Ausmelt Technology – Developments in Copper Converting

Mr Robert Matusewicz, Dr Joe Sofra

Ausmelt Limited
12 Kitchen Road, Dandenong 3175
Victoria, Australia

Abstract

The copper smelting industry has been characterised by ever increasing competitive and environmental pressures. This has resulted in the need for increased scale of production and the continual pursuit of improvements in operating efficiencies to ensure financially viable operations. Overlying this is the considerable investment needed to ensure community expectations of environmental performance are met.

Ausmelt's Top Submerged Lancing (TSL) technology for copper production has proven to be a low cost solution in addressing these challenges and has gained widespread acceptance in the concentrate smelting application. The application of the technology for converting applications promises to deliver the same benefits.

Ausmelt has continued to achieve success over the past 5 years in establishing a strong market position for its converting technology. Installations in Zimbabwe, China, South Africa and India have demonstrated its effectiveness. Ausmelt has continued to pursue developments that enhance the productivity and efficiency of the converting process.

This paper reviews the application of Ausmelt Technology for converting processes, describing both current plant applications and recent process developments.

A History of Ausmelt TSL Converting

Ausmelt Technology evolved [1] from the original Top Submerged Lancing (TSL) technology invented and developed in Australia in the early 1970's by Dr. John Floyd and his team at the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The first application of the technology was in reducing tin slag and was known as "Sirosmelt". Dr. Floyd, seeing the potential for the technology, formed Ausmelt in 1981 to commercialise the technology and expand its range of use from tin to many other processes.

Since then the plants and projects completed by Ausmelt have covered a broad range of materials [2], mainly in the non-ferrous metals area. More recently, the technology has been applied to the fields of waste treatment and iron making.

From very early in its history Ausmelt has been involved with copper production through work conducted in 1984 at Roxby Downs in Australia. This plant operated at feed rates of up to 2 tonnes per hour processing uranium containing copper concentrates. The purpose of this plant was to investigate deportment of uranium and copper to products including copper matte. The operation progressed through to the production of blister copper and so began application of TSL and Ausmelt Technology in the area of copper processing through to blister copper.

From these beginnings, TSL copper smelting is now an established, proven and increasingly preferred treatment route. TSL converting is now moving to become the new technology to watch in its field.

Milestones

In the field of copper smelting and converting, Ausmelt has supplied systems for several commercial smelters as shown in Table 1.

Table 1: Commercial Copper Operations using Ausmelt Technology

Year	Company	Copper Application
1992	Eifel Flats, Zimbabwe	Cu/Ni leach residue smelting
1995	Bindura Nickel Corporation, Zimbabwe	Cu/Ni leach residue smelting, converting & metal production
1997	Gold Fields, Namibia	Cu/Pb concentrate smelting
1999	Zhong Tiao Shan, China	Concentrate Smelting & Converting
2002	Anglo Platinum, South Africa	Cu/Ni/PGM matte converting
2003	Anhui Tongdu, China	Concentrate Smelting
2003	Birla Copper, India	Concentrate Smelting & Converting
2005	Korea Zinc, South Korea	Residue Smelting
2005	Russian Copper Company, Russia	Concentrate Smelting

Rio Tinto Zimbabwe

Rio Tinto Zimbabwe operates the Empress Nickel Refinery at Eiffel Flats, Zimbabwe. The refinery was commissioned in 1968 to refine nickel and copper produced as a matte from the nearby Empress Nickel Mine. The mine closed in 1982 after depletion of the economic mineral reserves, however, operation of the refinery continued, treating mainly matte from the BCL operations in Botswana.

In 1992 a nickel plant using an Ausmelt furnace system was installed. The purpose of the plant was to smelt 10,000 tonnes a year of leach residues (13.5% Ni, 56.1% Cu, 15.8% S), producing granulated matte with low sulphur levels (6% S) suitable for treatment in the refinery.

Although this first plant had "teething" problems, modifications to equipment and operating procedures allowed continuous improvements to be made in both throughput and efficiency, resulting in a successful operation at design production rates [3].

Bindura Nickel Corporation

The Ausmelt Technology smelter at Bindura Nickel Corporation in Zimbabwe processed 10,000 tonnes a year of nickel plant copper sulphide leach residue (0.75% Ni, 70.0 % Cu) to produce blister copper and discard slag [4].

In the process the residue material was smelted to produce matte. The subsequent convert and slag reduction stages produced blister copper and discardable slag respectively. The process was novel as it incorporated smelting, converting and slag reduction process steps in a single Ausmelt vessel. To comply with downstream processing requirements the Ausmelt furnace was required to meet tight blister copper quality requirements for arsenic and nickel, from a feed that was high in these impurities.

The plant operated to design after acceptance into service in September 1995. The residue feed has since obtained highly favourable direct sale terms under existing copper market conditions and the plant was shutdown in 2000.

Developments at Bindura were particularly significant for the copper industry in commercially demonstrating use of Ausmelt Technology for direct copper converting.

Tsumeb Corporation

This single furnace facility was initially designed and operated as a lead concentrate smelter, but was later used to process lead-rich copper concentrate (20% Cu and 12% Pb) to produce clean copper matte and a lead rich fume.

In early 1998, the Ausmelt furnace changed from a lead smelter to a copper smelter and processed 25-30 tonnes an hour of copper concentrates (15-27% Cu, 8-12% Pb, 2-5% Zn and 20-27% S) to produce copper matte at an operating temperature of 1180 °C. The annualised throughput of the plant was between 100,000 to 120,000 tonnes a year of concentrate. Matte produced from the Ausmelt furnace contained 55-65% Cu, 7% Fe and 20% S. A copper content of 0.4% in the discard slag was achieved. Fume produced from the furnace contained 39% Pb, 0.1% Cu, and 8% Zn.

Zhong Tiao Shan

Commissioned in late 1999, the first integrated TSL operation for blister copper production was the Zhong Tiao Shan (ZTS) Smelter in Houma City, People's Republic of China. This smelter processes varying grade concentrates (17-30% Cu) to produce 35,000 to 40,000 tonnes a year blister copper. The blister copper produced is processed to anode and cathode copper in the existing ZTS refinery complex located approximately 70 km away.

The ZTS copper smelter is a three furnace system, incorporating Ausmelt smelting and converting furnaces and an Ausmelt designed settling furnace [5] [6]. Copper concentrate is processed in the smelting furnace to produce copper matte containing 60% Cu and a discard slag containing 0.6% Cu. The mixture of slag and matte is transferred to the settling furnace via a specially designed launder-outlet/inlet weir system. Matte is separated from slag in the settling furnace and transferred into the Ausmelt Converting furnace via another launder-weir system where it is converted to blister copper. Discardable slag is tapped from the settling furnace via an outlet weir and granulated. This slag is environmentally safe is used for road building or as a cement additive.

The Ausmelt converting furnace accepts feed matte in either granulated or liquid form. The converting furnace operates in semi-continuous mode and produces blister copper with less than 0.3% sulphur.

Anhui Tongdu

Anhui Tongdu's copper plant in Tongling, China constructed an Ausmelt smelting facility to replace two blast furnaces.

The Ausmelt smelting furnace and electric settling furnace process 330,000 tonnes a year of low grade copper concentrates (~18 to 20% Cu), producing matte containing 50% copper. The Ausmelt smelting system is located at the end of the present converter aisle, enabling matte to be transferred by ladle to three existing Peirce Smith converters.

The plant has been in service since the 4th quarter of 2003.

Anglo Platinum

The first of two Ausmelt converting furnaces to be constructed as part of the modernisation of Anglo Platinum's Rustenburg plant, South Africa has been in operation since 1st quarter 2003. The Ausmelt converter technology was chosen to reduce overall plant SO_2 and solid emissions by replacing the existing six Peirce Smith converters. Each Ausmelt converter will process approximately 213,000 tonnes a year of electric furnace matte, containing copper, nickel and PGM's to produce a high grade product matte. The composition of the product matte is crucial to the recovery of the contained platinum and palladium.

Apart from cleaner operation, this project makes particular use of Ausmelt Technology's ability to automate process control and enable iron and sulphur in product to meet tolerances of ± 0.5 and ±0.2% to be achieved.

Design and construction work on the second converter is now underway.

Birla Copper

The second generation of the integrated 3 furnace Ausmelt smelting, settling and converting system commenced operation at Indo Gulf Corporation Limited's Birla Copper Division in 2004. This plant treats 270,000 to 350,000 tonnes a year of concentrates to produce approximately 70,000 tonne a year blister with the expectation of achieving 100,000 tonnes a year blister in the near future.

Design and Construction was completed within 20 months and the plant is now in full production.

Korea Zinc

Korea Zinc have installed an Ausmelt furnace for secondary copper treatment at their facility in Onsan, Korea.

This furnace is rated to process 70,000 tonnes a year of copper dross from Korea Zinc's lead refinery and other secondary copper materials. The copper matte product will be processed in a new electro-refinery.

The Ausmelt plant is scheduled to be in full operation in the first half of 2005 and is the eighth Ausmelt furnace used by Korea Zinc.

Russian Copper Company (RCC)

Ausmelt has recently entered into a contract with Russia's third largest copper producer, RCC, to provide Ausmelt smelting technology as part of the modernisation of the Karabash smelter in the Cheliabinsk region in the Urals of Russia.

An Ausmelt smelting furnace will replace three shaft furnaces. The new smelting system will process approximately 500,000 tonnes a year of concentrates, producing matte for subsequent conversion to blister copper in existing Peirce Smith converters.

The design and construction of the plant has been fast tracked, with operation expected to commence in mid-2006.

Development of Continuous Converting

Converting Needs

The copper marketplace has seen a trend towards increased site capacity usually through the implementation of large scale single smelting vessels [7]. This push towards large scale single vessel operation has not been matched on the whole by a corresponding progression in converting technology. Here the reliance remains typically with batch type smaller operating units, such as the venerable Pierce-Smith converter which remains as the dominant copper converting process used throughout the industry. For all its strengths, its batchwise operation, high gas volume and difficult emission control, will see Peirce-Smith converters being replaced by more efficient and environmentally acceptable converting processes.

Ausmelt already provides a direct replacement alternative in the form of semi-continuous converting. This is similar to the operation of a Peirce-Smith converter, without the operational and hardware difficulties. Semi-continuous converting in a single furnace is a suitable direct replacement for several Peirce-Smith converters, up to approximately 100,000 tonnes a year copper, but the future trend is for single vessels at large scale exceeding 200,000 tonnes a year.

In order to meet this requirement, Ausmelt undertook development of the Ausmelt Continuous Copper Converting (C3) Process. This has the potential to provide significantly greater capacities, while simplifying operation and control. The Ausmelt C3 Process also offers the advantage of being easily implemented using the existing Ausmelt smelting and converting integrated flow sheet.

The Foundations

The foundations for the Ausmelt C3 Process are built on Ausmelt's commercial experience with semi-continuous converting operations, using essentially the same type of furnace and hardware. The approach is to provide an integrated blister copper process that does not isolate converting from the smelting operation.

The base semi-continuous process can be illustrated by a simplified flowsheet as shown in Figure 1. In this mode the converting operation comprises two stages; the production of white metal followed by the final oxidation of copper sulphide through to blister copper. At the start of a converting cycle matte, whether molten or granulated, is fed at a fixed rate while a controlled amount of reaction air is injected via the lance. The oxidation of the feed reduces the iron content from typically 15% in the feed matte to white metal containing approximately 0.5% iron. During this operation silica and sometimes other materials are added to flux the oxidised iron and produce a fluid slag.

Once the furnace is full matte feeding is stopped and the final stage of copper sulphide oxidation begins.

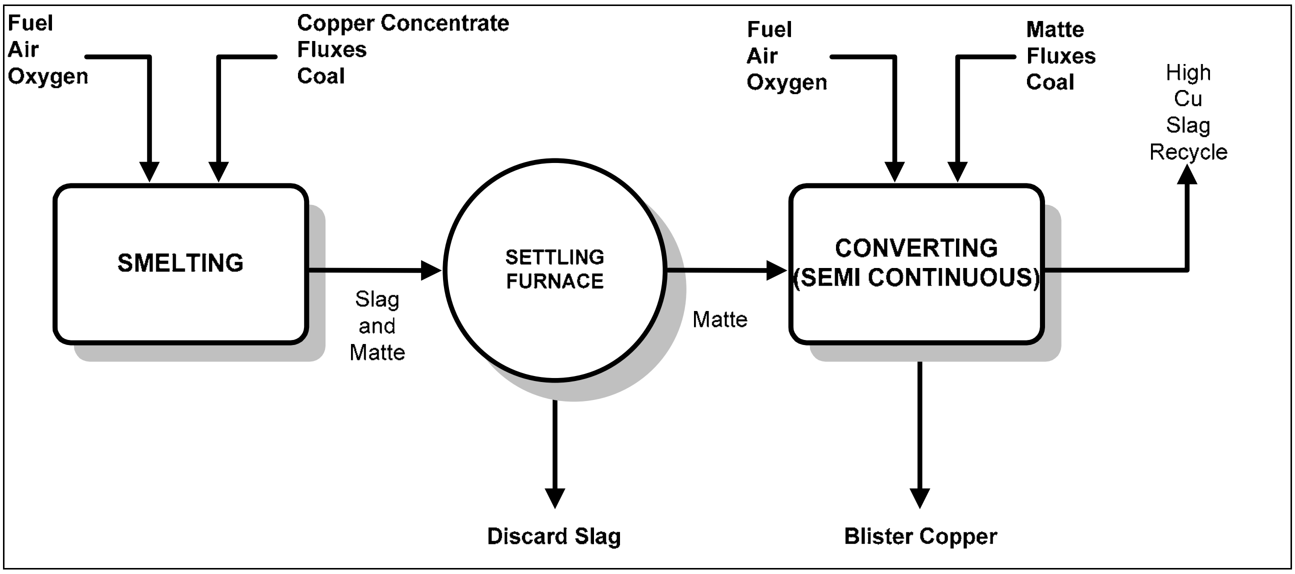

Figure 1: Ausmelt Semi Continuous Copper Converting Flowsheet

The Concept

The development of the Ausmelt C3 Process started with the concept of eliminating the production limiting stage of the semi-continuous which is the dead time arising from the final blow to copper. By doing this and thereby making more time available for feeding matte to the system, the potential for vast improvement in converter throughput can be recognised as can be seen in Table 2.

Table 2: Comparison Converting System Productivity

Converting System	Productivity (Cu t/ m^3 bath)
Peirce Smith	1,500
Ausmelt Semi Continuous	3,500
Ausmelt C3	10,000 +

It is in the implementation of this seemingly simple concept that issues present themselves. These mainly revolve around the slag system used and the quality of blister produced.

Slag Systems

Of the three major slag systems potentially available for converting; fayalite, calcium ferrite and ferrous calcium silicate, the calcium ferrite system appears to be favoured by others for continuous converting processes. This widely accepted opinion is well summarised by Yazawa [8] in a comparison of factors relating to these systems for copper processing as shown in Table 3.

Table 3: Comparison of Slag Systems after Yazawa

Slag	**Iron Silicate**	**Calcium Ferrite**	**Ferrous Calcium Silicate (Olivine)**
Viscosity	High	Low	Medium
Entrainment of copper	High	**Low**	Medium
Magnetite Precipitation	High	**Low**	Medium
Tendency to foam	High	**Low**	Medium
Refractory wear rate	Medium	High	Medium
Basicity	Acidic	Basic	Basic

Underline = Disadvantage, **Bold =** Advantage

Whilst iron silicate slags have been traditionally used in copper converting, the main concern comes from the effect of high oxygen partial pressures that increase the ferric iron (Fe^{3+}) content in slag. The limited solubility of ferric iron in pure iron silicate slags leads to magnetite precipitation which increases the apparent viscosity and unless higher temperatures are used the result can be foaming.

A solution to this has been the use of calcium ferrite slags (CaO-FeO-Fe_2O_3), as used commercially by Mitsubishi, in the MI-C process. This is due to two major factors; the higher magnetite solubility limit and the lower viscosity (typically ~0.03 Pa.s cf ~ 0.20 to 0.30 Pa.s for silicate slag). However, such a low viscosity gives rise to other issues, mainly in furnace containment and refractory wear and these have been experienced in furnaces operating with this type of slag.

Copper losses in the form of Cu_2O are reportedly lower than in iron silicate slags. Other features include the high solubility for acidic oxides including arsenic and antimony and lower capacity of more valuable metals such as cobalt and nickel.

Calcium ferrite slags are only suitable for converting due to the higher affinity for sulphides in the slag. In addition, operational difficulties arise in calcium ferrite slags if too much silica is present in the feed. Silica levels of only ~5 wt% are enough to achieve saturation of dicalcium silicate and subsequent precipitation. If more silica is added, the viscosity of the calcium ferrite slag increases considerably and removal of slag from the furnace becomes difficult.

The ferrous calcium silicate (olivine) slag system is another that has been proposed [9] and is between the two slags already mentioned. They may avoid most of the previously mentioned problems encountered when using either iron silicate or calcium ferrite slags in converting. However, these slags do present issues with increased slag volume and via this, copper loss to slag.

From its extensive operation in converting, Ausmelt has found that magnetite can be controlled within typical smelter slag systems, the iron silicate and ferrous calcium silicate type slags, without the need to resort to extreme operating temperatures or slag systems which are specially tailored to converting, such as calcium ferrite slags, but have their own drawbacks. This knowledge is reason to believe that continuous converting operation with iron and ferrous calcium silicate type slags is achievable and offers the following advantages:

- A slag system consistent with conventional copper smelting slags providing a level of familiarity for operators when using iron silicate slags.
- The ability to recover copper from converting slag streams, including the capacity to absorb larger recycles of convert slag in comparison of calcium ferrite convert slags where limitations exist in feed rate of recycles to maintain optimal slag chemistry for the smelter (≤ 5 wt% CaO).
- A less aggressive slag that poses fewer containment issues, a factor that is especially important in bath smelting operations.

Blister Quality

Another critical factor in converting is the metal product quality, in particular the expected sulphur levels in blister copper. The target for this is usually dependent upon the process and the level of copper in slag and iron as Fe^{3+} that can be accepted. Typical sulphur levels in blister copper are between 0.25 and 1.20 wt%. Closely linked to this is the copper loss to slag and the relationship between sulphur in blister copper and copper in slag. To achieve low copper in slag normally means high sulphur in blister.

Since virtually all copper produced by converting goes to electro refining, it must be suitable for casting into strong smooth anodes for interleaving with cathodes. This requires that most of its sulphur and oxygen is first removed. A high sulphur blister requires a prolonged oxidation in the anode furnace and more costly treatment of anode furnace offgas to recover the sulphur. But this transfers load to the anode furnace where the excess sulphur must be removed and captured from the offgas.

To be an acceptable alternative it is expected that a process technology that can deliver low values of both should be targeted. From review and analysis of producer requirements, Ausmelt has targeted 0.2 wt% sulphur in blister with a slag containing 20 wt% copper.

Pilot Scale C3

Objectives and Results

As with many developments Ausmelt has completed, pilot plant testwork provides the basis for defining the envelope within which commercial scale operations can operate. As described above, the best starting point for the Ausmelt C3 Process was the typical plant slag system currently used by Ausmelt semi-continuous converting operations.

Ausmelt is fortunate to have state of the art pilot plant facilities to simulate commercial operations. This facility allows tight control over all input streams, from feed materials to gases injected via the lance, an aspect that is especially crucial to any such development.

In preparation for the pilot trials desktop studies were undertaken to review process control and in doing so Ausmelt's converting process tool was extended to provide guidance to metallurgists in assessing feed forward control based on quick turnaround sampling and assays.

The primary objective of the test work was to continuously convert a typical commercial copper matte (purchased) and produce a blister copper product containing approximately 0.2 wt% sulphur in copper, while maintaining a copper in slag of around 20 wt%.

Three slag systems were trialled; iron silicate, lime modified iron silicate and olivine type slags. Blister copper was successfully produced in all trials.

No foaming problems were encountered during the testwork and good sulphur in blister levels were achieved. These results were particularly encouraging, especially for iron silicate slags and negated the common view that high iron slags are not suitable for continuous converting.

The blister copper quality is also of crucial importance and in converting the trade off for producing low levels of sulphur in blister is the increase in loss of copper as copper oxide to the slag. The blister copper produced from the pilot plant trials compares favourably to current levels produced in industry. The results from the testwork vary from 0.03 % and 0.3% S. Most notably the high figure was from the first trial conducted. The best result obtained was sulphur in blister of 0.03% at a copper in slag of 23 %. This result alone suggests that the Ausmelt C3 Process could be a more attractive commercial alternative to current continuous converting technologies.

Pilot Trial Conclusions

The result of these trials has enabled Ausmelt to conclude the following in relation to its C3 Process:

- Both iron silicate and ferrous calcium silicate type slags are suitable slag systems, types which are not conventionally seen as ideal for continuous converting application.

- Blister copper containing between 0.03 and 0.3 wt% sulphur, from either lump or fine matte, can be produced.
- Low copper in slag levels can be achieved while still maintaining an acceptable level of sulphur in blister copper.
- Oxygen utilisation for converting was high.

The Next Step – Commercial Operation

Ausmelt is currently examining commercial scale application of its C3 process, with the conceptual flowsheet as shown in Figure 2. One avenue to rapid implementation is through existing Ausmelt operations, with the potential to increase production levels.

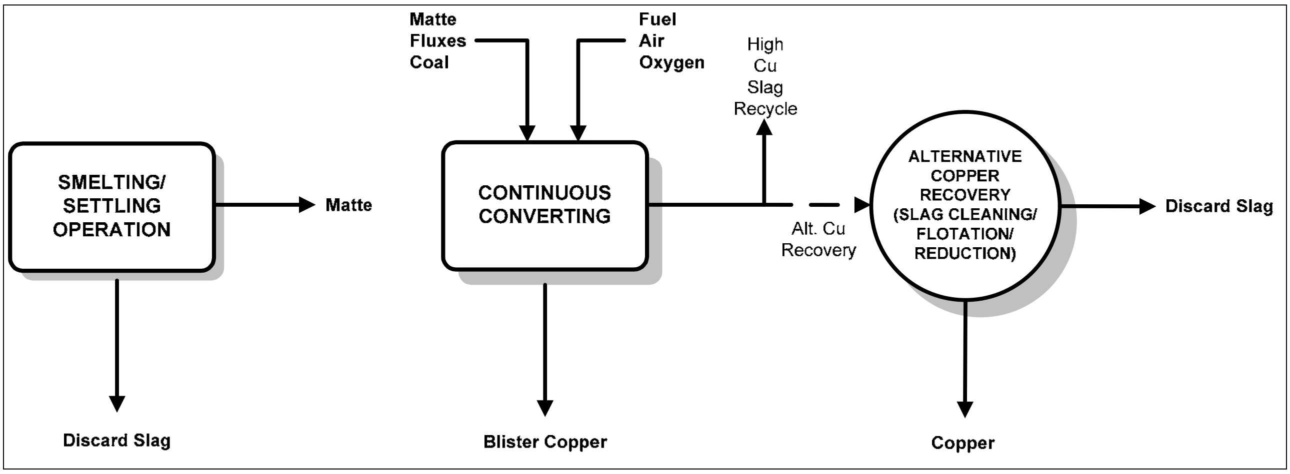

Figure 2: Commercial Concept Flowsheet of the Ausmelt C3 Process

The potential benefits to industry over conventional converting include:

- Large scale production of blister copper in a single furnace, a major step-up in available productivity from the conventional single vessel converters.
- Production of high-grade blister copper containing low sulphur and other impurity levels.
- The ability to process molten matte, solid matte or a combination of both.
- The high level of bath agitation ensures high energy transfer and oxygen utilisation.
- Unlike conventional rotary technologies, Ausmelt converters continuously process matte through to blister copper with no requirement to stop operation between stages to add flux or remove slag. Ausmelt converters have higher availability, with the converter in operation for 90% of the time compared with 40 to 50% for Peirce Smith converters. This means fewer vessels, less maintenance expenditure and higher energy efficiency per tonne of copper produced.

- As with the Ausmelt smelting furnace arrangement, the fixed nature of the Ausmelt C3 Process converter ensures excellent sealing between the furnace and off gas system, high sulphur capture in excess of 98% and low dilution of the off gas stream, resulting in high SO_2 concentrations (> 8% SO2 in off gas).

It is expected that as the technology becomes more widespread, the envelope of operation could be expanded.

The Ausmelt Continuous Copper Converting (C3) Process is now in a position that TSL smelting was almost a decade ago. The first commercial operation will mark a new milestone in converting operations that will see TSL increase its application into yet another area of metals production.

References

[1] Floyd, J.M., Conochie, D.S.: Sirosmelt – The First Ten Years. The AusIMM Melbourne Branch Symposium on Extractive Metallurgy. November, 1984, pp. 1 – 8.

[2] Baldock, B.R., Short, W.E.: Australian Technology on the World Scene – Update on Ausmelt Plants and Projects. MINPREX 2000. International Congress on Mineral Processing and Extractive Metallurgy. Melbourne. September 11-13, 2000, pp. 169-174.

[3] Markham, P., Mwenye, T., Vernon, P.N.: The Smelting of Nickel – Copper Leach Residues in a Sirosmelt Furnace. XVth CMMI Congress. Johannesburg, 1994, Vol 2. pp 295 – 302.

[4] Floyd, J.M., Mounsey, E.N., Baldock, B.R.: Copper Converting at Bindura Nickel Corporation using Ausmelt Technology. Sulfide Smelting ’98 Current and Future Practices. 1997 TMS Annual Meeting, Orlando, Florida. February 10-13, 1998. pp 287-301.

[5] Mounsey, E.N., Li, H., Floyd, J.W.: The Design of the Ausmelt Technology Smelter at Zhong Tiao Shan’s Houma Smelter, People’s Republic of China. Copper 99 – Cobre 99. TMS Conference. Arizona, USA. October 10-13, 1999. pp 357-370.

[6] Li, H., Floyd, J. M.: Ausmelt’s Copper Smelting and Converting Technology for Chinese Projects. The 2nd Annual Conference of China Non-Ferrous Metals Association - Base Metal Metallurgy Conference. Yunnan Province, People’s Republic of China. 7-12 October, 1996.

[7] Ramachandran, V., Lehner, T., Diaz, C., Mackey, P.J., Eltringham, T., Newman, C.J., Jiang, C.Y., Tarasov, A.: Primary Copper production – A Survey of Operating World Copper Smelters. Copper 2003-Cobre 2003, Volume IV – Pyrometallurgy of Copper (Book 1), The Hermann Schwarze Symposium on Copper Metallurgy. Santiago, Chile. pp 3-107.

[8] Yazawa, A.: Table from series of lectures at RMIT University, Melbourne, Australia, January 1999

[9] Yazawa, A., Takeda, Y., Nakazawa, S.: Ferrous Calcium Silicate Slag to be used for Copper Smelting and Converting. Copper 99 – Cobre 99 International Conference. TMS pp 587 – 599.