An Overview of the Base Metal Removal Plant at Northam Platinum Limited

Presented by: Ashley Corbett
Plant Manager BMRP
Granulated Cu-Ni-PGM matte from Smelter
50% Ni, 29% Cu, 16% S <1.0% Fe and 0.4% 3 PGE’s + Au

BMR Plant

PGM Concentrate
(45-50% 3PGE’s + Au)

Metallic Copper Cathode Plate (99.96% Cu)

Granulated Nickel Sulphate Hexahydrate crystals (22% Ni)
Personnel

Operations Personnel Complement  51

Engineering Maintenance Complement  20
BMRP BLOCK DIAGRAM FLOWSHEET

Granulated converter matte from Smelter

Matte Grinding → Atmospheric Leach

Atmospheric Leach → Crystallizer

Pressure Leach → Nickel Sulphate Crystals

PGM filtration → PGM concentrate

Selenium Removal → Copper Electrowinning

Copper Electrowinning → Copper cathodes

Spent Electrolyte
Granulated converter matte from Smelter

Matte Grinding

Atmospheric Leach ➔ Crystallizer

Pressure Leach ➔ Nickel Sulphate Crystals

PGM filtration ➔ PGM concentrate

Selenium Removal

Copper Electrowinning ➔ Copper cathodes

Spent Electrolyte
Grinds granulated matte to a size suitably fine for subsequent leaching to take place at an acceptable rate.
BMR Plant

Matte Grinding Circuit

Grinds granulated matte to a size suitably fine for subsequent leaching to take place at an acceptable rate.
Atmospheric Leaching Circuit

To leach Nickel & Iron from the ground matte and at the same time precipitate copper and PGM’s from the copper spent electrolyte.

Ground Matte Slurry

Sulphuric Acid

Spent Electrolyte

Oxygen

pH 0.5

pH 2.5

pH 3.5

Thickener

Thickener U/F tank

Flocculant

Nickel Sulphate solution

Atmospheric leach residue

Typical Free acid concentrations

Tank 1

10 - 25 g/l H₂SO₄

Tank 2

0 g/l H₂SO₄
Suggested Chemical Reactions in the first stage leaching circuit

\[ \text{Ni}_3\text{S}_4 + \text{H}_2\text{SO}_4 + 0.5\text{O}_2 \rightarrow \text{NiSO}_4 + 2\text{NiS} + \text{H}_2\text{O} \]

Heazlewoodite reacts with sulphuric acid and oxygen to produce to millerite with the dissolution of 33 % of its nickel content as nickel sulphate

\[ \text{Ni}^0 + \text{H}_2\text{SO}_4 + 0.5\text{O}_2 \rightarrow \text{NiSO}_4 + \text{H}_2\text{O} \]

The nickel alloy content reacts with sulphuric acid and oxygen to form nickel sulphate.

\[ 5\text{NiS} + \text{CuSO}_4 \rightarrow 2\text{NiSO}_4 + \text{Ni}_3\text{S}_4 + \text{Cu}_2\text{S} \]

Further leaching from the sulphide phase occurs by means of a metathesis reaction. Millerite is converted to polydymite, heazlewoodite and copper is precipitated from solution as digenite.
BMR Plant
Atmospheric Nickel Leach

To leach Nickel & Iron from the ground matte and at the same time precipitate copper and PGM’s from the copper spent electrolyte.

Typical Dry solids feed rate
500 kg/hr

Nickel extraction 70 - 75%

Iron dissolution 65 - 70%
Granulated converter matte from Smelter

Matte Grinding

Atmospheric Leach → Crystallizer

Pressure Leach → Nickel Sulphate Crystals

PGM filtration

Selenium Removal → PGM concentrate

Copper Electrowinning → Copper cathodes

Spent Electrolyte
The crystallizer circuit enables easily handled nickel sulphate hexahydrate crystals to be formed from nickel sulphate solution.
Crystalizer

Produces easily handled Nickel Sulphate hexahydrate crystal from Nickel Sulphate solution
Moist nickel sulphate crystals

Induced Draught

Dry Nickel surge bin

Weigh flask

Dry nickel sulphate crystals

Dryer vent to scrubber

Tube Conveyor

48°C

Rotary Dryer

Centrifuge

Nickel sulphate solution Returned to crystallizer

Steam

Heat exchanger

Induced Draught

Condensate
Nickel Sulphate Crystals are dried and packaged in 1 ton bulk bags
Daily production 28 tonnes (NiSO$_4$.6H$_2$O)
Granulated converter matte from Smelter

1. Matte Grinding
2. Atmospheric Leach
3. Pressure Leach
4. PGM filtration
5. Selenium Removal
6. Copper Electrowinning
7. Crystallizer
8. Nickel Sulphate Crystals
9. PGM concentrate
10. Copper cathodes
11. Spent Electrolyte
Pressure Leaching stage

Extracts the Copper, Sulphur, Iron & remaining Nickel in the atmospheric leach residue, leaving a high grade PGM residue.

Process control of Autoclave Discharge
100-110 g/l of Total Metals in solution
20-25 g/l of Free Sulphuric acid in Solution
Suggested Chemical Reactions within the Autoclave

The first stage leach residue typically contains nickel in the form of millerite, NiS, and polydymite, Ni$_3$S$_4$, and copper in the form of the original Djurlite, Cu$_{1.96}$S, and the precipitated digenite, Cu$_{1.8}$S. These sulphides undergo total oxidation to the corresponding sulphates in the second stage leach. Principle overall reactions are of the type shown below.

\[
\begin{align*}
\text{Ni}_3\text{S}_4 + 7.5 \text{O}_2 + \text{H}_2\text{O} & \rightarrow 3\text{NiSO}_4 + \text{H}_2\text{SO}_4 \\
\text{NiS} + 2\text{O}_2 & \rightarrow \text{NiSO}_4 \\
\text{Cu}_2\text{S} + \text{H}_2\text{SO}_4 + 0.5 \text{O}_2 & \rightarrow \text{CuSO}_4 + \text{CuS} + \text{H}_2\text{O} \\
\text{CuS} + \text{O}_2 & \rightarrow \text{CuSO}_4
\end{align*}
\]
To extract the Copper, Sulphur, Iron & remaining Nickel in the atmospheric leach residue, leaving a high grade PGM residue.
Granulated converter matte from Smelter

- Matte Grinding
- Atmospheric Leach
- Pressure Leach
  - PGM filtration
    - Selenium Removal
    - Copper Electrowinning
      - Spent Electrolyte
    - PGM concentrate
- Process Water
  - Crystallizer
    - Nickel Sulphate Crystals
    - PGM concentrate
- Copper cathodes
To filter, wash and dry the 2\textsuperscript{nd} stage leach discharge slurry to obtain a bone dry PGM rich residue.
To filter, wash and dry the 2nd stage leach discharge slurry to obtain a bone dry PGM rich residue.
Autoclave Residue 45 - 50% 3PGE's + Au
Granulated converter matte from Smelter

1. Matte Grinding
2. Atmospheric Leach
3. Pressure Leach
4. PGM filtration
5. Selenium Removal
6. Copper Electrowinning
7. Spent Electrolyte
8. Crystallizer
9. Nickel Sulphate Crystals
10. PGM concentrate
11. Copper cathodes
Selenium Removal Circuit

Removal of Selenium from filtered autoclave solution to prevent contamination of Copper cathode as well as recovery of dissolved PGM’s.
Process Chemistry

The second stage leach solution contains Nickel Sulphate, Copper Sulphate, free sulphuric acid with low levels of Selenium, Tellurium, Palladium, Rhodium and ruthenium. This solution is treated with sulphur dioxide solution to precipitate selenium as copper selenide and tellurium as copper telluride together with most of the dissolved palladium and rhodium.

Overall chemistry can be represented by

\[
\text{CuSeO}_3 + \text{CuSO}_4 + 4\text{SO}_2 + 5\text{H}_2\text{O} \rightarrow \text{Cu}_2\text{Se} + 5\text{H}_2\text{O}
\]

\[
\text{CuSeO}_4 + \text{CuSO}_4 + 5\text{SO}_2 + 6\text{H}_2\text{O} \rightarrow \text{Cu}_2\text{Se} + 5\text{H}_2\text{O}
\]

Tellurium which is present as Te (IV) and Te (VI) behaves similarly.
BMR Plant

Se Removal

Removal of Selenium from filtered autoclave solution to prevent contamination of Copper cathode as well as recovery of dissolved PGM’s.
Process Chemistry

In Northam’s copper electrowinning circuit, metallic copper is deposited at the cathode, and oxygen is liberated at the anode. The individual reactions are shown below.

Cathode: \[ 2\text{CuSO}_4 + 4\text{e}^- \rightarrow 2\text{Cu}^0 + 2\text{SO}_4^{2-} \]
Anode: \[ 2\text{H}_2\text{O} - 4\text{e}^- \rightarrow \text{O}_2 + 4\text{H}^+ \]
Overall: \[ 2\text{CuSO}_4 + 2\text{H}_2\text{O} \rightarrow 2\text{Cu}^0 + 2\text{H}_2\text{SO}_4 + \text{O}_2 \]

Typical Analysis within the Electrowinning circuit

<table>
<thead>
<tr>
<th>Component</th>
<th>Electrolyte Feed</th>
<th>Spent Electrolyte</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu (g/l)</td>
<td>48</td>
<td>32</td>
</tr>
<tr>
<td>Free H$_2$SO$_4$ (g/l)</td>
<td>24</td>
<td>48</td>
</tr>
<tr>
<td>Ni (g/l)</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Selenium (ppm)</td>
<td>&lt;3</td>
<td></td>
</tr>
</tbody>
</table>
Electrowinning circuit

To recover clean Copper cathode product free of PGM’s and to return a Copper spent electrolyte for the operation of the leach stages.

Rectiformer rating up to 15KA with a voltage of 25V
BMR Plant

Electro Winning

To recover clean Copper cathode product free of PGM’s and to return a Copper spent electrolyte for the operation of the leach stages.
BMR Plant

Copper Stripping

Typical Production Rate: 4 t/day    Quality: (99.96% Cu)
The End