Evaluation of Electrical Conductors in Thermal Insulation: Literature Review, Gap Analysis & Development of a Research Plan

Background
NFPA 70, The National Electrical Code\textsuperscript{®} (NEC\textsuperscript{®}), has provided for the practical safeguarding of persons and property from hazards arising from the use of electricity since its origin in 1897. Article 310 of the 2023 edition contains requirements for conductors for general wiring rated 2000 volts and less. Section 310.3 specifies the minimum size of conductors for voltage ratings up to and including 2000 volts to be 14 American Wire Gauge (AWG) copper or 12 AWG aluminum or copper-clad aluminum, unless otherwise permitted elsewhere in the Code. This section also specifies conductor material to be of copper, aluminum, or copper-clad aluminum, unless otherwise specified. For copper-clad aluminum conductors, the copper is required to be 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 is required to be made of an AA-8000 series electrical grade aluminum alloy conductor material. Copper-clad aluminum conductor material is required to be listed.

Ampacity is defined by the NEC\textsuperscript{®} as "the maximum current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating". Section 310.14 provides the ampacity selection and overall performance requirements for conductors rated 0 volts to 2000 volts. The general temperature limitation requirement for insulated conductors contained in Section 310.14 (A)(3) states:

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

Additional information on the overall objective of Section 310.14 (A)(3) is provided in the Informational Notes that follow the requirements which state:

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

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

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

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

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

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

Many of the prescriptive installation requirements contained in Article 310 are focused on achieving compliance with Section 310.14(A)(3). During the two most recent revision cycles of NFPA 70, proposed changes to add new conductor sizes have not achieved the necessary consensus of the Code-Making Panel (technical committee). These proposed changes have sought to add conductor sizes 16 AWG copper and 14 AWG copper-clad aluminum with their associated ampacities to Section 310.3(A) and to two of the most frequently used ampacity tables in the NEC, Tables 310.16 and 310.17. Because the current product certification standards for the most widely used wiring methods do not contain testing requirements for thermal insulation impact, concerns have been raised that thermal insulation required by modern building and energy codes can adversely impact the performance of electrical conductor insulation. While the current discussion in the NEC® development process is focused on two specific conductor sizes, the technical committee needs the requisite information to make an objective assessment on whether the minimum level of safety can be achieved by adding new conductor sizes and materials to the Code. The guiding principle for this assessment is means by which the technical body can determine if the objective of 310.14(A)(3) is met. There is a need to provide a methodology by which any conductor can be assessed to meet the general requirement provided above.

Additionally, Table 310.16 provides the allowable ampacities of insulated conductors under specific installation conditions. To ascertain if a problem exists or could exist with small branch circuit conductors, research is needed on
the performance of 16 AWG copper and 14 AWG copper-clad aluminum along with presently identified small conductors in 240.4(D)(2) through (D)(8).

Research Goal
The overall goal of this project is to determine the minimum level of safety and develop an assessment method for small branch circuit wiring installed in thermal insulation envelopes required by current building and energy codes.

This phase of the project includes a literature review, gap analysis and development of a research plan to address the knowledge gaps which describes any additional modeling and/or testing needed.

Project Sponsors

Project Tasks
This research project will involve the following tasks:

Task 1: Literature Review
Conduct a literature review on the impact of thermal building insulation on small branch circuit conductors. This review should include history of the existing requirements, relevant fire data, test methods and standards, and research conducted on this topic. This review should also include a peer review of all the protocols and results from the testing performed for the 2020 and 2023 NEC® revision cycles.
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**Task 2: Identify Knowledge Gaps**

Based on the information found in Task 1, identify the knowledge gaps related to the performance of small branch circuit conductors in thermal building insulation. This should include the performance of existing small conductors in Section 240.4(D)(2) through (D)(8) and proposed conductor sizes 16 AWG copper and 14 AWG copper-clad aluminum. Develop an interim report for review by the Panel.

**Task 3: Develop a Research Plan**

Develop a research plan to address the knowledge gaps that describe any additional modeling and/or testing needed to determine the minimum level of safety for small branch circuit wiring. This research plan will include the following elements:

- A methodology for which any conductor can be assessed to meet the general requirement of Article 310.14(A)(3) of the 2023 NEC®.
- Performance criteria to determine the allowable ampacities starting with the insulation temperature ratings provided in the Article 310 ampacity tables in the 2023 edition of the NEC® for representative wiring methods installed in thermal insulation.
- Identification of the impact of thermal insulation envelopes required by current building and energy codes on small branch circuit conductors in Section 240.D(2) through (D)(8) and proposed conductor sizes 16 AWG copper and 14 AWG copper-clad aluminum.

**Deliverables**

- Interim Report
- Draft final report
- Final Report
- A presentation to the relevant NEC panels and a presentation to an appropriate industry conference/venue.
Evaluation of Electrical Conductors in Thermal Insulation: Literature Review, Gap Analysis & Development of a Research Plan

Schedule and Implementation
This 5-month research project will be conducted under the auspices of the Fire Protection Research Foundation and will be conducted in accordance with the “Research Foundation Policies for the Conduct of Research Projects”. The project will be guided by a Project Technical Panel who will provide input to the project, recommend contractor selection, review periodic reports of progress and research results, and review the final project report.

About the Fire Protection Research Foundation
The Fire Protection Research Foundation plans, manages, and communicates research on a broad range of fire safety issues in collaboration with scientists and laboratories around the world. The Foundation is an affiliate of NFPA.

About the National Fire Protection Association (NFPA)
Founded in 1896, NFPA is a global, nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. The association delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy; and by partnering with others who share an interest in furthering the NFPA mission. All NFPA codes and standards can be viewed online for free. NFPA’s membership totals more than 65,000 individuals around the world.

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