ELECTRIFYING THE FUTURE

Copper Metallurgy

Huelva, December 20th 2022

Good practices of metallurgy of copper

European Institute of Innovation & Technology

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ELECTRIFYING THE FUTURE

Before we start…

FREEPORT
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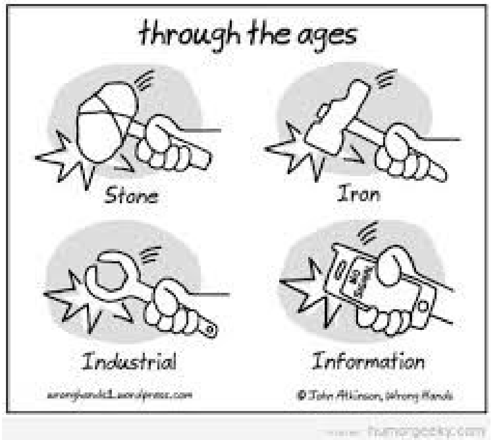
Metals have been part of Mankind's history since the Stone Age



Metallurgy and Technology have always gone hand in hand

I would also like to make a claim before we start. May be most of you associate technology and development to your tables, new apps, etc. whereas the metal mining and metallurgy are seen as an old fashion activity…but it is exactly the opposite.
Metals have been part of Mankind's history since the Stone Age when, as you can see in this image, the first humans began to use them to make the first tools and ended up in our modern cell phones…
So the fact is that without metals most of our innovations would not exist…as an example modern planes and passenger-transportation all around the World would not have been possible without the extensive production of aluminun which at the same time would not have been possible without the development of molten alumina electrolysis which in fact would no have been possible without the discovery of the dynamo and the massive use of electricity that required the production of high grade copper and so on an so on ….because Metallurgy and Technology have always gone hand in hand

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    - Solvent extraction and electrowinning
- The Atlantic Copper case
- Final remarks

What are going to talk about today?
First some ideas related to R&D and innovation, then we will review the different processes for obtaining copper and then I will share with you our experience at Atlantic Copper.

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What are going to talk about today?
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ELECTRIFYING THE FUTURE

R+D and innovation

FREEPORT
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What is innovation?

Innovation is a Tool that companies use to adapt and evolve in order to prevail in this everchanging World

Anonymous

Innovation means applying knowledge and money to generate more money

whereas…
R+D means applying money to generate knowledge

Knowledge is the key to innovation

The first question to be answered is…What is innovation?
So the easy way to find out the meaning of a word is to use a dictionary, which is what I did so we have the Oxford dictionary answer (READ) which is very similar to another one such as Merrian Webster (READ)
Another way is to look for what the "gurus" have said on this and among them the very well know Peter Drucker has his own definition (READ)
Another possibility is the official definition given by an organization such as The Organisation for Economic Co-operation and Development (READ)
But what do all these definitions have in common….one word… New but I want to remark on the importance of another one…Change because from my point of view Innovation is the tool that companies use to adapt and evolve in order to prevail in this a everchanging World
Nevertheless, in order to understand how this tool works I had to use another definition Innovation is (READ) and these two lead us to the fact that R+D and hence knowledge is the key driver to innovate

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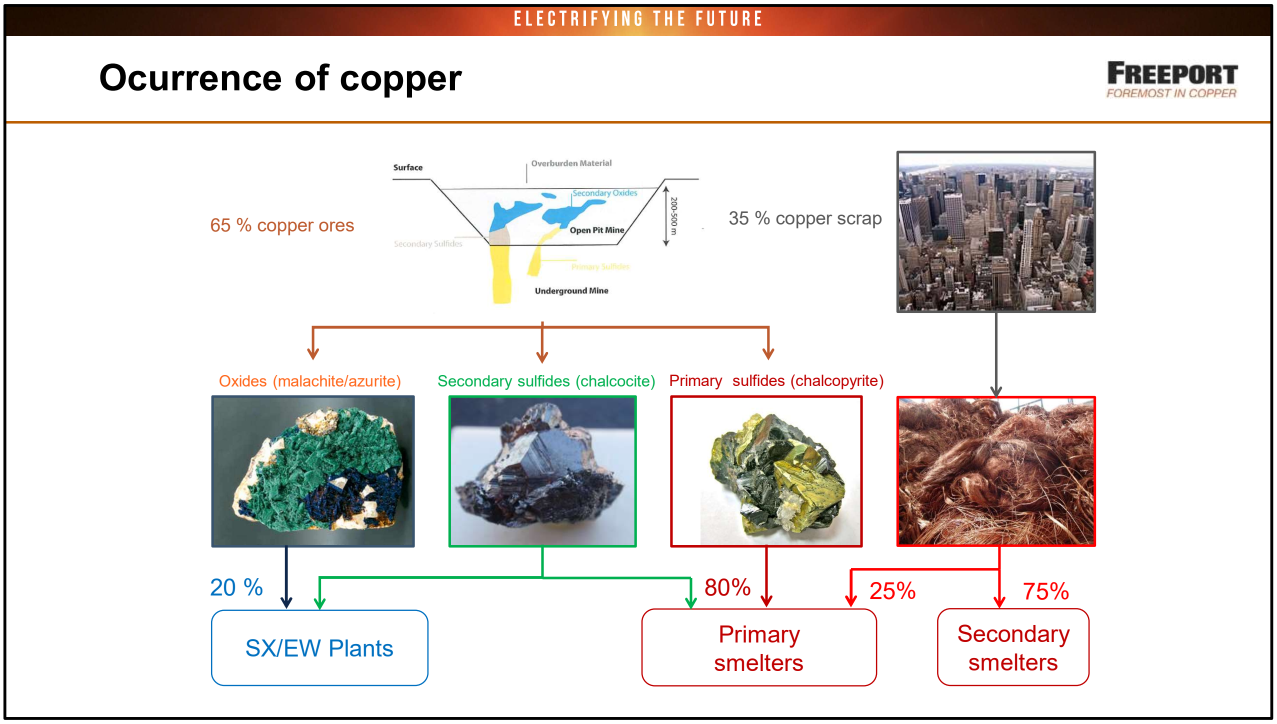
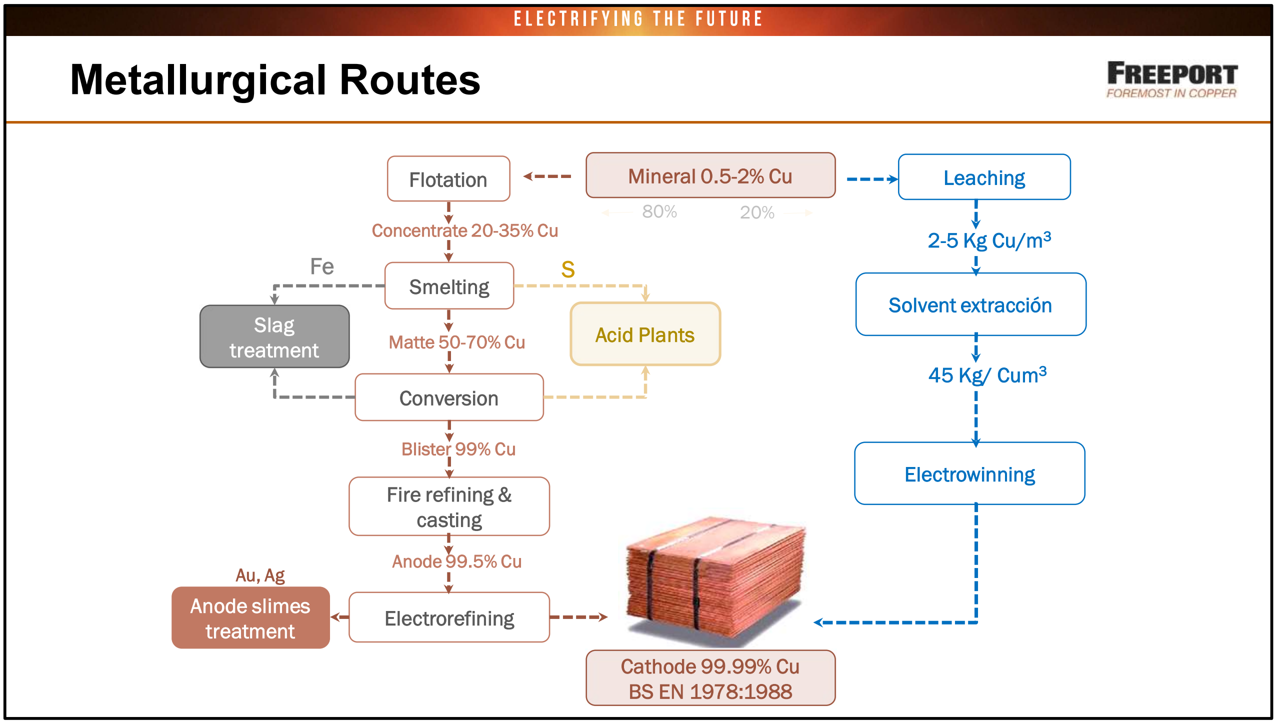
Now we have agreed on the definition of innovation as a tool relying on knowledge. Let’s review the way in which innovation has changed the processes to produce copper



The World copper consumption is estimated at 25 MM T. A 65 % of it comes from the mining operations and it is defined as primary copper production. But, as you me see in this typical deposit sketch, different minerals are obtained as the mine is exploited. Near the surface oxidic minerals and malachite and cuprite are found, then there is a transition zone in which the main minerals are the so called secondary sulphides with a high copper content like chalcocite and in a deeper layer the primary sulphides like chalcopyrite are found.

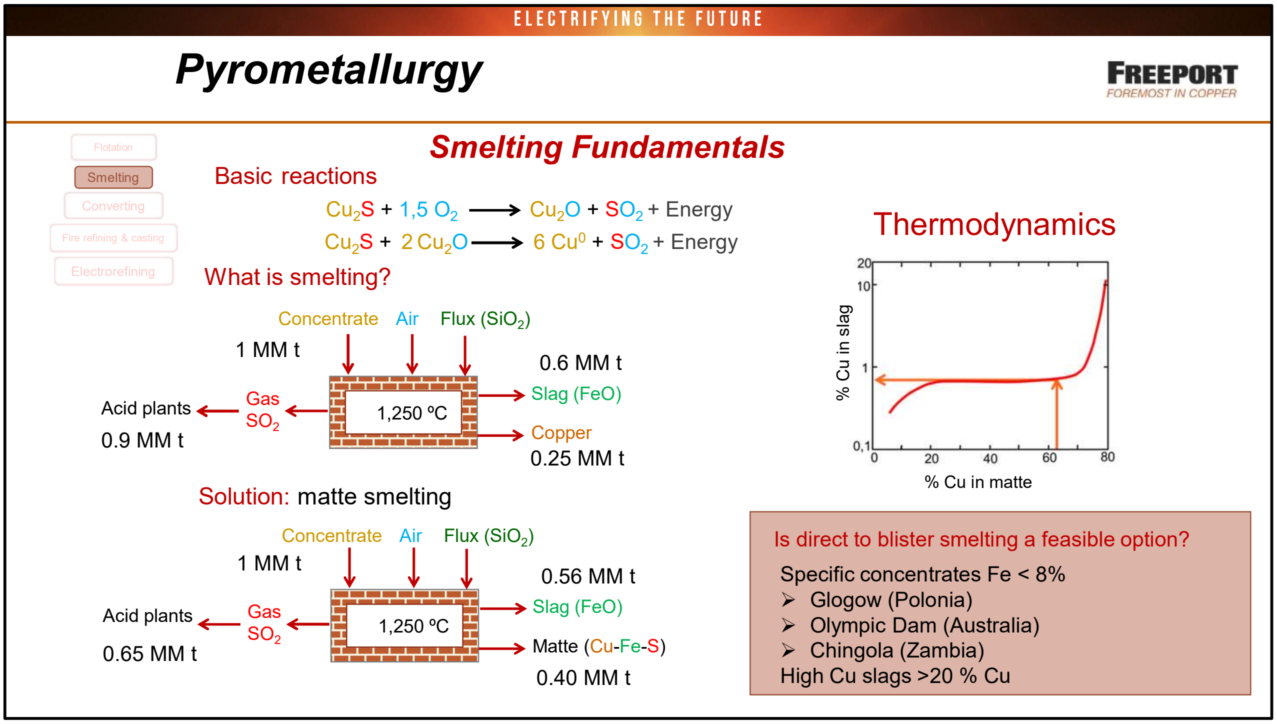
Whereas the oxides are treated in SX/EW Plants at the mine sites the primary sulphides are treated by primary copper smelters. The secondary sulphides could treated by both plants. Nowadays a 20 % of the mined copper is treated in the SX/EW plants and the remaining 80 % by copper smelters

The rest of the copper we are consuming comes from the so called Urban Mine, that is comes from copper scrap recycling, or the urban mine, from which a 25 % is treated by the primary smelters and the rest by secondary smelters.



But today we will discuss the two routes for primary copper production. In both cases the final product is the so called "copper cathode" as it is obtained by be electrochemical technologies to guarantee the high purity, according the international standards, of the copper and hence its electrical conductivity as the main use is for electrical applications. Che copper cathode is a commodity which is deliverable and tradeable upon the metal exchanges such as LME in London.
The pyrometallurgical routes entails
Isolating the sulfide mineral particles in an ore to a concentrate by flotation
Smelting the concentrate to Cooper matte while the Sulphur is removed as So2 in the smelter offgas and fixed in at the acid plants while the Iron reports to the slag which is usually treated to recover the cooper it contains
Conversion, by further oxidation, of the matte into a blister copper .
Which is then fire refined and casted into anodes that are fed to the copper eletrorefinery
The precious metals a present in the concentrated are collected in the anode slimes from which Gold, Silver and PGMs are obtained
On the other hand the hydrometallurgical route means a sulphuric acid leaching of copper from copper ore to produce an impure aqueous copper solution which is transferred by solvent extraction to a depleted copper electrolyte from which the copper cathode is obtained by electrowinning

Why floating?
The main reason is that the copper grade of copper ores is usually too low (0.5- 2 %) for economic direct Smelting, just some numbers. Obtaining 1 t of copper means smelting 4 tons of copper concentrate in comparison to 400 tons of ore
The main technology to concentrate sulfide minerals is froth flotation and consistis of these steps
Griding and milling of the ore to an appropriate size, as 50 microns, to ”liberate” the sulfide particles and suspension of this milled ore in aqueous slurry in which soomre reagents called collectors have been added to created water repellent surfaces on sulfide minerals
So by means of passing a dispersed stream of air bubbles the sulfides attach to the rising bubbles as you can see in this picture. This is done in flotation cells like this so the minerals are collected at the top of the cell. This process requires also the addition of foaming agents to have a stable froth like this.
The whole process is designed to optimize copper recovery which ranges from 85 to 90 %
Nevertheless, playing with other parameters such as pH a differential flotation to separate different sulfides, for instance pyrite from chalcopyrite can be done



In a very easy way we could say that smelting a metallic sulfide is a combustion reaction from which we have and ash, which is the metal oxide, and off gas containing SO2 and a lot of energy

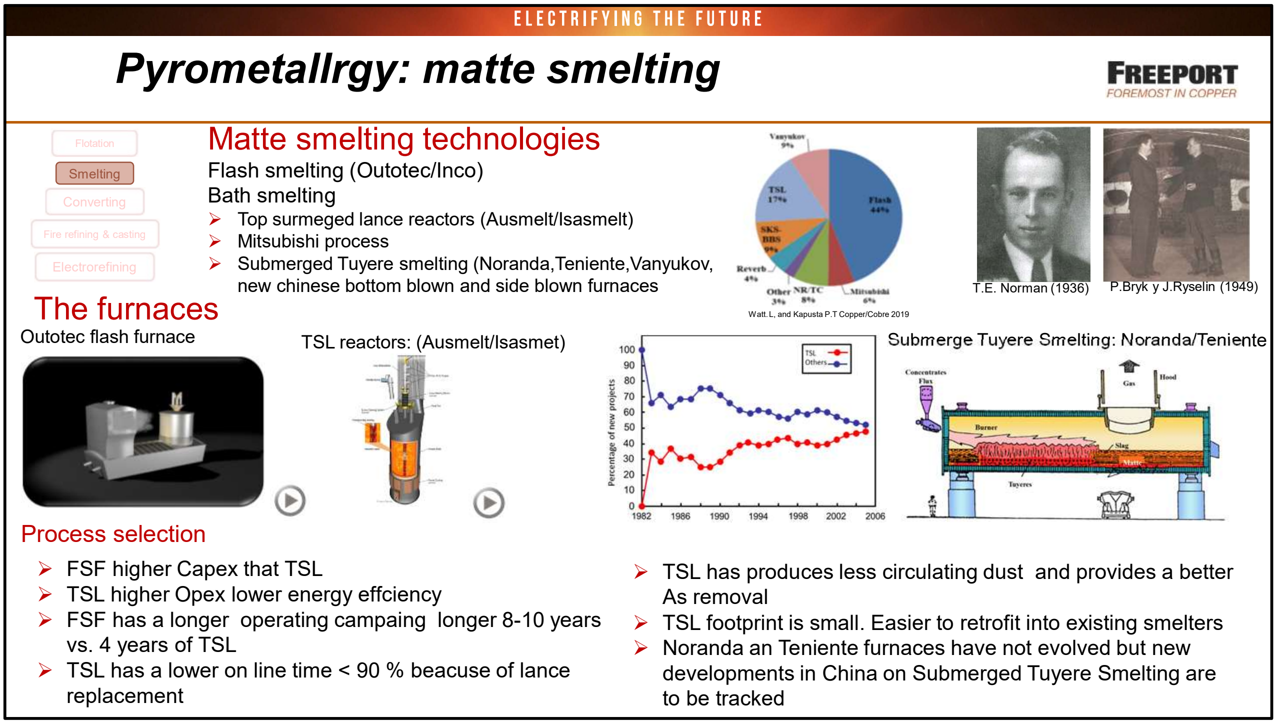
And this is how it works with ion or zinc but one of the unique properties of copper is that its oxide may react with copper sulfide producing copper metal…

So in a very simplified way smelting is feeding a furnace, at the right temperature, copper concentrate together with air and a flux, silica, to produce a molten iron silicate, molten copper and an offgas containing SO2 which ins fixed as a sulfuric acid in the acid plants

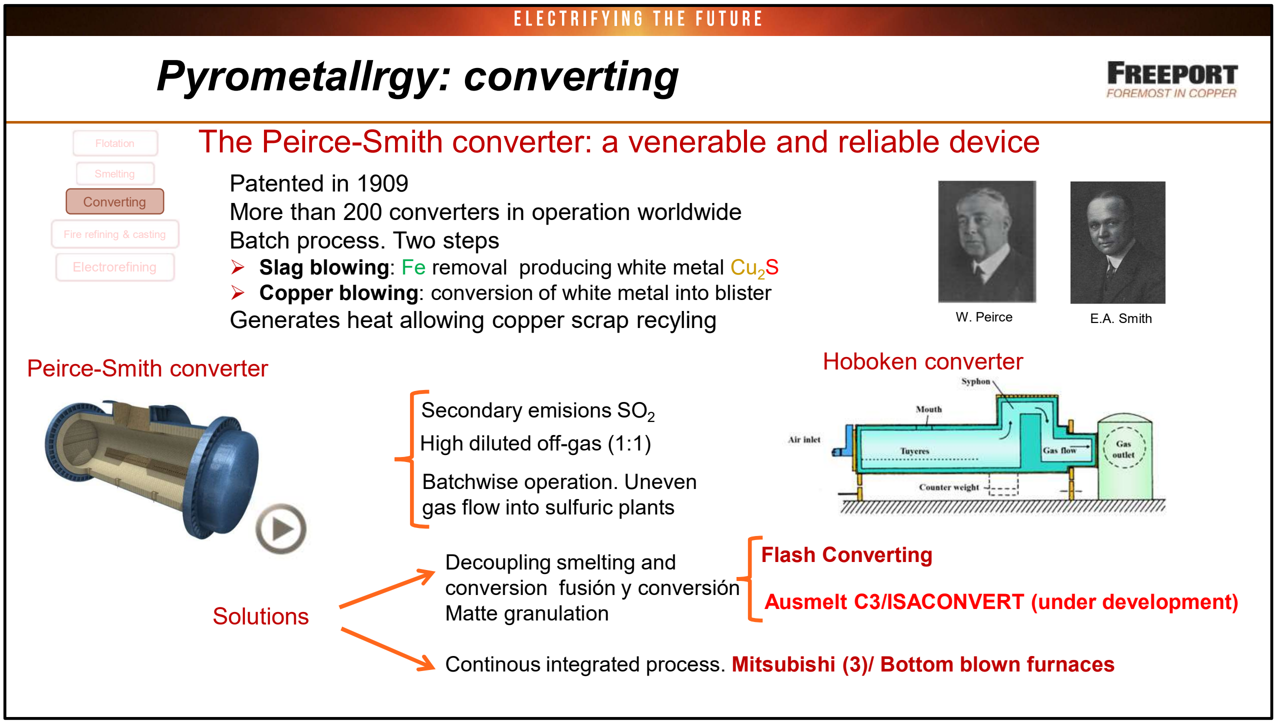
But there is a problem which is thermodynamic and phase equilibrium which states that the more we advance in the copper making reaction, that is the more copper we have in the molten copper matte phase the more which is reporting as copper oxide to the slag phase…as you may see in this very well known graph

The solution to this and hen minimize copper losses in the slag is the so called matte smelting that it's the oxidation reaction is stopped in a intermediate copper matte containing 60-70 % copper that once separated from the slag phase while oxidized to blister copper in the converting step

Is direct to blister a feasible option? The asnwe is that ina ver few cases in which the iron content in the concentrate is low < 8 % wheras an "standard concentrate may range from 20-30 %, that is producing a low amount of slag but with a high copper content 20 % that has to be treated in an electric furnace to recover this copper There are three smelters in the world (Glogow, Olympic Dam, Chingola) running a direct to blister process

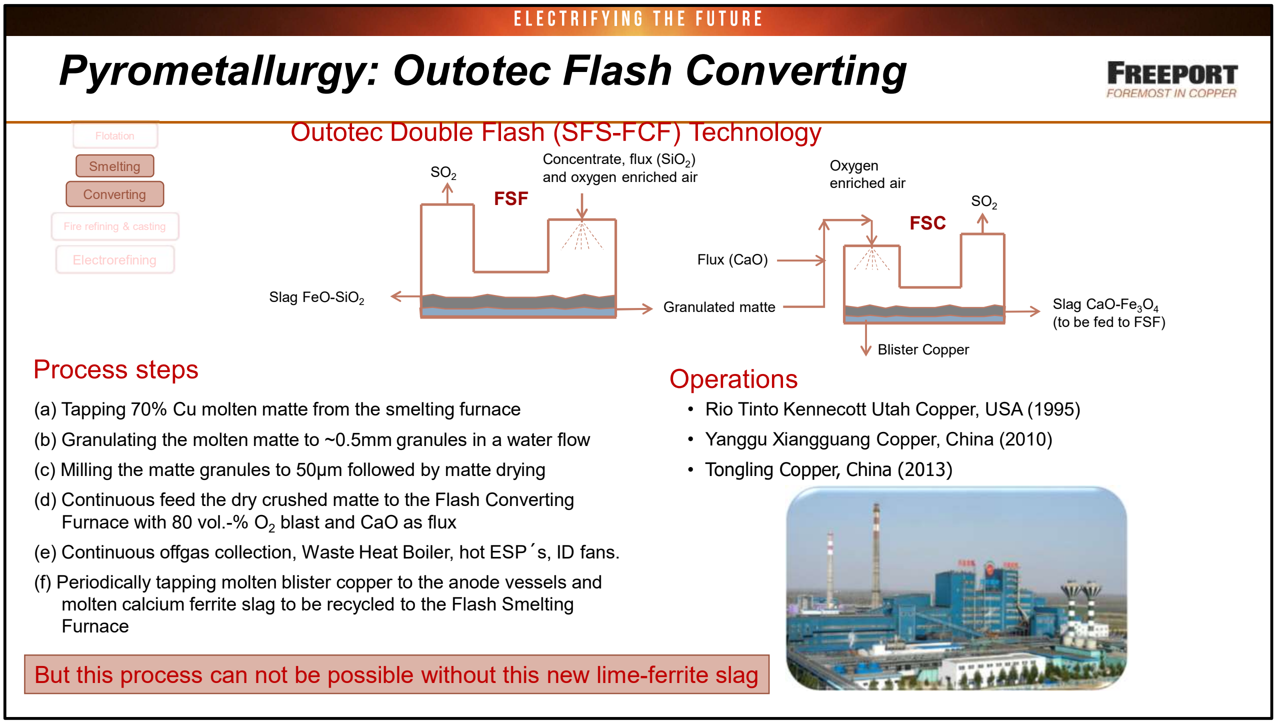


There are two main technologies for matte smelting
The first is the Flash smeting which my colleague Ismael has explained to you in his prior presentation as it is the one we run in an Outotec Flash Smelting Furnace but there is a very interesting story here I would like to tell you
The concept of flash smelting was discovered by a young Canadian PhD student, whose name was Telfer E. Norman as it was explained in its graduation thesis in which he proposed the smelting a dried concentrated mixed with oxygen or oxygen enriched air …, I guess it sounds familiar to you…but unfortunately he was unable to convince the top management of the two major canadian copper smelters at that time, Noranda an INCO, to continue this research…it seems that top the management of these smelters was reluctant to develop a new technology that would require them to scrap their relative new large reverbatory furnaces….
So it was that ten years later, and looking for a more energy efficient smelting technology after the second world war, a team of engineers from the company Ouokumpu, nowadays Outotec, found out independently the same flash smelting concept, and they developed the Outokumpu Flash smelting furnace whose first unit was commissioned in Harjvalta (Finland) in 1949, in the picture we many see the two fathers of this technology that since then had became dominant technolohy accounting for 44 % of the primary copper production. What about Norman ? He had a successful professional career as a metallurgist in different companies and participate in the development of the INCO flash smelting furnace in the fifties but there are only a couple of units in operatrion and it is not an alternative to the Outotec furnace furnace
What it is an alternative is the so called bath smelting which basically is to feed the concentrated in an agitated matte-slag bath by blowing oxygen enriched air in it so the smelting reactions takes place in the bath. There are three different bath smelting technologies
Top submerged Lance reactors or TSL are relatively new technology that was developed by a Australian research group in a publica research recenter called CSIRO. This technology is now marketed by two different companies Glencore whish selling the ISASMELT furnace and Outotec that it selling the AUSMELT furnace, the are very similar and he story behind this and why these research group ended into two competing companies is to long to be told today. Nevertheless we may say that this technology was relatively successful ad could be an alternative to the Outotec Flash smelting
There is another other bath smelting technology which is the such as the Mitshubishi that I explained later and finally Submerged tuyere reactors such as the Noranda/Teniente or the new Chinese furnaces developed in the first decade of this century
So when we look at the big picture in this pie chart it seems that bath smelting because of the TSL and new Chinese developments is an alternative to Outotec Flash smelting
Regarding the furnaces as Ismael has explained to you the Outotec Flash smelting furnace I will jump to the description of an TSL by watching this video….
And this furnace it is really an alternative as you may see in this graph that shows the percentage of new smelting projects using this technology , in red, versus others, mainly flash smelting in blue…And last but not least on the right you may see Noranda/Teniente reactor that was developed in the 70s TSL
So what are the criteria to select the best Technology…?



Ismael has already explained to you the converting reactions and the operation of the Peirce Smith converter, a venerable and reliable copper making device that was patented in 1909 and it is still the dominant converting technology with200 converters in operation accounting for 80 % of the matte conversion in the World
As you have seen this is a batch reactor working in two stages
Slag blowing in which iron is removed producing a slag containing 4- 5 % copper and a white metal which is converted into copper in the copper blowing step
The process is exothermic and allows the meting of copper scrap as a coolant during the copper blow
As Ismael has explained to you how it works but this technology has the following drawbacks such as
Secondary SO2 emissions during the charging and skimming operations that have made necessary the installation of secondary hoods in the last decades
There is a relatively high dilution of the off-gases and this means a highe capex and opex
As it is a batch operation and despite the operation of several converters is being coordinated there is an uneven gas flow to the acid plants
There has been some alternatives such as the Hobeken converter in which the feeding mouth and the off gas outlet have been separated but it was not a definitive solution as it seems that there tow alternatives to avoid this batch opeatrion
Decoupling smelting and conversion bay granulating the matte and processing it in a new

converter, as a flash converting furnace or new TSL converters
Or going into a continuous integrated operation such as the Mitshibishi or the new Chinese processes based on the bottow blowing technology



When talking about Flash Converting we have to talk about the Double flash Technology as you may see in this sketch
As you may see the first step is to produce a 70 % copper matte in the Smelting furnace which is then granulated and milled to reach the appropriate size to be fed to the flash converter with oxygen enriched air (80 %) and lime as a lux
There is a continuous off gas flow to the acid plants and the copper is periodically tapped and transferred to the anode furnaces whereas the converter slag is granulated and remelted in the smelting furnace
This technology was developed together by Outotec and the Kennettcot smelter which the first flash converting furnace was commissioned in 1995
Since then, this technology has been improved in other to have a longer furnace campaign by a better design of its cooling system and has been incorporated by new chinese smelters such as Xiangguang and Tonging and there are more to come….
But this process would have been possible without the development/discovery of the calcium ferrite slag that it is fluid at high oxygen potentials as lime reacts with the magnetite leaden to a molten and fluid sleg
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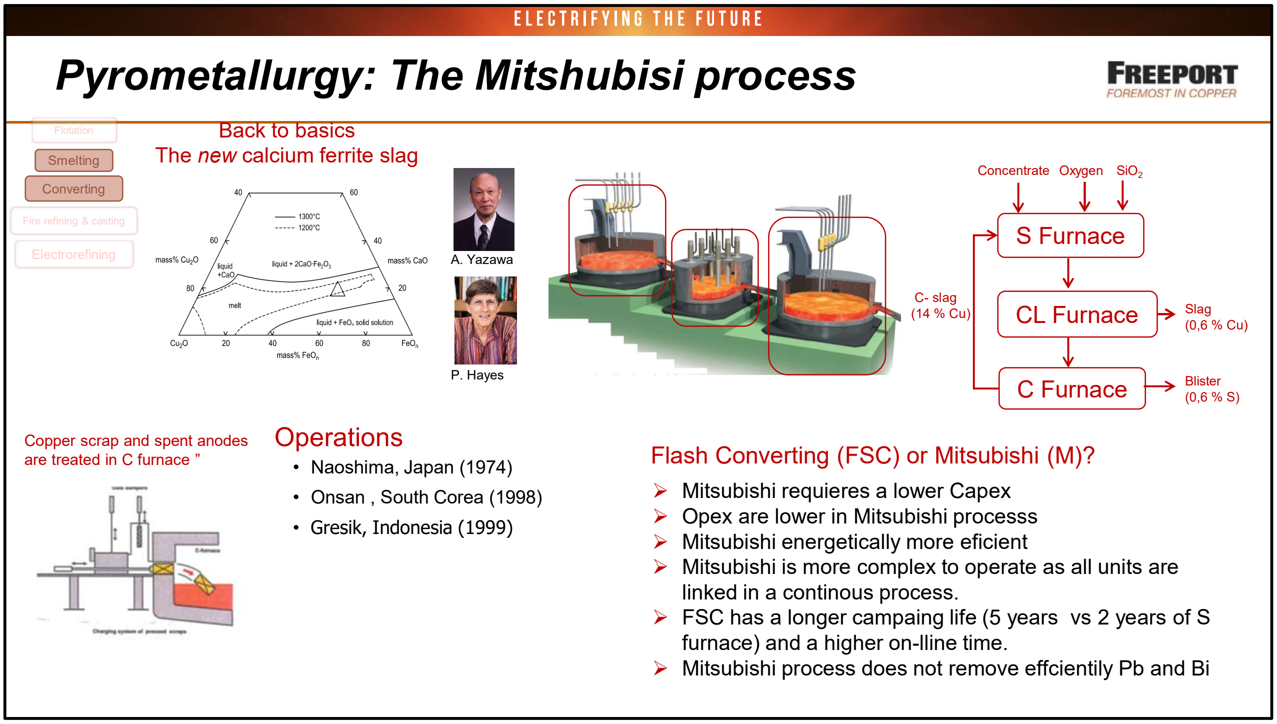

But this new Slag was discovered well before by the Japanese scientists and engineers that developed the Mitshubishi continuous process, as one of the first things they found quite early in the development was that when usus a silica based slag in the conversion stage a crust of solid magnetite was created in the bath making further converting impossible, so the had to make this magnetite soluble and this is what happens when lime is used.
But here is when I want to point out that in cooper smelting it is said that a good metallurgist is the one that makes a good slag and none of these would have been possible with the extensive research work done buy very well know scientists as Yawaza, Hayes and many others
But lest describe this continuous process, as it consists of three connected furnaces via launders so the molten material flows continuously by gravity from one furnace to thee next one. The first furnace is the S-furnace in which concentrate and oxygen enriched air are injected into the molten bath a molten mixture of matte and slag flows to the next slag clearing furnace in which phase separation takes place so the slagged is tapped and granulated and the molten matte flows to the next converting furnace where calcium carbonate and oxygen are injected in the bath via lances. The slag from the C- furnace is granulated and fed
It should be noted that copper scrap may also be treated in the C- furnace as a coolant it is done in the peirce Smith converters
This process was developed in the early seventies being the first plant commissioned in Naoshima (japan) and it is now in operation in three smelters
So, what to choose? looking to Chine and the new smelters built there we may think that the better choice is double flash but lets review the advantages and drawbacks of each one
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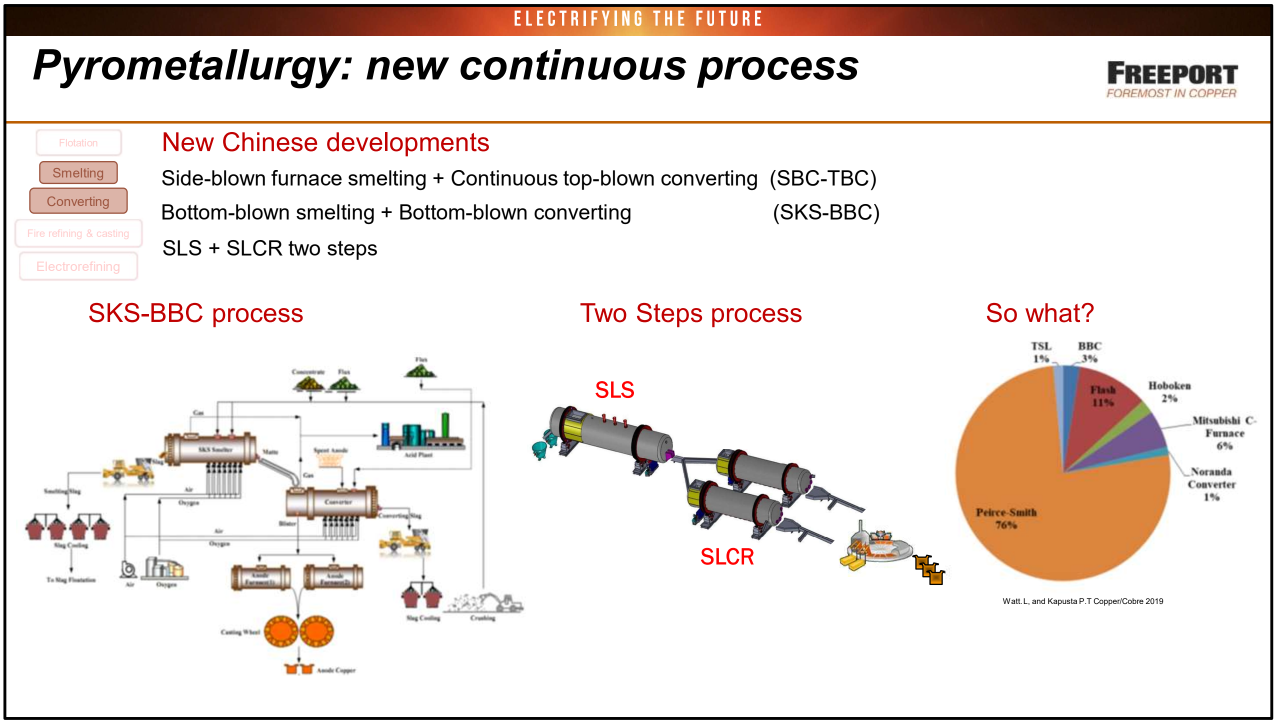
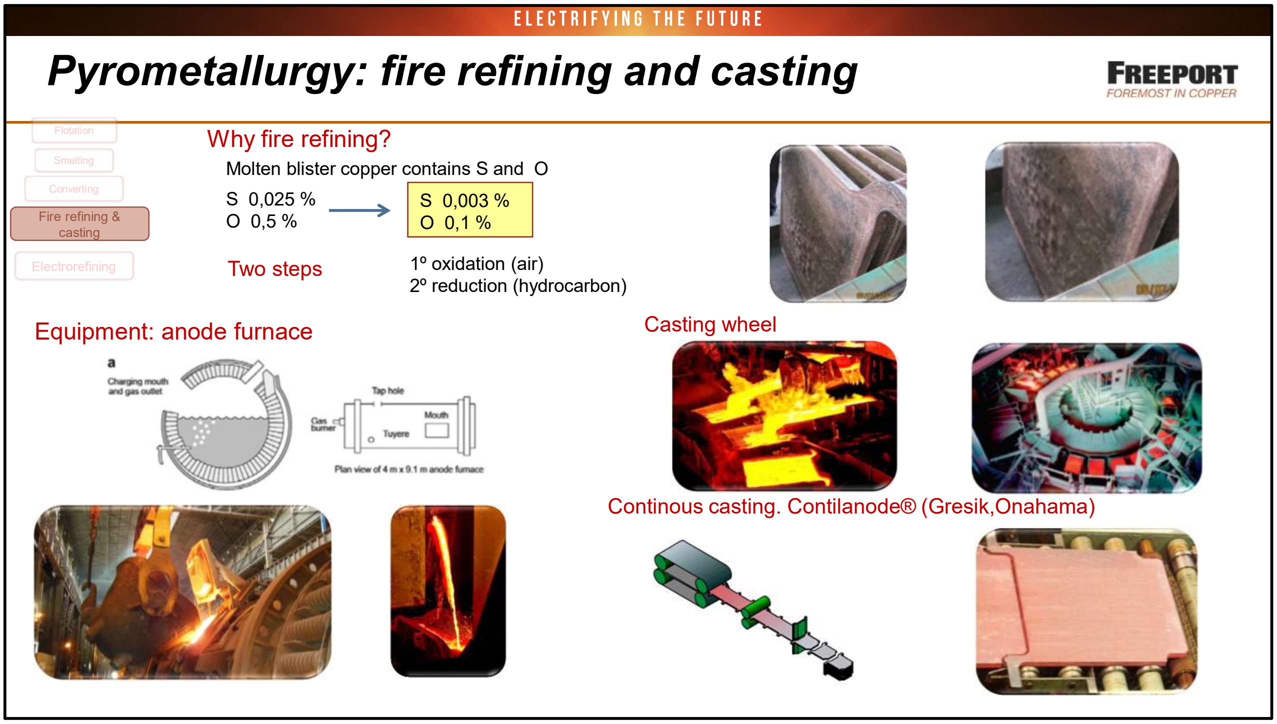


And it seems that it is exactly what the Chinese engineers have done as they have adopted the idea of a continuous process but using submerged tuyere furnaces which could be seen as a new and improved version Noranda/Teniente or Submerged lance smelting as Mitshubishi S and C furnace
These new process are classified in these three categories

- SDB-TBC
- SKS-BBC
- SLS-SLCR

On the left you may see a basic sketch of the two bottom blowing process which consist of two furnace so the matte flows from the smelting furnace to the continuous converter whereas the slag is granulated. The blister copper is fed to the fire refining furnaces
But lets have a look on this new “two steps process” as it consists of two furnaces
The Frist furnace is the SLS *(Submerged Lance Smelting furnace)* in which a wet concentrate is treated producing a high grade matte (75.78 %) that is treated in the SLCR (Submerged Lance Converting Reactor) in which the conversion and fire refining seps are done, as you may see the fire refining is still a batch process o that is why there two furnaces in parallel and this is the main innovation of this new process so far there is only one plant in operation an it is too early to know if this is going to be a successful technology
So what be concluded? It is clear that the Peirce-Smith converters are still the dominant technology but it seems that for new smelting projects the double flash seems to be the alternative, specially for higher treatment capacities, together with these new Chinese processes that account for 22 % of the copper which is being produce in China.



As Ismael has told you the blister copper is called this way because of its relatively high content in Sulphur and Oxygen that make that when casted into anodes some physical defects as blisters appear on the anode Surface making it not suitable to be treated in the copper refineries. So t afire refining to redece it it neede. As I mention before this is a batch process carried out in two steps

Oxidation (for S removal)

Reduction (for O removal)

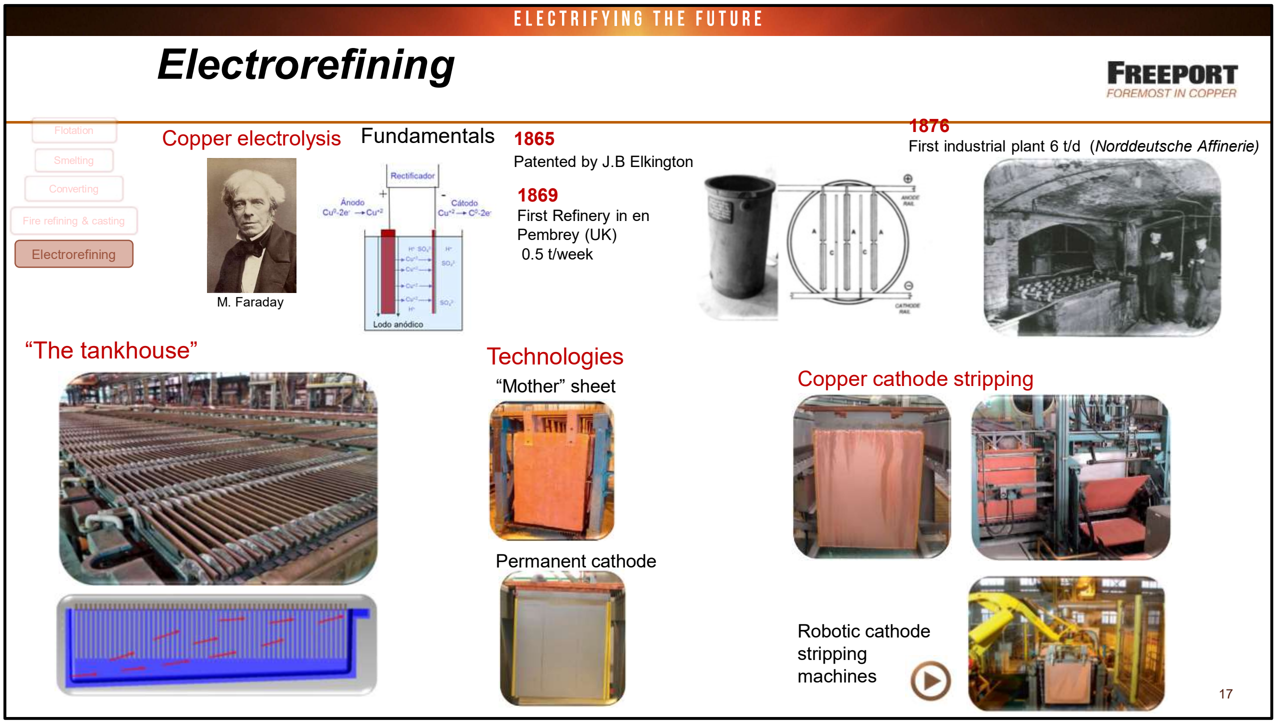
Ismael has also explained the details of these furnaces but review it. The anode furnace is similar to the Peirce smith Converter but it has only one or two tuyeres

here you may see some pictures of the furnaces

The refined copper is finally casted into anodes and the most extended technology, I would say the only one, is the casting wheel you have seen before

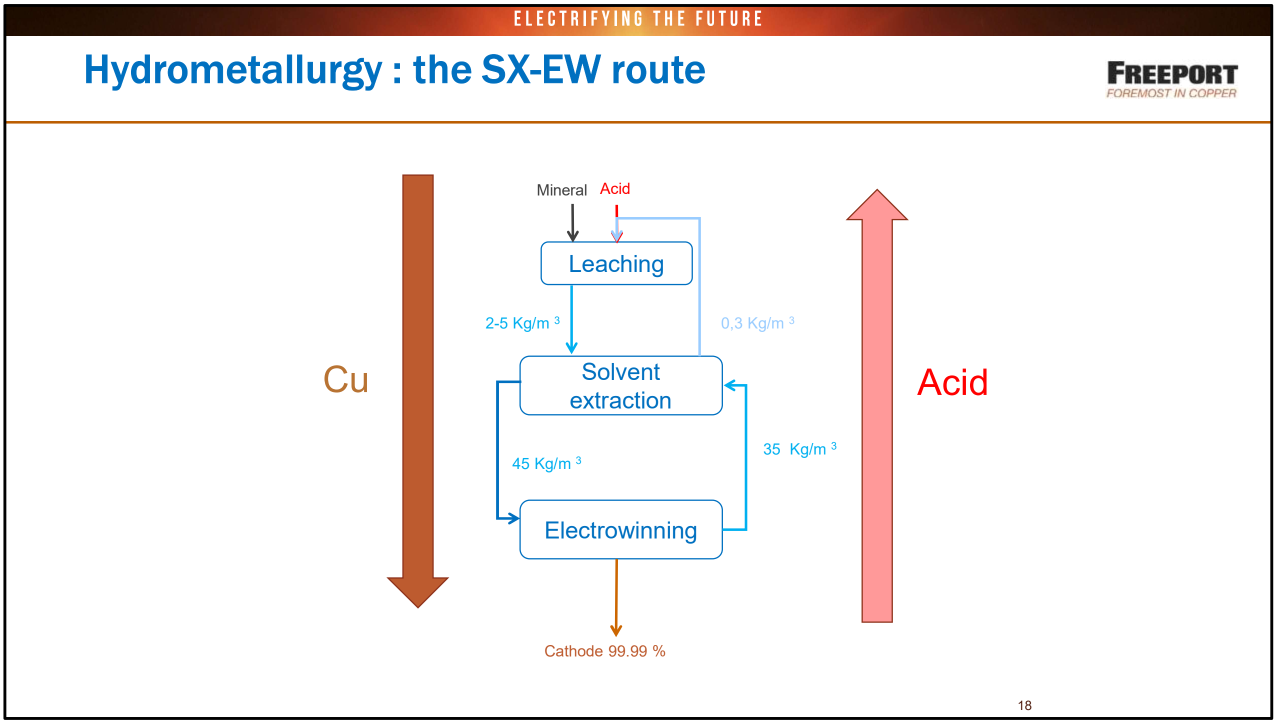
But there is a technology that uses a continuous casting process called contil anode It is similar to a "rolling mill" and produces an almost perfect anode but this technology has been only adopted in two smelters as

- There is a limit in the thickness of the anode
- Maintenance costs
- Difficulties to to adapt a batch process to a continuous casting process

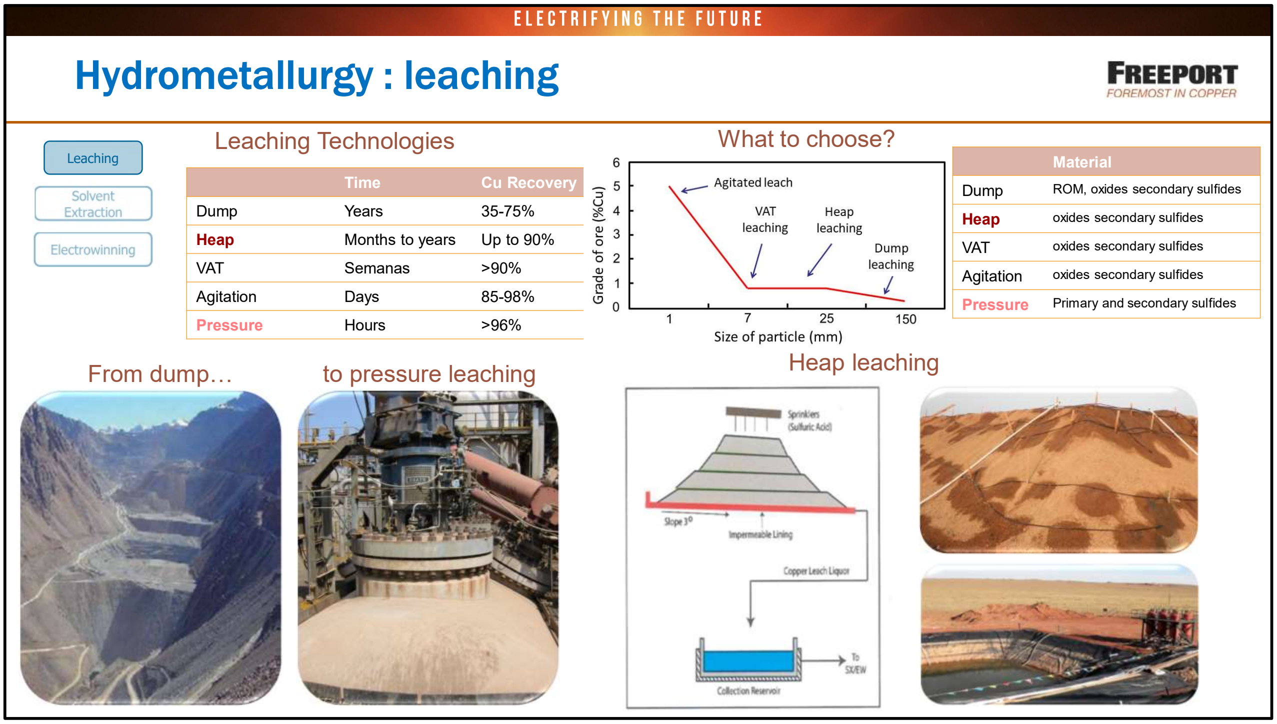


Why the smelting and converting processes date back to ancient times in Mankind history the electrochemistry is a relatively new science at was born in the 19th century thanks to the discoveries made by Faraday, Volta, Daniell….
The fundamentals of the electrorefining are the opposite to a battery, in which a chemical reactions produces electricity, as now it is electricity that drives the reaction so copper dissolved from the anode and plates as pure copper in the cathode. All this takes place with a copper sulfate/sulfuric acid electrolyte in which the electrodes are immersed. The anode impurities dissolved in the electrolyte and those more noble than copper are being collected in the anode slimes
The electrolytic refining of copper was invented by a British electroplater, James Elkington, in 1865 [1]. The first refinery was constructed in 1869 in Pembrey, near Swansea in Wales, where electricity was supplied by Voltaic cells and the electrorefining process was carried out in cells that were "ceramic jars" like this This first tankhouse was constituied of 1200 "jasrs" with a capacity of 0.5 t a week
After the invention of the dynamo by Siemens in 1866 , the first continuous working tankhouse for the electrolytic refining of an "anode copper", coming from a copper smelter, was commissioned in 1876. This took place at Norddeusche Affinerie (nowadays Aurubis) in Hamburg with a capacity of 6 t/d of copper using rectangular cells, instead of "jars", as you may see on the right pricture
This the design adopted by modern new tankhouses reaching a production from 1.000 to 1,500 tp
Besides an increase in the number of cells and number of anodes/cathodes per cell on of the main drivers of this productivity increase of copper refineries has been a continuous increase in current density since 90 A/m2 in 1869 to 350 A/m2 in modern The copper plated blanks are washed with hot water and send to the stripping machines in which the copper cathode is mechanically separated from the steel blanks. This technology was developed by Glencore Technology (formerly Mount Isa Mines) in the 1970's as was first implemented in 1978 in the Townsville (Australia) refinery and began to be adopted by most European tankhouses in the 1990's and it can be said than today this technology is considered the industry standard when building a new tankhouse. The most recent improvement of this technology are the new robotic stripping machines handling up to 500 electrodes an a hour

(Onsan, Jinlong, Xiangguang).



Now lets talk a Little bit about the hydrometallurgical, route that I as I said accounts for 20 % primary copper Production
As you may remember it implies leaching of copper, extract it from the leach licuor into a copper electrolyte and feed it to the electrowinning plant to produce a copper cathode.
But I want to draw you attention to the fact the acid goes in the opposite direction so the acid generated in the EW step is finally used for leaching



The leaching of the ores can be carried out by very several methods with significant differences in in time and copper recovery as you may see in this table

The reason of why there different technologies is that each one is suitable form certain copper concentration in the ore as well as particle size as you may see in this graph as well as the mineralogy of the material to be treated

So we could be ranging for leaching for years in huge dump where run of mine ore with a very low content are leached for years to the very fast pressure leaching reactors in which high grade secondary sulfides are treated and it may be that one day primary sulfides as well but so far as the profitable leaching of primary sulfides is still seen as the “Holy Grial “ of copper metallurgy

But the most extended process for oxides an secondary sulfides leaching is heap leaching

This process implies percolating an acid solution through a heap in ore that have been crushed in order to ensure the heap permeability, The heaps had a heigh f about 7 meters and may occupies a surface 1 km^2.

The oxides are easily leached but the secondary sulfides requires the presence if iron and some bacteria that somehow acts as a catalyst if this process making it feasible

In the lower part of the of the there is a plastic lining so the leach liquor is collected and directed to ponds from which is pumped to the next step

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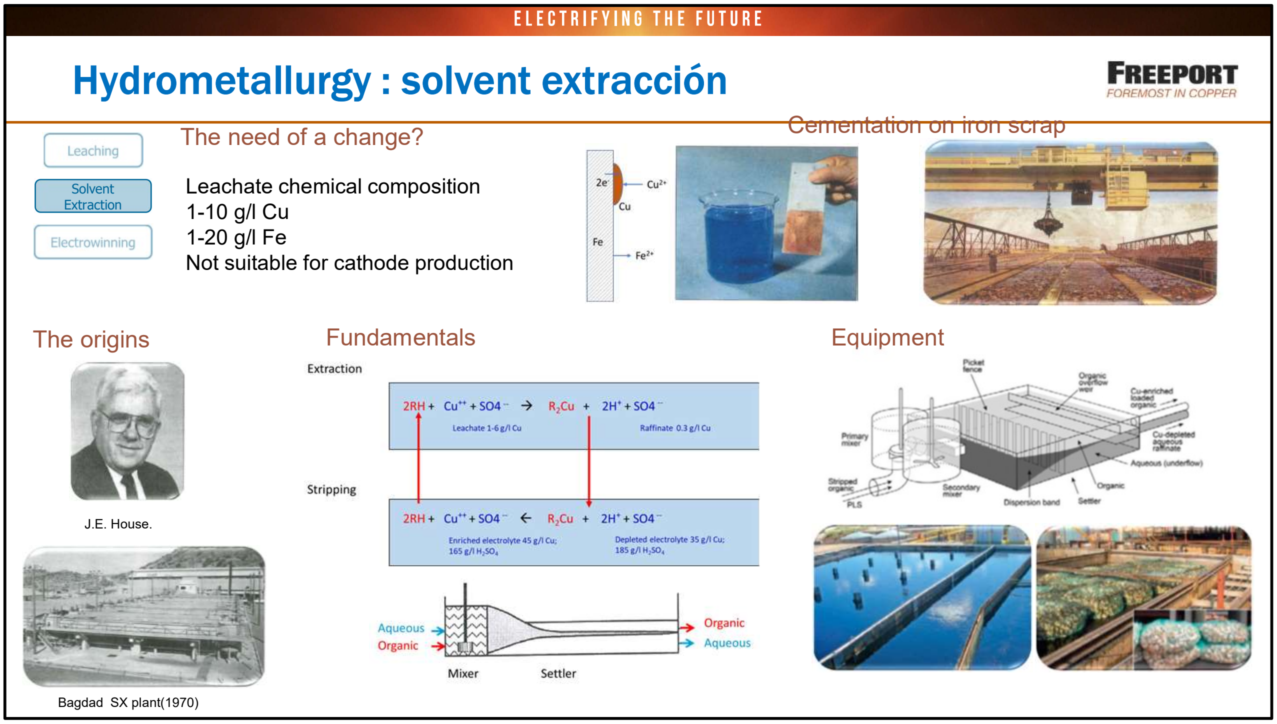


Because of its chemical composition the leach was not suitable to produce a copper cathode liquor so the usual practitice was to cement the copper on iron scarp, as a curiosity let me tell you that this technique was known by the medieval alchemist an this idea of transform iron into coper led them to the search of the "philosopher's Stone to transform iron into gold but this is another story Sy by the seventies of last century this was the way in it was done producing a copper that was fed to the copper smelters

So what change? I would say a War….aswe have to go back to 1942 , the Manhattan project and the development of the Atomic Bomb that led to the use of technique known as solvent extraction to obtain the uranium needed for it

Part of this knowledge was declassified at the first international conference on the Peaceful uses of Atomic Energy in Geneva in 1955 leading to its extensive use for uranium mining and the formulation of new extractant reagents , but the use iof this technology in the copper metallurgy is due to this man. Joe E House and the company he worked for "General Mills" that in 1962 formulated reagent that may extrac copper from an aqueous solution, and they call it LIX-63 (liquid ion exchange 1963)

And they came up with the idea of using solvent extraction as an alternative to cementation…But the response of thecopper industry was negative, plant operates believed it was expensive or may kill the bacteria in the heaps. More over the R&D of a large copper company predicted that "there would never be a pound of copper recovered using solvent extraction"

But two small companies trusted Joe, Bagdad mining and Asarco and bet for the development of this teachnology so afether some pilot plant studies the first commercial plant with a capacity of 13.6 t/d was built in Bagdad (Arizona) in 1970 since then the uses of this technology sky rocketed and by the 80s the cementation process can be considered as an abandoned technology.

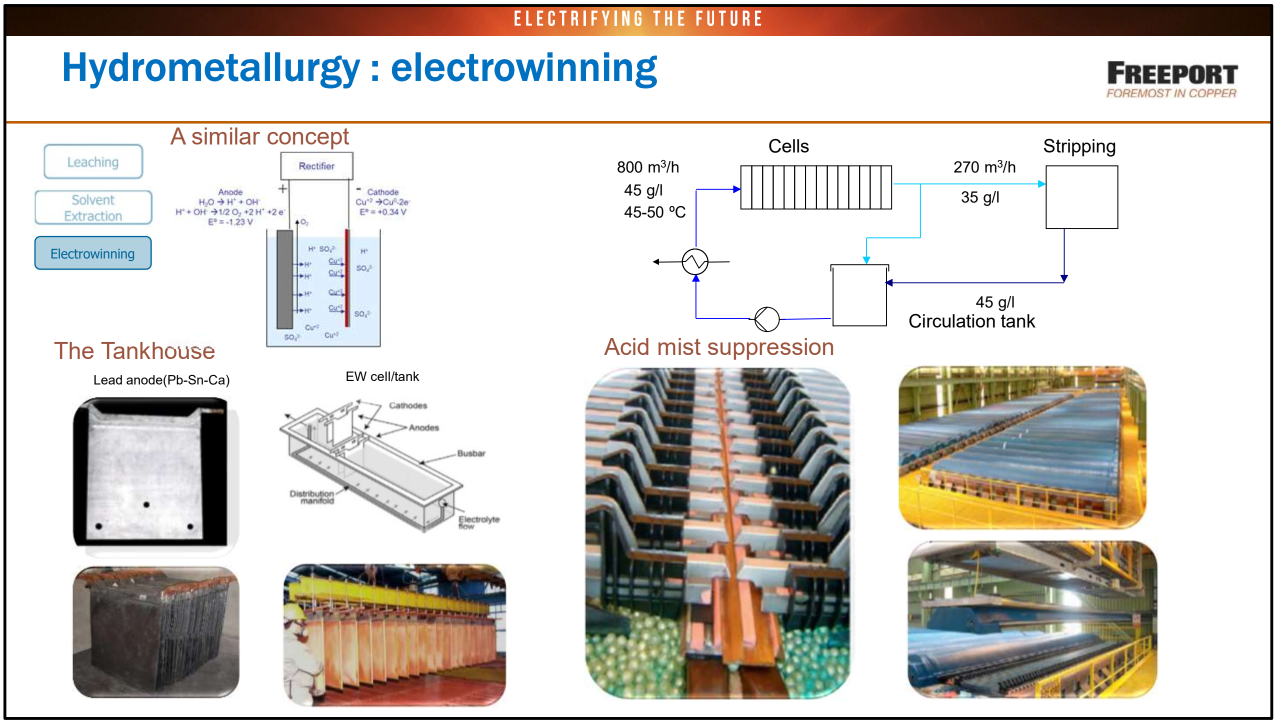
As a curiosity, as many "start ups" General Mills was taken over by a huge German corporation, Henkel, in 1978

Just a few ideas about the fundamentals

It can bee seen as a two stage process

- Extraction in which the metal in an aqueous phase reacts with an organic reagent present in a solvent, usually kerosene, which is the organic phase and form an organometallic compound dissolved in this organic phase and
- Stripping in which the metal I dissolved in an acid electrolyte and the reagent is regenerated and send to the extraction step

From a physical point of view the operation is an appropriate mixing for the two phases to carry out these reactions and then an appropriate phase separation by settling. In these pictures you may see the equipment used in these plants



Electrowinning is similar to electrorefining and the main difference that the anode is an inert lead anode in which the anodic reaction is the water electrolysis increasing the acid content of the electrolyte and generating oxygen while copper is being plated on the cathode .

So where is the copper coming from?, as you may see in this sketch this implies to keep an appropriate electrolyte circulation in the cells but also bleeding the depleted electrolyte to the striping step of the solvent extraction in order to get more copper

The tankhouses are similar to the electrorefining plants but there are some diferences

- The anodes are lead anodes and last for about 6-9 years
- It requires a higher electrolyte flow per cell which is fed from manifold in the bottom of the cell as you may see in this picture
- At it consumes more power, the cell voltage is up to 2 V in comparison to 0.3 V in electrorefining

The cathode handing is similar to the copper refineries but a relevant difference is the need for an acid mist, as a result of the oxygen evolution in the anode, suppression in the tankhouse for heath an safety considerations

This can be done using polyetilene beads on the electrolyte surface on by means of hoods as you may see in theses pictures

For the quality point of view the copper cathode is similar to one produced by coper refineries

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What we have learnt so far… is that there are different ways to obtain a copper cathode and that they have evolved over time, through R+D, as in the same way as smelters have done…. because the World nowadays is not the same as it was at the beginning of the last century, to say a date. Now Safety and Environmental performance are a top priorities for smelters that are competing on costs in a globalized World
So what about Atlantic Copper?
Let’s start talking about making the right decision….

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The right decisión

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1970 The Huelva Smelter

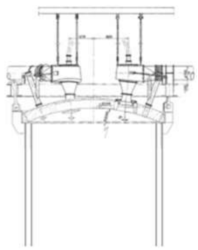
Two 30 ft. blast furnaces with a capacity of 510 dmtpd of concentrate

1972 The need of an expansion

Target: 1,000 dmtpd of copper concentrate

Alternatives	New FSF	4 Momoda Furnaces
Capacity (dmtpd of concentrate)	1,000	1,020
Final capacity (oxygen enrichment)	1,500	1,020
CAPEX Smelting	×	✓
CAPEX Converting	✓	×
CAPEX Acid Plants	✓	×
OPEX	✓	×
Environmental perfomnace	✓	×

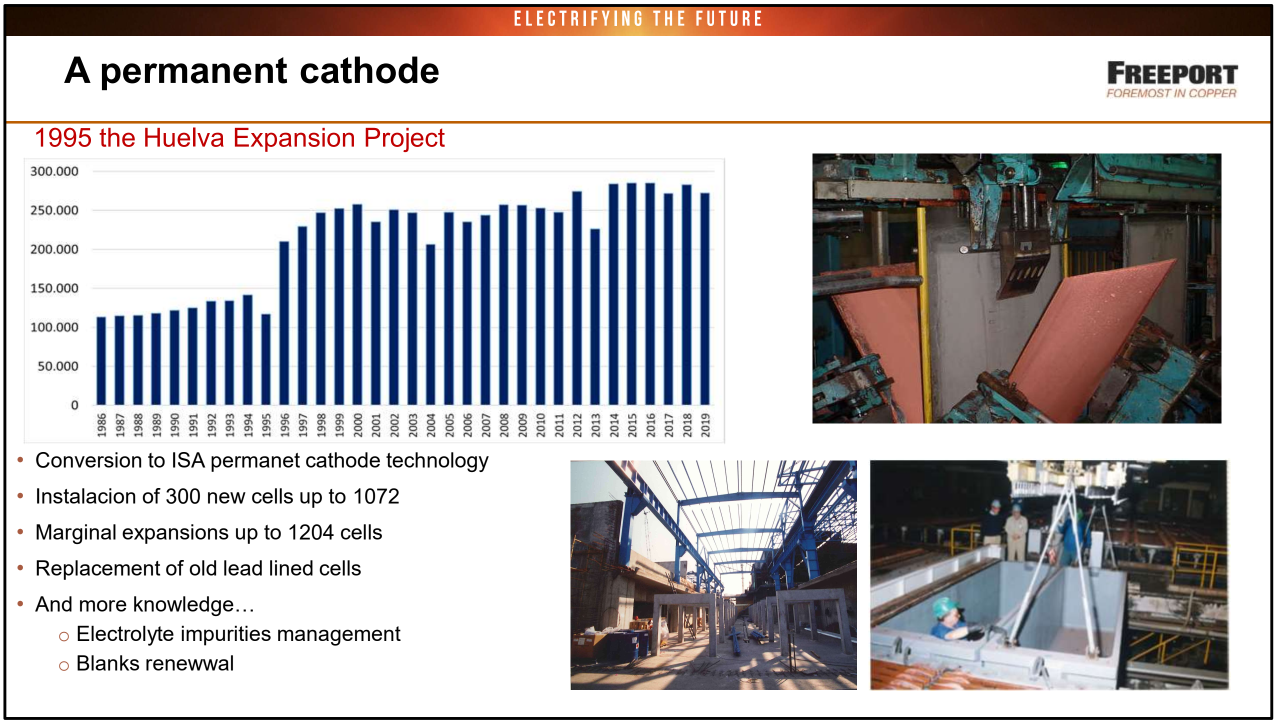
January 1973 Signature of a licence with Outokumpu
September 18th 1975 first concentrate was fed to the FSF



3rd IFSC Huelva 1977

11th IFSC Sofia-Huelva 2005

The original 1970 smelter consisted of
Two Momoda furnaces with a capacity of 510 dmtpd of concentrate
But in 1972, because of market conditions, an expansion of the smelter was needed in order to double its capacity.
So the team that run the smelter had two alternatives
The relatively new flash smelting technology or installing f two additional blast furnaces. That is keeping the same technology they had had.
So the made a comparison study an wen for the Flash technology because of its
Potential future expansion using oxygen enrichment
Regarding capital expenditure a flash furnace was more expensive but it required less additional equipment
Lower operating cost and a better environmental performance
So…
In January 1973 we signed a licence agreement with Outokumpu, nowadays Outotec, and the construction of the furnace began, as you may see in this picture
The eighteenth of September 1975 the first copper concentrate was fed to the furnace that had for concentrate burners at that time. But anode relevant issue is that e became part of a community of flash smelting users that share knowledge and experiences as you may see in these pictures from two international conferences held in Huelva



The second technological milestone in the history of Atlantic Copper took place during the Huelva Expansion Project in 1995 in which, in order to double the production of cathodes, the ISA permanent cathode technology was implemented in the tankhouse resulting in a higher production per cell as

The number of cathodes was increased from 33 to 39 and it was possible to increase the current density up to 344 A/m2

Nevertheless 300 more cells were also needed together with some marginal expansions up to 1204 cells, the replacement of the old lead lined cells and the use “knowledge” had led to our current production figures

But as the society changes companies do as well and nowadays concepts such as environmental performance are part of the daily management of an smelter
An the companies have to adapt be one step ahead of what the society, and hence the environmental regulation demands, so we had to innovate and here there are some examples such as
The new anode furnace off gas WESP which in combination with an scrubber was considered a BAT in the last review of the non ferrous metal BREF
The soncnday hood for the PS conveters
A unique system that may filter the Fash furnce gases in case they have to be vented in an emergency situation such as black out
The use of a ceramic filter that replaced the scrubber of the slag cleaning furnace offgas making it possible the recovery of the of the heat it contains in the concentrate dryers
And last but no least a new west water treatment plant

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Energy management

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In 2012, the Atlantic Copper system was certified under ISO 50001 becoming the first copper smelter in the world granted this certification.

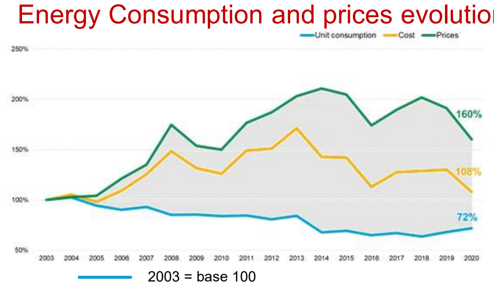
The implemented energy management system implied:

- From managing supplies to managing an overall energy balance From focus on equipment to focus on processes
- From analyzing electricity invoices to planning production considering energy consumption as a relevant decision making issue

In addition to “invest to save”, also “operate to save”

- ➢ More than 30 projects:
  - ✓ 1/3 management projects
  - ✓ 16 MM€ CAPEX
- ➢ Type of projects :
  - ✓ Debottlenecking-stable operation
  - ✓ New maintenance planning
  - ✓ Energy saving projects
  - ✓ Energy recovery projects

Energy Consumption and prices evolution



An finally, energy management

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As you may have noticed….we have changed a lot and I can assurer you that, as a company, we have new ideas and plans for the future but that would be part of other presentation
So please let me share with you all some final remarks

Wrapping up

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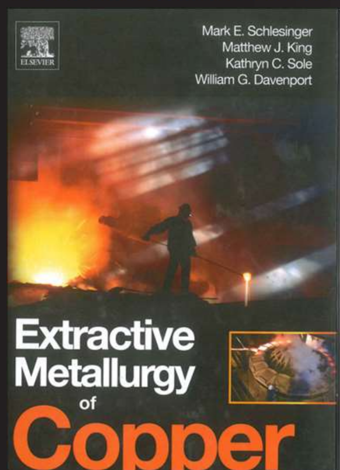
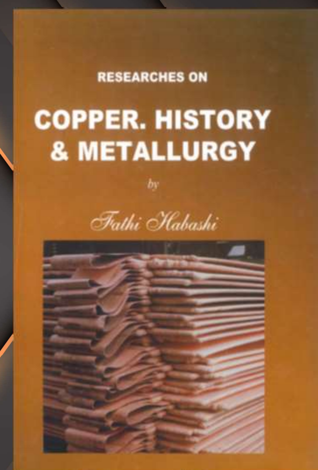
- We all have to anticipate and **adapt to a changing World** and this also applies to the processes for obtaining copper
- Choosing the most suitable process involves a series of decisions that take into consideration not only the technical factors but also others such as operating costs, environmental performance…
- The criteria that lead these decisions have evolved over time. For instance, nowadays the use of natural resources, such as water and energy, are also a main driver when assessing the environmental sustainability of these processes
- This ***adaptation*** relies on **innovation** which is based on **knowledge**
- **People**, the scientists, the engineers, the workers, the teachers, the students all of them have been the ones that have generated that **knowledge** and applied it
- All this highlights the need for skilled professionals in the non-ferrous industry, and hence a good education and training, as well as the importance of fundamental research activities. That is…cooperation between companies and universities

CHARGING AHEAD
RESPONSIBLY. RELIABLY. RELENTLESSLY.

References-suggested reading





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CHARGING AHEAD

RESPONSIBLY. RELIABLY. RELENTLESSLY.

Thanks

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