CONVERTING USING ISASMELT^{TM} TECHNOLOGY

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ABSTRACT

The ISASMELT^{TM} process is recognized worldwide as a modern, flexible, environmentally-friendly and low capital cost smelting technology. Due to the inherent simplicity, and the advanced process control that has been developed, personnel become competent within weeks of being introduced to the ISASMELT^{TM} technology. This compares with the years required to become proficient with alternative technologies. Copper smelters in Australia, USA, India, China, Peru and Zambia have installed ISASMELT^{TM} technology under licence from Xstrata Technology.

In the secondary copper business, plants in Belgium and Germany are processing copper and/or lead materials in ISASMELT^{TM} furnaces in a two stage process. In a single furnace smelting is followed by converting. Both plants have exceeded design capacities and are continuously improving their performance.

The next evolutionary step for the technology is the implementation of the continuous copper converting process on a commercial scale.

The present work describes the design status of the continuous converting process - ISACONVERT^{TM}.

INTRODUCTION

Over the last 25 years the ISASMELT^{TM} process has been developed into a process suited to various roles in the non-ferrous smelting industry including primary and secondary copper smelting, and primary and secondary lead smelting. Furnace capacities have increased from a feed rate of 12 tph of concentrate on the first copper demonstration plant to a feed rate of 180 tph at Mt Isa, or more than 300,000 tonne per annum of cathode copper equivalent from the Vedanta furnace in India. Development of the process continues for different feed qualities, higher throughputs and different processes.

The rate of adoption of the ISASMELT^{TM} furnace has been highest in the primary copper smelting industry with five furnaces in operation, one furnace due to be commissioned in 2007 and detail engineering commencing on two furnaces due for commissioning in 2009. Based on the survey of operating copper smelters in 2003 [1] the fraction of the world primary copper produced in ISASMELT^{TM} furnaces will have increased to approximately 12 % when the Southern Peru Copper Corporation furnace reaches full production in 2007.

The ISASMELT^{TM} furnace is also suited to continuous and batch converting of copper matte to blister copper. Continuous converting has been performed successfully in ISASMELT^{TM} pilot plants; blister copper was produced using a calcium ferrite slag with a matte feed rate of 250 kg/h. Batch converting in the ISASMELT^{TM} furnace is performed by two smelters in Europe. Umicore Precious Metals in Hoboken, Belgium, has been using the ISASMELT^{TM} furnace for converting since 1997, and in 2002 NA AG, Lünen, Germany, commissioned the second ISASMELT^{TM} furnace to be used for converting.

BATCH CONVERTING

Copper Converting at Umicore

Umicore is a speciality materials group with activities centred in Precious Metal Services, Precious Metal Products and Catalysts, Advanced Materials and Zinc Specialities [2] . The company, under its former name Metallurgie Hoboken Overpelt (MHO), initially developed the Hoboken converter, but during the 1990s came to realise that it could not meet the strict environmental regulations coming into force in the 21st century. As a result, Umicore elected to collaborate with Mount Isa Mines (now Xstrata) on further developing the ISASMELT^{TM} process to smelt and convert mixed copper feed materials.

A demonstration plant was designed by Xstrata and operated for some months at the Hoboken smelter site. Following successful operation of the demonstration plant a full scale commercial ISASMELT™ furnace was designed and constructed. The commercial smelter was commissioned at the end of 1997 and is now treating up to 300,000 tonnes per year of secondary feed materials. Figure 1 shows a general view of the ISASMELT™ plant at Hoboken [2].

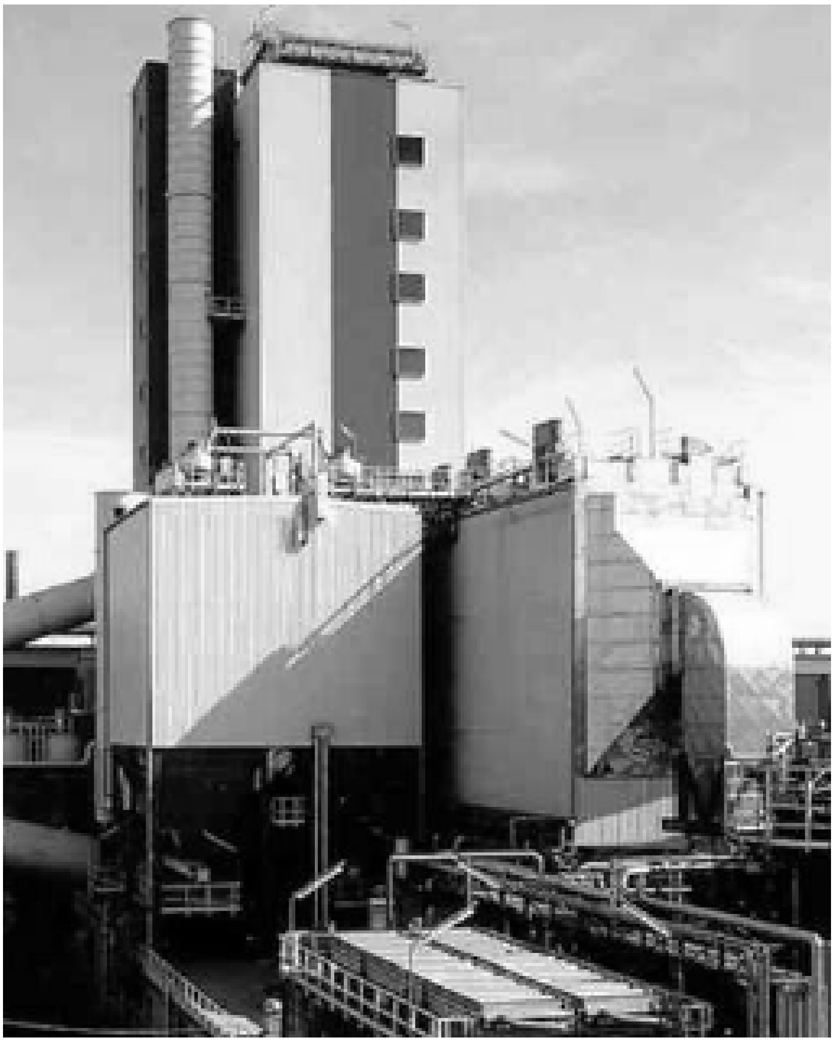

Figure 1 - ISASMELT™ plant at Hoboken

Figure 2 shows the Precious and Base Metals operation process flowsheet at Hoboken [3]. The ISASMELT™ furnace plays a key role in the overall metallurgical process. Complex lead/copper materials, containing valuable minor elements are treated in the ISASMELT™ furnace in a two step smelting and converting process.

The smelting stage involves the oxidation of the feed to form a copper matte and a smelting slag by injection of oxygen enriched air through the lance. The silica-based Pb-rich slag produced during smelting is tapped and the remaining copper matte is converted to blister copper. All the precious minor elements are captured into the copper phase [4].

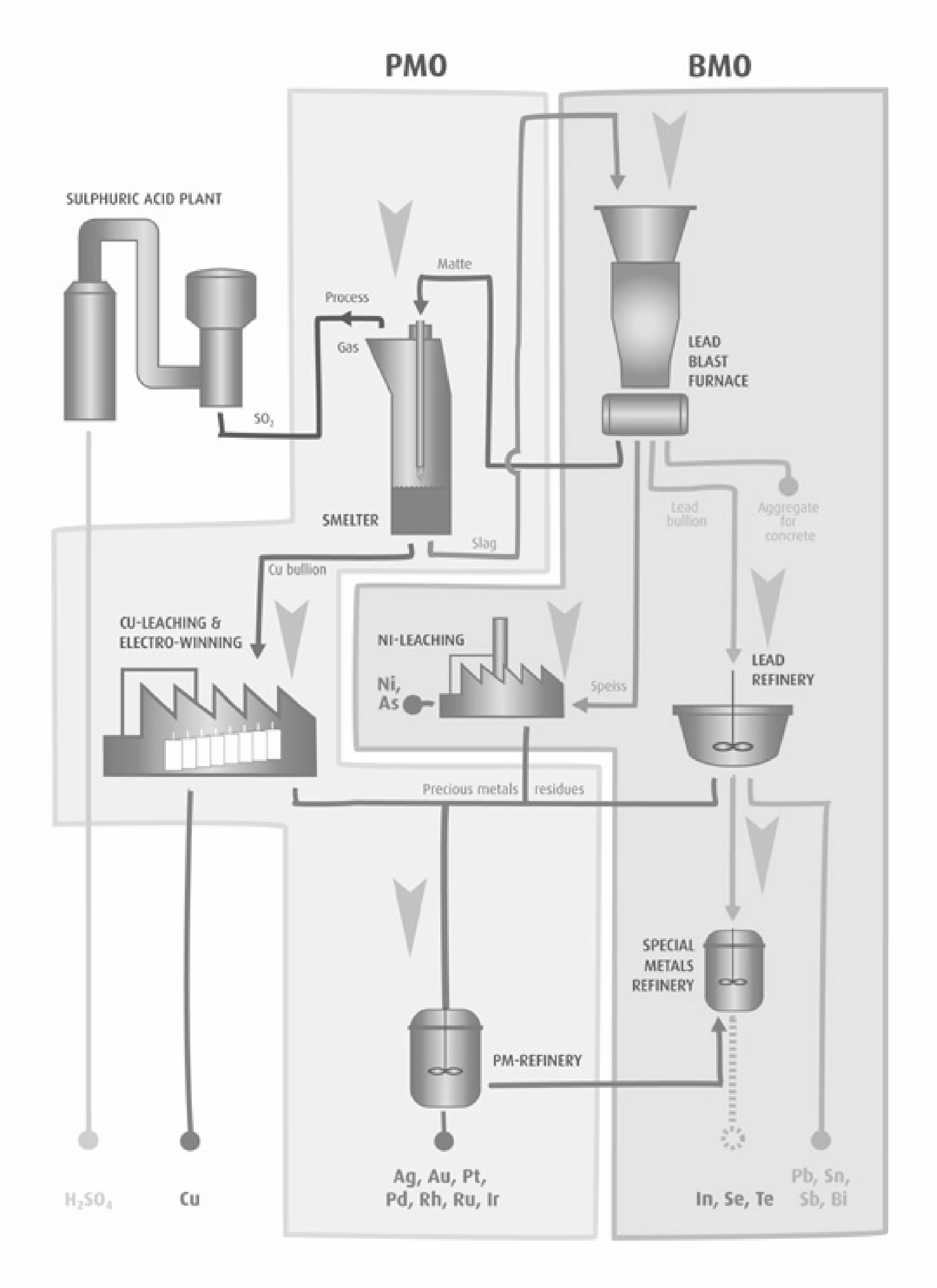

Figure 2 – Precious Metals and Base Metals Operations flowsheet at Hoboken

From the above process description it can be noted that the ISASMELT^{TM} furnace is operating in two very different environments: low oxygen partial pressure for the smelting and high oxygen potential partial pressure for converting. The different oxygen partial pressure conditions provide a harsh test for the refractory. Even in these extreme operational conditions, the ISASMELT™ furnace is achieving a campaign life of 15 months [5].

Copper Smelting and Converting at Norddeutsche Affinerie - Hüttenwerke Kayser

Norddeutsche Affinerie AG operates an ISASMELT™ plant for secondary copper smelting within a smelting and refining operation in Lünen, Germany [6]. Figure 2 shows an overall view of the plant at Lünen. The ISASMELT™ furnace replaced three blast furnaces and one Peirce Smith converter used for smelting residues and scrap copper and plays an essential role in the copper recycling process: Kayser Recycling System (KRS).

Figure 2 - ISASMELT™ Plant at NA in Lünen, Germany

Figure 3 shows the flowsheet for the KRS process. The smelting and converting of the copper bearing materials are carried out in the ISASMELT™ furnace in batch charges. Copper residues and scrap containing 1 to 80 % copper are charged into the ISASMELT™ furnace in a reductive smelting stage. A black copper phase and a silica-based slag that contains very low residual economic metals are produced during the reductive smelting. The slag is tapped and granulated.

After the tapping of slag the black copper phase is converted to produce blister copper with a copper content around 95%. A Sn-Pb-enriched converting slag is also generated and processed in a separate furnace. Due to the nature of the KRS process, the ISASMELT™ furnace operates in a wide range of oxygen partial pressure in each cycle providing a harsh test for the refractory.

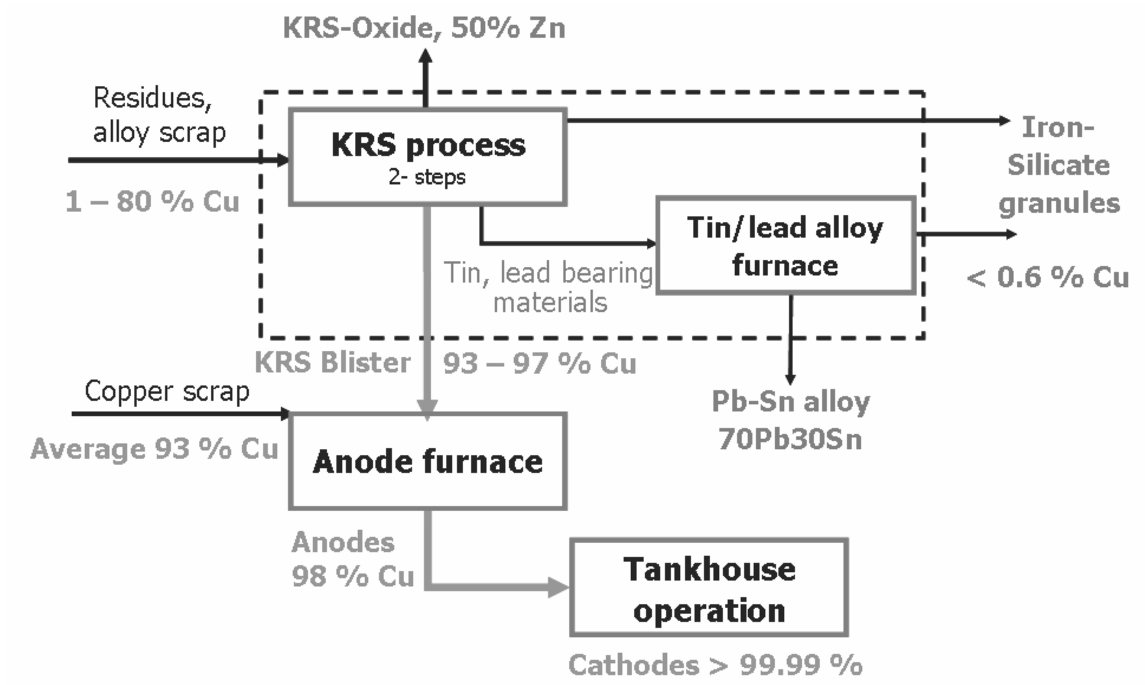

Figure 3 - Kayser Recycling System

The implementation of the ISASMELT™ technology as a main component of the KRS process has allowed NA to achieve an outstanding position in productivity, energy efficiency and environmental protection. The main benefits claimed by NA AG, Lünen, after the successful implementation of the ISASMELT™ process can be summarized as follows

- Improved overall copper recovery of the plant by achieving lower copper content in the dischargeable slag produced at the end of the smelting stage.
- Reduced number of furnaces in operation
- Significant decrease in off gas volume

- Production capacity exceeds the original design by 40%
- Decrease in energy consumption by more than 50%
- Decrease in CO_2 emissions by more than 64%
- Overall emissions reduced by 90%

CONTINUOUS CONVERTING

A combination of pilot plant continuous converting trials and the commercial batch converting operations show the ISASMELT^{TM} furnace to be well suited to the duty of continuous converting [7]. Areas of operation requiring consideration in designing a copper smelter using an ISASMELT^{TM} furnace for continuous converting – an ISACONVERT^{TM} furnace - are the slag chemistry, desulfurization of the blister copper, containment of the melt and smelter layout.

Slag Chemistry

The ISASMELT^{TM} process either in its smelting or converting mode involves the injection of oxygen enriched air into the molten slag. Control of the chemical composition and physical properties of the molten slag, such as the viscosity, is required.

Since the beginning of the development of the ISACONVERT^{TM} process it was noted a gap existed in the phase equilibria information available for the "Cu_2O"-CaO-"Fe_2O_3" system. Much of the existing information was under oxygen potential conditions that were not applicable for the continuous converting process conditions. Therefore, a cooperative research program was established with the Pyrometallurgy Research Centre (PYROSEARCH) at the University of Queensland in order to evaluate the copper converting slag systems and their potential applications to the ISACONVERT^{TM} process. Several experiments were carried out to determine phase equilibria in the following slag systems as a function of temperature and oxygen partial pressure:

- CaO-FeO-Fe_2O_3
- Cu_2O-CaO-FeO-Fe_2O_3 at copper saturation
- CaO-FeO-Fe_2O_3-SiO_2
- Cu_2O-CaO-FeO-Fe_2O_3-SiO_2 at copper saturation

The experimental work allowed for accurate determination of areas of interest in the above mentioned slag systems [8] [9]. Based on this fundamental work and a series of continuous converting pilot tests it was possible to define the slag composition region in which the ISACONVERT^{TM} process will operate. Figure 4 shows the slag composition region for the ISACONVERT^{TM} process, in the Cu_2O"-CaO-"Fe_2O_3" system at copper saturation at 1250 °C [8] The continuous line on the spinel saturation region shows the effect of the oxygen partial pressure on the copper oxide concentration on the slag phase. The grey filled area indicates the expected slag composition region in which the ISACONVERT™ process will be carried out, at a Fe/CaO ratio of approximately 2.3.

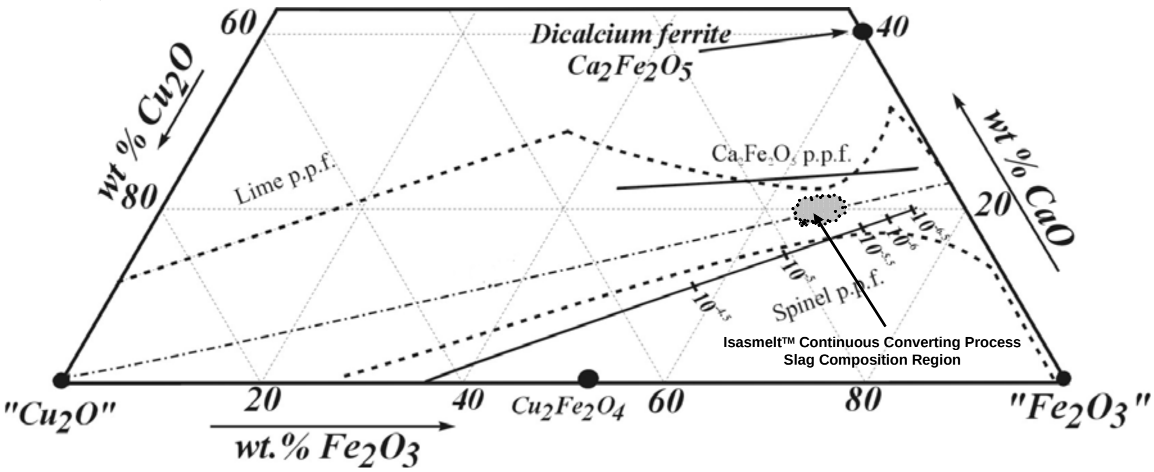

Figure 4 - "Cu2O"-CaO-"Fe_2O_3" system at copper saturation at 1250 °C

Anode Furnace Operation

Anode Refining Implications of Continuous Converting

Blister copper produced by continuous converting processes contains higher concentrations of sulfur compared with blister copper produced by batch processes such as Peirce-Smith converter. In continuous converting processes that involve three (3) condensed phases in equilibrium with a gas phase, such as the Noranda Continuous Converting process, the oxygen and sulfur potentials are fixed by the coexistence of liquid Cu_2S as a single phase at the desired temperature. This thermodynamic condition raises the sulfur content in blister copper to levels close to 1 %.

In the case of converting processes involving two (2) condensate phases, such as the ISACONVERT™ process, the oxygen partial pressure is selected aiming to control the copper oxide content in the converting slag between 12 to 18 % resulting in sulfur contents between 0.3 and 0.4 %. Alternatives for shortening the desulfurization time when operating a continuous converting process include modifications to anode furnaces such as adding extra tuyeres, and/or porous plugs to enhance the rate of desulfurization via addition of extra oxygen, and homogenization of temperature and oxygen content in the bath.

With the ISACONVERT^{TM} process, either a direct transfer to an anode furnace or a pre-treatment in a retention vessel can be adopted. In both cases, it will be preferable to have porous plugs to enhance the homogenization of the bath (thermal and chemical) and at least four tuyeres for air and/or oxygen enriched air injection to enhance oxidation of the bath. The size of the anode furnace will need to be determined by the processing time required.

From the minor elements elimination point of view, a relatively high Pb level in the blister copper produced by the ISACONVERT^{TM} furnace may be expected, compared with blister produced in a batch converting process. This is due to the relatively low Pb capacity of calcium ferrite slag compared with silica based slag. Depending upon the anode quality specifications, a slagging stage with silica addition may be required.

Melt Containment

For continuous copper converting, given the aggressive nature of the lime ferrite slag, the ISACONVERT^{TM} furnace would be designed with water-cooled copper at the slag line. A great deal of experience has been gained in the non-ferrous industry and the ferroalloy industry in water cooling system design over the past 20 years. Water cooling system designs are now available from a number of suppliers. Options available for the furnace design include copper elements behind bricks, copper elements interleaved with brick, or operating on water-cooled panels with an initial working lining of castable.

The proposed design for an ISACONVERT^{TM} furnace performing continuous copper converting is a steel shell with a brick hearth and vertical water-cooled copper panels in the slag line. The panels will be installed with a working lining of castable and will be designed to anchor slag as a wear lining as the castable wears.

Smelter Layout

Figure 5 shows a block diagram for a plant with an ISASMELT^{TM} furnace for smelting of concentrates followed by an ISACONVERT^{TM} furnace for converting of copper matte to blister copper. As already practised in the Kennecott flash converting plant matte is granulated and stockpiled in front of the converting furnace [10]. The use of a small stockpile decouples the smelting and converting furnaces. Feeding solid matte to the converting furnace increases the heat load on the furnace which is balanced by the removal of nitrogen from the system through the use of tonnage oxygen resulting in a high SO_2 tenor of the offgas.

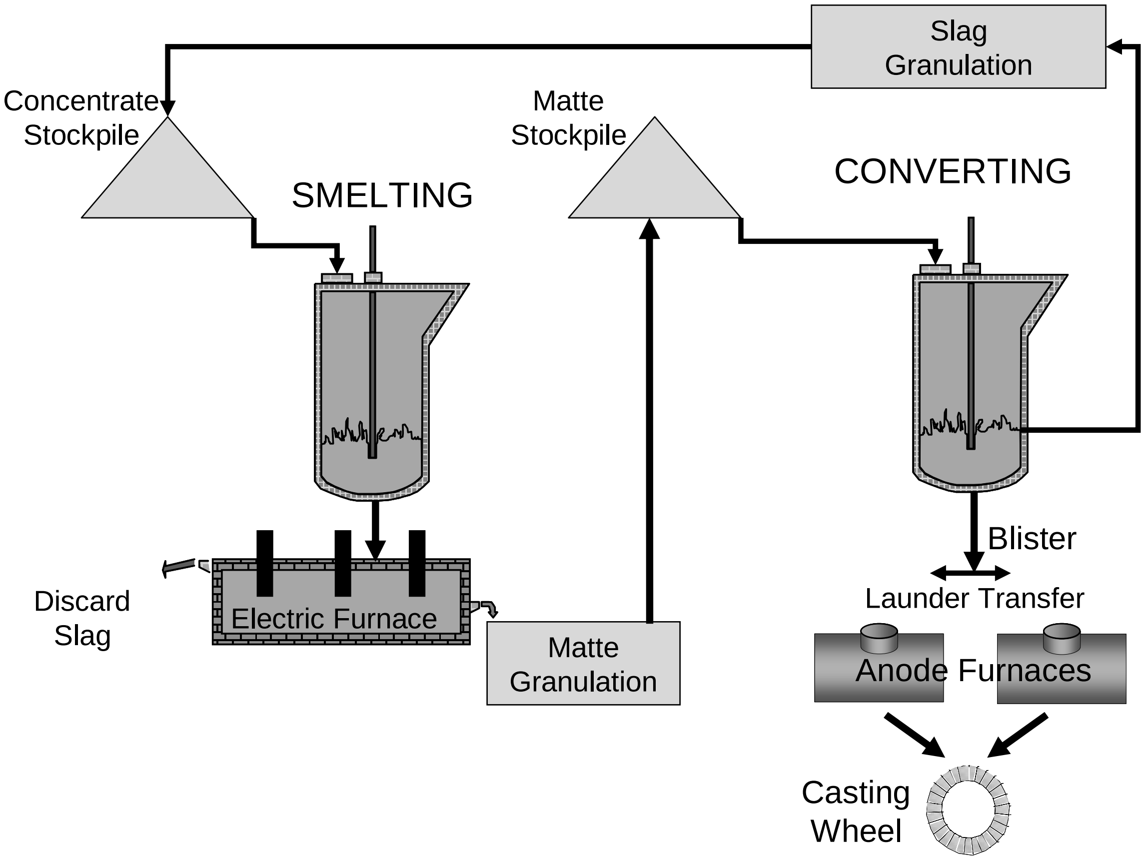

Figure 5 – Continuous converting plant flowsheet

Solid matte and flux will be dropped in through the roof of the converting furnace to be incorporated into the bath in the converting furnace. Slag will be tapped from the converting furnace to a granulation system, and the blister will be tapped to either a holding furnace or an anode furnace.

In a greenfield smelter where anode furnaces have been sized to treat blister containing 0.3 to 0.4 % sulfur the blister may be tapped directly from the converting furnace into an anode furnace. For existing smelters where anode furnaces have been sized to treat blister containing 0.05 % sulfur a holding furnace may be used after the converting furnace to allow pre-treatment of the blister copper before fire refining. The holding furnace would also act as surge capacity between the converting furnace and the anode furnaces.

Converter slag would be tapped from the ISACONVERT™ furnace to a granulation system. The granulated converter slag would be fed to the primary ISASMELT™ furnace. From previous experience solid slag fed to the ISASMELT™ furnace is readily incorporated into the bath and acts as an oxygen source.

The layout for a smelter using an ISASMELT™ furnace and an ISACONVERT™ furnace will be very compact and will require significantly less area than conventional copper smelters. The fact that the smelting and converting processes are very similar and easy to control via a proven robust process control system will also simplify operations and logistics within the smelter, allowing all operations to be carried out from one central control room. These factors will lower the operating costs of the new smelter compared with the conventional Peirce-Smith technology. The significantly reduced offgas volume from the converting process will result in lower capital and operating costs for offgas collection and cleaning systems.

SUMMARY

- Copper ISASMELT™ furnaces are operating successfully in 7 countries with capacities up to 180 tph of feed or 300,000 tpa of cathode copper equivalent.
- Batch converting of copper matte in commercial ISASMELT™ furnaces has been performed since 1997 in Europe.
- Continuous converting in an ISACONVERT™ furnace using a calcium ferrite slag has been successfully performed at a pilot scale.
- Slag systems for copper converting have been researched extensively and a lime ferrite slag appears the most practical for implementation of the continuous process in an ISACONVERT™ furnace.
- Containment of the lime ferrite slag will be achieved using water-cooled systems in critical areas of the furnace only.
- Furnace layout will allow a very small footprint to be achieved for new copper smelters. There will be advantages in operations and logistics resulting in reduced operating costs.
- The significantly lower offgas volumes from the continuous converting process will result in lower capital and operating costs for offgas collection and cleaning.

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