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COPPER ISASMELT – DEALING WITH IMPURITIES

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Abstract

The ability to efficiently remove impurities contained in concentrates is a key point to consider when selecting copper smelting technology for new plants or modernisation projects. Volatilisation of impurities such As and Sb should occur as early as possible in the process, and preferably in the smelting furnace, so that they do not impact on downstream unit operations.

The ISASMELT™ process has been demonstrated to remove impurities efficiently, through high levels of volatilisation. This behaviour is promoted by attributes of the process such as the strong bath agitation, and the flexible nature of the process design, allowing the operator to choose the optimal matte grade for impurity partitioning, and the positive effect of the moisture content in the feed.

This paper presents the distribution of minor elements in the copper ISASMELT™ furnace. Distribution impurities of As, Sb, Pb, Zn and Co observed in the ISASMELT™ furnace at Mount Isa Smelter are reported. Then, based on plant results and thermodynamic considerations, the potential application of ISASMELT™ technology for processing complex concentrates is discussed.

Introduction

Xstrata is a global mining and processing company whose main products are copper, ferro-alloys, coal and zinc. Xstrata's mining, smelting and refining operations are based in Australia, South Africa, Spain, Germany, England and Argentina, while the company's headquarters are in Switzerland. In 2003, Xstrata acquired the Australian company MIM Holdings Limited (MIM), including the technologies that MIM had developed over more than 80 years of operating copper, lead and coal plants in Australia and Europe. This suite of technologies included the ISASMELT™ process.

The ISASMELT™ process is a simple, cost-effective, non-ferrous smelting process. Today, it is designed by, marketed by, and supported by Xstrata Technology. It is one of the most efficient and flexible smelting technologies available in the world today.

ISASMELT™ was developed from pilot plant to commercial scale during the 1980's and 1990's at MIM's smelting operations in Mount Isa, Australia. It rapidly became a crucial part of MIM's smelting operations. Eight companies in seven different countries are now using the technology in large-scale operations, and two more plants, in Zambia and Peru, are going to be commissioned during 2006. The history of the process has been documented in a number of published papers [1-9].

The process is able to treat a wide range of feed materials, ranging from mineral concentrates to scrap metals and recycled smelter materials. Feed preparation requirements are simple, and concentrates do not need to be dried as required by some other copper smelting technologies.

A key component of the ISASMELT™ process is the unique ISASMELT™ lance. The lance is inserted into a molten slag bath contained within the ISASMELT™ furnace, which is a stationary, vertical, refractory-lined vessel. The lance is used to inject air – or oxygen-enriched air – into the slag, resulting in a highly turbulent molten bath. A layer of slag frozen on the outer surface of the ISASMELT™ lance protects it from the molten bath. A swirler inside the lance increases the velocity of the process air inside the lance, thus increasing the heat transfer rate from the steel of the lance body to the process air stream. The swirler is specially designed to produce only a small pressure-drop, and this allows the lance to operate with a total pressure-drop of less than 80 kPa. A single stage blower can thus be used to provide process air to the lance. Lance construction is simple and robust, and normal lance repairs can be carried out within 6 hours. Lance operating life is typically 10 – 20 days.

Feed material falling into the turbulent bath from above reacts rapidly, resulting in extremely high productivity for a relatively small bath volume. The copper ISASMELT™ furnace at Mount Isa has smelted up to 194 tonnes per hour of copper-bearing feed (concentrate, reverts, and other internal smelter recycle materials) in a total bath volume of approximately 15 m^3.

Since the beginning of the development of the ISASMELT™ technology it was noted its capacity to remove impurities efficiently, through high levels of volatilisation [3,4]. This behaviour is promoted by attributes of the process such as the strong bath agitation, the flexible nature of the process design, allowing the operator to choose the optimal matte grade for impurity partitioning, and the positive effect of the moisture content in the feed.

The present work presents the distribution of minor elements observed in the copper ISASMELT™ furnace at Mount Isa Copper Smelter. Then, based on the observed minor element distributions at Mount Isa, additional plant data from the ISASMELT™ furnace at Yunnan Copper Corporation and thermodynamic considerations, the potential application of ISASMELT™ technology for processing complex concentrates is analysed.

Mount Isa Copper Smelter

Plant Description

Figure 1 shows a flowsheet of the Copper ISASMELT™ plant (CIP) at Mount Isa. The primary smelting area of the copper smelter consists of a feed storage and delivery system, the ISASMELT™ Furnace, the offgas-handling system and two Rotary Holding Furnaces (RHF).

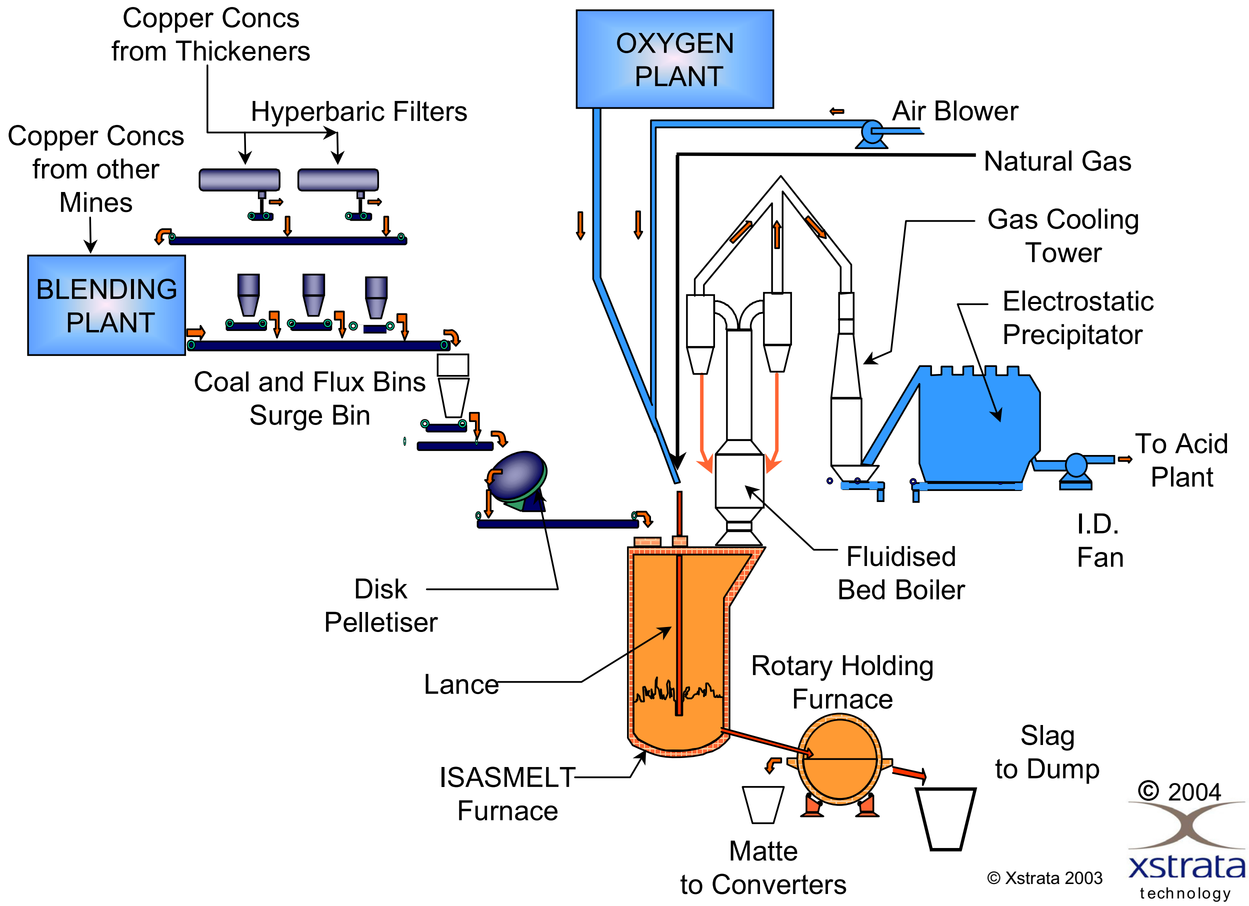

Figure 1- Flowsheet of the Copper ISASMELT™ plant at Mount Isa.

Table I shows the typical process parameters for the CIP at Mount Isa. The copper ISASMELT™ furnace treats about one million tonnes of copper concentrate per year with a normal target feed rate of 170 t/h (dry, unfluxed basis), a moisture content of 8% and a SiO_2/Fe ratio target of 0.85. The copper matte target is 60%. Typical oxygen content in the enriched air injected through the lance is 60%. Bath temperature is controlled to 1180 °C +/- °5 C.

Table II shows typical raw materials composition fed into the ISASMELT™ furnace at Mount Isa. As can be noted, lead is the main impurity present in the concentrate with a typical concentration of 2,000 ppm. Zinc, cobalt and arsenic are normally present in levels between 1,000 and 1,500 ppm. Bismuth is present in levels close to 100 ppm while antimony levels are near 30 ppm.

Table I- Typical Process Parameters for Copper ISASMELT™ Plant at Mount Isa

Parameter	Value	Unit
Maximum Feed rate	194	dry t/h
Normal target feed rate	170	dry t/h
Average Cu content in concentrate	25.8	%
Moisture	7 - 8	%
Average silica flux feed rate	3.7	dry t/h
Average coal feed rate	1.2	dry t/h
Average reverts feed rate	3.0	dry t/h
Average copper matte grade	59.5	%
SiO_2/Fe in slag	0.85 –	0.90
Average total lance flow rate	11.9	Nm^3/s
Oxygen Enrichment	60	%
Bath Temperature	1180	°C

Table II- Typical Process Parameters for Copper ISASMELT™ Plant at Mount Isa

Element/Species	Typical Value	Unit
Cu	25.8	%
Fe	24.0	%
S	25.0	%
Pb	2,000	ppm
Zn	1,000	ppm
Co	1,100	ppm
As	1,500	ppm
Sb	30	ppm
Bi	120	ppm
SiO_2	16	%
CaO	0.8	%
MgO	1.0	%
Fe_3O_4	1.0	%
Al_2O_3	0.9	%

Minor Element Distribution

Distributions of As, Pb, Zn and Co between matte, slag and gas phases in the ISASMELT™ furnace were calculated from the monthly mass balance and average chemical compositions drawn from plant data collected since 2002. Copper content in the feed during this period was almost constant. The distribution of minor elements to the gas phase was determined by ratio between the mass balance of the minor element in the feed and the condensate phases. In case of Bi and Sb, due to the low concentration in the feed, a four day measurement campaign was performed to accurately determine their concentration in the molten phase.

Figure 2 shows the arsenic distribution between the matte, D_{matte}, slag, D_{Slag}, and gas, D_{Gas}, phases, at a copper matte grade of 60%, bath temperature of 1180 °C and 60% oxygen enrichment, for arsenic contents in the feed between 0.10 and 0.26%. The symbols correspond to the calculated values (circles: matte, triangles: slag) while the lines shows the regression determined from the calculated values (continuous line: matte, dotted line: slag). The volatilisation of arsenic increases with increasing arsenic content in the feed achieving values close to 90%. The arsenic deportment to the slag phase decreases by increasing the arsenic content in the feed.

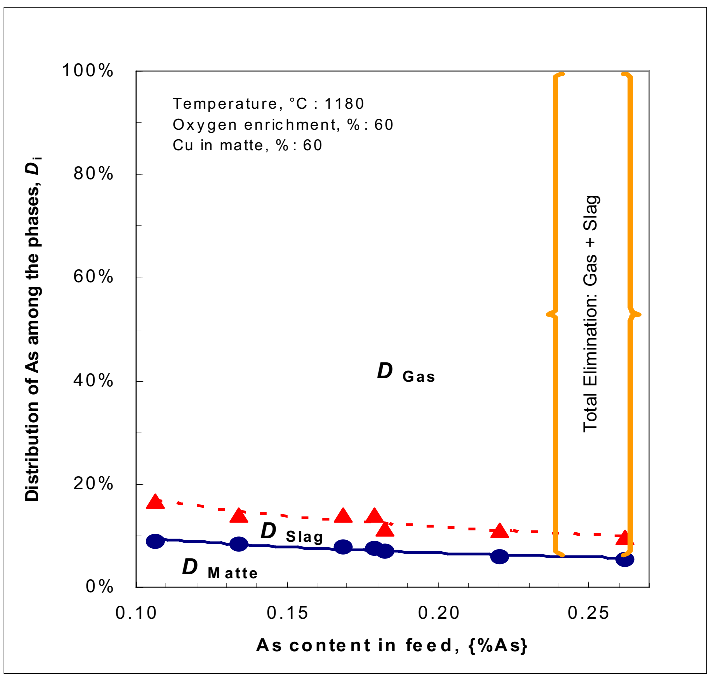

Figure 2 - Arsenic distribution between the matte, slag and gas phases (Cu matte grade: 60%, *T*: 1180 °C, Oxygen enrichment: 60%, $\{\%As\}_{feed}$: 0.10 and 0.26%.

Figure 3 shows the relationship between the arsenic content in the feed and the arsenic in the copper matte (full line, primary y-axis) and in the slag (dotted line, secondary y-axis). As can be noted, the arsenic content in the matte increases with increasing arsenic content in the feed. A similar behaviour is observed for the arsenic content in the slag phase.

Figure 4 shows the calculated lead distributions between the matte, slag and gas phases, at a copper matte grade of 60%, bath temperature of 1170 °C and 60% oxygen enrichment, for lead contents in the feed between 0.10% to 0.26 %. The symbols correspond to the determined distribution values while the lines show the calculated regression curves for the matte and slag distributions. The results obtained show a slight decrease in the lead deportment to the matte as the lead content in the feed increases. Removal rates of 35% - 40% are achieved for lead.

Figure 5 shows the relationship between lead content in the feed and its content in the matte (continuous line) and slag (broken line) phases, respectively. Lead content in the matte and slag phases increases when the lead content in feed increases.

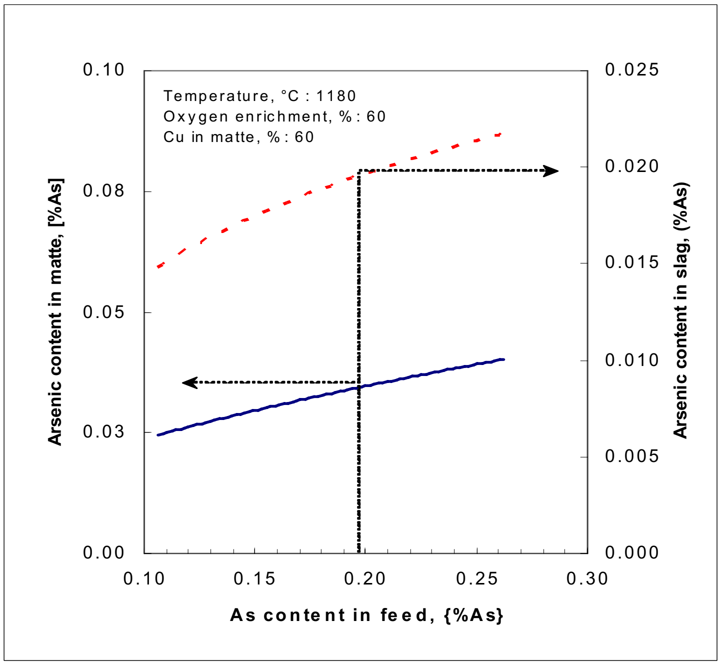

Figure 3 - Relationship between arsenic content in the feed and its content in copper matte (full line, primary y-axis) and slag (dotted line, secondary y-axis)

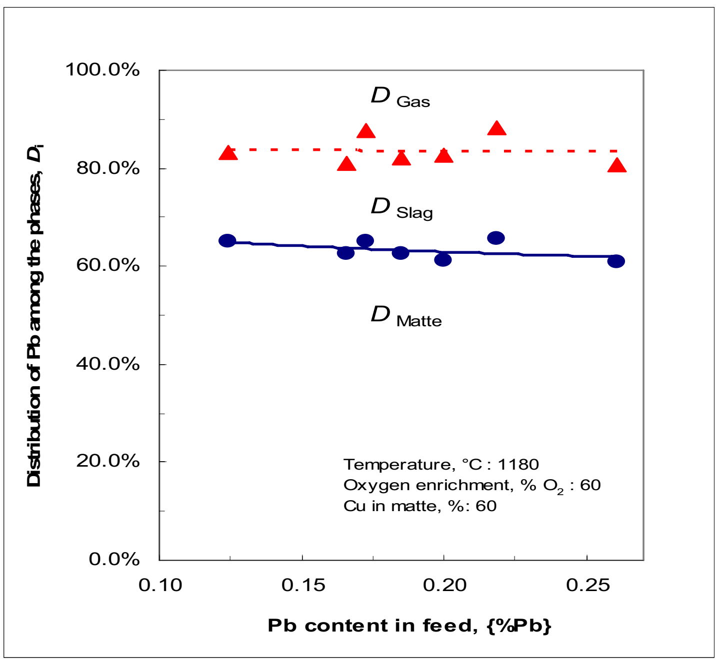

Figure 4 - Lead distribution between the matte, slag and gas phases (Cu matte grade: 60%, *T*: 1180 °C, Oxygen enrichment: 60%, $\{\%Pb\}_{feed}$: 0.10 and 0.26%.

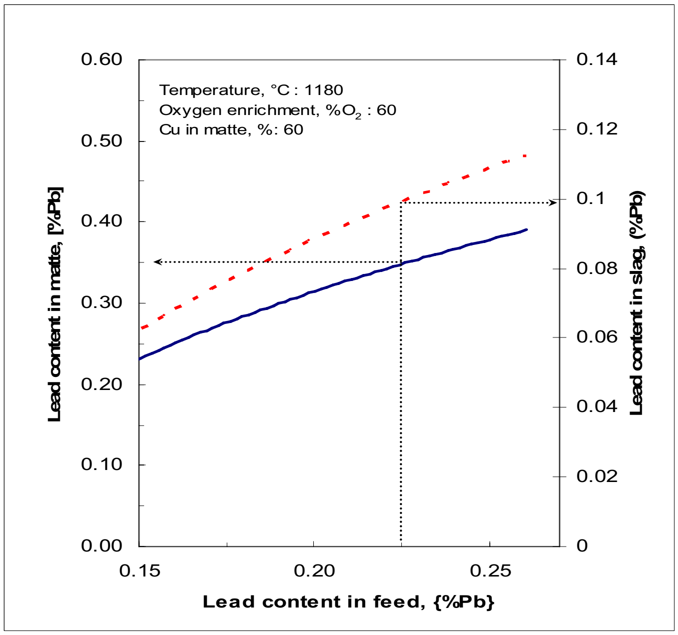

Figure 5 -Relationship between lead content in the feed and its content in copper matte (full line, primary y-axis) and slag (dotted line, secondary y-axis).

Figure 6 shows the relationship between the zinc content in the feed and its distribution to the matte, slag and gas phases, respectively, at a copper matte grade of 60%, bath temperature of 1180 °C and 60% oxygen enrichment, for zinc contents in the feed between 0.025% and 0.175%. The symbols correspond to the calculated values (circles: matte, triangles: slag) while the lines shows the regression determined from the calculated values (continuous line: matte, dotted line: slag). The zinc distribution to the matte, slag and gas phases remain constant by increasing the zinc content in the feed. Zinc is mainly removed to the slag phase. Figure 7 shows the relationship between zinc content in the feed and its concentration in the matte (continuous line) and slag (broken line) phases, respectively.

The relationship between the cobalt content in the feed and its distribution to the matte, slag and gas phases is shown in figure 8, for 60% copper matte grade, bath temperature of 1170 °C and 60% oxygen enrichment, for cobalt contents in the feed between 0.006% and 0.012%. The symbols correspond to the calculated values (circles: matte, triangles: slag) while the lines shows the regression determined from the calculated values (continuous line: matte, dotted line: slag). The calculated distribution shows that cobalt removal to the matte phase and slag phases increases by increasing its content in the feed. Figure 9 shows the relationship between cobalt content in the feed and its concentration in the matte (continuous line) and slag (broken line) phases, respectively.

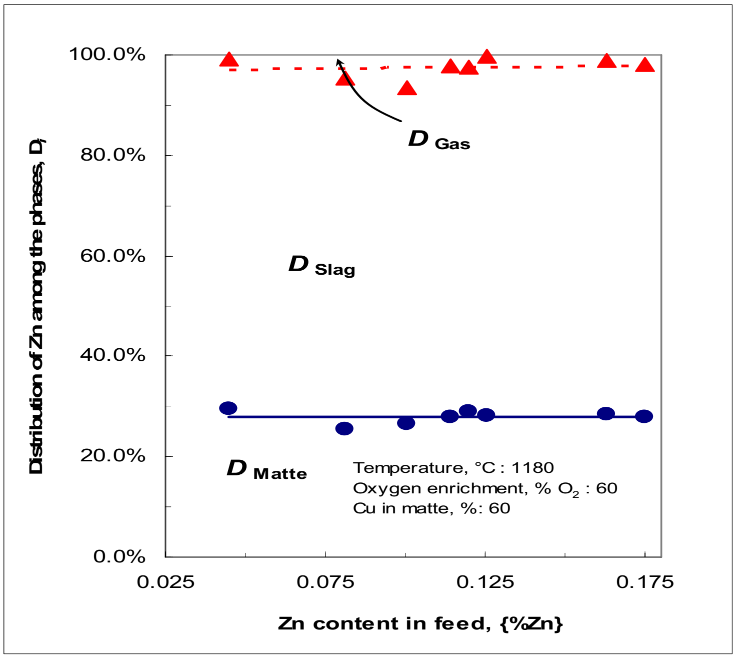

Figure 6 - Zinc distribution between the matte, slag and gas phases (Cu matte grade: 60%, *T*: 1180 °C, Oxygen enrichment: 60%, $\{\%Zn\}_{feed}$: 0.025 and 0.175%.

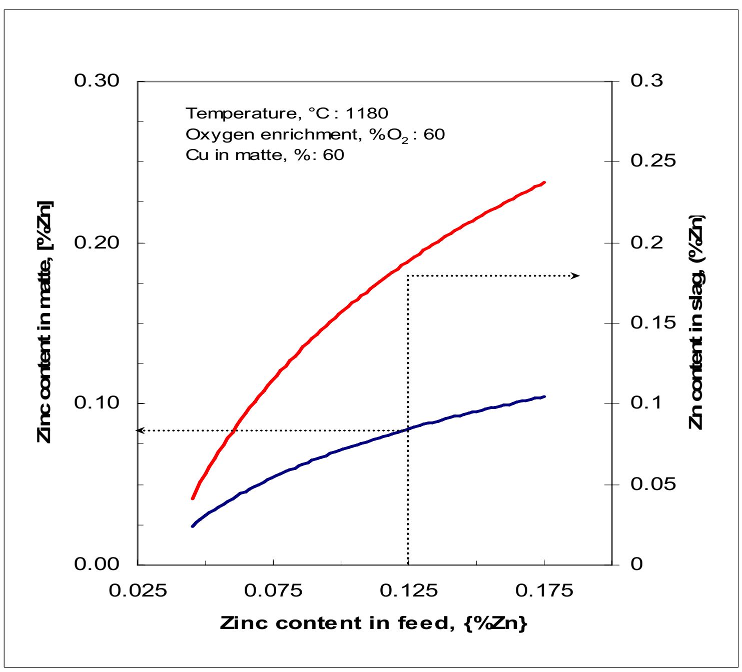

Figure 7 -Relationship between zinc content in the feed and its content in copper matte (full line, primary y-axis) and slag (dotted line, secondary y-axis).

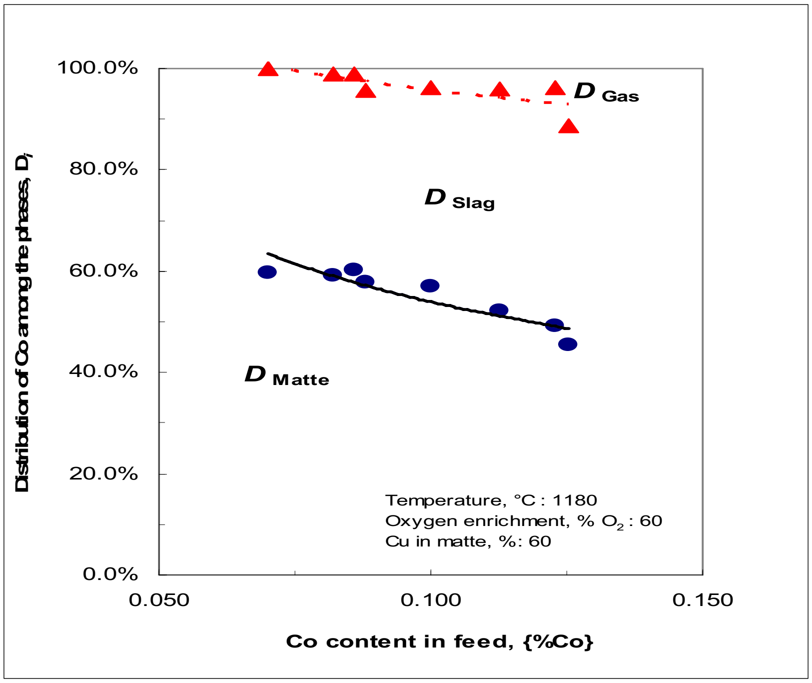

Figure 8 - Cobalt distribution between the matte, slag and gas phases (Cu matte grade: 60%, *T*: 1180 °C, Oxygen enrichment: 60%, $\{\%Co\}_{feed}$: 0.006% and 0.012%.

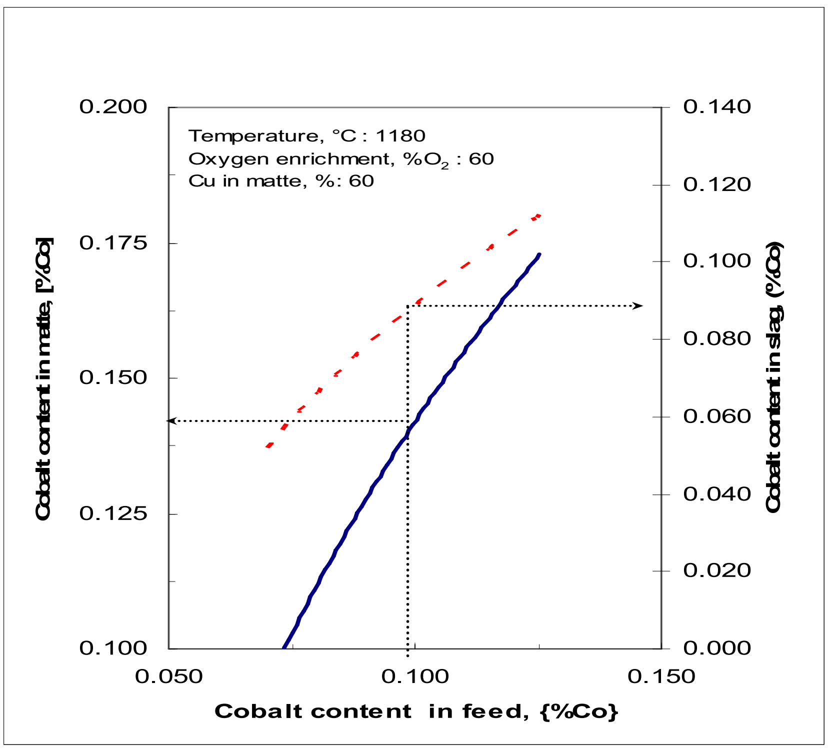

Figure 9 -Relationship between cobalt content in the feed and its content in copper matte (full line, primary y-axis) and slag (dotted line, secondary y-axis).

The concentration of antimony in the feed to the ISASMELT™ at Mount Isa is usually too low to obtain accurate distribution values. Chemical analysis precision at 1 ppm level are required to ensure a proper determination of its concentration in the matte and slag phases, respectively. To be able to determine the distribution of antimony and bismuth in the ISASMELT™ furnace, two measurement campaigns were carried out at Mount Isa Smelter in Australia and Yunnan Copper Corporation (YCC) in China. Table 3 shows the operational parameters for each ISASMELT™ furnace, under the measurements carried out, and the results achieved.

Table III - Distribution of antimony between matte, slag and gas phases observed at Mount Isa and YCC

Parameter	Unit	Mount Isa	YCC
Concentrate Feed Rate	tph	140.0	103.0
Cu content, concentrate	%	23.0	22.5
Moisture content	%	8.0	10.0
Oxygen Enrichment, O_2	%	61.2	50.0
Copper matte grade	%	60.9	55.0
Sb content in feed	%	0.0035	0.0150
Sb Distribution			
D_{matte}	%	19.0	31.0
D_{Slag}	%	9.0	3.0
D_{Gas}	%	72.0	66.0

Volatilisation of antimony varies between 66 and 72%. Itagaki reported an antimony volatilisation of 62% under air blowing conditions [10]. These values seem to be higher than normally expected volatilisation values. However, the antimony volatilisation is enhanced by the contribution to the gas volume of the moisture content in the feed.

ISASMELT™ for Treating High Arsenic Concentrates

Copper smelting relies on effective minor element control. This is required because of the mineralogical nature of sulfide ores which are normally accompanied with a number of minor elements in addition to the gangue.

For new projects that might consider the installation of smelting processes, it will be necessary to evaluate the ability of each smelting technology to volatilize or remove to the slag phase the minor elements present in the copper concentrates. Moreover, special attention should be paid to the slag cleaning and settling processes that might result in back contamination of the recovered copper matte due to the reducing conditions used in the slag cleaning reactor.

A potential option to overcome these difficulties while producing a copper matte of acceptable quality for the converting stage is the combination of the ISASMELT™ furnace for smelting concentrates and the RHF for the gravity separation of matte and slag. The settling process performed in the RHF can be performed under a neutral atmosphere with minimum addition of reductant. This help to minimize any back contamination of the copper matte with impurities and therefore, ensure an effective removal of the impurities to the gas phase (in the ISASMELT™ furnace) and the slag phase.

As was shown in figure 2, the elimination of arsenic to the gas phase is very high in the ISASMELT™ furnace. Table 4 presents a comparison for the arsenic removal between ISASMELT, Flash Furnace, Mitsubishi Process, and Teniente Converter technologies.

Table IV – Arsenic Removal Comparison for Different Copper Smelting Technologies

Technology	**Ref.**	**As in Feed, {%As}**	**Oxygen Enrich-ment, %O_2**	**Matte Grade, %Cu**	D_{Matte}	D_{Slag}	D_{Gas}
Teniente Converter	[11]	0.30	36	70 - 75	12-20	13 - 38	75 - 42
Mitsubishi Process	[12]	0.30	48	68%	19.0	27.2	53.8
Flash Furnace	[11]	0.30	60	60 - 65	35	32	33
ISASMELT™	PW*	0.26	60	60	5.5	4.2	90.3

* Present Work

Although the matte grade, temperature and oxygen enrichment conditions are different for each process, the following statements can be made:

- Despite its lower matte grade and higher oxygen enrichment, the ISASMELT™ furnace shows the largest arsenic elimination to the gas phase
- High arsenic deportment to the slag phase followed by pyrometallurgical copper recovery processes under reducing conditions, as occurs with the Teniente Converter process, will result in back contamination of the copper matte
- In case of the ISASMELT™ furnace, even a settling process under reducing conditions in an electric furnace will not excessively back contaminate the copper matte with arsenic due to the very low distribution to the slag phase.

The high arsenic volatilisation achieved in the ISASMELT™ furnace is attributed to the strong bath agitation that provides a thorough mixing of the matte and gas phases allowing arsenic to saturate the gas phase. In addition, the positive impact of the moisture content in the feed increases the volume of gas available to remove arsenic from the bath.

The capability of the ISASMELT™ furnace to treat high arsenic content concentrates was evaluated based on the values observed at Mount Isa. Table 5 shows the expected arsenic distribution for the ISASMELT™ furnace as a function of the arsenic content in the feed for 60% copper matte, 60% oxygen enrichment at 1180°C (Assuming 25% of copper in concentrate). The results presented in table 5 indicate that the ISASMELT™ furnace an excellent reactor for treating high arsenic content copper concentrates.

Table V – Expected ISASMELT™ furnace arsenic distribution for high As concentrates

Arsenic in the feed, {%As}	Estimated As distribution for ISASMELT™			Estimated As distribution for Teniente Converter S = 0.7			Estimated As distribution for Flash Furnace S = 0.3		
	D_{Matte}	D_{Slag}	D_{Gas}	D_{Matte}	D_{Slag}	D_{Gas}	D_{Matte}	D_{Slag}	D_{Gas}
0.26	5.5	4.2	90.3						
0.50	4.0	3.0	92.0	22	22	56	32	42	26
1.00	3.0	2.0	95.0	15	15	70	26	36	38
3.00	1.0	1.0	98.0	8	6	86	16	20	64

In table 5 the estimated arsenic distributions for the ISASMELT™ furnace are compared with reported arsenic distributions for the Teniente Converter (36% oxygen enrichment, 1270 °C, 75% matte grade) and the Flash Furnace (55% oxygen enrichment, 1290 °C, 65% matte grade) (ref). Table 5 shows that the ISASMELT™ furnace has a higher elimination of arsenic to the gas phase than both the Teniente converter and the Flash Furnace. The ISASMELT™ furnace also has a lower deportment of arsenic to the slag phase than the Teniente converter. This means that there is less risk of back contamination of the matte during the slag cleaning process. Finally, it should be noted that the high arsenic removal expected in the ISASMELT™ furnace will reduce the impurity removal duty for the converting and anode refining processes compared with the other two technologies.

Conclusions

1. Distribution impurities for As, Sb, Pb, Zn and Co have been calculated for the ISASMELT™ furnace at the Mount Isa Copper Smelter

2. The ISASMELT™ process has been demonstrated to remove impurities efficiently, through high levels of volatilisation. This behaviour is promoted by attributes of the process such as the strong bath agitation, the flexible nature of the process design allowing the operator to choose the optimal matte grade for impurity partitioning, and the positive effect of the moisture content in the feed

3. The ISASMELT™ furnace has a higher arsenic elimination to the gas phase than the Flash Furnace or the Teniente converter

4. The ISASMELT™ furnace has a lower arsenic deportment to the slag phase than the Teniente converter resulting in less risk of back contamination of the matte in the slag cleaning process

5. The high arsenic removal expected in the ISASMELT™ furnace will reduce the impurity removal duty for the converting and anode refining processes compared with the other two technologies

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