Improvements to the Anglo Converting Process (ACP)  

tap-block management

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The Anglo Converting Process (ACP) forms part of the Anglo American Platinum smelting operations based in South Africa. The ACP converting vessels are two identical circular furnaces, each with one slag and two matte tap-holes. Each tap-hole has three graphite inserts, with a 75 mm tapping channel through which the molten material flows. Planned shutdowns at ACP are driven by maintenance requirements for replacement of the graphite inserts and sacrificial steel faceplates. Initiatives to extend the life of slag tap-hole graphite inserts started in 2010 and included measuring insert dimensions and tolerances and ensuring that there were no gaps during installation. From 2013, after internal benchmarking with other smelting operations, smaller drill bits were used to open the tap-holes and in 2014 drilling the slag tap-holes open was implemented. In 2016, the specifications of the graphite inserts were evaluated and improved further. Combined, these initiatives have extended the graphite inserts’ life, and the maintenance interval for tap-hole repairs has been extended, thereby delivering improved availability on the ACP.

Keywords: tapping channel, tap-hole, graphite inserts, slag.

INTRODUCTION

The Anglo Platinum Converting Process (ACP) is located in the Waterval Smelter complex in Rustenburg, North West Province, South Africa. ACP is where all the various Anglo American Platinum streams converge, making it a crucial part of the platinum pipeline. The converting furnace is based on the Ausmelt technology and consists of a top submerged lance configuration (Figure 1). Matte from the four primary electric smelting furnaces of Anglo American Platinum is injected down the converter lance together with oxygen-enriched air to produce an Fe- and S-deficient high-grade matte. The process is continuous and converts the approximately 40% Fe in the furnace matte down to approximately 3% Fe in the converter matte product.

There are two converters, viz. phase A (commissioned in 2002) and phase B (commissioned in 2006). Each converter comprises an air-cooled hearth system, a water-cooled crucible (a low-pressure waffle copper cooler in a circular arrangement), and a high-pressure boiler system with their individual auxiliaries. Each furnace is operated for 2—3 years while the other is on maintenance. Converter matte is tapped and slow-cooled in the slow-cool aisle before it is crushed and sent to the Rustenburg Base Metal Refinery for further processing. The slag tapped from the sole slag tap-hole is granulated, dried, and sent to the slag cleaning furnace (also located in the Waterval complex) for recovery of the base metals and platinum group metals (PGMs) in the converter slag (Viviers and Hines 2005). The converting process produces an SO2-rich off-gas, which is treated at the acid plant to produce sulphuric acid.
FURNACE OPERATION

Matte is tapped from the furnace through two tap-holes (Figure 2). The matte tap-hole elevation is in line with the top of hearth skew so that all the molten matte can be tapped out, while slag is tapped at the opposite side. The slag tap-hole elevation is 800 mm higher than the matte tap-holes and slag is tapped out of the furnace using a single slag tap-hole.

Tap-hole opening is conducted using a drilling machine and oxygen lances. The tapping channel is drilled to 500 mm, and the remainder is then lanced open. At the slag tap-hole, the tapping channel is drilled open and instances where lancing is required are seldom.

![Figure 1. Converter lance internal view.](image1)

![Figure 2. Location of the tap-holes.](image2)

(1) Planned maintenance shutdowns at ACP are generally scheduled around the lifespan/integrity of the tap-hole graphite modules, referred to as ‘inserts’. In particular, the slag tap-hole graphite inserts are of concern since these wear faster than to the inserts installed in the matte tap-holes. There is a distinct difference in the slag tap-hole channel between the phase A and phase B converters in that the insert sizes of phase A are smaller than those of phase B. The hole diameters (75 mm baseline) are identical and the tap-hole channel lengths are approximately the same. Poor insert integrity poses a number of safety risks, with the possibility of molten material coming into contact with the water-cooled copper tap-block and resulting catastrophic failure of the tap-block,

(2) Excessive wear of the insert hole causes high slag flow into the granulation tank, which affects the water to slag ratio in the granulation and thus results in poor slag granulation. Typical slag flows range between 3–5 t/min. Slag flow rates greater than 5 t/min are considered high and pose the risk of ‘bangs’ due to low water: slag ratio.

(3) The use of mud guns to close a running tap-hole introduces an additional risk in that the mud gun may not have sufficient pressure (typical mud gun pressure is 120–150 bar) to successfully plug the tap-hole with tap-hole clay, as a result of excessive wear in the hole.

This paper focuses on the work done to improve the lifespan of the graphite inserts in order to extend campaign life. The campaign life in the context of this paper is the period between slag insert change.
**TAP-HOLE DESIGN**

The ACP tap-hole channel is 535 mm deep. The operation is forced to stop and the converter has to be drained completely (typically 5 hours), blown cold, and drilled safe before inserts can be changed. By comparison, on the primary six in-line furnaces there is provision to maintain power on during shallow slag tap-hole repairs, which is not possible on the ACP converter due to the size of the tapping channel. The slag and matte inserts are identical, consisting of three graphite blocks. The design of the tap-block is such that the graphite inserts form a conical shape when installed, viz. shapes BB, CC, and DD (identification codes) (Figure 3) for phase A and shapes X, Y, and Z (Figure 4) for phase B slag side. A very thin layer of Jadeset is applied between each block during installation to plug any small gaps that may exist between the graphite inserts on installation. The inserts sit in a copper host block that is water-cooled.

![Figure 3. Graphite blocks phase A slag.](image)

![Figure 4. Graphite blocks phase B slag.](image)

The insert dimensions for phase A and phase B are shown in Table I. The phase B inserts are significantly larger in diameter than the phase A graphite inserts, due to the different slag copper block design.

<table>
<thead>
<tr>
<th>Graphite inserts</th>
<th>Phase A</th>
<th>Phase B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min. diameter (mm)</td>
<td>Max. diameter (mm)</td>
</tr>
<tr>
<td>Shape BB</td>
<td>150</td>
<td>175</td>
</tr>
<tr>
<td>Shape CC</td>
<td>175</td>
<td>200</td>
</tr>
<tr>
<td>Shape DD</td>
<td>200</td>
<td>224</td>
</tr>
</tbody>
</table>

**INSERT CHANGE LOGGING AND REPORTING**

Following an ACP incident in 2010 that resulted in damage to the phase B furnace due to poor insert installation, one of the actions was for the technical team to manage tap-hole maintenance and repairs. Over the years, the data collected and parameters measured have ensured that the sense of consistency is passed on from metallurgist to metallurgist. This information, coupled with innovations and testing of new materials or standardizing, has seen a positive shift in tap-hole campaign life. The metallurgists have also improved the log sheet over the years and increased the level of detail being captured.

The log sheet provides benefit in that when metallurgists are rotated into the tapping floor section, it makes it easy to capture the measurements on a consistent basis. It is also used to track insert change history in terms of measurements or any defects. It provides
new metallurgists with a learning ground in making decisions and understanding the importance of the tapping process.

The log sheet entries start with measurements of each new block that is ready to be installed. It contains the design length and diameter to help guide the actual measurements. This assists in eliminating supplier errors and proactive decision-making if the inserts are of incorrect size.

Photographs are taken before and after each block is broken out and hole diameters are measured. The pictures are useful in aiding decision-making if there is a problem at startup. Measurements are then taken of each new block installed. Here again the design measurements are contained to guide the installation process, thus rectifying deviations immediately.

A report is then compiled by the metallurgist using the information and deviations explained. The log sheet is then signed off by the metallurgical and section engineers.

**SLAG INSERT LIFE**

The insert life has been a journey of continuous improvement from when the converters were first commissioned in 2002 (phase A) and 2006 (phase B). The insert lifespan has significantly increased over the years through various interventions that the technical metallurgists have implemented. The focus of this paper is on interventions from 2013 to 2017.

**Standardized Drill Bits**

In 2012 the slag inserts lasted only 65 taps (approximately 2 weeks) before needing replacement. At that time, the operating philosophy was to drill with the mud gun to a depth of 500 mm and then oxygen lance the tap-hole open. The slag-side drill bit diameter was 52 mm. Since the tapping rates increase as the tapping channel diameter increases, a smaller drill bit of 45 mm diameter was trialled. The rationale behind this change was that starting with a smaller hole diameter would prolong the time taken for the graphite insert hole diameter to reach a critical size. The critical diameter is defined as the diameter at which the slag flow rate is greater than 5 t/min.

The change to a smaller drill bit increased the insert campaign life from 65 taps to about 110 taps.

**Drilling Open Philosophy**

In 2014 it was realized that oxygen lancing was causing significant wear to the inserts, especially the two deeper inserts. To mitigate this, elimination of oxygen lancing on the slag tap-hole was proposed, and as a result the drilling-open approach was adopted. Drilling open offered three benefits; firstly, it eliminated the use of high-pressure oxygen lancing, which posed a safety risk; secondly, it eliminated the risk posed by operators lancing skew, and possibly lancing the water cooled tap-block; and lastly, it minimized damage to the inserts from lancing. Drilling open was found to be successful and improved the insert campaign to 130 taps (approximately 4 weeks).

**Finer Grained Graphite Inserts**

In mid-2015 finer grained graphite was trialled as a possible replacement to the coarser grained graphite traditionally used. The grain size is 17 times smaller than the coarser grain inserts, which makes the material more compact. Although both types of insert have similar thermal conductivities, the finer grained graphite has significantly higher compressive strengths due to it being more compact (Table II). This reduced the wear
rate of the material. Initial trials were hampered by slag faceplate damage which resulted in premature failure of the first graphite insert, thus the improvement resulting from the first insert could not be quantified. The trials became more fruitful from November 2015 with evidence from the hole diameters and slag flow rates, increasing insert life.

Table II. Specifications of inserts.

<table>
<thead>
<tr>
<th>PROPERTIES</th>
<th>UNIT</th>
<th>COARSE GRAIN</th>
<th>FINE GRAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max grain size</td>
<td>mm</td>
<td>≤0.8</td>
<td>≤0.045</td>
</tr>
<tr>
<td>Bulk density</td>
<td>kg/m³</td>
<td>≥1.70</td>
<td>≥1.79</td>
</tr>
<tr>
<td>Apparent porosity</td>
<td>%</td>
<td>≤20</td>
<td>≤18</td>
</tr>
<tr>
<td>Bending strength</td>
<td>Mpa</td>
<td>≥13</td>
<td>≥30</td>
</tr>
<tr>
<td>Compressive strength</td>
<td>Mpa</td>
<td>≥30</td>
<td>≥60</td>
</tr>
<tr>
<td>Specific resistivity</td>
<td>μΩm</td>
<td>≤8.5</td>
<td>≤10.0</td>
</tr>
<tr>
<td>Hardness (shore)</td>
<td>HSD</td>
<td>≥20</td>
<td>≥40</td>
</tr>
<tr>
<td>Ash</td>
<td>%</td>
<td>≤0.3</td>
<td>≤0.1</td>
</tr>
<tr>
<td>CTE</td>
<td>x10⁻⁶/°C</td>
<td>≤2.5</td>
<td>≤2.5</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>W/m.K</td>
<td>≥100</td>
<td>≥100</td>
</tr>
</tbody>
</table>

From a review of data from the insert change log sheet, it was established that the inserts would form a conical shape at the end of their campaign life due to wear and tear (Figure 5).

The original insert hole diameter was 75 mm. In 2015, 130 taps were achievable with a 13% increase in hole diameter on the first insert (front face) and a 46% increase in hole diameter on the third insert (back end). The implementation of the finer grained inserts enhanced the insert life to 180 taps for similar wear patterns.

The hole diameters measured across the three inserts from 2015 (Figure 6) and compared to the finer grained graphite inserts hole diameters in 2016 (Figure 7) showed similar results, with greater insert life (130 taps to 180 taps) on the finer grained graphite.
The slag flow rate is the first indicator of the extent of wear of the inserts. As previously mentioned, typical slag flows range between 3 and 5 t/min. The peaks in the slag flows are indicative of the inserts reaching end of life (Figure 8).

Between 2012 and 2013, phase A was operational, and the smaller drill bits reduced the slag flows from an average of 3.6 t/min to 3 t/min and increased the slag taps from 65 to 110.

In 2014 phase B became operational and the slag flow rates increased to an average of 3.2 t/min. This is believed to be due to the different design of the copper slag tap-block, which provides less efficient cooling than the phase A copper slag tap-block. Although the flows had increased, the slag taps also increased, from 110 taps to 130 taps due to
drilling open and eliminating oxygen lancing. In November 2015 the finer grained inserts reduced the average slag flow to 2.9 t/min and also increased the slag taps to 180. Due to the fruitful results obtained from the finer grained inserts in the phase B campaign, it was decided that these be trialled on phase A in 2017. The slag flows on phase A averaged 2.6 t/min, with 180 slag taps.

The finer grained inserts trial conducted from November 2015 resulted in the campaign lifespan increase from 130 taps to 180 taps (Figure 9) and extended ACP shutdowns from 4-weekly to 6-weekly. In some instances the inserts were proactively changed due to other breakdowns that required a shutdown, thus offsetting the trial campaign.
CONCLUSIONS
The campaign life of the tap-block insert on the slag tapping channel at ACP has been increased by 176%, thereby extending the time between shutdowns from 2 weeks to 6 weeks. This was achieved through interventions over 9 years. The move from lancing the slag tap-hole to drilling open, the use of smaller drill bits, and more recently the use of finer grained graphite brought about this improvement.

ACKNOWLEDGEMENTS
This paper is published by permission of Anglo American Platinum. The contributions of our colleagues in technical and production management are gratefully acknowledged.

REFERENCE
http://www.academia.edu/14747517/The_New_Anglo_Platinum_Converting_Project

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