ALUMINIUM AS A CONDUCTOR MATERIAL: A LIGHTER AND MORE ECONOMICAL ALTERNATIVE
Choosing conductive metals for different industries and applications can be a challenge. Copper is often used in cables and wires because of its excellent conductivity and malleability. But it is relatively heavy and expensive compared to aluminum. Switching to aluminum, which is lighter and significantly less costly than copper, is a viable option in many cases. Using aluminum successfully is a matter of understanding the capabilities of this conductive metal and how to deal with the challenges it presents.

Copper, at $4,323 per ton, is currently more than twice as expensive as aluminum, which costs $2,043 per ton (as of 02/02/15). The greater availability of raw aluminum compared to copper accounts for this significant difference in price. After oxygen and silicon, aluminum is the third most common element in the Earth’s upper crust, while copper is ranked 25th in availability on the list of raw materials. Assessment of current prices is further reinforced by the volatility of the raw materials market.

If one looks at the numbers from the last five years (2010-2014), copper prices fluctuated within a range from $3,674 to $5,980 per ton. In 2004, the annual average value was still at $1,895 per ton. No such fluctuation range exists in the aluminum sector, which allows for better material planning.

If aluminum is used as a conductor material, its lower conductivity requires a wire size that is approximately one-third larger than that of a copper wire. In the end however, the insulating material used with the wire plays a crucial role in performance and an aluminum wire can possess the same current carrying capacity as a H07RN-F copper wire. Aluminum’s larger wire size would only be a disadvantage in applications requiring tight spacing, such as when installed in densely packed control boxes.

The facts for aluminum speak for themselves when it comes to the issue of weight. As a raw material, aluminum is approximately 70 percent lighter in weight than copper. This can be helpful in the efforts of numerous application fields looking to reduce the weight of all components. Naturally, when used in electrical cables, the lower weight makes them easier to install. High-voltage lines have long been made from aluminum; the lighter weight reduces the tensile force placed on wire and masts significantly. But even industries such as automotive manufacturing and the aeronautical industry are switching to aluminum wires. This is why entire wiring harnesses made of aluminum are already installed in the Airbus A380.

![Chart showing the fluctuation in price between copper and aluminum.](image)
Aluminum wires can be up to 60 percent lighter than comparable current-carrying copper wires.

Even for applications that require flexible cable connections, copper no longer needs to be the first choice. The HELUWIND® WK POWERLINE ALU series provides a fine-wired wiring program, including connection technology.

The material characteristics of aluminum are considerably different than those of copper. These differences must be taken into consideration when processing a cable and selecting connection components.

**Oxidation in the air**

When exposed to oxygen, a hard and resistant oxide coating forms within a short period of time on the surface of aluminum. The coating protects the subjacent material from further corrosion. This effect makes aluminum a highly durable material. However, the protective oxide coating on the material surface is not desirable when it comes to electrical engineering. It degrades the conductivity of the aluminum and makes contacting difficult. If an oxidized conductor is connected without any pre-treatment (to remove the coating), the contact resistance will be increased between the aluminum conductor and the connector component. This can result in temperature increases and, under worst-case conditions, cable fires.

To prevent such problems, the oxide coating must be broken or removed physically. This can be done by brushing the bare aluminum conductor ends before contacts are made and also during the crimping process: Connector components for aluminum conductors are equipped with special contact grease from the factory, usually a grainy, abrasive material such as corundum. Combined with high pressure, the corundum particles cause an abrasive effect that breaks the non-conductive oxide coating on the aluminum, improving contact properties and electrical connections. The grease also prevents moisture and oxygen from entering and causing new corrosion of the contact points. Better quality cable lugs are generally equipped with plastic plugs, which prevent the contact grease from drying out or leaking during storage.

**Optimal contacting with C8 crimping**

For fine-wire conductor designs, we recommend that IEC 61238-1 Cl. A-tested C8 crimps be used due to the larger oxidizing surface of the conductor. C8 crimp’s contours penetrate very deeply into a stranded bundle, equally tear up the individual strands, and thus allow for optimum contacts on all strands, even in a bundled conductor. The use of C8 crimps (that have been developed as part of the POWERLINE Aluminum series) allows for the best possible electrical values (low contact resistance) and mechanical extraction forces to be reached.

**Compatibility with electrochemical precious metals**

When it comes to specifying electrical connection components, the corrosive reactions of aluminum in the presence of other metals – mainly copper – must also be taken into consideration.

When aluminum comes into contact with more noble metals (those with higher electropotential) such as copper, iron, or brass, an electrochemical reaction may arise by means of contact element formation. This reaction is activated by conductive liquids — in the field mostly by condensed water (condensation). In this process, the potential differences produced by the electrochemical voltage series play a crucial role. The copper electrode (anode), electrolyte (water), and the aluminum electrode (cathode) create a contact element. Any voltage across these elements is
short-circuited by the contact between the copper and aluminum. The resulting current creates a decomposition process in the aluminum, which is visible as a radiant oxidation point revealing the contamination of tiny copper particles. However, the copper does not decompose. But the decomposition process negatively affects the electrical connection over the long term, with increasing contact resistances that lead to temperature increases and even to fires.

Therefore, we recommend using an aluminum/copper (Al/Cu) cable lug for connecting aluminum to copper peripherals. Bimetal connectors such as Al/Cu cable lugs, press connectors and connecting bolt pins are manufactured using a friction welding process. They are encapsulated to prevent liquids from penetrating the connection and causing any unwanted creepage. The use of Al/Cu connectors and connections is the most sensible way of combating the effects of oxidation on aluminum. Another means of protecting against moisture is installing a secondary insulation on the contact area. Depending on the field of application, mechanical load, and environmental conditions, a cold-, a roll-, or a hot-shrink tube can be used. The best protection results are achieved by shrink tubes with inside adhesive. At the same time, the electrical contacts should be thoroughly inspected during regularly scheduled maintenance.

Decreasing connection strength due to creepage

Finally, the creepage behavior of aluminum is something that must be considered. Aluminum is a softer metal than copper and tends to expand or stretch over time, especially when subjected to higher pressure and temperature. Classic crimp connections suffering from creepage lose strength and would no longer be reliable to ensure proper connectivity. HELUKABEL’s C8 crimp exhibits a filling degree of 95 percent, which cannot be obtained with conventional crimp connections. The described expansion/stretch process is compensated with outstanding extraction values. At the same time, we recommend performing regular maintenance and inspection on all clamping points in accordance with their load levels.