Sensor-based ore sorting of low-grade gold sulphide deposits

Colombia Gold Symposium 2018

Name: Lütke von Ketelhodt – Steinert US Inc.
Dr Tony Parry - OreSort Solutions
Date: November 2018
Introducing Steinert

Ore sorting in gold mining and processing operations – an economic analysis
Case study 1 – Brownfields plant

Case study 2 – Low-grade Stockpile

Mill pebble sorting

Conclusion
Introducing Steinert
STEINERT provides innovative solutions for the separation of valuable materials, increasing customer profitability through higher recovery & reducing operational costs.

**Secondary resource sector**

- **Scrap**
  - Electronic Scrap
  - Shredder Scrap

- **Waste**
  - Municipal Solid Waste
  - Waste to Energy (WtE)
  - Substitute Fuels

- **Other**
  - Incineration Slag
  - Waste wood
  - Demolition Waste

**Primary resource sector**

- **Industrial Minerals**
  - Silica, Feldspar, Limestone

- **Ores**
  - Iron ore
  - Base metals (e.g., Nickel, Copper)
  - Precious metals (Gold, Silver, Platinum)

- **Coal**

- **Precious Gemstones**
  - Diamonds
Subsidiaries: USA, Australia, Brazil, Japan, Germany, Africa
Sales cooperations: more than 50 worldwide
Sensor-based sorting

Differentiation using the electromagnetic spectrum for separation material by shape, colour and density, elements

<table>
<thead>
<tr>
<th>Wave Type</th>
<th>Wavelength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma rays</td>
<td>γ ≤ 1 pm</td>
</tr>
<tr>
<td>X-rays</td>
<td>Soft + hard X-rays (0.1 – 10 nm)</td>
</tr>
<tr>
<td>UV</td>
<td>Ultraviolet radiation (10 – 400 nm)</td>
</tr>
<tr>
<td>VIS</td>
<td>Visible light (400 – 700 nm)</td>
</tr>
<tr>
<td>NIR</td>
<td>Near-infrared radiation (700 – 2000 nm)</td>
</tr>
<tr>
<td>IR</td>
<td>Infrared radiation (1000 nm – 1 mm)</td>
</tr>
<tr>
<td>Microwave</td>
<td>Microwaves (1 mm – 1 m)</td>
</tr>
<tr>
<td>Radio-wave</td>
<td>Radio waves (1 m – 1 km)</td>
</tr>
</tbody>
</table>

Increasing wavelength

Increasing energy intensity
Magnet-based sorting

Differentiation using magnetic field intensity

- Low intensity
  - STEINERT MT
  - STEINERT UM/AM
  - ANOFOL Coils
- Medium intensity
  - STEINERT BR
  - STEINERT WDS
  - STEINERT HGF
- High intensity
  - STEINERT WDS
  - UniSORT CanMaster
  - STEINERT EddyC

STEINERT HGS
Inductions Sorting System
ISS (electromagnetic properties of entire particle)

X-Ray Sorting System
XSS-T (XRT) (Atomic density of entire particle)

3D Laser Sorting System
3DS (Surface detection of brightness/particle size)

Combined Colour and 3D Sorting System
KSS (Surface detection)
Ore sorting in gold mining and processing operations – an economic analysis
Sorting Principle - XRT

Poly-metallic Sulphides

Waste Rock
02 Sorting Principle - XRT

Sulphide product

Waste Rock
Sorting tasks are getting increasingly more complex, requiring combination of information on different characteristics of the material detected by more than one sensor system becomes necessary.

Different sensors provide broad variations of the scanned spectra which can be combined and overlaid to detect different material characteristics.
Multi-Sensor Sorting

Sulphide Product

Quartzite Product

Waste Rocks
Test Methodology
### Results – Grade/Recovery

<table>
<thead>
<tr>
<th>Test No.</th>
<th>MD Setting</th>
<th>Sensor</th>
<th>Total Sample kg</th>
<th>Feed Au (g/t)</th>
<th>Product kg</th>
<th>Mass Recovery %</th>
<th>Product Au (g/t)</th>
<th>Au Recovery %</th>
<th>Waste kg</th>
<th>Waste Au (g/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Step 1</td>
<td>XRT</td>
<td>305</td>
<td>0.25</td>
<td>37</td>
<td>12.1%</td>
<td>1.05</td>
<td>51.4%</td>
<td>268</td>
<td>0.14</td>
</tr>
<tr>
<td>2</td>
<td>Steps 1 &amp; 2</td>
<td>XRT</td>
<td>305</td>
<td>0.25</td>
<td>98</td>
<td>32.1%</td>
<td>0.49</td>
<td>63.5%</td>
<td>207</td>
<td>0.13</td>
</tr>
<tr>
<td>3</td>
<td>Steps 1 to 3</td>
<td>XRT</td>
<td>305</td>
<td>0.25</td>
<td>166</td>
<td>54.4%</td>
<td>0.32</td>
<td>69.8%</td>
<td>139</td>
<td>0.16</td>
</tr>
<tr>
<td>4</td>
<td>Steps 1 to 4</td>
<td>XRT</td>
<td>305</td>
<td>0.25</td>
<td>211</td>
<td>69.2%</td>
<td>0.26</td>
<td>72.8%</td>
<td>94</td>
<td>0.22</td>
</tr>
<tr>
<td>5</td>
<td>Steps 1 to 5</td>
<td>Laser</td>
<td>305</td>
<td>0.25</td>
<td>218</td>
<td>71.5%</td>
<td>0.31</td>
<td>88.2%</td>
<td>87</td>
<td>0.10</td>
</tr>
<tr>
<td>6</td>
<td>Steps 1 to 6</td>
<td>Laser</td>
<td>305</td>
<td>0.25</td>
<td>221</td>
<td>72.5%</td>
<td>0.31</td>
<td>90.0%</td>
<td>84</td>
<td>0.09</td>
</tr>
</tbody>
</table>
Results – Grade/Recovery

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<td>268</td>
<td>0.14</td>
</tr>
<tr>
<td>1 &amp; 5</td>
<td>XRT/Laser</td>
<td>Laser</td>
<td>305</td>
<td>0.25</td>
<td>44</td>
<td>14.4%</td>
<td>1.15</td>
<td>66.8%</td>
<td>261</td>
<td>0.10</td>
</tr>
</tbody>
</table>
Case Study 1 – No Sorter

Brownfields Expansion Of Existing Operations

Base Case – No Pre-Concentration – Total ROM Milled

ROM Stockpile 1.40 g/t

50,000 t/m

MINE OUTPUT

Cart to Mill 1.40 g/t

0 kilometres
Case Study 1 – With Sorting

KEY INPUTS
Sorter reject rate: 40%
Sorter gold recovery: 90%
Case Study 1: Gross Cash Flow

Increase in Gross Cash flow with Ore Sorter
Brownfields Expansion 600,000tpa Mill

<table>
<thead>
<tr>
<th></th>
<th>Annual Gross Cash Flow (A$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Sort</td>
<td>18,131,458</td>
</tr>
<tr>
<td>Sort 40% Reject</td>
<td>26,645,970</td>
</tr>
</tbody>
</table>
Case Study 2

- Low Grade Stockpile Treatment
Low Grade Stockpile Treatment

Base Case  
- No Pre-Concentration
- Hauling 20 km to Mill
- Total Run of Dump Milled

Stockpile  
0.70 g/t

60,000 t/m

Cart to Mill  
0.70 g/t

20 kilometres
Case Study 2 – With Sorting

KEY INPUTS
Sorter reject rate: 40%
Sorter gold recovery: 90%
Case Study 2: NPV

Increase in Pre-Tax NPV with Ore Sorter
720,000tpa @ 0.7g/t

Pre-Tax NPV (A$m)

NPV based on five year project life and 10% discount rate

No Sort

Sort 70% Reject

12.81

1.81
Mill Pebbles Sorting
Mill Pebble Circuit

<table>
<thead>
<tr>
<th><strong>Component</strong></th>
<th><strong>Baseline</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>SAG Mill</td>
<td></td>
</tr>
<tr>
<td>ROM feed, tph</td>
<td>1,200</td>
</tr>
<tr>
<td>Pebble circuit feed, tph</td>
<td>300</td>
</tr>
<tr>
<td>Total SAG feed, tph</td>
<td>1,500</td>
</tr>
<tr>
<td>SAG screen oversize, %</td>
<td>20</td>
</tr>
<tr>
<td>Oversize (pebble circuit), tph</td>
<td>300</td>
</tr>
<tr>
<td>Undersize (to ball mills), tph</td>
<td>1,200</td>
</tr>
<tr>
<td><strong>Pebble Circuit</strong></td>
<td></td>
</tr>
<tr>
<td>Sorter feed, tph</td>
<td></td>
</tr>
<tr>
<td>Sorter rejection as waste, %</td>
<td></td>
</tr>
<tr>
<td>Waste, tph</td>
<td></td>
</tr>
<tr>
<td>Ore, tph</td>
<td>300</td>
</tr>
<tr>
<td>Crusher feed, tph</td>
<td>300</td>
</tr>
</tbody>
</table>
Mill Pebbles - Copper Sulphides

Summary of test work results

- COPPER SULPHIDE SORTING (+50 – 100mm)
  - Waste rejection: 20 – 25%
  - Cu (%) Recovery: 99%
  - Cu (%) upgrade: Feed = 5.87% → 7.43% (Discard = 0.23%)
Mill Pebbles – Gold Ore

Summary of pilot plant results

- Gold sulphide sorting (+12 – 25mm) and (+25 – 45mm)
  - Waste rejection: 50 – 90%
  - Au (g/t) Recovery: up to 93%
  - Au (g/t) upgrade: Feed = 1.4g/t → 4.4g/t (Discard = 0.5g/t)
Conclusion
Conclusion

Multi-Sensor Sorting provides flexible solution for beneficiation of ores.

2 Case Studies comparing No-Sort vs. Sort Scenarios

• The Brownfields as well as the Low-Grade Dump treatment studies have shown significant improvements in profitability by adding a sorting process to the operation
• Removing waste rock before milling and reducing the amount of unnecessary comminution of barren hard rock is the biggest cost saver.
• Reducing transport cost by hauling less waste rock also contributes to the profitability

Mill-Pebble Sorting

• Reduces pebble crusher load
• Reduces recirculating mill load – resulting in higher mill-feed capacities.

• Don’t mill the Waste Rocks, Sort them!
Lütke von Ketelhodt
Engineer, MSc (Eng)
Steinert US Inc.
Email ketelhodt@steinertus.com