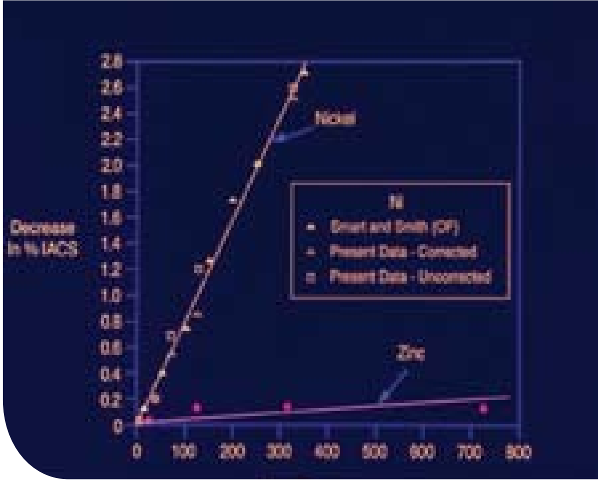
FIRE-REFINED COPPER: CHARACTERISTICS AND APPLICATIONS



Effect of nickel and zinc upon electrical conductivity of copper

Most of the copper that is used globally has been refined by an electrolytic refining process. If electrolytic copper contains oxygen, the term tough-pitch (ETP) is used. When high electrical conductivity is an important property, the minimum copper content including silver is usually not less than 99.9 %.

By ASTM's definition, high-conductivity copper must have a minimum electrical conductivity of 100 % IACS (International Annealed Copper Standard) in the fully annealed condition. Specific details of manufacturing methods to achieve this physical property do not need to be designated, and can therefore be either electrolytically refined or fire-refined. The latter term refers to copper of any origin or type that is finished by furnace refining. If this copper contains oxygen, it is designated as Fire-Refined Tough-Pitch (FRTP), but if it has the aforementioned minimum 100 % IACS, it is known as FRHC (Fire Refined High Conductivity).

Although fire-refined copper had been used commercially in the form of wire bars for more than half a century, there has been a surge of interest in FRHC rod and wire during the past two decades or so. Major reasons for the increased usage of this copper alloy include lower manufacturing costs and an increase in production efficiency while still attaining many of the required physical and mechanical properties. Some of these factors are briefly discussed in this article, together with technical merits.
In consideration of the growing importance and quantity of FRHC rod produced with Properzi equipment, the ASTM Committee on Copper and Copper alloys is conducting work to update the B49 Standard pertaining to copper rod for electrical purposes.

Inasmuch as the recycling rate for copper is greater than that of any other metal, it is not surprising that nearly as much copper is recovered from recycled material as is derived from newly mined ore. Considerable technological efficiency has been developed of late by the design and construction of extremely large top loading refinery furnaces.

However, the fundamental metallurgical processing steps for fire-refining have not changed appreciably, and include charging copper scrap as low as 93 % - 94 % melting, oxidizing, fluxing, slag removal, reduction of excess oxygen, and casting, oftentimes within a 24 hour cycle. A few of the impurities that have high vapor pressures such as S, Cd, and Zn are partially lost during melting due to volatilization. More important, however, impurities whose oxides have a higher free energy of formation than copper, such as Al, Cr, Fe, Ag, Sn, Zn, Ni and Pb will tend to form stable oxides that can be easily removed from the slag, albeit some fluxing may be required.

Residual impurities in both ETP and FRHC copper may cause identical detrimental effects, such as reducing electrical and thermal conductivity, increasing the annealing (recrystallization) temperature, hampering fine wire drawability, and degrading wire conformability during coil winding. Much of the basic work on annealing behavior and electrical properties was performed during the 1940's on high purity copper (99.999) that was alloyed with different elements to produce binary alloys for subsequent laboratory investigations. These studies have served as the foundation for commercial wirebars and continuously cast ETP and FRHC rod. Unfortunately, four important metallurgical variables make prediction

THROUGH A THERMAL REFINING PROCESS

Copper scrap: a real bank of energy

of the behavior and properties from measured chemical compositions alone somewhat difficult.

First, the laboratory studies were made on alloys in which the residual elements were dissolved in the copper matrix, where they have their maximum unit effect. In contrast, their effects are diminished if the elements precipitate out of the copper solid solution, which can easily occur during hot rolling and annealing by slow cooling from elevated temperature.

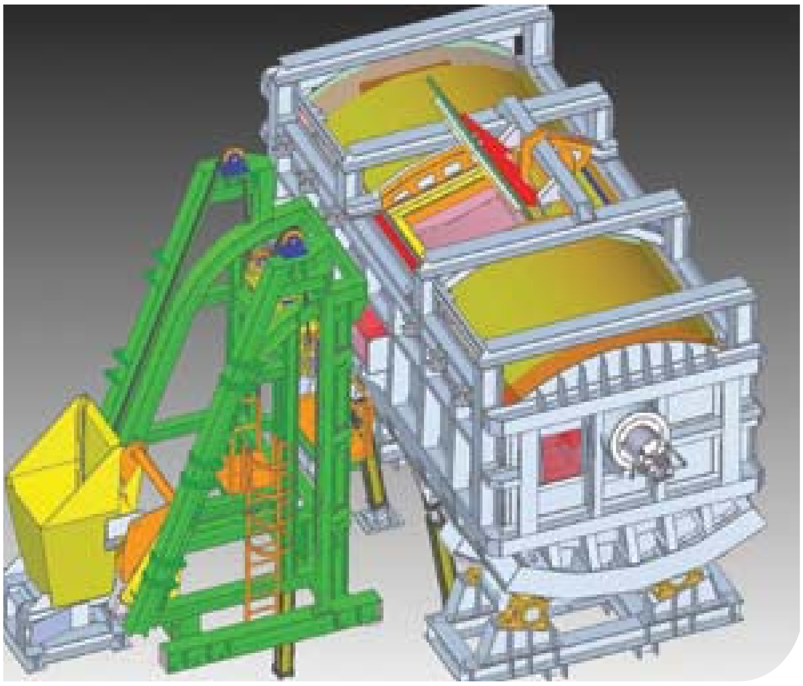
Second, interactions may occur between the different residual elements in commercial copper to form intermetallic compounds, as for example, when lead reacts with sulfur to form PbS, thereby negating the detrimental effects of each element.

Third, oxygen tends to react with the impurities, making them less harmful because they are removed from the copper matrix.

Finally, certain elements such as lead have been shown to be beneficial at higher levels than permitted in ETP because they reduce the tendency to have high temperature cavitation fracture occur during solidification and hot rolling.

In summary, the benefits of FRHC copper rod compared with ETP copper rod include lower manufacturing costs, very good electrical conductivity (>100 % IACS), the ability to recycle scrap, good drawability in rod breakdown machines, and being able to produce wire in multi wire drawing machines. Disadvantages include higher annealing temperatures. Both ETP and FRHC alloys ought to have similar uniform surface oxide thicknesses and sub-surface oxide contaminants, twist test performance, adequate drawability at larger gauge sizes, and eddy-current quality on finished rod. Although use of FRHC rod for magnet wire applications is questionable at this time, potential markets include building and automotive wire, power cable, can wire, telecommunications applications, and ground wire.
By Horace Pops

Typical coils of FRHC rod



View of the state-of-the-art Properzi patented refining furnace: the heart of the technology