CYANIDE OPTIMIZATION AND THE USE OF OZONE FOR WAD CYANIDE DESTRUCTION

South Deep Gold Mine
Metallurgical Plant
2009

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1. INTRODUCTION

- Gold Fields South Deep is located in the South West Rand
- New gold plant was commissioned in 2002
- Design capacity of 220,000 t/month
- The mining method by Trackless mining
- Gold recovery achieved by Milling, Classification (cyclones), Gravity gold, Thickening, Leaching, CIP, Elution, Electro-wining and Smelting
2. METALLURGICAL PLANT
3. ICMI CODE AND IMPLICATIONS

- In the year 2000 the ICMI (International Cyanide Management Institute) Code was developed after an accidents in *Baia Mare*.

- Mines that are compliant with the ICMI code they have to implement the Principles and Standard of practice:
  - *Production*
  - *Transportation*
  - *Handling and storage*
  - *Operation*
  - *Decommissioning*
  - *Workers safety*
  - *Emergency response*
  - *Training*
  - *Dialogue*
Gold Fields South Deep Gold Mine has been certified as fully compliant with the ICMI Code as from the 1 April 2009.

The Metallurgical Plant had to demonstrate that it has implemented programs, procedures and practices as required by ICMI.

Principle 4: Standard of Practice 4.2 of the code “Has the operation introduced management and operating systems to minimize cyanide use, thereby limiting concentrations of cyanide in mill tailings”.

Standard of Practice 4.6.3 “Has the potential impacts to workers health and the beneficial uses of ground water been evaluated and have been measures been implemented as necessary to address them?”
Cyanide Addition and Monitoring

- Cyanide Tanks
- Leach Tanks
- Lime Dosage Tank
- Make up Tank
- Tailings Screen & Sump
- Shaft Backfill Storage Tank
- Ultracepts
- Spillage Tank
- Backfill Tailings Tank
- TK 21
- TK 22
- TSF
- Cyclone Cluster
- O/F
- U/F
- Shaft Backfill Storage Tank
Areas of concern (Underground and Slimes dam)

- Possibility of HCN gassing
- No CN monitors
- “Cyanide tracking underground as a function of backfill seepage”
  P. W. Lotz
Cyanide Addition

TAC 2000

- Leach TK 1
- TK1 Cyanide addition Set Point 200ppm
- TK4 Cyanide addition Set Point 90ppm
WAD 1000 (Plant and Backfill)

- Pump
- Probe at Tailings Sump
- Analyser for Analysis and Data collection
4. INITIATIVES
4.1. CYANIDE REDUCTION

4.1.1. Oxidation Trial

- Oxygen from Air Products was used to improve
  - Recoveries
  - Leach kinetics
  - Dissolved oxygen levels
  - Lower cyanide consumption

- First phase of the trial
  - Oxygen added in TK 1 together with cyanide and lime

- Second phase
  - Pre-Oxidation in TK 1 leach tank prior to adding cyanide and Lime in TK 2
4 Au + 8 CN⁻ + O₂ + 2 H₂O = 4 Au(CN)₂⁻ + 4 OH⁻

- The DO level during P1 was <4.2ppm and during P2 the DO levels increased in TK 1 and TK 2 to 10.02ppm and 7.16ppm
Cyanide consumption during P1 was 0.366kg/t and was 0.270kg/t during P2
During P1 and P2 there was a rapid increase in dissolution of gold within the first three tanks which resulted in increased leach kinetics.
The increase in residue resulted in an increase in cyanide set point.

During P2, residues dropped for both solution and washed solids, and that resulted in cyanide addition set points reducing from 350ppm to 180ppm.
Phase 1 results
- Oxygen trial improved
- Dissolved Oxygen levels
- No changes in cyanide consumption
- Leach profiles indicated faster leach kinetics

Phase 2 results
- Pre-oxidation resulted in reduction in cyanide consumption from 0.366 kg/t to 0.270 kg/t
- Increased leach kinetics
- Dissolved oxygen levels
- Leach could be operated with less tanks resulting in reduction in gold lock up and maintenance cost
- Cyanide set point was reduced from 350 ppm to 180 ppm
4.1.2. Two Stage cyanide control

- The aim
  - Optimize the cyanide addition at the Leach circuit
  - To reduce cyanide cost
  - Reducing the WAD cyanide leaving the Plant to < 50ppm as required by the ICMI

- The cyanide is dosed at TK 1 using TAC 2000
  - Cyanide set point in TK 1 is 200ppm and at TK 4 is 90ppm
  - The WAD Cyanide leaving the Plant is currently 28ppm which is below ICMI requirement of 50ppm WAD
TK 4 has been identified as the cyanide second stage addition point.
The installation of the second stage at TK 4 has been completed.
The cyanide reduction should impact the WAD cyanide to levels lower than 28ppm thus reducing cyanide consumption and cost.
4.2. WAD CYANIDE DESTRUCTION

4.2.1. Hydrogen Peroxide (H$_2$O$_2$) Trial

● The aim
  - Determine the effectiveness of Hydrogen peroxide (H$_2$O$_2$) with regard to WAD cyanide destruction to levels <20ppm
  - Determine if Hydrogen peroxide could be used as an alternative to Ferrous sulphate that is currently used

Fe$^{+2}$ + 6 CN$^-$ + $\frac{1}{4}$ O$_2$ + H$^+$ = Fe(CN)$_3^{-}$ + $\frac{1}{2}$ H$_2$O

4 Fe$^{+2}$ + 3 Fe(CN)$_3^{-}$ + $\frac{1}{2}$ O$_2$ + H$^+$ = Fe$_4$[Fe(CN)$_6$]$_3$ + $\frac{1}{2}$ H$_2$O

● The test works were done Plant scale and Lab scale
<table>
<thead>
<tr>
<th></th>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
<th>Test 4</th>
<th>Test 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density of Slurry (kg/l)</td>
<td>1.82</td>
<td>1.6</td>
<td>1.75</td>
<td>1.75</td>
<td>1.92</td>
</tr>
<tr>
<td>Volume of Slurry (l)</td>
<td>215000</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>96000</td>
</tr>
<tr>
<td>Mass of Slurry (kg)</td>
<td>391300</td>
<td>8</td>
<td>8.75</td>
<td>8.75</td>
<td>184320</td>
</tr>
<tr>
<td>Density of Hydrogen peroxide (kg/l)</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Volume of Hydrogen peroxide (l)</td>
<td>150</td>
<td>0.5</td>
<td>0.05</td>
<td>0.01</td>
<td>200</td>
</tr>
<tr>
<td>Mass of Hydrogen peroxide (kg)</td>
<td>180</td>
<td>0.6</td>
<td>0.06</td>
<td>0.012</td>
<td>240</td>
</tr>
<tr>
<td>Consumption (kg/t)</td>
<td>0.46</td>
<td>75.00</td>
<td>6.86</td>
<td>1.37</td>
<td>1.30</td>
</tr>
<tr>
<td>Duration (hr)</td>
<td>32</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>WAD first value (ppm)</td>
<td>52.8</td>
<td>19.6</td>
<td>23.6</td>
<td>21.6</td>
<td>31.5</td>
</tr>
<tr>
<td>WAD Last value (ppm)</td>
<td>20.1</td>
<td>0.1</td>
<td>2.7</td>
<td>4.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Efficiency</td>
<td>61.9</td>
<td>99.5</td>
<td>88.6</td>
<td>80.1</td>
<td>89.52</td>
</tr>
<tr>
<td>Cost per ton (R/t)</td>
<td>3.86</td>
<td>629.38</td>
<td>57.54</td>
<td>11.51</td>
<td>10.93</td>
</tr>
</tbody>
</table>
The results indicate that WAD cyanide was best reduced in Test 2 followed by 3 and 4 although Hydrogen peroxide consumption was high for Test 2, 3 than 4.

\[ \text{CN}^- + \text{H}_2\text{O}_2 = \text{OCN}^- + \text{H}_2\text{O} \]

Hydrogen Peroxide does reduce the WAD cyanide levels to <5ppm in 2 hours.
● It was concluded
  - Hydrogen Peroxide does reduce the WAD cyanide levels to even <5ppm effectively
  - Hydrogen Peroxide can be used as an alternative to ferrous sulphate

● It was recommended
  - Attempts be made to lower consumptions to minimize operational cost
  - WAD Cyanide be destroyed at Metallurgical Plant Tailings to levels <50ppm
4.2.2. Ozone Trial

- The cyanide destruction using Ozone is done to reduce the WAD cyanide leaving the Plant to Slimes dam and Underground.
- The Ozone is a powerful oxidant and highly destructive toward WAD cyanide according to Lab test results.

1. $\text{CN}^- + \text{O}_3(\text{aq}) = \text{OCN}^- + \text{O}_2(\text{aq})$
2. $3\text{CN}^- + \text{O}_3(\text{aq}) = 3\text{OCN}^-$
3. $\text{OCN}^- + 3\text{O}_3(\text{aq}) + \text{H}_2\text{O} = 2\text{HCO}_3^- + \text{N}_2(\text{g}) + 3\text{O}_3(\text{aq})$

- These are initiatives taken to protect the people and the environment.
Ozone skid/generation

- Oxygen Storage Tank
- Pressure/Vacuum Vessel
- Oxygen Generator
- WEDECO
- Feed Sample
- Sampling Point
- Discharge Point
- O2
- O3
- H2O
The Ozone Trial was planned for 3 months at following streams:
- Backfill Tailings to Slime dam
- Backfill to underground
- Ultracep underflow
- Ultracep overflow
- Spent sample

WAD cyanide was analysed using WAD 1000.
Relationship between Power (W) and Power consumption % is linear
Relationship between Power consumption % and Ozone concentration

<table>
<thead>
<tr>
<th>Power consumption (%)</th>
<th>Ozone concentration (g/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>40</td>
<td>44</td>
</tr>
<tr>
<td>60</td>
<td>59</td>
</tr>
<tr>
<td>80</td>
<td>73</td>
</tr>
<tr>
<td>100</td>
<td>80</td>
</tr>
</tbody>
</table>
● WAD cyanide reduction of 98.7% for the slurry pumped from Backfill Tailings to Slimes dam at 60% power consumption
• Ultracep underflow WAD cyanide was reduced by 94.6% at 60% power consumption
- Ultracep overflow WAD cyanide was reduced by 94.7% at 20% power consumption.
Backfill to underground WAD cyanide was reduced by 94.5% at 60% power consumption.
Spent sample WAD cyanide was reduced by 92% at 80% power consumption.
● Ozone trial was successful in WAD cyanide destruction for all the streams tested as >92% destruction at optimum condition
● Alternative method to destroy WAD cyanide
● WAD levels < 50ppm at all times
Advantages of the ozone includes

- Rapid WAD cyanide destruction
- No formation of harmful off gases

Cost

- Operating cost associated with ozone to be further investigated
5. CONCLUSION

- South Deep has achieved WAD <50 ppm
- Compliant with the ICMI Code
- Reduced and maintained cyanide addition levels from 0.366 kg/t to 0.270 kg/t
- Initiatives successful in WAD cyanide destruction to lower levels
- Alternative in both cyanide reduction and WAD cyanide destruction
- Prepared for the future changes in legislation
QUESTIONS?