INTERSTATES

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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Contents

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 drawn much attention lately in the construction industry, especially as copper prices increase and the aluminum market remains steady. Price alone is a compelling argument to consider modern aluminum conductors—at the time of this research, one can expect to spend approximately 3.5 to 5 times more on copper wire than aluminum wire. 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. This wire is currently successfully installed in many industrial applications. In utility applications, aluminum has a long-standing track record; 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 facilities, 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; instead, it proves to be a useful, high-performing material.

Why aluminum may be right for your facility

Cost savings

Every businessperson 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 80 percent if aluminum is utilized in every possible way.

One commodity price comparison study[i] found that the total price of aluminum wiring was 75 to 80 percent less than if the client had chosen to use only copper. Not only is aluminum significantly less expensive than copper, but its market pricing is also much more stable. It should be noted that the price of aluminum is currently rising but only steadily increasing in minimal percentages compared to the market for copper, which fluctuates greatly. There has been a historic rise in copper pricing (a substantial 91 percent increase 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 are from technical design problems of the older alloys that now have better product design or higher quality installations. In the past, aluminum may have failed when installers would land small aluminum wire on terminations with different 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 persists.

One crucial product advancement is in the physical properties (the chemistry) of aluminum. The alloys currently used in conductors have 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 used, whereas the previous alloys were part of the 1305 series. Besides the 8000 series, there are several other good options of aluminum from which to choose. These new alloys, notably 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 element contributes to more accessible 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 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 showing aluminum conductors' properties, including resistance, impedance, temperature rating, ampacities, etc. See the newest edition of the National Electric Code for more details.

Where aluminum can be utilized

Consider trying aluminum conductors from transformers to switchboards in service entrance applications and 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.

You can also use aluminum in medium voltage applications. These applications usually involve long runs of medium voltage cable from a utility pole, substation, or switchgear. Most medium voltage applications involve copper wire that is 1/0 and larger, so these cases would be prime targets for substituting copper wire with aluminum. In most instances, utilities provide the medium voltage power distribution in and around a facility and utilize aluminum wire in their design. Aluminum is a common installation material for utilities in underground and overhead line applications.

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

Overcoming installation and design challenges

Installation

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

Some steps 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 forming a very thin oxide layer that 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 NO-OX 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 reduces the current carrying capacity through deformation and causes a hot termination.
- Aluminum-rated, two-hole compression connectors are to be used. Mechanical connections are not a suitable connection type because of the expansion properties of aluminum. However, some vendors disagree, claiming field electricians have more trouble using the wrong dyes 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 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. Using a pigtail or adapter from aluminum to copper and vice versa is also a viable option. However, this technique probably requires 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 of copper's. Because of this, aluminum cables must be larger to allow for the same current-carrying capacity as 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 often remains the same, but it still must be checked on a case-by-case basis. Today, aluminum cable is commonly compact stranded, compensating 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, explaining 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 are essential for any electrical distribution system, whether 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 are also an excellent practice to employ.

Conclusion

As with any significant change, there are risks involved in selecting aluminum for your design. You must weigh the pros and cons of aluminum vs. copper and ultimately decide based on each of their propositions. Finding an experienced electrical construction and engineering company will help you make an informed decision. Further, using a trusted installer means having properly trained field personnel who make good connections, reducing service calls and potential downtime.

Using aluminum at all in industrial projects may be a significant change for some, but every project can be evaluated for this financially beneficial option. The availability of alternative materials, at the very least, is an opportunity to examine the marketplace and make specific decisions about value for each unique facility.

Biographies

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As a Senior Project Engineer, Brent is responsible for projects from the proposal stage to completion. As Design Manager, Brent acts as a client sponsor, technical advisor, and leader, and assists in developing and mentoring his team members. Contact Brent at brent.kooiman@interstates.com.

Interstates

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[i] Since industrial applications are considered Interstates' main area of expertise, we have conducted research on using aluminum conductors as an alternative to copper.