Ust-Kamenogorsk Metallurgical Complex: A Silent Achiever

Alistair Burrows and Turarbek Azekenov

Abstract Situated in the oblast of East Kazakhstan, the Ust-Kamenogorsk Metallurgical Complex has spent the past twenty years renovating and remodelling itself as a modern polymetallic sulphide smelting facility, and a regional centre of excellence for custom smelting. Along the way there have been changes to the company structure, introduction of new technologies, investments in expanded capacity, environmental improvements, and addition of new metal products and by-products to the site's repertoire. These changes have been gradual and incremental, but taken together they represent a significant contribution to placing Kazakhstan's sulphide smelting industry on a strong foundation for enduring success in the international custom smelting market. In achieving these changes, a workforce that was historically isolated from much of the world now has recognised expertise, internationally competitive skills, and confidence to embrace the future. Further improvements in energy efficiency, environmental compliance and polymetallic processing capabilities are challenges that UKMC stands ready to face.

Keywords Copper · Zinc · Lead · Precious metals · Kazakhstan

Introduction

Formerly part of the Soviet Union, the Republic of Kazakhstan has been an independent nation for more than 25 years. It is larger than Western Europe and has a wealth of mineral resources spread throughout the country. The capital of Eastern Kazakhstan oblast 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. For many years Ust-Kamenogorsk has also been home to a multi-smelter metallurgical complex specialising in the production of zinc, lead, copper, silver, gold, antimony, bismuth and various other by-products. The Ust-Kamenogorsk Metallurgical Complex (UKMC)

A. Burrows (✉) · T. Azekenov
Kazzinc Ltd., 1 Promyshlennaya Street, 070002 Ust-Kamenogorsk, Republic of Kazakhstan
e-mail: aburrows@kazzinc.com

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has an interesting history, a series of notable metallurgical achievements in the field of sulphide smelting and bright prospects for the future.

The development of UKMC is best understood when set in its geographic, political and economic context. Both the advantages and the challenges UKMC face include features that are not commonplace in sulphide smelters elsewhere. This paper seeks to introduce the modern plant to a wider audience, so that its statistics and achievements might be better known and discussed.

History and Geography

In the wide area of Central Asia there have been many rich deposits of non-ferrous and precious metals, known from the time of Imperial Russia. The Altai mountains were a particularly prospective area [1] and one rich mine, near today's city of Ridder, has been in constant operation for more than 200 years. Ust-Kamenogorsk lies at the foothills of the Altai mountains, at the confluence of the Irtysh and Ulba Rivers. Road, rail and (in past times) river are the major transport routes for trade.

Ust-Kamenogorsk was proclaimed a city 150 years ago, and its development has been closely linked to the mining and metallurgical industry ever since. In the early 20th century a port was built on the Irtysh River, a rail link was built to the mines of Ridder [2, 3] and Ust-Kamenogorsk became a transport hub for the mineral wealth of the region.

The city was developed into a major metallurgical processing centre during the Soviet period. Non-ferrous metals, especially uranium, beryllium, titanium, magnesium, copper, lead, silver and zinc were produced in various parts of the city. Zinc production began in 1947, and lead production began in 1952. These two metals form the core of what is today's UKMC, which was for many years the headquarters of zinc and lead metallurgical development within the Soviet Union. From its technical and operating expertise many processes were developed. Among the most famous is the KIVCET furnace for smelting lead concentrates, which has been adopted by smelters in Italy, Canada and China.

In past decades some of Ust-Kamenogorsk's achievements in metal processing have been well publicized internationally, but other achievements have not received similar attention. This may in part be due to Ust-Kamenogorsk's post-war industrial history being associated closely with uranium refining. The city was therefore kept closed to outsiders, and the isolation of this time may have helped to foster some local trademark professional attitudes such as resilience, resourcefulness, self-sufficiency, along with a tiny bit of pride.

The Formation of "Kazzinc"

The disintegration of the Soviet Union brought with it an upheaval of the socio-political system, which for several years had a negative impact on the mining and metallurgical production of lead, zinc and precious metals in the area. By 1996, the Kazakh government faced the fact that the nonferrous metallurgy enterprises it owned in East Kazakhstan were in decline [4]. There had been investment in local precious metals refining capacity, but in all other respects the plants of the region were deprived of new capital. With little investment for the past 10 years, it was no longer possible to maintain a cost-effective and coordinated operation of the mines, concentrators and smelters.

As a result, the three main non-ferrous metal companies in the East Kazakhstan region, plus a local hydroelectric power plant, were merged into a single corporatized entity suitable for privatisation. These entities were—"Ust-Kamenogorsk Lead and Zinc Combinate", "Leninogorsk Polymetallic Combinate" and "Zyrianovsk Lead Combinate". The company "Kazzinc" was formed in January 1997, with Glencore International becoming the company's main investor.

Some issues facing the new company of Kazzinc included:

- A need to improve environmental performance
- A need to bring forward the development of new mines to replace diminishing reserves
- An urgent need for "catch-up" maintenance to overcome recent neglect
- A need to improve the economics of all fixed plant assets, by investment in modern technology

Over the twenty years that followed the privatization, there has been a gradual capital investment of over USD$1.5 billion to progressively address these needs. The process has not been fast, but the transformation has been thorough, noteworthy and rewarding. The ongoing development of UKMC has been at the core of the transformation. Figure 1 shows a schematic representation of UKMC's place within the broader Kazzinc group.

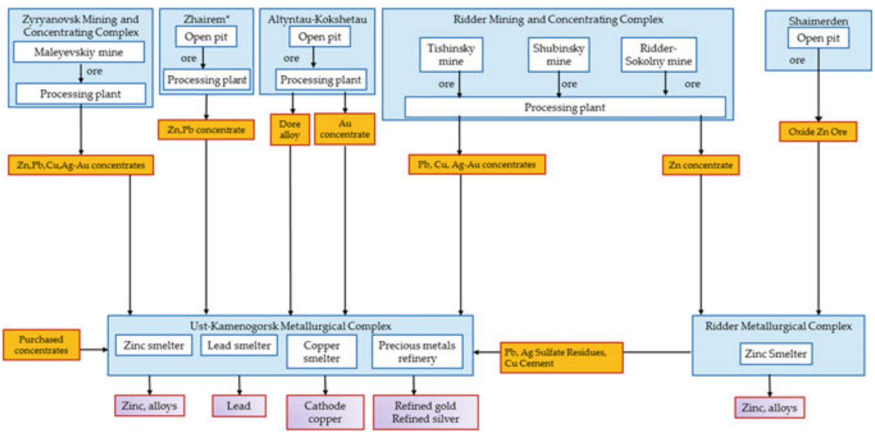

Fig. 1 Structure of Kazzinc

Zinc

As the company's name implies, historically the major focus of Kazzinc Ltd has been the production of zinc. Construction of UKMC began during World War II using equipment evacuated from the Vladikavkaz zinc smelter in 1941 and continued after the war when equipment from Magdeburg zinc plant was brought from Germany as part of war reparations. A lack of design drawings severely complicated and delayed the reassembly and integration of the Magdeburg equipment, resulting in plant commissioning in 1947. Today's production is fully integrated, with the vast majority of zinc sales being in the form of alloys or refined zinc ingots, and a small amount as zinc sulphate that is used as a flotation reagent at Kazzinc's concentrators. In total, the company accounts for around 95% of Kazakhstan's zinc production [5], with around 60% processed via UKMC.

In the first 5 years following the formation of Kazzinc the investment at UKMC's Zinc Plant amounted to tens of millions of dollars in like-for-like refurbishment of the dilapidated roasting and tankhouse equipment. The plant capacity is now approximately 190,000 tpa of zinc.

The major concentrate supply to the Zinc Plant is a sulphide zinc concentrate (assaying approximately 50% Zn) originating from the Maleyevskiy mine. The Zinc Plant uses a conventional RLE production process, as shown in Fig. 2. There are some local idiosyncrasies. Concentrates are treated in oxygen-enriched fluid bed roasters. Although not widespread elsewhere, the use of oxygen-enrichment in zinc fluid bed roasters was commonplace among former Soviet countries. The oxygen concentration in roaster blast air may vary between 21–39%O_2 and in practice it is rarely the heat balance that limits the Zinc Plant's use of tonnage oxygen, but rather internal competition with hungry oxygen consumers in the Copper Plant and the Lead Plant.

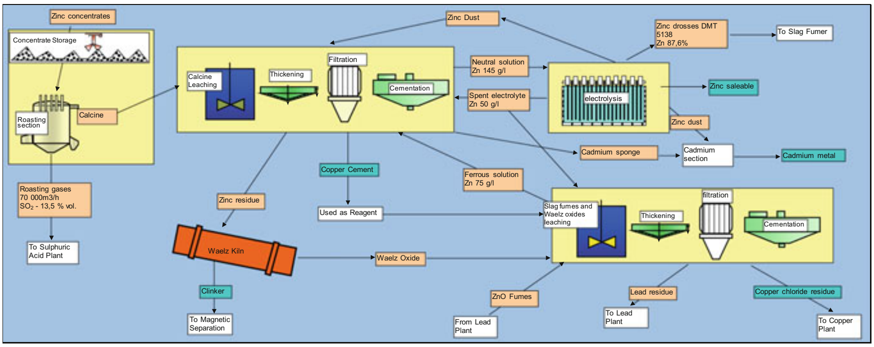

Fig. 2 Schematic flowsheet of UKMC Zinc Plant

UKMC has three fluid bed roasters, of which sometimes one and sometimes two are operational at any given time. Roaster off-gases are captured and converted into sulphuric acid in a contact acid plant. Zinc calcine from the roasting process is leached with spent electrolyte. Copper and cadmium are removed from the resultant zinc solution. Cadmium is refined for sale while the copper is removed as copper chloride, which becomes one of the feed materials for UKMC's Copper Plant. Zinc residues are processed pyrometallurgically in Waelz kilns, producing Waelz oxide from which lead, chlorine, arsenic and antimony are removed prior to treatment in the calcine leaching circuit. The Waelz slag is further processed for recovery of useful carbon, and valuable copper and precious metals. These are examples of the integrated nature of UKMC processing plants.

So while Kazzinc is a large integrated zinc producer, with operations spanning 6 towns in Kazakhstan, UKMC has become a metallurgical hub that links all of the operations and provides benefits that can only be achieved when treatment of by-products is holistically integrated into the company operations.

Maleyevskiy Mine

Although this article is principally focused on sulphide smelting at UKMC, a brief mention of Maleyevskiy mine is necessary to appreciate the motivating force behind our site's development of the last 20 years. The Maleyevsky mine is Kazzinc's largest underground operation, commissioned by the company in June 2000. By the end of 2001 the mine had been expanded, bringing production up to 2.25 Mt/y of ore, with average ore grades of Zn 7.5%, Cu 2.3%, Pb 1.3%, Au 0.75 g/t and Ag 75 g/t [6]. The proven reserves at that time suggested approximately twenty years of mine life. Maleyevskiy mine accounts for the vast majority of UKMC's zinc production and about 50% of UKMC's copper production. Maleyevskiy lies 18 km east of the town of Zyrianovsk, so after the mine was commissioned an existing concentrator at Zyrianovsk was used to process the ore.

Previous ores from Kazzinc's mines were mainly Zn-Pb ores, but since its inception the Maleyevskiy mine has produced a Zn-Cu ore. Of recent times Maleyevskiy ore typically contains the following grades: 5.7% Zn, 1.9% Cu, 0.9% Pb, Au 0.56 g/t Au and 56 g/t Ag. Concentrates produced from Maleyevskiy ore have some characteristic features. The copper mineralisation is distributed between chalcopyrite: tennantite in the approximate mass ratio of 15:1, which limits the potential smelting outlets for the copper concentrate.

In the years since 2001 an increasing dependence on Maleyevskiy mine has driven UKMC's development to deviate from its history and strike out in a new direction: it has forced the company to become a copper producer, and it has forced the Lead Plant to change from a captive smelter to a custom smelter.

Copper

In 2005 Kazzinc instigated a project to build, from scratch, a copper smelter, another acid plant and a copper refinery to complement the existing processing plants within UKMC. Despite its rich smelting history, copper had not previously been among UKMC's major products. 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.

The flow sheet of the copper plant, shown in Fig. 3, has been described by others [7, 8]. It includes the following process stages:

- smelting of copper concentrates and by-product materials in an ISASMELT™ furnace;
- settling of matte and slag, and slag cleaning, in an electric furnace;
- copper matte converting in Peirce-Smith converters;
- fire refining of blister copper in rotary anode furnaces; and

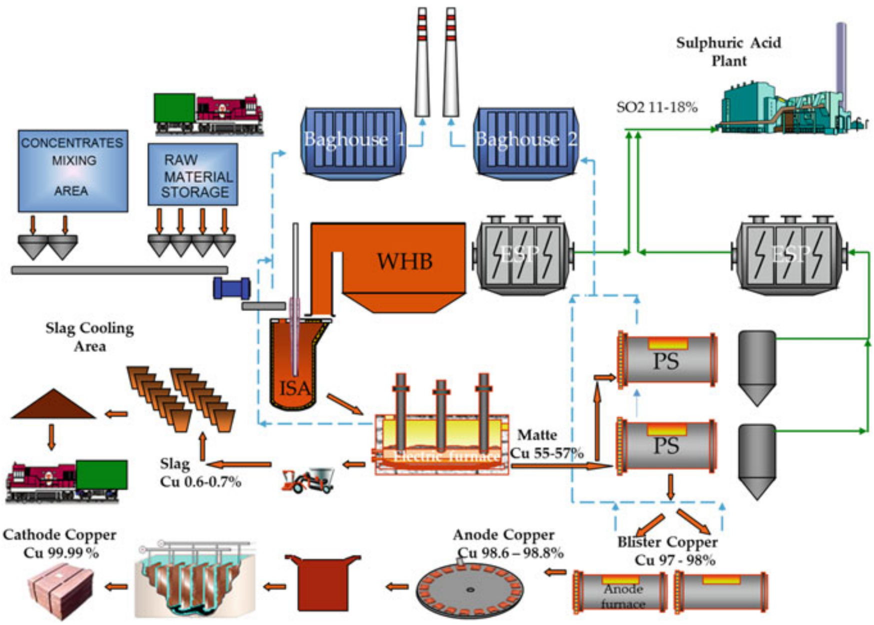

Fig. 3 Flowsheet of UKMC Copper Plant

- electrorefining of anodes on IsaProcess™ permanent cathode plates.

Copper and gold concentrates, zinc plant residues and copper-bearing reverts are smelted in the ISASMELT™ furnace to produce a gold- and silver-bearing matte. Dust produced in the ISASMELT™ is leached to provide an arsenic bleed, and for recovery of lead. De-dusted gas is sent for sulphur dioxide capture at a new Acid Plant. Copper anodes, after fire-refining, are sent to the tankhouse for production of refined copper with purity predominantly corresponding to M00 K brands (equivalent to LME grade 'A'). Gold- and silver-bearing copper anode slimes are treated at the Precious Metals Refinery.

Kazzinc's mined copper represents only 10% of Kazakhstan's production [5]. With a surplus of concentrates and a deficit of smelters the UKMC Copper Plant was a necessary asset for an integrated producer to capture added value, but a Copper Plant with 70,000 tpa capacity for refined copper cathodes is remarkably small by modern standards. The plant is economically viable only because of several local anomalies such as: copper residues being available from zinc plants, copper dross being available from the lead smelter, cheap electrical power from the Bukhtarma hydroelectric power station being available for the copper refinery, and a tariff applying to the export of copper concentrates from the Republic of Kazakhstan.

As the Copper Plant production grows and exceeds the output of Maleyevskiy mine, UKMC is looking farther afield at potential polymetallic copper concentrates that are available elsewhere in Central Asia, and which may provide an attractive feed for the smelter. The Copper Plant is gaining the flexibility required to treat various feed types in the future.

Lead

Today lead from UKMC accounts for nearly 100% of the lead production in Kazakhstan [5]. For the first five years after the formation of Kazzinc, the principal task was to rationalize the lead production facilities. Crude lead production previously had been conducted at Ridder with pyrometallurgical refining centralized in UKMC. This was changed so that all lead production was centralized in UKMC, which had immediate environmental benefits. The atmospheric dispersion of SO_2 was thus greatly reduced in Ridder.

If UKMC is the "hub" of Kazzinc, then the Lead Plant is the "hub" of UKMC. The Lead Plant is responsible for providing the primary feed to the Precious Metals plant, and for accepting all manner of by-product materials that come from the Zinc Plant and Copper Plant. Schematically the relationship between the plants resembles the diagram in Fig. 4.

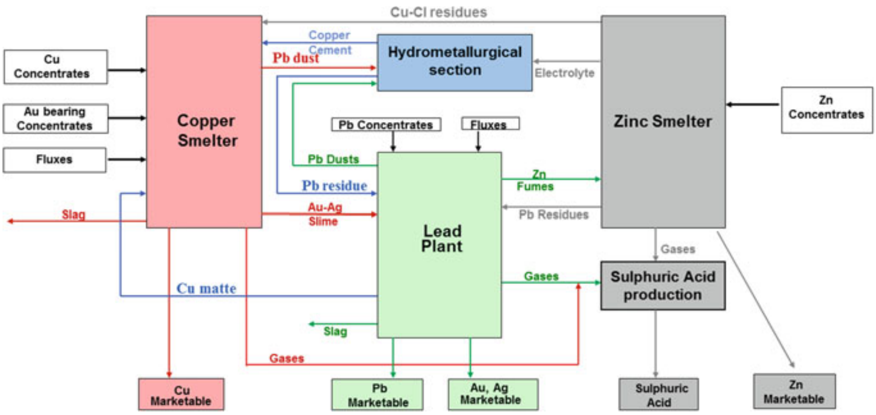

Fig. 4 Relationship between Lead Plant and other plants of UKMC

The Lead Plant is a sprawling complex that has grown over many years. Construction of the Lead Plant began in January 1951. The first metal was produced on June 25, 1952. In January 1956 a slag-fuming plant was started up for recovery of zinc from the blast furnace slag. An updraught sinter plant, of Lurgi design, was installed in 1974 and most of the equipment in the extant sinter plant dates from that time. A KIVCET furnace with production capacity of 40,000 tpa crude lead bullion operated from 1987-1997, but since 1997 all lead production relied on the sinter plant—blast furnace production route, until in August 2012 an ISASMELT™ furnace was introduced as a part of the New Metallurgy Project [9, 10]. This process broadened the range of treated lead-bearing products compared with sintering. Ingots of lead-rich slag are added to the blast furnace, at grades which were considered unfeasible with sintered agglomerates. Complete sulphur removal prevents matte generation in the blast furnace and has resulted in further reduction of atmospheric dispersion of SO_2 gases from the UKMC site.

The Lead Plant modernization was conceived in 2005 at the same time as the Copper Plant construction project was instigated. What was not expected at that time, was that the lead ISASMELT™ furnace would go on to exceed its design capacity by 40% and contribute to a significant reduction in the costs of lead production at UKMC. This year's 151,000 tonne of refined 99.99% Pb represents the highest production forecast in decades. It has resulted in a re-think for the operation of many downstream processes and equipment items.

Kazzinc proceeded with the modernisation of its Lead Plant flowsheet assuming that the existing lead blast furnaces would be satisfactory for treating the slag produced in the lead ISASMELT™ plant, with little or no capital investment required. This assumption has since been validated. The instantaneous capacity of the ISASMELT™ furnace to generate slag is approximately twice the instantaneous capacity of a single Kazzinc blast furnace to smelt slag, so two blast furnaces are in use most of the time. The present flowsheet is represented schematically by Fig. 5.

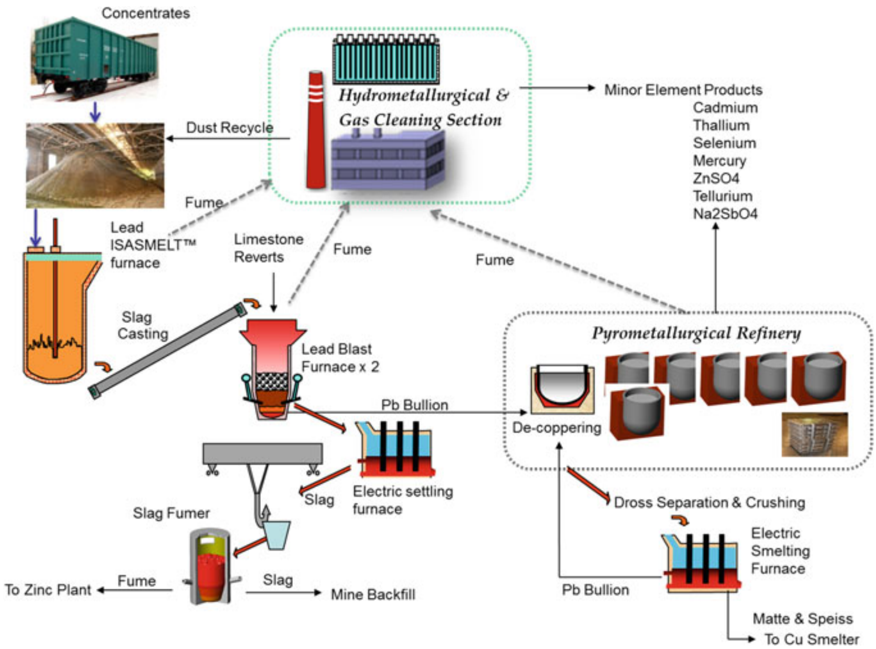

Fig. 5 Present Lead Plant flowsheet for UKMC

Precious Metals

Within UKMC both the Copper Plant (anode slimes) and the Lead Plant (Parkes crust) have significant by-products of precious metals that need to be refined. Parkes crust from the Lead Plant is distilled electrothermically to produce a predominantly lead-silver alloy for cupellation. Dried anode slimes from the Copper Refinery is also added to the cupels. The doré metal produced in the cupels is spooned manually for casting into moulds, creating anodes ready for refining. Until 1993, the refining was done in Russia.

Kazzinc's precious metals refinery was the first in Kazakhstan [11]. It dates from the period, just after independence, when it was constructed for reasons of establishing national gold reserves in the newly-independent Republic of Kazakhstan.

The refinery was developed by local experts using a unique design. It has a compact silver refining area where particularly large doré anodes are refined to produce silver cathode granules. This allows more precious metal production in a small plant footprint. The purity of gold and silver produced is "four nines". The refinery was added to the LBMA's Good Delivery List in 1995 under the "Deer" brand.

The precious metals refinery has proven to be a versatile asset. In recent years Kazzinc has developed (dedicated) gold mining as a new business venture. The Altyntau Kokshetau mine (literally translated from Kazakh it is the "mountain of gold") now produces a substantial portion of the company's revenue. Doré metal from Altyntau Kokshetau is brought to UKMC for processing into refined gold and refined silver. The annual capacity of the precious metals refinery is approximately 45 tons of gold and 1000 tons of silver.

Sulphur

An acid plant was already in use at UKMC at the time of Kazzinc's formation, but it was connected only to the roasters of the Zinc Plant. Reducing sulphur dioxide gas emissions across its metallurgical operations was one of Kazzinc's founding ambitions. As described above, the first step was to centralize lead smelting operations at UKMC. In 2002 this step was followed by constructing a "wet sulfuric acid" plant at UKMC using the Haldor Topsoe technology to harvest "strong gases" from the strand of the Lead Plant sinter machine. It has been in operation since 2004. In practice, the wet sulfuric acid plant achieves excellent sulphur capture (tail gas strength is typically around 500 ppm SO_2).

With the 2005 decision to construct a Copper Plant, a new sulphuric acid plant was required. A double-contact/double-absorption acid plant using MECS technology was installed. The design of both the acid plant and the gas cleaning system allowed for gases to be harvested from a single blowing PS Converter, a single Copper ISASMELT™ furnace, plus the possibility of some surplus gases from the Zinc Plant or the Lead Plant operations. This results in a complicated "spaghetti" of

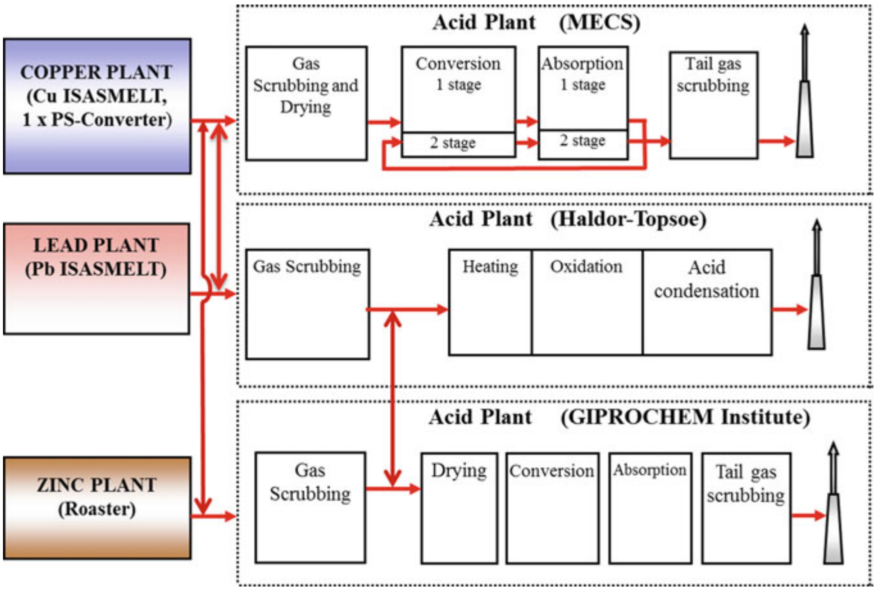

Fig. 6 Arrangement of smelters and acid plants at UKMC

large duct connections, as shown in Fig. 6, but it has added to the overall operating flexibility of UKMC because in the event of an Acid Plant breakdown there is the possibility by adjusting damper positions to choose, and change, which smelter is idle and which operational.

UKMC continues on the path of incremental reductions in SO_2 emissions, and in the past twenty years has succeeded in reducing by more than 50,000 tpa the SO_2 that was previously released to the atmosphere, all while increasing the production of metals. UKMC is now in full compliance with local environmental standards.

People

Kazzinc is Eastern Kazakhstan's largest industrial producer, and employs about 22,000 people in mining, mineral processing, metallurgical smelting and refining operations, as well as in electricity generation and machinery construction. The company strives to develop and improve its application of mining and metallurgical industry technologies. Some of the technology has been developed in-house, some is sourced from Russian-speaking companies based within former Soviet countries, but a large degree of Kazzinc's success may be attributed to its willingness to learn from, and import equipment and knowhow from, leading companies all around the world.

Over a twenty year period there has been a continuous and swift pace of learning by the workforce. The change should not go unremarked, because it is almost certainly the strength that has ultimately given rise to UKMC's relative success. In this twenty year period the workforce has in some places adopted mechanization, automation, sophisticated control systems and safer work culture that were not within the employees' dreams at the time of Kazzinc's formation in 1997. No part of the company is untouched by this culture of development, but UKMC is a particular area of focus owing to the complexity of its operations.

To learn the operations of various new metallurgical technologies adopted in the past twenty years, UKMC has selected employees and organised for them to spend time training in Sweden, Australia, Zambia, China and many other countries. The training itself and the various working trips to learn from foreign specialists have broadened the ambitions of each trainee involved. This process has nearly come full circle, most recently a few foreign companies have expressed interest in sponsoring their employees to travel to the Republic of Kazakhstan to spend time learning the operation of metallurgical technologies in common use at UKMC [12]. This is a source of considerable pride for those who have travelled the whole journey from trainee to trainer.

Approximately 5500 people are employed at UKMC in metallurgical processing and various support services. The challenge for the next decade will be to manage the attrition of experienced workers with a gradual infusion of young employees. There are ambitions to realise further improvements in labour productivity across the site.

Production

As a result of sustained investment in fixed plant assets, training and work practices, UKMC has increased its output of base and precious metals during the past twenty years. Aside from the zinc smelter, which is a mature plant with a relatively stable feed suite, the production increase has been "bumpy" rather than steady, as illustrated in Fig. 7. In particular there have been rises and falls in precious metals as different mine sources have become abundant and then scarce again. At present the Lead Plant has over twenty different external suppliers in addition to ten suppliers internal to Kazzinc. Fluctuations in the amounts from different suppliers can have a significant effect.

Melal production from UKMC

		2000	2001	2002	2003	2004	2005	2006	2007	2008
Metal Lead	mt	133 925	107 584	101 643	88 741	99 149	88 929	86 198	91 025	90 446
Metal Zinc	mt	145 077	156 515	165 176	172 117	175 722	178 528	180 313	184 491	189 630
Metal Copper (Cu blister+ Cu cathodes)	mt	5 866	7 002	6 512	7 787	7 727	6 133	5 904	5 345	4 601
Metal Gold	toz	231 213	267 095	226 346	205 335	221 609	171 524	124 251	125 311	135 777
Metal Silver	toz	11 148 538	9 285 795	5 842 190	5 928 055	5 027 105	5 503 479	4 029 398	3 766 532	3 499 363

	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Metal Lead	79 501	101 023	100 989	83 356	90 982	125 390	120 105	134 059	147 284	**1 870 328**
Metal Zinc	190 382	191 148	190 024	190 781	190 134	194 261	193 750	194 407	201 212	**3 283 666**
Metal Copper (Cu blister+ Cu cathodes)	6 211	5 327	16 426	52 061	58 827	58 186	62 249	64 790	62 914	**443 868**
Metal Gold	185 189	294 771	398 010	547 577	633 113	610 947	566 529	621 163	575 981	**6 141 742**
Metal Silver	2 826 489	3 544 518	6 775 603	18 072 766	17 859 008	25 090 207	30 059 877	27 213 579	21 945 304	**207 417 804**

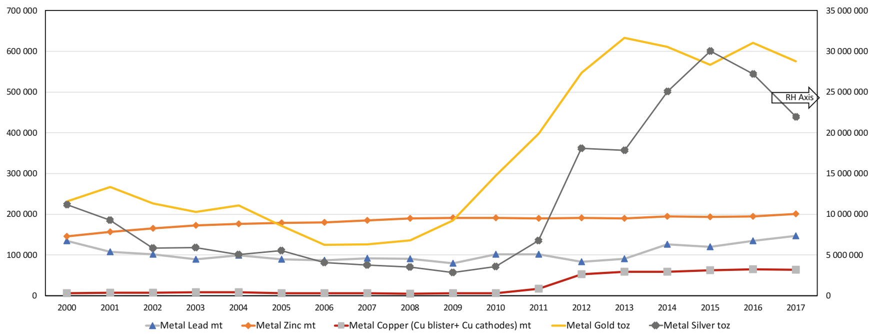

Fig. 7 UKMC metal production

Complementary with the five major production metals, a variety of impurity elements are processed through to final products. These products include small amounts of Selenium, Indium, Thallium, Mercury, Bismuth, Tellurium, and Cadmium as well as sodium antimonate. In some cases the equipment for production of these metals is an inheritance from the plant architecture as it existed many decades ago. However, UKMC foresees an ongoing role in processing most of these impurity elements through to final products. UKMC lies within the city boundaries of Ust-Kamenogorsk and residential buildings exist within 300 m of the smelter production areas. UKMC has a "zero emission" rule for liquid water, and disposal of any impurity elements other than by vitrification in inert iron silicate slag would likely not receive regulatory approval.

Power and Transport

The availability of, and prices of, electrical power and bulk transport are respectively the largest structural advantage and disadvantage of UKMC's future operation. Much planning is required to formulate annual production budgets with these in mind.

Power
The Irtysh River is one of the major river systems of the world, with seasonal water flow, subject to snow melt. Kazakhstan alone has 3 hydroelectric power plants along its length with the Bukhtarma plant, leased and operated by Kazzinc, being one of them. Its annual generation capacity is 2.4 billion kWh, and Bukhtarma's power is used for balancing the national grid [13]. Average power costs after distribution are about USD$0.03 per kWh [13].

Transport
Geographically UKMC is farther from the sea than just about any place on earth, which is a significant disadvantage for both custom concentrate purchases and metal sales to consumers. The nearest sea ports are either in Russia on the Black Sea coast, or in China on the Pacific Ocean's west coast. Many thousands of kilometres of rail travel are required in either direction. This factor has driven some of the development initiatives at UKMC. To minimise the impact of logistics costs on the business it is most attractive to purchase concentrates with the highest metal value per tonne, and this has encouraged UKMC to look beyond base metals and become an integrated precious metal producer.

Conclusions

The Ust-Kamenogorsk Metallurgical Complex (UKMC) has a long and proud history in sulphide smelting for base metals and precious metals. The foundations have been put in place to achieve the environmental compliance and the workplace productivity improvements that a prosperous future will demand. There has been dynamic growth at UKMC over the past twenty years and the current team is proud of the company's achievements in this period. An important role will exist for responsible sulphide smelting for a long time to come, and UKMC wants to be part of that future.

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