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Aluminum Conductors

Considering risk, hedging and cost management strategies.

Electrical contractors operate in a business environment where they are constantly confronted with risk: poor workmanship can result in death or injury; poorly negotiated contracts can result in costly litigation; and poor cash-flow management can mean impending bankruptcy in a world of paper-thin margins. Most contractors have enough business acumen and experience to deal with these controllable risks. However, few are prepared to deal with a new form of risk that has emerged as result of escalating commodity prices — base metal pricing.

In the business world, risk is synonymous with volatility. The more volatility the more risk. Few would ever leave their money in the bank if interest rates fluctuated between -15 per cent to +15 per cent. One would rather invest in high-risk, penny

stocks, where such risk or volatility is not only expected, but also rewarded, by higher returns when they materialize. However, electrical contracting is not the stock market, and contractors are ill-equipped to deal with the 30 per cent price rise experienced in certain metals prices such as copper or steel in the last 18 months. It's important that small businesses and contractors are aware of some strategies that they can use to control this risk.

Hedging: Complex & Very Simple

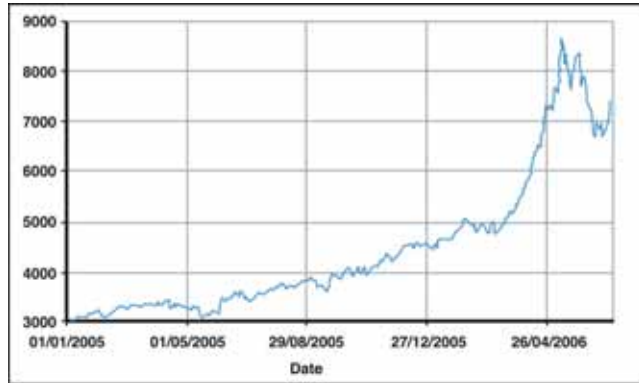
Hedging merely refers to the act of guarding against risk by taking an opposite position to that risk. Everybody has used hedging in one form or other. For example,

the act of buying RRSP's is hedging against inflation. If inflation goes up, interest rates and returns also increase at least at the rate of inflation; if inflation decreases, returns also decrease, but the compounded interest received on the tax savings, realized when purchasing the RRSP, more than makes up for the decreased returns. Hence, we have a simple hedge against the risk of inflation eroding retirement income.

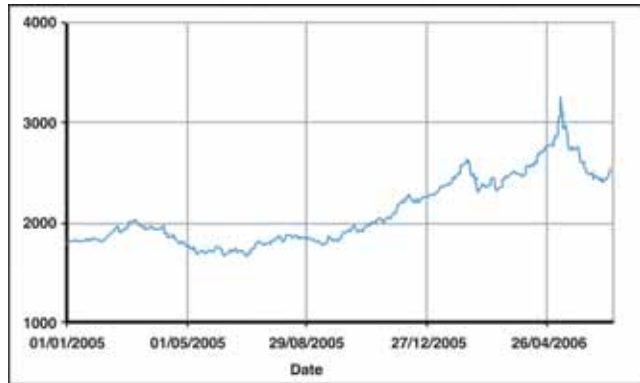
How does hedging relate to the contracting business? In a period of rising base metal prices, contractors can take an opposite position to the risk affecting a receivable or payable by using either forward contracts or futures. For example, a contractor can easily refer to a website such the London Metal



LME High Grade Copper Price US\$/mt



LME Primary Aluminum Price US\$/mt



These two pricing charts are available on the LME website. Prices shown are in \$US/mt and cover the period from Jan. 1, 2005 to July 1, 2006

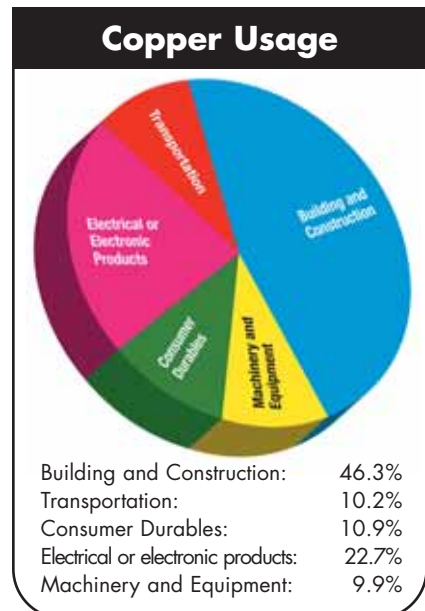
Exchange (www.lme.com) and obtain the market's prediction of where metal prices may go over the next 27 months (see chart above).

Suppose that conductors purchased in six months must be paid in nine months, and that metal prices are predicted to increase by 20 per cent during the next nine months. The contractor can do either of three things: negotiate an escalation clause when bidding to make sure he/she is properly compensated for rising metal prices; purchase enough forward contracts or futures with the proper duration (nine months) so that he/she can cash in the contracts at expiration and use the profits made (+20 per cent) to cover the losses on the contract (-20 per cent) and transaction fees (one per cent); or avoid using a

The Scoop on Copper

To understand the volatility of copper pricing (and the stability of aluminum pricing), one must first understand where copper is used. The following information from the Copper Development Association website describes where copper is used:

Building construction accounts for more than 40 per cent of all copper use. Residential construction is about two-thirds of the building construction market. The average single-family home is about 2,100 sq. ft., while a multi-family unit averages about 1,000 sq. ft..



Building and Construction:	46.3%
Transportation:	10.2%
Consumer Durables:	10.9%
Electrical or electronic products:	22.7%
Machinery and Equipment:	9.9%



volatile metal altogether and use one that has inherent price stability — the simplest solution of all. This metal in the case of electrical conductors would be aluminum conductor material or ACM.

- *An average single-family home uses 439 pounds of copper:*

195 pounds	building wire
151 pounds	plumbing tube, fittings, valves
24 pounds	plumbers' brass goods
47 pounds	built-in appliances
12 pounds	builders hardware
10 pounds	other wire and tube

- *An average multifamily unit uses 278 pounds of copper:*

125 pounds	building wire
82 pounds	plumbing tube, fittings, valves
20 pounds	plumbers' brass goods
38 pounds	built-in appliances
6 pounds	builders hardware
7 pounds	other wire and tube

- *General levels of copper use in major appliances:*

52 pounds	unitary air conditioner
48 pounds	unitary heat pump
5.0 pounds	dishwasher
4.8 pounds	refrigerator/freezer
4.4 pounds	clothes washer
2.7 pounds	dehumidifier
2.3 pounds	disposer
2.0 pounds	clothes dryer
1.3 pounds	range

- *Some 10,000 copper range hoods and 20,000 weather vanes are produced annually, using about seven pounds of copper each.*

- *There is an average of 50-55 electrical outlets per home and some 15-20 switches. That translates to between two-and-a-half and three pounds of copper alloy for these uses per house.*

Obviously, electrical and electronic products are associated closely with building and construction. As a result, an increase in building and construction will also positively impact the amount of copper used for electrical and electronic products. As such, nearly 70 per cent of copper usage is closely tied to the building and construction cycle. With the economies of China and India growing at 10 per cent and eight per cent (estimated for 2006) respectively, the global building and construction sector will continue to place a great

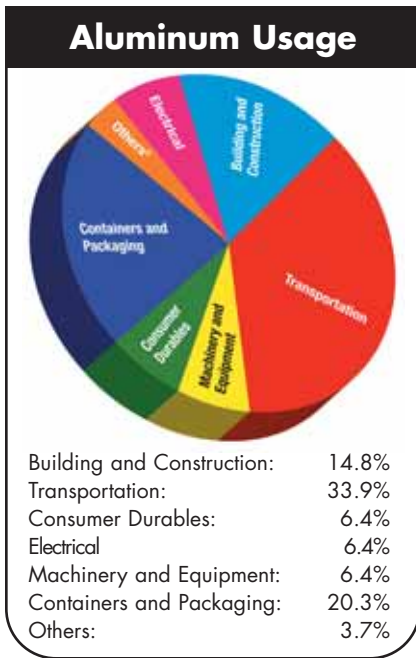
demand on copper. Consequently, unless there is a surge in production, copper prices may remain high for the foreseeable future.

The Diversity of Aluminum Usage

Aluminum usage on the other hand is much more diversified than copper. Information from the Aluminum Association on aluminum usage indicates the following breakdown by domestic (North American) market. The remaining 8.2 per cent is export.

Aluminum usage is much more diversified and much less affected by increased consumption in any one sector. Consequently, this diversification is the main reason for aluminum's stable pricing over the years.

However, in order to understand the suitability of aluminum as a current carrying conductor used in industrial, institutional and residential markets, one must look at a number of characteristics.



Conductivity of Metals

There are numerous metals on Earth that are suitable for use as electrical conductors.

Below is a list of metals and their relative conductivity based on volume (500 kcmil conductor).

1. Silver	108.4% IACS (volume basis)
2. Copper	103.1% IACS (volume basis)
3. Aluminum	64.9% IACS (volume basis)
4. Magnesium	38.7% IACS (volume basis)
5. Steel	9.0% IACS (volume basis)

Below is the same five metals' conductivity based on weight (one pound or kilogram of metal).

1. Aluminum	213.7% IACS (weight basis)
2. Magnesium	197.7% IACS (weight basis)
3. Copper	102.6% IACS (weight basis)
4. Silver	91.9% IACS (weight basis)
5. Steel	10.3% IACS (weight basis)

Although silver has the highest conductivity by volume of any metal, its high cost makes it uneconomical. Magnesium's and steel's low conductivities by volume make them impractical for building wire applications. This leaves copper and aluminum to be the most economical and practical metals to be used as current-carrying conductors. As shown above, it takes two pounds of copper to equal the same current-carrying capacity of one pound of aluminum.

Aluminum's high strength-to-weight

ratio and high conductivity based on weight resulted in utilities using aluminum transmission wires almost exclusively. In the U.S. and Canada, utilities have used aluminum wire for over 100 years. The lightweight conductors enable the utility to run transmission lines with half the number of supporting structures. The utility system is designed for aluminum conductors, and utility installers are familiar with installation techniques for the types of aluminum conductors used in utility applications.

Coefficient of Thermal Expansion of Various Metals

During the late 1960s, copper shortages and high prices made aluminum branch-circuit conductors a very attractive alternative. At the same time, steel screws became more common than brass screws on receptacles. The aluminum wire and the receptacle devices were both listed in accordance with the available product standards. As aluminum wire was installed more frequently, the industry discovered that changes were needed to improve the

means of connecting and terminating smaller aluminum wire. Installation methods for utility grade aluminum conductors were also different, and workmanship was an important factor in making reliable connections.

The use of steel screws with utility grade aluminum wire resulted in a connection point that was more sensitive than copper or aluminum wire terminated with the previously used brass screws. Almost all reported problems involved 10 AWG and 12 AWG branch-circuit connections.

Poor workmanship is generally recog-

nized as the primary source of failed connections. Incorrect installation methods included incorrectly tightened connections, wires wrapped the wrong way around binding screws, and aluminum conductors used in push-in connections or with devices meant only for copper. Poor workmanship caused a chain of events to be initiated that sometimes led to failure at the connection. The connection was loose to begin with due to improper tightening torque, and the physical properties of the aluminum/steel interface tended to loosen the connection more over time.



Coefficients of Thermal Expansion of Various Metals in $\mu\text{m}/\text{m}/^\circ\text{C}$

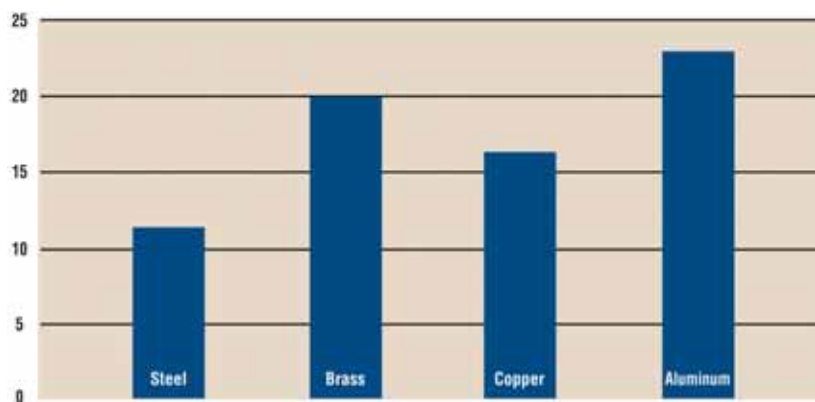


Table 1. Coefficients of expansion

Aluminum and steel have significantly different rates of expansion (see Table 1). Because the two materials would expand and contract at different rates under varying load and temperature conditions, they would gradually develop a smaller contact area. Since the contact area was reduced, the resistance increased. As the resistance increased, the temperature also increased at the termination point. A similar problem

occurred when the aluminum conductors were incorrectly terminated in the push-in connections intended only for copper conductors.

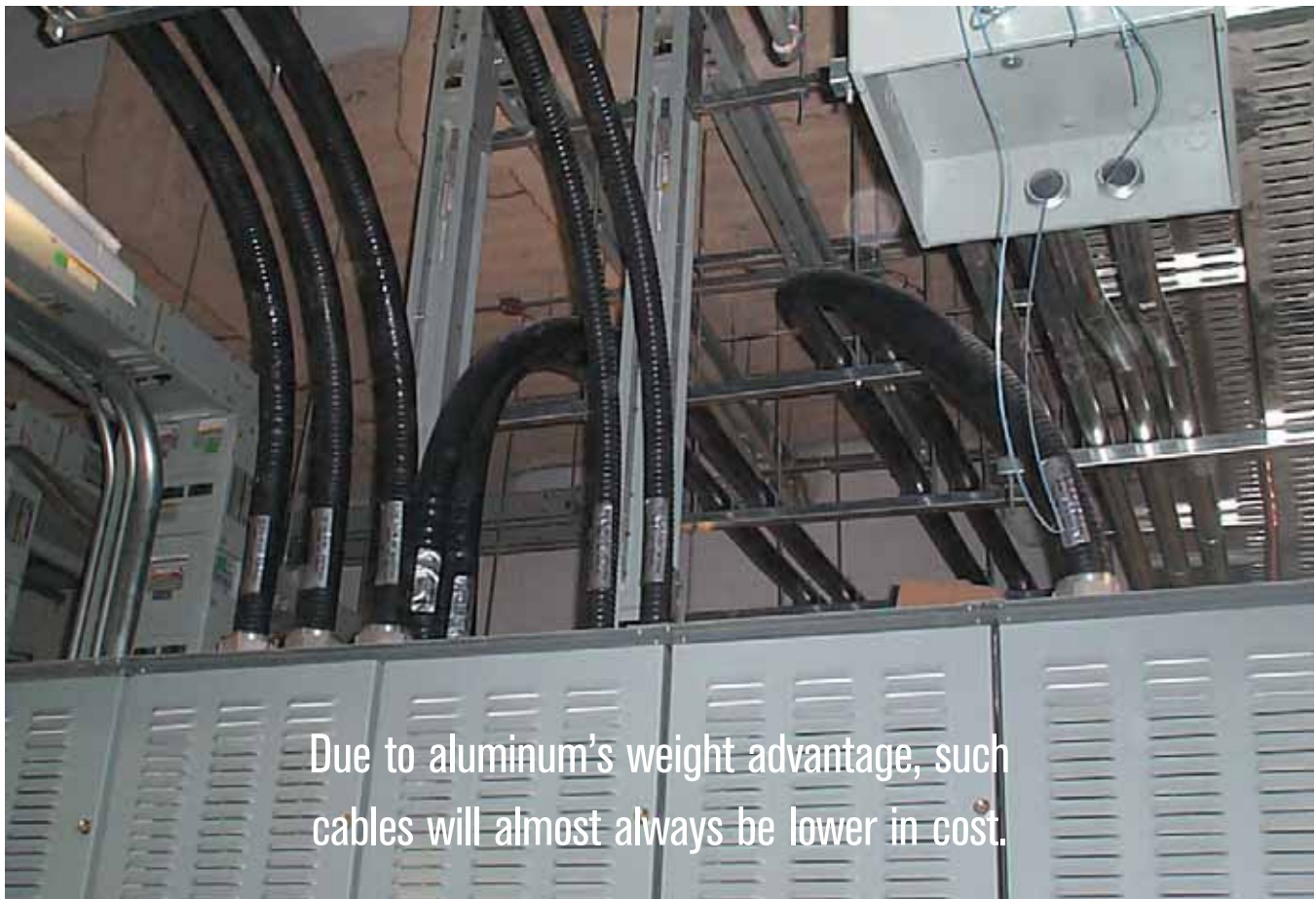
Aluminum Wire in the Canadian Electrical Code (CEC)

The CEC has required aluminum alloy conductors for branch-circuit wiring (12 -

8 AWG) since 1981. The Code never explicitly prohibited 1350 EC Grade aluminum building wire; however, recent changes to the CEC Code Part II (January 2006) have in effect made the requirement that building wires be made of ACM (AA8000-series alloy). These alloys were developed in the late 1960s and were listed and manufactured beginning in 1972. At about the same time, CO/ALR devices were required for aluminum wire branch circuits and listed by UL. These devices were developed to be used reliably with 10 and 12 AWG conductors and must have brass screws.

Creep Characteristics & Connection Stability

Another property of aluminum that is often referenced is known as the creep of a conductor. Creep is a property of all metals, and each metal has a unique rate of creep. Creep is the measurement of the rate of change of a material's dimensions over a period of time when exposed to a force at a particular temperature. EC grade aluminum



Due to aluminum's weight advantage, such cables will almost always be lower in cost.

building wire has a higher creep rate than copper building wire. In comparison, AA-8000 aluminum alloys have creep rates very similar to copper building wire. This means that AA-8000 conductors perform very much like copper conductors at terminations.

Cold flow is a related term that also refers to the permanent deformation of a material when subjected to a force; however, cold flow is the result of a momentary force and does not vary over time. Cold flow is a necessary property of metals that allows a good connection to be made between separate components during the connection process.

Corrosion Resistance

Corrosion is often cited as a contributing cause of failure at aluminum connections. In 1980, the National Bureau of Standards performed a study to determine what caused the high resistance at aluminum/steel connections in receptacles. The study revealed that the formation of intermetallic compounds (alloys of aluminum and steel) caused the high resistance terminations, not corrosion or aluminum oxide.

A thin film of corrosion products does form on an aluminum surface spontaneous-

ly, acting as a barrier to further oxidation. When this layer stops growing at less than a micrometre thickness under the conditions that a material will be used in, the phenomenon is known as passivation. For example, rust usually grows to be much thicker and is not considered passivation (the oxide layer is not protective anyway). While this effect is in some sense a property of aluminum, it serves as an indirect kinetic barrier. The reaction is often quite rapid unless, and until, an impermeable layer forms. This thin, protective layer of oxide on aluminum conductors contributes to the excellent corrosion resistance of aluminum. When terminations are made correctly, the oxide layer is broken during the termination process allowing the necessary contact to be made between conducting surfaces.

Costs

Due to the weight advantage of aluminum (two pounds of copper to equal the same current carrying capacity of one pound of aluminum), aluminum will almost always be lower in cost. However, the cost savings is but one part of the whole picture. When bidding a project, contractors must have predictable costs that are within their control over the course of the construction period. Volatile fluctuations in material cost will end up eating into the contractor's profit.

Aluminum with its diverse applications lends itself to long-term stable pricing. Stable and predictable pricing translates to stable and predictable profits.

For more information on aluminum conductors, circle reader information no. 15 ■

Footnote:

ACM conductors are marketed and sold in Canada by Alcan Cable under the brand name NUAL®

References:

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3. Christel Hunter, Alcan Cable, "Aluminum Building Wire Installation and Terminations"
- 4, 5, 6. *ibid*
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