

Process Description and Abbreviated History of Anglo Platinum's Waterval Smelter

M. Jacobs

Waterval Smelter, Kroondal, South Africa

Keywords: Smelting, converting, sulphide, sulphide smelting, platinum, platinum group metals, PGM, base metals, nickel, copper, matte, slag, furnace, electric furnace, Söderberg, electrode, granulation, converter, flash drier, sulphuric acid, acid plant, Ausmelt, Siros melt, pyrometallurgy, metallurgy, Anglo Platinum, South Africa

Abstract – Waterval Smelter complex is situated in Rustenburg, in South Africa's North West Province. The smelter objective is to process wet concentrate to produce crushed, slow-cooled, sulphur-deficient nickel-copper matte rich in platinum group metals (PGMs), gold, and base metals for despatch to the Magnetic Concentration Plant at the Base Metals Refinery.

Throughout its history, the smelter complex has been continuously upgraded in line with increasing production demand, changing feeds, environmental initiatives, and advances in available technology.

The smelter receives filter cake and slurry from Anglo Platinum concentrators and joint ventures. Wet concentrate is fed through a flash drying process utilising coal-fired, fluidised bed hot-gas generators, to produce dry feed material for the electric furnaces and slag-cleaning furnace.

For primary smelting, two electric furnaces are used, each with a rated capacity of 34MW. Furnace matte, containing the bulk of the base metal sulphides and PGMs, is tapped periodically into refractory-lined ladles and granulated using high-pressure water jets, then dried through electrically powered pneumo-driers to become the main feed to the Anglo platinum Converting Process (ACP). Slag is tapped semi-continuously, granulated, and treated through the slag mill.

The ACP treats the combined matte output of Waterval, Polokwane, and Mortimer smelters. It is a top-blown furnace, with furnace matte, air, and oxygen being injected into the converter via a lance submerged in the slag. Converter matte is tapped and bottom cast into moulds, slow-cooled, crushed, and despatched to the refineries. Slag is granulated and dried for recycling to the slag-cleaning furnace.

ACP slag is fed to the slag-cleaning furnace along with a reductant and a sulphur source. Slag-cleaning-furnace matte is granulated for processing by the ACP, while slag is granulated and processed in the slag mill.

The slag mill and flotation circuit treats granulated slag from the electric furnaces and slag-cleaning furnace to recover entrained matte containing valuable PGMs and base metal sulphides.

Innovative technology keeps SO₂ emissions well below legal limits. Furnace and converter off-gas are treated through the tower and contact acid plants for production of 76% and 98.5% H₂SO₄ respectively. These are mixed to produce 98% H₂SO₄ for sale to the fertiliser industry.

INTRODUCTION

Anglo Platinum is the world's leading primary producer of platinum. The group owns and operates various mines and concentrators in South Africa, as well as three Smelters, a Base Metals Refinery and a Precious Metals Refinery. The company is also involved in several joint ventures and empowerment initiatives.

Mining operations in the Limpopo and North West Provinces exploit the Bushveld Complex, the largest known layered igneous complex of its type in the world, extending over 65 000km² and reaching a depth of 7km¹. On the eastern and western limbs of the complex, PGMs are extracted from two stratiform deposits, known as the Merensky and UG2 reefs. On the northern limb, the Plat reef, substantially thicker than the Merensky and UG2 reefs, is exploited.

The Anglo Platinum Process Route

Ore from mining operations reaches the various concentrators at a platinum head grade of ~3 g/t, while metallics are sent directly to the Precious Metals Refinery (PMR). The ores undergo crushing, milling, and separation by sulphide flotation, to concentrate the base metals sulphides and the associated platinum group metal (PGM) content.

Concentrate, containing 35-110 g/t platinum, is transported by road to one of the three smelters (Polokwane, Mortimer, or Waterval) where it is dried, then melted down in electric furnaces. Granulated slag (comprising gangue material from the melt) is discarded, sold, or re-circulated to the concentrators.

Granulated or crushed matte from the electric furnaces is sent to the Anglo Converting Process (ACP) at the Waterval Smelter complex, where excess iron sulphide is removed.

The converter matte product, containing 1000-1800 g/t platinum, is bottom cast, slow cooled, crushed, and sent to the Magnetic Concentration Plant at the Rustenburg Base Metals Refinery (RBMR).

Here, the magnetic PGM-containing fraction is removed and sent to the PMR, while the remaining material is treated at the RBMR to recover nickel, copper, and cobalt. At the PMR, the PGMs are separated and refined to produce pure metals. The PMR currently produces platinum at 'four nines fine' *i.e.* better than 99.99% pure.

The History of Waterval Smelter

In 1924, Andries Lombaard found evidence of platinum on the farm Maandagshoek, initiating explorations leading to the now famous discoveries by geologist Hans Merensky. Thirteen years later, Klipfontein Smelter, a small blast furnace and converting unit became the first platinum smelting operation in the area.

With electric smelting approved in 1967, development started on the present Waterval Smelter site. The first 19.5 MVA (18 MW) Elkem electric furnace was commissioned in 1969, closely followed by a second of identical design. Four 6.1 m Peirce-Smith converters were used for removal of iron sulphide^{2,3}. A contact acid plant was commissioned in 1976 to reduce the emission of sulphur dioxide (SO₂) to the atmosphere.

In order to take advantage of new opportunities, extensive upgrades took place during the 1990s. This included commissioning of flash driers, pneumatic feed systems, and a concentrate silo, to replace the rotary driers and pellet feed systems; as well as upgrading both furnaces to 34 MW, and commissioning ceramic filter units to remove dust from off-gas streams.

In 2002, the ACP converter and new acid plant were commissioned and ramp-up got underway. The Slag Cleaning Furnace followed in 2003, to treat the converter slag. In 2004, ACP took over the full converting load for all of Anglo Platinum. Construction started on Phase B, expanding converting capacity and providing backup in the form of a second converter. The Acid Plant Rectification project started in 2005, including modification of both the Tower and Contact Plants.

CURRENT WATERVAL SMELTER OPERATIONS

The smelter objective is to process wet concentrate to produce crushed, slow-cooled, sulphur-deficient nickel-copper matte rich in platinum group metals, gold, and base metals for despatch to the Magnetic Concentration Plant at the Base Metals Refinery.

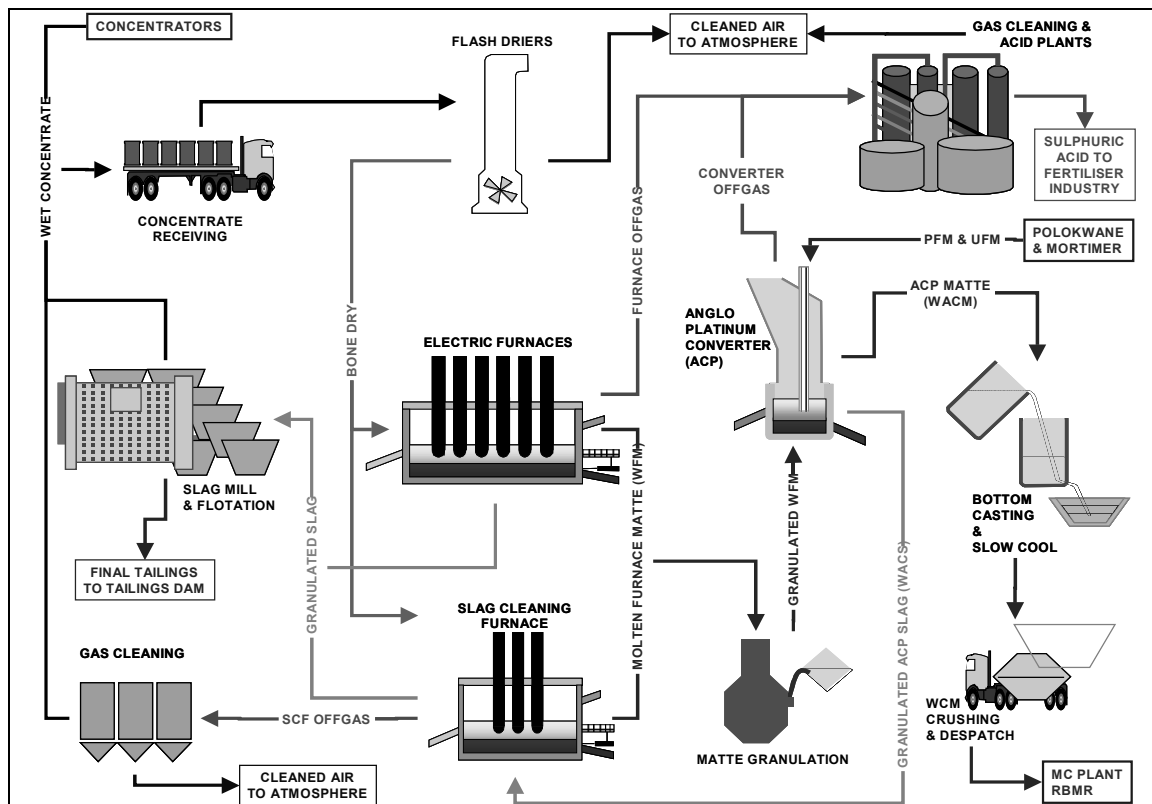


Figure 1: Simplified Smelter Process Flow Schematic

Wet concentrate is dried, then melted in electric furnaces, and excess iron sulphides are removed in the ACP converter. A slag-cleaning furnace treats gangue from the converter, while a slag milling and flotation circuit treats the slag from the electric furnaces.

The concentrate handling section currently treats around 72 000 t of wet concentrate per month. The electric furnaces smelt between 42 000 and 60 000 t of new concentrate per month (excluding recycle streams), while the converting section treats upward of 14 000 t of furnace matte per month. The slag-cleaning furnace is in an optimisation phase, and is currently treating upward of 6 000 t of ACP slag per month.

Concentrate Drying

Wet concentrate with an average moisture content of 16-17% by mass is delivered by road in flexi-side tippers or containers, and offloaded in the concentrate-receiving shed. Slurries with a solids content of 50-60% are pumped or delivered by tanker to the Waterval Complex Concentrate Handling plant (WCCH) for dewatering.

Slurries are dewatered in one of four Larox filter presses, and the filter cake is transferred to the concentrate shed via conveyor, with a moisture content of less than 12% by mass. Water is sent to the effluent thickeners.

In the flash drying process, moisture is removed from the wet concentrate, producing a dry furnace feedstock (<0.5% H₂O). The energy for the process is provided by burning coal in a fluidised bed (silica sand) combustor known as a hot gas generator (HGG).

There are four flash driers at the Smelter. Flash Drier 1, with total rated drying capacity of 3 875 kg/h water evaporation⁴, is kept as a standby unit, while the other units are normally in production on a 24-hour basis. Flash 2 & 3, identical in design, are rated at 8 265 kg/h, and Flash 4 is designed for 12 000 kg/h. The feed-rate is controlled by energy loading, and depends on the moisture content of the incoming feed. Typical feed-rates are 35-40 t/h for Flash Driers 2 and 3, and 35-58 t/h for Flash Drier 4.

Wet concentrate from the shed is conveyed to the back mixer, which breaks up incoming material while blending it with dry material recycled from primary cyclone underflow. The back mixer discharges to the disintegrator, where the impeller blades break up lumps, and mix concentrate with hot gas supplied from the HGG via refractory lined ducting. The hot gas evaporates the water, and the resulting stream is carried up the 40 m drying column by the vacuum-driven air movement.

At the top of the column, the bulk of the dry concentrate (~90%) is separated from the gas stream by means of a parallel arrangement of primary cyclones. Flash Driers 2 and 3 each have two primary cyclones operating in parallel, and

Flash Drier 4 has three. At each flash drier, the underflow of one primary cyclone is fed to a diverter, where a portion of the material may be fed to the back mixer. Exhaust gas from the primary cyclones is passed through a multi-clone, consisting of 96 small cyclone nozzles, where another 5% of the concentrate is removed. Overflow from the multi-clone passes through the dedicated four-unit bag-houses that remove the remaining particulates. Finally, cleaned gas is vented to the atmosphere via the flash drier stacks.

The underflow material from all primary cyclones, multi-clones, and bag-houses is fed to the product bin at each flash drier. FD2 and FD3 have 250 t product bins, and FD4 has a 500 t bin. From the product bins, dry concentrate is pneumatically transferred to the 2500 t silo. Concentrate is mixed with limestone from the lime silo, and the final blend is pneumatically transferred to the feed bins at the electric furnaces. Flash Drier 4 has the option to transfer directly from the product bin to any of the three furnaces (without flux addition). This facility is used mainly to deliver concentrate to the slag-cleaning furnace (SCF) as a sulphur source.

Primary Smelting

The two electric furnaces are of Hatch design, with a rated transformer capacity of 39 MVA (34 MW maximum or 30 MW nominal design), and a design operating factor of 90%. The rectangular furnaces have internal dimensions of 8.0 x 25.8 m, and the calculated power flux at nominal design is 146 kW/m². The shell is constructed from refractory bricks held together by a precision-designed tension system. The refractory linings are zoned, with chrome-magnesia bricks and ramming in the hearth (matte contact zone), magnesia in the side and end walls, with water-cooled copper plates in the slag-contact zone, and super-duty alumino-silicate bricks in the upper wall (freeboard) and roof.

Incoming electrical power at 88 kV is stepped down to 6.6 kV by five 20 MVA transformers. This is then further stepped down to operating voltage by the six secondary 6.5 MVA transformers on each furnace, with on-load tap changers for 17 taps, giving a voltage range of 100-200 V in the star connection, and 170-350 V in the delta connection. The maximum current per phase (electrode pair) is 32 kA. Each furnace accommodates six 1.250 m diameter Söderberg electrodes. The electrodes are continuous, and new segments are welded on at the top of the casing when required, with paste being loaded into the electrode column on a daily basis in 300 kg blocks.

Blended concentrate is roof-fed to the furnaces via air slides to either side of the electrodes. ACP slag (also known as WACS, for Waterval ACP Converter Slag), reverts, and other materials can be batch fed to the furnace, through charge ports in the sides of the furnace roof, using the old pellet conveying system. Concentrate is melted by energy generated in the furnace when electrical current passes through the electrodes and the resistive slag layer. The lime blended with the concentrate acts as a flux, aiding formation of a fluid slag at normal operating temperatures.

During primary smelting, dry concentrate melts to form two immiscible liquid phases. The matte, containing most of the base metal sulphides and PGMs, is denser than the slag and settles naturally to the bottom of the furnace, while the slag layer, containing most of the oxides, floats on top.

The furnaces normally operate with a layer of non-molten concentrate (black top) on top of the molten bath. The temperature differential between the matte and slag (usually 100°C) is regulated by the electrode position, slag depth, and applied voltage. The concentrate throughput and furnace power level depend on the composition of the blended feed, which determines both the amount of fluxing required and the specific smelting energy requirement of the feed. The feed-rate may vary from 25 t/h to 54 t/h.

Furnace matte is tapped periodically into 18 t refractory-lined ladles that are transported by overhead crane to the granulation station. Slag is tapped almost continuously through water-cooled copper blocks. The slag is granulated using a high-flow water stream, and is fed to the slag milling plant for recovery of PGMs, nickel, copper, and cobalt.

Off-gas is ducted to the ceramic filters to remove entrained dust. This dust is returned to the furnaces. There are 12 ceramic modules (6 per furnace), each containing 864 candles. The gas is then ducted to the Tower Plant via the gas conditioning section.

Matte Granulation and Drying

Waternival furnace matte (WFM) is tapped into matte ladles and transported by crane to one of two granulation stations. The ladle is placed on a hydraulically driven tilter that pours the matte into a granulation launder at a predetermined rate. The launder discharges above a stream of granulating water that shear-quenches the matte, forming fine particles suitable for dry feeding into the ACP converter.

The resulting slurry is pumped to one of four dewatering bins, fitted with slotted screens. Once a particle filter has formed on the screens, the bin is gravity dewatered before being discharged onto a conveyor at a target moisture level of less than 10% by mass. Damp matte is conveyed to the pneumo driers, where it is dried to less than 0.5% H₂O by means of hot air (350°C) that serves to both dry and pneumatically lift the material for discharge into a 3 000 t silo ahead of the ACP converter.

Hot air for drying is generated by forced drafting of ambient air through banks of electrical heating elements. The humid air and dried matte is discharged into a knockout pot where the bulk of the material drops down. The air and remaining entrained fines are drafted to a bag house. The bag house returns the fines to the silo, while the cleaned air is vented to the atmosphere.

ACP Converter

The converter is a top-blown furnace, using Sirosmelt submerged-lance injection technology from Ausmelt, modified for the specific application. Hatch copper-cooling technology in the 4 m high crucible, and Foster-Wheeler high-pressure membrane coolers in the upper parts of the furnace, helps maximize campaign life.

A mixture of granulated Waterval Furnace Matte and SCF Matte and crushed Polokwane Furnace Matte and Union Furnace Matte is fed continuously through the lance, which is submerged in the slag layer. Air and oxygen are also injected into the slag via the lance, where they react with the furnace matte at high temperature. The bath temperature in the converter is controlled at 1300°C, with most of the energy supplied by the reactions. Additional energy can be supplied by burning coal, which is added via the lance or a feed port in the roof.

Oxidation of iron sulphide converts the matte from 40% to approximately 3.5% iron. Silica flux is injected through the lance to encourage the formation of a fayalitic slag.

Converter matte is tapped in batches into matte ladles that are positioned under the matte tap-hole launders, using a matte trolley. Once the tap is complete, the trolley is moved into the slow-cooling aisle where a crane lifts and moves the ladle to one of 108 moulds. The matte is then poured, using the crane, into a bottom-cast ladle that cascades into the designated mould.

The converter slag (Waterval ACP Converter Slag, or WACS) is tapped in batches and granulated with water. The granulated slag is then pumped into one of three dewatering bins after which it follows a similar dewatering and drying process to the furnace matte, before being discharged into the WACS silo as feed stock for the slag-cleaning furnace.

Off-gas from the converters is cooled in the water-cooled membrane wall uptake and an evaporative spray cooler. The off-gas is scrubbed prior to feeding the contact acid plant.

The converter currently treats upward of 14 000 t of furnace matte per month, the bulk of the material produced by the Waterval electric furnaces with the remainder coming from Polokwane and Mortimer Smelters.

Although the full output of all three smelters can be processed through a single converter, a second is currently under commissioning. This unit will serve as a backup, as well as expanding converting capacity to cater for future growth.

Slow Cooling

Converter matte is bottom cast into one of 108 refractory-lined moulds in the ACP slow-cooling aisle. Each mould is capable of holding 12 t of material, and is covered with an insulating lid. This slows down the cooling of the matte

significantly, allowing enough time to elapse in the critical temperature ranges for fractional crystallisation to take place. During the process, metal alloy crystallises out as a distinct phase, forming magnetic platelets that contain the bulk of the PGMs.

After removal from the moulds, the converter matte (WACM) ingots are broken up using a pingon, then crushed through a jaw and cone crusher to produce a product suitable for further treatment at the MC Plant. After crushing and milling, the platelets can be removed from the bulk of the material by magnetic separation in the MC plant.

Slag Cleaning

The slag-cleaning furnace (SCF) is a 12 m-diameter round furnace, designed by Pyromet, rated at 30 MVA (23 MW). Three Söderberg electrodes, each 1 400 mm in diameter, deliver power into the bath at currents up to 80 kA. The high currents are required due to the high conductivity of the slag. The resulting high slag temperatures led to the design choice of water-cooled copper sidewalls in the form of Pyromet Maxicoolers. This maximises energy removal, and eliminates the need for annual refractory repairs.

The hearth and matte areas are bricked with chrome-magnesia refractory bricks. The furnace has a flat roof constructed of super-duty alumino-silicate bricks suspended from a steel grid by means of metal anchors.

WACS is stored in a 4 500 t silo, and is transported via conveyor to one of four feed bins above the furnace roof. Two concentrate feed bins are filled pneumatically from the concentrate silo or directly from the Flash Drier 4 product bin. The remaining feed bin is filled via conveyor with a mixture of silica and reductant (typically coke) at a pre-determined ratio. From each bin, a screw conveyor supplies material to the vibrating feeder that gravity feeds the furnace via a knife gate valve that seals the furnace feed port when no feeding is taking place.

Because WACS is highly oxidised, reductant addition is needed to reduce the metal oxides to metal. In addition, a sulphur source is needed to form metal sulphides, in order to collect the metal in a matte phase. This is achieved by the addition of either concentrate or furnace matte. The latter can be added as crushed or granulated material through the dry feed system or as molten matte from the six-in-line furnaces through a charge port near the roof of the slag-cleaning furnace. Silica is added to the furnace to modify the slag properties, significantly reducing the electrical conductivity of the slag so that acceptable electrode immersion can be achieved.

A combination of WACS, concentrate, reverts, silica, and coke is roof-fed to the furnace; the feed ratios calculated to maximize metal recoveries. All the concentrate, coke, and silica, as well as the bulk of the WACS is fed into the delta section of the furnace, while additional WACS can be charged via six feed

ports distributed on the furnace circumference to help maintain wall temperature and freeze-lining thickness.

Matte is tapped batch-wise, as required, through two tap holes situated on the north side of the furnace, and slag through two tap holes situated on the south side. Matte is sent to the granulation section to be processed by the ACP, and slag is granulated and processed further in the slag mill.

The off-gas, carrying dust and SO₂, is treated in the gas cleaning plant. The plant consists of three towers that scrub out the particulates and SO₂ using a caustic solution.

The first tower, commonly referred to as the quench tower, reduces the gas temperature to 80°C as well as removing most of the solids. A venturi valve is situated in the duct between the quench tower and the venturi tower. This assists in controlling the pressure drop across the two towers thus ensuring good contact between the caustic solution and the gas, assisting formation of a weak sulphuric acid solution.

The sulphuric acid then reacts with the sodium hydroxide in solution to form sodium sulphite, which readily oxidises to sodium sulphate, generating sulphuric acid in the process.

The final tower, known as the alkali tower, scrubs out the remaining SO₂ and particulate matter, ensuring 96% efficiency across the plant. The slurry consisting of dust, sodium salts, and weak sulphuric acid, flows counter current to the gas stream in a series of underflow settlers below each tower, before finally being sent to the flue-dust thickener via the acid neutralisation section.

Slag Milling

The granulated six-in-line and SCF slag are separated from the bulk of the granulating water by rake classifiers. Classifier product is conveyed to the horizontal dewatering screens, and the dewatered slag stored in the slag mill silo, while classifier overflows are pumped to dedicated thickeners for further treatment.

Slag is fed from the silo to a ball mill with a closed-circuit cyclone to achieve a tank cell flotation feed with a particle size of 60 to 75% passing 75 µm. The design mill feed rate is 100 t/h, resulting in a residence time of approximately 13 minutes in the flotation circuit. The current feed rate varies from 60 to 70 t/h.

The flotation circuit is currently in an optimization phase, after installation of new equipment.

The circuit consists of two 30 m³ cascading Outokumpu tank cells, followed by 14 flotation cells, currently functioning as a single rougher bank. Concentrate is pulled from each of the two tank cells and every flotation cell, then sent to the

flue dust thickener. Tailings from the flotation cells are pumped to a tailings dam.

The underflow from the flue dust thickener is pumped to the dedicated high-rate thickener. The underflow from this thickener is filtered on a horizontal belt filter. The belt filter discharges its filter cake directly into the concentrate shed.

Acid Plant

Originally, a Lockwood-Greene-Petersen combined conventional contact plant and Peterson-Fattinger system (Tower plant) was installed to treat both converter and six-in-line furnace off-gas. The contact plant has recently been upgraded to a Monsanto Enviro-Chem double-contact-double-absorption acid plant, and the section is currently being optimized.

Contact Plant

The high SO₂ strength converter off-gas is passed through a gas cleaning section consisting of a pre-quench and post-quench tower, followed by a jet scrubber and finally three electrostatic mist precipitators operating in parallel. This cools the gas down to around 30°C and removes most of the entrained solids from the stream.

The main acid-plant blower drafts the gas through the gas conditioning section, where it is diluted with air or electric furnace off-gas to around 10% SO₂. The diluted gas stream is then contacted with 65% H₂SO₄ in the pre-drying tower, to reduce the moisture content to approximately 1% by volume. The partially dried stream is contacted with 96% H₂SO₄ in the post-drying tower to reduce the moisture content to <77mg / Am³, then passed through a set of demister pads to remove any entrained acid droplets.

The gas stream exits the blower under pressure, at a temperature of 120-140°C. The feed gas is heated in the cold heat exchanger by indirect contact with gas exiting the fourth pass of the converter, then passes through the hot heat exchanger, where the heating medium is gas moving from the first to the second pass of the converter. This heats the feed gas to approximately 420°C, before it moves into the first pass of the converter.

The converter consists of four packed beds (passes) of vanadium pentoxide (V₂O₅) catalyst. In the first pass, approximately 69% of the SO₂ is converted to SO₃, raising the gas temperature to 614°C⁵. The gas is cooled to 435°C in the hot heat exchanger before entering the second pass. Here, further conversion raises the temperature to 503°C and the overall conversion to 92.8%. The gas leaving the second pass is again cooled to 435°C, this time in the hot inter-pass heat exchanger, before entering the third catalyst pass. Here the further conversion of SO₂ to SO₃ raises the temperature to 447°C and the overall conversion to 97.2%.

At this stage, the high $\text{SO}_3 : \text{SO}_2$ ratio in the gas inhibits further conversion. The gas is therefore cooled in the cold inter-pass heat exchanger before entering the inter-pass absorption tower, where SO_3 is absorbed in 98.5% H_2SO_4 .

The gas leaving the tower is passed through a set of candle mist eliminators to reduce the acid mist content of the gases to $<35 \text{ mg} / \text{Am}^3$, then reheated in the cold and hot inter-pass heat exchangers to 425°C , before entering the fourth stage of the converter. Here, approximately 97% of the remaining SO_2 is converted to SO_3 , bringing the overall conversion to approximately 99.91%.

The tail gas leaving the converter is cooled in the cold heat exchanger, and then further cooled in an air-cooled FAT to less than 200°C , before entering the final absorption tower. Here, the gas is absorbed in 98.5% H_2SO_4 , then passed through candle mist eliminators to remove entrained acid droplets. The final tail gas is vented to the atmosphere via the stack at $<100 \text{ ppm } \text{SO}_2$.

The concentration of 96% H_2SO_4 in the post-drying tower acid circuit, and 98.5% in the inter-pass absorption tower circuit, is maintained by means of two cross-bleed streams between them and by the addition of tower plant acid at 70-76% H_2SO_4 , or alternatively potable water, to the acid circuit at the inter-pass absorption tower. The concentration of 98.5% H_2SO_4 in the final absorption tower acid circuit is maintained by means of potable water addition.

Product acid from both absorption towers is cooled in Alfa Laval plate coolers. Acid generated in the final absorption tower is pumped to the inter-pass absorption tower circuit on a level control basis, while product acid at the inter-pass tower is removed to acid storage by level control to maintain the amount of acid in the circuit.

Tower Plant

The tower plant is essentially a low SO_2 strength scrubbing plant that produces a low-strength sulphuric acid.

Electric furnace gas is drafted continuously through a dedicated gas cleaning plant at a strength of 0.5 to 1.9% SO_2 . The gas cleaning equipment is practically identical to the converter gas cleaning section described above, though with a slightly lower solids-handling capacity.

The cleaned gas is drafted across the site to the new acid plant area where the gas conditioning area removes water prior to the tower plant blower. The dried gas is discharged into the de-nitration section of the tower plant. The incoming SO_2 is partially absorbed and is used to strip nitrogen oxides (NO_x) out of the counter-flow product acid to produce a nitric free product acid at 70-76% H_2SO_4 . This acid is used both to make up the drying acid level in the contact plant and for blending with high-strength acid or oleum to produce 98% H_2SO_4 .

The gas stream leaving denitration carries off the remaining SO_2 and the stripped NO_x and is passed through a balancing vessel to establish an $\text{NO} : \text{NO}_2$

ratio of 1 : 1 that is critical for subsequent recovery of NO_x. The gas then enters the acid generation tower where the remaining SO₂ is absorbed to produce a strengthened nitrosyl sulphuric acid (a combination of sulphuric and nitric acid formed in the presence of SO₂ and NO_x).

Finally, the SO₂-free gas is ducted to the NO_x absorption plant consisting of three vessels in series. In two of the towers, chilled nitrosyl sulphuric acid is sprayed counter current to the NO_x laden gas, absorbing the NO_x for re-use in the acid generation step. The final absorption tower has a peroxide spray to remove any residual NO_x prior to stacking. The final gas must contain less than 10 ppm SO₂ and 100 ppm NO_x, to meet emission targets.

CONCLUSION

The Waterval Smelter Complex is one of the largest primary platinum smelting facilities in the world. With its innovative application of both new and proven technologies, and its amazing crew of smelter giants and magicians past and present, some already legends in the industry, the Smelter is set to meet the challenges of this new era and prove its claim to being the world's premier platinum smelter.

ACKNOWLEDGEMENTS

This paper is published by permission of Anglo Platinum. The contributions of fellow metallurgists and other colleagues are gratefully acknowledged.

REFERENCES

1. R.G. Cawthorn, The platinum and palladium resources of the Bushveld Complex, *South African Journal of Science*, Vol.95, 1999, pp.481-489.
2. J.C. Mostert and P.N. Roberts, Electric smelting of nickel-copper concentrates containing platinum group metals at Rustenburg Platinum Mines Limited, *Journal of South African Institute of Mining and Metallurgy*, Vol.73, No.9, 1973, pp.290-299.
3. R.T. Jones, Platinum smelting in South Africa, *South African Journal of Science*, Vol.95, 1999, pp.525-534.
4. Technical Services Division, Anglo Platinum Management Services, Process Division Technical Review, 2003.
5. Grinaker-LTA Process Engineering Limited, ACP Acid Plant Rectification Project, 2005 *Metallurgy Operators Conference*, 2005.