

**J. ARONSTEIN**

**CONSULTING ENGINEER**

**MECHANICAL AND MATERIALS ENGINEERING**

**BME, MSME, Ph.D., N.Y.S. P.E. LIC. NO. 39860**

**50 PASTURE LANE POUGHKEEPSIE, N.Y. 12603**

**(845) 462-6452**

**aronsteinj@verizon.net**

## **REDUCING THE FIRE HAZARD**

## **IN ALUMINUM-WIRED HOMES**

**Jesse Aronstein, PH.D., P.E.**

Vice President, Special Engineering Projects,  
Wright-Malta Corp., Ballston Spa, NY  
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## **PREFACE**

This report is based on more than thirty years of investigation and testing of aluminum wire branch circuit connections. Included are in-home inspections, in-home testing, investigation of burnouts and fires, laboratory testing, and extensive review of industry and public agency test results and documents. The laboratory testing and investigations performed by the author were done for the U.S. Consumer Product Safety Commission (CPSC), for litigants and insurance interests with respect to fires which may be aluminum wire related, and for Canadian consumer groups, among others.

The most important new item in this (Nov. 2011) revision is information on the Consumer Product Safety Commission's revision of their pamphlet #516, "Repairing Aluminum Wiring". The pamphlet now includes a recommendation of an alternate connector for the "pigtail" repair method (see Section 1-C).

This report was first issued by Wright-Malta Corporation, which, at the time, had one of the largest aluminum branch circuit connection testing operations in the world. In 1982, there were approximately 7,500 aluminum and aluminum-copper connections on long-term test, plus (for comparison purposes) a substantial number of copper-wired connections. The results of many of the tests performed at Wright-Malta Corp. have been documented in reports written for CPSC and in published articles and technical papers. Some of these reports and papers are listed in this report as references (Sec. 6) and in the Bibliography (Sec. 7).

In initiating this report, Wright-Malta Corporation did not represent any commercial interests. The company did not (and still does not) manufacture or market any of the products or services involved or any competitive products or services. Wright-Malta Corporation's aluminum wire testing activity was completed in the late 1980's, and the company has not been involved in this matter (including the revisions of this report) since then. From that time to the present, J. Aronstein, the original author of this report and project engineer for the aluminum-wire testing performed at Wright-Malta Corporation, has continued evaluation and testing of aluminum wiring and its connections.

This report is made publicly available by the original author for the use of homeowners, inspectors, and people in the electrical trades. The report reflects best information and test results available through the revision date.

## INTRODUCTION

A fundamental principle of electrical safety for wiring in buildings is that high temperatures are hazardous. While some protection is provided by electrical enclosures, the high temperature that can develop at failing branch circuit connections can lead to fire in many ways. [1]

Aluminum-wired connections in homes have been found to have a very high probability of overheating compared with copper-wired connections. [2][3][4] The aluminum-wired connections that fail tend to progressively deteriorate at a slow rate, and after many years can reach very high temperature when carrying current while still remaining electrically functional in the circuits. A large number of connection burnouts have occurred in aluminum-wired homes. Many fires have resulted, some involving injury and death. Examples of overheating of two common types of aluminum wire connections are shown in Figures 1 and 2 (following page).

The probability of aluminum-wired connection overheating in a home varies considerably according to the types of connections, the installation methods used, and the circuit usage, along with many other factors. Without detailed knowledge of the installation in a particular home, it is not possible to provide specific advice on corrective measures.

The most certain corrective action for all cases would be to rewire the home with copper wire. This is expensive and impractical in most cases. A practical approximation to rewiring can be achieved by a method known as "pigtail", using a specially-selected connector and installation method to splice a short length of solid copper wire to each aluminum wire end. The copper wire "pigtail" is then connected to the circuit breaker, light fixture, receptacle, appliance, or other termination. This method is effective provided that the connections between the aluminum wires and the copper pigtails are extremely reliable. Pigtail with some types of connectors, even though they might be presently listed by UL or certified by CSA for the application, may increase the hazard. [5][6] (See Figure 1.)

Other actions and partial repairs are less effective, but they still can substantially reduce the risk of fire due to aluminum wire connection overheating. Among the possibilities are replacing certain failure-prone types of devices and connections with others more compatible with the aluminum wire, and removing the ignitable materials from the vicinity of the connections. These actions can be accomplished at lower cost than rewiring or complete pigtail, but with less reduction of the hazard. The homeowner has choices to make. The objective of this report is to present the choices with a relative ranking of fire risk reduction.

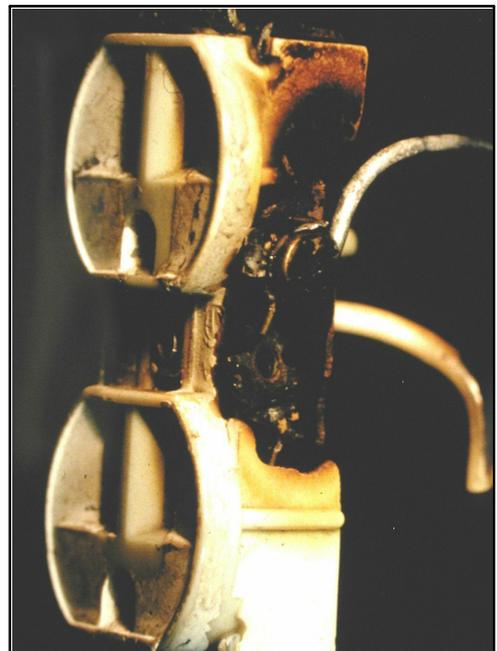
The corrective methods and fire preventative actions described in this report are based on the best information available at this time. The installation and repair information in this report is provided only for guidance in establishing specifications for contracted work, which must be done in accordance with applicable codes and regulations by qualified electricians.

This is an "occupant beware" (or "buyer beware") situation. You are (or will be) living in the home and raising your family there. Not the electrician, not the sales agent, not the previous owner (seller), not the inspector. If you are considering the purchase of an aluminum-wired home, the aluminum wiring need not be a "show stopper". It becomes a question of cost of the home, cost of improvements, your budget, and your own set of value judgments and sense of the relative risks that you are willing to take.



**FIGURE 1 - ALUMINUM WIRE SPLICES MADE WITH TWIST-ON CONNECTORS CAN BE DANGEROUS.** The use of most types of twist-on connectors with aluminum wire can lead to hazardous results. This twist-on pigtail connection (two #10 aluminum wires with one #12 copper wire, in a 20-amp circuit), made with a twist-on connector that was UL listed for use with aluminum wire at the time, remains electrically functional in the circuit, but it becomes extremely hot whenever a significant amount of current flows. The heat has deteriorated the insulation on both the connector and the wires. In this photo, a portion of the connector's spring is red hot, at current well below the circuit rating.

**FIGURE 2 - EXAMPLE: OVERHEATING OF ALUMINUM-WIRED TERMINALS ON A RECEPTACLE.** Enough heat was generated by current flowing through the aluminum wire connections to cause charring of the receptacle body and disintegration of the insulation that was on the wire. Note that the face of the receptacle, as the homeowner or an inspector would have seen it, with the cover plate on, would look normal.



## **ELECTRICAL SAFETY WARNING**

**There is risk of property damage, injury, and death associated with working on the electrical system of a home. Shock, electrocution, and fire hazards are present. All work involving electrical components in the home wiring system should be done by persons trained and qualified for the job, with the power turned off at the main disconnect (main breaker, switch, or fuse block). Refer to appropriate industry and trade publications for safety precautions that should be taken.**

## **DISCLAIMER**

**The information contained in this report is based on a large body of documented test data and sound engineering analysis. It is considered to be accurate and up to date. However, since the practical application of the information contained in this report is totally in the contractor's and/or homeowner's control, and application of the information in the report can only reduce but not totally eliminate the hazards associated with aluminum wiring, the author and the provider of this report disclaim any responsibility or liability of any sort related to the application of the information that it contains.**

## 1. REDUCING THE POSSIBILITY OF CONNECTION OVERHEATING

### A. USE OF CORROSION INHIBITOR AND ABRASION

To make the safest, lowest resistance, and most permanent connections to aluminum wire, the following procedure must be followed:

- 1) After stripping the insulation off the wire for the proper distance, by using a stripping tool that does not nick the wire, coat the bare aluminum with a noncombustible corrosion inhibitor compound.\*
- 2) Abrade the surface of the aluminum wire -- with the compound\* on it -- with #240 grit "wet-or-dry" abrasive paper. Maintain the coating of compound while abrading.
- 3) Coat mating parts of the connector (if not factory prefilled) with corrosion inhibitor compound\*.
- 4) After completing the connection, thoroughly clean off excess compound that is outside the connector.

*\* Note: Corrosion inhibitors for aluminum wire and cable connections are known by different names, such as "oxide inhibitor", "connector aid", and "joint compound." They are generally a greasy substance. Some are simply petroleum jelly (Vaseline), some have various added ingredients. Among the electrical inhibitor compounds available, try to obtain one that does not flame readily. This can be tested by placing a small "glob" of the compound on the end of a piece of wire and trying to ignite it with a match. If possible (depends on availability), avoid the use of any compound that ignites readily and flames vigorously. If the connector is pre-filled with inhibitor compound, it is preferable - but not necessary - to use the same compound for protecting the abraded wire.*

The aluminum wire is normally covered with a thin layer of invisible but hard oxide that is an electrical insulator. Abrading the wire exposes fresh aluminum metal for the contact surface. The purpose of the corrosion inhibitor used during the abrasion is to prevent oxidation of the fresh aluminum metal surface. Then, in a completed connection made by this method, the corrosion inhibitor serves to exclude air from the contact interface and, in the long term, prevent deterioration of the connection from oxidation and/or corrosion.

The inhibitor compounds are chemically inert -- they do not dissolve existing aluminum oxide. It is frequently claimed that use of an inhibitor compound (without abrasion) results in penetration of -- or elimination of -- the insulating oxide film on the wire. Such claims are generally not true, and are not substantiated in the technical literature. Similarly, simply smearing an inhibitor compound over an existing aluminum wire connection is not effective in preventing future overheating failure.

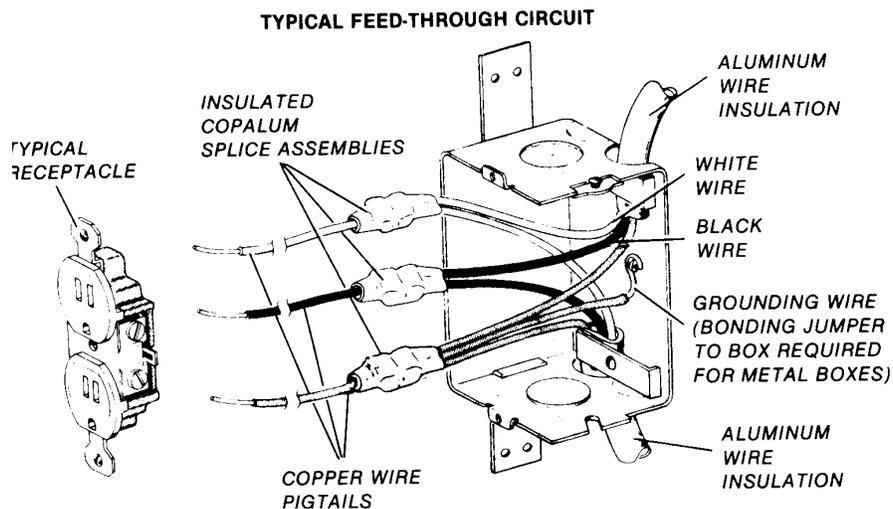
**\*\*\* CAUTION - THESE REPAIRS MUST BE DONE BY A QUALIFIED ELECTRICIAN \*\*\***

## **B. PIGTAILING USING "COPALUM" CONNECTORS**

Repair by pigtailing, using COPALUM\* connectors installed by a qualified electrician, is considered by the U.S. Consumer Product Safety Commission ("CPSC") to be the best method for a permanent repair short of rewiring with copper.[7] Their recommendation is based on extensive testing and successful long-term field experience. The application of COPALUM connectors is considered to be satisfactory without special preparation of the aluminum conductor.

The "COPALUM" connector is applied using a special set of dies in a power-driven tool. After application of the connector, a heat-shrink insulator is applied. Solid copper wire "pigtails" spliced to the aluminum wire this way may be connected to receptacles, switches, circuit breakers, lamps, appliances, and all other terminations in the normal manner. (Note: all aluminum branch circuit wire terminations in the home, including the ground wires, must be treated this way for a complete and permanent repair, as the overheating problem involves all types of aluminum-wired connections.) The COPALUM repair can only be obtained through an installer who has been trained and certified by the connector manufacturer. For information on availability in your location, call the manufacturer at 800-722-1111.

***WARNING - Use of other types of crimp-on connections with aluminum branch circuit wire can be hazardous. Do not use commonly-available crimp connectors applied with a plier-like hand tool, even though they are often sold as applicable for "all wiring repairs", and in fact may be made by the same manufacturer that makes the "COPALUM" connector. If the COPALUM connector (with its special tooling and factory trained installer) is not locally available, see Section 1C.***



**FIGURE 3 - Illustration of copper wire pigtails spliced to aluminum circuit wires using COPALUM connectors (Source: CPSC)**

\* Manufactured by T.E.Connectivity, formerly TYCO, and originally AMP.

### C. PIGTAILING USING KING INNOVATION "ALUMICONN" CONNECTORS

In mid-2006 a new connector became widely available for the aluminum wire pigtail application. This connector is shown in Figure 4. Test results for this connector have been published and are publicly available. [13] The CPSC now accepts use of the AlumiConn connector as an acceptable alternative repair method if the COPALUM repair cannot be implemented.



**FIGURE 4 - King Innovation "AlumiConn" Connector**

On the basis of the test results, the AlumiConn connector is predicted to have a high probability of failure-free long-term safe performance, *provided that the setscrews are carefully tightened according to the manufacturer's recommendation.*\* If not tightened to the manufacturer's recommendation, there is a possibility that the connections will degrade due to wire stresses and/or motion when the completed connection is manipulated into the outlet (or junction) box.

\* SPECIAL NOTES:

1. The manufacturer provide two alternative instructions for tightening. Either method may be used (instruction card, item #3 or 3A).
2. It is difficult to properly tighten the setscrews if the connector is hand-held. The connector needs to be held in a tool while tightening. The manufacturer has indicated that some electricians are using "channel-lock" type pliers for this purpose. A special holding tool may be developed and made available by the connector manufacturer.

Prior to the April 25, 2007 revision of this report, a different connector had been identified as having the best probability of long-term safe performance if the COPALUM repair was not available. Provided that special installation methods were used (inhibitor, abrasion, and pre-twisting), 3M Scotchlock connectors were considered to be the best available alternative to the COPALUM crimp connector for pigtailing. The field performance of the Scotchlock connector, installed as had been noted, has been good. A major drawback of that repair method, however, is that these connectors are not presently "listed" for use with aluminum wire. The AlumiConn connector, having favorable test results, UL listing for use with aluminum wire, and CPSC acceptance, has replaced the Scotchlock in this report as the best alternative if the COPALUM repair is not available.

**\*\*\* CAUTION - THESE REPAIRS MUST BE DONE BY A QUALIFIED ELECTRICIAN \*\*\***

#### **D. PIGTAILING USING IDEAL #65 "TWISTER" CONNECTOR**

After 1987, when UL adopted a revised standard (UL486C) applicable to twist-on connectors for aluminum wire, twist-on connectors were no longer being marked (in the USA) as UL listed for aluminum wire applications. In 1995, UL accepted a twist-on connector - the Ideal #65 "Twister" - for aluminum-to-copper wire combinations, including those commonly used in the "pigtail" retrofit. The Ideal #65 has been heavily promoted for that application. The connector is essentially the same as twist-on connectors that had performed poorly in previous testing, the major difference being that it is pre-filled with inhibitor compound. Based on its construction, there is good reason to question the long-term performance of the Ideal #65. Because of its UL listing, however, most electrical inspectors would accept this connector for pigtail of aluminum wiring.

As soon as it appeared on the market, the Consumer Product Safety Commission (CPSC) questioned UL's listing of this connector for the aluminum wire pigtail wire combinations. Although the manufacturer claims that the connector has been thoroughly tested for the application, neither the manufacturer or UL have released any detailed test data. The manufacturer states that the connector has received CSA certification for the same wire combinations. Information developed so far indicates the following:

- The manufacturer did not initially claim that the connector is intended for use in the pigtail retrofit application. Instead, the manufacturer stated (to CPSC) that the Ideal #65 is intended for such applications as connecting lighting fixtures and ceiling fans. Ideal's engineering manager at that time committed to CPSC that the company would change its advertising and instructional information accordingly, but Ideal did not follow through on that commitment.
- UL did not independently perform the "heat-cycle" life tests required by their standard. These tests were performed by the manufacturer, with UL accepting the manufacturer's results.
- The connector was not "heat-cycle" tested for the common pigtail wire combinations with current passing through the aluminum-aluminum wire path (in an aluminum-aluminum-copper splice).
- The "heat-cycle" tests that were performed by the manufacturer on the Ideal #65 "Twister" connector were not done using aluminum wire of the type actually installed in homes built in the 1960's and early 1970's.
- The CSA certification was based on UL's acceptance for listing. CSA did not independently evaluate the Ideal #65 connector. In fact, the use of a zinc-plated steel spring in the connector violates a CSA general requirement for connectors for aluminum wiring.
- The inhibitor compound/plastic shell of the connection in combination can ignite readily and burn freely. This increases the chance of fire ignition if connection failure occurs.

**\*\*\* CAUTION - THESE REPAIRS MUST BE DONE BY A QUALIFIED ELECTRICIAN \*\*\***

Independent testing of the Ideal #65 "Twister" has demonstrated the following:[11]

- Installed according to the manufacturer's instructions (without abrasion or pretwisting), the connector does not reliably establish low-resistance connections. (This finding contradicts the manufacturer's claim that particles in the inhibitor within the connector eliminate the need for abrasion of the wires.)
- The Ideal #65 connector does not consistently pass the UL "heat-cycle" test requirement when tested with aluminum wire of the type actually installed in homes with current passing through the aluminum-aluminum path in a pigtail (aluminum-aluminum-copper) splice.
- The performance of the Ideal #65 Twister is essentially the same as that of poorly-performing twist-on connectors previously evaluated for the aluminum wire pigtail application.

Additionally, field burnouts have now been reported with the Ideal #65 connectors in their rated applications. With CPSC skeptical (and requesting that UL withdraw its listing), the manufacturer initially agreeing that the connector is not for the pigtail retrofit application, independent tests clearly demonstrating poor performance, and field failures reported, the use of the Ideal #65 "Twister" connector for the pigtail application is definitely not recommended. If the COPALUM repair is not available, use the AlumiConn connector (See Section 1C).



A. These two failed splices are adhered together by the melted plastic insulating shells.



B. Severe failure, plastic shell melted and charred. The charring indicates that it had probably ignited.

**FIGURE 5 - FIELD FAILURES OF ALUMINUM TO COPPER SPLICES MADE WITH IDEAL #65 CONNECTORS [12]**

**\*\*\* CAUTION - THESE REPAIRS MUST BE DONE BY A QUALIFIED ELECTRICIAN \*\*\***

### E. FIELD EXPERIENCE WITH "PIGTAILING" OF ALUMINUM WIRE

The previous sections have discussed "pigtailing" using different connectors, in terms of relative assurance of long-term safety in actual use, based on lab test results and field experience. For those connectors that have been in use for some years, the reported field experience for each connector is consistent with the lab test results -- good for the COPALUM and the 3M Scotchlock, and poor for the Ideal #65. There are no adverse field reports for the AlumiConn connector, which has been in use for a shorter time.

Feedback regarding field experience with the various connectors is summarized as follows:

1. COPALUM Connector: has been used in this application since the early 1970's, and is present in a significant number of aluminum-wired homes. To date, to my knowledge, there have been no reports (to CPSC or other) of burnouts or other in-home failures of aluminum-wired pigtailing splices employing the Copalum connectors.
2. 3M Scotchlock twist-on connector (using special installation method): was originally proposed for use as a more readily available alternative to the COPALUM in about 1980, based on superior laboratory test results relative to other twist-on connectors that had been evaluated (for CPSC) for the pigtailing repair.[5] The number of homes in which this connector has been used for aluminum wire pigtailing is unknown, but no doubt is far less than for the COPALUM or the IDEAL #65. There have been no reports of burnouts or other in-home failures of these connectors used for aluminum-wire pigtailing.
3. IDEAL #65: came on the market in the mid 1990's. Within three years of its introduction, the first report of field failure surfaced. [12] There have been additional failures reported since then.
4. AlumiConn: This connector has been on the market since 2006, and there are no reports of burnouts or other in-home failures.

(Similar setscrew connectors have been in use for many years, but the application is different. In particular, other applications do not involve severe distortion and stressing of the wires that occurs in the pigtailing application when the connections are forced into the outlet (or junction) box.)

## **F. BOX FILL**

Most aluminum wire splices and terminations that are to be pigtailed are in metal or plastic electrical enclosures ("boxes"). Some boxes are too small to accept the pigtailed connectors in addition to the items originally in the box. When this happens, the available volume can be increased by changing the box, extending it, or adding an adjacent box. Some cutting and subsequent touchup of finished surfaces may be necessary when boxes are changed or added.

## **G. ALTERNATIVE CORRECTIVE ACTIONS**

With less certainty of safe, permanent, and complete correction relative to pigtailed connections, the following actions can reduce the probability of aluminum-wired connection overheating, thereby reducing the hazard. Note that ground connections should be addressed as well as the neutral and line connections.

***1) Service Panel Connections CAUTION - SUBSTANTIAL HAZARD: THE SERVICE ENTRANCE CONDUCTORS AND CONNECTORS ARE LIVE (ELECTRICALLY ENERGIZED) EVEN WHEN THE MAIN BREAKER OR SWITCH IS "OFF" OR THE MAIN FUSES PULLED. SOME PANELS MAY NOT HAVE MAIN BREAKERS/FUSES, BUT, INSTEAD, THEY HAVE UP TO SIX DOUBLE POLE BREAKERS THAT MUST ALL BE TURNED OFF TO DISCONNECT ALL OF THE BRANCH CIRCUITS. SERVICING OF THE SERVICE ENTRANCE CONNECTIONS CAN ONLY BE DONE SAFELY WITH POWER COMPLETELY DISCONNECTED AT THE UTILITY POLE OR METER. USE A METER OR TEST LIGHT TO ASSURE THAT THERE IS NO VOLTAGE (TO GROUND) ON THE WIRING BEING SERVICED.***

Remake all branch circuit aluminum wire connections (including to the neutral buss) using corrosion inhibitor compound and abrasion of the aluminum wire, as described above in Section 1A. Make sure all connections are tight. Recheck tightness after one year, and thereafter at intervals determined by the amount of loosening detected, if any.

Visually inspect the service entrance cable connections. If there is any abnormality or signs of corrosion or overheating, then servicing by a qualified electrician is required.

***2. Receptacles and Switches ("wiring devices") CAUTION - SUBSTANTIAL HAZARD - USE A METER OR TEST LIGHT TO ASSURE THAT THERE IS NO VOLTAGE (TO GROUND) ON THE WIRING BEING SERVICED.***

Replace with CO/ALR devices installed per industry recommendations. [9] NOTE: Some CO/ALR wiring devices that are available are old stock and should not be used. The indium plating used on the terminals of some brands degrades with time, so the devices have a limited shelf life. Inspect the screw terminals and the terminal plate. If the terminals have a fresh metal look, they are probably OK. If the screws and/or terminal plate look tarnished or off-color, do not use them with aluminum wire, as the long-term performance and safety would be questionable.

***\*\*\* CAUTION - THESE REPAIRS MUST BE DONE BY A QUALIFIED ELECTRICIAN \*\*\****

If full replacement receptacles and switches cannot be done due to economic factors or limited availability of fresh CO/ALR rated devices, then the following actions are suggested:

- If CO/ALR devices are not available for replacement, the next best alternative, besides pigtailing, would be the use of devices with brass (nonmagnetic) 8-32 terminal screws. Connect per the industry recommendations after preparing the wire as described above in Section 1A.

*NOTE: In all cases, when installing the connected device into the box in the wall, push it into place while folding the wires behind it, then pull the device out slightly and check the tightness of the terminal screws prior to screwing the device to the box.*

- Reconnect all "push-in" wire terminations to screw terminals. If there are no screw terminals on a wiring device to reconnect to, then replace it.
- Replace all devices which have 6-32 size terminal screws. (Outside diameter is 0.138", the same as the screws which hold the device to the box: 8-32 screw threads are 0.164".) Make sure that the replacements have brass (non-magnetic) screws.
- Replace all devices which have steel terminal screws. (Check with magnet *after turning the MAIN POWER OFF!*)
- Priority should be given to the replacement of unsuitable devices in the more heavily loaded circuits, in which portable heaters, cooking appliances, air conditioners, and similar loads are used. All unsuitable receptacles and switches on these circuits should be replaced, not just those into which the loads are plugged. (Since the wiring devices are most often "daisy-chained" in the circuit, full current flows through the wiring terminals on all of the devices "upstream" of the device into which a load is plugged.)
- Receptacles and switches which are not being considered for replacement should be inspected for heat damage. (Replace all damaged receptacles.) Reconnect the aluminum wire at the screw terminals by preparing the aluminum wire per Section 1A, above, and connect to the screw terminal per the industry recommendations. [9] Re-tightening existing screw terminal connections, without remaking them, is easier but less effective.

3) Other Connections: Pigtailing to solid copper wire, as described in previous sections, should be used for connections between branch circuit aluminum wire and screw terminals or stranded leads of built-in appliances, heaters, furnaces, fixtures, and controls. Do not connect aluminum wire directly to stranded copper wire leads. Use an intermediate solid copper pigtail. The solid copper is then spliced to the stranded copper lead in the conventional manner. In some instances, such as connections to motors, there is often not enough space in the junction box for the pigtailing connectors, and an external junction box must be added.

Splices involving only the branch circuit aluminum wire (ie: aluminum-to-aluminum wire connections) should be made using the AlumiConn connector. (There are no twist-on connectors rated for aluminum-to-aluminum wire combinations.)

## **H. NEW CIRCUITS AND CIRCUIT ADDITIONS**

Use copper or copper-clad wire for all circuit additions and for the installation of new circuits.

## **I. HOMES WIRED WITH ALLOY ("NEW TECHNOLOGY") ALUMINUM WIRE**

The Corrective actions described in the sections above are required for homes wired with "new technology" wire just as they are for the "old technology" wire.

Homes wired with some types of "alloy" aluminum wire may have lower probability of overheating at the binding head screw connections. With other types of terminations, however, there is little improvement in the probability of overheating. In particular, the alloy aluminum conductors show high failure rates in tests with twist-on connectors. [6][8]

The so-called "AA-8000" alloy aluminum wires may have improved mechanical properties but most of them have an electrically-insulating oxide surface film. As with the "old technology" ("EC" grade) aluminum wire, the oxide must be removed to reliably make a low resistance connection. It should be noted that there is no electrical testing required of the AA-8000 alloys to assure that they will perform properly with the wiring devices and splicing connectors that they are connected to.

## **J. HOMES WIRED WITH PLATED ALUMINUM WIRE**

Aluminum wire plated with tin or nickel was listed by UL in the early 1970's. The number of homes in which it was installed - if any - is very small. The only known brand name (on the cable jacket) that is known to indicate plated aluminum wire is "SINIPAL". In general, it can be assumed that the aluminum wire in a home is not plated.

Tests of plated aluminum wires with twist-on connectors showed that the plating did not solve the connection deterioration and overheating problem. [10] If it is known with certainty that the aluminum wire is plated, omit the abrasion step in the connection procedures described above. The corrosion inhibitor compound is still required, however. (Note: abrasion of the plated aluminum wire is not harmful provided that the inhibitor compound is used.)

## **K. HOMES WITH COPPER-CLAD ALUMINUM WIRE**

Copper-clad aluminum wire has a thin copper outer skin and a core of aluminum. Therefore it looks like copper, except on close examination of a cut end. Markings on the cable jacket would include "Al" or "Aluminum". There is no known history of connection overheating problems associated with copper-clad aluminum wire. No corrective actions are required for copper-clad aluminum wire.

### **L. MISIDENTIFICATION - PLATED COPPER WIRE**

Plated copper wire is relatively common in older homes, and it looks like aluminum wire. It was commonly used with rubber-based insulation. Identification can be made by careful inspection of a cut end of the wire. In general, plated copper wire would not be present in nonmetallic sheathed cable ("Romex"); it is most generally found in metallic sheathed cable ("BX"). Cable of the "BX" type is not likely to contain aluminum wire.

### **M. CIRCUIT USAGE**

Keeping the circuit current low will minimize the possibility of fire hazard due to overheating aluminum wire connections. Heat generation at a connection is related to current flow. The lower the current, the less heat produced at a given failing connection. Where no corrective actions have been taken, occupants of aluminum-wired homes should minimize the use of plug-in appliances that draw current approaching the circuit rating, such as portable heaters, cooking appliances, and air conditioners. Additionally, the total of all loads active at any time on a given circuit, due to TV's, computers, lighting, etc., should be minimized.

### **N. BAD ADVICE - "DO NOTHING"**

The electrician, handyman, inspector, or realtor who suggests that nothing needs to be done, perhaps because there have been no problems so far, is most often badly mistaken. Even if it is correct that "nothing happened" in previous years (or while a previous owner resided there), changes in occupancy patterns and electrical circuit usage can heavily load some wiring connections that had never before been subjected to any significant current.

For example, in my own home, a circuit feeding the receptacles in two of the bedrooms has never carried more than the current to a few lamps and an alarm clock, perhaps 5 amps maximum with all the lights on at once. If the next owner plugs a portable heater into a receptacle in the corner bedroom (which tends to be chilly), and perhaps a TV and a computer are added, the maximum current in this circuit can be as high as its circuit breaker will allow without tripping. (A 15-amp breaker typically will trip at somewhere between 16 and 20 amps.) The current is passing through a daisy chain of wiring terminals on other receptacles -- as many as 22 of them in this particular circuit in my home. It would only take one deteriorated wiring connection in that daisy chain circuit to cause a problem (in the worst case, a fire) even though it had previously appeared to be OK at very low electrical loading.

A further point to consider is that the aluminum wiring terminations tend to degrade with time. Some may actually be "as good as new". Others may be deteriorated (relatively high electrical resistance) but show no visible signs of overheating for lack of any significant current flow up to that time. As the house ages, so do the aluminum wire terminations. They do not improve with age.

**O. BAD ADVICE - IT IS "SAFE IF PROPERLY INSTALLED"**

Many inspectors, realtors, and electrical professionals make the claim that aluminum wiring is "safe if properly installed". This may or may not be true, depending on what is meant by "properly installed". The industry recommendations for installation of aluminum wire underwent drastic changes over the years, and what was considered proper at the time of original installation may no longer be acceptable. "Safe if properly installed" is a promotional (or defensive) statement for aluminum wire, and not an evaluation of the condition or safety prospects of the wiring system in your particular home. Does the person making that statement know whether **all** of the aluminum wire terminations in the home are "properly installed"? With respect to receptacles, are all of the aluminum wires terminated at screw terminals, or are there some that use the push-in "backwire" terminals? If screw terminals were used, are they clamp type (not good) or the type where the wire is wrapped around under the screw head ("binding-head" screw terminal)?

If binding-head screw terminals were used, are the wires all properly wrapped under the screw head (2/3 wrap, clockwise direction, no overlap)? Are the screws steel (worst) or brass (not as bad)? Are the screws zinc plated (worst), indium plated (questionable), or tin or nickel plated (better than zinc)? Were all the screw terminals originally tightened adequately? Are they all still tight? Are all the receptacles marked "CO/ALR"? No other type is presently considered safe for use with aluminum wire, whether or not they are marked "AL/CU" or "CU-AL". Were the aluminum wire terminations made using a corrosion inhibitor? Were the bare wire ends abraded before making the connections?

Those questions (above) apply to the receptacle wiring terminals. One also has to consider the wiring splices (twist-on connectors, "wire nuts"), and aluminum wire terminations at various built-in appliances (heating, air conditioning, hot water heater, dishwasher, etc.) and at the circuit breaker panel. Has anyone inspected all of these aluminum wire terminations in the home to certify that all of them are "properly installed" and do not show signs of overheating (yet)?

The phrase "safe if properly installed" has no meaning for the occupants of an aluminum wired home.

**P. ARC-FAULT INTERRUPTERS**

Some electricians are recommending the installation of arc-fault-interrupters to help alleviate the hazard that develops from overheating aluminum wired connections. The arc fault interrupters do nothing to stop the deterioration of the connections and the ultimate development of hazardous levels of overheating. Overheating aluminum-wired connections, such as shown in Figures 1 and 2, generally do not cause arc fault interrupters to trip.

## **2. DETECTION OF OVERHEATING CONNECTIONS**

Detecting an overheating connection in the early stages - and taking corrective action - can be an effective fire-prevention procedure. This is an inexpensive way of reducing the fire hazard where complete corrective actions have not yet been taken. The effectiveness is limited, however, and strongly depends on the thoroughness and frequency of inspection.

### **A. DETECTION OF OVERHEATING AT RECEPTACLES AND SWITCHES**

With main power off, remove the cover plates of the receptacles and switches ("wiring devices"). Using a bright flashlight, carefully inspect the area of each wire terminal. The wires should be connected at the screw terminals (not inserted into "push-in" wiring holes in the back of the device). Look for the following signs of overheating: 1) charring or discoloration of the plastic wiring device body around the screw terminals, 2) abnormal tarnishing or corrosion of wire and screw terminal, and 3) melting, bubbling, burnback, or discoloration of the wire insulation. If any of these signs of overheating exist, or if the device is push-in backwired, replace or reconnect the device as previously described. Each and every wiring device should be inspected (not just a random sample). Replace all cover plates before restoring main power.

***WARNING:*** The often-quoted advice to "feel the outlet faces" to detect overheating is ineffective and may be dangerously misleading. The person feeling the outlet faces cannot be expected to know how much current, if any, a receptacle's connections have been carrying, and for how long, prior to being checked in that manner.

### **B. DETECTION OF OVERHEATING AT OTHER CONNECTIONS**

Periodic visual inspection, looking for signs of discoloration, insulation deterioration, or other abnormalities, is the only readily available method for detecting overheating of the various wire splices and terminations in the home. Inspection of electrical boxes and panels other than at wiring devices should be done by a qualified electrician or inspector, and must include all connections, not just a random sample.

***WARNING:*** So-called "warning signs", such as flickering lights, inoperative circuits, strange odors, smoke, sparks, and arcing, sometimes occur at advanced - and hazardous- stages of connection failure, but they cannot be counted on as warning signs in all instances.

***WARNING:*** Inspections can reveal what has happened in the past, but cannot assure future safe performance. A high resistance connection may not have overheated simply because no significant current was ever flowing in its part of the circuit. It will look "like new". The same connection may then overheat to hazardous levels when a new load (TV, portable heater, cooking appliance, or other) is plugged into the circuit.

### **3. REDUCING THE POSSIBILITY OF FIRE IF CONNECTION OVERHEATING OCCURS**

Overheating connections can get hot enough to ignite fire, if there is an ignitable material nearby. Whether one has a "burned out connection" or a serious fire loss is determined to a great extent by the materials that are near the overheating connection. Removing the easily ignited materials from the vicinity of the aluminum wire connections can substantially reduce the possibility of fire ignition if a connection overheats. This activity is most efficiently done as part of a general inspection for overheating connections (Section 2, above), and should be done with the main power off.

#### **A. INSIDE THE ELECTRICAL ENCLOSURES**

Wallpaper and wood paneling material are often installed so that they intrude into the wiring device boxes, sometimes in actual contact with the wire terminals. These materials should be cut back beyond the border of the box. Remove all dust, wood chips and splinters, paper material, and other extraneous combustible materials from the receptacle and switch boxes and all other electrical enclosures.

#### **B. COVER PLATES ON RECEPTACLES AND SWITCHES**

Use metal coverplates on receptacles and switches. Most "decorator" type plastic and wood coverplates ignite relatively easily. Metal coverplates provide better protection and also serve to dissipate the abnormal amount of heat that may be generated inside the box by a failing aluminum wire termination on the wiring device.

#### **C. ADJACENT TO THE RECEPTACLES AND SWITCHES**

Bedding, furniture, drapes, books, newspapers, and other potential fuels are often found in direct contact with the wiring devices. Remove all combustible materials that are in contact at the face of receptacles and switches, so that there is at least 2" of clearance.

### **4. IF FIRE OCCURS (from any cause)**

***KNOW WHAT TO DO IF FIRE OCCURS. HAVE A PLAN. DISCUSS IT WITH THE WHOLE FAMILY. SEE YOUR LOCAL FIRE DEPARTMENT FOR GUIDANCE.***

***INSTALL DETECTORS. EARLY WARNING IS IMPORTANT.***

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