SMELTING OF KAZAKHSTAN CONCENTRATES AT UST-KAMENOGORSK USING A COPPER ISASMELT™ FURNACE

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ABSTRACT

In July 2011 a new copper ISASMELT™ furnace was commissioned at Kazzinc Ltd's Metallurgical Complex in Ust-Kamenogorsk, Kazakhstan. It was part of a brownfield smelter project, situated inside an existing metallurgical complex. Kazzinc had up to that time been primarily a zinc and lead producer so the entire copper circuit was new, from feed blending through to cathode strapping. Within 14 months it was achieving its design production capacity.

For the project to be brought to successful fruition, numerous challenges had to be met: new technology had to be brought into the Republic of Kazakhstan and the local operating team had to become competent to operate it; the complex polymetallic concentrates of the East Kazakhstan region had to be smelted without compromising the production rate or product quality; and the copper production circuit had to be integrated into the overall metallurgical complex to derive greatest economic benefit from the polymetallic nature of the raw materials.

This paper describes how the copper ISASMELT™ furnace fitted into this strategy, and how the coordinated actions of Kazzinc and Xstrata Technology personnel brought this project to fruition.

INTRODUCTION

Formerly part of the Soviet Union, the Republic of Kazakhstan has been an independent nation for more than 20 years. It is the world's largest landlocked country by land area, being larger than Western Europe. It has a wealth of mineral resources spread throughout the country. Kazzinc Ltd is a major, fully integrated, zinc producer established in 1997 through the merger of Eastern Kazakhstan's three main non-ferrous metals companies. In addition to zinc, the concentrates from Kazzinc's mines contain significant amounts of lead, copper and precious metals. The capital of Eastern Kazakhstan province is Ust-Kamenogorsk, a city of about 350,000 people, which has been a hub for transporting and processing base metals concentrates for more than a century. Since 1943, Ust-Kamenogorsk has also been home to a multi-smelter metallurgical complex specialising in the production of zinc, lead, silver, gold, antimony, bismuth and various other by-products. The Ust-Kamenogorsk Metallurgical Complex (UKMC) is one of Kazzinc's assets, and in 2005 when Kazzinc wished to add a copper smelter and refinery to UKMC it approached Xstrata Technology to provide the ISASMELT™ and ISA PROCESS™ technologies for the new copper plant.

Despite UKMC's rich smelting history, copper had not previously been a major product. About 5000 tonnes per annum (tpa) of blister copper was produced as a by-product of lead smelting. A completely new plant was required for the copper smelter and refinery. The new plant would be akin to a greenfield project in scope, except that its location amid a major metallurgical complex had all of the complications associated with a brownfield expansion project. The concept of the new copper plant was that it should have a nominal production capacity of 70,000 tpa of cathode copper, be able to treat polymetallic copper concentrates and a range of by-products from zinc and lead refining, be tolerant of minor element fluctuations, and be readily expandable in the future. For the primary copper smelting furnace, an ISASMELT™ was a logical choice to meet these objectives. During the course of the next 6 years, many things changed in the process of evaluating, locating, designing, constructing and commissioning the copper plant, but the original project objectives remained unchanged.

With a capacity of just 70,000 tpa of copper, the UKMC copper smelter was destined to be small by world standards, and subject to a high ratio of fixed:variable costs. For the project to make sense, the key performance characteristic would be that the smelter could run well on a fluctuating supply of polymetallic concentrates sourced locally from Kazzinc mines, recover the precious metals contained therein, and eliminate the transportation and penalty costs associated with sales of concentrate to third parties.

DISCUSSION

Plant Description

The copper smelter at UKMC has a conventional flowsheet. Concentrate smelting is performed in the copper ISASMELT™ furnace, matte is converted in one of two P-S Converters, and fire refining occurs in two anode furnaces, prior to anode casting. The sulphuric acid plant is able to accept gas from the ISASMELT™ furnace and one blowing P-S Converter. The flowsheet is shown schematically in Figure 1.

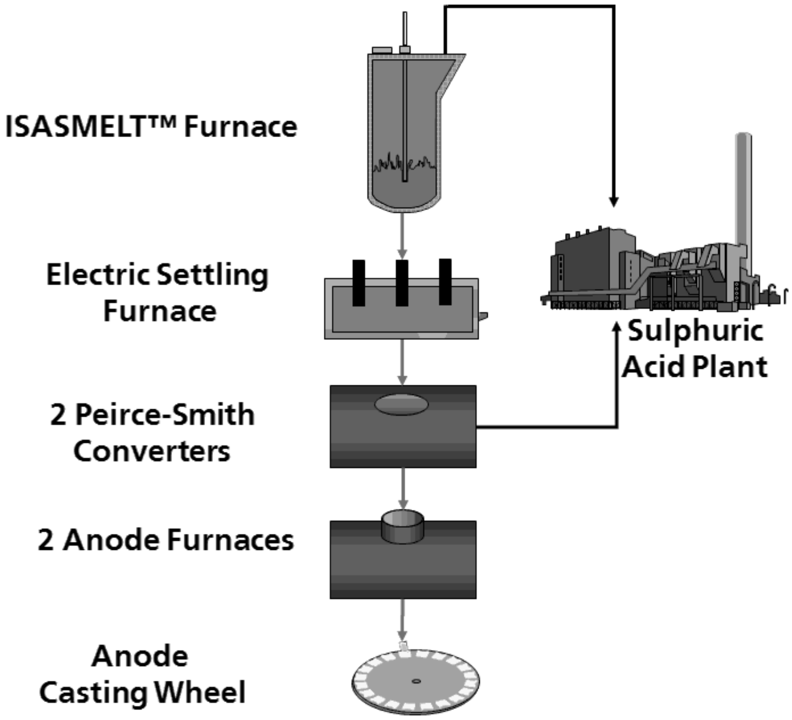

Figure 1: Schematic Diagram of Copper Smelter Flowsheet

Within this flowsheet, impurity removal was to occur via a dedicated bleed of slag from the P-S Converter copper blow, and via dusts produced from the smelting furnaces. Direct recycle of dust streams was calculated to be impractical owing to the build-up of volatile impurity elements. Instead, an existing metallurgical facility was modified to perform dust leaching duties, thereby removing target elements and producing a clean copper cement that could be recycled to the smelter.

Smelter Feed

Among countries of the former Soviet Union, the highest purity designation of traded cathode copper is referred to as MOOK grade, with technical specifications comparable to LME grade A copper. The design basis of the UKMC copper smelter and refinery was to produce MOOK grade cathode from a concentrate feed containing significant quantities of lead, arsenic, zinc, bismuth, and antimony. It has been noted elsewhere [1] that the ability of the ISASMELT™ furnace to tolerate and eliminate volatile impurity elements was of benefit for the Kazzinc copper smelter. The deportment of impurities to intermediate products and recycle streams was considered during the design phase. Assays for the major elements of the "design" smelter feed are shown in Table 1.

Table 1 – Kazzinc Copper Smelter Design Feed Composition

	Wt, %							
	Cu	Pb	Zn	Fe	S	SiO2	Sb	As
Design	25.0	2.68	3.14	24.85	31.74	5.11	0.16	0.55

Copper ISASMELT™ Plant

The copper ISASMELT™ plant at UKMC encompasses the supply of feed materials to the copper ISASMELT™ furnace and the handling of the off-gases and molten products produced in the furnace. The flowsheet, shown schematically in Figure 2, is similar to plants that have been described previously [2,3]. A variety of concentrates are blended in a blending plant, and the blended concentrate is loaded into one of two concentrate bins using an overhead grab crane. From the feed bins the concentrate is accurately dispensed to the ISASMELT™ furnace. Feed bins are also used for dispensing accurately weighed amounts of coal, reverts, limestone flux and silica flux onto a collector conveyor and then to the ISASMELT™ furnace. The moist feed mix is charged from the final feed conveyor through a ventilated port in the furnace roof and into the agitated molten bath below. The roof of the furnace is an integral part of the waste heat boiler.

Delivery of process air and tonnage oxygen (98% purity) to the ISASMELT™ lance is controlled automatically be the Distributed Control System (DCS) that is used throughout the smelter operation. Lance immersion in the molten slag bath is also controlled automatically by the DCS, so that the lance tip is always at the optimum position in the molten bath regardless of the bath level.

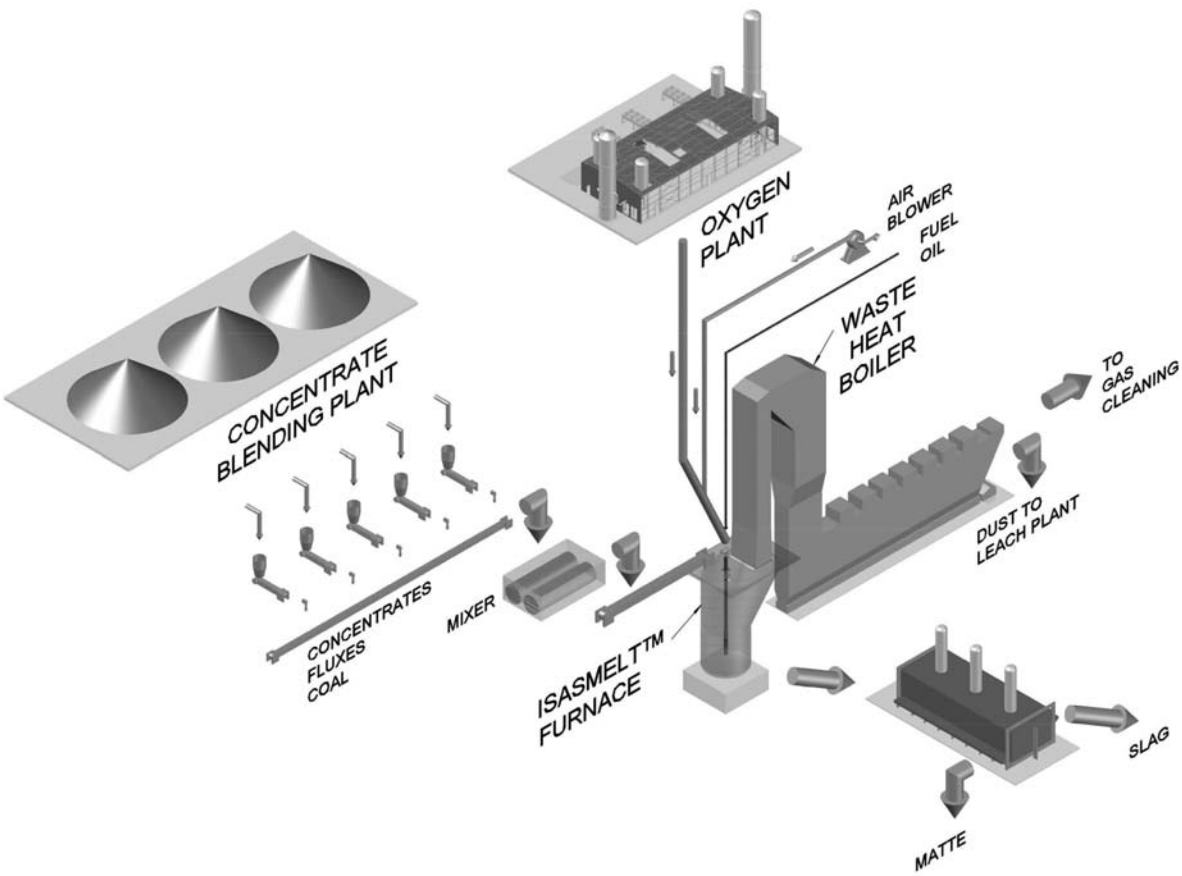

Figure 1: Schematic Diagram of Copper ISASMELT™ Plant

Matte and slag produced in the ISASMELT™ furnace are tapped intermittently from a single water-cooled tapping block at the base of the furnace. These flow into an electric settling furnace located next to the ISASMELT™ furnace. The design matte grade was 60%, but Kazzinc has found that an optimum balance of production can be achieved using approximately 55-58 %Cu in matte.

Off-gases from the process exit the furnace through a hole in the ISASMELT™ furnace roof and pass into a waste heat boiler. Cooled gas leaves the waste heat boiler at approximately 350°C and is then de-dusted in an electrostatic precipitator.

Technology Transfer

In the world of pyrometallurgy, changes to plants, flowsheets and accepted practices are usually slow. Technology transfer, innovation and implementation of new technologies always face technical challenges. An important strength of the ISASMELT™ technology has been its capacity and versatility to be incorporated into new innovative applications, by customers throughout the world.

The Kazzinc copper smelter management team made preparations to improve the ramp-up of the copper smelter, and to effectively integrate foreign technology into the operational and management practices of UKMC. In the case of the copper ISASMELT™ plant, the technology transfer process was aided by a significant investment of both time and people in the training of operations and maintenance personnel, as has been practised by other ISASMELT™ licensees [4]. Theoretical training in the classroom, practical training at other ISASMELT™ licensee plants, and in situ practical training were all employed to the benefit of Kazzinc personnel.

About three months of practical training occurred at Xstrata Copper's copper smelter in Mount Isa, Australia. There, the Kazzinc personnel received valuable hands-on training from experienced operations and maintenance staff. This enabled Kazzinc trainees to become competent operators and understand the basics of the ISASMELT™ furnace hardware and operating technique. At the peak of the Mount Isa training programme, the delegation of Kazzinc trainees, supervisors and interpreters numbered 45 in total, requiring careful organisation to manage their activity schedule and ensure that the training was both effective and safe.

Supplementary to the training at Mount Isa, Kazzinc personnel visited the copper ISASMELT™ plant at Mopani's Mufulira smelter in the Copper belt of Zambia. An attractive feature of this training exercise was that a common vendor (SMS Siemag AG) was chosen for the electric settling furnace at both UKMC and the Mufulira smelter, so Kazzinc trainees were able to develop experience in the integrated operation of an ISASMELT™ furnace with a 3-in-line electric settling furnace.

In addition to the full scale plant training, Kazzinc control system engineers spent several weeks with Xstrata Technology specialists in Brisbane, Australia to collaborate in the configuration and testing of the DCS, which is at the heart of ISASMELT™ operation. The training that they received during this time helped to ensure that the local maintenance team was able to participate fully in the plant commissioning.

In the final three months preceding smelter start-up, when the copper ISASMELT™ plant was ready to run, but minor delays affected downstream equipment and prevented start-up, Kazzinc and Xstrata Technology personnel organised numerous plant training drills for the ISASMELT™ operators. These varied in sophistication from single equipment items up to the entire plant, including live transport and control of all input material flows.

Throughout the entire design, procurement, construction, installation, commissioning and ramp-up period, Kazzinc personnel benefited from attending ISASMELT™ Licensee Workshops held in India, Peru, Belgium and Zambia, and from the exchange of information that was possible with their peers and fellow licensees from other countries and other companies. Commissioning a new smelter is always a complex and challenging task and there is comfort and reassurance to be gained from discussing with others their past experiences and tips for success.

Plant Start-up

For a completely new copper smelter and refinery complex, especially one in a cold climate, a plant start-up is not a single event that takes place on a particular day. By necessity the activities span many weeks as various parts of the flowsheet are brought into production. Seasonal plant and equipment are brought into operation on schedules of their own, such as concentrate thawing sheds, building heaters or ventilators, steam heating plants and fuel supply equipment. Concentrate is delivered, stored and blended weeks in advance of its consumption. An inventory of anodes must accumulate in an electrolytic refinery before entire cell sections can be energised together.

At UKMC the operations team implemented an astute practice of commissioning an entire sulphuric acid plant (designed by SNC Lavalin) ahead of the copper smelter. This was made possible by interconnecting ducts with existing non-ferrous smelting plants and the supply of SO_2-rich gases for several months in advance of commissioning the copper smelter. Similarly the air separation unit (designed by Kryogenmash) was also commissioned and operating at full capacity well in advance of its required duty for the copper smelter.

In part because of the care and planning that occurred during pre-commissioning, UKMC achieved 100% of the copper ISASMELT™ plant's design smelting capacity, measured on an 8-hour shift basis, within a few days of first adding feed to the ISASMELT™ furnace. However, the job of ramping up a smelter to full production does not end there. The following year of operation was spent achieving both consistency and reliability across the whole copper smelter, qualities that are necessary for stable plant operation. Xstrata Technology personnel provided some assistance in this endeavour, whenever asked to do so. For the first few weeks after deciding to heat the ISASMELT™ furnace Xstrata Technology was able to assist all operations shift crews, with two specialists per shift, on a 24 hour basis. The required assistance diminished significantly as the operations team gained experience and competence in their tasks. Within a couple of months the UKMC team were "flying solo" with proficiency, and have continued to optimise and improve the smelter operation ever since.

Operation

Operating statistics of a typical month in the copper ISASMELT™ plant, taken 7 months after start-up, are shown in Table 2. For the average monthly production to be greater than 80% of design capacity within a few months of operation, it is clear that the greater proportion of operating practice, equipment selection, installation and commissioning must have been performed with care and thoroughness.

Table 2 – Operating Statistics from Kazzinc Copper ISASMELT™ Plant

	Unit	February 2012
Availability	%	89.4
Concentrate	t/h	32.0
Silica	t/h	7.7
Reverts	t/h	2.6
Coal	t/h	0.4
Limestone	t/h	1.3
Feed Moisture	%	9
Lance life	days	6
Cu in feed	%	21.7
Cu in matte	%	57.0
ISASMELT™ Lance Flow	Nm^3/h	16500
O_2 in Lance Air	%	58

Variations in Smelter Feed

One of the main advantages identified by Kazzinc in employing the ISASMELT™ process was its ability to treat a wide range of copper concentrate compositions. In fact, the composition of the feed available at the start of smelter operation (refer to Table 3) deviated significantly from the design basis for certain elements. The differences included a proportional increase of lead and antimony in the actual concentrate by more than 50 %, and a proportional decrease of silica in the actual concentrate by more than 50 %, compared with the design concentrate.

Table 3 – Comparison of Actual Kazzinc Copper Smelter Feed at Start-up with Design

	Wt, %							
	Cu	Pb	Zn	Fe	S	SiO2	Sb	As
Design	25.0	2.68	3.14	24.85	31.74	5.11	0.16	0.55
Actual	25.68	4.35	3.53	26.65	32.92	2.39	0.25	0.49
Absolute Deviation	+0.68	+1.57	+0.39	+1.80	+1.18	-2.72	+0.09	-0.06
Relative Deviation	+3%	+59%	+12%	+7%	+4%	-53%	+56%	-10%

The lower level of silica in the copper concentrate required the simple action of greater addition of silica flux material. The increased level of antimony in the concentrate made the task of producing MOOK grade cathode more challenging.

The increase in the level of lead in the concentrate, which was reasonably high to begin with, required modification to the flowsheet and management strategies after the commissioning process was complete. The main strategy for coping with the higher loads of lead was to install a bleed by milling and flotation of the slag from the end of each P-S Converter copper blow. This approach avoided the buildup of recirculating lead that occurred when the slag was charged to the electric settling furnace for electrothermal reduction.

In combination, these measures have been sufficient to prevent problems, such as inadvertent generation of lead bullion by chemical reduction of slag in the electric settling furnace, and the smelter has settled into its role of treating lead-laden copper concentrate without great difficulty. In particular, the waste heat boiler for the copper ISASMELT™ furnace (designed by Foster Wheeler) has experienced no problems attributable to the concentrate composition. Concerns raised during project planning that the internal components of the waste heat boiler would be coated with lead-bearing accretions, thereby reducing its heat transfer efficiency, proved unfounded. Careful attention to the detail design of the waste heat boiler size, shape and flow profile have allowed Kazzinc to have a robust off-gas system for their copper ISASMELT™ furnace.

CONCLUSIONS

The Ust-Kamenogorsk Metallurgical Complex has commissioned a new copper smelter and refinery, treating mostly feeds sourced from its own mines and metallurgical facilities. The new plant was conceived with a future vision of polymetallic concentrates being a major component of the feed material.

Personnel from Kazzinc and Xstrata Technology worked together on an extensive programme of training and pre-commissioning activities to prepare the people and plant equipment for their respective roles in plant operation. The plant started well, and continues to run well. Plans exist for expanding the plant production capacity in the future and the plant is designed to accommodate such expansion should it be required.

ACKNOWLEDGMENTS

The authors would like to acknowledge Kazzinc Ltd and Xstrata Technology Pty Ltd for permission to publish this paper.

REFERENCES

1. G. R. F. Alvear F, P. Arthur, P. Partington, "Feasibility to Profitability with Copper ISASMELT™", Copper 2010, Volume 2– Pyrometallurgy I, J. Harre, Ed., GDMB, Hamburg, 2010
2. Y. Li, P. Arthur, "Yunnan Copper Corporation's new smelter – China's first ISASMELT", Yazawa International Symposium on Metallurgical and Materials Processing, Volume II – High Temperature Metal Production, F. Kongoli, K. Itagaki, C. Yamauchi, H.Y. Sohn, Eds., TMS, Warrendale, 2003
3. J. Ross and D. de Vries, "Mufulira smelter upgrade project – 'Industry' Smelting on the Zambian Copperbelt", Pyrometallurgy 05, Capetown, Minerals Engineering International, 2005
4. H. Walqui, C. Noriega, P. Partington, &G.R.F. Alvear F, "SPCC's 1,200,000 TPA Copper ISASMELT™", Sohn International Symposium on Advanced Processing of Metals and Materials, Volume 8 – International Symposium on Sulfide Smelting 2006, F. Kongoli & R.G. Reddy, Eds., TMS, 2006