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Process Description and Short History of Polokwane Smelter

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Abstract
Anglo Platinum's Polokwane Smelter is situated outside Polokwane, in the Limpopo Province of South Africa. Wet concentrate is received from various concentrators along the Eastern Bushveld Complex, with 60% of the total concentrate received being from UG2 reef and 40% from Merensky reef. The concentrate grade differs from 35 g/t to 110 g/t, and from this a PGM-rich nickel-copper matte is produced. The furnace matte produced is sent to the ACP converter in Rustenburg.

The Anglo Platinum concentrators, from which concentrate is received, are Lebowa, Potgietersrus, Amandelbult, and Union, as well as the joint venture Modikwa. The concentrate is fed to two flash dryers that utilise coal-fired, fluidized-bed hot-gas generators to produce the hot gas that will drive off the moisture, leaving a fine bone-dry concentrate to feed to the furnace. The dry concentrate is pneumatically transferred to a storage silo before being transferred to the feed bins situated above the furnace. Lime, if required as a flux, may be transferred separately to the furnace feed bin by a pneumatic system.

The concentrate and lime is fed from the feed bins onto airslides and into the furnace. The feed rate is automatically controlled, and the system is set up to optimize the power to feed ratio. The electric furnace is nominally rated at 68 MW and the power is transferred into the furnace using six 1.6 m diameter Söderberg electrodes. Concentrate is melted by energy generated when electric current passes through the electrodes and resistive slag layer. On melting, two immiscible phases form: slag and matte. Furnace matte, containing the bulk of the base metal sulphides and PGMs, is denser than slag and collects naturally at the bottom of the furnace. The furnace is constructed of a combination of refractory brick and water-cooled copper coolers. The furnace sidewalls and hearth are cooled by air drawn through the area by cooling fans. The hearth and matte zone are constructed from refractory bricks. The copper coolers reside only in the slag zone of the furnace along the entire perimeter of the furnace. One staggered row of plate coolers is installed above the waffle coolers along the perimeter of the furnace.

Matte is tapped periodically through one of the two matte tapholes into 35-ton refractory-lined ladles, and cast into matte ingots on a casting machine. The cooled matte is discharged onto a concrete slab for cooling and then transferred by front-end loaders to the crushing plant. The matte is first crushed in a jaw crusher and

then a Rhodax cone crusher to a size of 2 mm before it is loaded into tankers and sent to the ACP.

The low-grade slag is tapped from the furnace through a water-cooled copper insert into a short water-cooled copper 'hot launder' which discharges into a granulation cold launder. The granulated slag slurry flows to three rake classifiers, from which the coarse slag is discharged onto a conveyor to dewatering silos. The dewatered slag from the silos is dumped. The water overflow from the classifiers reports to two thickeners where the water is clarified, and the thickener underflow is returned to the rake classifiers. The smelter is a zero-effluent plant and all the water from the slag silos where the slag is dewatered, as well as the storm water, is pumped to the process water dam from where it is pumped back into the plant for process water use.

The off-gas from the furnace is drawn through a forced draught cooler and into a high temperature baghouse. The dust collected in the baghouse is pneumatically transferred into bins above the furnace and is fed via the concentrate airslides. The cleaned off-gas is then vented through the main stack.

INTRODUCTION

Polokwane Smelter is the only platinum-producing smelter on the Eastern Limb of the Bushveld Complex. Anglo Platinum's longer-term expansion plans include the development of several mines and concentrators on the eastern limb, and the smelter was designed to treat the arisings from these concentrators. For a general discussion of the smelters of the Southern African platinum producers see Jones.[1]

The smelter is situated approximately 15 km south of Polokwane, on the Palmietfontein Farm on the Burgersfort Road in the Limpopo Province in South Africa. Wet concentrate is received from various concentrators along the Eastern Bushveld Complex, with 60% of the total concentrate received being from UG2 reef and 40% from Merensky / Platreef. The concentrate grade (Pt) differs from 35 g/t to 110 g/t, and from this a PGM-rich nickel-copper matte is produced. The furnace matte produced is sent to the ACP converter in Rustenburg.

The focus of this paper is on the process description, auxiliary equipment, and some metallurgical considerations, as a detailed account of the furnace has been provided in a previous paper by Ndlovu *et al.*[2] A simple schematic of the operation is provided in Figure 1.

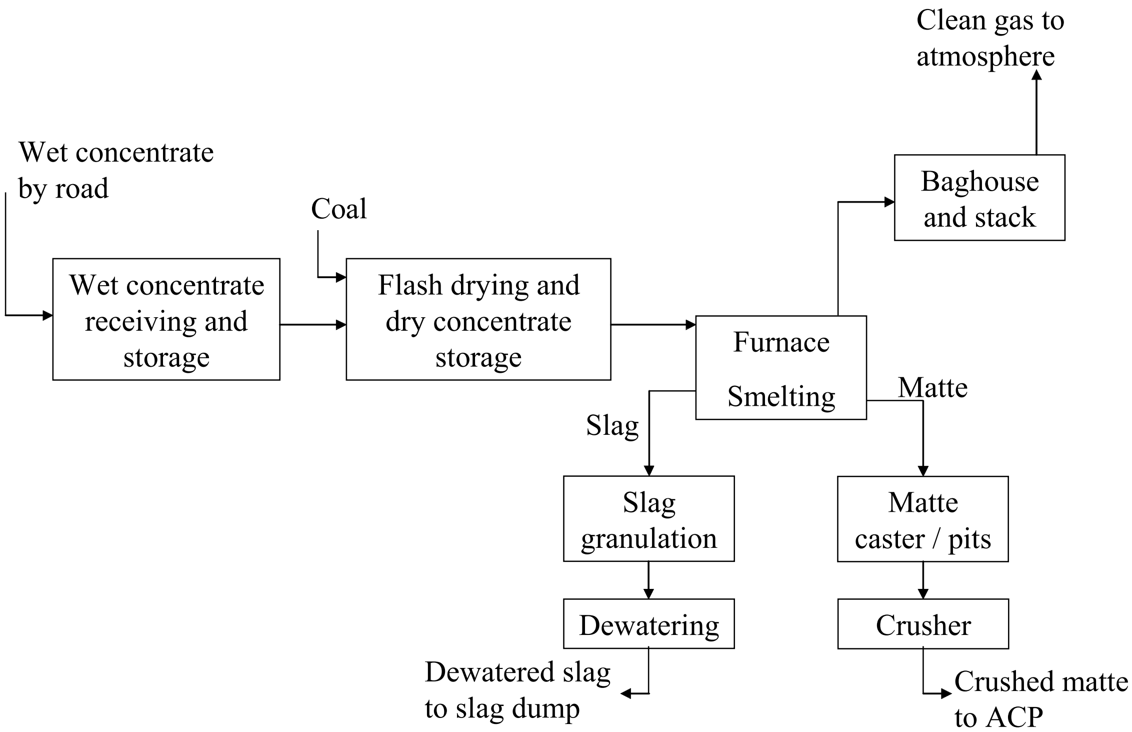

Figure 1: Simple schematic of Polokwane Smelter operation

The smelter has been in operation since March 2003. The ramp up of the furnace went extremely well.

PROCESS DESCRIPTION

Concentrate receiving and flash dryers

Concentrate is received by road from the various concentrators within the Anglo Platinum group. The majority of the concentrate (~50%) is received from Potgietersrus Platinum Limited (PPL), with other receipts made up by Modikwa Joint Venture, Lebowa Platinum Mines, and, on occasion, concentrate from Amandelbult and Union sections. The wet concentrate varies in moisture content from 12-18%. Metal accounting is carried out by means of a weighbridge and auger samplers, with samples being analysed in the on-site robotic laboratory.

The concentrate is offloaded in a covered shed. Concentrate can either be dumped directly from the truck through a grizzly to a hopper, or a front-end loader may be used. The concentrate is conveyed up to 12 concrete silos (with a total capacity of 10 000 t). The silos were designed to allow for individual storage of the various types of concentrates, in order to facilitate blending of concentrate prior to feeding to the flash dryers.

Two identical flash dryers (Drytech design) are employed at Polokwane Smelter. The units are nominally rated at 80 t/h (wet) each. Hot gas is generated by means of coal combustion in a fluidized sand bed in the hot-gas generator (HGG). The gas, at a temperature of 600-700°C, is drawn co-currently with the wet concentrate up a drying column. Separation of the dried concentrate is achieved through three cyclones, a multiclone, and a high-temperature baghouse. The dry concentrate reports to a dry product bin (500 t capacity), from where it is pneumatically transferred to a 3 000 t silo.

Coal for the flash dryers is received by road, and is screened before being conveyed to a coal silo. From here it is pneumatically conveyed to the HGG coal feed bins.

Furnace

The technical aspects of the furnace design and operation have been discussed at length by Ndlovu *et al.*[2], and will not be repeated here in the same amount of detail. The six-in-line furnace is of Hatch design, and is unique to the platinum industry in that it is the largest capacity furnace, as it is rated nominally at 68 MW (168 MVA). The furnace is designed to treat 650 000 t/a of concentrate at an operating factor of 90%. The smelter achieved design monthly throughput for the first time during August 2005.

Concentrate from the 3 000 t silo is pneumatically transferred up to two feed bins (150 t capacity) above the furnace. The concentrate is fed into the furnace via airslides and double flap valves. The feed is controlled by means of an automated control system that matches the feed rate to the power input and energy losses (calculated by an on-line energy balance).

The electrical supply to the furnace is via six Söderberg electrodes of 1 600 mm diameter, and three single-phase transformers, each with a rating of 56 MVA. Electrode currents are kept in the region of 35-45 kA, which results in furnace operating resistances of 8 – 12 mΩ (and electrode immersion depths around 20-40%). The operating resistance is set according to the operating power of the furnace. There is the ability to operate at considerably high currents in order to obtain deep electrode immersions, however, the physico-chemical properties of the slag and matte have not necessitated this. Experience over the past three years has shown that excellent separation of matte and slag is obtained even with consistent chromium contents of 3% in both molten phases. The good separation is attributed mainly to the high operating temperatures of both phases, where slag operates at 1600 – 1700°C and matte at 1450 – 1550°C. This is achieved both with and without the addition of lime or limestone. Approximate compositions of slag and matte are provided in Table I. As can be seen from the compositions provided in the table, the base metal losses in the slag are low and very little matte remains entrained.

Table I: Approximate compositions of Polokwane matte and slag, mass %

Component	Slag composition	Matte composition
Al_2O_3	5	
CaO	5 (10 with lime addition)	
Co	0.001	0.35
Cr_2O_3	2	2-3
Cu	0.06	9
Fe		40
FeO_x	11	
MgO	23	
Ni	0.07	15
S	0.3	30
SiO_2	52	

The slag is tapped from the furnace through three water-cooled copper inserts and slag tap-block arrangements (65 mm hole diameter). The slag tapholes are opened by means of a mud-gun drill, and oxygen lancing is very seldom necessary. The slag is tapped onto a short water-cooled copper launder before falling into the water launder. Rake classifiers are employed to separate the slag and water. The slag is conveyed to two dewatering silos and thereafter placed on a slag dump. The water handling and recovery system is discussed later in a separate section.

Matte is tapped from the furnace through brick-lined, water-cooled copper tap-blocks. The refractory tapping modules have a hole diameter of 38 mm. Originally, only two matte tapholes were installed; however, in order to increase the overall availability of the furnace, a third matte taphole has recently been installed. The tapholes are situated approximately 48 cm above the centre line of the hearth.

The off-gas from the furnace (typically 500-700°C) is withdrawn from the furnace, either on the matte or slag end, through 2 m diameter ducts. The gas passes through a forced draught cooler before reporting to a high-temperature baghouse with four compartments. The dust that drops out in the forced draught cooler and the baghouse compartments is pneumatically transferred back to bins above the furnace roof, from where it is fed back into the furnace. The dust recycle is of the order of 5% of the total feed to the furnace. The draught on the furnace is controlled at –20 Pa. The cleaned gas is vented to the atmosphere through a 165 m high stack.

All fumes from tapping operations, on both the matte and slag ends, are captured by means of fume-hoods, and vented via a separate secondary off-gas system up the main stack.

Furnace refractory and cooling system

The details of the furnace refractory and cooling system have been discussed in a previous paper.[2] Briefly; the furnace consists of a mag-chrome brick hearth and matte zone. The sidewalls consist of Hatch-designed water-cooled copper waffle coolers. The upper sidewall contains magnesite bricks, and plate coolers, and above that there are super-duty bricks and a high-alumina roof.

There has been media coverage of the two failures of the waffle coolers in August 2004 and September 2005. The mechanism for the failure of the coolers is corrosion of the copper by sulphur and possibly chlorine. The labile sulphur in the furnace feed is suspected to be the major contributor to the corrosion. The area of corrosion is localized to the slag – concentrate bed interface, and eventually causes wear back to the water piping that is cast into the copper coolers.

Advanced techniques are now being used to determine the thickness of the copper coolers, and trials are taking place with various other materials of construction.

Matte handling and crushing

The matte is tapped into refractory-lined ladles (35 t capacity). A trolley car is used to move the ladles from under the ladle fume-hood, and an overhead crane then either transports the ladles to the matte caster, or the matte is directly cast into sand pits.

The matte caster makes use of a hydraulic tilter which pours the matte into a spill-box that overflows into the caster moulds. The moulds run on a chain, and are then spray cooled with water to cool the matte. The cooled matte is discharged from the moulds onto a pad by means of a mechanical hammer. The empty moulds then run back, are spray coated with a carbon-based mould wash and dried with an LPG burner.

The matte from the sand pits, when solidified, is removed using a front-end loader, and broken up with a pingon. The ingots and pieces of broken matte are fed through a grizzly into a jaw crusher. The crushed matte is conveyed to a Rhodax crusher where it is further reduced to –2 mm. The crushed product is conveyed to a screen with the oversize returning to the Rhodax crusher, and the undersize reporting to a product bin. The final crushed matte is pneumatically conveyed to a 500 t silo from where it is loaded into road tankers that transport the matte to the ACP at Waterval Smelter in Rustenburg for converting.

Water handling and recovery

Polokwane Smelter was designed to be a zero-effluent operation. All water used in the operation (apart from evaporative losses) is recovered either in thickeners or via a system of dams.

The slag granulation water is recycled as follows: the water containing slag is pumped to a high-rate thickener, with the overflow going to a conventional thickener, and its overflow going to the cooling tower and supply sump. The underflow from the thickeners is combined and is pumped back to the rake classifiers for further solid separation. The granulation water is cooled by means of six Evapco coolers, and evaporative losses are made up by process water. The water from the slag dewatering silos may be returned either to the slag granulation water circuit or to the process water circuit. Any water that drains out from the slag dumps is collected in dedicated dams and is returned into the process water circuit.

Process water comprises rainwater runoff from the plant, water from the slag dewatering silos and pads, and is topped up with potable water from time to time. Process water is used for cleaning concentrate and other trucks, to make up the slag granulation water, and for other general washing purposes. Any washings from the plant are collected in a conventional thickener. The thickened slurry is filtered using a Larox filter. The filter cake from the Larox is conveyed onto the main wet concentrate conveyor and is thus recycled.

A comprehensive on-line water balance is employed to ensure efficient use of this natural resource. The usage of potable water is monitored continuously, and alarmed when above set flow limits.

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