THE VOICE OF THE CALIFORNIA REAL ESTATE INSPECTION PROFESSION
Inspector eNews

TECHNICAL ARTICLE

Aluminum Wiring

March 2009

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Based In Part On An Article By Douglas Hansen in 1999

There are about 2 million homes in the U.S. that are believed to have solid aluminum branch-circuit wiring. For decades this type of wiring has been publicized as a potential fire and safety hazard. Today, Americans are loading up their homes with high-tech appliances and products that draw more electrical current through these aging circuits. Overloaded convenience circuits may exacerbate the issues associated with older solid aluminum wiring. This can result in overheated plugs and receptacles that may result in a fire. Research suggests that older solid aluminum wire, generally wiring installed prior to 1972 may be more likely to experience connection problems than post-1972 solid aluminum wire or copper wired connections.

“You could say that electricity practically runs our lives when you think of all the modern day necessities that need it, yet most people are unaware that electrical problems are factors in nearly 150 home fires each day,” said Lorraine Carli, NFPA vice president of communications. “Electricity is a leading cause of home fires, but there are things that people can do to avoid these fires.” A free consumer information toolkit designed to help individuals learn how to protect themselves and their property is available at www.NFPA.org.

According to the NFPA, electrical failures or malfunctions result in an average of 19,100 home fires each year. These fires cause more than 140 deaths, injure 1,400 people and account for $349 million in property damage. Statistics on fires specifically caused by aluminum wiring are not kept

CPSC official’s say that what's upsetting is that many homeowners still don't recognize the hazard that solid aluminum wire represents. Although the CPSC estimates that "tens of thousands" of homeowners have heeded its advice and made appropriate electrical system repairs, many more have not. "All fires are of concern to us, but electrical fires concern us more because they occur behind the drywall and are hard to detect and to react to. When it comes through the wall, it is a fully involved fire," said Scott Wolfson, a CPSC spokesman.

David Hannemann and his wife were made aware that their home had aluminum electrical wiring when they purchased their Washington, DC home over 22 years ago. However, they waited almost 18 years to make the fix that has been recommended by the Consumer Product Safety Commission since. What prompted the delayed response to this known fire hazard? "My wife worked in insurance, and she suggested we'd better do it," said Hannemann, a federal employee in Washington, DC. At the time, an underwriter at his wife's former agency "told her he wouldn't write the line anymore" unless a house had been repaired as the CPSC recommends, Hannemann said. This event occurred several years ago.

In researching this updated article, most insurance companies would not comment directly on underwriting policy. Of those that did, one indicated that solid aluminum wiring might trigger a requirement for an electrical inspection before a policy is issued. Most representatives were

unaware that aluminum-wired houses posed any issue and indicated that their underwriters were not inquiring about the presence/absence of aluminum wiring. Insurance companies go through cycles in policy underwriting. When any kind of issue produces a string of underwriting losses, the companies typically react by enacting underwriting restrictions. This apparent lack of insurance company concern on this issue implies that solid aluminum wiring is currently perceived to be a low risk issue.

The National Electrical Code® has recognized conductors made of aluminum since for many years. Aluminum wiring was UL listed for residential use in 1946. The use of aluminum wire for feeders and service entrances was common by the early 1950's and continues today. In the early 1960's, Kaiser Aluminum and other aluminum manufacturers introduced solid-wire aluminum non-metallic (Type NM) sheathed cable. This wire was installed in the same manner as copper conductors, often with disastrous results. The problem with solid aluminum wire is not the reduced current-carrying capability of aluminum. The failures occurred at the mechanical connections. This was especially true in the original aluminum alloys. The safety hazards were well publicized. There seems to be little verifiable research that identifies the actual mode of the connection failures.

The original NM cable aluminum alloys of the 1960's lost their UL® listing in 1971. NM wire using modern 8000-type alloys was first UL® listed around 1972. Southwire® was the first company to gain a listing for these new alloys. The newer alloys appear to be far less trouble-prone than original aluminum alloys. Today, the National Electrical Code® requires aluminum conductor alloys be at least an "AA-8000" series (section 310.14). These 8000-series alloys exhibit much greater terminal retention and have superior mechanical strength as compared to the "old technology" wire. A piece of the old alloy solid aluminum wiring can be broken by simply bending it back and forth a few times, whereas the 8000-type alloy wire has far greater pliability and holds up well to repeated bending/flexing.

In evaluating any older solid aluminum wiring system, it is not always possible to rely on the dates given above; older stock could have been put to use long after superior products were available on the market. The wide variety of methods and materials used in these older wiring installations means that all solid aluminum wiring installation should be evaluated on a case-by-case basis. Unfortunately, there is no one right answer that applies to every dwelling with solid aluminum wiring

Solid aluminum alloy wire was only available as type NM sheathed cable. Inspectors should be careful not to mistake older tin-coated copper wiring for aluminum wire. The dull-silver coating on older rubber-insulated copper wire was necessary to prevent the chemicals in the rubber from interacting with the copper.

Older receptacles and switches used steel terminal screws. The combination of steel screws and aluminum wiring was bad and certainly would seem to have contributed to connection issues. However, switches and receptacles with steel terminals were also problematic with copper wiring. In response, manufacturers switched to brass terminal screws as a way to improve overall connection performance. This change occurred in the early 1970's, about the same time as the switch to 8000-type aluminum alloys occurred. Unfortunately, there has been no research into the performance of the old and new solid aluminum wire alloys with both steel and brass connections to determine what impact the terminals had on connection performance.

It is our responsibility as professional property inspectors, to report on any issue that impacts the safety and habitability of the property. The presence of solid aluminum wiring in branch circuits is a recognized safety hazard and as such is a reportable condition. There may be a temptation to assume that since an installation is 30 years old and has never been a problem that somehow it is ok. That could be a potentially dangerous assumption. Issues with electrical wiring are directly related to the quality of the installation, the frequency of use and load conditions. Proper

workmanship is even more critical with solid aluminum wiring. The fact that a suspect connection has not failed can change quickly when a new owner moves in. The new occupant's usage patterns may vary significantly from the previous owners, i.e. they plug in a major appliance at that receptacle with a marginal connection.

It is always prudent to watch for the signs of faulty electrical connections when inspecting any property. Tell tale signs may include:

- Are there sparks, smoke, or the smell of burning plastic emanating from receptacles/switches?
- Are there receptacles and switches that are warm to the touch?
- Do the lights that flicker, shine unusually bright or do the occupants complain that light bulbs burn out quickly?
- Do the occupants complain of fuses that blow or breakers that trip for no apparent reason?

Circuit testing devices such as the "Sure-Test" and TASCO Inspector III circuit analyzers are capable of measuring voltage drop at receptacles. In theory, these devices might be used to identify potential loose connections. In practice, these devices may not be reliable and are likely to produce false positives. Infrared/Thermography cameras may also be used as a tool to isolate hot spots in the wiring system. The use of specialized tools such as circuit analyzers and infrared cameras is beyond the scope of a general property inspection as outlined in our CREIA Standards of Practice and most other nationally accepted standards of care. The simplest approach for us as inspectors is to clearly recommend to the client that the electrical system be fully evaluated by a qualified electrical contractor or consultant familiar with the issues involved and the available repair methods.

Many of these older homes have small main service panels that could stand upgrading anyway. For owners also faced with aluminum wiring in their homes, there are several viable repair alternatives. The homeowner may choose to replace the solid aluminum wire with copper wiring. It is also possible to make less invasive repairs by "pig-tailing" copper wires onto the solid aluminum at all connection points. For that, there is the Copalum® system, from AMP Industries, the AlumiConn® Connector by King Innovations, the Purple Ideal 65® wire nut connector and "Kearny" split-bolt connectors. Unfortunately, pig-tailing repair methods are not a cure-all. In some cases, they may do more harm than good. The repeated bending strain imposed on the conductors during the retrofit process can damage the wire inside its insulation. This is especially true on pre-1972 older aluminum alloys that are inherently more brittle. Receptacles/switches may also be replaced with devices listed for direct connection to aluminum (CO/ALR rated).

The Consumer Product Safety Commission actually made an outright endorsement of AMP Industries Copalum® system. This has lead many to believe that no other viable repair method exists. The Copalum® system carries a relatively high cost per connection. The Copalum® system requires the consumer to use an electrical contractor certified to participate in the Amp/Tyco program. The system requires a special tool to make the connections.

The AlumiConn® Connector by King Innovations was listed by UL® in mid-2006 for solid aluminum wire pig-tailing repair applications. As with all repair methods, the manufacturer's installation instructions must be adhered to rigorously. Unlike, the Copalum® system, the AlumiConn® connector is readily available and does not require a special tool to use. The AlumiConn® connectors may be found on the shelf at big box retailers in many areas. Wide product availability can be both a blessing and a curse. It makes this repair system accessible to individuals that may be improperly trained/ill equipped to successfully repair the system property.

The Purple "Ideal 65®" wire nut has a UL® listing for copper-to-aluminum connections. Like the AlumiConn® connector, the Purple "Ideal 65®" wire nuts are readily available. The Ideal 65 connectors are listed for connecting a copper conductor to one or two aluminum conductors. Curiously, they are not listed for direct aluminum-to-aluminum connections, possibly because the copper is needed as a heat sink. The "Ideal 65®" is not without its detractors. Most vocal is Dr. Jess Aronstein, a consulting engineer in New York State. Aronstein has campaigned to have the Ideal 65 product recalled. He presented his case to the Consumer Product Safety Commission. The CPSC declined to act on the information Aronstein presented. Aronstein's tests have not been supported through independent third party testing. It may be advisable to take Aronstein's publications with a grain of salt.

Aronstein's papers on solid aluminum wiring and other related information can be found at Daniel Freidman's InspectaPedia site: www.inspect-ny.com/aluminum/aluminum.htm It is possible that clients may find this information and ask questions about it. As inspectors, we should be aware of this information and be prepared to offer unbiased counsel to our clients.

Split-bolt connectors (Kearney's) are another method that can be used. The split-bolts must be rated for aluminum-to-copper connections. This method is labor intensive, and really only practical for larger wire sizes.

The switches/receptacles can also be replaced with devices listed for direct connection. The National Electrical Code® requires that devices directly connected to aluminum wiring be rated "CO/ALR." "CO/ALR" rated devices have screw posts designed for superior retention and compatibility with aluminum. "CO/ALR" rated receptacles and switches may be harder to find and cost about $3 - $5 more per device than non-"CO/ALR" rated devices. There are other disadvantages to replacement with CO/ALR rated devices. What if a handyman or homeowner may replaces a receptacle with a standard device later on – not realizing the problems associated with doing so?

The Leviton website makes the following statement about this issue: *"CO/ALR switches and outlets are required anywhere aluminum wiring has been installed. The terminal screws on CO/ALR devices are made of special materials and designed to grip aluminum wire very tightly.* ***STANDARD DEVICES MUST NEVER BE USED WITH ALUMINUM WIRE****. Doing so is a code violation and dangerous because it increases the likelihood of electrical arcing, short circuits, fire and shock."*

A number of 1970's solid aluminum wire systems were assembled with copper pigtails between the aluminum conductors and devices or fixtures. The copper pigtails eliminate the problems posed by the direct connection of aluminum to the devices. However, the problem with this method is that the pigtail connections themselves then become the weak point. The connectors used in some of those older installations may not be listed for copper-to-aluminum connections.

Another defect commonly associated with older aluminum wire is over fusing. Aluminum has approximately 61% the ampacity of copper by size, and in wire applications this translates to needing 15-amp breakers for #12 aluminum (aluminum wire is not manufactured in 14 gauge). A 20-amp breaker does not properly protect #12 aluminum wire. A number of circuits in modern dwellings are required to be 20 amps, including the kitchen countertop appliance circuits, bathrooms and laundry. To supply these circuits with aluminum wire would require #10, which would be rare in this application. #10 aluminum requires 25-amp breakers, a size that is manufactured, but is not allowed for multi-outlet branch circuits. In the "real world" we may find #10 aluminum protected "incorrectly" by 30 amp breakers. Some installations get around these issues by using copper for the 20 amp circuits and aluminum for the remaining circuits.

In some homes, dryer circuits have been improperly wired with the #10 aluminum wire and should use #8 wire. An ongoing and common wire size issue with larger circuits is the use of #6 aluminum with 50-amp range and oven circuits. This could theoretically be allowed with aluminum type SER service entrance cable and 75° terminations at least until the adoption of the 2008 NEC (applicable in California in 2011). The 2008 NEC removes the exception for temperature limitation, and effectively limits #6 aluminum to 40-amp circuits.

Another common use is to find aluminum used for "home runs" with splices to copper for individual branch circuits. In such situations, an inspector might see aluminum wiring in a panel, but no aluminum wiring at individual switches or outlets because it has been spliced to copper for the home runs.

Arc-Fault Circuit-Interrupter (AFCI) breakers may be used to provide an additional layer of safety protection on convenience circuits. However, the AFCI circuit breakers must be the new "combination" type in order to afford any protection. The combination type AFCI devices can recognize the signature pattern of arcing currents (and distinguish these from the normal arcing that might occur in a properly operating snap switch). The AFCI breakers initially available were ***not*** combination type devices and afford ***no*** protection against series arcs resulting from loose terminals, or from glowing arcs. The real life-safety potential of AFCI's might be realized by installing them with in dwellings with solid aluminum or older knob-and-tube systems. AFCI protection alone should not be considered a substitute for re-wiring or approved pigtail type remediation for solid aluminum wiring installations.

Washington, DC area homeowner Hannemann, who made the repairs after 18 years, said the cost put them off for a long time. "People are funny about this kind of thing," he said. "It's a lot of money to spend on something you can't see." When he finally saw some of the burnt wire nuts, he said, he thought the six-day retrofit was time and money well spent.

There is a wealth of great information available online regarding this issue for both our clients and us. Inspectors and clients alike are encouraged to read the documents available at www.CPSC.gov. The Loss Control Technical Information Paper Series (TIPS) on Aluminum Wiring published by the *Hartford Insurance* Company provides a simple and factual overview of the issues. The document lays out clearly the recommended repair options in an unbiased manner. See the document online at: The Hartford – TIPS Aluminum Wiring Loss Control. The *Professional Investigative Engineers/Investigative Engineers Association* published a useful newsletter article that can be found online at: IENGA Aluminum Wiring Newsletter.

Aluminum wire is actually 200% more effective as a conductor than copper by weight. For this reason, it is used extensively in high voltage distribution lines. In general, 99% of *ALL* electrical fires are the result of installation/workmanship issues. In the case of solid aluminum wiring, it is almost always the connections that will fail – not the material. Fortunately, we have some effective tools to deal with this older, if not somewhat forgotten safety hazard.

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