

# Recent operation and environmental control in the Kennecott Smelter

C. J. Newman, D. N. Collins, and A. J. Weddick  
*Kennecott Utah Copper Corporation*  
8315 West 3595 South  
P. O. Box 6001  
Magna, Utah 84044-6001  
U.S.A.

## ABSTRACT

The new Kennecott Utah Copper smelter, started in 1995, was designed to be the cleanest smelter environmentally in the world. The plant is operating at production rates above the original design capacity. Copper concentrate is smelted in an Outokumpu flash smelting furnace. Matte is granulated and processed using Kennecott-Outokumpu flash converting. Copper anodes are processed in a modernized copper refinery using the Kidd Process while anode slimes are processed for precious metals recovery using a unique hydro-metallurgical process.

To allow the production of high quality cathode, using modern smelting and converting technology to minimize emissions, impurity control had to be carefully addressed. All process bleed streams from the smelter and refinery are treated in a hydro-metallurgical plant to fix impurities in a stable form, allow for the rejection of impurities as required and recover valuable metals. Special technology was developed for the copper refinery to ensure production of high quality cathode from anodes containing high levels of impurities.

The smelter routinely achieves a sulfur capture in excess of 99.9% which is equal to less than 2 kg of SO<sub>2</sub> per tonne of copper produced. This paper describes the design of the smelter and refinery and includes recent production and emission data and modifications carried out to allow operation at above the original design rates. It emphasizes the unique features required to achieve environmental and quality goals and compares environmental performance data to that published on other smelting operations. The processing of intermediate streams, the management of recycled materials and the impurity control strategy will be covered in detail.

## INTRODUCTION

Kennecott Utah Copper Corporation (KUCC) expanded its mine and mill facilities in 1988 increasing the production rate to 773,000 tonnes per year of copper concentrate. A further expansion of the mill in 1992 raised the concentrate production to 1.0 million tonnes per year. The smelter facilities could only process about half this tonnage primarily because of insufficient acid plant capacity to meet increasingly restrictive air emission regulations. The remaining concentrate production was sold.

In 1989, KUCC initiated a study of smelting requirements to process all of the available concentrate resulting from the current expansion of mining and milling facilities and also possible future expansions. As a result of this study, the Outokumpu flash smelting furnace was chosen as the primary smelting vessel, to be coupled with Kennecott-Outokumpu flash converting technology to process solid matte through to blister copper.

The strategy developed for the smelter was to construct a state-of-the-art facility that would include the best available emission control equipment to meet present and future anticipated environmental regulations. The permitted emissions of sulfur dioxide were reduced to 982 tonnes per year, only 5% of the previously approved limit. The KUCC smelter was designed and constructed to be one of the cleanest smelters in the world, with a sulfur capture in excess of 99.8%. This strategy enabled air permitting to be completed in five months.

To achieve this low sulfur dioxide emission rate the design incorporated a number of unique steps. These included continuous processes for the production of copper matte and blister copper, elimination of ladle transfers of molten metal, secondary gas collection at tapping and other furnace locations, secondary gas scrubbing, concentrate dryer off-gas scrubbing, anode furnace off-gas scrubbing and an acid plant guaranteed to have less than 100 ppm sulfur dioxide in the tail gas, from a feed gas of 14% sulfur dioxide.

In addition to stringent limits on air emissions, recycle of water and solid waste disposal were carefully addressed in the design. All water from the process is collected in lined ponds and reused in the smelter or pumped to the concentrator operations. Run-off from those areas of the plant that may contain heavy metals is also directed to the process water ponds. All run-off from areas outside of the smelter is diverted around the plant and collected in storm water ponds. This water is then either discharged to the surrounding wet lands or pumped into the process water ponds for reuse.

The only solid wastes produced from the plant are tailings from the slag concentrator and from the smelter hydro-metallurgical plant. The latter processes a stream of dust removed from the flash smelting furnace electrostatic precipitator and extracts metal values for recycle to the smelting process. It can also separate an arsenic

bearing waste to be sent to a permitted hazardous waste treatment and disposal site and produces gypsum tailings which are blended with slag tailings before being pumped to the tailings impoundment. This waste stream from the smelter hydro-metallurgical plant undergoes regular Environmental Protection Agency (EPA) toxicity testing to ensure the contents are environmentally acceptable.

As a result of the selection of continuous smelting and converting processes to minimize emissions, the recycle of many intermediate products and the variability of the ore from the mine, the copper refinery had to produce high quality copper cathode from anodes with high and variable impurity content. The KUCC copper refinery uses special technology to allow routine production of high quality cathode from anodes containing impurities that the majority of other copper refineries in the world would not want to treat. The refinery was converted to the Kidd Process licensed from Falconbridge Ltd. to plate copper onto stainless steel blanks. To control impurities in the tank-house electrolyte, electrolyte bleed is pumped to the smelter hydro-metallurgical plant for metal recovery.

Precious metals, contained in the anodes, settle to the bottom of the refinery cells. From here they are pumped to a new hydro-metallurgical process where gold, silver, selenium, tellurium and lead are recovered. All bleed streams from this precious metals plant are also pumped to the smelter hydro-metallurgical plant for processing.

## **SMELTER PLANT DESCRIPTION**

### **Material Handling**

Copper concentrates are received at the smelter via slurry pipelines from the two Kennecott concentrators. They are blended with recycle streams from the flash smelting furnace slag concentrator and the smelter hydro-metallurgical plant and then dewatered using pressure filters. The resultant filter cake, containing about 9% moisture, is conveyed to a storage shed where it is blended into two beds each containing about 4,500 tonnes. Other miscellaneous secondary streams are also blended into these stockpiles as they are being built. Bedded material is uniformly reclaimed using a linear reclaimer and conveyed to the wet feed bins.

Concentrate is combined with silica flux and flash converting furnace slag and dried in a natural gas-fired rotary dryer to reduce the moisture content to less than 0.5%. The dryer uses nitrogen from the air separation plant to minimize oxidation of sulfides. The dryer off-gases are cleaned in a bag-house and any contained sulfur dioxide is removed using sodium hydroxide in a reverse-jet scrubbing tower before passing on to the main stack. Dried feed is pneumatically conveyed to a storage bin above the flash smelting furnace reaction shaft.

## **Flash Smelting Furnace**

Feed to the flash smelting furnace is metered using a loss-in-weight system and fed to the concentrate burner via two drag conveyors. Oxygen-enriched air (80-85% oxygen) is also fed to the burner located in the top of the furnace reaction shaft.

Slag is tapped at a target temperature of 1,315° C (2,400° F). Target matte grade is 69% copper.

Matte is tapped down heated launders to a water-granulation facility. This fine granulated matte is conveyed to a covered storage building to produce a blended stockpile. The slag is tapped into pots and slow-cooled before being processed in a slag concentrator to recover the residual copper.

The elimination of crane transfers of molten matte to the converting vessel, as is required with conventional Peirce-Smith converters, results in a major reduction of in-plant fugitive emissions.

Hot furnace off-gases contain 35-40% sulfur dioxide. The gases are cooled in a waste-heat boiler and cleaned in an electrostatic precipitator and wet gas scrubber before being sent to the sulfuric acid plant. Dust is normally recycled back to the furnace feed but a portion can be removed from the system and sent to the smelter hydro-metallurgical plant to control bismuth and arsenic levels in the copper anode product.

## **Flash Converting Furnace**

Granulated matte is automatically reclaimed from the blended stockpile and conveyed to a vertical roller mill where it is ground and dried. The ground matte is then pneumatically conveyed to a storage bin above the furnace.

Matte, burned lime and dust are fed to a matte burner on top of the furnace reaction shaft together with oxygen-enriched air at 75-85% oxygen. The copper matte is converted to blister copper and the residual iron combines with lime to form a calcium ferrite slag. The slag is granulated in water, reclaimed by bucket excavator and returned to the flash smelting furnace for copper recovery. Blister copper is laundered to the anode furnaces.

Furnace control is accomplished by monitoring the composition of the slag and the furnace temperature. Increasing copper content is an indication of over-oxidizing of the bath with a corresponding decrease of sulfur in the blister, and vice-versa. The sulfur content of blister in a stable operation is 0.3% which corresponds to approximately 18% copper in the slag.

As in the case of the flash smelting furnace, the off-gases contain 35-40% sulfur dioxide. They are cooled and cleaned in a waste-heat boiler, electrostatic precipitator

and scrubbing system before being sent to the sulfuric acid plant. Dusts recovered in the boiler and electrostatic precipitator are recycled either to the flash converting furnace or the flash smelting furnace.

### **Anode Plant**

Blister copper is collected in one of two anode furnaces and when the furnace is full (650 tonnes), the remaining sulfur is removed by injecting air into the molten bath. The oxygen content is then reduced to target levels by injecting a mixture of steam and natural gas. The finished refined copper is cast into 335 kg anodes using a twin-wheel casting system. Product anodes are loaded onto rail cars for transportation to the refinery. Spent and reject anodes are returned to the smelter for remelt in a natural gas-fired shaft furnace and recast into anodes. The lead level in anodes is controlled by applying a deleading procedure if the blister copper rises above a predetermined level.

### **Off-gas System and Powerhouse**

Cooled gases from each furnace scrubber combine and are further cleaned in the wet electrostatic mist precipitators. The gases then pass to the double absorption sulfuric acid plant. The gas strength is controlled at 14% by adding dilution air to the 30-35% sulfur dioxide stream. The acid plant produces either 94% or 98% sulfuric acid with tail gas containing typically 50-70 ppm sulfur dioxide.

Steam, produced in the furnace waste-heat boilers, is used to drive the acid plant blowers that move the gases through the plant. Excess heat from the reactions on-going in the acid plant is used to generate low pressure steam which is blended with the residual steam from the blowers and directed to a turbo-generator at the powerhouse. Approximately 24 MW of electrical power is generated in this manner representing 70% of the smelter's electrical requirements.

### **Hydro-metallurgical Plant**

The hydro-metallurgical plant processes dust from the flash smelting furnace electrostatic precipitator primarily to control impurities in anode copper. It also processes electrolyte bleed from the refinery and furnace scrubber blowdown.

Two leach stages using water and acid dissolve most of the metals except lead and precious metals. This residue is returned to the primary copper concentrate filter plant. Three stages of selective precipitation separate arsenic, copper and bismuth. The copper sulfide precipitate is returned to the filter plant. The arsenic product can either be combined with the copper sulfide or separately filtered and sent to a disposal site. The bismuth is combined with the gypsum precipitate that becomes the hydromet plant tailings.

### **Secondary Environmental Control Equipment**

Part of the goal to build the “cleanest” smelter in the world was to minimize fugitive gases in the workplace. To attain this, a significant amount of environmental control equipment was incorporated into the design. Permit levels for PM<sub>10</sub> emissions were 418 tonnes/year, approximately half of the emission rate from the old smelter.

Ventilation equipment is designed to collect gas and fume from both furnace tapping areas as well as any emissions from the top of the reaction shafts, settlers and uptakes. They are collected and subjected to bag filtration followed by sodium hydroxide scrubbing prior to discharge through the main smelter stack.

Anode furnace combustion and refining gases are processed through desulfurizing scrubbers to remove fine particles and sulfur dioxide before being emitted to the atmosphere through the stack.

All feed handling equipment is vented through high-efficiency bag filters and the gases formed in the granulation of matte and slag are contained and processed through the secondary ventilation system.

## **REFINERY PLANT DESCRIPTION**

### **Material Handling**

Anodes are received from the smelter on railcars and are automatically unloaded by a robotic crane and placed on a chain conveyor which then feeds the anode preparation machine. The anode preparation machine has six process stations arranged around a revolving carousel to inspect and prepare the anodes for loading into cells in the tank-house. The six stations are:

- Weigh and load Identifies anodes outside of the pre-set weight specification.
- Body press Straightens the anode body and lugs in the vertical plane and measures anode thickness at seven points.
- Reject Rejects anodes that are outside the weight and thickness specifications.
- Lug press Aligns the lugs of the remaining good anodes enabling the anodes to hang vertically in the cells.
- Lug milling The bottom edge of each lug is milled to further ensure anode verticality in the cells.
- Unload and space Removes good anodes from the carousel and correctly spaces them in batches of 47.

At this point the 47 anodes are interleaved with 46 stainless steel blanks and placed in an automatically guided vehicle (AGV) which transports the cell load to the tank-house.

### **Tank-house**

In the tank-house, the AGV's are unloaded by crane and the electrodes placed directly into the tank-house cells. The Kennecott refinery uses the Kidd Process technology, licensed from Falconbridge Limited. The tank-house contains 1,424 polymer concrete cells each holding 46 electrode pairs. At a current density of 230 amps/m<sup>2</sup>, the design capacity of the refinery is 280,000 tonnes per year of cathode copper.

The tank-house anode cycle is 21 days. Cathodes are pulled at 10 and 21 days and the anodes replaced at 21 days. The scrap anodes, representing about 16-18% of the anodes' original weight, are washed to remove precious metals-bearing slime and returned to the smelter. They are remelted at the smelter in the shaft furnace and cast into anodes.

Cathodes are harvested, returned to the material handling department by AGV, washed to remove residual electrolyte and positioned on the cathode stripping machine. This process then separates the cathode copper from the stainless steel blanks and conveys the copper to a sampling station, followed by corrugation of every other sheet, bundling, weighing and labeling. Cathodes are then sent to storage or shipping. Stainless steel blanks are returned to the anode receiving station for interleaving.

### **Precious Metals**

The Bingham Canyon ore body contains significant quantities of precious metals including gold, silver and minor amounts of platinum and palladium. Anodes received at the refinery contain 40-60 g/tonne of gold and 350-500 g/tonne of silver. During the refining process these precious metals along with other insoluble impurities in the anode settle on the bottom of the electrolyte cell. At the end of the 21 day cycle these precious metal "slimes" are washed out of the cells and pumped to the new hydro-metallurgical precious metals processing plant.

The first process stage in the recovery of gold and silver is the removal of copper and tellurium using a sulfuric acid leach under oxygen pressure in an autoclave. The filtrate is circulated through a column containing copper scrap where copper telluride is deposited. The detellurized solution is returned to the liberator cells for copper recovery.

The remaining slimes are then subjected to a hydrogen chloride / hydrogen peroxide leach that dissolves the gold and selenium leaving insoluble silver and lead chlorides. Soluble gold is recovered from the leach liquor using solvent extraction. Gold

is then reduced from the organic extractant using oxalic acid and the gold sands are dried, melted and cast into bars for sale.

Selenium is recovered from the raffinate by reduction with sulfur dioxide and sold as crude selenium.

The solids from the autoclave are leached with sodium carbonate to convert the lead salts to lead carbonate. This product is either sold or can be dissolved in nitric acid and converted to pure lead sulfate by the addition of sulfuric acid.

Silver is recovered from the delead slimes by an ammonium hydroxide leach followed by conversion to silver oxide using sodium hydroxide and then reduced to the metal with dextrose. Finally the powdered silver is melted and cast into bars for sale.

## **RECENT PLANT OPERATION**

### **Smelter**

#### Flash Smelting Furnace

The flash smelting furnace and associated feed systems and off-gas systems have generally operated very well. Furnaces feed rates are often 170 - 190 t/h - well above the nominal design rate. Experience has shown that the flash smelting furnace has the ability to process high levels of recycled secondary materials. At times as much as 20% of the bedded concentrate stockpiles consists of secondary material, including pugged dust, granulation overflow solids, silica-containing granulated matte and miscellaneous materials recovered from the demolition of the old Smelter. This is in addition to the recycle of flash converter slag.

A key feature of the new Kennecott-Outokumpu flash converting technology is the ability to granulate matte with water for long periods of time. This granulated matte is subsequently dried and ground to produce the optimum size distribution. Flash smelting furnace matte and flash converting furnace slag granulation has proceeded without difficulty and granulation rates of 120 t/h - 140 t/h are typical.

One of the key parameters in maintaining control of flash converting furnace slag metallurgy is to control the silica content in flash smelting furnace matte. The converting furnace is operated using a lime-based slag to help in impurity elimination. If the silica level in flash smelting furnace matte from slag contamination is greater than 1%, the silica level in flash converting furnace slag increases to more than 5%. At this point, the slag viscosity significantly increases and results in tapping difficulties. With flash converting using a lime based slag, additional care must be taken in minimizing the amount of slag tapped with matte from the flash smelting furnace and additional

sampling is required. This is not an issue with smelters using traditional converting methods.

The flash smelting furnace production results for the four month period March – June 1999, are summarized in Table I and compared to design.

Table I - Flash Smelting Furnace Operation - March – June 1999

	Average	Best Month	Design
New concentrate smelted, tonnes/day	2,680	2,830	2,742
Dry charge smelted, tonnes/day	3,526	3,665	3,294
Dry charge feed rate, tonnes/hour	166	170	152
Matte produced, tonnes/day	1,227	1,264	1,175

During this four month period the emphasis was on adding higher than normal amounts of high-grade copper secondaries to the charge. This reduced the quantity of new concentrate smelted compared to the year 1998 but increased the average daily matte production. The flash smelting furnace has demonstrated the ability to sustain feed rates in excess of 200 t/h. The maximum daily throughput of dry feed to-date (excluding dust recycle) is 4,780 tonnes.

## Flash Converting Furnace

The flash converting furnace produces blister copper on a continuous basis from ground granulated matte. The flash converting furnace and associated feed systems and off-gas systems have generally operated well.

The choice of calcium ferrite slag chemistry was primarily a function of minimizing the risk of foaming together with reduced impurity recovery to blister copper. With calcium ferrite slag chemistry it is practical to maintain a protective layer on the furnace sidewall. This is done by controlling the magnetite level in the slag by control of lime, silica and copper levels in the slag. Any reduction in the protective layer can be readily detected by monitoring the heat losses to the settler sidewall cooling system.

The evolution of the sidewall cooling element design to extend the time between furnace rebuilds has been a continuing activity. During a scheduled furnace repair in April 1997, improved skew and sidewall coolers were installed based on a proprietary design.

The flash converting furnace production results for the period March – June 1999, are summarized in Table II and compared to design.

Table II - Flash Converting Furnace Operation March –June 1999

	Average	Best Month	Design
Matte converted, tonnes/day	1,290	1,353	1,175
Matte feed rate, tonnes/hour	64	66	54
Blister Cu produced, tonnes/day	811	848	756

The flash converting furnace has also demonstrated that there is excess processing capability, as feed rates of up to 82 tonnes of matte per hour have been sustained for extended periods. The maximum daily throughput to date is 1,800 tonnes of matte.

## Anode Plant

Each anode furnace had a design capacity of 550 tonnes. In early 1997, modifications were made to the location and size of the mouth and tuyeres to increase the capacity to 650 tonnes.

To maintain low sulfur dioxide emissions, the elimination of ladle transfer of blister copper is essential. With the anode furnaces directly coupled to the flash converting furnace, their role becomes even more important than in a conventional smelter. Any delay in the anode operation impacts directly on the flash converting

furnace operation.

Originally, ammonia was used for deoxidization in the anode furnaces. Although the chemistry worked well, the use of ammonia resulted in the production of higher levels of nitrogen oxides in the off-gases than the permit allowed. As a result, the conversion was made to a steam / natural gas system, which has proved successful.

The original casting wheel was a dual pour, dual take-off system incorporating two concentric rings of 20 molds per ring and designed for 100 t/h casting rate. This equipment proved difficult to operate and maintain and was not able to produce quality anodes at a rate that would support design production levels.

The decision was made to completely replace the casting equipment with an Outokumpu-Wenmec twin M-16 system. In this system, two small wheels of 50 t/h each operate in concert to yield a total 100 t/h casting rate. Demolition and installation took place over a 43-day period in April - May 1997.

The anode plant production results for the period March – June 1999 are summarized in Table III and compared to design.

Table III – Anode Plant Operation 1998

	Average	Best Month	Design
Anodes cast from blister copper, tonnes/day	814	844	751
Anodes cast from shaft furnace, tonnes/hour	207	234	176
Total good anodes cast, tonnes/day	1,021	1,078	927

The anode plant has demonstrated the ability to cast up to 100 t/h and the maximum tonnage of anodes cast in one day is 1,664 tonnes.

### Process Gas Handling

The flash furnace gases are cooled in waste-heat boilers where excess oxygen, injected into the furnace uptake, reacts with dust to form non-sticky sulfates. Both of the boilers have operated effectively since startup, with most areas of concern having been successfully addressed during the design and construction phases of this project. Additional access ports have been provided to allow any dust buildup to be controlled.

## Acid Plant

In recent months, with high feed rates on both furnaces and higher than design sulfur levels in concentrate feed rates, acid has been produced at the acid plant design rate of 145 t/h for extended periods.

Sulfur dioxide emissions, at this full rate, have been maintained at less than the design of 100 ppm representing 99.95% collection efficiency of the 14% sulfur dioxide in the feed gas. Under normal operating conditions acid plant tail gas concentration is 50-70 ppm sulfur dioxide.

## **ABILITY OF THE SMELTER AND REFINERY TO HANDLE IMPURITIES**

As one of the requirements to allow operation of the smelter with annual sulfur dioxide emission rates of less than 1,000 tonnes, impurity control throughout the smelter and refinery had to be improved. With known variable impurity content ore from the mine, and with impurity recoveries projected to increase due to the continuous process requirement and required recycle of intermediate products, an extensive investment was required both in equipment and in process design.

Design impurity concentrations in copper concentrate were 2,000 ppm of lead, 1,500 ppm of arsenic and 200 ppm of bismuth, which are close to the average concentrations in concentrate over the last ten years.

The smelter was designed to control recovery of impurities to anode copper by varying dust bleed to the smelter hydro-metallurgical plant to allow elimination of bismuth and arsenic. High lead levels were to be controlled by deleading using slag additions in the anode furnaces. When arsenic in concentrate feed is low, recycling arsenic from the hydro-metallurgical plant to mix with new concentrate can maximize arsenic recovery to anode copper. When arsenic in concentrate feed is high, arsenic can be removed from the system to keep arsenic in anode copper within the optimum range for the tank-house operation. The design impurity levels in anode copper were 300 ppm bismuth, 2,900 ppm lead and 1,100 ppm arsenic.

Figures 1 to 3 show the actual variation seen in impurity content of anode copper processed in the tank-house.

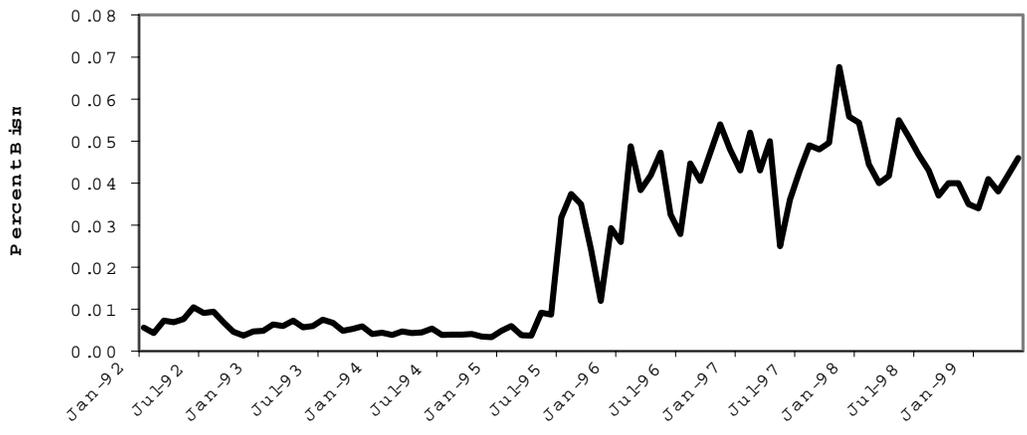


Figure 1 - Bismuth in Anodes - Monthly Composite 1992 – 1999

Figure 1 shows the large impact that changing the process and eliminating the expensive direct disposal of dusts had on bismuth recovery to anode copper. The average bismuth concentration in anode for 1998 and 1999 has been 430 ppm with a maximum monthly average of 550 ppm.

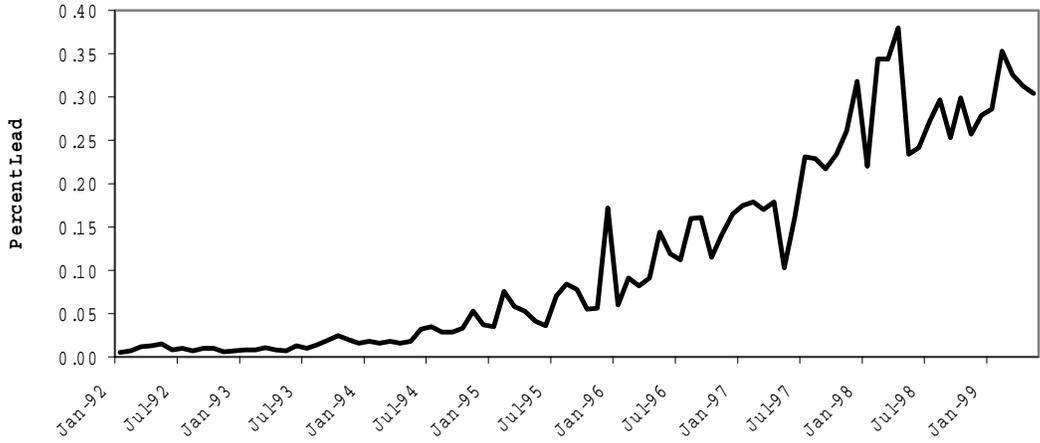


Figure 2 - Lead in Anodes - Monthly Composite 1992 - 1999

Figure 2 shows the trend for lead in anode from 1992 to 1999. Again, there was a large impact on lead recovery when the process was changed. The average lead concentration in anode for 1998 and 1999 has been 2,940 ppm with a maximum monthly average of 3,800 ppm.

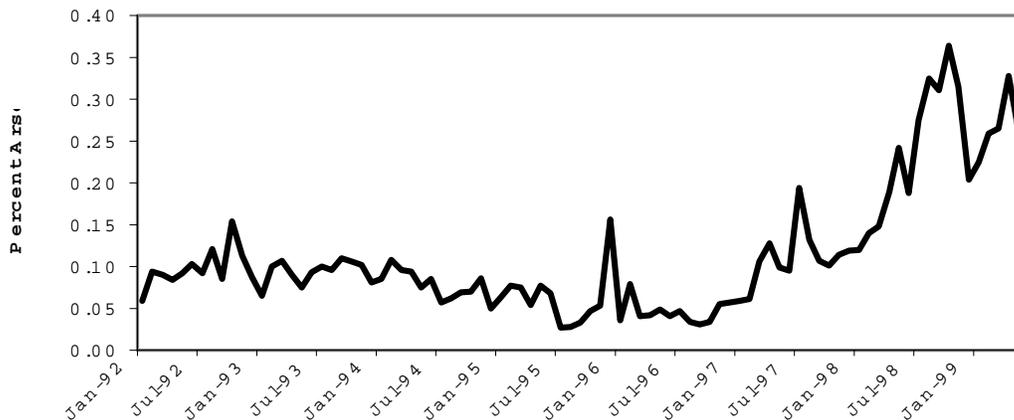


Figure 3 - Arsenic in Anodes - Monthly Composite 1992 - 1999

Figure 3 shows the trend for arsenic in anode from 1992 to 1999. The average arsenic concentration in anode for 1998 and 1999 has been 2,450 ppm with a maximum monthly average of 3,640 ppm.

The KUCC copper refinery has shown that it can not only handle anode copper to make high quality copper cathode at design impurity levels but that high quality copper can still be produced with impurity levels significantly higher than design.

Table IV is a comparison between the average impurity levels in anode copper that KUCC has treated over the last year and the average, minimum and maximum impurity concentrations reported for other medium / large capacity (>100,000 tonnes/year) copper refineries around the world. The data for other copper refineries has been taken from the proceedings of "Copper '95" held in Santiago, Chile.

It can be seen from this table that there is no other medium / large capacity copper refinery in the world that processes anodes containing bismuth concentrations as high as those at KUCC. There are very few refineries in the world that are reported as treating anodes that have as high a combined bismuth, lead and arsenic average concentration as those at KUCC.

Table IV - Anode Impurities

	Arsenic ppm	Lead ppm	Bismuth ppm
Kennecott - average 1998 - 1999	2,450	2,940	430
Kennecott - maximum monthly	3,640	3,800	550
Kennecott - design	1,100	2,900	300
World - average	700	600	70
World - maximum	2,700	3,500	320

### SMELTER EMISSIONS

At the onset of permitting the modernized smelter, KUCC committed to meeting or exceeding all applicable New Source Performance Standards, Best Available Control Technology, National Emissions Standards for Hazardous Air Pollutants and to comply with applicable State Implementation Plan requirements. Much of the voluntary emission reductions went significantly beyond both State and Federal requirements including the anode/shaft furnace area.

The final compliance point is the main stack. The majority of off-gases from the smelter facility are routed to the 367-meter main stack that remained from the old smelter installation. The Approval Order specifies limits on opacity, PM<sub>10</sub>, sulfur dioxide and nitrogen oxides at the main stack. Continuous emission monitors have been installed in the main stack to record opacity, sulfur dioxide and PM<sub>10</sub>.

To achieve the low annual emission target for sulfur dioxide of less than 1,000 tonnes/year, an extensive investment was made in equipment and in on-going operating costs that many other smelters are not subjected to. All exit gas streams are treated in scrubbers using sodium hydroxide except the acid plant tail gas stream.

Recent operation has demonstrated measured sulfur dioxide emission rates of less than 2.0 kg/tonne of new copper production and measured sulfur fixation as greater than 99.9%. Using previously published data, this sulfur dioxide emission rate ranks as one of the lowest of copper smelters in the world. The data used is shown in Figure 4.

In addition to low sulfur dioxide emissions, PM<sub>10</sub> emission rates are also significantly under permit levels. PM<sub>10</sub> emission rate for 1998 was 234 tonnes/year, 56% of the permit level of 418 tonnes/year. While sulfur dioxide and PM<sub>10</sub> emission rates are under control, there are still some minor emissions issues remaining but they are expected to be resolved in the near future.

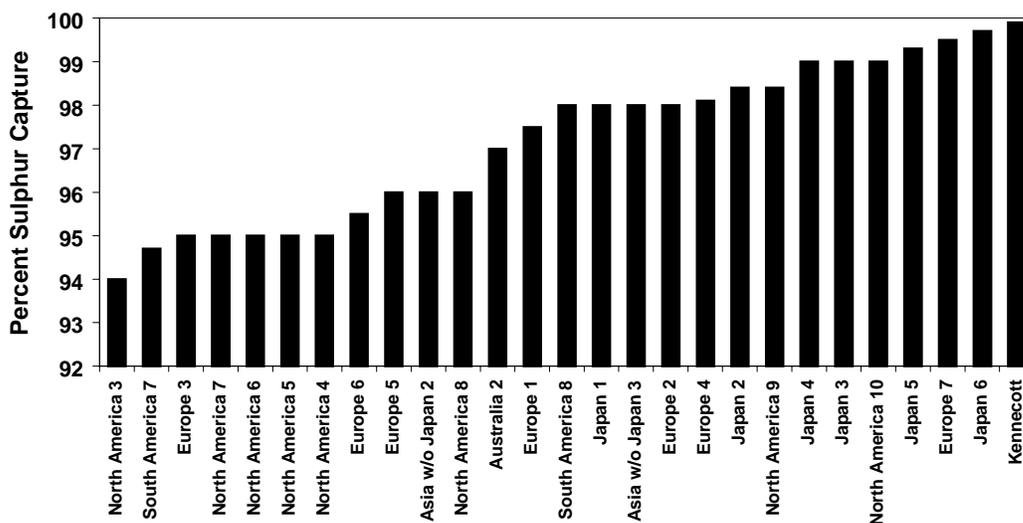


Figure 4 - Sulfur Capture (Smelters with greater than 94% Sulfur Capture)

## CONCLUSION

The KUCC smelter and refinery were designed to minimize their environmental impact and thus set the best environmental practice for the industry. They have met this goal while at the same time demonstrating the ability to reliably process above-design tonnage of copper concentrates and matte to cathode copper.

The flash smelting furnace has shown that it can handle feed-rates of 20% above design on a routine basis. The granulation systems for matte and converting furnace slag have proven to be effective and reliable.

The flash converting process itself has been successfully proven as an effective commercial method of converting matte directly to blister copper. Furnaces feed rates of 30% above nominal design rates have been demonstrated on a routine basis.

Considerable effort was put into the design of the waste-heat boilers by analyzing problems experienced at other smelters. The result of this has been relatively trouble free operation.

The acid plant was intended to operate at capacity with a tail gas containing 100 ppm of sulfur dioxide. Tail gas concentrations of 50-70 ppm are consistently obtained from a 14% sulfur dioxide feed gas stream demonstrating a conversion efficiency in excess of 99.95%. All other process gas exit streams are treated in scrubbers to remove sulfur dioxide and particulate.

The smelter hydro-metallurgical plant has demonstrated that it is a versatile and effective processing route for impurity control in the smelter and use of bleed streams from the smelter and refinery as reagents.

The tank-house has shown that it is capable of operating at design capacity while producing high quality cathode from anodes containing impurities that are higher than those treated by other refineries in the world.

The new hydro-metallurgical precious metals plant technology has been successfully implemented for recovery of gold, silver and other metals from tank-house slimes.

To achieve these successes, much use was made of modern technology and a major capital investment was required. The results achieved have shown the benefits of this investment and have set the environmental performance of the KUCC smelter and refinery as the benchmark for other copper smelting and refining operations to attain.