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Aluminum Wiring

Aluminum wire may be used as a substitute for copper wire in branch wiring circuits in residential, commercial, and industrial properties. Concerns were raised in the mid-1970s that structures that were wired with aluminum wire manufactured prior to 1972, so-called “old technology” wire, had a significantly increased risk of fire from faulty electrical connections over structures that were wired with post-1972 “new technology” wire or copper wire. This report provides background information on the problem and describes the measures that are commonly used to reduce fire risk in properties wired with aluminum wire. It also discusses requirements for new installations of aluminum wire in branch circuits required by NFPA 70, *National Electrical Code*, published by the National Fire Protection Association (NFPA). This report does not address large diameter aluminum conductors, such as those used for high-tension utility wires, service entrance cables, and feeder cables within buildings.

Aluminum has been recognized as an electrical conductor. Most large-diameter transmission and distribution cables, service entrance cables, and feeder cables are made from aluminum due to the conductivity-to-weight ratio advantage of aluminum over copper.

In the mid-1960s, contractors began to use small diameter, solid core, aluminum wire for 15 to 20 ampere (A) branch wiring circuits in residential, commercial, and industrial properties, instead of copper wire. Between 1965 and 1971, an estimated 1.5 to 2 million single-family homes, mobile homes, and multiple-family dwellings were completely wired with aluminum, along with an unknown additional number of properties that were partially wired with aluminum wire as a result of renovations, alterations, or additions.

Several fires occurred in properties wired with so-called “old technology” aluminum

wire that was manufactured prior to 1972.

These fires were attributed to faulty connections. Aluminum has different metallurgical and mechanical properties than copper. Unless strict workmanship practices were followed, there was potential for the generation of excessive heat at splices and connections, which could result in fire if combustible materials were close by. A connection could also fail, which could lead to arcing.

Changes in wiring system design and installation methods largely addressed the problems associated with aluminum wire, and aluminum wire is still permitted for use today. These changes did not affect existing properties, which were typically “grandfathered” in by local electrical codes. Such properties are considered to pose significantly higher fire risk from failed electrical connections than properties wired with either “new technology” aluminum wiring systems or copper wire.

These risks are increasing as the wiring systems age and new technologies place increasing demand on electrical distribution systems.

This report provides background information on the problems associated with “old technology” aluminum branch wiring systems and describes the measures that are commonly used to reduce fire risk in properties wired with this wire. This report does not address large-diameter aluminum conductors, such as those used for high-tension utility wires, service entrance cables, and feeder cables within buildings. Such conductors pose lesser risk than the small-diameter conductor used in branch circuits.

Scope of the Problem

A branch wiring circuit is the wiring circuit from the last overcurrent device in an electrical system to the outlets, such as receptacles, lighting outlets, or the terminals of electrical equipment wired directly into a circuit. There may also be splices or additional devices within the circuit, such as electrical switches. The rating of the circuit will vary depending on the expected use of the circuit; for example, wiring circuits for general lighting loads are typically rated at 15 A, while circuits for small appliance loads are rated at 20 A.

The concerns with aluminum wiring are generally limited to branch wiring circuits rated 20 A or less, where pre-1972, solid core, “old technology” aluminum wire was used as the electrical conductor. Such wire was typically #8, #10, #12, and #14 AWG (American Wire Gauge).

A research project commissioned by the U.S. Consumer Product Safety Commission (CPSC) in the mid-1970s found that residences

wired with such wire were significantly more likely to have one or more electrical connections reach “fire hazard conditions” than houses wired with aluminum wire manufactured after 1972, so-called “new technology” aluminum wire, or copper. Such conditions were defined to occur when receptacle cover plate mounting screws reached 149°C (300°F), sparks were emitted from the receptacle, or materials around the receptacle were charred.

In non-technical terms, the source of the problems with the early wire could be described as follows:

- Aluminum has a higher resistivity than copper, so aluminum wires must be larger than copper wires and may not fit easily around screw terminals on devices sized for copper wire making the quality of the connection suspect.
- Aluminum wire is “softer” than copper and can be squeezed flat by too much pressure or reduced in area by excessive pulling. This results in a phenomenon called “creep” (i.e., the slow deformation of the material away from the stressor), which leads to increased resistance, overheating, and eventual failure.
- Aluminum wire is more brittle than copper, so it will break if nicked or scratched (e.g., by wire strippers) or if bent or twisted too frequently.
- Aluminum expands more than copper when heated so that binding screws can be loosened by alternative heating and cooling. This action causes minor arcing thereby increased heating, which causes more loosening and more arcing.
- Aluminum oxidizes when exposed to air and develops a surface coating with high electrical resistance. The buildup of this material at the connection interface creates high resistance to electrical flow that can result in heat buildup at the interface.

- Aluminum corrodes readily when connected to dissimilar metals in the presence of moisture, salt films, or chemicals from the breakdown of electrical insulation, such as vinyl chloride. This can cause mechanical failure of the joint or electrical failure of the connection.

Changes made to the aluminum alloys used for wire production after 1972 addressed many of the mechanical problems related to the aluminum wire, and changes made to the design of electrical devices and installation methods increased the reliability of electrical connections. Oxidation of exposed wire is still a concern, but this may be managed with chemical inhibitors.

In 1978, the CPSC sued several aluminum wire manufacturers to have the companies pay to repair or replace the pre-1972 wiring installed in U.S. homes. This lawsuit was ultimately unsuccessful because the court found that fixed wiring was not a "consumer product" and was outside CPSC's enforcement authority. The adverse publicity did effectively end the wide-scale installation of aluminum wire smaller than #8 AWG.

Managing Existing Installations

This section provides general recommendations for managing hazards associated with "old technology" aluminum wiring. It is important to check with the local authority having jurisdiction (AHJ) before making any changes to determine the specific requirements that must be followed.

Inspection

Structures that were constructed or had substantial repairs, renovations, or additions made during the mid-1960s through the later 1970s should be inspected to determine whether aluminum wiring is present. Inspections should be performed by a

qualified electrical inspector. In addition to identifying the presence of aluminum wiring; the inspector should document areas where visual signs of overheating are present, such as charring of plastic wiring device bodies or melting of wire insulation, and the presence of prior repair efforts.

Wire Repair

Since most concerns about aluminum wiring are related to overheating at connections and terminations, a common method of repairing old aluminum wiring is to splice short pieces of solid copper wire to the end of the aluminum wire. This copper wire can be used to make connections with the electrical device. There are several methods for making these "pig-tail" connections that may be accepted by the local jurisdiction. However, COPALUM and AlumiConn are the only methods that are recognized by CPSC to provide a "complete and permanent repair."

The COPALUM repair method uses a proprietary crimp-on connector, called a COPALUM connector, to join the copper wire to the aluminum wire. This connector is manufactured by AMP Electronics (now TE Connectivity) and must be installed using a special set of dies and powered crimping tool. An insulating sleeve is placed around the crimp connection to complete the repair. The dies and tool are only made available to electricians who receive training from the manufacturer, and qualified repairers may not be available in all areas. Additional information on COPALUM is available on the TE Connectivity website at <http://www.te.com/usa-en/products/application-tooling/intersection/copalum.html?source=header-match>.

The AlumiConn, manufactured by King Innovation, is a lug-style wire connector designed as a permanent repair for aluminum wiring in homes and commercial buildings. When an aluminum wire is inserted into the AlumiConn lug, it is coated with a thin layer of silicone grease to provide resistance from oxidation. Once seated in the connector, a

set screw is tightened down and provides a secure mechanical connection. No special tools are required to complete the connection and repair process. Additional information on AlumiConn is available on the King Innovation website at <http://www.kinginnovation.com/products/alumiconn>.

CPSC Publication 516, *Repairing Aluminum Wiring*, contains additional information on these repair methods. This publication is available on-line at www.cpsc.gov/s3fs-public/516.pdf.

Wire Replacement/Rewiring

Complete replacement of "old technology" aluminum wiring is the surest method of eliminating the potential hazard from wire overheating. In most cases, this will be impractical because of the substantial cost of installing the new wire inside the walls of finished areas. Where rewiring may be easily done, for example, in unfinished areas where wire is exposed, this provides the most permanent solution to the problem.

Switch/Outlet Replacement

The electrical products industry has developed special electrical devices that may be used with aluminum wiring. Such devices are labeled as "CO/ALR" devices. The 2017 edition of the *National Electrical Code (NEC)*, NFPA 70, published by the National Fire Protection Association (NFPA), requires that listed and approved CO/LAR devices be used for all receptacles and the approved CO/LAR devices be used for all snap switches joined to aluminum wire.

CPSC recommends that such devices be used for emergency temporary repairs, when existing terminations show signs of overheating. The commission does not consider such devices to cover complete repairs, since they are not available for all fixtures and are not permanent.

Maintenance of Connections

Existing aluminum wiring connections should be inspected and maintained by a competent electrician. Such maintenance can include inspecting connections, remaking loose connections, applying oxidation-inhibiting compounds to exposed wiring, and replacing damaged or improper termination devices, as needed. This maintenance can reduce the potential for overheating caused by long-term degradation of the connection.

Other Hazard Reduction Measures

The electrical load on electrical circuits, using uncorrected/repaired aluminum wiring, should be reduced to lessen the potential for over-heating from excessive current flow, until permanent corrective actions can be taken. The use of multiple plug-in appliances or high-current appliances, such as electric heaters or air conditioners, should be avoided.

Metal cover plates should be used for outlets and switches instead of plastic or other potentially combustible materials. Combustible materials may ignite should overheating occur. A secondary advantage of using metal cover plates is that the metal plates conduct heat, which can help dissipate any excessive heat that is within the connection box.

Flammable and combustible materials should be removed from direct contact with receptacles, switches, and other wiring devices. Such materials may ignite or serve as fuels should overheating occur.

New Installations

New installations of aluminum wiring should comply with applicable code requirements. Since 1987, the *NEC* has specifically required that aluminum wire be manufactured from AA-8800 series electrical grade aluminum alloy

conductor material. The 2017 edition of the NEC specifies requirements for aluminum branch circuit wiring. These requirements include:

- The conductor must be of AA-8800 series electrical grade aluminum alloy conductor material (Sec 310.106(B)).
- Receptacles rated 20 amperes or less and designed for the direct connection of aluminum conductors must be marked CO/ALR (Sec. 406.3(C)).
- Snap switches rated 20 amperes or less directly connected to aluminum conductors must be listed and marked CO/ALR (Section 404.14(C)).

Section 110.12 of the NEC contains a general requirement that all electrical installations be performed in a “workmanlike manner,” and notes that American National Standards Institute (ANSI) approved installation standards may be used to define accepted industry practice. The National Electrical Contractors Association (NECA) and the Aluminum Association (AA) jointly publish an installation standard NECA/AA 104, *Recommended Practice for Installing Aluminum Building Wire*

and Cable. This standard describes installation procedures and design considerations for wiring systems in residential, commercial, institutional, and industrial applications not exceeding 600 volts. It should be referred to when evaluating new installations of aluminum wire.

References

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2. National Fire Protection Association (NFPA). *National Electrical Code*. NFPA 70. Quincy, MA: NFPA, 2017.
3. U.S. Consumer Products Safety Commission (CPSC). *Repairing Aluminum Wiring*. Pub. 516. Washington, DC: CPSC, June 2011 <https://www.cpsc.gov/PageFiles/118856/516.pdf>.

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