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ISASMELT™ AT MUFULIRA – INCREASED FLEXIBILITY ON THE ZAMBIAN COPPERBELT

Alistair Burrows[1], Phil Partington[1], John Sakala [2], Paul Hermit Mascrenhas[2]

[1]Xstrata Technology, Lv 10, 160 Ann St., Brisbane, QLD, 4000, Australia;
[2]Mopani Copper Mines plc, Mufulira Smelter, PO Box 22000, Kitwe, Zambia;

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ABSTRACT

Since the first plant was built at Mount Isa, twenty ISASMELT™ plants have either been constructed or are under construction. A recent addition to the family of ISASMELT™ licensee plants is the Mufulira smelter in the Zambian Copperbelt, where the ISASMELT™ plant has replaced a rotary drier and an electric smelting furnace. The change has been beneficial to Mufulira smelter.

The primary copper ISASMELT™ top submerged lance (TSL) technology continues to attract interest from potential users who seek high productivity smelting. In addition to the known benefits of productivity, and flexibility, ISASMELT™ operators have also achieved improved energy efficiency. Plant production statistics from the Mufulira smelter shows that power consumption per unit of production has been significantly reduced following the introduction of ISASMELT™ technology.

INTRODUCTION

The ISASMELT™ process, based on the Sirosmelt lance invented by the CSIRO and commercialised by Mount Isa Mines (MIM) over the last three decades, was originally intended to be used for lead concentrate smelting. MIM soon found it to be a suitable smelting technology for copper smelting [1,2] as well. As was the case for MIM, other copper smelters seeking process improvements have realised advantages from its low operating costs and a capability to produce off-gases with a high SO_2 content so that the smelter gas can be most economically treated in an acid plant.

Mopani Copper Mines Plc (MCM) decided, at the end of 2003, to replace its electric smelting furnace and to upgrade its smelting facility in Mufulira with the installation of an ISASMELT™ furnace and a matte settling electric furnace (MSEF). The new facility was designed with a view to toll treat concentrate in addition to those produced from MCM mines [3]. The ISASMELT™ furnace was designed, constructed and commissioned within 30 months, and production has been steadily increasing in the years since, and further increases are possible in the future.

The features of the ISASMELT™ furnace make it readily adaptable to copper concentrates across a wide composition range. This adaptability has enabled the Mufulira smelter to accept a blend of feed that would have made the previous smelting flowsheet inefficient and unproductive.

PRE-2006 MUFULIRA SMELTER FLOWSHEET

Mufulira smelter began operation in 1937 [4]. From 1991 to 2006, the smelter capacity was around 400,000 tonnes of copper concentrates per annum, mostly sourced from MCM's mines (i.e. Mufulira and Nkana mines) via a flowsheet that included a FFE-designed heavy fuel oil (HFO) fired rotary drier and an Elkem-designed 36MVA submerged-arc, six-in-line electric furnace. There was no sulphur dioxide abatement facility [3].

The electric furnace itself produced little SO_2 directly, with its role being to "melt" a concentrate mix, rich in copper and relatively low in iron, producing matte with a natural grade exceeding 50 wt% Cu. Typical compositions of concentrates from MCM's mines are shown in Table 1.

Table 1 - Typical Compositions of MCM Concentrates

	%Cu	%Fe	%S	%SiO_2	%CaO	%MgO	%Al_2O_3
Mufulira	38-41	15	23	16	0.8	2.1	2.5
Nkana	30-32	23	30	12	1.5	1.1	1.9

The electric furnace had a nominal treatment capacity of 420,000 tonnes per annum (tpa) of concentrates. Leading up to 2003, it was recognised that the electric furnace would require rebuilding or replacement with alternative technology. MCM chose the latter option, in part because having a new smelting technology would enable the low-cost production of sulphuric acid. It was also advantageous to build the new facility adjacent to the old one, linked to the same Peirce Smith (PS) Converter aisle, with the aim of achieving a seamless transition from old to new at the end of the electric furnace campaign.

POST-2006 MUFULIRA SMELTER FLOWSHEET

The new primary smelting flowsheet of the Mufulira smelter is shown in Figure 1. The ISASMELT™ furnace is the central feature of the plant.

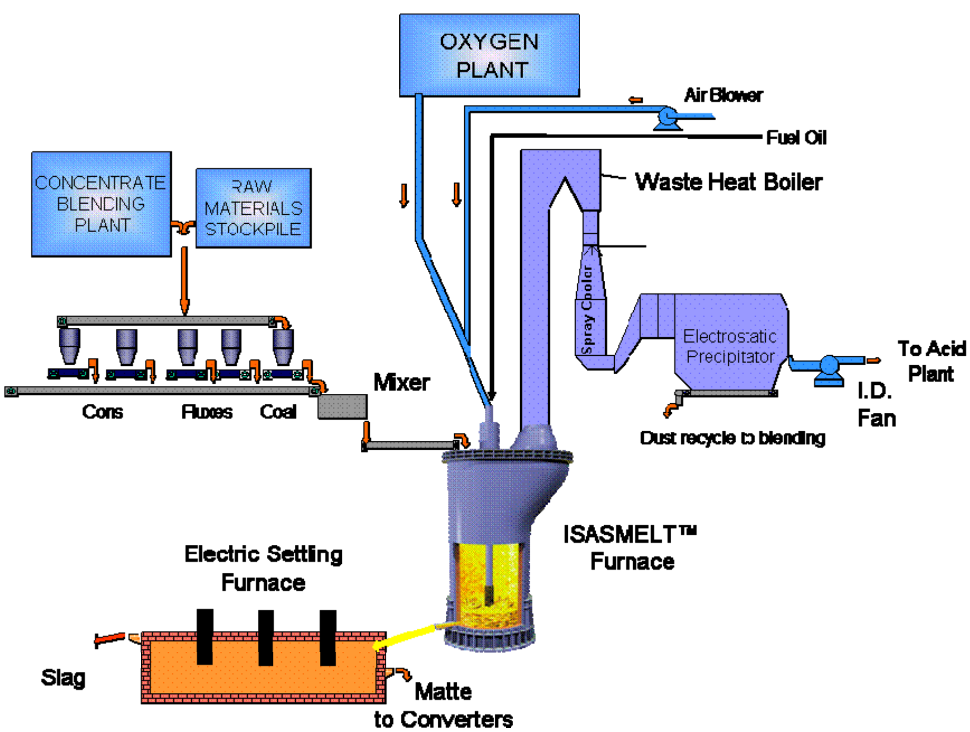

Figure 1- ISASMELT™ Flowsheet as used at Mufulira

Also included in the current plant are:

- An upgraded concentrate storage and handling area.
- A 650 tpd cryogenic oxygen plant.
- A purpose-designed matte settling electric furnace (MSEF) capable of handling ISASMELT™ products and return slag from the Peirce-Smith converters producing a discard slag for disposal at the slag dump.
- A single-contact sulphuric acid plant to treat the ISASMELT™ off-gas.

Together these key elements are responsible for Mufulira smelter's current production of copper and its future prospects of toll-treating concentrate from within the Copperbelt of Zambia and the Democratic Republic of the Congo (DRC).

Role of Xstrata Technology in Mufulira Smelter Development

Xstrata Technology (XT), the licensor of the ISASMELT™ process, was involved in the development and implementation of the new smelting flowsheet at Mufulira smelter, including the key activities of design, supply, operator training and commissioning.

The scope of work for XT was divided into the following stages:

<u>Design Engineering:</u>

In March 2004, MCM signed a Professional Services Agreement with XT and an Engineering Agreement with an engineering, procurement and construction management (EPCM) contractor. Design engineering for the ISASMELT™ furnace was carried out at the XT office in Australia with active participation of the owner's team and the EPCM office in South Africa. Regular use of advanced project management tools allowed the three parties to share and review documents on both sides of the Indian Ocean. XT reviewed the mechanical and structural engineering completed by the EPCM contractor during this stage. HAZ-Op studies were completed on both the XT-designed equipment and all interfacing equipment.

<u>XT Equipment Supply:</u>

As part of the services agreement with MCM, XT was awarded with the supply of core equipment for the ISASMELT™ plant. The core equipment package included automatic lance hoisting, lances, specialized burners, fuel control systems, waste heat boiler (WHB) with evaporative gas cooler, combustion and hygiene exhaust fans, combustion and lance process air blowers and specialised instrumentation.

<u>Process Control System Design and Supply:</u>

An important part of the success of the ISASMELT™ technology is its process control system. XT in conjunction with its partner MIPAC delivered a complete process control package for the new smelter plant. This included the distributed control system hardware and software and configuration for a plant wide control system, covering the control for the feed preparation plant, ISASMELT™ operation, WHB, smelting process off gas system, acid plant and oxygen plant.

<u>Training Programme:</u>

Thorough training is essential to enable successful transfer of technology. The process training for MCM took place in two phases:

- Full-scale three month operations and maintenance training at the MIM smelter in Australia.

- On-site training during commissioning of the plant where cold and hot commissioning of the furnaces, cold test runs, start-up, shut-downs, and maintenance and trouble-shooting cases were explained.

Technical Assistance:

An important part of the project was the technical assistance provided by XT to MCM during the engineering, pre- and post- commissioning stages of the project. The technical services included secondment of XT personnel to MCM and the Mufulira smelter to carry out the following duties:

- To assist with installation of key equipment items.
- To assist with the supervision of plant wide control system installation.
- To assist with supervision of plant commissioning and startup.

The plant was commissioned in September 2006, 30 months after signing of the Professional Services Agreement, and is shown in Figure 2.

Figure 2 – The ISASMELT™ Plant at Mufulira Smelter

MAJOR CHANGES IN CONCENTRATE SUPPLY

At the time of initiating the Mufulira smelter upgrade project, MCM's production forecasts anticipated relatively consistent production of approximately 400,000 tpa concentrate from MCM's mines (Nkana and Mufulira) and concentrators [3], with these providing much of the feed to the ISASMELT™ furnace. Typically, Nkana produced 55-60% of Mopani's mined production, with Mufulira producing the remainder [4]. During the past few years toll-treated concentrates, most notably from First Quantum Minerals' mine "Kansanshi", have gradually become more prevalent due to increased smelter throughput. A typical breakdown of the new copper bearing material currently received by the Mufulira smelter is shown in Table 2.

Table 2 - Typical breakdown of new feed materials to the Mufulira Smelter

	%	%Cu	%Fe	%S	$\%SiO_2$	%CaO	%MgO	$\%Al_2O_3$
Mufulira	15	38-41	15	23	16	0.8	2.1	2.5
Nkana	35	30-32	23	30	12	1.5	1.1	1.9
Kansanshi#	50	26	27	33	8	0.3	0.7	1.4

Other mines' concentrates are also toll-treated but this is the most notable component.

As indicated in Table 2, there has also been a secondary effect of receiving more third party concentrate: a decline in the average copper grade of the smelter feed. Whereas Mufulira concentrate contains a significant amount of bornite and chalcocite, the toll-treated concentrates overwhelmingly contain only chalcopyrite. Although this would have been detrimental to smelter production using the original primary smelting flowsheet, which involved a rotary drier and an electric furnace, MCM have been able to smelt productively using the current flowsheet including the ISASMELT™ furnace and MSEF. In fact, it has been an excellent fit. Mufulira smelter now produces, per unit of copper production, much more sulphuric acid than would otherwise have been the case. The acid can be used for leaching operations or sold to other operations in the region.

BEFORE & AFTER COMPARISON OF PRIMARY SMELTER FLOWSHEET

A statistical comparison of the relative merits of the current and previous flowsheets has been attempted. There is no standard method of doing this. Difference in production scale and raw material peculiarities can complicate the task of making meaningful comparisons between industrial operations. In a detailed treatment of this topic, Goonan [5] used a generic copper smelter flowsheet and normalized flows of material and energy for the purposes of comparing different copper smelters. Goonan's approach has been adopted, except with the necessary modification that the boundaries under consideration in this work extend only around the primary smelting and slag cleaning stage of the smelter – not downstream into the converting and fire-refining sections.

A generic primary smelter flowsheet is shown in Figure 3. The primary smelting area is enclosed within the broken red line. Material and energy streams subject to comparison are labeled individually. All mass flow measurements are in the units of tonnes per tonne of copper produced. Electricity measurements are in MWh per tonne of copper produced. Not all streams are applicable at any given smelter. For example, stream J is defined as zero for an electric slag cleaning furnace, but would be a non-zero value if slag cleaning were performed using a flotation process.

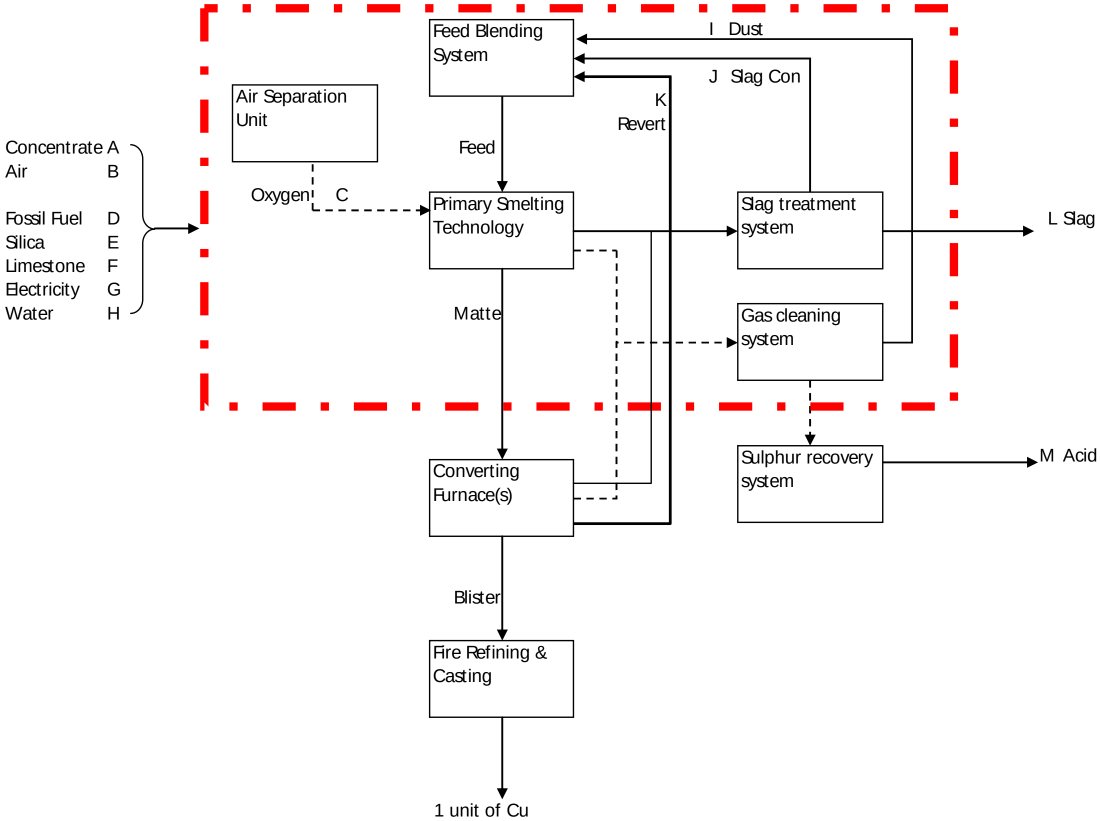

Figure 3 - Simplified copper smelter diagram.

For reasons of consistency, the electricity figures quoted in this work:

- Include the generation of industrial oxygen;
- Include the compression of air by the primary smelting process air blower;
- Include the electricity for the MSEF;
- Include the primary smelting off-gas fan(s);
- Include minor consumers around the primary smelting area; but,
- Exclude any off-setting benefits from electricity generated using steam from the waste heat recovery system (that in the case of Mufulira smelter is zero).

The main results of the before-and-after comparison at Mufulira smelter are that a substantial saving in electricity consumption was realized, and an increase (from zero) in sulphuric acid generation, when expressed per unit of copper production. The result of replacing the electric smelting furnace with an ISASMELT™ and MSEF was that the specific electricity consumption fell substantially (by 39%), even after accounting for the introduction of a 650 tpd oxygen plant. The fall in specific electricity consumption was accompanied by a modest rise in specific fossil fuel consumption. These data are shown in Table 3.

Table 3 – Before & After Comparison for Mufulira Smelter

		Mopani Copper Mines Mufulira Zambia	
Primary Smelting Technologies		EF	ISASMELT + MSEF
Time period		CY 2004	CY 2009
Concentrate	A	1.87	2.80
Air	B	0	0.27
Oxygen	C	0	0.67
Fossil Fuel	D	0.02	0.15
Silica	E	0	0.06
Limestone	F	0.24	0
Electricity	G	1.57	0.96
Water	H	0	0.26
Dust	I	0.07	‡
Slag Concentrate	J	0	0
Reverts	K	0.35	0.52
Slag	L	1.36	1.61
Sulphuric Acid	M	0	1.14

Notes: Streams defined in Figure 3. Power units are MWh / t Cu. Mass units are t / t Cu.
Abbreviations: EF = Electric Furnace, CY – Calendar Year, ‡ – not available

COMPARISON AGAINST SIMILAR ISASMELT™ OPERATORS

The Mufulira smelter is the third copper smelter to replace an electric smelting furnace with an ISASMELT™ furnace, and to combine it with an MSEF. The two previous smelters to follow this path were in Freeport Miami [6] in Arizona and Yunnan Copper in Kunming, China [7] respectively. It is instructive to see how Mufulira compares with these two established smelter operations.

The histories of the ISASMELT™ operations at Miami and Kunming are similar in some respects. Both had six-in-line electric smelting furnaces that were modified to act as settling furnaces only. The Mufulira smelter differs from these two operations in that it has a purpose-built MSEF to accompany the ISASMELT™. All three smelters produce matte with a similar copper content (52-59%), although Miami and Kunming start with lower grade copper concentrates.

Comparative data for the three smelters are shown in Table 4. The data indicate that Mufulira smelter uses less air and less oxygen in the ISASMELT™ furnace and produces less slag from the MSEF than do Miami and Kunming, when expressed per tonne of copper produced. This is to be expected for a plant treating higher concentrate grade.

Mufulira smelter consumes more water in the ISASMELT™ plant than Miami. This can be attributed to the partial use of evaporative cooling for the off-gas at Mufulira, whereas Miami and Kunming cool their ISASMELT™ off-gas to a similar temperature using the convection section of their respective waste heat boilers.

In other respects, each plant is of similar capacity and has achieved similar statistics.

Table 4 - Benchmarking parameters for copper smelters using ISASMELT™ technology + MSEF

		Freeport Miami U.S.A.	Yunnan Copper Kunming China	Mopani Copper Mines Mufulira Zambia	
Primary Smelting Technologies		ISASMELT + MSEF	ISASMELT + MSEF	EF	ISASMELT + MSEF
Time period		CY 2007	CY 2006	CY 2004	CY 2009
Concentrate	A	3.45	4.25	1.87	2.80
Air	B	1.29	0.88	0	0.27
Oxygen	C	1.02	0.82	0	0.67
Fossil Fuel	D	0.18	0.14	0.02	0.15
Silica	E	0.16	0.06	0	0.06
Limestone	F	0.05	0.00	0.24	0
Electricity	G	0.94	0.86	1.57	0.96
Water	H	0.014	0.50	0	0.26
Dust	I	0.02	0.007	0.07	‡
Slag Concentrate	J	0	0	0	0
Reverts	K	0.33	0	0.35	0.52
Slag	L	2.41	2.62	1.36	1.61
Sulphuric Acid	M	3.35	3.33	0	1.14

Notes: Streams defined in Figure 3. Power units are MWh / t Cu. Mass units are t / t Cu.
Abbreviations: EF = Electric Furnace, CY – Calendar Year, ‡ – not available

The fact that Mufulira smelter alone has a purpose-built MSEF, whereas Miami and Kunming have modified their previous electric smelting furnaces seems not to have influenced the specific energy consumption of the overall primary smelting flowsheet. The Mufulira MSEF [3] is a three-in-line electric furnace, rated at 12 MVA using Søderberg electrodes. The furnace dimensions are 18.1 m x 7.4 m x 5.7 m (L x W x H) and the matte holding capacity is approximately 400 tonnes. A small amount of coke is fed to the MSEF, mainly to reduce the more highly oxidised PS converter slag. The MSEF has proven to be an effective settling and slag cleaning unit for Mufulira smelter. It produces a discard slag with a copper content of <0.7 wt% Cu, and also serves an important role in retaining sufficient matte to provide surge capacity between the continuous ISASMELT™ furnace and batch PS Converters. The MSEF complements the ISASMELT™ furnace very well.

FUTURE OUTLOOK FOR MUFULIRA SMELTER

The key process parameters for the Mufulira smelter ISASMELT™ plant for May 2010 are given in Table 5. At time of writing this paper the plant was running at high availability with a feed rate of up to 105 t/h (of copper concentrate, excluding internal recycle streams, dry basis).

Smelter production at Mufulira is still expanding as continual improvements are occurring to the smelter operation. A modernization and expansion to the PS Converter operation is planned, which will also result in the installation of another sulphuric acid plant to capture the remaining sulphur gases that are currently dispersed to atmosphere.

Table 5 - Typical Process Parameters for Mufulira ISASMELT™ Plant for May 2010

Parameter	Value	Unit
Typical concentrate feed rate	90-100	dry t/h
Average Cu content in concentrate	29	%
Average Moisture of the feed	9	%
Average silica flux feed rate	1.5	dry t/h
Average coal feed rate	1.5	dry t/h
Average reverts feed rate	15	dry t/h
Average copper matte grade	54-55	%
Average SiO_2/Fe in slag	0.95	--
Average ISASMELT™ lance air flow rate	6.0	Nm^3/s
Average oxygen content in ISASMELT™ lance air	76-78	%
Bath Temperature Range	1175 - 1185	°C

New mines have been opening on the Zambian copper belt, and more are planned in the coming years. Mufulira is well placed to take advantage of the increased concentrate supply in this region, and its future looks secure. Additional acid production is also welcome with local consumers available who have both existing and prospective hydrometallurgical operations.

CONCLUSIONS

The Mufulira smelter has modernized its smelting flowsheet and included an ISASMELT™ furnace and MSEF. Operation of the current plant began as the previous smelting technology, a rotary drier and electric smelting furnace, reached the end of its campaign life. The smelter production has increased steadily, utilizing the new technology to toll-treat an increasing amount of copper concentrate to supplement the production of MCM's Nkana and Mufulira mines.

Specific consumption of electricity (i.e. consumption per unit of copper produced) decreased by 39% upon introduction of the new Mufulira smelter flowsheet. The Mufulira smelter is performing with similar operating statistics as other well-established smelters (Miami and Kunming) who are also using an ISASMELT™ and MSEF flowsheet.

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