Secondary Copper Processing using Outotec Ausmelt TSL Technology

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ABSTRACT

Steady depletion of the world’s primary copper reserves coupled with a meteoric rise in electronic waste (e-waste) generation has led to secondary copper processing assuming an ever-increasing importance within the global copper industry. Treatment of secondary copper feeds at existing smelting operations has traditionally been performed in the Blast furnace, Peirce-Smith converter and/or anode furnace. In the past decade or more, bath smelting technologies have been preferred for the processing of these materials due to their superior environmental performance and flexibility to operate under a wide range of conditions. This paper focuses on the pyrometallurgical processing of copper secondaries in the Outotec Ausmelt TSL Furnace and some of the unique issues facing secondary copper smelters and downstream gas handling/cleaning equipment.

INTRODUCTION

Primary copper smelting has long been the dominant processing route for copper production. In the past decade the proportion of global copper production derived from copper secondaries has hovered around 35% (Fig. 1) (International Copper Study Group, 2010).

![Fig. 1 – Global Copper Production (International Copper Study Group, 2010)](image-url)
More recently, the copper industry has witnessed significant growth in the recovery of copper and other metal values from secondary materials (Reuter and Van Schaik, 2008), a number of which are listed and illustrated below (Fig. 2):

- Metallurgical wastes - low grade slags, residues, anode slimes, oxide residues etc.;
- industrial wastes - copper sheeting, bars, pipes, wire, ship screws, etc.;
- consumer wastes - brass and bronze applications;
- electrical and electronic waste (e-waste) - domestic electrical, audio-visual, computer and telecommunication appliances.

A significant fraction of global copper production is derived from copper secondaries (International Copper Study Group, 2010), with key factors for this being:

- Tightened supply of copper concentrates;
- a drive towards improved energy efficiency during copper production, with copper recycling providing energy savings of up to 85% compared with primary smelting (Bureau of International Recycling, 2010);
- the desire to enhance the environmental performance and sustainability of the copper industry, with the recycling of copper scrap reducing CO₂ emissions by 65% (Bureau of International Recycling, 2010);
- increased availability of secondary copper materials, particularly e-waste, for which global production has soared to more than 40 million tonnes per year as a result of the rapid growth of electronic markets and short lifespan of electronic products (United Nations Environment Program, 2009);
- increased profitability of e-waste processing due to the high levels of copper (typically 5 - 30 wt. %), precious metals and platinum group metals (PGMs) compared with sulphide concentrates (United Nations Environment Program, 2009);

SECONDARY COPPER PROCESSING

The recovery of copper and other metal values from secondary copper feeds has traditionally been carried out via:

- The 'Knudsen Process', patented in 1915 and its variants, whereby an impure ‘black copper’ product is generated under reducing conditions (typically in the blast furnace) and
subsequently oxidised to raw copper using Peirce Smith or Hoboken converting (European Commission, 2009);

- re-melting/alloying copper and copper based alloy scrap (brass mills and wire rod plants);
- remelting in existing Reverberatory, Peirce-Smith converting or anode furnaces.

In the last 15 years however, there has been a shift towards secondary copper processing using bath smelting technologies such as the Outotec Ausmelt Top Submerged Lance (TSL) and the Outotec Kaldo Top-Blown Rotary Converter (TBRC) processes. A number of hydrometallurgical processing routes have also attracted some interest in recent times (Cui and Zhang, 2008), although there are ongoing concerns over the handling of intermediate products such as sludges, precipitates and other solutions from these operations. Table 1 summarises a number of smelting technologies recently adopted by selected global operations for the processing of secondary copper feeds.

Despite growing interest in the treatment of secondary copper feeds, the pyrometallurgical processing of these materials is characterised by a number of issues not prevalent in primary smelting. Furthermore, the presence of elements/compounds not typically contained in concentrate feeds have implications on the design and operation of equipment and processes, presenting difficulties in the treatment of secondary copper materials within existing smelter operations.

To address these factors and the increasing availability of secondary copper feedstocks, a number of facilities have been established in the last decade or more for the dedicated processing of these materials. These operations have focussed on achieving the necessary flexibility to adapt to changes in feed composition and availability in combination with the tight control of key process variables to ensure stable operation for the effective recovery of metal values while ensuring best practice in environmental control.

### Aspects of Secondary Copper Processing

One of the primary issues faced during the pyrometallurgical processing of secondary copper materials and end-of-life consumer goods lies in the highly variable physical and compositional nature of feeds being treated.

In primary concentrate smelting, despite differences in the composition of feeds treated by the world’s copper smelters, process flowsheets and operating conditions at these facilities are largely the same. Variations in concentrate grade, gangue content and impurity levels, intrinsically linked to the geology and mineralogy of the parent ore body are typically managed via appropriate changes to the smelting operating conditions, without the need for extensive modification of plant equipment. Well known ore mineralogies have made it possible to optimize smelting processes over many years, enabling relative robust process control of the smelting process. In contrast to primary concentrates, the availability, physical characteristics and composition of secondary copper feeds is subject to both significant and rapid variation.

With reference to concentrates, secondary copper smelter feedstocks are often made up of many different materials obtained from a wide variety of sources. Hence the quantity and characteristics of the overall feed blend are strongly dependent on material availability, economics and sourcing practices employed. E-waste feeds in particular are influenced by factors such as consumer trends, product designs, technological developments and government legislation (e.g. replacement of lead with other elements in solder, increased antimony content as a flame retardant in resins/plastics and replacement of CRT devices with LCD units which contain for example indium-tin-oxide etc).
<table>
<thead>
<tr>
<th>Process</th>
<th>Technology</th>
<th>Location</th>
<th>Feed Materials</th>
<th>Metals Recovered</th>
<th>Process Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSL</td>
<td>Outotec Ausmelt TSL</td>
<td>Dowa Mining Co. Ltd. Kosaka Copper Smelter Akita, Japan</td>
<td>E-waste Cu residues</td>
<td>Cu, Ni, Ag, Au, PGMs, Pb, Zn, Sb, Sn</td>
<td>Multi-stage batch smelting and reduction operation to produce raw Cu and recover Pb, Zn and other metal values.</td>
</tr>
<tr>
<td></td>
<td>Outotec Ausmelt TSL</td>
<td>Global Resources &amp; Materials (GRM) Danyang, Korea</td>
<td>E-waste Cu residues</td>
<td>Cu, Ni, Ag, Au, PGMs, Pb, Zn</td>
<td>Continuous smelting under reducing conditions to produce a ‘black copper’ product treated in downstream operations.</td>
</tr>
<tr>
<td></td>
<td>Xstrata ISASMELT®</td>
<td>Umicore Precious Metals Hoboken, Belgium</td>
<td>E-waste Industrial wastes Cu residues</td>
<td>Cu, Ni, Ag, Au, PGMs, Pb, Sb, Sn, Bi, Se, Te, In</td>
<td>Batch smelting and converting to produce blister Cu. Part of the overall Base Metal and Precious Metal Operations Flowsheets.</td>
</tr>
<tr>
<td></td>
<td>Xstrata ISASMELT®</td>
<td>Aurubis Lünen, Germany</td>
<td>Cu scrap Cu Residues</td>
<td>Cu, Pb, Sn, Zn</td>
<td>Batch smelting (reductive) to ‘black Cu’ and converting to produce raw Cu. Part of the overall Kayser Recycling System (KRS).</td>
</tr>
<tr>
<td>TBRC</td>
<td>Outotec Kaldo</td>
<td>Boliden Rönnskär Smelter Rönnskär, Sweden</td>
<td>E-waste</td>
<td>Cu, Ni, Ag, Au, PGMs, Se, Te</td>
<td>Batch converting of e-waste to produce a mixed Cu alloy treated in downstream converting operations.</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Metallo Chimique N.V. Beerse, Belgium</td>
<td>‘Black copper’</td>
<td>Cu, Ni, Pb, Sn</td>
<td>Processing of ‘black copper’ sourced from external operations.</td>
</tr>
<tr>
<td>Noranda Process</td>
<td>-</td>
<td>Horne Smelter Quebec, Canada</td>
<td>E-waste Cu concentrate</td>
<td>Cu, Ni, Ag, Au, PGMs, Se, Te</td>
<td>Continuous smelting of primary and secondary feeds to produce Cu matte treated in downstream converters.</td>
</tr>
</tbody>
</table>
To address variability in feed composition, feed size, impurity levels and plastics/organics content, preparation and blending operations are often utilised prior to feed introduction to the smelting vessel. Crushing, grinding, drying and/or agglomeration stages are commonly used to transform ‘raw’ secondary copper materials into a form amenable to smelting. Consumer and e-waste materials usually undergo some form of manual, semi-automated or automated dismantling, mechanical pre-processing and/or sorting.

For example E-wastes are often manually dismantled to separate batteries, printed circuit boards (PCBs) and hazardous materials prior to shredding and mechanical sorting to separate copper and recover ferrous, aluminium and plastic fractions which are recycled via other means. Due to the complexity and functionality of electronic products, the extent to which liberation/separation of desired metal values can be achieved through feed pre-treatment is driven by economics (e.g. the inherent value of contained precious metals and PGMs in the recyclates). Smaller items such as mobile phones, portable MP3 players and cameras are consequently introduced to the smelter with minimal pre-processing (United Nations Environment Programme, 2009) due to these economic considerations especially as every additional processing step could increase the loss of valuable materials/metals.

Despite use of such feed pre-treatment and blending practices, establishing a long-term homogeneous feed blend is still extremely difficult to achieve. Consequently, secondary copper smelters must be flexible and sufficiently versatile to adapt their operating conditions so as to account for variability in feed morphology and composition. This is especially so given that the physical and compositional characteristics of secondary copper materials have design and operation implications to both the smelting vessel and downstream offgas handling and cleaning systems. Furthermore, tight control of process operating conditions during secondary copper smelting is required for the separation of impurities and desired metal values between the various product streams.

Secondary Copper Processing in the Ausmelt TSL Furnace

Outotec’s Ausmelt TSL Furnace is ideally suited to the processing of secondary copper materials given that the physical characteristics of feeds introduced to the furnace are not overly critical to its operation (unlike technologies such as Flash Smelting). Feed materials able to be treated in the Ausmelt TSL Furnace include:

- Heavy, bulky items and/or lumpy materials (e.g. fittings and crushed metallurgical wastes);
- fine, ‘fluffy’ and/or dusty materials (e.g. shredded materials and metallurgical dusts);
- complex waste electrical and electronic equipment (WEEE);
- irregular sized materials (e.g. scrap off-cuts and fittings);
- high moisture content materials (e.g. residues).

The complex and variable composition of copper secondaries are also easily handled by the Ausmelt TSL Furnace through precise control of the process chemistry, temperature and bath oxygen potential ($pO_2$). Operating conditions within the bath are regulated via the injection of fuel, air and in some cases, oxygen directly into the slag phase using a submerged lance (Fig. 3). Conditions above the bath ‘splash’ zone are regulated independently of the bath through the addition of air via a dedicated lance ‘shroud’ system. Shroud air also provides for the efficient recovery of heat generated from the combustion of volatile components of the feed without influencing the bath oxygen potential.

The precise level of control achieved in the Ausmelt TSL Furnace enables the recovery of metal values to targeted product phases from which they can be economically recovered whilst impurities and gangue components are directed to a discard slag or by-products from which can be safely treated (Fig. 3).
Typically, secondary copper materials are processed in the Ausmelt TSL Furnace using one of two basic flowsheets (Fig. 4), both of which are variations of the Knudsen process.

**Fig. 3 – Possible Distribution of Elements for Secondary Copper Smelting in the Ausmelt TSL Furnace Under Neutral/Oxidising Process Conditions**

**Fig. 4 – Two possible Ausmelt TSL Furnace Secondary Copper Flowsheet Options**
In Flowsheet 1, a continuous ‘reductive smelt’ stage is used to generate an intermediate black copper product and low copper content discard slag. Treatment of this black copper to produce a raw copper product may subsequently be achieved via:

- An oxidative converting stage in the same Ausmelt TSL Furnace (two-stage batch process);
- converting in separate units (e.g. Peirce-Smith converters).

This flowsheet provides benefits in instances where an Ausmelt TSL Furnace is used to replace a blast furnace within an existing secondary copper operation, given that downstream converting and refining operations typically already exist. This flowsheet may also be favoured when treating lower grade materials, as the generation of a discard slag in the smelting stage eliminates the need for downstream processing (copper recovery) of this material.

Conversely, in instances where feed materials are characterised by large variations in copper, precious metal and/or impurity levels, it is often beneficial for smelting to be carried out using a multiple stage batch process (Flowsheet 2). Selective introduction of customised feed blends in each stage and the precise control of furnace operating conditions (particularly Po2) in this flowsheet provides for the maximum recovery of valuable metals and elimination of impurities with the slag.

In the first oxidative smelting stage, the high-grade copper product generated acts as a collector for valuable minor elements (PGMs, precious metals, cobalt etc.) which are recovered using sophisticated downstream refining operations. Slag from this stage is subsequently processed under reducing conditions in Stage 2, providing for the recovery of desired metal values to a ‘dirty’ black copper product, retained in the furnace for next smelting cycle. Impurities and gangue components of the feed meanwhile are distributed to the discard slag.

Additional benefits of this flowsheet include:

- Desired metal values may be recovered in separate product streams;
- an ability for the thermal duty in each stages to be optimised;
- slag chemistry adjustment in each stage, reducing the overall process flux requirement.

Ultimately, flowsheet selection is based on the grade of secondaries being treated, the type and concentration of impurities in the feed, the nature and capacity of existing processing/refining infrastructure and client’s preferred product stream/s. Furthermore, the inherent versatility and flexibility of Ausmelt TSL Technology allows for the addition and/or removal of extra stages, even if not included within the original design.

In addition to control of the furnace bath conditions (temperature, Po2, slag composition etc.), handling and cleaning of process offgas is also considered as part of the overall Ausmelt TSL Plant. Secondary copper materials are commonly associated with various types of plastics and ceramics, many of which contain elements which produce toxic/hazardous substances if processed under certain conditions.

As a result, gas collection and abatement systems typically located downstream of the Ausmelt TSL Furnace (Fig. 6), incorporates capabilities to handle:

- Nitrogen oxides (NOx) and carbon monoxide (CO);
- sulphur dioxide (SO2) generated from the treatment of sulphidic materials such as residues;
- volatile metallic species (Pb, Zn, Hg, Cd etc.) and dusts;
- halides (Cl, F, Br etc.);
- polychlorinated dibenzoparadioxins (PCDD) and polychlorinated dibenzofurans (PCDF) generated from the processing of organic and chlorine containing compounds.
In spite of various feed treatment and sorting initiatives, which can mitigate the formation of harmful dioxins, furans and other compounds; tight control of operating conditions both within the smelting furnace and offgas handling system is still required.

CONCLUSION

The recycling of secondary copper materials and processing of 'end-of-life' consumer goods is a significant contributor to global copper production. Flowsheets and technologies employed in secondary copper operations differ considerably from those in primary copper smelting operations due to variability and complexity in the composition and physical characteristics of materials being processed. Consequently, secondary copper smelters must incorporate technology with the flexibility to vary operating conditions and practices with the ever-changing nature of feed materials being treated. Outotec’s Ausmelt TSL Technology offers precise control of key process parameters and versatility in flowsheeting options, necessary for secondary copper smelting. This is complemented by the Outotec range of offgas handling solutions which may be customised for a particular process or application to ensure that the technology operates well within best available practice and strictest environmental legislation.

REFERENCES


