Coal Preparation Plant Advancements

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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 Flow Sheet For Steam Coal Production

Circuit Feed | SIZING | CLEANING | DEWATERING
---|---|---|---
COARSE | Raw Coal Deslime Screens | Dense Medium Vessel | D&R Screens
| Stoker Centrifuge | Sieve Bends/Clean Coal Cyclones | Clean Coal
MEDIUM | Dense Medium Cyclones | D&R Screens | Screen-Bowl
| Centrifugal Dryer | Thickener | Waste Disposal
SMALL | Classifying Cyclones | Compound Spirals | Dewatering Screen
FINE | Deslime Cyclones (Optional) | Advanced Flotation | Dewatering Screen
| Screen-Bowl | Thickener | Clean Coal

SIZING CLEANING DEWATERING
FINE COARSE MEDIUM SMALL
A number of major plant design changes have been based on poor distribution to various process units.

Poor distribution results in unequal feed volumetric and mass flow rates.

Unequal flow rates typically lead to varying separation performances.
Poor Distribution = Reduced Efficiencies

- 1.5 RD Separation Density
- 1.6 RD Separation Density
- Overall Separation

- Ep increased from 0.03 to 0.06;
- 50% reduction in efficiency.
Rules-of-Thumb

For two or more separators having the same efficiency but different separation densities, the overall efficiency is lower than the efficiency of the single unit.

For two or more separators having different separation efficiencies, the overall efficiency is the weighted average of the efficiencies from the individual units.
Ramifications on Plant Design

- Large Diameter DMC vs. Standard DMC.
- Water-Only Cyclone/Spiral Circuit versus Spiral Circuit.
- Teeter-Bed Separators versus Spiral Circuits.
- Large (3') Diameter Classifying Cyclone versus 15” Cyclones.
- Banana Screen versus Incline Screen.
New Steam Coal Plant Design: Reduced Distribution

Circuit Feed

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<thead>
<tr>
<th>SIZING</th>
<th>CLEANING</th>
<th>DEWATERING</th>
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<tbody>
<tr>
<td>Raw Coal/ Deslime Screens</td>
<td>Dense Medium Cyclones</td>
<td>D&amp;R Screens</td>
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<tr>
<td>Coarse/Medium</td>
<td>Centrifugal Dryer</td>
<td>Clean Coal Cyclones</td>
</tr>
<tr>
<td>SMALL/FINE</td>
<td>Dewatering Screen</td>
<td>Centrifugal Dryer</td>
</tr>
<tr>
<td>Classifying Cyclones</td>
<td>Thickener</td>
<td>Waste Disposal</td>
</tr>
</tbody>
</table>

Teeter-Bed or Spirals
Trend Problems

- The efficiency of large units over a given particle size range may be lower than that achieved by smaller units.

- Efficiency of high capacity technologies may be less than the lower capacity separators that require feed distributors.
Banana Screens

- Australian technology
- Used for deslime screening and drain & rinse screen applications.
- Screen-deck with multiple slopes (2 to 6) which reduces in inclination from the feed end.
- As a result, the velocity of the material is fast at the feed end and slows toward the discharge.
- The high inclinations provide a very thin particle bed which allows the undersize material to pass through the screen more efficiently.
- 50% increase in feed capacity.
Common U.S. Fine Coal Circuit

38cm Classifying Cyclone
1 x 0.15 mm

Compound Spiral Concentrator

1 mm Deslime Screen Unders

Coarse Reject

High Frequency Screen

Sieve Bend

Screen Bowl Centrifuge

Clean Coal

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; $\varepsilon_p = 0.15 - 0.18$.
- Typical 5-10% high density particle by-pass.

![Spiral Concentrators Diagram](image)
Luttrell et al. performed circuit analysis to reduce separation density and improve efficiency.

Rougher-Cleaner arrangement with middling recycle the most practical.

Separation densities of around 1.7 at Ep = 0.18.

Significant economic gains have been reported from plant installations.

Single units using Rougher-Cleaner cleaning action have been developed.
Water-Only Cyclone – Spiral Circuit

- Unloads feed distribution to spirals.
- 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.

![Graph showing probability to product (%) vs relative particle density for Water-Only Cyclone (WOC), Spiral, and WOC-Spiral Circuit.]

- WOC: $\text{Ep} = 0.10$
- Spiral: $\text{Ep} = 0.15$
- WOC-Spiral: $\text{Ep} = 0.06$
Water-Only/Spiral Fine Coal Circuit

- Water-Only Cyclone
- Compound Spiral Concentrator
- 38mm Classifying Cyclone
- Sieve Bend
- 1 mm Deslime Screen Unders
- Coarse Reject
- High Frequency Screen
- Cleaning Cyclone
- 38mm Classifying Cyclone
- Column Flotation
- Screen Bowl Centrifuge
- Clean Coal
- Thickener
Teeter-Bed Separations

- High capacities (2 tph/ft²) eliminates distribution problems associated with spirals.
- 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.
- 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.
Teeter-Bed Performance

- Parametric evaluation was performed to improve start-up performance.
- 9% ash product achieved with organic efficiency greater than 95%.
Reflux Teeter Bed Separator

- Utilizes inclined parallel plates to accelerate particle movement.
- Typical of TBS units, performance varies with particle size.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Overall</th>
<th>Particle Size Fraction (mm)</th>
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</thead>
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<tr>
<td></td>
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<td>2 x 1.4</td>
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<tr>
<td>ρ&lt;sub&gt;50&lt;/sub&gt;</td>
<td>1.70</td>
<td>1.47</td>
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<tr>
<td>Ep</td>
<td>0.15</td>
<td>0.04</td>
</tr>
</tbody>
</table>
Ultrafine Gravity Circuit

-1 mm Fine Circuit Feed

Classifying Cyclones
- 0.250 mm

Classifying Cyclones

Spirals

Enhanced Gravity

0.25 x 0.044 mm

1.0 x 0.25 mm

Reject

Clean Coal

Reject
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></th>
<th>Spiral Product</th>
<th></th>
<th>Spiral Mids 1</th>
<th></th>
<th>Spiral Mids 2</th>
<th></th>
<th>Spiral Tailings</th>
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<tbody>
<tr>
<td></td>
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<td>Ash (%)</td>
<td>Weight (%)</td>
<td>Ash (%)</td>
<td>Weight (%)</td>
<td>Ash (%)</td>
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<td>Ash (%)</td>
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### Test 2 Performance (Lower Product Ash)

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<th>Spiral Product</th>
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<td>Ash (%)</td>
<td>Weight (%)</td>
<td>Ash (%)</td>
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<td>Ash (%)</td>
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# Ultrafine Spiral Concentrator
## Total Sulfur Rejection Performance

### Test 1 Performance

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<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>
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<td>Weight (%)</td>
<td>T. Sulfur (%)</td>
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<tr>
<td>Total</td>
<td>100</td>
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### Test 2 Performance

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<th>Spiral Product</th>
<th>Spiral Mids 1</th>
<th>Spiral Mids 2</th>
<th>Spiral Tailings</th>
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<tr>
<td></td>
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</table>
Dry Coal Cleaning

- Dry coal cleaning was popular from 1930 – 1990.
- Peak production was 25.4 million tons annually in 1965.
- Largest all-air cleaning plant was 1400 tph in Pennsylvania (1968).
- Several commercial technologies developed in the period of 1900 – 1950.
- Decline was due to the need for efficient low density cuts and environmental health concerns (underground & surface).
- Recent U.S. resurgence is in large part due to the need to reduce transportation costs and clean western U.S coals.
- Alminerals modified the Stomp jig to provide a completely automated commercial unit.
- Allair jig has been commercially successful (Mining Engineering, 2007).
Potential Dry Cleaning Applications

- Dry coal cleaning technologies effectively achieve density separations > 1.85 RD.
- Separations at relatively high densities to remove ‘nearly’ pure rock is referred to as deshaling.
- Dry deshaling technologies are less expensive than wet cleaning processes:
  - Capital Cost: $6,200/tph versus $13,000/tph
  - Operating Cost: $0.50/ton versus $1.95/ton.
- Deshaling can be applied at the mine site prior to loading and transportation to the end user.
The All-Air Jig is a unit modified from the Stomp Jig.

Coal is fluidized by a constant flow of air across a perforated table.

Pulsating air provides the jigging action.

Nuclear density gauge used to assist the control of reject rate.

Units up to 100 tph are available.
# 100 tph All-Air Jig Performance

<table>
<thead>
<tr>
<th>Coal Type</th>
<th>Feed Ash (%)</th>
<th>Product Ash (%)</th>
<th>Tailings Ash (%)</th>
<th>Mass Yield (%)</th>
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<th>Coal Type</th>
<th>Feed Sulfur (%)</th>
<th>Product Sulfur (%)</th>
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<td>4.33</td>
<td>3.17</td>
<td>22.79</td>
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</table>
FGX Separator

- Separation based on riffling table principles with air as medium.
- Processes 75 x 6 mm coal; however, -6 mm may be cleaned separately.
- 10%-20% minus 6mm material needed as an autogenous medium.
- Less than 7% surface moisture.
- High separation densities; ~2.0 Relative Density (RD).
- Probable error (Ep) values between 0.2–0.3.
- Chinese Technology based on previous designs. (10 – 480 tph units).
- Eriez Manufacturing represents the technology in the U.S..
## FGX Deshaling Performance

### Deshaling Performance:
33.5% Reject Rate

<table>
<thead>
<tr>
<th>Test No.</th>
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<th>Product Ash (%)</th>
<th>Middlings Ash (%)</th>
<th>Reject Ash (%)</th>
<th>Yield (%)</th>
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<td>12.63</td>
<td>73.30</td>
<td>89.38</td>
<td>42.9</td>
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</tbody>
</table>

### Aver. | 49.27 | 21.47 | 74.32 | 89.17 | 49.5 |

Note the ability to reduce ash from 49.3% to 12.6%
East Kentucky Underground Coal
(20 mile haul distance)

![Graph showing cumulative reject ash and reject mass yield for different tests. Test 16 reaches 88% ash.](image)
Central Appalachia Bituminous Coal (Site No. 2)

- West Virginia underground coal containing around 60% ash.
- Yield to the reject & 1.6 RD float-sink performed.

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Middlings &amp; Reject Combined</th>
<th>Reject Only</th>
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<tbody>
<tr>
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<td>% of Feed</td>
<td>% Float 1.6 RD</td>
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</tr>
<tr>
<td>4</td>
<td>52.4</td>
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</table>
Economic Benefit

- Unit Capacity = 500 tph
- Yield to Reject = 36.4%
- Reject Amount = 500 \times 0.364 = 182 tph
- Annual Operating Hours = 6000 hrs/yr
- Total Reject left at mine = 182 tons/hr \times 6000 hrs/yr = 1,092,000 tons
Transportation Savings

- **Transportation Cost**
  \[ = 0.30 \text{ \$/ton} \times \text{mile} \]

- **Mine-to-Plant Distance**
  \[ = 20 \text{ miles} \]

- **Transportation Cost/ton**
  \[ = 20 \times 0.30 = 6.00 \text{ \$/ton} \]

- **Reduction in Tons Hauled**
  \[ = 1,092,000 \text{ tons/yr} \]

- **Annual Transportation Savings**
  \[ = 1,092,000 \times 6 = 6,552,000 \]
Lost Coal Cost

- Total Deshaler Reject
  - = 182 tons/hr

- % 1.60 Float in Reject
  - = 0.78%

- Total Coal Loss
  - = 182 x 0.0078 = 1.42 tph

- Annual Coal Loss
  - = 1.42 x 6000 hrs/yr
  - = 8518 tons

- Sales Price = $50/ton

- Lost Coal Cost
  - = 8518 x 50 = $425,880/yr
Summary Economic Benefit

- **FGX Operating Cost**
  - \(= \$0.50/\text{ton}\)

- **Annual Operating Cost**
  - \(= \$0.50 \times 500 \times 6000\)
  - \(= \$1,500,000/\text{yr}\)

**Summary:**

- **Transportation Savings** = \$6.55M
- **Coal Loss Cost** = \$0.43M
- **Operating Cost** = \$1.50M
- **Net Profit Gain** = \$4.62M

Capitol Cost = \$3200/\text{tph}
500 tph unit = \$1.6 M
Summary

The most recent changes in coal processing plants are linked to two issues affecting plant efficiency:

– Maintaining constant incremental qualities across each circuit.
– Reducing effects of distribution errors.
Summary

Higher capacity units are being employed which has reduced circuit complexity.

Performance problems have occurred with the large single units.

Various fine coal technologies and circuits have been commercialized to reduce separation density.
A resurgence in dry coal cleaning has occurred due to the need to process low rank coals and deshale high-ash eastern U.S. coals.

Separators have demonstrated the ability to remove material having an ash content > 88% which represents up to 60% of the feed.

Current commercial installations are successful.
Comments/Questions?