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"COPPER SCRAP: AN OLD CHALLENGE…AND AN OPPORTUNITY OF TODAY"

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Abstract

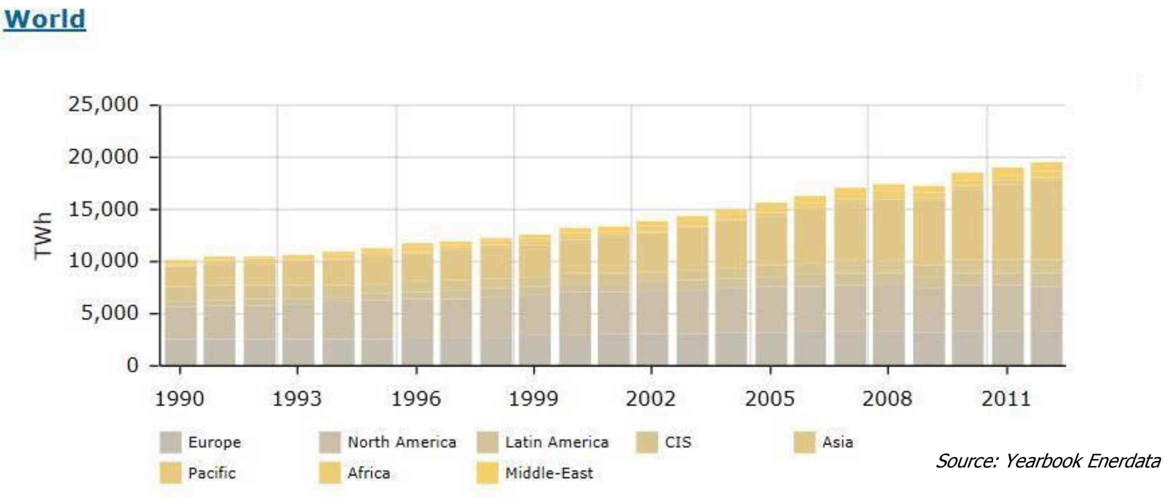
The growth of any country implies the growth of the demand for electrical power and fuel and the improvement of the telecommunication network. This process involves a growing demand for raw materials such as steel, aluminium, plastic, copper, etc. In this scenario the role of recycling in the industry chain is oftentimes the discriminant factor for sustainable growth. For instance, copper scrap and residues provide a valuable raw material for a wide range of semis including rod, ingots, billets, and slabs that are then transformed in a myriad of fabricated products. For this reason the trade of scrap worldwide has reached nearly 6 million tons per year. The present paper illustrates the recycling technology and the related equipment to resurrect low-grade copper scrap into copper rod (FRHC – Fire Refined High Conductivity) with mechanical characteristics and conductivity suitable for a wide range of applications in the cable industry. In particular, this paper will analyze and describe what kind of copper scrap can be used in the thermal refining process for producing FRHC copper rod and how it compares, quality wise, with ETP rod.

1. Electric Energy – A Vital Lymph for Growth and Development

Available data indicates world population reached seven billion during the year 2012 while approximately 900 million people had very scarce access to food and more than 2.1 billion people were considered overweight. According to some research made available by ONU, in 27 years from now the world population will reach nine billion growing at an average rate of 1.4% per year.

It goes without saying that a country's economy, and by that, the welfare of its people, depend on secure, reliable and up-to-date energy and communication networks in addition to access and availability of natural resources. Electric energy (EE) plays a fundamental role.

The chart below displays the growth of EE consumption during the past 20 years (more precisely from 1990 through 2012) with reference to the main macro-geographic areas.



Picture 1 – Chart of EE Consumption 1990-2012

As we can see, during this period of observation (1990-2012) the demand/supply of EE has continued growing despite a minor setback in 2009 as a consequence of the global crisis of the last quarter of 2008, jumping from 10,000TWh (1990) to approximately 19,000TWh in 2012; we could say that in 22 years it has almost doubled.

Referring to the data available relevant to 2012, China – 1.35 billion people – has been the largest consumer of EE with an aggregated demand of approximately 4,300TWh, followed by the USA – 310 million people – with approximately 3,800TWh. It is important to note the modest demand of India – 800TWh for 1.2 billion people – when compared with the demand of China since the two huge countries are comparable in population. Why so? Evidently this is due to the different levels of industrialization and urbanization and, among the others, we should not forget the fact that currently about 400 million people in India live without access to EE. However, several years ago, India instituted the Electricity Act 2003 that has liberalized the production of EE. In the sector of aluminium, this circumstance has encouraged the big players, Vedanta and Hindalco, to add an astounding aggregated amount of 800,000tpy of rod to their existing production capacity.

Although we have now focused our attention on India, we should not forget that approximately 20% of the world's population currently has no access to EE.

According to the forecast of ExxonMobil, in the next 27 years the aggregated demand of EE will reach 32,500TWh with a growth of approximately 80%. It will take time but the portion of population without access to EE will diminish remarkably in the coming years. We all hope that this growth will be environmentally and socially sustainable and, in our capacity as a supplier dedicated to this sector, we will have the tremendous responsibility and the unique privilege of contributing, with our equipment, products, technologies and services, to the success and swift realization of the dream…"*electric power for everybody*".

2. The Nonferrous Rod; the Backbone of EE Transmission and Utilization

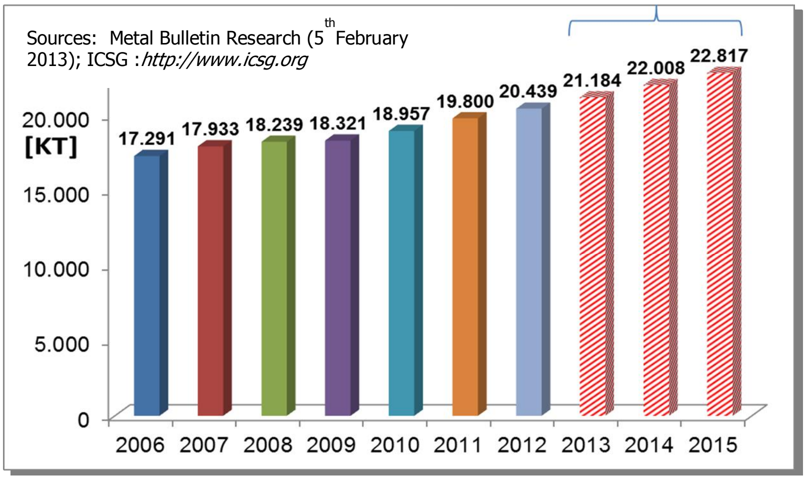
Continuus-Properzi started this mission more than six decades ago bringing its technology and its equipment for producing nonferrous rod – mainly aluminium rod at that time – to the major players of the Cable Industry worldwide. Picture 2 displays the Properzi Rolling Mill Mod. 6B. We could say that this machine contributed to the electrification of our world during the period 1950-1965. Just to put some reference numbers on the table, in that period the aggregated demand of EE worldwide went from 1,850TWh in 1950 to 3,700TWh in 1965. In 1960 the overall production of aluminium was in the range of five million tons and there were approximately 50 Properzi Al rod lines in operation in 19 countries. The total annual output of those 50 lines, optimistically, was in the range of 500,000 tons; five modern Lines of 15tph each give the same output today!

Picture 2 – The Hystorical Rolling Mill 6B

Over the years, aluminium rod and copper rod have remained the basic semi-finished products concerned with the various utilization of electric energy (production, transportation, distribution, motors, transformers, etc.).

At the end of 2012 we estimated the aggregated annual production of aluminium rod worldwide to be approximately 5.3 million tons, whereas the total production of primary aluminium was in the range of 45 million tons. Considering these figures, on a global basis the portion of aluminium transformed into rod is in the range of 11% of the total.

The scenario in the copper sector is completely different. Picture 3 displays the production of refined copper from 2006 through 2012 and the forecast for 2013 through 2015.



Picture 3 – Trend of Copper Demand (2006-2012); Forecast till 2015

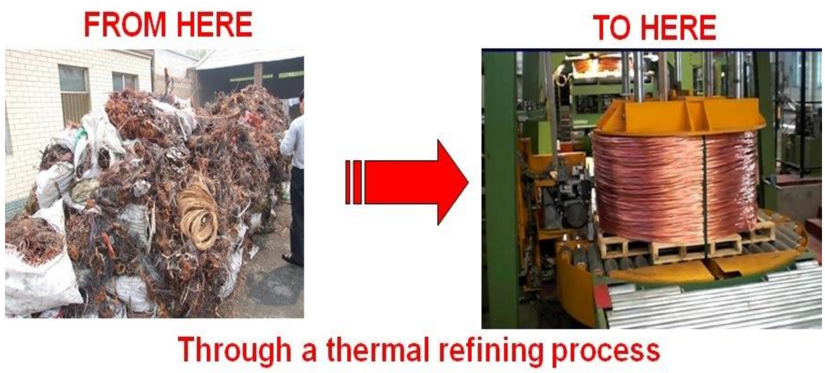
Analyzing the data made available through Wood Mackenzie [Metals Market Insight – Nov. 2011], we can assume that 57% of copper goes for electrical applications while the balance (43%) is used for applications other than electrical. Although the above analysis concerning the use of aluminium and copper for electrical applications might be affected by minor imprecisions or discrepancies, nonetheless this will give a reliable idea about the utilization of copper worldwide.

What follows will be related only to copper rod and the usable/available raw material for producing copper rod.

3. Possible Raw Material for Producing Copper Rod

Copper rod is available worldwide in the form of coils having a weight ranging from 3,000kg to 5,000kg and standardized geometrical dimensions. Currently, only two main technologies are used for producing copper rod: the Up Cast Unit and the Continuous Casting & Direct Rolling System either based on Wheel and Belt Caster or on Twin-Belt Caster followed by three-roll rolling technology or two-roll technology.

The vast majority of copper rod producers use electrolytically refined cathodes as raw material to get either OF (Oxygen Free) rod or ETP (Electrolytic Tough Pitch) rod. A valid alternative to the use of cathodes is the use of 100% copper scrap as raw material to produce, through proper refining technology and equipment, the well-known FRHC (**F**ire **R**efined **H**igh **C**onductivity) rod. Over the years several technical papers have illustrated the technology for going from scrap to rod in one step, skipping the costly phases (1) from scrap to anodes, (2) from anodes to cathodes, (3) from cathodes to rod, and the range of application for FRHC rod; therefore we will not revisit these topics again. It is however interesting to recall that Properzi started dealing with the technology of refining copper scrap in the late 1950s/early 1960s when the trials aimed at extending the method of continuous casting and direct rolling to the production of copper rod were begun.



Picture 4 – From Scrap to Rod

In 1960 the overall production of refined copper was slightly less than 4 four million tons but cathodes were not available on the open market and therefore the use of copper scrap was the only way to test and set up the "new" technology of continuous casting and direct rolling for copper. It should not be hard to imagine how difficult it must have been to set up a new technology using a raw material (bright copper from the drawing shop and old wires) to get molten metal with little chance for repeatability of chemical composition and oxygen content. In addition, the laboratory, as we know it today, was either non-existent or very rudimental.

Melting furnaces were static and fired by oil containing a high content of sulphur! Scrap was refined bringing the oxygen content of the melt up to a range of 8,000 to 10,000 ppm without measuring the ppm but only by observing the manner in which a sample solidified and the color of the cracked sample.

Reduction of the oxygen content was done submerging an entire, fresh tree into the melt until the next copper sample seemed good enough. Despite the enormous difficulties that we have tried to briefly describe, the Properzi System was created and successfully delivered to the copper wire industry; can we say it was almost a miracle?

Meanwhile, during the 1970s copper producers made cathodes available to the open market and ETP copper rod became the winning commodity worldwide.

During the mid-1980s we had the chance of supplying to La Farga Lacambra – Spain – a complete plant for the production of copper rod using scrap as raw material. The "*feasibility trials*" were done in Turkey by adapting, in some way, a 20-ton holding furnace, part of a running ETP Properzi plant, for the refinement of copper scrap. This was the "hardware", while the "software" was the updated experience accumulated during our pioneer trials in the 1960s, as explained above, and coupled with the experience of the Spanish company.

The entire project was a great adventure and finally a rewarding success. During the years La Farga increased their business, their technology and their products, eventually becoming one of the largest participants of the copper industry in Europe.

In June 1988 the two companies formalized a cooperation agreement involving the licence of La Farga refining know-how in combination with the sale of Properzi refining furnace and CCR plant. The Cold War was nearly over and, in one year or so, the world would have witnessed the fall of the Berlin Wall and the birth of the era of globalization with the admission of China into the WTO.

We all know that copper is recyclable, more so than any other commercial engineering material, without incurring any major deterioration. Therefore, copper scrap can truly be considered as "the Bank of Energy" storing the precious energy that has been used to convert the ore into copper. Scrap is being consumed, where available, in both the supply and consumption chains so, if we look at the data available for 2012, it illustrates that the trade of scrap worldwide has reached nearly six million tons. However, approximately only 10% is converted into FRHC rod solely using, at the present time, Properzi plants. We should also point out that the most aggressive "competitor" to copper - aluminium – is also recyclable, but in each refinement it loses some of its properties; therefore, it is not used as raw material for producing electrical conductors but is used mainly for billets, ingots and, eventually, rod for de-oxidation of steel for steel makers.

Continuus-Properzi's commitment is to make all reasonable efforts to render the use of scrap for the production of copper rod more widespread by making the plants more and more user friendly and environmentally sustainable.

4. <u>Improvements in the Equipment</u>

Great work has been done by La Farga and Properzi as the FRHC rod of today is an economic commodity which, by resurrecting copper scrap of first, second and third quality, can comply with ASTM-B49 and EN1976 standards. It can be processed in high speed multiwire drawing machines down to 0.4mm–0.3mm (0.25mm for experienced producers) and used in many engineering applications other than fine wire, ultra-fine wire and magnet wire, as we have remarked.

The FRHC rod is produced in a batch process (the basic input design considers 300 working days per year) meaning that each day the copper scraps are loaded into the empty refining furnace where the phases of melting and refining are completed in about 17-18 hours. After that the furnace pours the liquid metal into the CCR line for transformation (through casting and rolling) into 8mm rod or larger diameters up to 23mm.

The table below displays the typical chemical composition and characteristics of FRHC rod.

Parameter	Reference	Value
Chemical Composition	Cu+Ag %	>99.90
Oxygen	Ppm	150 ÷ 250
Elongation	A_{100} %	45 ÷ 51
	A_{200} %	38 ÷ 43
Tensile Strength	Kg/mm^2	22.8 ÷ 23.5
Conductivity	IACS %	100.5 ÷ 101.3
Twist Test to Failure	No	43 ÷ 50
Best Drawability	mm	0.25
POPS Test – Surface Oxides	Ångstrom	100 - 200
Re-crystallization Temperature	°C	250 ÷ 280

Over the last twenty and more years Continuus-Properzi has delivered and put into operation several dozen refining furnaces and copper rod lines in many countries around the world including Italy, Korea, Iran, China, India, former Soviet Union, etc. The smallest plant has a capacity of 10,000tpy whereas the largest plant recently commissioned in the USA, at the SDI-La Farga Facility, has a capacity of 75,000tpy and is equipped with a revolutionary refining furnace, patented by Giulio Properzi, which loads the scrap from the top.

Picture 5 – View of Properzi Refining Furnace during the Erection

It is part of the nature of business relationships that even the most consolidated ventures and cooperation agreements must be checked and revisited from time to time in order to assess the actual compliance of their objectives with the needs of the market, taking into consideration the rapid obsolescence of the most updated concept design and points of view.

Under such logical considerations, La Farga and Properzi decided on the consensual termination of their previous cooperation agreement and agreed to proceed independently to anticipate and follow-up different ideas about the market and the technology, although not excluding the possibility for collaboration on a case-by-case basis. This news was made public in November 2012.

We have now developed and realized our ideas on how a system to produce FRHC rod should be configured. Below are the main points under development:

a) The furnace must have our patented system for charging scrap from the roof and not from the side.
b) The charging of scrap into the furnace must be done with a conveyor belt or a skip hoist machine and not by wheeled front loaders, for a faster and less energy intensive result, thereby keeping this phase near to a seven-hour period.
c) The slagging operation must be facilitated by a dedicated device and should not be totally manual.
d) The CCR line must be powerful enough to empty the furnace in a maximum of seven hours, instead of eight hours as previously preferred, providing the opportunity for a refining phase that can be up to ten hours, if so required by the circumstances.

We would like to provide further explanation about items a) and b), while items c) and d) are self-explanatory.

Picture 6 – View of the Previous Charging System

Charging scrap, especially loose scrap, is an inefficient operation in itself because of several reasons: difficulty in loading, labour intensity, low thermal efficiency and pollution.

As the furnace gets bigger, the charging operation becomes more difficult. This is due to the fact that the capacity of the charging machine or the front loader is limited by the size of the door and is further exacerbated because of the need to spread the scrap inside the furnace. This will cause several cycles of opening and closing of the door: for instance, to feed one furnace with 150 tons of loose scrap approximately 60-70 door openings are needed. This equates to almost two hours of fumes and heat loss resulting from the opened door; two hours of the eight-hour charging/melting shift is 25% of the time!

In other words, our current system of recycling copper scrap into FRHC rod is more energy efficient, more user friendly, more environmentally friendly and dedicated to refining with less stress for the operators. In summary, it is more profitable.

This new idea sounds simple, but one could also say that the vast majority of inventions sound simple once the inventor has explained how to do that which has never been done before.

5. <u>Conclusions</u>

"Prediction is very difficult, especially about the future." However, prominent sources forecast that in the next 27 years – we could call it "vision 20-40" - the global population will reach nine billion and the total figure for EE demand will be 32,500TWh.

Wire and cable will play a fundamental role in the sustainability of such an increased demand for EE. Renewable energy will grow, especially solar and wind farm; the latter will cover approximately 20% of the extra demand from today's figure. All telecommunication devices, including wireless devices, generate signals but, again, these signals need to be transported via wire and cable.

Copper rod and aluminium rod are and will remain the basic semi-finished material for producing wire and cable. Certainly new standards will be required for making the overall process of fabrication of cable and wire more economical.

In its capacity as the industry leader, Continuus-Properzi has the privilege and the responsibility of innovating the technologies and the equipment that have been designed and supplied to the industry for several decades.

In particular, Continuus-Properzi's commitment will address the modernization of FRHC plants to exploit the refining technology for making rod from scrap more efficient, more sustainable and more and more environmentally and user friendly.

Our industry is sometimes invisible but always indispensable: imagine life without wires and cables!

6. References

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