to be ~~used as service-entrance conductors~~ used for underground service conductors, including direct burial in the earth and shall be installed in accordance with 230.6 , 230.7 , and Parts II, III, and IV of Article 230.

(B) Branch Circuits or Feeders.

(1) Grounded Conductor Insulated.

Type SE service-entrance cables shall be permitted in wiring systems where all of the circuit conductors of the cable are of the thermoset or thermoplastic type.

(2) Use of Uninsulated Conductor.

Type SE service-entrance cable shall be permitted for use where the insulated conductors are used for circuit wiring and the uninsulated conductor is used only for equipment grounding purposes.

Exception: In existing installations, uninsulated conductors shall be permitted as a grounded conductor in accordance with 250.32 and 250.140, where the uninsulated grounded conductor of the cable originates in service equipment, and with 225.30 through 225.40.

(3) Temperature Limitations.

Type SE service-entrance cable used to supply appliances shall not be subject to conductor temperatures in excess of the temperature specified for the type of insulation involved.

(4) Installation Methods for Branch Circuits and Feeders.

Informational Note No. 1: See 310.15 for temperature limitation of conductors.

Informational Note No. 2: For the installation of main power feeder conductors in dwelling units refer to 310.12.

(a) *Interior Installations.*

(2) In addition to the provisions of this article, Type SE service-entrance cable used for interior wiring shall comply with the installation requirements of Part II of Article 334, excluding 334.80 .

(3) Where more than two Type SE cables containing two or more current-carrying conductors in each cable are installed in contact with thermal insulations, caulk, or sealing foam without maintaining spacing between cables, the ampacity of each conductor shall be adjusted in accordance with Table 310.15(C)(1).

(4) For Type SE cable with ungrounded conductor sizes 10 AWG and smaller, where installed in contact with thermal insulation, the ampacity shall be in accordance with 60°C (140°F) conductor temperature rating. The maximum conductor temperature rating shall be permitted to be used for ampacity adjustment and correction purposes, if the final ampacity does not exceed that for a 60°C (140°F) rated conductor.

(e) *Exterior Installations.*

(6) In addition to the provisions of this article, service-entrance cable used for feeders or branch circuits, where installed as exterior wiring, shall be installed in accordance with Part I of Article 225. The cable shall be supported in accordance with 334.30 .

(7) Type USE cable

~~installed as~~

(1) shall be permitted to be used for underground feeder and branch

~~circuit cable shall comply~~

(1) circuits when in compliance with Part II of Article 340.

Exception: Single-conductor Type USE and multi-rated USE conductors shall not be subject to the ampacity limitations of Part II of Article 340.

Statement of Problem and Substantiation for Public Comment

Uses permitted should allow USE cable to installed underground and direct buried for services, feeders, and branch circuits; see 326.10, 328.10, 330.10, 336.10, and 340.10.

Related Item

• PI-1029

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Sun Aug 05 08:28:45 EDT 2018
Committee: NEC-P06

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Public Comment No. 1914-NFPA 70-2018 [Section No. 338.10(B)(4)]

(4) Installation Methods for Branch Circuits and Feeders.

Informational Note No. 1: See 310.~~15~~ 14(A)(3) for temperature limitation of conductors.

Informational Note No. 2: For the installation of main power feeder conductors in dwelling units refer to 310.12.

(a) *Interior Installations.*

(2) In addition to the provisions of this article, Type SE service-entrance cable used for interior wiring shall comply with the installation requirements of Part II of Article 334 , excluding 334.80 .

(3) Where more than two Type SE cables containing two or more current-carrying conductors in each cable are installed in contact with thermal

~~insulations~~

(1) insulation , caulk, or sealing foam without maintaining spacing between cables, the ampacity of each conductor shall be adjusted in accordance with Table 310.15(C)(1).

(2) For Type SE cable with ungrounded conductor sizes 10 AWG and smaller, where installed in contact with thermal insulation, the ampacity shall be in accordance with 60°C (140°F) conductor temperature rating. The maximum conductor temperature rating shall be permitted to be used for ampacity adjustment and correction purposes, if the final ampacity does not exceed that for a 60°C (140°F) rated conductor.

(d) *Exterior Installations.*

(5) In addition to the provisions of this article, service-entrance cable used for feeders or branch circuits, where installed as exterior wiring, shall be installed in accordance with Part I of Article 225 . The cable shall be supported in accordance with 334.30 .

(6) Type USE cable installed as underground feeder and branch circuit cable shall comply with Part II of Article 340 .

Exception: Single-conductor Type USE and multi-rated USE conductors shall not be subject to the ampacity limitations of Part II of Article 340.

Statement of Problem and Substantiation for Public Comment

It looks like Terra underlined almost everything, but the only changes were correcting a reference in IN 1 and deleting an "s" at the end of insulation.

Related Item

• FR 7955

Submitter Information Verification

Submitter Full Name: Christel Hunter
Organization: Cerro Wire
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 30 12:14:37 EDT 2018

Committee: NEC-P06

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Public Comment No. 917-NFPA 70-2018 [Section No. 338.100]

338.100 Construction.

(A)

Cabled assemblies of multiple single-conductor Type USE conductors shall be permitted for direct burial. All conductors shall be insulated.

Informational Note: The term “cabled” refers to a manufacturing process of twisting single conductors together and may also be referred to as “plexed.”

(B)

Type SE or USE cable with an overall covering containing two or more conductors shall be permitted to have one conductor uninsulated.

Additional Proposed Changes

File Name	Description	Approved
CN_5.pdf	70_CN 5	

Statement of Problem and Substantiation for Public Comment

NOTE: This Public Comment appeared as CC Note No. 5 in the First Draft Report on First Revision No. 7950.

The Correlating Committee directs the panel to reconsider the text and add titles for first level subdivisions in compliance with the NEC® Style Manual.

This action will be considered as a public comment.

Related Item

- FR 7950

Submitter Information Verification

Submitter Full Name: CC on NEC-AAC
Organization: NEC Correlating Committee
Street Address:
City:
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Zip:
Submittal Date: Mon Aug 20 16:01:13 EDT 2018
Committee: NEC-P06

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Correlating Committee Note No. 5-NFPA 70-2018 [Section No. 338.100]

Submitter Information Verification

Submitter Full Name: Sarah Caldwell
Committee:
Submittal Date: Wed May 09 11:38:34 EDT 2018

Committee Statement and Meeting Notes

Committee Statement: The Correlating Committee directs the panel to reconsider the text and add titles for first level subdivisions in compliance with the NEC® Style Manual. This action will be considered as a public comment.

First Revision No. 7950-NFPA 70-2018 [Section No. 338.100]

Ballot Results

This item has passed ballot

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

Affirmative All

Brunssen, James E.
Dressman, Kevin L.
Hickman, Palmer L.
Hittinger, David L.
Holub, Richard A.
Johnston, Michael J.
Kovacik, John R.
Manche, Alan
McDaniel, Roger D.
Pierce, James F.
Saporita, Vincent J.
Williams, David A.

Public Comment No. 1918-NFPA 70-2018 [Section No. 338.100(A)]

(A)– Assemblies.

Cabled assemblies of multiple single-conductor Type USE conductors shall be permitted for direct burial. All conductors shall be insulated.

Informational Note: The term “cabled” refers to a manufacturing process of twisting single conductors together and may also be referred to as “plexed.”

Statement of Problem and Substantiation for Public Comment

Added a heading for the list item.

Related Item

• CN 5

Submitter Information Verification

Submitter Full Name: Christel Hunter
Organization: Cerro Wire
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 30 12:20:38 EDT 2018
Committee: NEC-P06

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Public Comment No. 1922-NFPA 70-2018 [Section No. 338.100(B)]

(B)– Uninsulated Conductor.

Type SE or USE cable with an overall covering containing two or more conductors shall be permitted to have one conductor uninsulated.

Statement of Problem and Substantiation for Public Comment

Added a heading.

Related Item

• CN 5

Submitter Information Verification

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Organization: Cerro Wire
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 30 12:22:39 EDT 2018
Committee: NEC-P06

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Public Comment No. 2042-NFPA 70-2018 [Section No. 400.4]

400.4 Types.

Flexible cords and flexible cables shall conform to the description in Table 400.4. The use of flexible cords and flexible cables other than those in Table 400.4 shall require permission by the authority having jurisdiction.

Table 400.4 Flexible Cords and Flexible Cables

Trade Name																

Electric vehicle cable	EV 5,6	1000	18–500	2 or more plus equipment grounding conductor(s), plus optional hybrid data, signal communica-tions, and optical fiber cables	Thermoset with optional nylon	18–15	0.76(0.51)	30(20)	Optional	Oil-resistant thermoset	Electric vehicle charging
						14–10	1.14(0.76)	45(30)			
						8–2	1.52(1.14)	60(45)			
						1–4/0	2.03(1.52)	80(60)			
						250–500	2.41(1.90)	95(75)			
	EVJ 5,6	300	18–12			18–12	0.76(0.51)	30(20)			
EVE 5,6	1000	18–500	2 or more plus equipment grounding conductor(s), plus optional hybrid data, signal communica-tions, and optical fiber cables		Thermoplastic elastomer with optional nylon	18–15	0.76(0.51)	30(20)		Oil-resistant thermo-plastic elastomer	Extra-hard usage
						14–10	1.14(0.76)	45(30)			
						8–2	1.52(1.14)	60(45)			
						1–4/0	2.03(1.52)	80(60)			
						250– 500	2.41(1.90)	95(75)			
EVJE 5,6		300	18–12		18–12	0.76(0.51)	30(20)	Hard usage			
EVT 5,6	1000	18–500	2 or more plus equipment grounding conductor(s), plus optional hybrid data, signal communica-tions, and optical fiber cables		Thermoplastic with optional nylon	18–15	0.76(0.51)	30(20)	Optional	Oil-resistant thermo-plastic	Electric vehicle charging	Wet Locatio
						14–10	1.14(0.76)	45(30)			
						8–2	1.52(1.14)	60(45)			
						1–4/0	2.03(1.52)	80(60)			
						250– 500	2.41(1.90)	95(75)			

	EVJT 5,6	300	18–12	18–12	0.76(0.51)	30(20)	Hard usage	
Portable power cable	G	2000	12–500	2–6 plus equipment grounding conductor(s)	Thermoset	12–21–4/0 250–500	1.522.032.41	608095
Oil-resistant thermoset				Portable and extra-hard usage				
G-GC 7	2000	12–500	3–6 plus equipment grounding conductors and 1 ground check conductor		Thermoset	12–21–4/0 250–500	1.522.032.41	608095
Oil-resistant thermoset								

Heater cord	HPD	300	18–12	2, 3, or 4	Thermoset	18–1615–12	0.380.76	1530	None	Cotton or rayon	Portable heaters	[
Parallel heater cord	HPN 8	300	18–12	2 or 3	Oil-resistant thermoset	18–16151412	1.141.522.41	456095	None	Oil-resistant thermoset	Portable	[
Thermoset jacketed heater cords	HSJ	300	18–12	2, 3, or 4	Thermoset	18–1615–12	0.761.14	3045	None	Cotton and thermoset	Portable or portable heater	[
	HSJW	300	18–12									
Thermoset												
Cotton and thermoset												
HSJO	Damp loca- tions											
	300											18–12
Cotton and oil-resistant thermoset												
Damp and wet locations												
HSJOW 9	300	18–12										
Damp locations												
HSJOO	300	18–12										
Oil-resistant thermoset												
HSJOOW 9	300	18–12										
Damp and wet locations												

-

Non-integral parallel cords	NISP-1	300	20–18	2 or 3	Thermoset	20–18	0.38	15
	NISP-2	300	18–16			18–16	0.76	30
	NISPE-1 [8]	300	20–18		Thermoplastic elastomer	20–18	0.38	15
	NISPE-2 [8]	300	18–16			18–16	0.76	30
	NISPT-1 [8]	300	20–18		Thermoplastic	20–18	0.38	15
	NISPT-2 [8]	300	18–16			18–16	0.76	30
Twisted portable cord	PD	300600	18–1614–10	2 or more	Thermoset or thermoplastic	18–1615–10	0.761.14	304
Portable power cable	PPE [7]	2000	12–500	1–6 plus optional equipment grounding conductor(s)	Thermoplastic elastomer	12–21–4/0250–500	1.522.032.41	6080

-

	Oil-resistant thermo-plastic elastomer	Portable, extra-hard usage									
Hard service cord	S [7]	600	18–2	2 or more	Thermoset	18–1514–108–2	0.761.141.52	304560	None	Thermoset	Per or por
Flexible stage and lighting power cable	SC [7,10]	600	8–250	1 or more	Thermoset	8–21–4/0250	1.522.032.41	608095			

-

Thermoset	Portable, extra-hard usage

-

SCE [7,10]	600

- -

Thermoplastic elastomer

- - - - -

Thermo- plastic elastomer

-

SCT [7,10]	600

- -

Thermoplastic

- - - -

Thermo- plastic

-

Hard service cord	SE [7]	600	18–2	2 or more	Thermoplastic elastomer	18–1514–98–2	0.761.141.52	304560	None	Thermo-plastic elastomer	Pendant or portable

-

SEW [7, 9]	600

- - - - - - - - - -

													Damp and wet locations
-													
SEO [7]													600
- - - - - - -													
													Oil-resistant thermo- plastic elastomer
-													
													Damp locations
- -													
	SEOW [7,9]												600
- - - - - - - - - -													
													Damp and wet locations
-													
SEOO [7]													600
- -													
													Oil-resistant thermoplastic elastomer
- - - - - -													
													Damp locations
- -													
	SEOOW [7,9]												600
- - - - - - - -													
													Damp and wet locations
-													
Junior hard service cord	SJ	300	18–10	2–6	Thermoset	18–1110	0.761.14	3045	None	Thermoset	Pendant or portable	Damp loca- tions	Hard usage
-													
	SJE												300
- -													
													Thermoplastic elastomer
- - - -													
													Thermo- plastic elastomer
- - - -													
	SJEW [9]												300
- - - - - - - - - -													
													Damp and wet locations
-													
SJEO													300
- - - - - - -													
													Oil-resistant thermo- plastic elastomer
-													
													Damp locations
- -													

SJEOW 9 300

Damp and wet locations

SJEOO 300

Oil-resistant thermoplastic elastomer

Damp locations

SJEOOW 9 300

Damp and wet locations

SJO 300

Thermoset

Oil-resistant thermoset

Damp locations

SJOW 9 300

Damp and wet locations

SJOO 300

Oil-resistant thermoset

Damp locations

SJOOW 9 300

Damp and wet locations

SJT 300

Thermoplastic

Thermo- plastic

Damp locations

SJTW [9]												300	
Damp and wet locations													
SJTO												300	
			18–1210				0.761.14					3045	
Oil-resistant thermo- lastic													
Damp locations													
SJTOW [9]												300	
Damp and wet locations													
SJTOO												300	
Oil-resistant thermoplastic													
Damp locations													
SJTOOW [9]												300	
Damp and wet locations													
Hard service cord	SO [7]	600	18–2	2 or more	Thermoset	18–15	0.76	30	None	Oil-resistant thermoset	Pendant or portable	Damp loca-tions	Extra-hard usage
SOW [7,9]												600	
Damp and wet locations													
SOO [7]												600	
Oil-resistant thermoset							14–98–2					1.141.52	4560
Damp locations													
SOOW [7,9]												600	
Damp and wet locations													

All thermoset parallel cord	SP-1	300	20–18	2 or 3	Thermoset	20–18	0.76	30	None	None	Pendant or portable	Damp loca-tions	Not hard usage
SP-2	300	18–16	18-16	1.14	45	SP-3	300	18–10	18–1615–141210	1.522.032.412.80	608095110	Refrigera-tors, room air condi-tioners, and as permitted in 422.16(B)	
All elastomer (thermo-plastic) parallel cord	SPE-1 8	300	20-18	2 or 3	Thermoplastic elastomer	20–18	0.76	30	None	None	Pendant or portable	Damp loca-tions	Not hard usage
SPE-2 8	300	18–16	18–16	1.14	45	SPE-3 8	300	18–10	18–1615–141210	1.522.032.412.80	608095110	Refrigera- tors, room air condi- tioners, and as permitted in 422.16(B)	
All thermoplastic parallel cord	SPT-1	300	20–18	2 or 3	Thermoplastic	20–18	0.76	30	None	None	Pendant or portable	Damp loca-tions	Not hard usage
SPT-1W 9	300	2	Damp and wet locations	SPT-2	300	18–16	2 or 3	18–16	1.14	45	Damp locations		

SPT-2W [9]									300		
-											
				2							
- - - -											
				Damp and wet locations							
- -											
	SPT-3	300	18–10	2 or 3	18–1615–141210	1.522.032.412.80	608095110	Refrig-erators, room air condi-tioners, and as permitted in 422.16(B)	Damp loca-tions	Not hard usage	
Range, dryer cable	SRD	300	10–4	3 or 4	Thermoset	10–4	1.14	45	None	Thermoset	Pc
-											
SRDE		300	10–4	3 or 4	Thermoplastic elastomer						
- - - -											
	None	Thermo- plastic elastomer									
- - -											
SRDT		300	10–4	3 or 4	Thermoplastic						
- - -											
	None	Thermo- plastic									
- - -											
Hard service cord	ST [7]	600	18–2	2 or more	Thermoplastic	18–1514–98–2	0.761.141.52	304560	None	Thermo-plastic	Pendant or portable	D lo ti
-											
STW [7,9]									600		
- - - - - - - - -											
								Damp and wet locations			
- -											
STO [7]									600		
- - - - - - -											
								Oil-resistant thermo- lastic			
- -											
Damp locations											
-											
STOW [7, 9]									600		
- - - - - - - - - -											
								Damp and wet locations			
-											
STOO [7]									600		
- -											

Oil-resistant thermoplastic

Damp locations

STOOW [7]												600	
Damp and wet locations													
Vacuum cleaner cord	SV	300	18–16	2 or 3	Thermoset	18–16	0.38	15	None	Thermoset	Pendant or portable	Damp loca-tions	Not hard usage
SVE												300	
Thermoplastic elastomer													
Thermo- plastic elastomer													
SVEO												300	
Oil-resistant thermo- plastic elastomer													
SVEOO												300	
Oil-resistant thermoplastic elastomer													
SVO												300	
Thermoset													
Oil-resistant thermoset													
SVOO												300	
Oil-resistant thermoset													
Oil-resistant thermoset													
SVT												300	
Thermoplastic													
Thermoplastic													

SVTO						300	
Thermoplastic							
Oil-resistant thermo- plastic							
SVTOO						300	
Oil-resistant thermoplastic							
Parallel tinsel cord	TPT [11]	300	27	2	Thermoplastic	27	0.76
Jacketed tinsel cord	TST [11]	300	27	2	Thermoplastic	27	0.38
Portable power cable	W [7]	2000	12–500501–1000	1–61	Thermoset	12–21–4/0250–500501–1000	1.522.032.412.8
Oil-resistant thermoset					Portable, extra-hard usage		

Notes:

All types listed in Table 400.4 shall have individual conductors twisted together, except for Types HPN, SP-1, SP-2, SP-3, SPE-1, SPE-2, SPE-3, SPT-1, SPT-2, SPT-3, SPT-1W, SPT-2W, TPT, NISP-1, NISP-2, NISPT-1, NISPT-2, NISPE-1, NISPE-2, and three-conductor parallel versions of SRD, SRDE, and SRDT.

The individual conductors of all cords, except those of heat-resistant cords, shall have a thermoset or thermoplastic insulation, except that the equipment grounding conductor, where used, shall be in accordance with 400.23(B).

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

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

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

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

[4]Elevator cables in sizes ~~20 AWG~~ 26 AWG through 14 AWG are rated 300 volts, and sizes 10 AWG through 2 AWG are rated 600 volts. 12 AWG is rated 300 volts with a 0.76 mm (30 mil) insulation thickness and 600 volts with a 1.14 mm (45 mil) insulation thickness.

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

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

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

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

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

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

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

Statement of Problem and Substantiation for Public Comment

Reduce the minimum gague allowed in elevator cables from 20 to 26 to allow for Ethernet cables to be included in elevator traveling cables. Requirements for Ethernet communications to elevator cars are becoming commonplace. In addition Ethernet in elevator travel cables is needed in order to provide the bandwidth needed to comply with the two-way video requirements specified in the IBC-2018 and soon to be released ASME A17.1-2019

Related Item

• FR 7917

Submitter Information Verification

Submitter Full Name: Jeffrey Blain
Organization: Schindler Elevator Corporation
Affiliation: National Elevator Industry Inc. (NEII)
Street Address:
City:
State:
Zip:
Submittal Date: Thu Aug 30 15:31:56 EDT 2018
Committee: NEC-P06

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Public Comment No. 29-NFPA 70-2018 [Section No. 400.12]

400.12 Uses Not Permitted.

Unless specifically permitted in 400.10, flexible cords, flexible cables, cord sets, and power supply cords shall not be used for the following:

(1) As a substitute for the fixed wiring of a structure

(2) Where run through holes in walls, structural ceilings, suspended ceilings, dropped ceilings, or floors

Exception to (2): Designed and engineered openings are not considered holes: for example in support structures, racks and modular panel systems.

(3) Where run through doorways, windows, or similar openings

(4) Where attached to building surfaces

Exception to (4): Flexible cord and flexible cable shall be permitted to be attached to building surfaces in accordance with 368.56(B) and 590.4.

(5) Where concealed by walls, floors, or ceilings or located above suspended or dropped ceilings

Exception to (5): Flexible cord and flexible cable shall be permitted if contained within an enclosure for use in other spaces used for environmental air as permitted by 300.22(C)(3).

Exception to (5): Raised access floors are not considered concealed.

(6) Where installed in raceways, except as otherwise permitted in this *Code*. Raceways through engineered openings are allowed.

(7) Where subject to physical damage

Informational Note: For proper application see UL 817, *Cord Sets and Power-Supply Cords*, and UL 62, *Flexible Cords and Cables*.

Additional Proposed Changes

File Name	Description	Approved
404ecm17fig1.jpg	Example image	

Statement of Problem and Substantiation for Public Comment

Holes refers to where someone punches a hole through a wall, shoves a cord through a ceiling or floor. The intent is to prevent unprofessional installations as well as prevent the substitution as fixed wiring of a structure.

In more complicated facilities, the interpretation of holes, walls, floors and ceilings can get blurred. Larger facilities may be designed to have continuous air space between levels without having finished floors. Also, sometimes floors are removed to install a support structure for the equipment. If the support structure has space or designed openings, these should not be considered holes. Also, just because the support structure is level with the floor does not mean this is a "floor".

For example, see the attached image; a piece of equipment sitting on the floor with the cord plugging in below the floor. Raised access floors are not considered concealed, but technically, this can be viewed as the cord passing from the equipment through a hole in the floor below it. If you remove a tile to allow the cord to pass through, is this considered a "hole"? If there is a support structure, is this considered a hole?

Also, related to the above instance, there should be clarification that raised access floors are not considered concealed. It has been interrupted this way by experienced individuals like Mike Holt in EC&M, it is general accepted practice in data centers and can be seen in manufacture offerings for servers and power products.

For the raceway allowance (50 feet), in facilities with multiple levels, existing openings in structures and permit-wise the same air space, the raceway should be allowed to run between levels. In this case, the openings in the

structure is not considered a finished floor. Also, in the case of facilities that have walls that are fabricated of modular removable panels (for example to control air flow), larger openings without doors should not be considered a "hole".

Related Item

•

Submitter Information Verification

Submitter Full Name: Evan Zaker
Organization: Intel Corporation
Street Address:
City:
State:
Zip:
Submittal Date: Tue Jun 26 12:22:38 EDT 2018
Committee: NEC-P06

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Public Comment No. 391-NFPA 70-2018 [Section No. 400.12]

400.12 Uses Not Permitted.

Unless specifically permitted in 400.10, flexible cords, flexible cables, cord sets, and power supply cords shall not be used for the following:

(1) As a substitute for the fixed wiring of a structure

(2) Where run through holes in walls, structural ceilings, suspended ceilings, dropped ceilings, or floors

(3) Where run through doorways, windows, or similar openings

(4) Where attached to building surfaces

Exception to (4): Flexible cord and flexible cable shall be permitted to be attached to building surfaces in accordance with 368.56(B) and 590.4.

(5) Where concealed by walls, floors, or ceilings or located above suspended or dropped ceilings

Exception to (5): Flexible ~~cord and flexible cable shall~~ cords, flexible cables, and power supply cords shall be permitted if contained within an enclosure for use in other spaces used for environmental air as permitted by 300.22(C)(3).

(6) Where installed in raceways, except as otherwise permitted in this *Code*

(7) Where subject to physical damage

Informational Note: For proper application see UL 817, *Cord Sets and Power-Supply Cords*, and UL 62, *Flexible Cords and Cables*.

Statement of Problem and Substantiation for Public Comment

Slight edit to include power supply cord in the exception, since that is more times than not, the most common item to use the exception.

Related Item

• FR-7907

Submitter Information Verification

Submitter Full Name: Mike Holt
Organization: Mike Holt Enterprises Inc
Street Address:
City:
State:
Zip:
Submittal Date: Sat Aug 04 16:37:07 EDT 2018
Committee: NEC-P06

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