General Cable AA8030 Aluminum Alloy Conductors:

A Successful Counter-Measure against Theft of Copper Street Lighting Cable

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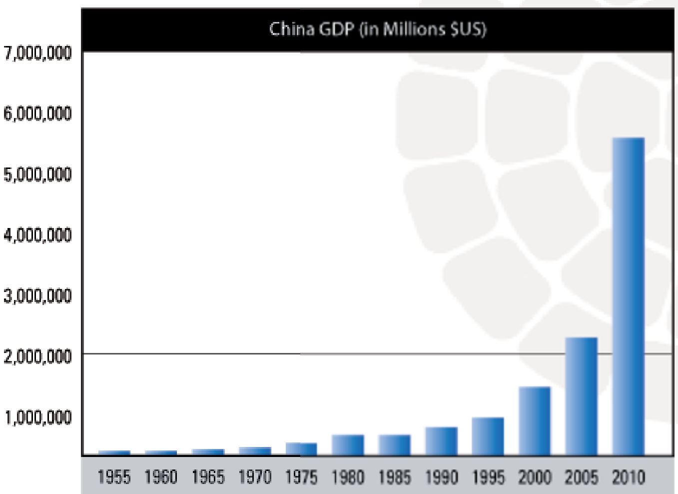
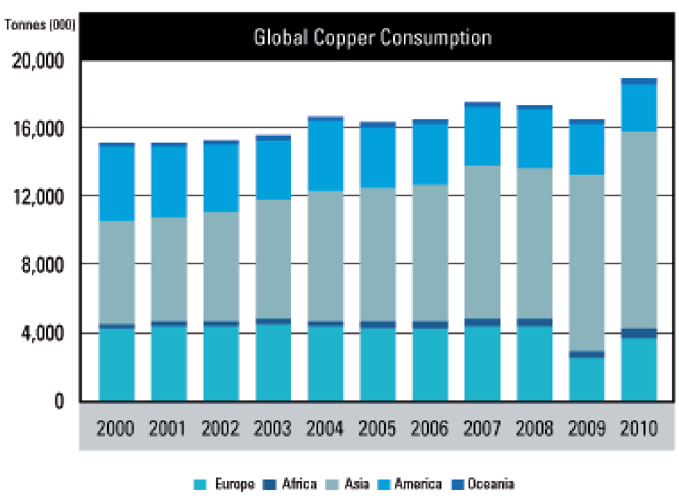
The Never Ending Rise of Copper Prices

Copper is one of the oldest metals used by humans and is important in its contribution to the development of human civilization. Copper has been used as a barometer for global economic health due to its widespread use in industrial and construction applications; thus allowing copper to acquire the title, Doctor Copper.

In 1990, China had a population of 1.13 billion and a Gross Domestic Product (GDP) of $US 388 billion. The same year, Canada had a population of 27.79 million and a GDP of $US 583 billion. Twenty years later in 2010, China's GDP stands at $US 5.76 trillion. This represents a nearly 15 fold increase in GDP. Economic development of this magnitude and pace is unheard of in recorded human history.





As a result of the rapid economic development, by 2010, China consumed approximately 40% of the world supply of copper and placed tremendous upward pressure on copper prices. As a result, copper prices on the London Metal Exchange rose from approximately $1500 US per ton ($0.68 per pound) in 2002 to $8500 US per ton ($3.86 per pound) in 2010. The rapid development of other large emerging nations such as India and Brazil also places upward pressure on copper prices. Consequently, the price of copper is expected to fluctuate between the $3.00US - $5.00US per pound for the foreseeable future.

Record Scrap Value

There are typically three kinds of scrap copper wires:

1. #1 Bare Bright Copper shall consist of No. 1 bare, uncoated, unalloyed copper wire, not smaller than No. 16 B & S wire gauge. #1 Bare Bright Copper has the highest scrap value.

On March 6, 2012, the scrap value of #1 Bare Bright Copper was $3.43 US per pound.

2. #1 Copper shall consist of clean, unalloyed, uncoated copper clippings, punchings, bus bars, commutator segments, and wire not less than 1/16 of an inch thick, free of burnt wire which is brittle; but may include clean copper tubing.

On March 6, 2012, #1 Copper has a scrap value of $3.33 US per pound.

3. #2 Copper shall consist of miscellaneous, unalloyed copper scrap having a nominal 96% copper content (minimum 94%) as determined by electrolytic assay. Should be free of the following:

   Excessively leaded, tinned, soldered copper scrap; brasses and bronzes; excessive oil content,
   iron and non-metallics; copper tubing with other than copper connections or with sediment; copper wire from

burning, containing insulation; hair wire; burnt wire which is brittle; and should be reasonably free of ash.

On March 6, 2012, #2 Copper has a scrap value of $3.13 US per pound.

This high scrap value is causing incidences of copper theft to rise throughout the US and Canada. In December 2011, the Federal Bureau of Investigation (FBI) released an article indicating that the unprecedented rise of copper theft due to the high scrap value is causing black outs that impact public safety and compromise critical infrastructure.[1]

From Hawaii to Florida, thieves have electrocuted themselves, caused electrical and telephone failures, and street light blackouts. Many municipalities, which have been hard hit by budget deficits, have been unable to afford repairs[2] . The biggest cost isn't what's being taken – it's fixing the damage. "For every dollar stolen, it is $10 to $25 worth of repairs[3].

In Canada, similar incidences have caused municipalities from the Pacific to the Atlantic millions of dollars each year. For instance, in 2011, the street lighting cable theft cost the city of Surrey, a municipality of the Greater Vancouver region, $3,070,000 and tied up significant local police resources. All forms of anti-theft measures deployed did not deter the theft of the copper street lighting cable. The reason stems from the fact that as long as the value of copper in the ground is sufficiently high, the thieves will find a way to steal the copper.

The only viable theft deterrent is to replace the copper cable with another type of cable that can provide equivalent performance and reliability but not the same scrap value. After considerable study and research, the city of Surrey decided on the use of General Cable's NUAL® AA8030 aluminum alloy RW90 conductors. Prior to the decision, the City of Surrey embarked on a number of trial locations and discovered that wherever NUAL® AA8030 aluminum alloy RW90 was installed, the thieves did not attempt to steal the cable. The thieves may cut into the conduit but upon seeing the conductors are aluminum, they opt to leave it in place. The reason for that can be clearly illustrated in the discussion below.

Prior to studying the cost of aluminum conductors versus copper conductors, it is important to understand the two different metals' physical and electrical characteristics. Below is a comparison table from an article written by General Electric.

Characteristics	Copper	Aluminum
Tensile Strength (Lb/In^2)	50,000	32,000
Tensile Strength for same conductivity (Lb/ In^2)	50,000	50,000
Weight for same conductivity (Lb)	100	54
Cross section for same conductivity (% of copper)	100	156
Specific resistance (Ohms-Cir/Mil Ft) (20°C ref)	10.6	18.52
Coefficient of Thermal Expansion (per deg. Cx10^{-6})	16.6	23

Source: A Comparison of Aluminum vs. Copper as used in Electrical Equipment, General Electric

As illustrated in the above table, copper is approximately twice the weight as aluminum with the equivalent conductivity. The weight of copper coupled with its cost is the main driver for street lighting cable theft.

The table below compares the scrap value of copper RW90 versus NUAL® AA8030 aluminum alloy RW90 on March 4, 2012. The table illustrates scrap values of copper and aluminum scrap that has been stripped clean of insulation.

Material	Size AWG	Ampacity 90° C	Metal Lbs/kft	No. Conductors	Total Lgs/kft	Scrap Value $/Lb	Length (Ft)	Total Scrap Value
CU RW90	#6	65	95	3	285	$3.43	3000	$2,932.65
NUAL® AL RW90	#4	65	39	3	168	$0.81	3000	$408.24

The fact that the equivalent ampacity #4 AWG aluminum conductors are less than half the weight of the equivalent #6 AWG copper conductors and the scrap value of aluminum in $/lb is about one fourth that of copper makes stealing aluminum wiring not profitable (keep in mind that there is considerable insulation stripping to be done after the cables are stolen and prior to selling the stolen product to the scrap yard in order to yield maximum salvage value). This means that the risk of getting incarcerated does not justify the value of stolen goods. As a result, there is a much lower tendency to steal aluminum cables.

Reduction in Initial Capital Cost

The use of AA8030 aluminum alloy conductors not only drastically reduces the probability of street lighting cable theft; it also drastically reduces the initial (or replacement) cable cost. Below is an approximate pricing comparison between copper and NUAL® AA8030 aluminum alloy RW90 conductors in the same 1 ¼" PVC conduit:

CEC Table 4 (NUAL® Ampacity no more than 3 conductors in raceway 75° C)	NUAL® Conductor Size (AWG	NUAL® RW90 Budgetary $/km	CEC Table (Copper Ampacity no more than 3 conductors in raceway 75° C)	Copper Conductor Size (AWG)	Copper Budgetary $/km
50	6	$639	50	8	$1,105
65	4	$787	65	6	$1,620

Safety and Performance Aluminum Conductors

Despite the fact that AA8030 aluminum alloy conductors have been used reliably since the 1970's, the general public is still under the impression that any aluminum wiring is not safe due to the issues stemming from aluminum branch circuit wiring of the 1960's and 1970's. The truth is that AA8030 aluminum alloy was specifically designed to obtain the desired mechanical properties necessary for building wire applications. In the late 1960's and early 1970's, AA1350 (also known as EC1350, or Electrical Conductor 1350), which is widely used for aerial transmission wire applications, was introduced for branch circuit wire applications. Although EC1350 has been and continues to be used successfully in transmission wire applications, it did not have the proper mechanical characteristics to be successfully used in branch circuit wiring.

Below is an excerpt from the article: Al-Fe Aluminum Conductor Alloys Part 1 from Key to Metals, One of the World's Most Comprehensive Metals Database:

> "Aluminum alloys with 0.5-0.9% Fe content have largely supplanted 1350 EC alloy for building electrical circuits because the latter frequently suffered from gradual loosening at terminals, which gave rise to overheating. This problem has been completely overcome in the new

conductor alloys without sacrifice of conductivity.
Aluminum 1350 Electrical Conductor alloy with a conductivity 61% of International Annealed Cu Standard has a mass resistively (0.0764 / for a 1 gm conductor 1 m long) which is only one half that of Cu (0.15328 / g/m2). The primary application is electrical distribution in buildings with potential in automobiles, aerospace, telephone lines and magnet winding.

To economically realize the weight advantage, aluminum wire must be capable of attaching securely to standard fixtures without special handling techniques. However, EC wire on binding screw terminals tightened to a standard torque can become loose. When the connection heats slightly due to a minor overload, the wire expands more than the Cu-alloy fixture and creeps to relax the added stress.

On cooling it contracts to a smaller dimension, thus reducing the area of contact and allowing oxide to form at the interface. On a subsequent large current flow the overheating increases so that additional plastic flow and loosening occur to further diminish the integrity of the joint. EC wire, annealed for adequate bend ability, has a substructure softening at 200° C and consequently fails due to repetition of such cycles.

The new alloys (8000 series) of 0.5-0.9% Fe have greatly improved microstructural stability and creep resistance and are not subject to such junction failure. At 180° C, the strength of annealed aluminum alloy falls from 125 to 116 MPa in 500 hrs and to 100 in 2000 hrs, whereas EC-Al falls rapidly to 104 and 82 MPa, respectively.

When annealed to the same ductility or bendability, the high Fe alloys are about twice as strong. This capability has been confirmed by field trials of several years in the United States, Europe and South Africa after these alloys were introduced in 1968."[4]

Connection Performance

As indicated in the Key to Metals Article: Al-Fe Aluminum Conductor Alloys Part 1, the composition of General Cable AA8030 conductors provides a major improvement in connection performance, which is at the heart of its ACM (CSA designation: Aluminum Conductor Material) designation. In particular, the addition of iron imparts a high level of resistance to creep when the conductor is fully annealed, and guarantees connection stability even during prolonged overloads and overheating. The key to ensuring exceptional connection reliability and performance is to pair the General Cable AA8030 conductors with connectors (mechanical set screw or compression) that are rated to accept the higher thermal expansion rates of aluminum. In Canada and the United States, these connectors are marked ALCU or CUAL. When used with CSA or UL certified 90° C rated mechanical connectors (marked AL9CU) the evidence from connector tests carried out at the Georgia Power test facility indicates a level of performance equal to or better than that of copper, connected in the same manner. In fact, the tests merely substantiate over 30 years of trouble-free operation in the field.

Note that connections to General Cable conductors should not be tightened on a regular basis, as this may deteriorate the connection.

Coefficient of Thermal Expansion

The coefficient of thermal expansion is used to calculate dimensional variations of any material subjected to a change in temperature. General Cable's aluminum alloy has a thermal coefficient slightly higher than copper, which means that it will expand or contract slightly more than copper. For this reason, aluminum conductor cannot be terminated with a copper-bodied connector. The converse is not true: aluminum-bodied connectors have been used reliably for years on both copper and aluminum conductors. As a result, the lower cost of aluminum-bodied ALCU connectors represents the majority of electrical connectors used today. When paired with the aluminum-bodied ALCU connectors, the expansion and contraction of General Cable's conductor and connector are identical; thus negating any response in the material due to changes in temperature.

Corrosion Resistance

Corrosion resistance is of primary concern in underground cable connections. The inherent corrosion-resistance of aluminum is due to the thin, tough oxide coating that forms instantly when a fresh surface of metallic aluminum is exposed to air. This type of oxide is particularly resistant to most types of corrosion. The ability of aluminum to withstand harsh environments is responsible for its widespread use in trays and conduit for electrical cable as well as many industrial components and vessels. When corrosion does appear, it is usually related to connections between dissimilar metals in the presence of moisture.

When connecting General Cable's AA8030 aluminum alloy feeder conductors to existing copper wiring in street lighting applications, it is very important to ensure the connectors used are designed to:

1. Accept both copper and aluminum conductors (ALCU).
2. Be rated for underground and direct burial applications to eliminate moisture ingress into the connection point. This is particularly important to ensure galvanic corrosion does not take place.

FeederPlex HS Conductors

General Cable produces a three (3) conductor or four (4) conductor multi-plexed product called FeederPlex HS®. This product has significant advantages for street lighting cable.

FeederPlex HS® is a factory produced cable assembly consisting of UL or CSA certified conductors. The plexed assembly significantly reduces the number of reels at the job site (typically from four reels down to one). Due to the fact that complete circuits, or multiple runs of shorter circuits can be wound onto one reel, set up time for pulling and materials management at the site are significantly reduced compared to pulling many single conductors from individual reels in conduit. In addition, magnetic fields between phases cancel each other out in the plexed assembly resulting in lower voltage drop.

FeederPlex HS® cables use a proprietary polymer in the insulation which significantly reduces the coefficient of friction. This allows FeederPlex HS® cable assemblies to be pulled with lower tension by winch or by hand. Eliminating lubricant application and clean-up also allows for faster and safer installations.

Conclusion

The theft of copper street lighting cable not only impacts the municipalities economically, it also presents a major safety issue for its residents. The relentless rise of copper prices due to the economic rise of China (India and Brazil to follow closely) will not stop anytime soon. As municipalities in North America experiment with numerous copper street light cable anti-theft measures, a few municipalities have found the most successful solution is to replace copper street lighting cable with AA8030 aluminum alloy cables. The advances in aluminum alloy technology ensure that AA8030 aluminum alloy cables perform equal to, or better than, the copper equivalent.[5]

References

[1] *FBI Stories, December 3, 2008: Precious Metals, Copper Theft Threatens US Infrastructure.*

[2] *The New York Times, February 7, 2011: Copper Prices and Incidences of Copper Theft Rise.*

[3] *Bloomberg Business Week, November 29 – December 5, 2010, The Great Copper Heist..*

[4] *Key to Metals, March 2012, Al-Fe Aluminum Conductor Alloys Part 1.*

[5] *Comparison of Conductor Performance, Georgia Power Research Center.*

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