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Fundamentals of Aluminum Conductors, Part 1

By John Roach, The Hartford Steam Boiler Inspection and Insurance Company

Introduction

There are many myths, beliefs, and opinions in the industry on why aluminum conductors should or should not be used in certain applications. The use of aluminum conductors causes questions and concerns for many electricians, engineers, inspectors, and owners. In Part 1 of this article, we will address the background and the characteristics of aluminum conductors. Part 2 will discuss installation and maintenance of aluminum conductors.

Aluminum is Low Cost, Low Weight

Current electrical grade aluminum (Al) conductors are actually an aluminum alloy and not pure aluminum. An alloy is a metal made up of a primary metal with additional elements added to it in varying amounts to achieve more desirable characteristics based on the needs of specific applications. Various aluminum alloys differ in their strength; corrosion resistance; machinability; ability to harden; and temperature performance. Aluminum alloys are categorized in series having multiples of 1000. The 1000 series is essentially pure aluminum (greater than or equal to 99 percent). Other series have one or more additional major elements with might include copper, manganese, magnesium, silicon, tin or lithium.

Aluminum conductors can be round or bar shaped. Both of these shapes are used in a large majority of transmission and distribution circuits as well as industrial plants. The use of Aluminum conductors is recognized by various codes and agencies such as the National Electric Code and Underwriters Laboratories (UL). Aluminum conductors have been listed by UL since the mid 1940s for interior wiring. The two primary reasons for using aluminum conductors are its lower cost and low weight to conductivity ratio.

Modern Aluminum Alloys Have Been Improved

Round conductor prior to the mid 1970s was made of aluminum alloy 1350, which was essentially pure aluminum. It had undesirable mechanical characteristics such as a large coefficient of thermal expansion and a susceptibility to bending and creep failure.

The current alloy utilized for round conductor inside buildings is the 8000 series, which became commercially available in the mid 1970s. To improve its mechanical characteristics over pure aluminum, additional elements were added to the 8000 series. In addition, it undergoes an annealing process. Because of these improvements, it has a higher strength to weight ratio than copper and greater flexibility based on ampacity. Aluminum is also used in applications requiring

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bus bars. The predominant alloy for aluminum bus bars is 6101. The alloy also has added elements and is hardened to ensure adequate mechanical properties. This alloy is very machinable but it is not considered to be a high strength material.

Earlier Aluminum Conductors were Susceptible to Failure

Several issues were encountered with the use of aluminum alloy 1350 for conductors. The issues included a large coefficient of thermal expansion, a susceptibility to bending and creep failures, a high rate of oxidation and a vulnerability to galvanic corrosion. These concerns are minimized today with the use of the 8000 series alloys, proper electrical connectors, proper installation and appropriate connecting methods.

Thermal Linear Expansion

The thermal linear expansion coefficient is the fractional change in length of a particular material, for each degree of temperature change. This coefficient is based on the properties of the material. The thermal linear coefficient of expansion for aluminum is 36 percent greater than copper. If the proper connector is not used, high stresses could occur due to uneven growth between the conductors and the connectors during normal thermal cycling.

Creep

Creep is the continued deformation of material under stress. The aluminum alloy 1350 had a much higher creep rate than copper. This fact was not taken into account in installation techniques or termination devices and this contributed to heating issues at the connections. These issues associated with creep have been mitigated with the use of 8000 series aluminum alloys and suitably designed connectors.

Oxidation

Aluminum quickly develops a layer of oxide when exposed to air. The oxide layer rapidly builds and stabilizes. The oxide layer provides the benefit of corrosion prevention. But its drawback is high resistance. This oxide layer is very brittle and can be removed by simple mechanical means. By scraping the outside of the wire and using a connecting compound between the wire and connector, the oxide layer is removed and prevented from reforming. Bus bar is typically plated in the connection area to prevent oxidation related issues.

Corrosion

Corrosion can occur in aluminum conductors due to galvanic action. Galvanic action occurs if dissimilar metals are used in an electrolytic solution. The dissimilar metals are the aluminum and copper conductors and the electrolytic solution can be as simple as humid air. There is a difference in potential (voltage) between the positive anode (aluminum) and negative cathode (copper). The electrolyte (moisture) allows for the conduction of current. This action damages the aluminum and leaves the copper intact. This corrosion can be avoided by the proper selection of connectors and the use of a connecting compound.

Summary

Aluminum is a proven, cost effective means to conduct electricity. It is recognized by codes and agencies such as the National Electric Code and Underwriters Laboratories. The characteristics of aluminum allow for a beneficial design from a cost and weight standpoint. The issues of the early aluminum alloy 1350 have been addressed in the 8000 series alloys, the proven connection methods and the connectors in use today. Aluminum and aluminum alloys should be considered as acceptable materials for conductors in power circuits provided the correct series of material is used and appropriate design, installation, and connection techniques are utilized.

About the Author

John Roach is a principal electrical engineer with The Hartford Steam Boiler Inspection and Insurance Company. John has a B.S. degree in Electrical Engineering from the University of New Haven and a Master's of Engineering degree in electrical power engineering from Rensselaer Polytechnic Institute. He has almost 20 years of industrial electrical engineering experience and is an active member of the Institute of Electrical and Electronics Engineers, Inc. (IEEE).