

# **MUFULIRA SMELTER UPGRADE PROJECT - 'INDUSTRY' SMELTING ON THE ZAMBIAN COPPERBELT**

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## **ABSTRACT**

When the privatisation of the Zambian copper industry was concluded in 2000, the assets of Mopani Copper Mines Plc (MCM), including the Mufulira smelter, benefited from external investment that allowed for significant increases in productivity during the following four years. However, by end 2003, the integrity of the Mufulira smelter's electric furnace had deteriorated to an extent where the end-of-campaign was imminent and a furnace rebuild was necessary to continue smelting MCM concentrates.

In November 2003, MCM committed to upgrade the smelting facility in Mufulira within two and a half years with the installation of an Isasmelt furnace and a matte settling electric furnace (MSEF) with a design capacity of 850,000 tpa concentrate. The increased smelting capacity considered the potential sources of 'imported' concentrates and copper bearing material produced from new mining developments in northern Zambia and the Democratic Republic of Congo (DRC).

This paper describes the equipment, technologies and processes that constitute the Mufulira Smelter Upgrade Project (MSUP), which when commissioned during the first quarter of 2006 will provide capacity for 'industry' smelting on the Zambian Copperbelt.

Key Words: Pyrometallurgy, Copper, Zambia, Isasmelt.

## INTRODUCTION

The Mufulira smelter, one of two operating copper smelters on the Zambian Copperbelt, currently processes over 400,000 tonnes of copper concentrates per annum, most of which is sourced from MCM's mines i.e. Mufulira and Nkana mines. Concentrate and other copper bearing feed materials (eg. copper oxides) are also obtained from surrounding operations in Zambia, most notably from First Quantum Minerals' Kansanshi mine, Konkola Copper Mines (KCM) operations and the Democratic Republic of the Congo (DRC).

The main process operations at the Mufulira smelter are copper concentrate reception and handling, copper smelting and converting, and fire refining. The product is anode copper, which is refined electrolytically at the nearby Mufulira Refinery to produce cathode copper. Currently, there is no sulphur dioxide abatement facility and all sulphur dioxide produced in the smelting and converting operations is vented to the atmosphere. Approximately 94,000 tonnes of sulphur dioxide is annually vented to the atmosphere. Discard slag from the smelting operation is deposited onto nearby slag dumps.

The primary smelting vessel is an Elkem designed 36MVA submerged-arc, six-in-line electric furnace that was installed and commissioned in 1971 and last rebuilt in 1991.

The electric furnace was selected to replace three coal-fired reverberatory furnaces and has a nominal capacity of 420,000 tonnes per annum (tpa) of concentrates, or up to 180,000 tpa new copper. The design of an electric furnace permits a relatively long campaign life of typically ten years or more. At the end of this period, due to the inevitable furnace hearth deformation and structural deterioration caused by mechanical and thermal stresses, there is a requirement to shutdown and rebuild the electric furnace, a process that potentially can have a duration of up to six months.

When operational problems with the electric furnace began to increase in 2000/2001 immediately following privatisation, it was not possible to conduct a campaign shutdown for rebuild due to financial and logistical reasons. In particular, the existence of toll treatment contracts which obliged MCM to treat a significant tonnage of concentrates from KCM operations until December 2002 was problematic as the cumulative smelting capacity on the Copperbelt meant that both MCM concentrates and the contracted KCM concentrate would either have to be stockpiled for the period of the rebuild, or exported for treatment in South Africa or Namibia. Both options (i.e. stockpile or toll treatment) would have been economically disadvantageous and there were also concerns about the capability of the available transport systems to move the requisite tonnage of concentrates to the custom smelters outside the country.

Consequently a programme to improve the electric furnace integrity commenced in 2001 with the aim of extending furnace life through to 2006. This programme provided time to consider all available options for continued smelting at the Mufulira site. This programme has to date proved successful with the electric furnace operations now re-

established at a level that is sustainable and reliable, consistent with the overall aim of extending furnace life to 2006.

In considering the options for continued smelting at the Mufulira site, MCM management recognised that the recent redevelopment of copper mining activities on the Zambian Copperbelt and the potential development of the industry in the DRC presented an opportunity to process an increased quantity of copper concentrates. As such, in 2003 a study was completed that evaluated the options of either rebuilding the existing Electric Furnace, or alternatively, replacing the Electric Furnace with a more efficient high-intensity smelting technology that would allow for an expansion of the current copper smelting capacity. This study concluded that the high intensity smelting technology was the preferred option for an increased capacity smelting facility that could be constructed and commissioned without interrupting anode productivity i.e. the smelter could be constructed independently from the existing facility as a “redfield” site.

There has never been a provision for sulphur fixation at the Mufulira smelter since the initial furnace was commissioned in the 1930’s with all process offgas being vented to atmosphere. However, as provided for in the Development Agreement signed between MCM and Government of the Republic of Zambia (GRZ), MCM has an obligation to achieve compliance with Zambian environmental legislation in relation to sulphur dioxide emissions from the smelting operations. Therefore the above study also included a review of gas collection options and specifically, the economics of installing a sulphuric acid plant at the smelter.

On the basis of technical and engineering studies the Mufulira Smelter Upgrade Project (MSUP) was defined as the phased upgrading of the Mufulira smelter to a treatment capacity of 850,000 tpa of concentrates by the replacement of the existing electric smelting furnace with a high-intensity Isasmelt smelting furnace. In summary, the project includes the following elements:

- Upgrading of the concentrate storage and handling area
- Installation of an Isasmelt furnace and ancillary equipment capable of treating 850,000 tpa copper concentrates.
- Installation of a 650 tpd cryogenic oxygen plant to supply tonnage oxygen to the Isasmelt furnace.
- Installation of 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.
- Installation of a single contact sulphuric acid plant to treat ~85,000 Nm<sup>3</sup>/hr of 9-16% SO<sub>2</sub> tenor process offgas produced in the Isasmelt furnace for the production of 98.5% sulphuric acid.

- Phased upgrading of the converting and anode casting areas to accommodate the initial 650,000 tpa concentrate treatment rate and the subsequent increase to 850,000 tpa.

## **SMELTING ACTIVITIES AT MUFULIRA**

### **History of Smelting at Mufulira**

The Mufulira Smelter was initially commissioned in 1937 with two reverberatory furnaces and four Pierce-Smith converters to produce a final product of blister copper that was cast from a holding furnace. The smelter was upgraded in 1952 with the inclusion of two anode furnaces and a common casting wheel and further expansion occurred in 1956 with the construction of a third reverberatory furnace, a fifth converter and anode processing and casting facilities duplicating that which had been installed in 1952.

In 1966 there was a loss of production potential with the reverberatory furnaces due to the use of higher ash content coals and the availability of additional concentrates from the Mufulira and Roan Consolidated Mines that could not be processed. This initiated a study in 1968 that determined that on the basis of its much improved thermal efficiency and the very low cost of hydroelectric power available in Zambia, an electric furnace was the most advantageous option for expanding smelting capacity. The electric furnace was commissioned in 1971 and operated with one reverberatory furnace to provide capacity for 230,000 tpa new copper. The installation of the electric furnace was followed by a sixth converter in 1972 and a new holding furnace in 1973.

Following a six year campaign that experienced difficulties with refractory failures (particularly the electrode rings), electrode breakages and the gas handling system, the electric furnace was rebuilt in 1977 and again operated with one reverberatory furnace until a reduction in the availability of concentrates allowed the reverberatory furnace to be taken offline in 1978.

The electric furnace was last rebuilt in 1991 and has since operated with four converters and the anode processing and casting configuration that was installed in 1956. No significant modernisation has occurred since 1991 and this fact coupled with the preference of Zambian Consolidated Copper Mines (ZCCM) to divert concentrates during the 1990's to the Rhokana, Kitwe smelter has resulted in progressive deterioration of smelting and converting units due to the 'stop-start' nature of the campaigns. Since the inception of Mopani Copper Mines (MCM) in April 2000, concentrate availability has improved and the productivity of the Mufulira smelter has increased to pre-1990 levels

## Existing Smelter Operation

The existing smelter treats approximately 420,000 tpa copper concentrates to produce anode copper, which is treated at MCM's Mufulira refinery.

Concentrate is received either by road or rail wagon and offloaded into discrete stocks in a 14,000 t capacity concentrate storage shed. Each concentrate is separately conveyed to one of fourteen 250t 'charge' bins and blended on discharge. The blended concentrate is conveyed to a FFE designed heavy fuel oil (HFO) fired rotary drier where the concentrate is dried to <0.2% moisture before being charged through the roof ports of the electric furnace using drag link conveyors.

Concentrates are smelted in the 36 MVA electric furnace with the matte being tapped through any of six matte tap holes into 4.9 m<sup>3</sup> ladles which are transported to the converter aisle on bogies. Three 45 tonne main hoist capacity (18t auxiliary hoist capacity) Clarke Chapman main aisle cranes are used to transfer matte to the converters. Electric furnace slag is tapped through any of three slag 'notches' and granulated in secondary launders before being reclaimed from granulation pits using bucket elevators. The slag, nominally containing between 0.7-0.85% Cu, is discarded off-site using tipper trucks.

Matte produced in the electric furnace is converted in four 13\*30' Peirce-Smith Converters (PS converters). Charge size is nominally 150 tonnes of matte (10 ladles at 15 tonne per ladle). Offgas from the PS converters is captured with uncooled steel hoods and directed to atmosphere through dedicated stacks. Currently, the PS converters are manually punched. The main aisle cranes are used to add flux, reverts and scrap through the mouth of the converters using 5 tonne 'boats' suspended from the main and auxiliary crane hoists. Normally three converters are hot while the fourth converter is under refurbishment following a two/three month campaign of typically 160-180 cycles. The converter under refurbishment can be unavailable for between 13 and 35 days, depending on the extent of refractory replacement necessary.

Blister from the PS converters (normally 4 ladles of 23 tonnes per converter charge) is fire refined in one of four 220 tonne anode furnaces with 280-320 kg anodes being cast on two 22 mould, 30-35 tph casting wheels. Offgas from the anode furnaces is directed to atmosphere through dedicated stacks. Current plant layout is given in Figure 1.

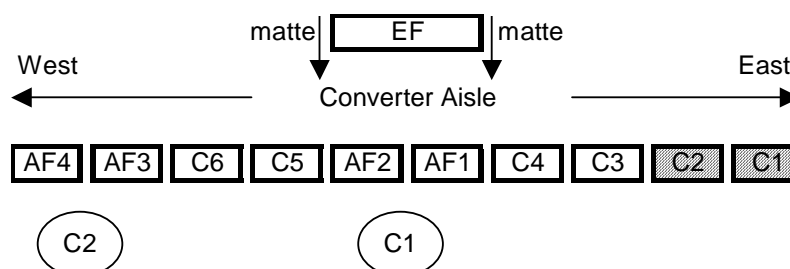


Figure 1 – Current Aisle Equipment

## PROJECT QUALIFICATION

### Project Motivation

Other than with the expected productivity losses associated with continued operation of the existing electric furnace beyond the end-of-campaign condition, the MSUP, incorporating alternative smelting technologies, was justified on the following basis:

- *The potential opportunities in Zambia for treating additional concentrate in excess of 420,000tpa (the current capacity).*

The two copper smelters on the Zambian Copperbelt, namely, the MCM Mufulira smelter and the KCM SmelterCo, Kitwe smelter have treatment capacities of 420,000 tpa and 450,000 tpa respectively with production from KCM mines ensuring that the SmelterCo smelter capacity was fully utilised.

MCM production forecasts indicate a relatively consistent production of approximately 400,000 tpa concentrate from MCM's mines (Nkana and Mufulira) and concentrators. After evaluating and discussing developments in the Zambian mining industry there was significant confidence in MCM's ability to source additional concentrate, above that produced by MCM mines, that would allow for the potential to treat 850,000 tpa concentrate with an alternative smelting technology and an upgrade of downstream processes. Figure 2 references operations that currently export concentrates to alternative smelters overseas or in South Africa, or require a smelting facility to process concentrates after mine / project development has been completed.

<b>Company</b>	<b>Operation</b>	<b>Projected Concentrates Tonnes/annum</b>
Metorex	Chibuluma W / S	24,000
Anvil	Dikulushi	40,000
J & W	Baluba	78,000
NFC Africa	Chambishi	120,000
First Quantum	Kansanshi	180,000
<b>TOTAL</b>		<b>442,000</b>

Figure 2 - Projected Concentrate Production Requiring Smelting Facilities

Although there remains some uncertainty about the eventual achieved production rates, there is a high degree of confidence that there will be 250,000 tpa of

concentrates available for treatment by 2006, and this figure could well increase if potential arisings from the north-western province of Zambia or the DRC are included.

- *The potential to install an environmentally compliant and self-financing sulphur fixation facility at the Mufulira site.*

With alternative smelting technologies producing high tenor process offgas, there would be potential for sulphur fixation at the Mufulira Smelter using proven and robust acid plant technology. The tonnage acid produced from a sulphuric acid plant would allow MCM to become self-sufficient in respect of acid consumed in its recently commissioned leaching operations (i.e. in-site leach, heap leach and agitated leach) and minimise any requirement to import acid at excessive expense. The installation of a sulphuric acid plant would also allow the Mufulira smelter to comply with the statutory requirements of the Environmental Council of Zambia (ECZ) as stipulated in the Development Agreement signed by MCM and the Government of the Republic of Zambia (GRZ) in 2000.

### **Selection of Project Technology**

The selection of the new primary smelting technology was seen as the most significant decision in the definition of the MSUP. In evaluating the various smelting alternatives the following five points were kept in focus:

- The indefinite increase in concentrate availability from new mine developments in Zambia that would potentially allow for treatment rates above 500,000 tpa but would also require significant furnace turn-down capability if the primary smelting technology was initially designed at 850,000 tpa.
- Increasing consumable and power costs in Zambia,
- Recent global developments and applications of more efficient high intensity smelting technology.
- The legislative requirement for sulphur fixation at the Mufulira Smelter.
- The technical and engineering resources and capabilities in Zambia i.e. requirement for proven and robust technologies located in third world environments.

Electric furnace technology (i.e. new furnace construction on a separate foundation) was not considered a viable technology above the 500,000 tpa treatment rate as there are no known operating references in the copper industry of the furnace design required for treatment of 850,000 tpa concentrate. A further disadvantage with electric furnace

technology was the low sulphur dioxide tenor of electric furnace offgas, greatly increasing the capital cost of sulphur dioxide abatement.

Other smelting technologies that were evaluated for installation at Mufulira are detailed below. These alternatives are predominantly high intensity oxygen smelting technologies, namely:

- *Flash Furnace Technology*

Flash Furnace technology is widely used throughout the world in copper and nickel smelting applications. However, most recent applications are in first world countries where precision engineering capability and extensive provision for technical support is readily available. This technology has a high capital and is renowned for being difficult to commission to nameplate capacity

Direct to Blister (DTB) flash smelting, utilising the high copper content of the Mufulira concentrate to produce blister copper in a single furnace was also considered. However, the current life-of-mine plan for the Mufulira Mine schedules ore reserves to be exhausted by 2014, with the replacement concentrates being low grade and unsuitable for DTB smelting.

Flash Furnace technology was excluded on the basis of; (1) technical complexity for the Zambian environment; (2) not being well suited to the retrofit nature of the Mufulira project; (3) high capital requirement.

- *Mitsubishi Continuous Smelting Process*

The Mitsubishi Continuous Smelting process was first established in Japan but has expanded to include commercial operations in Canada, Indonesia and Australia, of which the latter has now closed. As with flash furnace technology, the Mitsubishi process has a significant capital requirement and engineering support services normally associated with first world economies. Additionally, there was no commercial template for a Mitsubishi process retrofit into a similar operation to Mufulira.

The technology was excluded on the basis of; (1) technical complexity for the Zambian environment; (2) not being well suited to the retrofit nature of the Mufulira project; (3) high capital requirement.

- *Reactor Technology*

The horizontal CMT reactor was initially developed at Codelco El Teniente division and is widely accepted in Chile and more recently Mexico. The KCM SmelterCo smelter in Zambia has the only CMT reactor operating in Africa and the operability of this smelter since the CMT was installed in 1994 has been problematic. Noranda have had limited acceptance as primary smelting technology with the exception of three operations in Chile, Australia and China.



Both the CMT and the Noranda horizontal reactor were excluded on the basis of; (1) the poor performance of the CMT reactor in the Zambian environment; (2) the relatively inexperienced technical resources readily available.

- *Top Submerged Lance (TSL) Technology*

Top Submerged Lance (TSL) technology was considered to be a viable alternative to electric furnace smelting based on preliminary data and marketing-level studies provided by two technology suppliers (Xstrata Technology marketing the Isasmelt furnace and Ausmelt Limited marketing the Ausmelt furnace).

The TSL smelting process was first commercialised in Australia in the late 1980's and has recently been gaining increasing acceptance in a wide range of applications in such diverse countries as USA, England, Belgium, Germany, India, China, South Korea, Peru, Malaysia, South Africa, Zimbabwe and Namibia. The advantages of the process include:

- Compact size and small footprint, which could be easily accommodated in the Mufulira Smelter.
- Relatively low capital cost.
- Low operating costs.
- High strength offgas well suited for sulphuric acid production.
- Relative ease of operation.
- Feed rate flexibility, suitable for operation at an initial production rate in 2006 of 650,000 tpa while still having capacity for future upgrades greater than 850,000 tpa.

After consideration of the benefits and visits to operating plants in Australia, USA and China, MCM decided to install TSL technology, specifically an Isasmelt furnace.

Isasmelt technology has commercially demonstrated ability to process in excess of 1,000,000 tpa copper concentrate, and the Phelps Dodge Miami smelter (USA) has ramped up from 650,000 tpa to 850,000 tpa while the Xstrata, Mount Isa Mines smelter (Australia) has ramped-up from 650,000 tpa to 1,000,000 tpa. In the case of MCM, an Isasmelt furnace is being installed to process 650,000 tpa concentrate (the current inferred capacity of the converting and anode refining and casting sections) and after being installed, will be upgraded to 850,000 tpa through a second phase expansion of downstream processes. This upgrade will be achieved with no additional capital required for the Isasmelt furnace which will be capable of processing the additional concentrate by increasing the degree of oxygen enrichment of process air required for the oxidation of concentrates in the furnace.

## PROJECT DESCRIPTION

### Phase 1 – Primary Smelting and Sulphur Fixation

The objective of Phase 1 of the MSUP is to increase the Mufulira Smelter’s concentrate smelting capacity from 420,000 tpa to 650,000 tpa. This will be achieved by the installation of a new Isasmelt furnace, Matte Settling Electric Furnace (MSEF) and upgrades to the concentrate storage and converter aisle areas. Partial capture of sulphur dioxide will also be achieved by the installation of a new acid plant to treat the offgas from the Isasmelt furnace. The Phase 1 flowsheet is show in Figure 3.

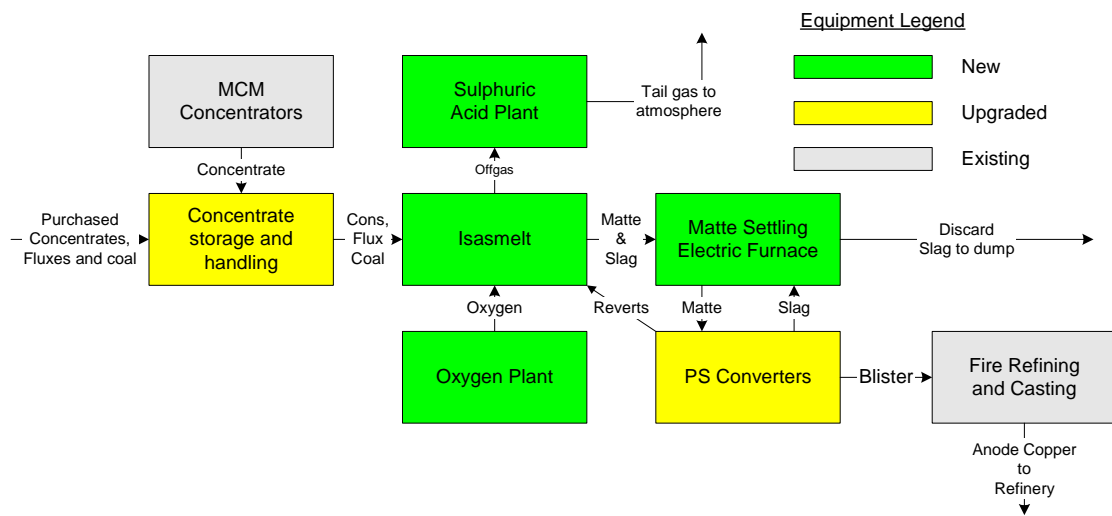


Figure 3 - MSUP Phase 1 Flowsheet

The new Isasmelt furnace and MSEF will be located in a vacant area adjacent to the converter aisle. The Mufulira Smelter plot plan is shown in Figure 4.

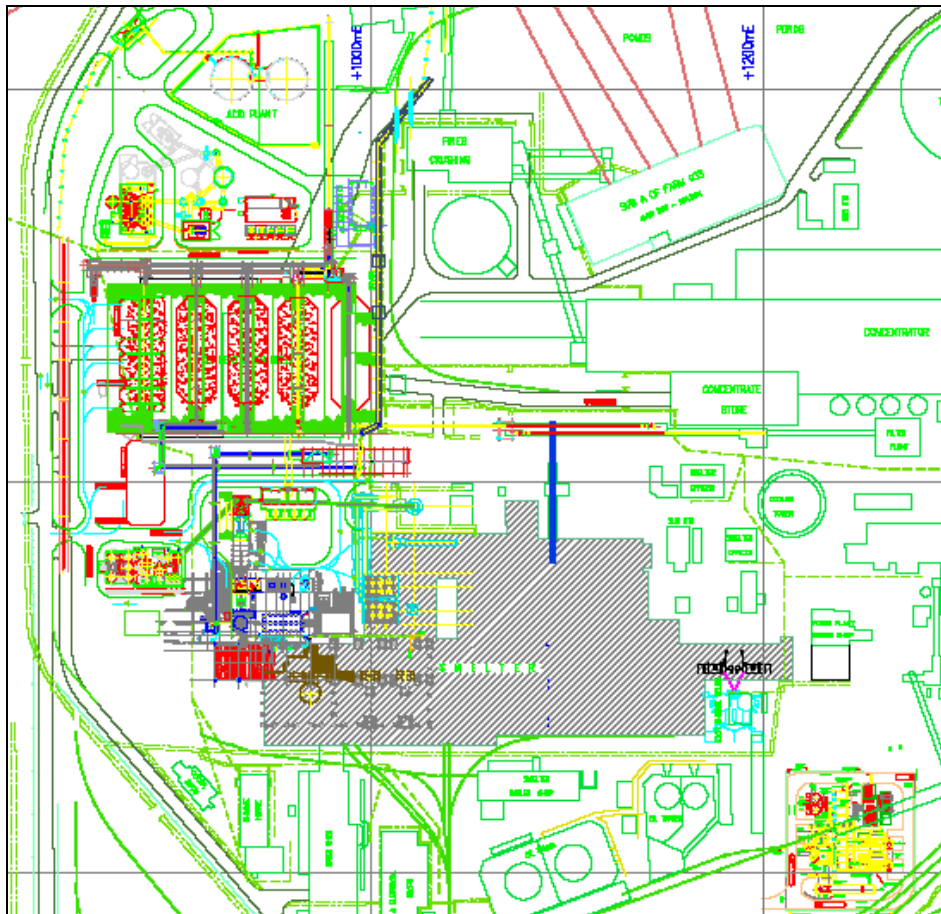


Figure 4 - MSUP Overall Layout

## Materials Handling

The Isasmelt process is a high intensity, low residence time smelting process. Therefore it is an important operating requirement for the concentrate to be consistently blended to ensure stable process control of the furnace, as well as providing a consistent matte grade for the PS converters. The furnace is sensitive to excessive moisture in the feed material (as no dryer is used), therefore expansion of the covered concentrate storage is also required.

Imported concentrates (from MCM's Nkana concentrator and purchased concentrates) are currently delivered by road and rail. Rail concentrates are offloaded using a rail tippler and conveyed into the concentrate storage shed. Road concentrates are offloaded onto the ground and distributed inside the concentrate shed by front end loader (FEL). The concentrate shed is equipped with one overhead tripper conveyor (fed by the rail off loading conveyor).

Concentrate offloading and storage following completion of Phase 1 of the project will remain essentially the same as the current operation. However the existing

concentrate storage shed will be extended to provide additional covered storage. The extended shed has been designed to accommodate the addition of two overhead tripper conveyors during Phase 2 of the project.

Concentrate, fluxes, coal and reverts will be reclaimed from segregated stockpiles by FEL and charged into a common feed hopper. The various materials will then be conveyed to the charge bins. The charge bin area will consist of:

- 4 x 150 tonne Concentrate bins
- 180 tonne Reverts bin
- 80 tonne Limestone bin
- 50 tonne Silica bin
- 55 tonne Coal bin
- 10 tonne Dust bin (Isasmelt ESP dust)

Each bin will be fitted with a weigh feeder, which will be used to accurately control the feed blend to the Isasmelt furnace.

The feed mix discharged from the weigh feeders will be conveyed by a collector conveyor to a twin shaft paddle mixer where water will be added to produce a mixed feed containing approximately 10% moisture. The conditioned feed will be conveyed to the Isasmelt building.

### **Isasmelt Furnace**

Xstrata Technology of Australia is supplying the Isasmelt furnace design and proprietary equipment.

The Isasmelt furnace building as designed is shown in Figure 5. The Isasmelt furnace shell is a vertical cylinder approximately 16 m tall, 5.5 m internal diameter, supported on a concrete base. The steel shell will be lined with 450 mm of chrome-magnesite refractory bricks. The roof of the furnace is constructed from boiler tubes containing ports for feed addition, lance insertion, holding burner insertion and offgas removal.

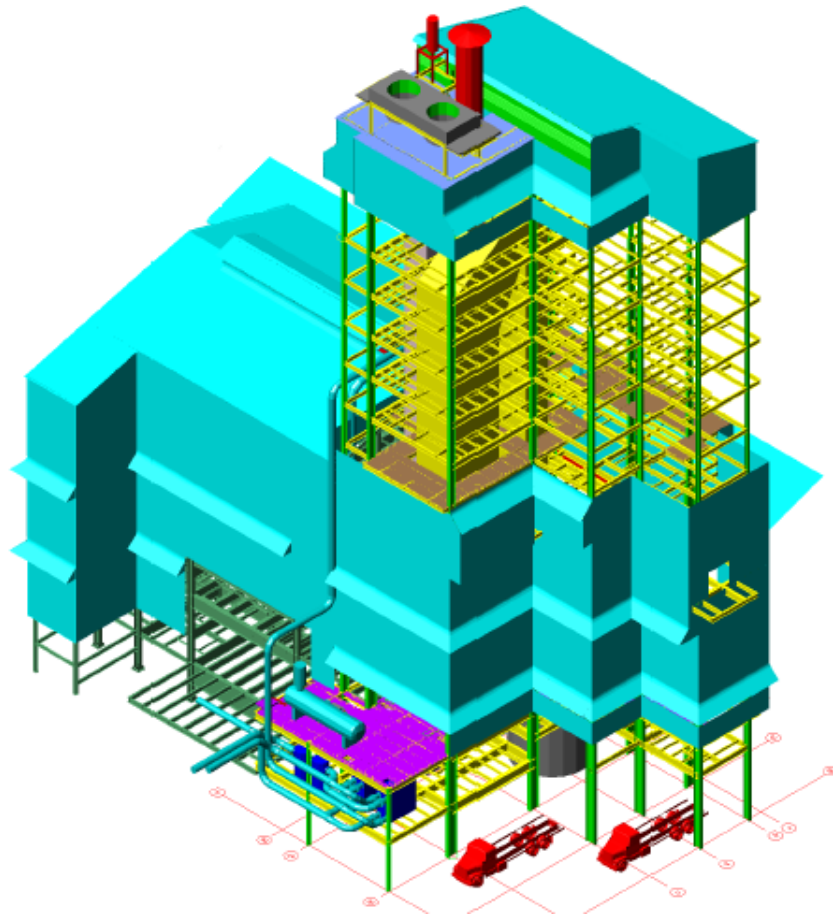


Figure 5 – North East View of Isasmelt and MSEF building

Mixed feed from the paddle mixer will be conveyed to the final feed conveyor, located above the Isasmelt furnace. The feed mix will be discharged from the final feed conveyor through the feed port in the furnace roof and fall into the molten bath below.

The Isasmelt lance will be approximately 18 metres long with a diameter of 350 mm. Process air (from a dedicated blower), industrial oxygen (95% O<sub>2</sub> from the oxygen plant) and diesel will be injected into the bath using the Isasmelt lance. The furnace heat balance will be controlled by blending coal with the feed, adjusting the oxygen enrichment and injecting diesel through the lance. Lance oxygen enrichment will range between 50 and 70% O<sub>2</sub>.

Matte and slag produced by reaction of the feed material with the process air/oxygen will be tapped intermittently using a tapping machine (combined drill and clay gun) through a single water-cooled tapping block located at the bottom of the vertical bricked section. The matte/slag mixture will flow along a water-cooled copper launder into a purpose designed matte settling electric furnace (MSEF) for settling into separate copper matte and slag phases. The furnace design was based on operating at matte grades between 60 and 64% copper, consistent with industrial Isasmelt furnace operation.

The offgas from the Isasmelt furnace will be cooled in an Oschatz designed and supplied waste heat boiler (WHB). The WHB will consist of a vertical radiation section directly above the furnace (shown schematically in Figure 6). The offgas will then pass down into an evaporative gas cooler. The exit temperature of the gas cooler will be controlled to approximately 350°C before entering a hot electrostatic precipitator (ESP). Furnace draft will be supplied by an induced draft (ID) fan downstream of the ESP. Offgas from the ID fan will be directed to the acid plant gas cleaning section. Dust collected in the WHB will be recycled to the concentrate storage area. Dust from the ESP will be pneumatically conveyed to a bin in the Isasmelt feed system.

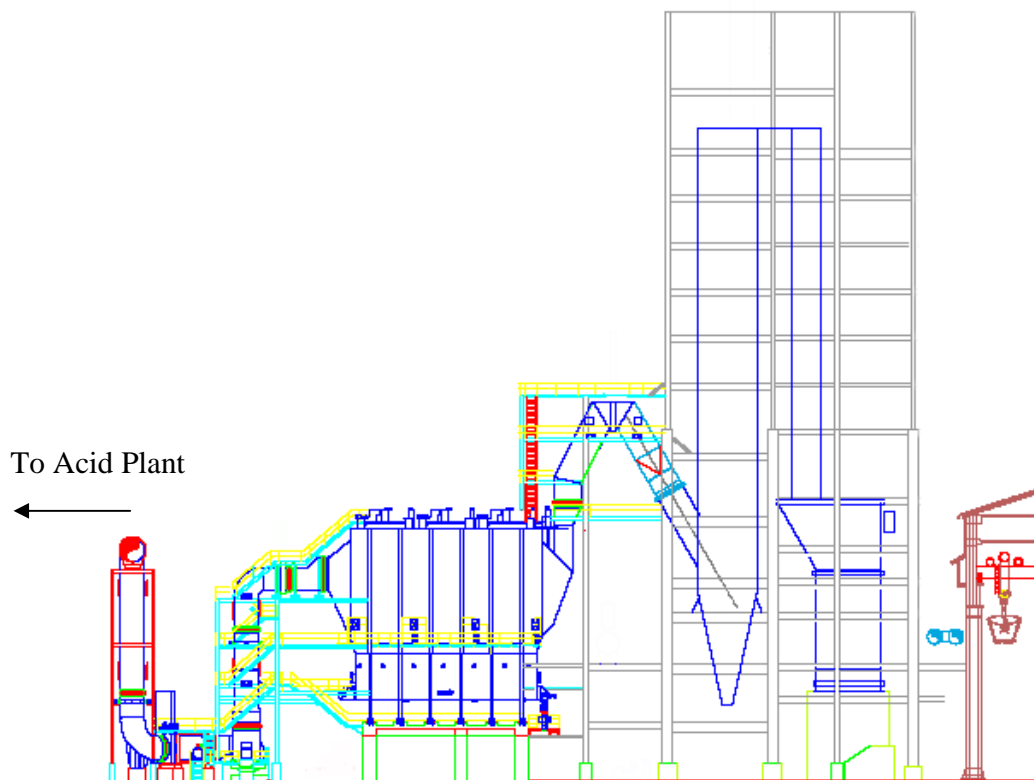


Figure 6 - Isasmelt Gas Handling

Steam produced in the WHB will be condensed using two air cooled condensers located at the top of the Isasmelt building and recycled back into the boiler. Recovering the energy from the WHB is uneconomical due to the low cost hydro-electric power available in Zambia. Although producing steam is of no value to MCM, this type of gas handling equipment was chosen due to demonstrated reliable operation at other Isasmelt plants.

Secondary ventilation hooding will be installed over the Isasmelt tapping port. Furnace temperature will be maintained with a fuel-air burner during furnace maintenance shutdowns.

## Matte Settling Electric Furnace

Matte and slag tapped from the Isasmelt furnace will be separated in a purpose designed matte settling electric furnace (MSEF) being supplied by SMS Demag. The MSEF is designed to treat molten product from the Isasmelt furnace (at the 850,000 tpa concentrate treatment rate) and recycled slag from the PS converters. The MSEF will produce a discard slag with a copper content of <0.7 wt% Cu as well as hold sufficient matte to provide surge capacity between the continuous Isasmelt furnace and batch PS converters. The furnace building elevation is shown in Figure 7.

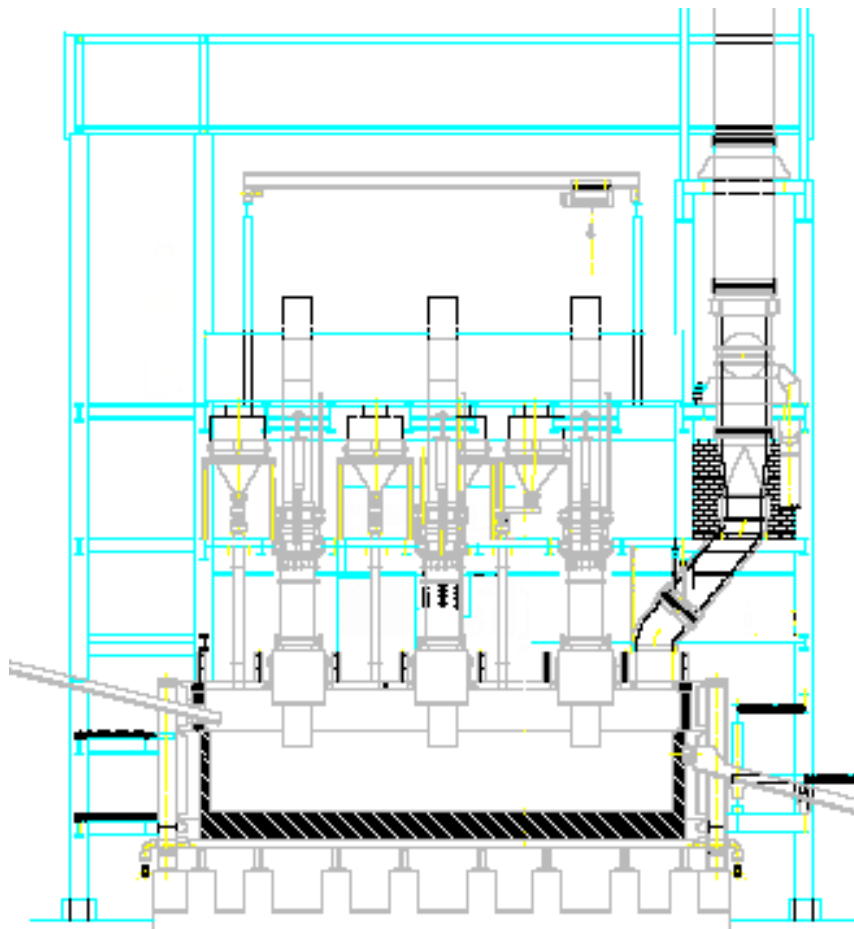


Figure 7 - MSEF Elevation

The MSEF is a three-in-line electric furnace, rated at 12 MVA using Soderberg electrodes. The furnace dimensions will be 18.1 m x 7.4 m x 5.7 m (L x W x H). The matte holding capacity will be 400 tonnes, providing an effective buffer between the Isasmelt furnace and PS converters.

A small amount of coke will be required, mainly to reduce converter slag. Coke will be charged into the MSEF through six coke bins located above the furnace. Converter slag will be returned to the MSEF in ladles at times that are dependent on the

converter blowing cycle. The converter slag return launder will be constructed of refractory, with a spoon-shaped end to receive the slag from a ladle.

The MSEF furnace will have two slag and four matte tapholes. Matte will be tapped into ladles and taken to the converters for further processing. A common clay gun/drill will service the four matte tapholes.

Slag will be tapped using one of the two installed tap holes. Slag will flow down a water cooled copper launder into a granulation pit. The granulated slag will be retrieved from the granulation pit using an overhead grab crane and discharged to a surge bin from where it will be loaded into road trucks for off-site disposal at existing slag dumps

Offgas from the MSEF will be combined with the slag taphole ventilation gases and discharged at elevation through a dedicated stack. Offgas from the matte taphole ventilation system will be directed to the Isasmelt secondary ventilation system.

### Converting and Fire Refining

To accommodate the increased copper production at the Phase 1 concentrate treatment rate an additional PS converter and blister holding furnace are required. The additional converter will be installed in the existing Converter 2 position (currently redundant). The new converter will be larger (13x37’), compared to the existing 13x30’ converters. The enlarged converter is being installed to facilitate the future installation of a second acid plant. A holding furnace, which has been redundant since 1986, will be re-established between Anode Furnace 1 and Converter 4. The blister holding furnace will be required to provide surge capacity between the PS converters and the anode furnaces, mainly when one of the existing four anode furnaces is being refurbished.

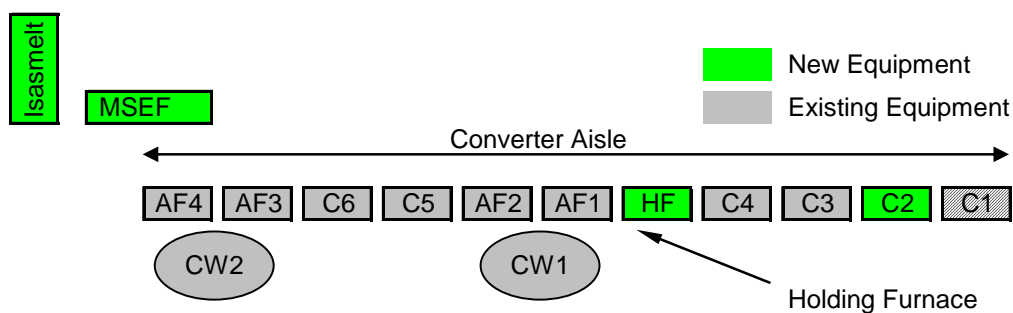


Figure 8 - Phase 1 Aisle Configuration

There is adequate crane, anode furnace and casting wheels capacity for the Phase 1 production rate.



## Environmental Compliance and the Acid Plant

At inception in 2000, MCM was required to develop a detailed Environmental Plan which would include proposals to bring the Mufulira Smelter into compliance with Zambian Environmental Laws within a period of five years of completion of the privatisation process and in accordance with and subject to all provisions of the Development Agreement (DA). The DA identified provision of an acid plant for fixation of sulphur dioxide at the Smelter as one such means for bringing the facility into compliance.

The principal Zambian Environmental Law in respect of the Smelter is Statutory Instrument No.141 of 1996, which among other things, specifies Long-Term Emission Limits to be achieved by facilities that emit pollutants into the atmosphere. The limits are specified below.

Facility	Parameter	Long-Term Emission Limit
Smelter & Converters	SO <sub>2</sub> (concentration)	1 000 mg/Nm <sup>3</sup>
	SO <sub>2</sub> (mass discharge)	700 – 4 300 kg/day
	Dust	50 mg/Nm <sup>3</sup>
Heavy Metal Content in Dust	Arsenic (As)	0.5 mg/Nm <sup>3</sup>
	Cadmium (Cd)	0.05 mg/Nm <sup>3</sup>
	Copper (Cu)	1.0 mg/Nm <sup>3</sup>
	Lead (Pb)	0.2 mg/Nm <sup>3</sup>
	Mercury (Hg)	0.05 mg/Nm <sup>3</sup>

Figure 9 – Zambian Environmental Law Long Term Emission Limits

The five year period for compliance with Zambian Environmental Law was superseded by the approval by the Environmental Council of Zambia (ECZ) of the Environmental Project Brief (EPB) for the MSUP. The ECZ approved the EPB in September 2004 but stated a requirement for MCM to comply with the following “approval conditions” following commissioning of the acid plant:

1. The emissions from the MSEF stack and the acid plant stacks will meet the long-term emission limits listed in Figure 9 by June 2015, in accordance with the expiry of the Stability Period provided for in the Development Agreement.

2. Following commissioning of Phase 1 of the MSUP, MCM shall capture 55-59% of the sulphur dioxide generated by the processing of concentrates through the smelter (specifically, capture 97% of sulphur dioxide generated by the Isasmelt furnace).
3. MCM shall by December 2008 implement measures to capture sulphur dioxide emissions from the Converters. Detailed studies (including acid market studies) shall be conducted and approved by the ECZ before the new project (i.e. the No.2 Acid Plant) is implemented.

To meet the “approval conditions” of the EPB and satisfy the requirement for MCM to comply with environmental law, offgas from the Isasmelt furnace will be treated in a new Sulphuric Acid Plant (SAP) supplied by Grinaker-LTA Process Engineering (South Africa) using Monsanto technology. The SAP has been sized for the full Phase 2 production rate.

The SAP will be a single contact plant with conversion efficiency greater than 97%, producing 98.5% strength sulphuric acid. The plant layout has been designed for future conversion to double contact double absorption.

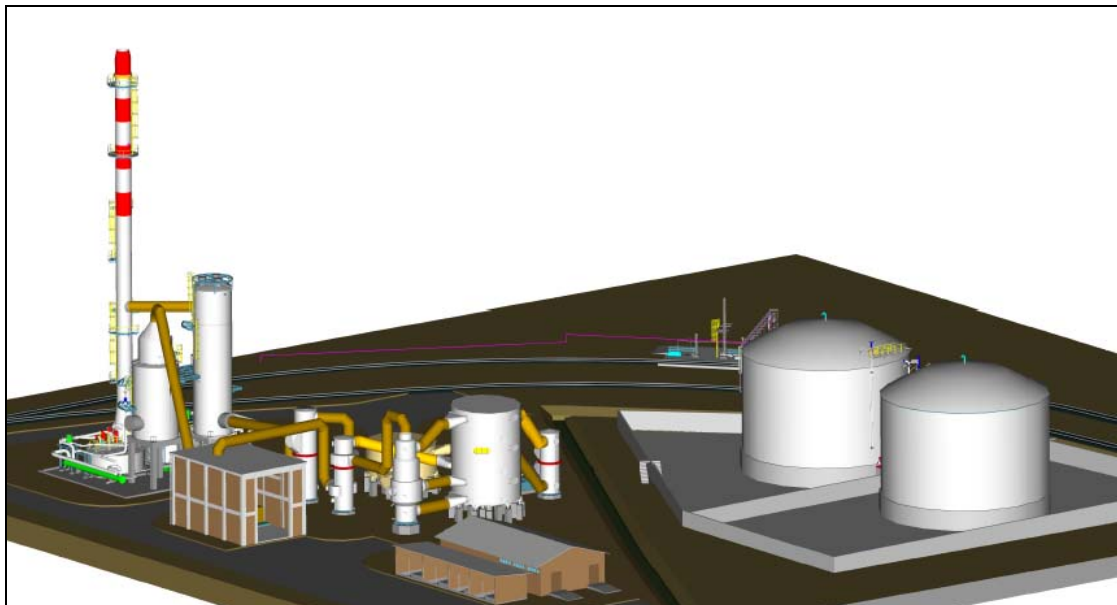


Figure 10 – 3D View of Acid Plant

Feed gas to the SAP will be approximately 85,000 Nm<sup>3</sup>/h at 13% SO<sub>2</sub> for the Phase 2 production. The SAP will produce up to 950 tpd of sulphuric acid during Phase 1 and 1,150 tpd during Phase 2.

The SAP will consist of three main sections, the gas cleaning, contact and storage. The gas cleaning section will be located near the Isasmelt hot ESP. The gas cleaning section will consist of a primary dynawave scrubber, gas cooling tower, secondary

dynawave scrubber and four wet electrostatic mist precipitators. The contact section will consist of a drying tower, SO<sub>2</sub> blower, three pass catalytic converter and absorption tower. The contact section will be located remotely from the gas cleaning section due to space constraints. Product acid will be stored in two 7,500 tonne tanks. The contact section and storage tanks are shown in Figure 10. Acid will be consumed by MCM's internal customers (refinery and leaching projects) with surplus production being exported to customers in the region. Acid will be able to be exported by either rail or road.

Compared to the current smelter operation, installation of the SAP will result in a 17% reduction in sulphur dioxide emissions. This is equivalent to an overall sulphur dioxide capture of 55-59%.

A diesel fired oil burner will be used to preheat the SAP for the initial operation or after an extended shutdown.

## Oxygen Plant

An air separation unit (ASU) supplied by Air Products (UK) will produce oxygen required for the Isasmelt furnace. The ASU will produce 650 t/day of 95% O<sub>2</sub> gaseous oxygen with the oxygen discharge pressure being 175 kPag. An isometric drawing of the ASU is shown in Figure 11. The oxygen plant will be located remote from the converter aisle to ensure clean air is drawn into the plant.

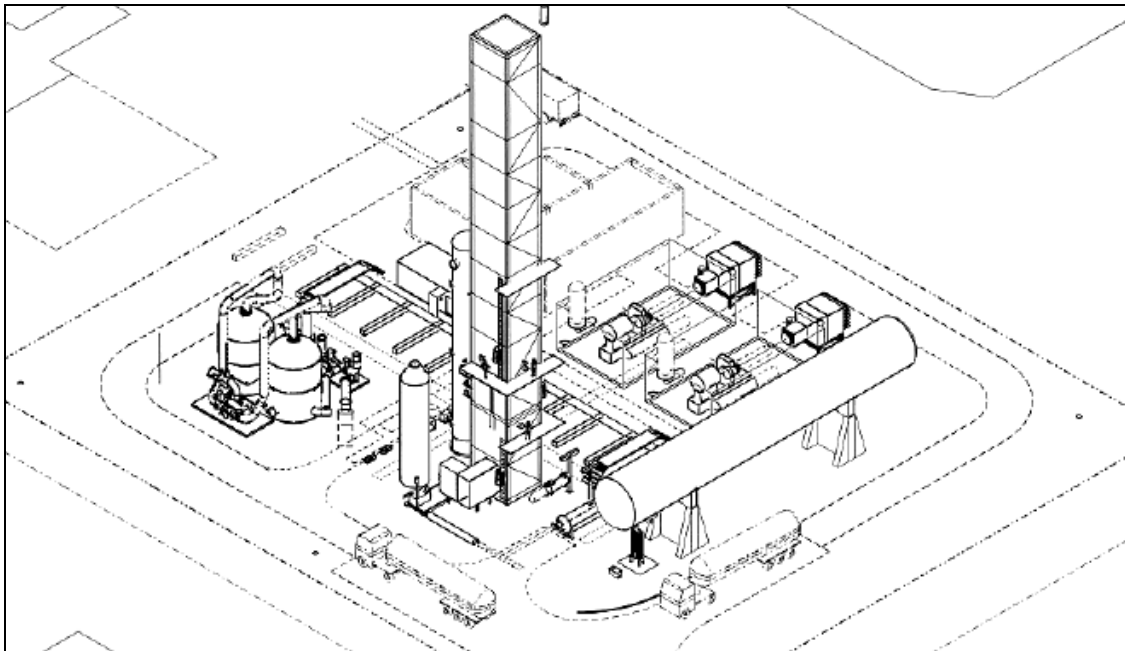


Figure 11 - Oxygen Plant Isometric

## Phase 2 – Materials Handling, Converting and Fire Refining

The objective of Phase 2 of the MSUP will be to increase the overall smelting capacity from 650,000 tpa to 850,000 tpa. This will be achieved by upgrading the converting, fire refining, and casting areas. As well as increasing converter aisle capacity appropriate modifications will be made to enable the PS converter offgas to be directed to a second sulphuric acid plant.

### Materials Handling

The concentrate storage and blending area will be upgraded by the installation of a below ground truck offloading hopper (and associated conveying system) and two new overhead trippers in the existing concentrate storage building. These modifications will enable concentrate blending in beds, as well as through the Phase 1 bin system. The concentrate storage and blending layout is shown in Figure 12.

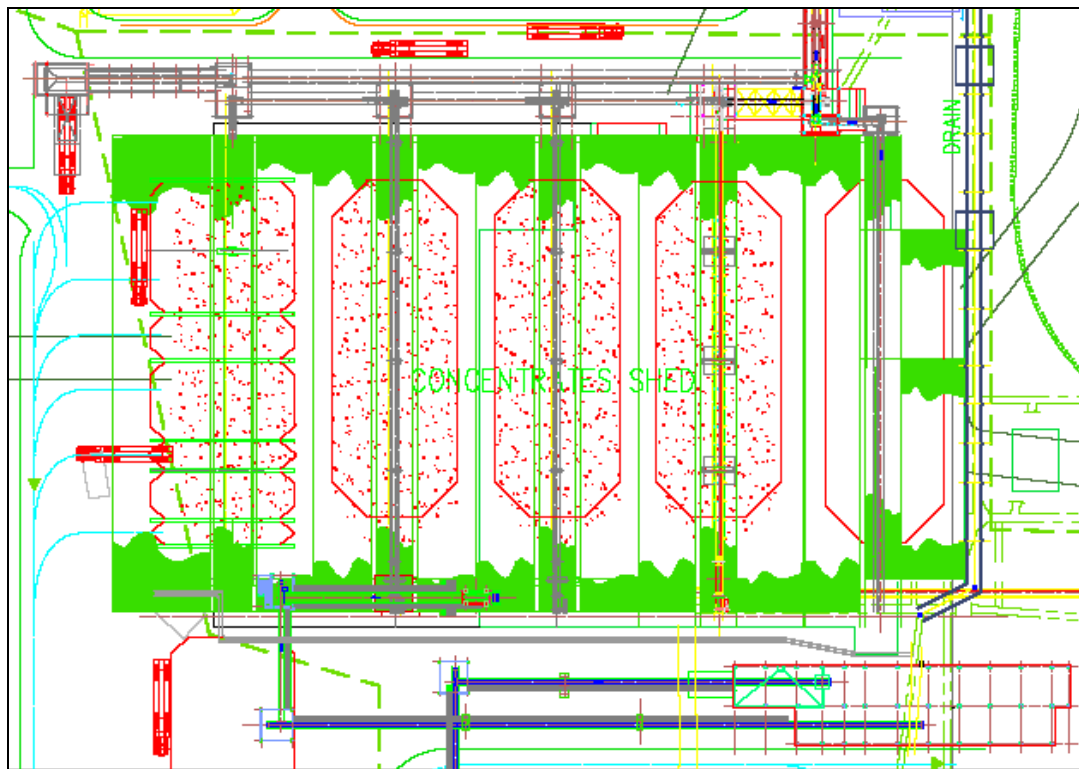


Figure 12 - Phase 2 Concentrate Storage and Blending.

### Converting and Fire Refining

The converter aisle configuration for Phase 2 is shown in Figure 13. The PS converter configuration was optimised for treatment of offgas through a second acid plant. The second new converter (C1) will also be 13x37'. Converters 5 and 6 will be

extended to the same size. This converter size was chosen to reduce the number of blowing converters, and therefore the size of the second acid plant, while enabling the reuse of a significant amount of existing equipment (eg PS converter shells, riding rings etc). Converters 5 and 6 were chosen as the 3<sup>rd</sup> and 4<sup>th</sup> extended converters to simplify construction (eg. avoiding foundation clashes with C2) and to minimise the average distance between the MSEF and the converters. A staged transition from Phase 1 to Phase 2 has been developed to eliminate any production delays due to construction in the aisle.

Additional fire refining and casting capacity is required for the Phase 2 production level of approximately 295,000 tpa (new copper from concentrates). Two anode furnaces and a new casting wheel will be installed east of Converter 1 to meet this requirement. The new equipment will be installed in the existing crane maintenance area and will be sized for the full Phase 2 production as the existing casting wheels are very old and in poor condition. Anode furnaces 1 and 2, and Casting Wheel 1 will be retained as standby units.

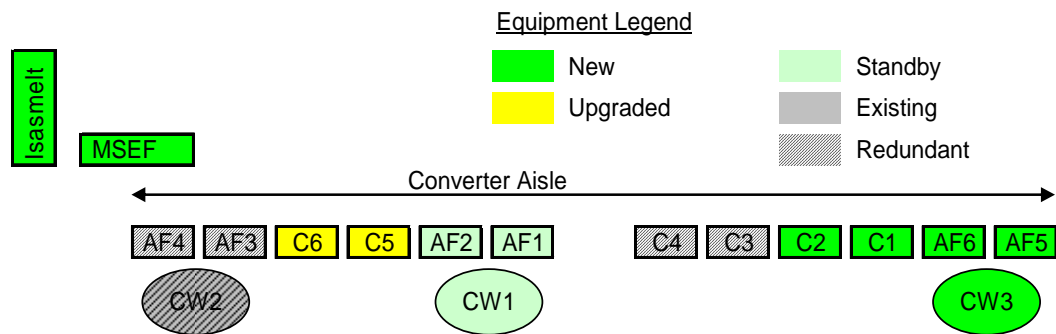


Figure 13 - Phase 2 Aisle Configuration

## PROJECT MANAGEMENT

A joint venture (JV) between SNC-Lavalin (Europe) and Grinaker-LTA Process Engineering is managing the MSUP on an EPCM contract basis from Johannesburg, South Africa. A small but discrete MCM Smelter Project team consisting of a Project Manager, Process Engineer, Site Superintendent, Project Administrator and Document Controller liaise directly with the JV to provide input and supervision into engineering design, project control and construction on an “as needs basis”.

Due to the limited time available to complete definitive engineering studies (as a consequence of the deteriorating condition of the existing electric furnace), contracts were awarded to the four main technology vendors in advance of the award of the EPCM contract. A fundamental component of the JV scope of services has therefore been to integrate the equipment supplied by the four main technology vendors into a functional smelting process and provide all ancillary services required for future operations i.e. material handling, electrical, water, air etc. The JV provides construction management

services using a multi-discipline supervisory approach for construction contracts on site in Mufulira.

Project controls are being managed using SNC-Lavalin's PM+ system incorporating modules specific to sub-contract supply, material control, document control and cost control. Project scheduling is being achieved using Primavera P3 software.

## **CONCLUSION**

The MSUP constitutes a significant investment by MCM in the future of the Zambian pyrometallurgical industry and provides confidence for alternative investors to develop and mine copper sulphide deposits with an option to sell or toll treat the concentrates produced through the Mufulira smelter.

The 'deliverables' on completion in 2008 of Phase 1 and Phase 2 of the MSUP are:

1. An 850,000 tpa copper concentrate smelter with capacity to process all internal (MCM) concentrates and external concentrates from Zambia or the neighbouring DRC.
2. A target of 55-59% sulphur fixation from the smelter with the No.1 acid plant following completion of Phase 1 of the MSUP, leading to compliance with Zambian Environmental Law long term emission limits prior to the expiry of the Stability Period provided for in the MCM privatisation Development Agreement.
3. A supply of 98.5% strength sulphuric acid from the No.1 acid plant that will exceed MCM's internal acid and provide a potential surplus for sale with alternative Zambian copper producers at reduced unit cost when compared with sulphuric acid importation.