Common-Sense Improvements to Electric Smelting at Impala Platinum

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Abstract – In 1992, a paper was compiled highlighting a common-sense approach to electric smelting at Impala Platinum. Since then, the smelter complex has undergone considerable changes. Mineral economics, UG2 exploitation, and changing environmental legislation have enforced numerous process upgrades, yet a common-sense approach has always been adopted. This document details the major changes in the smelter complex at Mineral Processes (Minpro) over the past 15 years, and provides the rationale for the changes.

COMPANY BACKGROUND

Impala Platinum Holdings Limited (Implats) is in the business of mining, refining, and marketing platinum group metals (PGMs) and associated base metals.

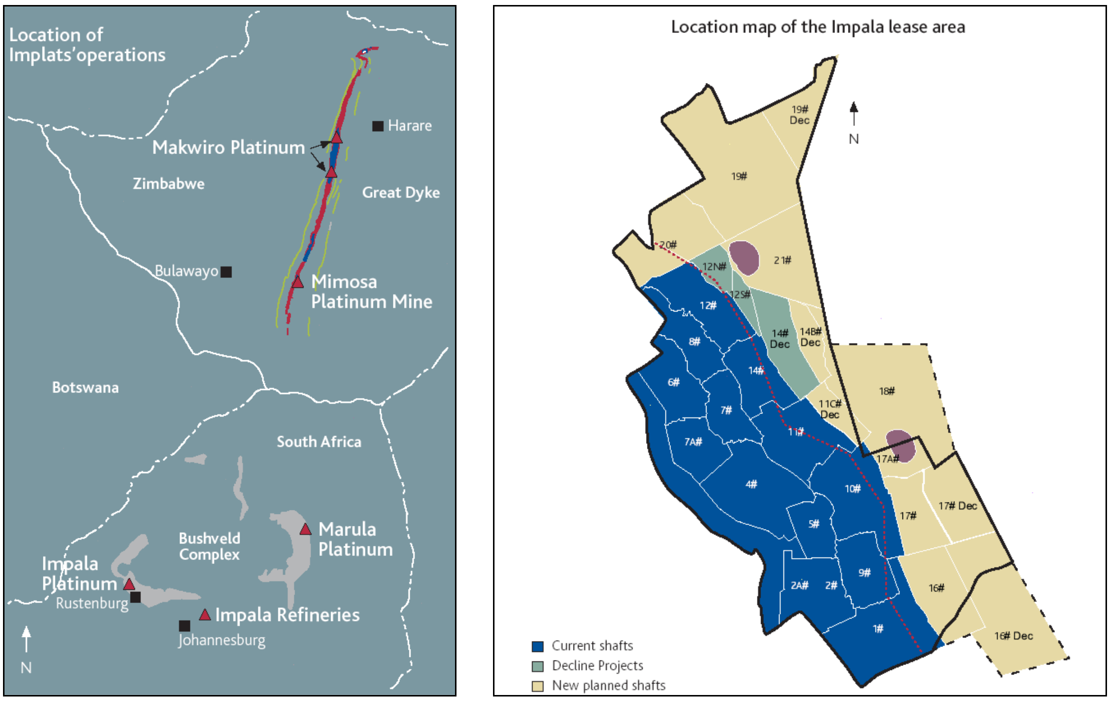

Figure 1: Maps of Impala Platinum's operations

The group has a three-pronged operational strategy, namely:

- Mine-to-market operations, where Implats has operations on the Bushveld Igneous Complex (BIC) in South Africa (on the Western Limb – Impala Platinum Limited, and on the Eastern Limb – Marula Platinum), and the Great Dyke in Zimbabwe (Zimplats, which is listed on the Australian Stock Exchange)
- Impala Refining Services (IRS) which was established as an entity in 1998 to take advantage of the group's smelting and refining infrastructure
- Strategic alliances and investments with other players in the industry, vital to the Implats growth strategy

Impala (Rustenburg operations)
Impala Platinum Limited, the group's primary operating unit, has operations based some 25 km north of the town Rustenburg, located in the North West Province, with refining operations performed in the East Rand town of Springs, Gauteng. This unit contributes more than 60% of the total Implats production and approximately three quarters of the net profit. Growth in Rustenburg has continued, and the unit currently produces 1.2 million ounces (Moz) of platinum (1.9 to 2.0 Moz PGMs) annually, operating with 13 shaft systems and 5 declines (covering a total area of 250 km^2), 30 run-of-mine mills (17 Mt milled), and two immersed arc electric furnaces (0.8 Mt smelted at the Mineral Processes complex).

Ore types mined
The world's largest known deposits of PGMs are concentrated in the Bushveld Igneous Complex (BIC), which extends for more than 400 km in the northern parts of South Africa. The BIC system is divided into an eastern and western lobe, and includes two major narrow-seamed reefs exploited by Impala, namely the Merensky reef and the UG2 reef. The Merensky reef, which is estimated to contain some 17 000 tons of PGMs, generally has more sulphides than the UG2 reef. The UG2 reef, which is more consistent throughout the BIC, generally contains much higher levels of chrome than the Merensky reef, and significantly less base metals.

The UG2 reef is believed to contain PGM reserves twice as large as those of the Merensky reef, and is consequently receiving more attention in present operations, with the depletion of Merensky reserves, which have been successfully exploited since the late 1920s. The increased tonnages of UG2 ore have been providing challenges in smelting or furnace processing, as a result of the increased chrome content. The changes in mining and concentrating strategies have also led to a need to consider different smelting approaches, although the fundamentals have not changed much.

Concentrating
Ore is delivered from underground via a rail network of 92 km to two concentrator plants: the Central Concentrator, comprising the Merensky and MF2 Sections, and the UG2 Concentrator.

Merensky ore is crushed to a top-size of 150 mm by jaw crushers, prior to delivery to the silos. The 15 Merensky Mills run in parallel as 15 single-stage run-of-mine ball-milling circuits with single-stage hydrocyclone classification. The milling circuit is followed by a single-stage bulk sulphide flotation circuit. Two flotation banks are run in parallel, receiving feed from 8 and 7 mills respectively.

With the current circuit design, the Merensky plant recoveries are strongly dependent on mass pull. Increased tonnages, together with mechanised mining, have resulted in a steady decrease in head grade over the past decade. In an effort to maintain metal recovery, plant mass pulls have steadily increased to the current level of 5%. This, coupled with the substantially improved throughput of the mills, has resulted in larger volumes of concentrate sent to the smelter. In an effort to reduce concentrate volumes, a second stage of flotation is currently being tested on the Merensky plant.

UG2 ore is largely processed at the UG2 plant, with the excess being taken up at the MF2 plant, along with some Merensky and all the opencast material. The UG2 plant consists of two primary autogenous mills which both receive run-of-mine ore. The mill discharge is screened, and this effects the ore separation for which the circuit is known: the screens separate the chromite-rich fraction from the silicate-rich fraction. The fine, chromite-rich material reports to the undersize, along with about 90% of the PGMs, and is therefore known as the high-grade fraction. The remaining 10% of the PGMs are associated with silicates, and report to the screen oversize with the coarse silicate, or low-grade, fraction. The high-grade fraction is treated through a classic MF2 circuit, with the low grade treated in a MF1 circuit, similar to the Merensky ore.

The conversion of the UG2 plant to an open-circuit primary milling operation has led to more efficient milling of the high-grade fraction, and has reduced over-grinding of chromite. The effect of this has been seen as a reduction in chrome in concentrate, and an associated increase in PGM recovery. However, increased throughput at the UG2 plant has actually resulted in a larger quantity of chromite being processed at the smelter.

Smelting

A simplified metallurgical flowsheet of the Minpro smelting complex is shown in Figure 1. Electric smelting is still believed to be the most economical option to treat the flotation concentrate, when compared to hydrometallurgical alternatives. This belief stems mainly from the relatively low mineral (base metal) content of the concentrate. Flotation concentrate is treated together with IRS toll concentrates, through a thickening circuit to maximize on water recovery, and to facilitate blending. The thickened product is fed to four operational coal-fired Niro-technology spray-drying units, where an almost bone-dry product is pneumatically discharged to silo storage units. Two rectangular six-in-line furnaces, with a combined power of 73 MW, are used for sulphide concentration.

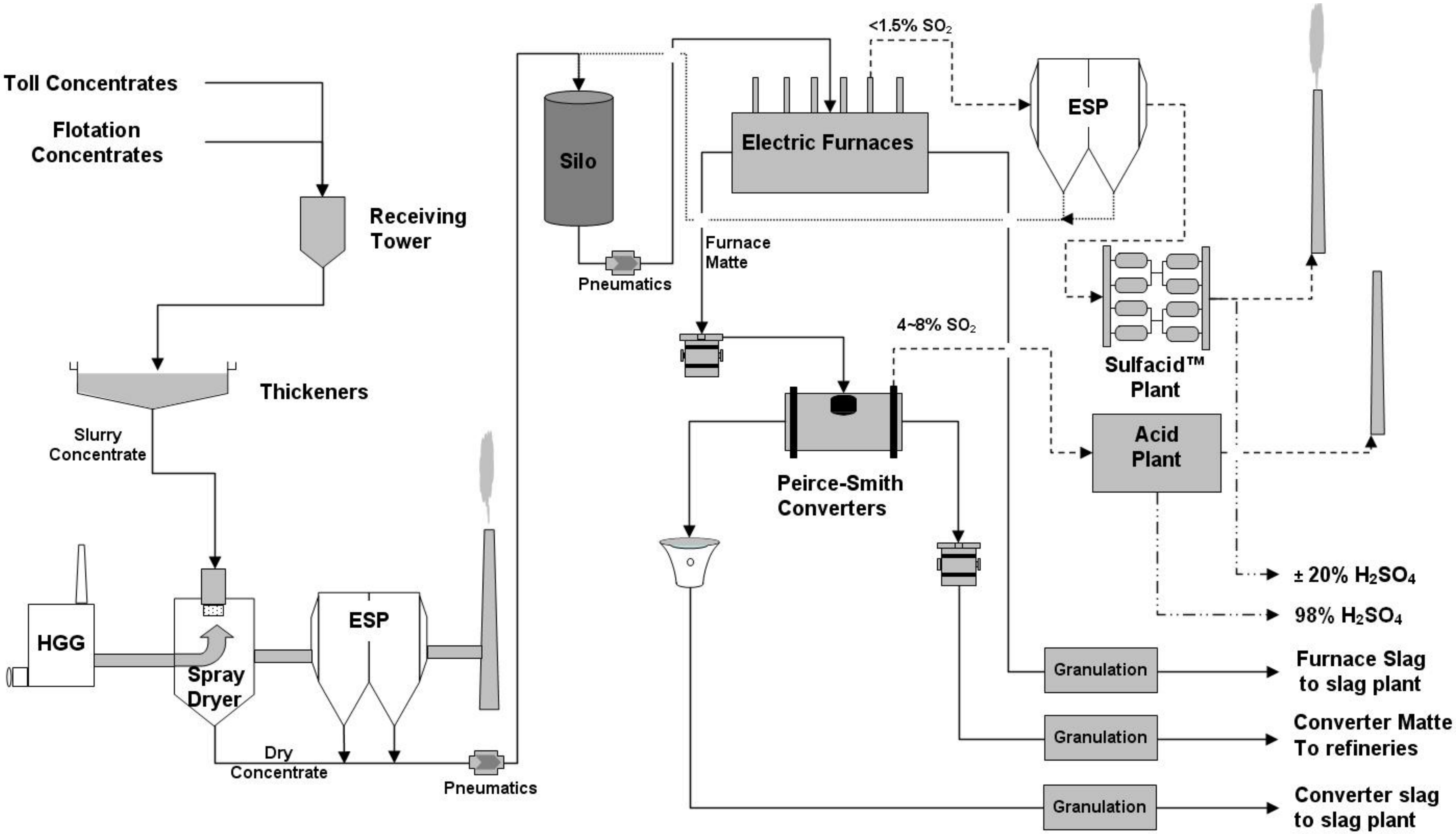

Figure 2: Simplified flowsheet of the Impala Platinum smelter

The sulphide matte (which is the PGM carrier) is further concentrated through iron removal in Peirce-Smith converters.

Table I: Typical converter matte analysis

TYPICAL CONVERTER MATTE ANALYSIS			
Nickel	46.7%	Iron	0.5%
Copper	31.0%	Sulphur	20.5%
Cobalt	0.3%	PGE & Minor impurities	< 1%

A low furnace matte fall enables converting redundancy, as only three to four of the six available Peirce-Smith converters are in operation at any time, allowing for enough turnaround flexibility. Off-gases withdrawn from the electric furnaces, generally containing below 15 000 ppm SO_2, are treated in a Sulfacid™ process. The process utilises activated carbon as a catalyst, to produce a weak sulphuric acid solution with concentrations less than 20% H_2SO_4. The stronger off-gas stream, removed from the Peirce-Smith converters, is treated in a conventional single catalysis, single absorption Lurgi-designed acid plant with SO_2 (40 000 – 80 000 ppm) fixated in a 94 – 98% H_2SO_4 product. All sulphuric acid products are sold over the fence to an adjacent fertiliser producer.

SMELTER EXPANSION

Table II displays the sequencing of major capital events at the Minpro smelter complex. Little capital was employed during the 1990s, while exciting growth with a variety of projects is evident thereafter. The majority of the projects have been aimed at either increasing production, reducing gaseous and particulate emissions, or simply improving efficiency.

Table II: Chronological sequence of major capital projects at the Minpro smelter

Sequence of major plant installations over the past 15 years
• 1991: 28 MW spray dryer and 30 MVA furnace • 1996: Concentrate pneumatics installed for furnaces 2 & 4 • 2000: Upgraded furnace off-gas ESPs • 2000: Two new 12’ x 24’ Peirce-Smith Converters and an Acid plant capacity upgrade • 2001: New 38 MVA Furnace and 1800 ton feed silo • 2002: Sulfacid™ plant installation • 2003: 32 MW Spray dryer, 50 t/h high-rate thickener and 1800 ton feed silo • 2004: New converter matte granulation facility • 2006: Toll business off-loading and sampling installation

The remainder of the document is focused on the common-sense approach followed in all capital expansions: approaching improvement through incremental advances, without adding unnecessary process risks.

FURNACE FEED PREPARATION SYSTEMS

Niro-Spray Dryer Design

During the 1970s, a technology change from drum filters and turbo-tray dryers to Niro-spray dryers was systematically introduced. The change was initiated because of a number of problems associated with the handling and subsequent charging of moist concentrates to the furnaces. The main problems included filter-medium blinding, concentrate hang-ups, feeder blockages, and furnace 'blow-backs' resulting from the generation of steam in the furnaces. These were major concerns both in terms of production and safety.

The 28 MW spray dryer installation in 1991 (double the capacity of the previous largest dryer) was done with some design improvements. The hot-gas generator type chosen was a type 'L' travelling-grate stoker, which was the same as the preceding installation. The main difference in design was automatic hydraulic speed control on the grate. The automation allowed for better dryer throughput control, without compromising on coal-combustion efficiencies. Changes made on the drying chamber included replacing the annular internal air-cooled ducting with an internal refractory-insulated mild steel ducting; the installation of a thick-walled mild steel drying chamber; the change to fibreglass of the material of construction of the stack; and changes to the air-disperser material and design. The remaining period of the late 1990s saw further incremental improvements to the drying circuits.

As part of an expansion plan, the largest dryer to date (a 32 MW spray dryer) was constructed in 2002. A decision was made to step away from the grate-type stoker, and revert back to a fluid-bed hot-gas generator, which was used in the first spray-dryer installation. The change in HGG type was aimed at raising efficiencies through ensuring complete coal combustion. A number of modifications were made to the older fluid-bed type design.

The fundamental difference was the emergency stack being positioned directly above the HGG (forming part of the HGG) as opposed to a separate emergency stack. This eliminated the need for two critical shut-off dampers to be positioned in the extreme heat zone (900ºC), and has subsequently reduced the energy losses resulting from inadequate sealing around dampers. It also reduced the likelihood of damper failure and maintenance resulting from the dampers warping, and has consequently improved dryer availabilities. The positioning of the emergency stack also allowed for improved temperature control to the drying chamber, without compromising on fluid bed air flow rates (thus significantly reducing the probability of bed sintering), by introducing cool air through the emergency stack.

In addition to the change in emergency stack positioning, the use of only four thermocouples (from more than twenty) monitoring the entire bed surface area allowed for ease of operation and monitoring. The rate at which the dryer could be brought on-line was also improved with optimized burner design and positioning (the new installation relies on four burners positioned above the bed, as opposed to two burners positioned in the plenum area on the older installation). The substitution of air-dispersers with a vena contracta eliminated problems experienced on the air-dispersers as a result of warping and corrosion. A water trap was also installed, and positioned below the drying chamber, allowing for rapid cooling of the drying chamber during adverse temperature conditions before damage could be inflicted on the chamber and costly atomisers.

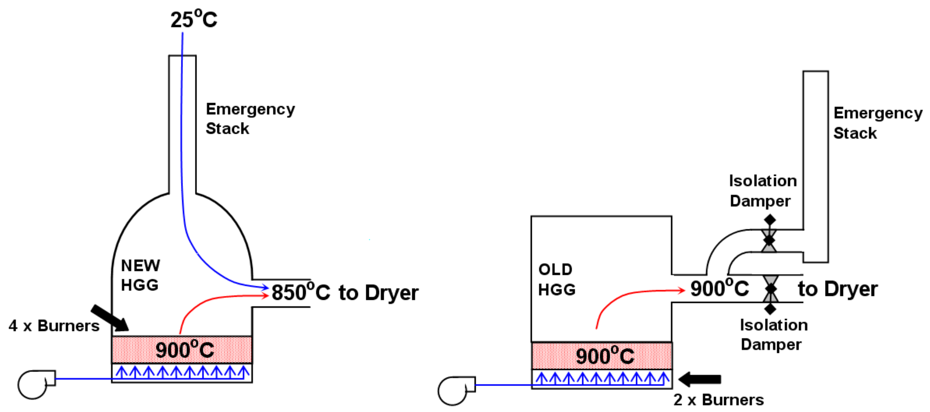

Figure 3: Illustration of the basic changes made to the new fluid-bed hot-gas generator

The design changes with the last two major dryer installations have been very successful. Further to enjoying the process improvements, efforts were made to raise operating efficiencies and reduce operating costs. The efficiency of a spray dryer is largely dependent on the feed density of the slurry to the dryer, and maximising the feed density lowers unit coal consumption. It was for this reason that emphasis was placed on thickener and slurry circuits to reduce coal consumption, ultimately improving operating costs and reducing gaseous emissions.

Slurry concentrate handling

Flotation concentrates, together with the majority of the toll concentrates, are thickened in conventional and high-rate thickeners prior to drying. This process takes place in four large concrete thickeners (30 to 35 metres in diameter). The 32 MW spray dryer and 35 metre high-rate thickener introduced a change to thickener and concentrate handling management. With the technological advancements on feedwell design, much higher underflow slurry densities, at lower thickener stock holding, have been achieved. This brought about severe pumping challenges.

Peristaltic pumps were initially installed with the recent dryer, but these proved to be maintenance intensive and costly to operate because of hose failures, pulsation problems, and high glycerine consumption. The peristaltic pumps were also incapable of providing the required slurry flow rates at elevated densities. (The pump application is difficult, as a static head of around 35 m, at low flow rates of approximately 30 m^3/h are required. This requires most centrifugal pumps to operate far outside the best efficiency point (BEP), and it was for this reason that peristaltic pumps were initially installed.)

As a result of the abovementioned problems, in-depth rheological investigations and slurry characterisation studies were undertaken, in conjunction with a number of pump trials. The investigations have revealed a necessity to bring process consultants on board with pump selection and hydraulic design for non-Newtonian system designs, rather than relying on pump suppliers for specifications. The implementation of the findings from the studies is currently been implemented, and will deliver further process optimization.

FURNACE FEED

Influence of feed characteristics on furnace operation

The main change to furnace feed characteristics in the past 15 years has been as a result of the increased amount of UG2 ore mined, as well as the effect of toll concentrates on the feed mix. The rate at which UG2 deposits are being exploited is fast outpacing that of the Merensky deposits. This has accordingly led to a substantial increase in the chromium content, as displayed graphically in Figure 4.

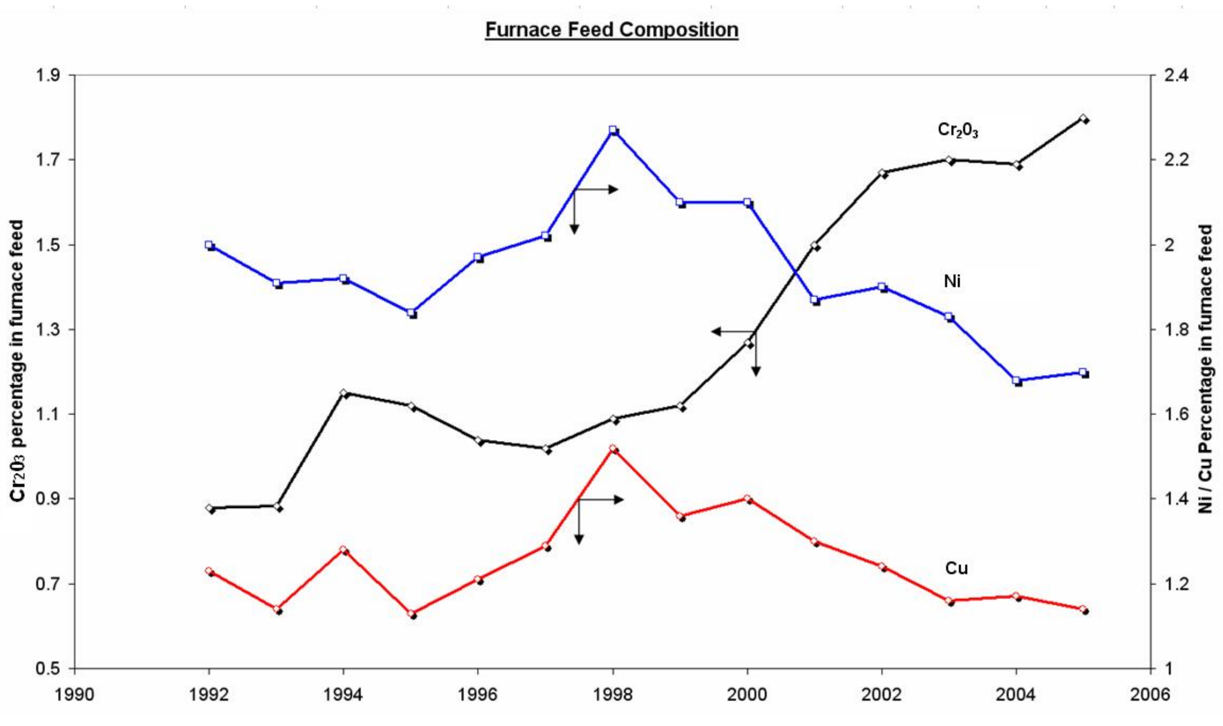

Figure 4: Change in furnace feed composition, with specific reference to base metal content, together with chrome concentrations

Negative Effects of Chrome

Chromium has a limited solubility in the slag, and increased feed concentrations (above the solubility limit) lead to the formation of crystalline chromite spinels. The spinels have a high melting point, and are dense, subsequently settling on the furnace hearth, resulting in reduced furnace volume. Intermediate density accretions typically form a 'mushy' layer between the slag and the matte, resulting in matte entrainment. Increased Cr_20_3 in the furnace matte also leads to chromite / magnetite formation in the converters.

The high melting point spinels obviously lower the fluidity (increased viscosity) of the slag and this leads to tapping problems. Higher chrome concentrations also result in decreased electrical conductivity (higher resistivity), leading to furnace electrical control problems. Furnace electrodes typically lift out of the bath to compensate, resulting in inadequate immersion (forming 'flat points' on the electrodes) and brush arcing.

Handling higher chrome

Chrome handling challenges led to numerous industry-wide studies, and brought about various debates regarding aspects of furnace design and the use of high productivity furnaces operating with high power densities.

Impala has always adopted what it believed was a simplistic approach to handling chrome through incremental advances and careful management, understanding and control of chrome levels. A number of simplistic changes were made to ameliorate the effects of higher chrome, without necessitating drastic technological changes.

The first major change implemented was opening the converter slag circuit. All converter slag was redirected to the concentrator slag plant, and no longer returned to the furnaces. The slag plant treats all current arisings from the converters and furnaces. Converter slag typically contains around 2.3% Cr_2O_3, and reintroduction into the furnaces naturally raised the overall chrome concentration, and limited flexibility of input options. The decoupling between the converters and furnaces, however, also resulted in lower furnace slag iron concentration, which in turn resulted in higher resistivity (converter slag contains on average approximately 62% iron oxide). This offset the effects of higher Cr_2O_3, which lowers the resistivity.

The second major change was stopping flux additions to the furnaces. Lime addition was predominantly required to raise the slag basicity, and reduce chemical attack on the refractories. It was also needed to lower the slag viscosity and the liquidus temperature. With the installation of copper-cooled furnaces, since the early nineties, plate coolers were used to ensure that a freeze lining kept the slag out of direct contact with the refractories. This negated the need for lime fluxing. The lower slag basicity further assisted with the chrome challenges experienced, in that lower CaO levels increased the solubility of chromite in the slag.

The development and use of pyrometallurgical simulation packages greatly aided the understanding and control of feed sources such as UG2 / Merensky and toll concentrates. Simulation has become an important activity at Minpro, to assist in the management of toll concentrates. Accurate calculation of spinel formation, thermal conductivities, temperature profiling, and likely matte / slag compositions, are readily available for any feed mix.

The abovementioned initiatives have helped Impala to increase Cr_2O_3 solubility from 0.9% to approximately 1.8%. This is enough to cope with foreseeable feed blends. To move beyond this point would however require further research and development.

Furnace Feed System

Dry furnace feed was progressively introduced in the late eighties. Although the spray dryers were capable of producing a bone-dry product, paddle mixers were still used to control the feed moisture content to 5%. This was necessary to eliminate the high dust losses resulting from the use of belt conveyors.

Pneumatic conveyance upgrades were carried out on all dryers, and silo storage units (approximately 6 000 tons capacity) were introduced to provide a buffer between the furnaces and dryers. The dry-feeding upgrades resulted in modifications to the furnace charging systems, with a dramatic reduction in the number of charge pipes needed per furnace. The change ultimately led to better control on blacktop levels, drastically reducing the likelihood of furnace 'blow-backs', and abolished the need for manual rabbling. The dry concentrate also provided some smelting rate improvements.

Pneumatic conveyance furthermore allowed for a change from limestone to burnt lime, during the early nineties. The inherent hazardous properties of burnt lime previously limited its use, but the introduction of an enclosed charging system made this possible, and led to an approximate 5% increase in the smelting rate. The removal of all flux to the furnaces thereafter, not only assisted with the chrome challenges, but also provided additional benefits. A further increase of about 5% was observed in the smelting rate, and a massive working cost reduction was realised.

The first pneumatic conveyance system installed (on the 35 MVA furnace) was a lean-phase high velocity system, but had high wear rates on the system components. Choking problems were regularly experienced, especially when the system was started with any product in the transfer line. Since 1996, all pneumatic systems installed have been dense-phase, low velocity systems almost approximating plug-flow. These have proved to have low wear rates, and can be started with product in the transfer line.

Furnace sizing and power input

The basic geometry changes with furnace installations to date are provided in Figure 5. The optimum ratio of internal width to electrode diameter and furnace surface area was established early in both the copper-cooled and non-copper-cooled furnaces. After all the dimensional changes, severe sidewall erosion issues were solved, nearly doubling the refractory life in the affected areas.

Furnace	Installation Year	Description (metres)					
		Length	Width	Electrode Diameter	Electrode Spacing	Matte / Electrode Dist.	Slag / Electrode Dis.
		(L)	(W)	(D)	(E)	(M)	(S)
1	1969	18.32	4.14	0.89	2.44	2.24	3.00
2	1972	18.32	4.14	0.89	2.44	2.24	3.00
3 (Old)	1973	18.32	5.36	0.89	2.44	2.24	3.00
3 (New)	2001	25.88	8.19	1.14	3.20	3.46	4.68
4	1974	23.81	6.89	1.14	3.20	2.76	3.91
5	1991	25.90	8.20	1.14	3.32	3.47	4.69

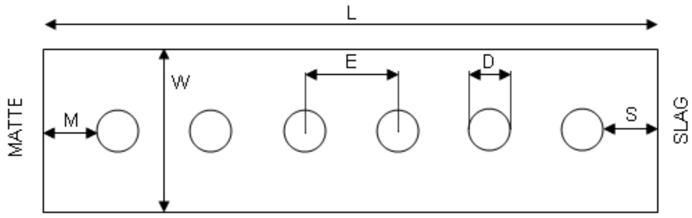

Figure 5: Changes in basic furnace geometry

With furnace geometries optimized over the years, the main challenge remained the increase in energy intensity in order to maintain constant temperature profiles throughout the bath, and to minimize spinel formation. This led to considerable industry innovation when high-intensity cooling elements entered the market, and debate raged on rectangular versus round furnaces. Impala still believes in a well-designed furnace with proven cooling elements and optimized geometry. It has also been realised that control of furnace inputs and maintaining constant power and furnace utilisation is essential to handling higher chrome contents. This has led to initiatives to minimize electrode breakages and ensure constant operation, which will be described in greater detail in forthcoming sections.

Application of higher phase voltage, without raising current levels, allowed for increased power input and higher furnace power densities, without affecting sidewall refractory life. The change in both the phase voltage and power density is illustrated in Figure 6. The figure illustrates a step change in installed power density and the phase voltage with the newer copper plate furnace installations.

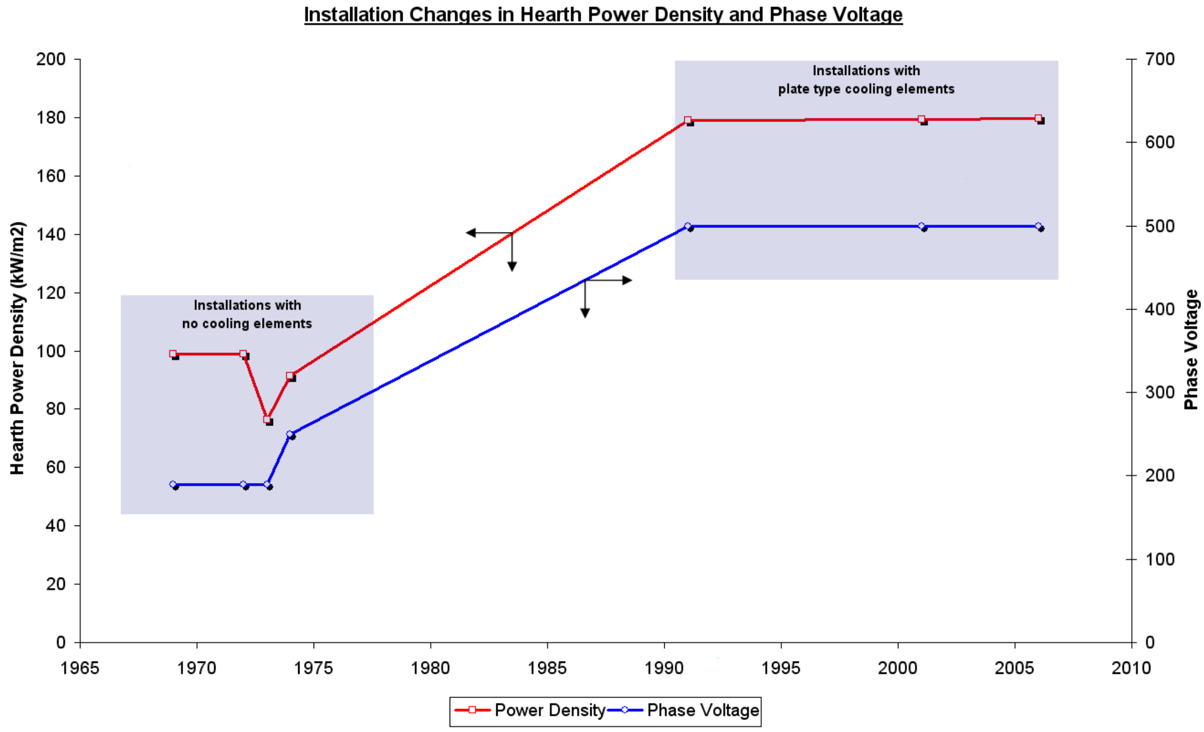

Figure 6: Changes in installed hearth power density and phase voltage

The most recent installations, operating around 180 kW/m², have proved to be well within safe operation for the selected cooling element type. Increased power density has, however, had an adverse effect on refractory life. Installations in the early sixties saw furnace lives of around 5 years, and this was increased to 10 years with the change to wider furnaces. Minpro furnaces operating today with plate coolers are requiring partial and full rebuilds every 5 – 6 years (as was the case in the 1960s).

This has led to investigations into refractory selection to improve refractory lives and will be discussed in the relevant section.

Furnace backup cooling water system

To maximize furnace refractory life, and ensure optimal furnace operation, the interruption of water supply to the coolers must be limited, to prevent accelerated erosion in the slag zone. With the newest 38 MVA furnace, a backup diesel generator was installed, to ensure water to the furnaces during periods of power and pump failure.

The backup system has been put to the test over the years, and has proved to be essential to limiting wall degradation. The success of the installation is, however, highly dependent on the availability of the generator. The infrequent need for its use necessitates maintenance and operational checks on a regular basis, to ensure its availability when required.

Electrode management
To limit spinel formation, and maximize furnace throughput, focus was placed on making full utilisation of furnace power. Operation for prolonged periods at reduced power levels has to be minimized to prevent build-ups in the colder furnace areas. Electrode breakages lead to reduced power levels, and result in colder areas forming around the affected phase area.

Impala makes use of Söderberg electrodes. The following design changes were implemented on the latest furnace installation, and significant benefits in terms of electrode breakages have been observed.

Contact pad water control system
Improvements were made to minimize electrode breakages by focusing on producing sound, dense electrodes at all times. In addition to increased attention to electrode management by maintaining adequate paste levels, minimizing paste contaminants and ensuring good quality welding on the electrodes casings, design changes were implemented to further reduce the risk of electrode breakages.

An improvement in producing dense electrodes was achieved by raising the temperature of the cooling water supplied to the bus tubes and contact pads. The first copper-cooled furnace installation made use of cold water to the bus tube and contact pad circuit. This resulted in temperatures below the paste softening point at the electrode pad area. In turn this results in gaps / pockets forming in the baked paste which affects the integrity of the electrode.

With the latest furnace installation, the inlet water to the bus tubes and contact pads was maintained at approximately 50°C. This was achieved by utilising a valve, controlled on a temperature loop, and a tank to mix the return water from the contact pads (approximately 60°C), with water supplied from the cooling circuit (45°C). The change ultimately ensured a more constant temperature profile, and improved electrode integrity.

Use of Rogowski Coils
The furnace transformer is electrically connected to the electrode column via a 40 kA water-cooled bus and flexible water-cooled cables. The distribution of electrical contact is adjusted with copper shorting bars at current distribution blocks mounted at the end of the water-cooled bus and on the electrode column.

Uniform current distribution to all eight contact pads is essential, to prevent the formation of holes in the electrode casing. This may result in pitting at the electrode tip, enhancing the probability of electrode breakages.

The older furnace systems relied on manual measurements (monthly) to ensure equal current distribution. Rogowski coils were installed on the newest furnace to improve this. The coils are connected to the down tubes, and allow for on-line measurement and rapid engineering response, ensuring proper current distribution and minimized casing burn-through.

Purge air system
In addition to current distribution control, maintaining clean contact between the pads and the electrode is essential. Older systems required switching off once per day to blow the electrode pads (this was obviously not efficient because of the power loss).

An automated cleaning system was installed, as a consequence. The purge air system makes use of compressed air, and is installed on a 'ring-main' around the electrode contact pad areas. The use of nozzles and solenoids allows for cleaning of the contact pads, ensuring good contact at all times without affecting production rates.

Dropper Cable Design
A further simplistic improvement was made from older designs, to ensure equalised current distribution at the contact pads. Older designs used dropper cables distributing from a single nodal point to the eight contact pads. This resulted in half the electrode receiving almost 80% of the current, while the other pads connected to the longest dropper cables received the current balance, schematically shown in Figure 7. This led to the formation of holes in the electrode casings, and ultimately resulted in many electrode breakages.

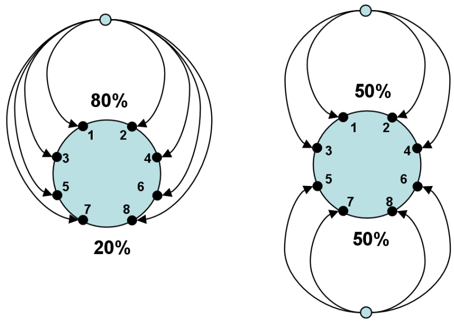

Figure 7: Electrical current distribution and the effect of dropper cable lengths

The system change eliminated the unequal current load by splitting the feed point, and utilising dropper cables of equal length. The effects were immediately noted with the change, and electrode breakages were further reduced.

Furnace refractory selection
The effect of basic furnace geometry on furnace refractory life has been addressed. Despite the presence of freeze-linings, the introduction of copper cooling and higher hearth power densities led to a reduction in furnace refractory life. The lives obtained in furnaces today are similar to what was observed in the sixties (5 – 6 years) before furnace geometries were optimized to reduce side-wall erosion. Higher chrome levels prevent any further increase in geometry as this will increase the likelihood of furnace build-ups.

At Mineral Processes, high-grade magnesia refractories have traditionally been utilised in the working lining of the furnaces. Although the Minpro slag is an acidic slag, the basic magnesia refractories were selected due to their ability to withstand high slag temperatures, and due to the good thermal conductivity of this brick type. As discussed, lime and limestone were also traditionally added to the furnaces, thereby increasing the basicity of the slag, and reducing the slag corrosion of the basic refractories.

The magnesia refractories are, however, prone to hydration and react with SO_2 gases at favouring temperatures. Hydration is likely to occur when magnesium oxide is exposed to moisture at temperatures below 350ºC (the reaction is accelerated at temperatures between 80ºC and 180ºC). Magnesia products will also react with sulphur and sulphur compounds at temperatures below 1100ºC.

In the years before copper cooling (side-wall cold-face temperatures in excess of 300ºC), refractory hydration was unheard of at Minpro, and sulphurous degradation of refractories had a negligible effect.

Copper cooling, however, brought the refractory linings into the temperature zone where these effects can have a detrimental impact. Typical copper plate cooler hot-face temperatures at Impala are of the order of 180ºC, while copper cooler cold-face temperatures can be as low as 45ºC. At present, the effects of hydration, and sulphurous attack on the refractories are evident in areas adjacent to the cooling elements in both operating furnaces at Impala.

Sulphurous attack of the copper plate coolers is also evident. This is, however, not a major concern, as there is no risk of water entering the furnace as a result of this type of attack, since all coolers at Minpro are shallow-cooled.

The need to consider alternative refractories for copper-cooled furnaces was realised, and a variety of combinations have been tested on the hot and cold faces in several furnace panels. Two general types of refractories tested (alumina-chrome and magnesia-chrome) proved to be very successful. The furnace panel tests were also confirmed in laboratory-scale slag induction furnaces.

The alumina-chrome bricks resist dissolution in slag to higher temperatures than all the other refractory options, are immune to hydration, and resist sulphurous atmospheres when used above 500ºC. These bricks are, however, more expensive than the magnesia bricks, and have a lower thermal conductivity. As such, the interruption of water supply to the coolers must be limited to prevent accelerated erosion in the slag zone.

Magnesia-chrome bricks have always been good candidates in non-ferrous acid slag processes, and provide specific advantages over high magnesia alternatives. Once again, better resistance to slag dissolution is evident, and the bricks are considered to be resistant to SO_2 attack above 1200ºC. The magnesia content still makes the brick prone to hydration, limiting its use on the cold wall and areas adjacent to copper coolers.

New furnace installations at Impala will see a move away from conventional magnesia refractories, and combinations of alumina-chrome and magnesia-chrome will be utilised on the hot and cold faces.

Tap-hole repairs

Prior to 1996, 'run-outs' were experienced on a regular basis during 700 mm drilling repairs of matte tap-blocks. This led to a procedural review, with particular attention placed on the drill preparation phase of the repair. The following changes were implemented to aid safe maintenance practice.

The cooling water to the tap-hole block and relevant copper cooler is now fully opened, while the furnace liquid level is dropped until slagging occurs, and the matte reaches an acceptable level. Immediately after achieving the required matte level, the hole is plugged with a clay stopper. Approximately 6 tons of reverts (cold dope) is then added directly behind each tap hole, and the first electrode phase is isolated while the other two phases are reduced to 1 MW each.

The changes to the preparation procedure have reduced the run-out frequency during any tap-hole repairs to zero. This has reduced the safety risks considerably, and has enhanced productivity by reducing the time required to drill to the required depth for the repair of a tap-block.

PEIRCE-SMITH CONVERTER CHANGES

Operational changes

To cope with high chrome peaks in the furnace feed, electrodes are pushed down to raise bath temperatures and ensure fluidity. The effects of higher furnace matte temperatures during these times are seen in Peirce-Smith converter operation. The reactions occurring during the blowing of furnace matte in the converters are exothermic, resulting in a rise in bath temperature. Unless controlled, through addition of reverts (cold dope), the high bath temperatures would result in much increased refractory wear.

Furnace matte temperatures have been seen to rise beyond 1355ºC at higher chrome levels, compared to approximately 1300ºC at normal levels. This resulted in reviewing blowing procedures, and heavy reliance on revert addition to limit refractory wear as well as base-metal losses.

Much emphasis was subsequently placed on optimizing converter lives, and significant improvements were observed when utilising larger quantities of cold dope immediately after matte is poured into the converters. This has become the norm during periods when higher furnace matte temperatures are experienced. The use and maintenance of pyrometers for temperature control also became increasingly more important.

Changes in converter design

Impala's unprecedented growth necessitated the installation of two new converters - double the volume, and double the blowing capacity of the existing converters. The two new 12′ x 24′ Peirce-Smith installations, operating with air flow rates of 22 000 Nm^3/h (through 32 tuyeres with a 50 mm diameter), were to supplement the existing four smaller converters each operating at 11 000 Nm^3/h. The main reason for exactly doubling the blowing rate, converter capacity and matte ladle capacity was that the basic blowing 'recipe' could be maintained, thus requiring minimal operator training and production interruption.

Both the old and the newer installations operate with Kennecott punching systems, and are lined with magnesia-chrome refractories.

A number of changes were made on the new installations to simplify operation and ensure maximum utilisation. These changes are briefly discussed below:

Automated flux and revert addition systems

A new flux and revert (cold dope) system was incorporated with the upgrade. The system consists of two automated skips and two batching bins for handling the reverts and the flux separately.

A weighing system was introduced on the flux and revert batching bins, to enable known quantities of flux and reverts to be added. In addition, a feeder from the bin was installed with a variable speed drive to enable control of the flux addition rate.

The main benefits that the system changes allowed for were:

- Enhanced control of flux and revert addition, enabling more consistent slag compositions
- Better control on bath temperatures, allowing for fine-tuning with the rate addition. This has become increasingly more important with campaigns to improve converter lives, and handling the temperature spin-off effects from higher chrome handling.
- Improved aisle coordination. The demand on crane activities for revert addition being eliminated
- Improved production rates, since converters are not required to turn out of stack for revert addition.

Drive Systems

The new converters were installed with electric drive motors for normal operation, and air motors for emergency conditions (*e.g.* during power failures). The air motors are essential to control the converter position during power outages or electric motor failure. The older small converter installations only had air motors.

The biggest design change was the use of a Bogi-flex drive consisting of a spider, gearbox, couplings, brakes, and clutches. The Bogi-flex drive provided two main benefits when compared to the traditional positioning at the bottom of the ring gear. The primary benefit is that the drive positioning on the side of the converter eliminated the risk of damage during a burn-through or in the situation of hot molten slag or matte running along the shell onto the drives. In addition to this, the Bogi-flex drives were able to accommodate the converter shell expansion due to the extreme operating temperature ranges, and also bending of the shell over the long term.

Adiabatic dry-wall evaporative coolers

Another major change from the older converting systems was the introduction of dry-wall evaporative coolers for each of the new converter installations. The coolers were introduced to limit the final gas temperature delivered to the acid plant scrubber, thus limiting the need for major changes to the scrubber plant and all associated auxiliaries.

The system is completely automated, with control direct from the PLC SCADA, and has proven to be a trouble-free system requiring minimal maintenance. The main areas of wear requiring monitoring are on the water lances.

ENVIRONMENTAL CHALLENGES

Sulfacid installation

The need to treat furnace off-gases in a separate process from the converter off-gases, led to an in-depth review of all available technologies. It was essential to de-couple the two off-gas streams (furnaces and converters) to limit emissions in the case of either process being off-line.

The treatment route for low strength SO_2 gas (<1% v/v), proved to be a difficult exercise, and, although a number of alternatives exist, many are undesirable options because of the by-products formed.

Keeping to a common-sense approach in process selection, it was decided to look at other industries (outside of platinum, and mining in general) to find the best-suited technology. Of all the options considered, the most sustainable and attractive process was that used in paint pigment industries of Europe, namely the Sulfacid™ process. The technology makes use of activated carbon and spray systems in a number of fibreglass reactor sets, allowing for removal efficiencies in excess of 80%.

The main reasons for selection were:

- Very simple process, requiring minimal number of operators and maintenance staff
- Proven technology, extensively used in the paint pigment industry worldwide
- Modular plant, can be expanded to improve throughput and efficiency
- A saleable sulphuric acid product can be sold over the fence to an existing fertilizer producer
- Low capital expenditure, erected for approximately R65m

- Low operating expenditure, only consumables are the catalyst, which requires replacement every 5 – 6 years. Minimal pump installations, and very little overall moving parts in the process.

The Sulfacid™ process relies on exothermic conversion of SO_2 on an activated carbon catalyst, and safe operation is dependent on concentration limits of sulphur dioxide and sulphur trioxide fed to the plant. The generation of hot spots, through high localised sulphur concentrations in the catalyst bed, does pose a fire hazard. This has demanded that the furnaces operate with enough black top to reduce freeboard temperatures and limit SO_3 formation to the Sulfacid™ plant. The furnace off-gas is furthermore diluted with an ambient air intake, to limit the formation of possible hot-spots, and remove any process risk.

The plant has been in operation for nearly 5 years, and has proven to be an excellent technology choice due to the various advantages it offers over alternative technologies.

Emission reduction strategies

With strategies aimed at reducing gaseous and particulate emissions, a focus has been placed on primary abatement processes currently installed, in order to derive maximum benefit from these processes, before proceeding with costly secondary and tertiary processing. This has been, and continues to be, an ongoing process at Impala, with a phased approach to minimize emissions in line with current legislation to limit the effects on the environment, employees, and the surrounding communities.

In addition to a major capacity upgrade on the acid plant, a number of smaller capital initiatives have been instigated to reduce fugitive gas emission by improving the gas capture mechanisms at source. Ducting designs have been revisited on both the converters and furnaces to ensure efficient gas transport, limit dust fall-out, and maintain temperature profiles to avoid gas condensation. Optimizing these parameters is essential to maintain good suction, limit downtime, and ultimately reduce fugitive gas release. A ring-main ducting was installed on the converter off-gas, to add redundancy to the circuit, enabling maintenance without jeopardising production or emission control.

A number of smaller changes were made in both the Acid and Sulfacid™ plants, aimed at improving throughputs and process efficiencies. Excellent results have been achieved with minimal capital investment. The result of the initiatives implemented, has been a large reduction in the SO_2 and particulate emission rate over the past few years. This has been attributed to the improved capture of gases at source, and availability of the abatement processes, notwithstanding the large increase in throughput and sulphur input.

CONCLUSIONS

This document was compiled in an attempt to briefly highlight and discuss the major changes made to the Mineral Processes smelter circuit over the past 15 years, in order to cope with processing and economical challenges presented.

The 1992 document[1] with a similar title to this one (by George Watson and Brian Harvey) stressed the importance of:

- Matching the process to the product treated
- Maximizing use of available equipment
- Avoiding technological change unless essential
- Approaching improvement through incremental low-risk modifications
- Developing and utilising internal expertise
- Treating the problems at source
- Keeping processes and equipment as uncomplicated as possible

This was Impala's approach in the sixties, and has remained so until now. It is still the belief that a common-sense approach, based on experience for specific circumstances, is a winning formula, and it is believed to be working for Impala.

REFERENCES

1. G.B. Watson and B.G. Harvey, A common sense approach to process improvements to electric smelting of nickel-copper concentrates at Impala Platinum, *Non-ferrous Pyrometallurgy: Trace Metals, Furnace Practices and Energy Efficiency*, Proceedings of the International Symposium, R. Bergman et al (eds.), The Metallurgical Society of the Canadian Institute of Mining, Metallurgy and Petroleum, 1992.