INNOVATIVE GRAVITY-BASED TECHNOLOGIES AND CIRCUITS FOR FINE COAL CLEANING

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Workshop on Coal Beneficiation and Utilization of Rejects: Initiatives, Policies and Best Practices
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Coal preparation involves processing to achieve the required quality for end users.

636 Mt of coal processed annually.

Coal is sized and cleaned in various circuits.

Fine (-1 mm) coal typically accounts for 12%-15% of feed (75 – 95 Mt annually).
TYPICAL PROCESS FLOWSHEET

<table>
<thead>
<tr>
<th>Size-Size</th>
<th>Solid-Solid</th>
<th>Solid-Liquid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw Screens</td>
<td>Heavy Media Vessel</td>
<td>Dewatering Screens</td>
</tr>
<tr>
<td>Deslime Screens</td>
<td>Heavy Media Cyclone</td>
<td>Basket Centrifuge</td>
</tr>
<tr>
<td>Small</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Classifying Cyclones</td>
<td>Coal Spirals</td>
<td>Screen-Bowl Centrifuges</td>
</tr>
<tr>
<td>Fine</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Froth Flotation</td>
<td>Disc Filter</td>
</tr>
<tr>
<td>Ultrafine</td>
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<td></td>
</tr>
</tbody>
</table>
Common U.S. Fine Coal Circuit

- 38cm Classifying Cyclone
- 1 x 0.15 mm
  - High Frequency Screen

- Compound Spiral Concentrator
  - Coarse Reject
  - 1 mm Deslime Screen Unders
  - Sieve Bend
  - Screen Bowl Centrifuge
  - Clean Coal

- Column Flotation
- Thickener
Spiral Concentrators

- Flowing film separator.
- Produces three product streams.
- 3-3.5 tph/start; 30 gpm/start.
- Three starts on one axis.
- Separation density = 1.8 RD; $E_p = 0.15 - 0.18$.
- Typical 5-10% high density particle by-pass.
Luttrell et al. performed circuit analysis to reduce separation density and improve efficiency.

Rougher-Cleaner arrangement with middling recycle is the most practical.

Separation densities of around 1.7 at $E_p = 0.18$.

Commercial manufacturers have since produced spirals that achieve the Rougher-Cleaner cleaning action in a single unit.
Recent emphasis in metallurgical coal production is lowering the separation density of the fine circuit.

Water-only cyclones provide a low density cut but tend to lose coal.

Spirals tend to ensure 100% coal recovery but have a high density cut.

Combining the two units provides an efficient low density separation.

- Water-Only Cyclone (WOC): Ep = 0.10
- Spiral: Ep = 0.15
- WOC-Spiral Circuit: Ep = 0.06
Teeter-Bed Separations

- Low pressure water injection at the bottom of the separation chamber fluidizes the high-density particles.
- Fluidized particle bed = autogenous medium.
- Can be used as an alternative or in conjunction with spirals.
- 2 tph/ft² capacity.
- Effective over a particle size range 5:1.
Teeter-Bed Installation

- 650 ton/hr plant
- HMC/Teeter-bed/Flotation plant
- 140 tph, 2 x 0.25 mm treated by Teeter-Bed.
- 3 x 3 m² Crossflow Teeter-Bed unit used.
Parametric evaluation was performed to improve start-up performance.

9% ash product achieved with organic efficiency greater than 95%.
A particle size-by-size analysis of the process streams shows that 56.5% of the ash-bearing material is removed from the +8 and 8 x 16 mesh fractions while recovering 95% of the combustible material.

A significant finding is the high ash contents in the +8 mesh tailings material (>70%). The ash content of this fraction in the initial tests was around 48%.
The average feed, product and tailing ash contents were 15.97%, 9.99% and 64.34%, respectively.
Ultrafine Gravity Circuit

Classifying Cyclones

-1 mm Fine Circuit Feed

Spirals

Enhanced Gravity

- 0.250 mm

0.25 x 0.044 mm

1.0 x 0.25 mm

Reject

Clean Coal

Reject
Spiral Concentrator Application for Ultrafine Coal Cleaning

- Recent studies have found that spirals such as the SX7 can provide an effective gravity-based separation performance for -100 mesh coal.
- Required volumetric flow rate is around 15 gpm/start and feed solids content should be nearly 15% by weight.
- Currently, two U.S. coal preparation plants use spirals in this application.
# Ultrafine Spiral Concentrator

## Ash Rejection Performance

### Test 1 Performance (Higher Yield)

<table>
<thead>
<tr>
<th>Particle Size (mesh)</th>
<th>Spiral Feed</th>
<th>Spiral Product</th>
<th>Spiral Mids 1</th>
<th>Spiral Mids 2</th>
<th>Spiral Tailings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight (%)</td>
<td>Ash (%)</td>
<td>Weight (%)</td>
<td>Ash (%)</td>
<td>Weight (%)</td>
</tr>
<tr>
<td>16 x 100</td>
<td>19.60</td>
<td>8.44</td>
<td>16.34</td>
<td>5.22</td>
<td>16.75</td>
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<tr>
<td>100 x 325</td>
<td>45.13</td>
<td>19.33</td>
<td>44.82</td>
<td>11.18</td>
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<tr>
<td>-325</td>
<td>35.28</td>
<td>53.74</td>
<td>38.84</td>
<td>46.39</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
<td><strong>29.34</strong></td>
<td><strong>100</strong></td>
<td><strong>23.88</strong></td>
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### Test 2 Performance (Lower Product Ash)

<table>
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<tr>
<th>Particle Size (mesh)</th>
<th>Spiral Feed</th>
<th>Spiral Product</th>
<th>Spiral Mids 1</th>
<th>Spiral Mids 2</th>
<th>Spiral Tailings</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Weight (%)</td>
<td>Ash (%)</td>
<td>Weight (%)</td>
<td>Ash (%)</td>
<td>Weight (%)</td>
</tr>
<tr>
<td>16 x 100</td>
<td>19.60</td>
<td>8.44</td>
<td>17.50</td>
<td>4.94</td>
<td>21.92</td>
</tr>
<tr>
<td>100 x 325</td>
<td>45.13</td>
<td>19.33</td>
<td>58.26</td>
<td>10.71</td>
<td>47.18</td>
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<td>-325</td>
<td>35.28</td>
<td>53.74</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
<td><strong>29.34</strong></td>
<td><strong>100</strong></td>
<td><strong>18.53</strong></td>
<td><strong>100</strong></td>
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</table>
## Ultrafine Spiral Concentrator
### Total Sulfur Rejection Performance

### Test 1 Performance

<table>
<thead>
<tr>
<th>Particle Size (mesh)</th>
<th>Spiral Feed Weight (%)</th>
<th>T. Sulfur (%)</th>
<th>Spiral Product Weight (%)</th>
<th>T. Sulfur (%)</th>
<th>Spiral Mids 1 Weight (%)</th>
<th>T. Sulfur (%)</th>
<th>Spiral Mids 2 Weight (%)</th>
<th>T. Sulfur (%)</th>
<th>Spiral Tailings Weight (%)</th>
<th>T. Sulfur (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 x 100</td>
<td>19.60</td>
<td>2.64</td>
<td>16.34</td>
<td>2.43</td>
<td>25.52</td>
<td>2.67</td>
<td>16.75</td>
<td>3.34</td>
<td>15.49</td>
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<tr>
<td>100 x 325</td>
<td>45.13</td>
<td>3.37</td>
<td>44.82</td>
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<td>43.21</td>
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<td><strong>4.07</strong></td>
<td><strong>100</strong></td>
<td><strong>2.50</strong></td>
<td><strong>100</strong></td>
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<td><strong>5.40</strong></td>
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</table>

### Test 2 Performance

<table>
<thead>
<tr>
<th>Particle Size (mesh)</th>
<th>Spiral Feed Weight (%)</th>
<th>T. Sulfur (%)</th>
<th>Spiral Product Weight (%)</th>
<th>T. Sulfur (%)</th>
<th>Spiral Mids 1 Weight (%)</th>
<th>T. Sulfur (%)</th>
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<td>2.45</td>
<td>25.26</td>
<td>2.54</td>
<td>21.92</td>
<td>2.97</td>
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<td><strong>Total</strong></td>
<td><strong>100</strong></td>
<td><strong>4.07</strong></td>
<td><strong>100</strong></td>
<td><strong>3.04</strong></td>
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<td><strong>3.50</strong></td>
<td><strong>100</strong></td>
<td><strong>4.97</strong></td>
<td><strong>100</strong></td>
<td><strong>6.67</strong></td>
</tr>
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</table>
Enhanced Gravity Concentration

- Commercial units available that provide up to 300 g’s
- Units utilize basic principles of jigging, tabling, fluidized bed or flowing film.
- The Knelson Concentrator is a fluidized bed unit.
- Feed slurry is injected into the center and accelerated by mechanical action.
- High density particles migrate to the bowl wall and discharged through controlled pinch valves.
- Low density particles flow naturally over the top lip of the bowl.
Knelson concentrator provided superior performance compared to flotation.
Falcon Concentrator

- Centrifugal flowing film separator.
- Feed slurry containing 20% solids is injected onto a spinning rotor and accelerated.
- Particle bed is formed with heaviest particles near the bowl wall.
- Valves along top circumference of bowl are controlled to discharge the reject.
Water-Only Enhanced Gravity Separations on 300 x 45 Micron Coal

- Altair Jig
- Falcon
- Release Analysis
- Washability
Dense-Medium Application in the Falcon Separator
Pittsburgh No. 8 Coal
Sulfur Rejection Performance

Pittsburgh No. 8 coal

- Washability
- Dense Medium

Total Sulfur Rejection (%) vs Combustible Recovery (%)
Ultrafine Gravity-Based Circuit Requirement

To produce an acceptable ultrafine clean coal product from a gravity-based system, the high clay slimes must be removed.

Unfortunately, the slimes tend to report with the water in classification systems.

When water recovery is restricted, density effects results in the loss of coal to the slime stream.

Screening is typically limited by a low open area and blinding.

The most efficient desliming process commercially available is column flotation.
Summary – Fine Gravity Circuits

- Innovative fine coal circuits involving two-stage, rougher-cleaner spiral units have been successful commercially using conventional low cost dryers for product dewatering.

- Teeter-bed separators have been found to provide very efficient fine coal cleaning for nominal 2 x 0.25 mm coal.
Summary-Ultafine Gravity Circuits

- Spiral concentrators operated under specified feed conditions provide significant ash and total sulfur rejections for the +44 microns coal.
- Similar results have been achieved from enhanced gravity separators on full-scale units.
- However, the inability to commercially achieve efficient ultrafine classification limits gravity-based technologies.
- Column flotation is the most efficient desliming technology.
- For coals containing a relatively high level of pyritic sulfur and/or middling particles, a spiral/enhanced gravity and froth flotation circuit provides better technical performance; economics must be proven.