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).
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.
Coal Deshaling Concept

Coal Operation → ROM Coal → Dry Coal Cleaner → Processing Plant → Haulage → High-Density Rock → Coal Operation
Many coals located <1000 km away from the utility are not cleaned.

As a result, 40%-45% ash coals are transported and used in utilities designed for 25%-35% ash coal.

For a relatively easy-to-clean India coal, dry cleaning has the ability to reduce the ash from 41% to 30%.
Most India coals have cleaning characteristics that are difficult.

The most efficient wet-based coarse cleaning technologies have difficulty in achieving effective ash reduction.

Dry deshaling concentrates on the density fractions that are easy to remove.

Using deshaling, ash reduction for a difficult coal could be from 45% to 34%.
Accelerator Technology

- Selective breakage technology.
- Unlike the Rotary Breaker, the amount of breakage can be operator controlled.
- Reduces 250 x 25 mm ROM coal to a more uniform -25 mm product.
- The raw material passes across a scalping grizzly to bypass coal finer than 25 mm.
- The remaining material is then propelled by variable-speed rotor assemblies into pointed impact-sizing grids.
- Coal that has fractured to a 25mm size then passes through a second scalping grizzly.
- The remaining material is hurled by the second rotor assembly into another set of impact grids.
Accelerator Application

- Run-of-Mine Coal
  - Trommel Screen
    - +25 mm Coal
    - Accelerator Technology
      - -25 mm Coal
        - Trommel Screen
          - Deshaled Coal
            - Rock
              - Deshaled Coal

**U.S. Bituminous Coal Results**

<table>
<thead>
<tr>
<th>Size</th>
<th>Weight (%)</th>
<th>Ash (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard No. 4 Seam Coal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ 3&quot;</td>
<td>10.62</td>
<td>96.62</td>
</tr>
<tr>
<td>3&quot; x 2&quot;</td>
<td>8.27</td>
<td>95.65</td>
</tr>
<tr>
<td>2&quot; x 1&quot;</td>
<td>40.40</td>
<td>86.92</td>
</tr>
<tr>
<td>1&quot; x 1/2&quot;</td>
<td>19.88</td>
<td>69.41</td>
</tr>
<tr>
<td>1/2&quot; x 1/4&quot;</td>
<td>9.35</td>
<td>64.94</td>
</tr>
<tr>
<td>1/4&quot; x 0</td>
<td>11.48</td>
<td>61.69</td>
</tr>
<tr>
<td>Alma Seam Coal</td>
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<td></td>
</tr>
<tr>
<td>+ 3&quot;</td>
<td>10.39</td>
<td>90.43</td>
</tr>
<tr>
<td>3&quot; x 2&quot;</td>
<td>12.74</td>
<td>87.88</td>
</tr>
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<td>2&quot; x 1&quot;</td>
<td>38.65</td>
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<td>1&quot; x 1/2&quot;</td>
<td>17.45</td>
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<td>1/2&quot; x 1/4&quot;</td>
<td>9.34</td>
<td>54.65</td>
</tr>
<tr>
<td>1/4&quot; x 0</td>
<td>11.43</td>
<td>55.59</td>
</tr>
</tbody>
</table>

Results obtained from a 250 tph unit evaluated at various mine sites in central Appalachia.
All-Air Jig: Density-Based Separation

- 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>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23.93</td>
<td>13.73</td>
<td>68.12</td>
<td>81.10</td>
</tr>
<tr>
<td>2</td>
<td>10.14</td>
<td>7.37</td>
<td>49.89</td>
<td>93.49</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Coal Type</th>
<th>Feed Sulfur (%)</th>
<th>Product Sulfur (%)</th>
<th>Tailings Sulfur (%)</th>
<th>Mass Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>6.05</td>
<td>3.77</td>
<td>8.06</td>
<td>81.10</td>
</tr>
<tr>
<td>2</td>
<td>4.33</td>
<td>3.17</td>
<td>22.79</td>
<td>93.49</td>
</tr>
</tbody>
</table>
Relative separation density = 2.12.

Probable error = 0.26

82% rejection of high density rock.
FGX Separator

- Separation based on riffling table principles with air as medium.
- Processes 75 x 6 mm coal; however, -6 mm may 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.
Operating Principles

- Feed enters the table from the far right corner.
- Fluidization air is injected through holes in the table.
- Light particles (coal) become fluidized with the assistance of autogenous medium (i.e., -6mm material).
- Fluidized coal is transported toward the front of the table and discharged on the right side.
- High-density material remains in contact with the table.
- Vibration motion moves the heavy material back and to the left.
- Product, middling, and tailing streams can be generated.
Test Program

- 5 tph mobile FGX unit tested at each site.
- 1 m² table deck
- Coal was prescreened to achieve a 25 x 6 mm feed.
- Recent tests focused on 25mm inch and 6mm coal cleaning.
- Parametric test design performed at each site.
- At several sites, the material exiting the table was split into six different fractions along the length of the table.
Objective: Maximize the rejection of high density rock from run-of-mine coal prior to transportation.

- Mobile 5-tph Air Table tested.
- Run-of-Mine bituminous coal.
- Raw coal was prescreened at 6 mm.
- 15 tests performed over a range of operating conditions.
- Timed samples of feed, product, middlings and tailings stream.
## FGX Deshaling Performance

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Feed Ash (%)</th>
<th>Product Ash (%)</th>
<th>Middlings Ash (%)</th>
<th>Reject Ash (%)</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
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<td>19.46</td>
<td>83.38</td>
<td>89.03</td>
<td>53.5</td>
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<td>2</td>
<td>51.69</td>
<td>34.05</td>
<td>87.08</td>
<td>89.51</td>
<td>66.5</td>
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<td>3</td>
<td>54.88</td>
<td>29.09</td>
<td>78.19</td>
<td>87.75</td>
<td>48.4</td>
</tr>
<tr>
<td>4</td>
<td>48.27</td>
<td>25.75</td>
<td>80.42</td>
<td>89.92</td>
<td>55.9</td>
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<td>78.41</td>
<td>91.37</td>
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<td>17.87</td>
<td>68.21</td>
<td>88.34</td>
<td>44.5</td>
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<td>7</td>
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<td>55.11</td>
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<td>34.6</td>
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<td>29.02</td>
<td>82.04</td>
<td>89.80</td>
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<td>50.18</td>
<td>19.69</td>
<td>78.26</td>
<td>90.09</td>
<td>51.1</td>
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<td>11</td>
<td>45.88</td>
<td>34.50</td>
<td>86.30</td>
<td>91.09</td>
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<td>12.88</td>
<td>72.51</td>
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<td>57.02</td>
<td>88.90</td>
<td>37.3</td>
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<td>71.90</td>
<td>87.95</td>
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<td>12.63</td>
<td>73.30</td>
<td>89.38</td>
<td>42.9</td>
</tr>
<tr>
<td>Aver.</td>
<td>49.27</td>
<td>21.47</td>
<td>74.32</td>
<td>89.17</td>
<td>49.5</td>
</tr>
</tbody>
</table>

- **Deshaling Performance:** 33.5% Reject Rate
- **Note the ability to reduce ash from 49.3% to 12.6%**
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>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% of Feed</td>
<td>% Float 1.6 RD</td>
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<tr>
<td>1</td>
<td>50.7</td>
<td>3.71</td>
</tr>
<tr>
<td>2</td>
<td>49.5</td>
<td>2.82</td>
</tr>
<tr>
<td>3</td>
<td>55.1</td>
<td>3.72</td>
</tr>
<tr>
<td>4</td>
<td>52.4</td>
<td>2.73</td>
</tr>
</tbody>
</table>
Economic Benefit

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

- Transportation Cost
  = 0.30 $/ton*mile

- Mine-to-Plant Distance
  = 20 miles

- Transportation Cost/ton
  = 20 x 0.30 = $6.00/ton

- Reduction in Tons Hauled
  = 1,092,000 tons/yr

- Annual Transportation Savings
  = 1,092,000 x $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/ton

- Annual Operating Cost
  $0.50 \times 500 \times 6000
  = $1,500,000/yr

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

Capitol Cost = $3200/tph
500 tph unit = $1.6 M
Economic Benefit vs. Haulage Distance

Deshaling Economic Gain ($ Million/yr)
- Tailings Only (Reject Rate = 36.4%)
- Middlings & Tailings (Reject Rate = 52.4%)

Mine-to-Plant Distance (miles)
Production of Marketable Coal

Coal Operation → Crusher → Dry Coal Cleaner → Screening → Loading → Market

Rock → Dry Coal Cleaner → -6mm Feed

Dry Coal Cleaner → +6mm Product

-6mm Feed → +6mm Product
Utah Bituminous Coal

- In-field testing conducted at a bituminous coal mine.
- +6mm raw feed coal was treated.
- Objective: Produce a marketable product.
- Parametric test program was conducted to evaluate and optimize the operating parameters.

Mobile 5 tph FGX Unit and Test Setup
Utah Coal Performance

- 32 tests.
- 4 parameters evaluated.
- Average Feed Ash Content = 18.2%.
- Average Clean Coal Ash Content = 10.8%.
- Average Tailings Ash Content = 72.9%.
- Average Yield to the Product = 76.8%.

Middlings stream considered as part of tailings stream.
Size-by-Size Partition Curves

- $\rho_{50} = 1.87$ RD
- $E_p = 0.24$
- Small amount of 1.4 RD float material middlings stream reporting to tailings.
- Rock rejection >85%
- Improvement will be realized when middlings are recycled to the feed stream!
To quantify the performance expected from middling recycle, linear analysis was performed.

\[ P = LR_1 \]

\[ T = L(1 - R_1)(1 - R_2) \]

\[ R_{overall} = \frac{P}{P + T} = \frac{R_1}{R_1 + (1 - R_1)(1 - R_2)} \]

where \( R_1 \) and \( R_2 \) are the probabilities of a particle reporting to the product and middlings stream, respectively.
Partition curves were generated from product, middlings and tailings data.

The partition curves were based on two cases:
- Product stream only to clean coal.
- Product and middlings stream combined as clean coal.

Linear analysis to evaluate Mids recycle revealed:
- Density Separation = 2.0
- Probable Error = 0.17
Sub-bituminous coal in the PRB is typically directly loaded without cleaning.

During extraction, out-of-seam rock mixes with some coal on the rib. The contaminated coal is left in the pit.

At a large operation, it is estimated that the amount of loss coal could total up to 10 million tons annually.

Dry cleaning provides an opportunity for recovery.
Sub-Bituminous Test Program

- Testing for cleaning sub-bituminous Powder River Basin Coal.
- Test program involved a parametric study of 15 tests.
- Six total samples splits were collected along the length of the table during each test.
- Thus, a yield versus product ash relationship was obtained for each test.
- Average feed ash content = 19.47%.
- Performance target was to produce clean coal in the +6mm fraction contain around 6% - 8% ash.
Ash reduction performance is based on the +6mm data. **Overall Yield** reflects amount of feed mass that is -6mm which will not be recovered. Feed ash content = 19.47%. In the summary, splits 1 - 3 were directed into the product stream and 4 - 6 to tailings. Several tests generated a product ash content less than 7% with mass yield values around 80%.

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Product Ash (%)</th>
<th>FGX Yield (%)</th>
<th>Overall Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.19</td>
<td>82.11</td>
<td>64.38</td>
</tr>
<tr>
<td>2</td>
<td>6.21</td>
<td>78.00</td>
<td>61.15</td>
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<tr>
<td>3</td>
<td>7.52</td>
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<td>59.16</td>
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<td>6.00</td>
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<tr>
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<td>6.41</td>
<td>82.83</td>
<td>64.94</td>
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<tr>
<td>15</td>
<td>6.93</td>
<td>69.71</td>
<td>54.65</td>
</tr>
</tbody>
</table>

Average 6.85 78.96 61.90
Gulf Coast Lignite Testing

- In-field testing conducted to reduce sulfur and mercury content in a run-of-mine lignite coal.

- +6mm raw feed coal was treated.

- Parametric test program was conducted to identify optimum setting and performances.
  - Required significant variations in test conditions.

*Mobile 5 tph FGX Unit and Test Setup*
# Lignite Separation Performances

<table>
<thead>
<tr>
<th>Test</th>
<th>Product Ash %</th>
<th>Product Yield %</th>
<th>Ash Reduction %</th>
<th>Sulfur Reduction %</th>
<th>Mercury Reduction %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.03</td>
<td>85.81</td>
<td>33.15</td>
<td>28.42</td>
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<td>4.90</td>
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<td>56.76</td>
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<td>32.84</td>
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<td>4</td>
<td>4.23</td>
<td>80.66</td>
<td>43.13</td>
<td>41.51</td>
<td>67.66</td>
</tr>
</tbody>
</table>

FGX Tailings Material
Weight & Quality Distribution

Dust

Feed

Yield (%) 3.25
Ash (%) 26.95
Sulfur (%) 3.04
Btu/lb. 7984

Yield (%) 100.00
Ash (%) 11.78
Sulfur (%) 3.17
Btu/lb. 7633

Sample No. 6 5 4 3 2 1
Yield (%) 1.29 2.58 5.16 16.77 32.25 38.70
Ash (%) 58.66 44.34 9.50 5.05 4.69 4.58
Sulfur (%) 5.36 5.90 2.70 1.31 1.18 1.12
Btu/lb 3744 5021 7559 7820 7956 7882
Coal recovery from a coarse gob pile located in Phelps, KY. Material was pre-screened at 6mm. Target was a product calorific value of around 10000 Btu/lb.

<table>
<thead>
<tr>
<th>Table Split Number</th>
<th>Weight (%)</th>
<th>Ash (%)</th>
<th>Heating (Btu/lb)</th>
<th>Weight (%)</th>
<th>Ash (%)</th>
<th>Heating (Btu/lb)</th>
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<td>54.80</td>
<td>6278</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Recent developments have lead to the redesign and commercialization of coarse density-based separators developed in the early twentieth century.

Dry separation technologies can be installed and operated at the mine site to remove rock prior to loading and transportation to the end user.

The ash content of run-of-mine India coals could be reduced to values in the range of 30% to 35%.

Dry deshaling technologies provide a low cost alternative to wet-based technologies for achieving density separations greater than 1.85 RD.

Units with capacities as high as 480 tph are available.

Probable error values in the range of 0.20 to 0.30 are typically achieved which indicates an efficiency that is adequate for the high density separations.
Summary & Conclusions

Recent testing with a 5 tph dry separator has demonstrated that:

- Up to 36% of the rock can be rejected from an eastern U.S. coal while losing only 0.78% of the material that floats at 1.60 RD.
- Waste sub-bituminous coal at a surface operation at a PRB site can be cleaned to reduce the ash content from around 30% to less than 7% ash.
- High sulfur (40%) and mercury (60%) reductions can be achieved for lignite coal.
- The heating value of coarse waste can be upgraded from 6000 Btu/lb to values approaching 10000 Btu/lb.

The Accelerator technology has the potential to provide selective breakage and allow for the rejection of 10% or more of the run-of-mine coal appearing as high density rock.
Comments/Questions?