

Aluminum vs. Copper Conductors A Serious Alternative?

A white paper discussing the pros and cons of aluminum vs. copper conductors in real-world industrial applications.

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Introduction

As plant facilities become more expensive to construct and maintain, the necessity of looking to alternative materials becomes increasingly critical to cost-conscious builders. One of these alternative materials, aluminum wire, has been the focus of a lot of attention lately in the construction industry, especially as copper prices continue to increase while the aluminum market remains steady. Price alone offers a compelling reason why modern aluminum conductors have a value proposition to offer: at the time of this research, one can expect to spend approximately 25 to 40 percent more for copper wire than its aluminum counterpart. It's no wonder that more engineers are examining the possibilities and functionality of aluminum wiring.

Today, aluminum conductors are already being used efficiently and their use is widespread within the construction industry. It is currently being successfully installed in many industrial applications. In utility applications, aluminum has a long-standing track record, and it continues to provide substantial performance in commercial and institutional applications. Aluminum is also being used more frequently in heavy commercial facilities. MC cable with aluminum feeders is becoming a staple in many high rise buildings, stadiums, shopping malls, commercial buildings, wastewater treatment, and manufacturing facilities. Contractors are installing them in service entrance conductors, large conductors, and power distribution conductors. These various uses demonstrate that choosing aluminum is not a 'novel' concept and it has been proven to be a useful, high-performing material.

Since industrial applications are considered Interstates' main area of expertise, we have conducted research on using aluminum conductors as an alternative to copper. We further present to our client the advantages, disadvantages, and some helpful hints for installing this option in order to better help our clients make an informed decision regarding which material would best meet their facilities' needs.

Why aluminum may be right for your facility

Cost savings

Every business person strives to reach a suitable return-on-investment (ROI) for his or her firm, but this only becomes more challenging in the current material pricing environment. That is why the most obvious advantage in selecting aluminum as a conductor is the savings incurred due to lower material prices. These savings can reach up to 70 percent if aluminum is utilized in every possible way. Interstates conducted a commodity price comparison study for a customer and found that the total price of aluminum wiring was 25 to 30 percent less than if the customer had chosen to use only copper. Not only is aluminum significantly less expensive than copper, its market pricing is much more stable. It should be noted that the price of aluminum is currently rising, but only steadily increasing in very small percentages compared to the market for copper, which fluctuates greatly. We are currently experiencing a historic rise in copper pricing (a substantial 85 percent increase in the last year!). This price jump has heightened the urgency and need for solid research on the topic of alternative conductors.

Technical design advances

Many of the historical "horror" stories associated with aluminum can be attributed to technical design problems of the older alloys that have now been overcome by better product design or can be addressed by quality installations. In the past, aluminum may have failed when installers

would land small aluminum wire on terminations with dissimilar expansion properties that were not listed for the application, such as steel screws in wiring devices. Unfortunately, many people are not aware of the advances that have been made in aluminum design and installations and the product's negative perception continues to exist.

One important product advance is in the physical properties (the chemistry) of aluminum. The alloys currently used in conductors have all but eliminated many of the historical problems associated with the aluminum conductors used in the past. The 8000 series aluminum is the newest of the alloys being used, whereas the previous alloys were part of the 1305 series. Besides the 8000 series, there are several other good options to choose from. All of these new alloys, particularly the 8000 series, have better conductivity, creep resistance, strength, and workability than previous aluminum alloys. Also, a property inherent in all aluminum conductors is that they weigh about 50 percent less than copper. This contributes to easier construction installation methods, i.e. bending, pulling cables, training of cables in tight enclosures, etc.

NEC Approved

One of the most compelling arguments for using aluminum is that the NEC has approved of its use. Section 310.14 states that aluminum conductors "shall be made of an AA-8000 series electrical grade aluminum alloy conductor material." Chapter nine includes several tables that show properties of aluminum conductors, including resistance, impedance, temperature rating, ampacities, etc. See the newest edition of the National Electric Code for more details.

Where aluminum can be utilized

Interstates recommends trying aluminum conductors from transformers to switchboards in service entrance applications and also installing the conductors from switchboards to motor control centers in feeder applications. The potential of using aluminum conductors from feeders to panel boards is also available, provided space considerations for the panel board terminations are met. One industry recommendation is to use aluminum wiring at 1/0 or larger, since installing smaller conductors tends to become more expensive. This is because terminations in branch circuits necessitate more space, as installation would require both an aluminum-to-copper termination and a copper-to-equipment termination.

Also, the bigger financial savings generally occur where larger cables are used, such as in feeders. Therefore, clients who use aluminum do so on larger ampacity runs. Aluminum wire is commercially available in sizes to service 50 amps and above. A common ampacity limit is 100 amps but larger limits are being used by different specifiers. It's necessary to note that branch wire is generally not aluminum.

Overcoming installation and design challenges

Installation

Installation criteria does exist to ensure the proper operation of the electrical distribution system in question. Connections for aluminum are more critical than copper, and although these installation steps are not difficult, they are indeed different from copper installation and need to be followed per instructions. When connections are made correctly, aluminum conductors actually run at a lower resistance, and therefore a lower temperature, than copper conductors.

There are steps that must be taken to ensure proper installation when using aluminum:

- ◆ First and foremost, a proper stripping tool should be used to avoid damage to the conductor. Also, the installer should be aware that aluminum is prone to the formation of a very thin oxide layer which is created within a few seconds of air exposure. For this reason, the conductor must be cleaned with a wire brush to remove this oxide layer, and then an antioxidant joint compound such as NOOX or Penetrox must be applied to keep the oxide layer from subsequently forming.
- ◆ The connections must be torqued to the manufacturer's recommendations. Failure to tighten the connections properly could result in an open circuit or arcing problems; however, terminations must also not be over-torqued and they should not be tightened annually. Doing so will reduce the current-carrying capacity through deformation and cause a hot termination.
- ◆ Aluminum-rated, two-hole compression connectors are to be used. Mechanical connections are not a favorable connection type because of the expansion properties of aluminum. However, some vendors disagree, claiming field electricians have more trouble with using the wrong dies in crimpers than with misusing the mechanical connectors. In either case, close attention must be paid to the details of lug installation. This design may cause some spatial concerns with some equipment, e.g. panelboards.

Design criteria

Another design issue challenge is that aluminum cannot be used to directly terminate to motors due to the current UL listing limitation on motors. This limitation can be overcome by running aluminum to the disconnecting means and running copper to the motor. The use of a pigtail or adapter from aluminum to copper and vice versa are also viable options. However, this technique will probably require additional space at the motor junction box.

Although the improved design of newer aluminum alloys has allowed their conductivity properties to increase, the conductivity of aluminum is still only about 80 percent that of copper. Because of this, aluminum cables must be larger to allow for the same current-carrying capacity of its equivalent in copper wire. Raceway sizes need to be checked and often increased; it is usually necessary to increase the conduit sizes on about 5 to 7 percent of runs. The conduit size will often remain the same, but it still must be checked on a case-by-case basis. Today, aluminum cable is commonly compact stranded, which compensates for some of this loss in conductivity due to a tighter packing of aluminum strands per cable diameter. Therefore, the aluminum wire can be made smaller than usual to meet ampacity requirements. Also, conduit sizes do not need to be increased as often, which explains the relatively low figure of only 5 to 7 percent of runs being increased.

Procedures

Equally important is the implementation of quality control procedures and their equivalent documentation. Good, non-destructive infrared testing and inspection is essential for any electrical distribution system, whether it be aluminum or copper. Systems should be inspected by qualified personnel at energization and again at 30 to 60 days after startup to determine early problems under full load. Annual follow-up inspections would also be an extremely good practice to employ.

Conclusion

As with any major change, there are risks involved in selecting the aluminum for your design. The client must weigh the pros and cons of aluminum vs. copper and ultimately make a decision based on each of their propositions. Interstates can educate our clients and make informed

recommendations if the client is interested in using aluminum. We also offer preventative maintenance programs to reduce the risk of increased service calls that lead to downtime. Our programs also increase the reliability of the installation as we guarantee the proper training of field personnel who make the connections.

Interstates does not recommend every project utilize aluminum conductors, and we realize the use of aluminum in industrial projects would be a major change for many of our clients. The research was performed only to help our clients evaluate the opportunity and make the decision for their specific situation based on the information we have presented in this paper and on our recommendations. However, we would like to educate customers that there are financially beneficial options available to them and one of those just may be using aluminum in their facility.

Interstates is pleased to have recognized that the availability of alternative materials gives us another opportunity to examine what is in the marketplace, and we strive to be of service to our clients in determining the value for them based on their unique facility needs. We hope the research presented in this white paper will be a step towards making your project successful.

Biographies



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As senior project engineer, Brent is responsible for all aspects of projects from the proposal stage to completion. As team lead, Brent acts as a client sponsor, technical advisor and leader, and assists in developing and mentoring his team members. Brent is registered as a professional engineer in Iowa, Nebraska, New Mexico, and Arkansas. Contact Brent at brent.kooiman@interstates.com.



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Interstates Engineering

Interstates Engineering specializes in industrial power design and consulting for facilities in industries such as food, beverage, and value-added agriculture. Interstates Engineering is a division of the Interstates Companies, which designs turnkey electrical systems for industrial and hazardous facilities.

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