An overview of the design, operation, and maintenance practices relating to tap-hole management of a PGM smelting furnace

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The PGM smelting industry is known for operating at significant high superheats. Both the slag and matte phases that separate via gravity need to be tapped out of the furnace in a safe and efficient manner, which can be achieved only through sound tap-hole management practices. This paper gives an overview of the tap-hole management approach followed in the operations at Lonmin's Western Platinum Smelter.

Five circular AC furnaces are operated, with each furnace comprising essentially a crucible and auxiliary equipment. Within the crucible, slag and matte tap-holes are situated at different elevations. The slag phase is tapped at a higher elevation than the matte phase. At the three older furnaces, tapping is done by the conventional method of lancing open the tap-hole and closing it with a dolly. However, at the two newer furnaces, tap-holes are opened and closed with the aid of a drill and mudgun.

Tap-hole management can be divided in a number of aspects. In order to achieve a safe opening and closure every time, Lonmin distinguishes between three important aspects – the design of the tap-hole system, the operating practices followed, as well as care and maintenance. This paper briefly describes the tapping channel and cooling requirements for handling superheated matte, together with the difference in design of the matte and slag tap-holes. Mention is also made of the importance of auxiliary equipment, which includes the launders, fume extraction, granulation water, and mudgun and drill units. Improvements made to the matte tapblock design are discussed.

The monitoring, alarm, and safety systems related to matte and slag tapping are described. Tap-hole life and different wear mechanisms are mentioned. Tapping can be done safely only if the tap-holes and equipment are maintained properly. Mention is made of the tap-hole refractory repair practices, and the improvements made in order to reduce repair time as well as to extend the time between deep repairs. The importance of the correct tap-hole clay selection in order to nurse the tapping channel after each tap is also discussed.

The paper finally touches on some research and development work that was done in order to improve the monitoring of the condition of the tapblock by means of fibre optic temperature sensors

Introduction

Lonmin's Western Platinum Smelter commenced operations in December 1971 with the commissioning of a 7.5 MVA six-in-line furnace smelting Merensky Reef ore. Since then a number of process changes and improvements have been made to the smelting complex. The latest addition was the 12 MVA Furnace No. 2, commissioned in July 2012.

As can be seen from the smelter process flow sheet in Figure 1, concentrated slurry or filter cake produced from the concentrators is dispatched to the smelter complex. After offloading, the slurry is blended to a base metal range of 3.2–5.5%. Plate filters are used to dewater the slurry to produce a filter cake. The filter cake is then dried through a flash dryer with hot air and stored in silos before it is fed to the furnaces.

The smelting furnaces make use of electrical energy to melt the dried concentrate. As the concentrate melts, two liquid phases form: a lighter magnesium-iron-silicate-based slag, and a denser molten matte. The platinum group metals and base metal sulphides report to the matte phase, which settles to the bottom of the furnace by gravity separation. The matte is tapped from the furnace at a temperature of 1400–1500°C. Five furnaces are used in different combinations to achieve the required production output. The focus of this paper will be on the tap-hole management at 60 MVA Furnace No. 1, which was commissioned in 2002.

The liquid furnace matte is poured into Pierce-Smith converters, where it is further processed to produce a converter matte that is transported to the Base Metal Refinery for further processing.

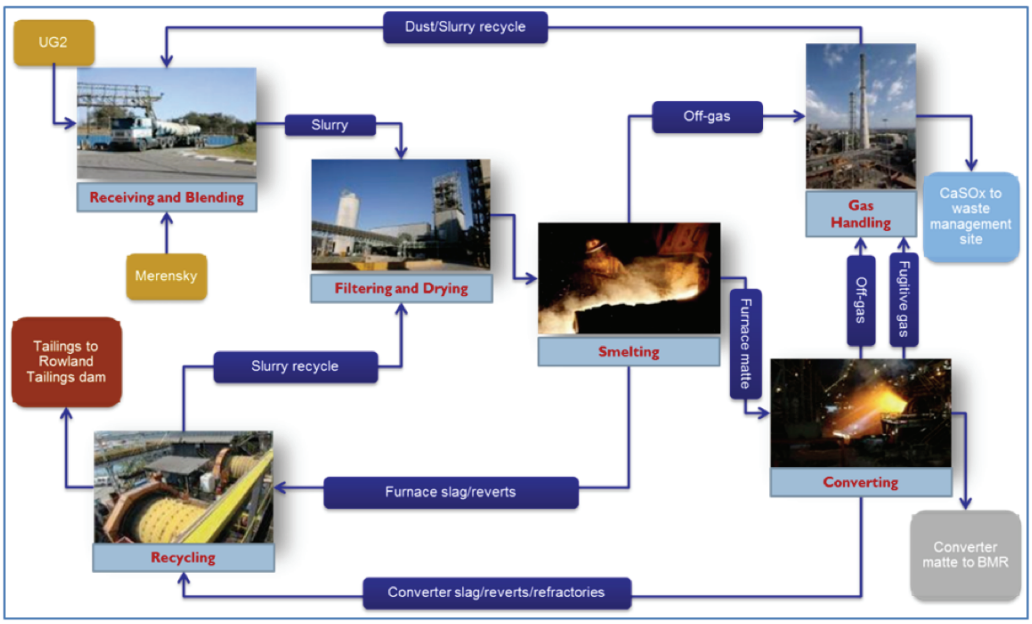

Figure 1. Smelter process flow sheet

The furnace matte and slag are tapped on a regular basis. Tapping needs to be performed as safely and efficiently as possible. In order to achieve safe opening and closure every time, Lonmin's smelting operations distinguish three important aspects – the design of the tap-hole system, the operating practices followed, as well as the care and maintenance of the tap-hole system.

Tap-hole system layout and design

Due to the different physical properties of liquid matte and slag, the tap-hole layout and design are completely different.

Slag tap-hole system layout and design

A total of three deep-cooled copper slag tapblocks are installed at Furnace No. 1 (Figure 2). The slag is in direct contact with the water-cooled copper and a freeze lining is formed between the liquid slag and copper during tapping. The centre of the slag tap-hole is situated 860 mm higher than the centre of the matte tap-hole.

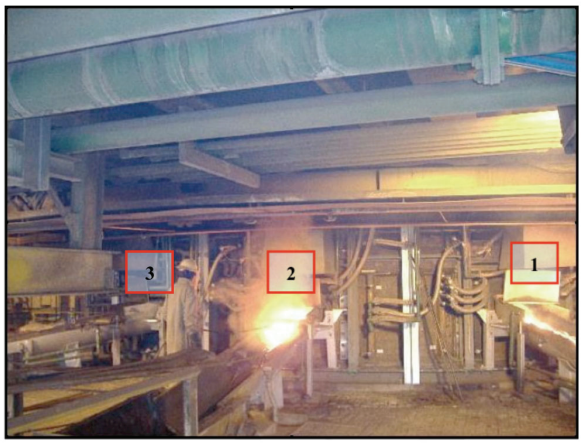

Figure 2. Slag tapblock layout

The slag tapping system (Figure 3) consists of a slag tapblock, slag insert (also known as a 'monkey', and a slag launder. Six thermocouples are used to monitor the copper of the slag tapblock in order to detect any temperature excursions for alarming purposes. The slag insert tap-hole diameter is initially 65 mm and the tap-hole needs to be decommissioned when it is eroded to 80 mm. At an estimated slag thermal conductivity of 1.8 W/mK, the heat flux removal capacity is sufficient to maintain a slag freeze lining, but not to freeze matte. Thus it is important to control the matte and slag levels within the control limits.

A constant supply of cooling water at a velocity 3 m/s is of utmost importance in order to ensure safe tapping of the slag. For this reason, apart from the normal cooling water supply pumps, an emergency header tank as well as a diesel-powered pump, is installed for emergency conditions.

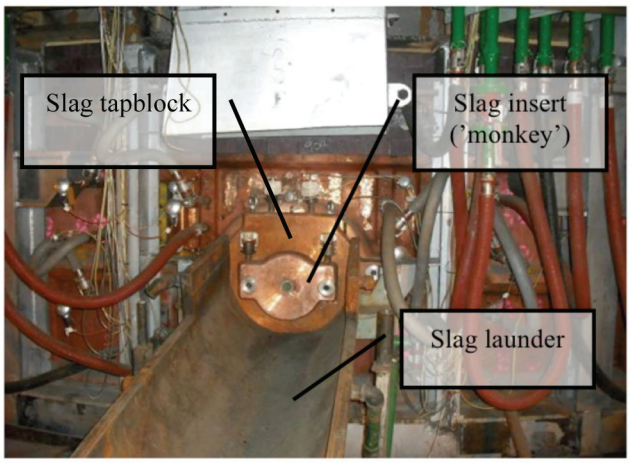

Figure 3. Slag tapping system

The slag launder is constructed of steel and is also water-cooled. The impact area of the slag stream is protected by installing sacrificial refractories in the first part of the launder. The slag that is tapped from the furnace is granulated in a jet of water at flow rate of 800–900 m^3/h (Figure 4). Tapping temperatures range from 1550–1650ºC, depending on the feed composition.

Figure 4. Furnace slag granulation

A mudgun and drill was used for a brief period in 2004 on the slag side to assist with tap-hole opening and closing, but after an incident, the review recommended reverting to the conventional opening and closing of the slag tap-hole. A tap-hole fume extraction hood is installed above each slag tap-hole to limit the exposure of tapping operators to fumes.

Matte tap-hole system layout and design

Furnace No. 1 is equipped with three deep-cooled matte tapblocks. As a result of the high superheat (>600ºC above liquidus) of the furnace matte, it is necessary to deep-cool the tapping channel in order to avoid frequent refractory repairs and resulting production delays. However, not only the tapping channel, but also the area around the tapping channel, needs to be cooled. The matte tapblock is surrounded by flanker coolers on the sides as well as a lintel cooler above, as can be seen in Figure 5. A total of 24 thermocouples are used per tapblock to monitor to hot face copper temperatures.

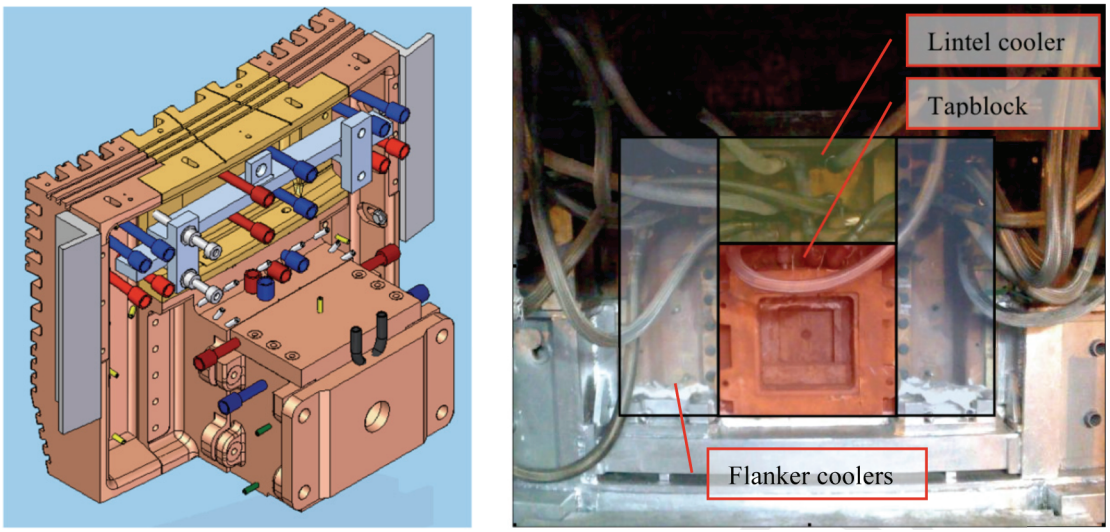

Figure 5. Tapblock and surrounding coolers

Key learning outcomes from tapping incidents led to several improvements to the tapblock design over the years. One of the first improvements, made in 2004, was the extension of the mag-chrome tapping channel length and the introduction of a larger tapping module, called the 'Mickey block'. As can be seen from Figure 6, the original tapping channel was much shorter than the current design. It was difficult to carry out online tap-hole repairs on the short tapping channel design, as the original design consisted of only four tapping modules.

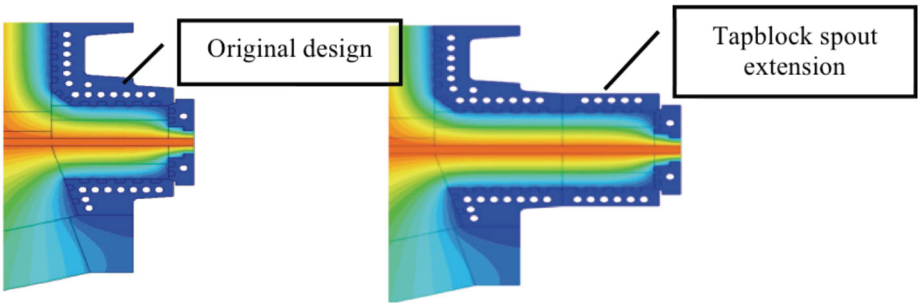

Figure 6. Original and extended tapping channel

The Mickey block with its surrounding blocks was positioned deeper into the furnace in order to protect the copper-cooled area above the tap-hole. Currently, the tapping channel consists of five tapping modules plus the Mickey block. The longer tapping channel of just over 1 m assists in throttling the flow rate as well as enabling more intermediate online repairs to extend the life of the Mickey block.

Originally, the furnace was commissioned with only two matte tapblocks (Figure 7), but a third tapblock was added in 2008 as a second improvement to the tap-hole system. The third tap-hole assisted in increasing the duration between deep tap-hole repairs. An additional benefit is that in the event that a problem is experienced with one of the tap-holes, production can still continue while preparation is made for a deep tap-hole repair.

Figure 7. Two versus three tap-hole layout

Experienced gained during repairs indicated that the area above the matte tap-hole experiences the highest heat flux during and after tapping. This results in a higher wear rate, thus the need for additional cooling and protection in this wash zone area. The risk to the wash zone, which can be seen in Figure 8, was that any high matte level excursion could result in copper damage, as heat fluxes of up to 130 kW/m^2 were measured. This initiated the third improvement, which focused around reinforcing the area above the matte tap-hole.

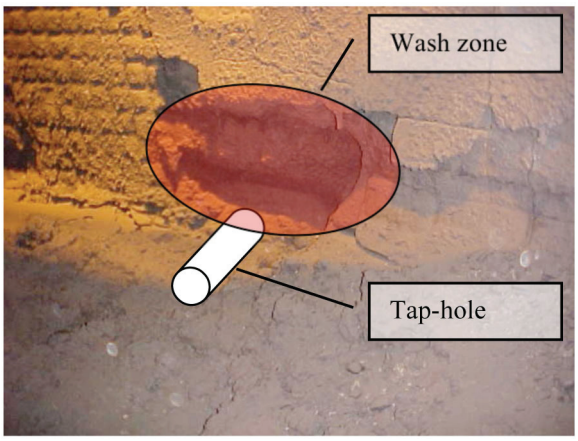

Figure 8. Wash zone above matte tap-hole

A number of design changes were made in this regard. The first was the introduction of a copper-cooled lip in order to cool the refractories above the tapping channel. This worked well, but wear was still experienced on the copper-cooled lip due to both corrosion and erosion. As a result of the success of the graphite cooler design in the slag zone, it was decided to protect the copper above the tap-hole with graphite as well. The alternative design was implemented in 2010 with the introduction of a graphite-cooled copper lintel cooler situated in that wash zone above the matte tap-hole. Results after the furnace rebuild in 2013 indicated that the graphite design lintel cooler performed well. Copper corrosion in the area above the tap-hole still occurred, but to a lesser extent. The corrosion was a result of the loss of graphite contact in some of the areas.

During the 2013 rebuilt a different design of graphite lintel cooler was installed. The graphite is now slotted in horizontally, and it is foreseen that the graphite will maintain contact with the copper during for longer the next campaign.

Auxiliary equipment

Apart from the abovementioned changes on the matte tap-holes, tapping matte from furnaces also requires some auxiliary equipment. At Furnace No. 1, two mudgun and drill units are used to assist in the opening and closing of the matte tap-holes. The design of these units allows for manual as well as semi-automatic operation. In semi-automatic mode the mudgun moves and stops at the selected tap-hole to be drilled or plugged. The lowering, drilling, and plugging action is still left to the tapping operator.

A number of improvements were made to the mudgun and drill units over the years. These included modifications to the positioning limits, moving the clay loading panel further away from the clay loading chamber, introducing a castle key system during clay loading, as well as controlling the units from a dedicated PLC with its own UPS systems.

The alumina-chrome refractory cast matte launder, mudgun unit, and fume extraction hood can be seen in Figure 9. The matte launder consists of two pieces: the spout and the launder itself from where matte is transferred to a 12 t refractory-lined ladle.

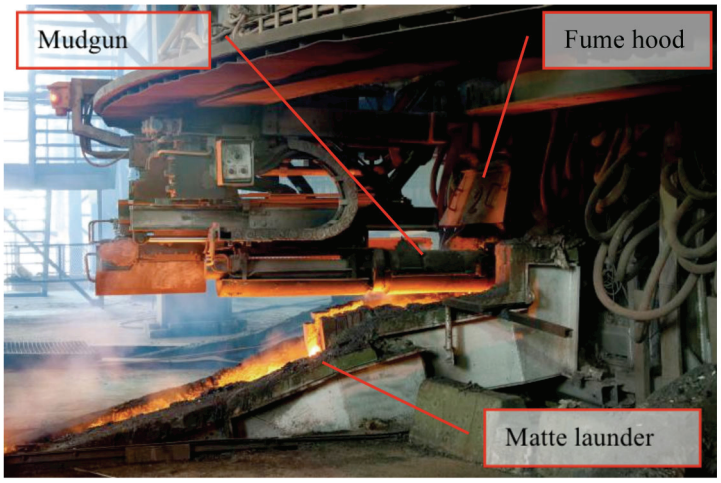

Figure 9. Mudgun and launder configuration

Tap-hole monitoring and alarms

As mentioned previously, the hot face copper temperatures of both the matte and slag tapblocks are monitored. Based on the results of finite element analysis a High and High-High alarm have been set for each copper temperature. The philosophy followed is that a High temperature alarm will send an action alarm to the SCADA operator and a High-High alarm will trip the furnace power. Similarly, the difference between the inlet and outlet water temperature are also monitored. Alarms are raised on these water temperature differences based on predefined alarm limits.

It is also important to detect any water leaks on the cooling circuits. For this reason the outlet flow rates of each water-cooled circuit are monitored. The low flow alarms are used to alarm and trip the furnace. The combination of the water temperatures and flow rates is used to calculate a heat flux for that specific area in the furnace. Alarming is also based on the specific heat flux in that area. An online pressure-testing system is also used on a daily basis to test the pressure drop over each cooling circuit while no tapping is taking place.

From the analysis of previous tapping incidents, the High-High alarm limits sometimes do not give sufficient warning to the tapping floor personnel to evacuate the area. The time from the start of the rise in temperature until the actual incident in some cases was between 1 and 2 minutes. For this reason a rate-of-change (ROC) alarm was introduced, which measures the rise rate of both the water and copper temperatures. The ROC alarms are based on the difference between two sample means. Figure 10 shows the SCADA pop-up of the lintel cooler on Furnace 1.

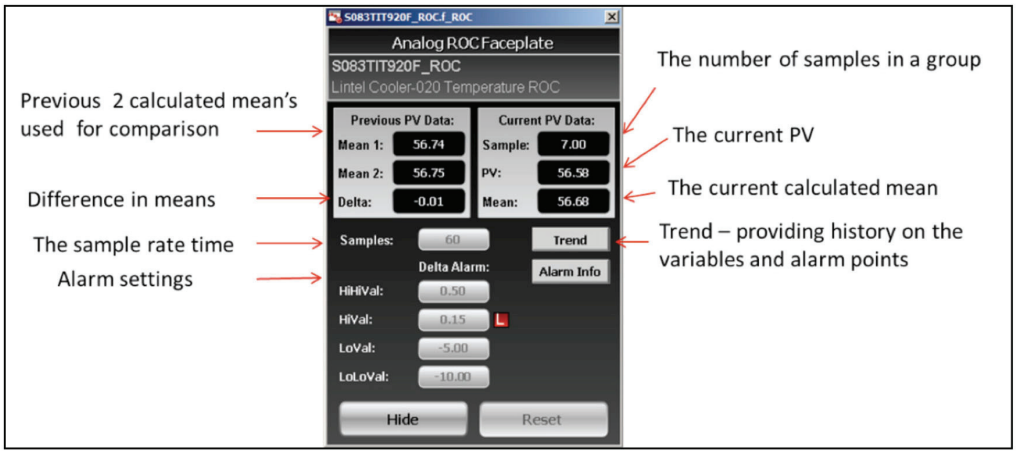

Figure 10. ROC pop-up configuration on SCADA

A number of initiatives have been implemented to improve the tap-hole design and monitoring. This is, however, only one aspect of tap-hole management. The physical tapping operation, as well as the maintenance and repair of the tap-holes, is equally important.

Matte and slag tapping operations

Matte tapping controls the matte in the furnace to the desired level. The matte is tapped four to five times per shift, depending on the percentage matte fall. The tapping operation consists of drilling, lancing, tapping, and plugging steps.

Drilling

When opening a matte tap-hole during normal operations, a hydraulic mudgun and drill is used to partially drill open the clay-filled tap-hole until the solidified matte layer is reached. The average drilling depth is normally between 700 and 900 mm. Before commencing with lancing, an operator measures the depth drilled and reports the measurement to the control room. In general, good drilling depths were achieved from 2011 to 2013, as indicated in Figure 11. An alignment check on the drilled hole is also done with a T-bar to prevent the operator from lancing skew in the event that the drill was misaligned.

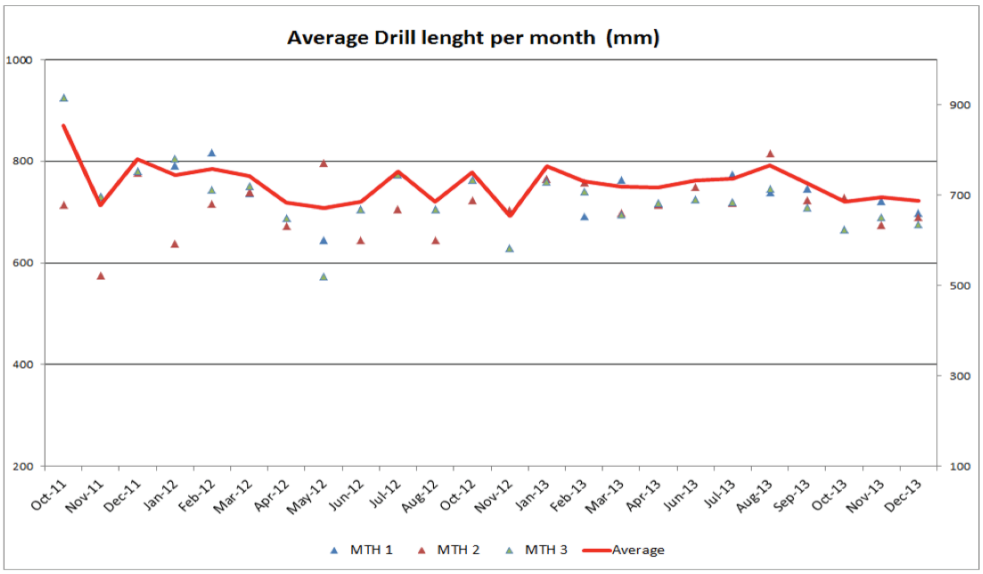

Figure 11. Average drill length per month

After the measurement has been taken, the mudgun and drill unit is moved to the park position, before lancing commences.

Oxygen lancing of matte tap-hole

Oxygen lancing is performed by two operators to penetrate into the solidified matte. One operator is responsible for regulating oxygen flow through the lance pipe while the second operator burns through the tap-hole with a 3 m long lance pipe until the liquid matte starts to flow. A V-shaped lance guide used by the operator (indicated in Figure 12) ensures straight lancing. The experience of the furnace tappers is of utmost importance to ensure prolonged tap-hole life. Every effort is made to ensure the limited use of oxygen and the number of lance pipes used per tap is recorded for this purpose.

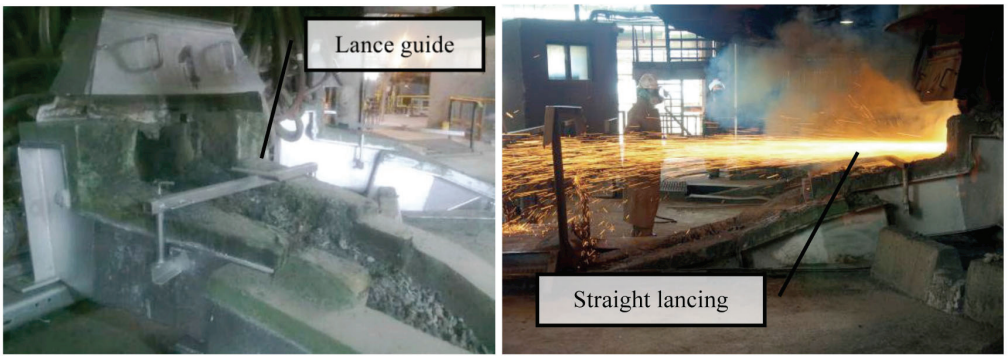

Figure 12. V-shaped lance guide ensuring straight lancing

Matte tapping

The furnace matte is tapped into a 12 t refractory-lined ladle which is then transported to the converter by an overhead crane. The matte tapping temperature is measured with the use of an optical pyrometer and must not exceed 1570ºC. A furnace matte temperature exceeding 1570ºC will cause the furnace to automatically power down. The tapping duration is monitored in order to determine the wear on the tap-hole refractories. Matte spoons samples are taken from the tapping stream and the analyses are used for metal accounting and process control purposes.

Special care is also taken to ensure that all three matte tap-holes are used evenly, and that one tap-hole is not used more than the others. All tapping data from tapping events is manually recorded into the SCADA and stored on the INSQL server. This data is monitored on a weekly and monthly basis, as matte tap-hole usage forms part of the furnace key performance indicators (KPIs).

Another important aspect during matte tapping is to ensure that limited amounts of slag are tapped through the matte tap-hole (slagging). The slag is chemically much more aggressive to refractory wear. Consequently, it is a practice to slag the matte tap-holes weekly to ensure that all matte and chromite layers are tapped out of the furnace.

Plugging of the matte tap-hole

When the matte ladle is almost full or when a mixture of matte and slag is detected, the mudgun and drill unit is brought from the parked position into the plugging position in semi-automatic mode. This operation is done from a refractory-protected mudgun cabin. The operator then lowers the mudgun and rams the clay into the tap-hole. In the event of a mudgun failure, manual clay stoppers are used to close the tap-hole.

Clay consumption is measured after every matte tap. On average, 4 litres of clay per tap is used, and any anomalies are reported so that the counter can be corrected by the Instrumentation Department. Excess clay can increase the amount of gas released from the clay, which in turn could potentially cause damage to the copper above the tap-hole. Less than the 4 litres of clay could result in the tapping channel not being full of clay, but rather matte. Consequently, the next tap will take considerably longer and could result in damage to the tapblock due to excessive lancing. The clay consumption forms part of the weekly and monthly KPIs.

Slag tapping operation

Slag tapping is semi-continuous, with a slag tap-hole open approximately 15–18 hours per day. As mentioned previously, the higher elevation of the slag tap-hole ensures that no matte is pulled into the slag stream during tapping. This is especially important when granulating slag with water, as the presence of matte in the slag can lead to violent explosions.

Slag tapping

The slag tap-holes are opened manually by oxygen lancing. The mudgun and drill unit is not used. The liquid slag is granulated and the granulation water enters the slag pond with the granulated slag. The slag is scooped out of the pond using an automated grab crane and transported for further processing. The three slag tap-holes are used sequentially to ensure an even load on the wall and prevent cold spots developing, which will require vigorous lancing and will damage the tap block.

When the slag tap-hole must be closed, a manual clay stopper ('dolly') is used. This device is simply a cone-shaped clay plug on the end of a long steel bar. Using the bar, an operator inserts the clay plug into the running slag stream. When the plug is in position, a second operator taps the end of the steel bar with a hammer, driving the plug deeper into

the slag tap-hole and stopping the flow of slag. A 10 mm steel bar is then hammered through the clay stopper to act as a 'leader bar' when the tap-hole is opened the next time.

The slag temperature is measured during tapping and recorded similar to the matte temperatures. The slag temperature is normally between 1550 and 1650ºC, and the slag viscosity is not a problem at these temperatures. As mentioned previously, the slag insert can wear back to a maximum of 80 mm before requiring replacement. Generally, damage to the water-cooled 'Monkey' occurs during lancing operations. By following proper lancing procedures, the working life of the insert can be extended. Current life of a 'Monkey' insert is approximately two years.

Spoon samples of the molten slag stream are taken and the analyses used to calculate the furnace PGM recovery.

Matte tap-hole repair and maintenance

The tap-hole refractories are deep-cooled with copper cooling elements. There are three copper cooling elements cooling the matte tapping channel – the deep matte waffle cooler, matte tapping spout, and the faceplate. All of these copper components rely upon the protection given by the tapping channel refractory bricks, and the refractory bricks in turn rely on the cooling received from the copper components. It is imperative that these refractories are maintained on a regular basis.

Tapping channel refractory configuration

As shown Figure 7, the tapping channel consists of five tapping modules and one larger tapping module, called the 'Mickey block'. These tapping modules are surrounded by so-called 'doghouse' refractories.

The copper faceplate is also fitted with a refractory insert. The design allows for proper contact between the refractory insert and the first tapping module in order to prevent any matte leaking through between the copper-cooled faceplate and first tapping module. The initial tap-hole diameter is 38 mm.

A summary of refractory modules with dimensions is given in Table I.

Table I. Summary of refractories of the matte tapping channel

Tapping channel name	Type	Dimensions
Five tapping modules	Fused grain Mg-Cr	230 mm × 230 mm × 114 mm
Faceplate insert	Fused grain Mg-Cr	ø164 mm/ø118 mm × 111 mm
Mickey block	Fused grain Mg-Cr	230 mm × 230 mm × 500 mm

The tapping channel will wear over time and require periodic maintenance. At Furnace No.1 the matte tapping channel repair is split into two stages:

- One to five block repair (tapping modules), or
- Deep matte tap block repair (Mickey repair)

In the next two sections, each repair will be discussed in more detail.

One to five block repair philosophy

The decision to conduct a tapping module repair is based on the time taken to fill a 12 t refractory-lined ladle. From operational experience, a tapping time of less than 11 minutes will indicate possible wear of the tap-hole and requires a tapblock repair. Tapping modules are replaced on a bi-weekly basis for every tap-hole. One to five tapping modules can be replaced, depending on the physical condition of the tapping modules during the repair. For this intermediate repair no doghouse refractories are replaced. The condition of the Mickey block is also monitored during these repairs.

Deep matte tapblock repair philosophy

A deep matte tapblock hot repair is done after every 3 to 4 months, depending on the condition of the Mickey block. As mentioned above, the cold face measurements of the Mickey block will give an indication of when to plan for a deep block repair. From historical data and operational experience, a deep repair is planned when matte penetration into the Mickey block is so severe that only 20–30 mm refractory brick is left. From a safety perspective, 20–30 mm brick is very close to the doghouse refractories, which in turn could lead to premature failure of the copper-cooled block. The possibility also exists that the operators could lance skew, damaging the copper and cause a major breakdown.

Procedures for five and deep matte tapblock repair

Both the five and Mickey block repair follow similar procedures. The only difference is the duration of the repairs and the extent of the preparations. For a one to five block repair, the tap-block is decommissioned at least eight hours before the repair and only the faceplate and tapping modules are removed during the repair.

For a Mickey block, however, the entire furnace is drained (Figure 13) and all the matte launders and spout have to be removed. Two schools of thought exist around whether to drain the furnace or to conduct the deep tapblock repair on a full furnace. It is Lonmin's opinion that the risk of doing a deep repair without draining the furnace is too high and that the additional throughput achieved with this practice is not worth pursuing.

Figure 13. Draining of furnace for deep tapblock repair

A five block repair can take two to four hours to complete. Power is reduced to between 2–3 MW when the fifth block is reached. Power is increased again after the fourth block has been replaced. Mickey block repair times ranges between eight and twelve hours, excluding the draining and heat-up period. During this time contact is maintained on two phases to keep the bath liquid.

For additional precautionary measures during a five block repair, a hole is drilled deeper than the fifth module with the mudgun. The surface temperature at the end of the drilled hole is measured before the repair. A surface temperature in excess of 300°C or a rise rate of 1°C/min will indicate that additional cooling is needed before the repair can be done. Forced cooling of fans and air blown through a hose are used to cool the matte tap-holes.

The surface temperature is monitored continuously throughout the repair by a hand-held pyrometer, with each tapping module's surface temperature being recorded. Photographs and dimensions are taken of the tapping modules as they are removed for quality control purposes. Any signs of cracking of the modules or surrounding refractories are highlighted to management and the relevant action is taken.

During a deep tapblock repair the surface temperature is also monitored. Extra care is taken in order to ensure that no liquid matte runs out while breaking out the Mickey block. A typical repair and wear pattern of the tapping modules and Mickey block is shown Figure 14. It can be seen that the tap-hole diameter and penetration increases the deeper one breaks into the tapping channel.

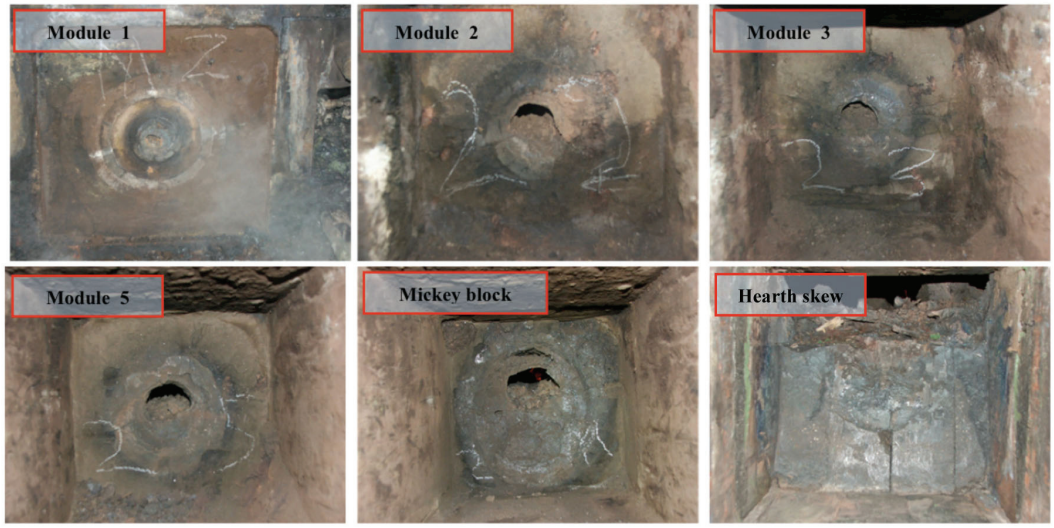

Figure 14. Cold face of tapping modules

After all the refractory has been replaced, the copper face plate is reinstalled. Finally a small fire is made in front of the tapblock to cure the castable refractories between the faceplates and launder.

Improvements made during deep tapblock repairs

Over the last six years, efforts were made to reduce the time taken to conduct a Mickey block repair. The aim was to avoid the hearth refractories cooling down rapidly as this can lead to gap formation. This could pose a major problem during the initial heating up phase as the bricks might not be completely sealed and matte penetration could occur, causing ratcheting of the hearth.

Since the re-commissioning of Furnace No. 1 in 2004, the average power-off time for a Mickey block repair decreased from 60 hours to 12 hours in 2013. This power-off time excludes the draining and bath building stages of the repair. The matte tap–to-tap duration is currently 3.5 days for a deep repair.

Figure 15 indicates how Mickey repair times have been reduced. From the graph it can also be seen that the frequency of Mickey repairs has been reduced from 2004 and 2008. The Mickey repairs between 2010 and 2013 during annual shutdowns or after furnace incidents were considered as special cases, and could not be documented and compared with the rest of the data as the Mickey repair time could not be distinguished from other activities during these events.

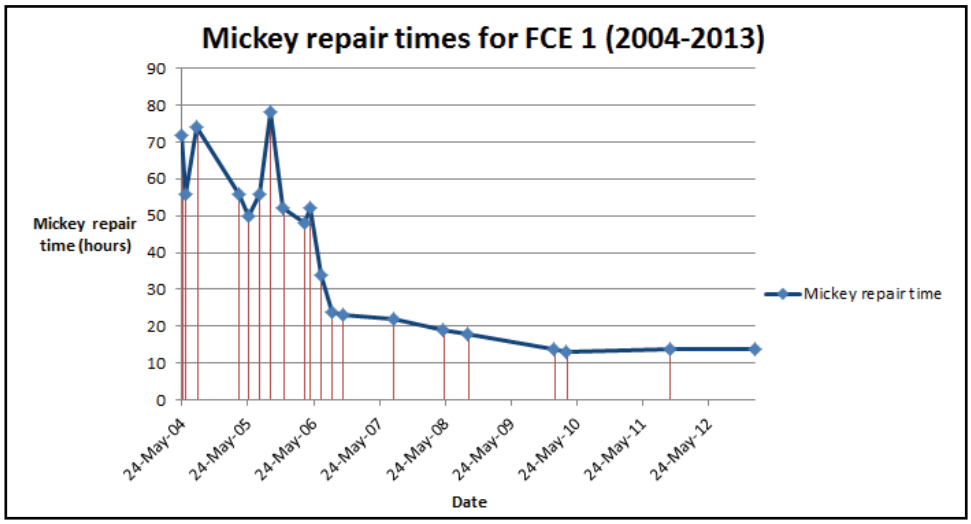

Figure 15. Reduction in repair times

The main contributors to the improvement were:

- Improved draining of the furnace to ensure a safe matte level
- Change in cooling method, switching from liquid nitrogen to air
- Improvement in refractory preparation for faster Mickey block installation
- Repairs are done at low power, typically between 1–2 MW (on/off) instead of switching off power to the furnace completely.

Apart from the shortening the repair time, a number of other improvements were made which, are discussed in the following section.

Improvements made for safe matte tapping operations

As is the case with any high-temperature process, tapping is a potentially hazardous operation. However, with the support of the dedicated tapping personnel, several changes were made to make the process safer for personnel and equipment.

Length of the tapping lance

The length of the oxygen was changed from the original 6 m to 3 m, in order to reduce the risk of skew lancing due to the flexibility of the lance. This change proved to be successful as it is also more user-friendly.

New oxygen hose design

In the past, frequent incidents occurred where operators sustained burns to their hands while lancing due to oxygen leaks between the connection of the bullnose and the flexible hose. A design change to the bullnose was subsequently made to make the connection to the flexible hose more robust and less prone to leaks. Figure 16 indicates the new design.

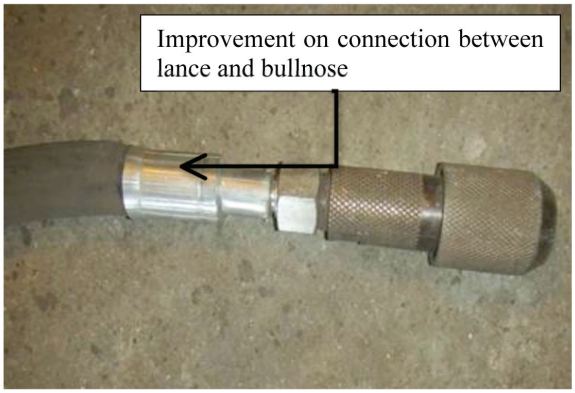

Figure 16. New bullnose design for oxygen pipe

A sacrificial plate made of mild steel is placed in front of the matte faceplate to protect the copper against hot matte splashes during the tapping process. The sacrificial plate is used as a consumable and is changed during every tapblock repair or when the plate is damaged during the tapping process. Figure 17 shows how the sacrificial plate is installed onto the copper faceplate.

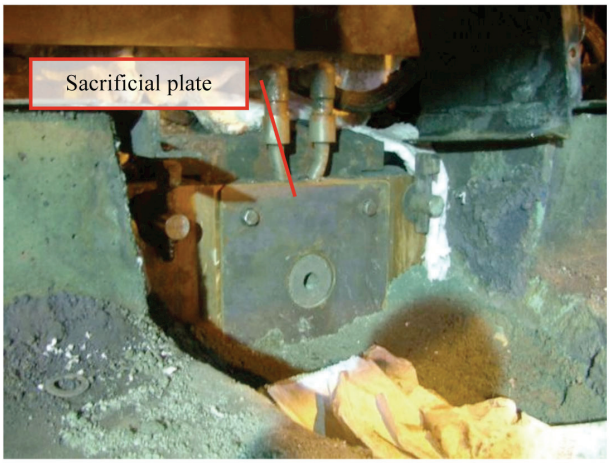

Figure 17. Sacrificial plate on copper faceplate

Tap-hole clay

Tap-hole clay is used during the operation of the mudgun. Operating the mudgun during tap-hole closures is safer for tappers than conventional manual plugging of the tap-hole. The tap-hole clay also assists with repairing the tap-hole as the clay penetrates deep into the tapping channel, forming a protective layer during the next tap. The original clay used for plugging of tap-holes had a high volatile content (LOI 8%), which meant that a lot of boiling occurred inside the furnace after tap-hole closures. This led to an increase in the wear rate in the wash zone . Since 2011, an alternative tap-hole clay with lower volatiles (less than 3%) and a higher alumina content (75%) has been used. Less boiling is observed and a protective layer is visible in the tapping channel during repairs.

Installation of emergency push-buttons for faceplate

In the event that the copper faceplate comes in contact with matte during the tapping process, water could leak from the faceplate into the liquid matte stream causing severe explosions. In order to mitigate this risk, three emergency push-

buttons were installed in each mud gun station for each matte tap-hole. When a leak at one of the tap-holes is detected, the emergency push-button is activated. This will in turn close the supply line valve of the cooling water to that circuit. The oxygen supply valve will automatically open to flush the system, making it safe for the operators. The supply valve can also be closed from the SCADA or from a manual isolation valve in the tapping cabin. Figure 18 is a schematic diagram of the emergency system currently installed at Furnace No. 1.

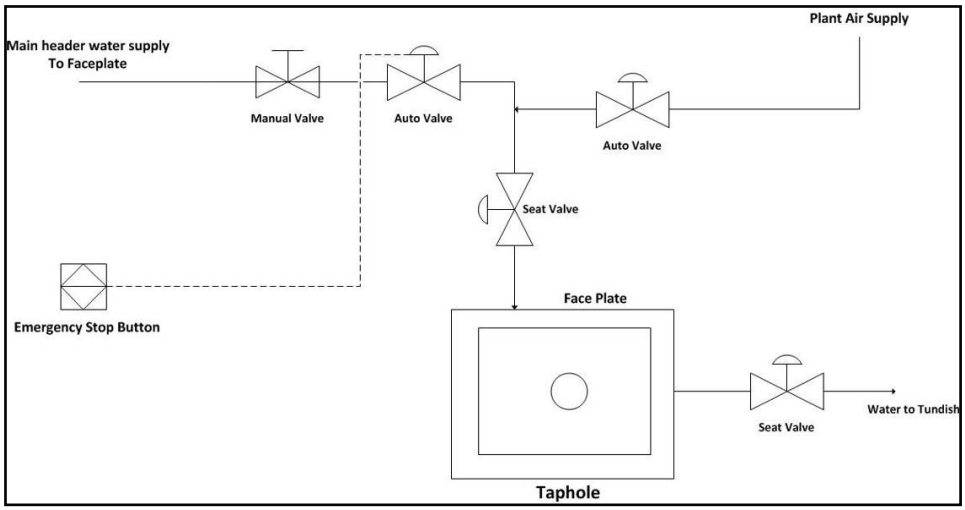

Figure 18. Emergency system for the water cooling supply

Fibre optic temperature system

As part of continuous improvement on the condition monitoring of the tapblocks, a fibre optic temperature system was installed and tested on the matte tapblocks. These fibre optic sensors provide temperature readings at the surface of the copper. The sensor cables were installed in a grooved channel on the hot face of the matte tapblocks. A protective tube was mounted on the copper blocks to accommodate the fibre-optic sensor. During the initial work, the following problems were experienced:

a. Gases from the process, causing the tube to corrode and damage the sensors
b. Cable connections to the junction box burnt off during tapping events
c. Damage to the cable connections during tapblock repairs.

Points (b) and (c) have been addressed, but to date corrosion remains a problem.

Useful data was obtained from the sensors and could have been correlated with process conditions. Currently development needs to focus on the successful embedding of the fibre optic tube below the copper cooler surface.

Conclusion

The Lonmin Smelter team has made great progress in ensuring that tapping is done as safely as possible every time. This paper has demonstrated that the design, operation, and maintenance of the tap-holes are all crucial for the successful operation of a furnace that is tapping superheated matte.

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The Authors

Burger van Beek, *Lonmin*, Process Specialist

Burger van Beek started as an Engineer in training at the old Iscor Vanderbijlpark in 1996. He enjoyed the Pyro-metallurgical challenges of the Steelmaking process and gained operational experience in Secondary Metallurgy. In 2002 Burger van Beek moved to the PGM smelting industry and held various positions at the Lonmin Smelter. Settling in the role of Process Manager, Burger van Beek gained experience in the operational and design aspects of PGM smelting furnaces. Experience was also gained in terms of best practices in metal accounting and process control and monitoring. In 2014 Burger van Beek took up the role of Process Specialist focusing on the long term strategy and development of the Smelting operation.

Trevor James Goff, *Senior Process Engineer*, Lonmin

Trevor Goff joined MINTEK in 1988 after completing his National Diploma in Chemical Engineering at Peninsula Technicon. During his stay at Mintek, he also completed his National Higher Diploma at Vaal Triangle Technicon in 1991. He worked at MINTEK from 1988-1994 and 1997-2007 in the Pyrometallurgy Department where he was mostly involved with high temperature processes, particularly ferro alloys and precious metals. During 1994-1997 Trevor worked at Richards Bay Minerals (RBM) as a Plant Metallurgist at the Iron Injection and Molten Product Transfer Plants. During his time at RBM he was also employed as Senior Production Supervisor: Iron Injection and Molten Product Transfer Plants. Trevor joined LONMIN in 2007 as a Senior Process Engineer at the Smelter where his duties revolved around process optimization, furnace integrity monitoring, metal accounting, process monitoring and maximizing smelting output.

Past Papers presented

TJ Goff and GM Denton, "Direct smelting of stainless steel dust". Infacon X, Cape Town, South Africa, 1-4 February 2004.

Philip Nel, *Production Superintendent*, Lonmin

Philip Nel started working at Columbus Stainless in 1989 as a Production Foreman until 1997. He left Columbus Stainless and started working at Assmang Manganese in Cato Ridge from 1997 until 2003 as a Production Foreman, Furnaces and Converters. As from 2003 Philip is employed at Lonmin Platinum as a Production Superintendent at the Smelter. His current responsibilities are around the operation management and control of all five furnaces (28 MVA, 10 MVA and 3x 5 MVA) within set parameters. Philip is also experienced in the refractory maintenance of furnaces that includes day to day tap-hole maintenance as well as furnace rebuilds. Experience was also gained in the commissioning and start-up of furnaces.

Ernest Rex, *Graduate Process Engineer*, Lonmin

Ernest studied Chemical Engineering at the North West University from 2009-2012 before joining Lonmin in 2013. He is currenlty busy with his engineer in training program at the Lonmin Smelter that started in January 2013. During this time he was exposed to rebuilding and starting up electric arc furnaces and gained an in depth understanding of PGM concentrate smelting. It was also during this time which he volunteered to help co- author the paper to be presented at the 2014 tap hole conference, titled "AN OVERVIEW OF THE DESIGN, OPERATION AND MAINTANANCE PRACTICES RELATING TO TAP-HOLE MANAGEMENT WITHIN A PGM SMELTING FURNACE".