Matte tapping is one of the most critical operations of a matte smelter. Every smelter has
developed particular matte tapping practices and tap-hole repair strategies that are often
based on the experience of the smelter personnel. As a result, very little information has
been published on these critical topics. This paper aims at providing the information
gathered from a survey conducted in the PGM and Ni industries on matte tapping practices
and tap-hole maintenance strategies for different PGM-Ni matte smelting operations.

Introduction

During tapping operations, a matte tap-hole and its environment encounter some of the highest heat fluxes in an
operating furnace, which make the operations around the tapblock critically important for safe and reliable tapping. This
is particularly the case for platinum group metal (PGM) mattes, which are tapped at higher temperatures and typically
superheated by 300–650°C (Shaw et al., 2012), making them aggressive towards the tap-hole refractories. Nickel
mattes are tapped at lower temperatures and are less aggressive in comparison to PGM mattes (Table I).

Table I. Overview of PGM and nickel matte compositions and tapping temperatures

|                     | PGM mattes          | Ni mattes         |
|---------------------|---------------------|------------------|
| Tapping temperature (°C) | 1180-1480          | 1165-1200        |
| Matte composition   |                     |                  |
| Fe (wt%)            | 34-44               | 22-36            |
| Ni (wt%)            | 14-19               | 16-48            |
| Cu (wt%)            | 9-12                | 1-14             |
| S (wt%)             | 22-30               | 25-30            |
| Cr (wt%)            | 0.1-2.5             | -                |
| Superheat (°C)      | 300-650             | 100-520          |

Matte tap-holes require frequent maintenance, involving repairs either with furnace power off or at reduced power,
which impact the overall smelter availability and utilization. The objective of all producers is to tap matte from the
furnace safely and reliably while minimizing downtime associated with tap-hole maintenance. This is done at various
levels of sophistication in the industry, depending on factors such as the smelter matte production (i.e. furnace size), the
dependency on downstream converting (on-site or off-site), smelter personnel experience, etc.

Very little information is published within the industry on matte tapping practices and tap-hole maintenance. A
questionnaire was distributed to PGM and nickel matte producers regarding four key aspects of matte tapping: tapblock
design, tap-hole maintenance, tapblock monitoring, and tapping practices. The questionnaire was divided into two parts:
Part A with questions asking for non-confidential information and Part B with questions that are more confidential in
nature. The purpose of this paper is to provide a summary of the information gathered in Part A from the various
participating smelters, for primary PGM and nickel matte smelting furnaces as well as slag cleaning furnaces. The
confidential results from Part B of the survey were analysed and distributed to participants that completed Part B of the
survey.
### INFORMATION ON PLANT, TYPE OF FURNACE AND MATTE/METAL-PRODUCED

| PARAMETER | WATERFALL F1-12 | POLOKWANE | MORRISONS | NORTHAM | LOMMIN | ZIMPLATS | STILLWATER | BCL FLASH |
|-----------|-----------------|-----------|-----------|---------|---------|----------|------------|-----------|
| Plant name | Waterfall Smelter | Polokwane Smelter | Mortimer Smelter | Northam Platinum Smelter | Lommin Zimplats | Stillwater Mining Smelter | BCL - |
| Plant location | South Africa | South Africa | South Africa | South Africa | South Africa | Zimbabwe | USA | Botswana - |
| Type of furnace | Furnace 1-2 | Furnace 1 | Furnace 2 | Furnace 1 | Furnace 2 | Furnace 2 | Furnace 2 | FU 508 - |
| Nature of matte/metal (primary commodity produced) | PGM | PGM | PGM | PGM | PGM | PGM | PGM | Ni | Ni |
| Metal/matte tapping temperature | °C | 1550 | 1480 | 1450 | 1480 | 1250-1400 | 1180-1280 | 1200 | 1165 |
| Estimated matte/metal liquidus temperature | °C | 900 | 900 | 900 | 850 | 850 | 850 | 850 | 645-720 |
| Mattes/metal Composition | Fe | wt% | 40 | 40 | 38 | 38 | 42-43 | 34 | 36 |
| | | Ni | wt% | 16 | 15 | 17 | 14.6 | 16 | 14.5 |
| | | Cu | wt% | 9 | 9 | 10 | 9 | 10 | 9-10 |
| Total mass matte/metal per tap | tonnes | 15 | 20-35 | 15 | 60 | 18 | 12 | 3 | 15 |

### MATTE/METAL PRODUCTION

- **Number of mattes/metal tap-holes**
  - # | 2 | 3 | 2 | 2 | 4 | 6
- **Number of matte taps per day (from all tap-holes)**
  - #/d | 12 | 6-12 | 9 | 8 | 10 | 6 | 40 | 50
- **Number of ladles per tap**
  - # | 3 | 2 | 3 | 1 | 1 | 1 | 1 | 1 |
- **Duration of each tap**
  - min | 15 | 20-35 | 15 | 60 | 18 | 12 | 3 | 15 |
- **Total mass matte/metal per tap**
  - tonnes | 15 | 20-32 | 17 | 30 | 12 | 9 | 11 | 5 | 21 | 15

### TAPPING PRACTICES

- **Tap-hole opening practice (drilling, lancing or combination)**
  - combination | mud gun | mud gun | mud gun | manual lancing | combination | lancing | combination | lancing | combination | combination |
  - combination | mud gun | mud gun | mud gun | combination | mud gun | mud gun | mud gun | combination |
- **Tap-hole closing practice (manual plugging or mud gun)**
  - mud gun | Y | Y | Y | Y | Y | Y | Y | Y | Y |
- **Total depth of tapping channel**
  - mm | 1374 | 1465 | 1773 | 250 | 1200 | 750 | 540 | 305 | 770 |
- **Average drilling depth (f drilling)**
  - mm | 800 | 850 | 1000 | 900 | N/A | 680 | N/A | 350 |
- **Number of mudgun/drill units on matte/metal side**
  - # | 2 | 2 | 2 | 0 | 2 | 2 | 1 | N/A | 2 |
- **If lancing, is a lance guide being used for alignment purposes?**
  - Y/N | Y | Y | Y | Y | Y | Y | N | Y | Y |
- **Tap-hole Clay - Binder type**
  - water | water | water | water | water | water | water | water | water | water | water |
- **Tap-hole clay - Type of material used (material composition)**
  - alumina based | alumina based | alumina based | other | alumina based | alumina based | other | alumina based | alumina based |

### TAPBLOCK DESIGN

- **Number of bricks in tap-hole**
  - # | 7 | 10 | 20 | 20 | 7 | 6 | 4 | 1-540mm block | 5 | 6 |
- **Primary refractory type used**
  - alumina-based | alumina-based | magnesia-based | magnesia-based | magnesia-based | magnesia-based | magnesia-based | magnesia-based |
- **Water-cooling used**
  - Water-cooled Block and Faceplate | Water-cooled Block and Faceplate | Water-cooled Block and Faceplate Only | Water-cooled Black and Faceplate | Water-cooled Black and Faceplate | Water-cooled Black and Faceplate | Water-cooled Black and Faceplate | Water-cooled Black and Faceplate |
- **Single block or multiple brick tapping channel design**
  - multiple brick modules | multiple brick modules | multiple brick modules | multiple brick modules | multiple brick modules | multiple brick modules | multiple brick modules | multiple brick modules |
- **Use of a maintainable faceplate**
  - | yes | yes | yes | yes | yes | yes | yes |

### TAP-HOLE REPAIRS

- **Typical tap-hole life before replacement**
  - months | 24 | 24 | 24 | N/A | 4 | 30 | 1 | 2.4 |
- **Preventative maintenance - frequency of repair of a given tap-hole**
  - days | 14 | 25-30 | 30 | 14 (Alternate between tap-hole) | 30 | 30 days (5-brick repair) | 90 taps | graphite components | 650 taps | MGO/brick |
- **Preventative maintenance basis**
  - Number of taps and tapping time | number of taps | number of taps | time-based | tapping time | tapping time | number of taps | number of taps | number of taps | number of taps | number of taps
### Tapping of PGM-Ni mattes: an industry survey

#### Table III. Matte tapping survey data for PGM and nickel slag cleaning furnaces (Part A)

| Parameter | Units | Waterfall SCF | Stillwater EF1 | BCL SCF1 | BCL SCF2 |
|-----------|-------|---------------|----------------|----------|----------|
| Plant name | - | Waterfall Smelter | Stillwater Mining Smelter | BCL | BCL |
| Type of furnace | - | slag cleaning (electric) | slag cleaning (electric) | slag cleaning (electric) | slag cleaning (electric) |
| Furnace name | - | SCF | Furnace 1 | FU 501 | FU 502 |
| Nature of matte/metal (primary commodity produced) | - | PGM | PGM | Ni | Ni |
| Metal/matte tapping temperature | °C | 1250 | 1230 | 1200 | 1200 |
| Matte/metal liquidus temperature | °C | 1200 | - | 1100 | 1100 |
| Matte/metal Composition | wt% | 35 | 39 | - | - |
| Fe | wt% | 35 | 14 | 24 | 23 |
| Ni | wt% | 15 | 12 | 19 | 17 |
| Cu | wt% | 15 | 28 | - | - |
| S | wt% | - | - | - | - |

#### MATTE/METAL PRODUCTION

| Parameter | Value |
|-----------|-------|
| Matte/metal tap-holes | 2 |
| Metal/matte taps per day (from all tap-holes) | 6 |
| Number of ladies per tap | 1 |
| Duration of each tap | 15 |
| Total mass matte/metal per tap | 21 |

#### TAPPING PRACTICES

| Parameter | Value |
|-----------|-------|
| Tap-hole opening practice (drilling, lancing or combination) | combination |
| Tap-hole closing practice (manual plugging or mud gun) | mud gun |
| Total depth of tapping channel | 800 |
| Number of mudgun/drilling units on matte/metal side | 2 |
| If lancing, is a lance guide being used for alignment purposes? | N |
| Top-hole clay - Binder type | water |
| Top-hole clay - Type of aggregate used (material composition) | aluminabased |

#### TAP-BLOCK DESIGN

| Parameter | Value |
|-----------|-------|
| Number of bricks in tap-hole | 7 |
| Primary refractory type used | aluminabased |
| Water-cooling used | Water-cooled Block and Faceplate |
| Single block or multiple brick tapping channel design | multiple brick modules |
| Use of a maintainable faceplate | yes |
| Typical tapblock life before replacement | 24 |
| Preventative maintenance frequency of repair of a given tap-hole | 14 |
| Preventative maintenance basis | Number of taps and tapping time |

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Tapblock design

All participating smelters (excluding Northam) use a water-cooled copper block surrounding the refractory tapping channel (Table II). The design consists of either several pieces or a single piece of copper, and the style of the block depends on several aspects, such as tap-hole location (sidewall vs. endwall, above or below skew), wall thickness, cooling configuration in the area, etc.

All smelters use water-cooled faceplates (Table II), which are installed external to the metal tapblocks. They are used to retain the refractory tap-hole modules against the internal hydrostatic bath pressure. At the same time the faceplate provides a flat face for the mudgun to bear against, ensuring a good seal for closing.

All participating smelters (excluding Stillwater) use multiple bricks in their tap-holes, allowing sequential repairs and requiring deep tap-hole repairs only very infrequently. The number of tap-hole bricks varies between 4 and 10 (Figure 1), depending on the length of the tapping channel.

Material selection in tap-hole bricks is often driven by a resistance to change. Alumina may be at risk if there is frequent practice of washing the tap-hole with slag; in such cases, MgO or MgCr are generally better suited. From Figure 1, 44% of all respondents have alumina-based matte tap-hole refractories whereas 56% have magnesia-based refractories. As seen in Figure 2, matte tapping temperature is not a criterion in refractory selection.
Tapblock operation and tapping practices

For the purposes of this paper, tap-hole productivity is defined as the tons of matte tapped per day per tap-hole. When comparing the PGM, nickel matte, and copper matte smelting industries, three distinct regimes are observed (Figure 3).
The tap-hole productivity is lowest for PGM smelting furnaces (15–90 t/d per tap-hole). The productivity per tap-hole is higher for the nickel matte furnaces (25–210 t/d per tap-hole), despite operating with more tap-holes (2-6). Literature data for copper flash smelters (operating with 4–6 matte tap-holes) shows a step change in tap-hole productivity to 220–470 t/d per tap-hole. The productivity benchmark for PGM smelting (>1350°C) is currently set by Polokwane and Waterval at 90 t/d per tap-hole (on average).

For a given matte tapping temperature, there is a large variability in tap-hole productivity. This is due to the fact that regardless of the size of the furnace, there is a minimum number of two matte tap-holes for redundancy and maintenance purposes. Hence, while the Stillwater furnace and the Waterval furnace both have two matte tap-holes, the Waterval furnace has a much higher matte production rate resulting in higher tap-hole productivity.

With regards to tapping frequency, it is important to consider if a particular furnace needs to be timed with a downstream converter operation. The tapping frequency at operations that are decoupled from converter operation should be driven by furnace levels, whereas furnaces feeding downstream converters (as molten feed) are typically tapped ‘on demand’ to suit the converter cycles (Figure 4).

At Northam in particular, matte is tapped only once per day to feed the daily converter cycle. This is the only operation tapping two ladles at a time in order to have sufficient material to feed the converter; all other furnaces tap one ladle at a time. This results in a very long time of 1380 minutes between taps for Northam.

BCL and the anonymous smelter produce a large amount of matte (750–840 t/d) and need to regularly feed downstream converters, resulting in a time of 17–21 minutes between taps (i.e. many short taps). PGM operations produce less matte (30–270 tpd), resulting in longer times of 100 to 237 minutes between taps (excluding Northam).

The slag cleaning furnaces are different and typically tap between two to six times per day (225 to 700 minutes between taps), except for Stillwater EF1 which taps only once a month. The time between taps can be plotted against tap-hole productivity, clearly showing three different zones for the slag cleaning furnaces (excluding Stillwater EF1), PGM smelting furnaces (excluding Northam), and Ni smelting furnaces (Figure 5).
Most furnaces have a tap duration of 10–15 minutes (Figure 6), except for Northam (60 minutes to fill two ladles) and the 68 MW Polokwane furnace (20–35 minutes due to their larger tap size of 28–32 t). Stillwater has very short tapping times of three minutes, because of their very small tap size of 5 t.
Excluding Stillwater because of their very short tap duration, average matte tapping rates vary between 0.5 and 1.4 t/min (Figure 6). None of the PGM smelting furnaces tap faster than 1.2 t/min. The nickel smelters tap faster (between 1.2 and 1.4 t/min), but at a lower matte temperature. Matte tapping time (obviously related to tapping rate) is an official tap-hole repair trigger criterion for five of the participating furnaces: all five participants show an average matte tapping rate of ≤1 t/min. Stillwater, Polokwane, and Mortimer are the only PGM smelters tapping matte at rates faster than 1 t/min (on average).

The majority (66%) of the participating primary furnaces use alternate tap-holes for consecutive taps. The objective of this practice is to enable the tapblock temperature to return to its baseline level before the next tap. Other smelters use the same tap-hole for consecutive taps and the tapblock remains ‘hot’ between taps.

For tap-hole opening, 36% of participating furnaces use oxygen lancing whereas the majority use a combination of drilling and lancing. Best-practice operations make use of a lance guide to minimize the potential for damaging the tap-hole when lancing it open. All participating smelters use mudguns for tap-hole closing, with the exception of Northam and BCL (Table II). Tap-hole clay also plays a role in tap-hole life. First, the quantity of clay injected must be monitored to avoid excessive clay causing gas bubble-driven turbulence in front of the tap-hole hot face. Best-practice operations measure and monitor the amount of clay injected for each tap-hole closure.

Tap-hole clay technology constantly evolves with new aggregates, binders and additives. In the blast furnace industry, additives such as SiC, SiN, zirconium, etc. are used to modify the flowing/hardening behaviour of the tap-hole clay. Water-based clays are no longer used in the blast furnace industry as they contribute to the oxidation of the carbon-based tap-hole refractories. Tar-bonded clays are still widely used but raise health concerns due to the carcinogenicity of their volatile component. Phenolic resins and pitch/resin mixtures are also used as binders in the blast furnace industry. In PGM and nickel matte smelting, water-based clays and pitch-bonded clays are widely used (Figure 7). Resin-bonded clay is being used only at one smelter (anonymous), which also reports using graphite components in their tap-hole. Most furnaces (79%) use alumina-based aggregates. One smelter (Northam Platinum) uses locally sourced soil and one other smelter (two furnaces) uses an unspecified tap-hole clay aggregate (Figure 7).

**Figure 7. Tap-hole clay – type of aggregate and binder used**

### Taphole Clay - Type of Aggregate Used

- Alumina-based, 79%
- Locally sourced clay, 7%
- Other (unspecified), 14%

### Taphole Clay Binder Used

- Pitch, 43%
- Water, 50%
- Resin, 7%

**Tapblock maintenance**

The tap-hole repair cycle affects furnace availability and utilization (i.e. productivity). The downtime associated with tap-hole repairs depends on many factors: the number of tap-holes that are repaired simultaneously, the number of bricks replaced, the ramp-down and ramp-up schedules, operating load during a repair (reduced load, no load), etc.

Most smelters repair only one tap-hole at a time. This could lead to an increased overall downtime for the furnace if the repairs are not scheduled optimally, depending on the duration and ramp-up/down schedule surrounding the repair. In some cases, the loss in production associated with the ramp-up/down can be as important, if not more, than the duration of the repair itself. Some smelters make use of nitrogen or plant air to cool the tap-hole during a rebuild.

It is standard practice to carry out both partial and deep tap-hole repairs, whereby only a certain number of bricks from the tapping channel are changed. In some cases, deep repairs are done with furnace power on (idling power).

Each smelter has developed its own set of criteria to trigger tap-hole repairs. Some smelters use the number of taps, others the tapping time, and some a combination of these parameters. One smelter simply repairs the tap-holes on a
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weekly basis, regardless of production indexes (Figure 8). In addition, some smelters also evaluate other factors such as copper temperatures and observations of inner brick condition during partial repairs as secondary repair trigger criteria.

It is difficult to compare tapblock campaign life reported in the survey because the basis varies from one smelter to another. For example, some smelters reported life of the entire tapblock, whereas others reported life before a partial repair.

Conclusions
A survey of this nature provides the means for a comparison of matte tapping practices across operations and across industries. It can provide stimulus for operators to challenge their own criteria to maximize the life of the tap-hole refractories before a repair is triggered. Beyond having an understanding of what is currently being done in the industry, it is critical to have a good knowledge of one’s own tapping practices. This can be achieved as follows:

• Maintain records of brick type and specifications, when they were installed and removed from the tap-hole
• Maintain records of tap-hole clay type
• Maintain records of tap-hole opening/closing events for each tap-hole, including time open, time close, tap durations, tons tapped (and derived tapping rate), etc.
• Maintain records of matte tapping temperatures and matte compositions for each tap
• Maintain photographic records of each tap-hole repair. Take a photograph of each brick before it is broken out and as it is re-installed.

The intent is to keep updating this matte tapping database and to involve more participants across a wider range of matte smelting industries. Anyone wishing to participate in this effort is invited to contact the author at inlet@hatch.co.za.

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