Pre-Gasification Coal Beneficiation by DryFining™ fuel enhancement system

7th International Freiberg/Inner Mongolia Conference on Coal Conversion
Huhhot, Inner Mongolia, China
Charlie Bullinger, PE
American Lignite Energy commissioned an engineering study in 2007 to integrate and evaluate Great River Energy’s patented DryFining™ fuel enhancement system to dry and refine lignite for a 1460 STPH coal gasification project.
Lignite drying and gasification

As-Received Lignite (37.5% moisture)
35,000 STPD
5,300 MW_{th} HHV

Hot water \pm LP Steam
330 MW_{th}

\begin{align*}
\text{H}_2\text{O} + \text{N}_2 + \text{air} & \rightarrow \text{DryFining x 22} \\
& \rightarrow \text{30\% N}_2 + 70\% \text{air}
\end{align*}

\begin{align*}
\text{Pulverizer x 9+1} & \rightarrow \text{As-Fed Lignite (8\% moisture)} \\
& \rightarrow 23,800 \text{ STPD}
\end{align*}

\begin{align*}
\text{ASU x 4} & \rightarrow \text{Gasifier x 9+1} \\
& \rightarrow \text{CO + H}_2 \\
& \rightarrow 1,000 \text{ MMSCFD} \\
& \rightarrow 4,000 \text{ MW}_{th} \text{ HHV}
\end{align*}
CTL general arrangement
DryFining area (upper left)
Two-stage coal drying system for a CTL plant

RAW COAL FEED
1,460 t/hr
37.5 % wet coal basis

Elutriated Coal
23.0 % wet coal basis
133 °F

Evaporated Coal Moisture

Baghouse
471 t/hr

Evaporated Coal Moisture

Waste Heat

1st Stage FBD
60% of Total

250 °F

Waste Heat

DRIED COAL (PRODUCT)

167 °F

2nd Stage FBD
40% of Total

989 t/hr
7.73 % wet coal basis

Waste Heat

AMBIENT AIR
65 % of Total Fluidization Flow

NITROGEN from ASU
35 % of Total Fluidization Flow
DryFining™ dryer + segregation
DryFining fluidized bed coal dryer

Feed (crushed coal) → Feed Stream → 1st Stage Fluidizing Air → In-Bed HXE → 2nd Stage Fluidizing Air → In-Bed HXE → Product Stream

Fluidization Air and Evaporated Coal Moisture → Segregated Stream → Gravitational segregation → Segregated Stream → Further Cleaning → Low-Temp. Heat → Further Cleaning

Low-Temp. Heat → Refined Coal

To bag house
Characteristics of DryFining™

- Low temperature, atmospheric pressure process
  - No high temperature or high pressure parts
  - No exotic materials
- Maximizes use of waste heat from plant to remove coal moisture
  - Improves efficiency
  - Reduces operating cost
- Simple design, few moving parts
  - Equipment is simple and inexpensive to manufacture
Drying rate for lignite coal
Moisture vs. time @ temperature

Coal Moisture Content vs. Time and Drying Temperature

Coal Moisture Content, $\Gamma$ (water/dry mass)

Time (min)

GREAT RIVER ENERGY™
Devolatilization curves

Figure 1: CO Concentration vs. Heater Surface Temperature
Segregation stream

Sulfur and Hg in Segregation Stream

![Graph showing Sulfur and Mercury content over dates from 5/31/06 to 6/14/06. The graph indicates fluctuations in Sulfur and Mercury percentages.]

- Sulfur content:
  - 0.00% to 50.00%
  - Peaks on 6/6/06 and 6/12/06
- Mercury content:
  - 0.00% to 60.00%
  - Peaks on 6/6/06 and 6/14/06

%S in UC vs %Hg in UC over the specified dates.
Ash segregation

Coal Ash Mineral Densities
J.C. Kennedy - 01/13/10

<table>
<thead>
<tr>
<th>Compound</th>
<th>Density (lb/ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FeS₂</td>
<td>150</td>
</tr>
<tr>
<td>SiO₂</td>
<td>100</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>100</td>
</tr>
<tr>
<td>TiO₂</td>
<td>100</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>150</td>
</tr>
<tr>
<td>CaO</td>
<td>200</td>
</tr>
<tr>
<td>MgO</td>
<td>200</td>
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<tr>
<td>K₂O</td>
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<tr>
<td>Na₂O</td>
<td>200</td>
</tr>
<tr>
<td>SO₃</td>
<td>200</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>200</td>
</tr>
<tr>
<td>SrO</td>
<td>200</td>
</tr>
<tr>
<td>BaO</td>
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<tr>
<td>MnO₂</td>
<td>200</td>
</tr>
<tr>
<td>Hg</td>
<td>200</td>
</tr>
<tr>
<td>Coal</td>
<td>200</td>
</tr>
</tbody>
</table>

Pyrite has the lowest density among the listed compounds.
Prototype Coal Dryer Performance: March to April, 2006

- Wet Feed
- Dried Product

Coal HHV [%]

Wet Feed
Dried Product

Total Coal Moisture Content [%]

Wet Feed
Dried Product

Test Dates:
DryFining™ emission results¹

54% lower $\text{SO}_2$ - Segregation of ash minerals, plus improved collection efficiency throughout AQCS system

Up to 40% lower $\text{Hg}$ - Segregation of ash minerals, plus improved collection efficiency throughout AQCS system

32% lower $\text{NO}_x$ - Reduced volumetric release rate, improved fineness and air & fuel distribution to furnace

3.4% lower $\text{CO}_2$ intensity - improved cycle efficiency plus increased net power output

¹Independent testing April 2010 compared to pre-DryFining process improvements September 2009
### Capital cost comparison – 1460 STPH

<table>
<thead>
<tr>
<th>Component</th>
<th>Competitor</th>
<th>DryFining™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dryers</td>
<td>$328 million</td>
<td>$149 million</td>
</tr>
<tr>
<td>BOP - hammer mills, wet coal bunkers, dry coal silos, structural &amp; stacks</td>
<td>Included above</td>
<td>$21 million</td>
</tr>
<tr>
<td>Incremental directs &amp; indirects (Licensing, detailed engineering and IDC)</td>
<td>$32 million</td>
<td>$59 million</td>
</tr>
<tr>
<td></td>
<td>$360 million</td>
<td>$229 million</td>
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</table>

¹Updated to 2015 dollars
## Operating cost¹ estimate – 1460 STPH

<table>
<thead>
<tr>
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<th>Competitor</th>
<th>DryFining™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power cost for Dryer system (excluding fans)</td>
<td>N/A</td>
<td>$6.5 million</td>
</tr>
<tr>
<td>Maintenance costs</td>
<td>$10.8 million</td>
<td>$6.2 million</td>
</tr>
<tr>
<td>Overhead, taxes &amp; insurance</td>
<td>$12.5 million</td>
<td>$7.2 million</td>
</tr>
<tr>
<td><strong>Estimated annual operating cost</strong></td>
<td>$23.3 million</td>
<td>$19.9 million</td>
</tr>
<tr>
<td>Export power revenue (based on steam balance)</td>
<td>($29 million)</td>
<td>($49 million)</td>
</tr>
<tr>
<td><strong>Net annual operating “expense”</strong></td>
<td>($5.7 million)</td>
<td>($29 million)</td>
</tr>
</tbody>
</table>

¹Updated to 2015 dollars
Comparison of drying systems

COMPETITOR

- Utilizes superheated steam
  - Higher operating cost
  - Limits export MWe
- No segregation offered
- Higher capital expense
  - High temperature & pressure
  - Stainless steel construction
  - Larger footprint

DRYFINING™ FUEL ENHANCEMENT

- Utilizes CTL waste heat
  - Uses 57% less steam
  - 14% lower operating cost
  - Up to 70% more export MWe
- Continuous segregation of dense fraction (Hg, FeS)
- 35% lower capital expense
  - Low temperature & pressure
  - Carbon steel construction
  - 23% less square footage required
Conclusions

- The **DryFining™** fuel enhancement system has been in commercial operation at GRE for more than **5 years** and has processed **30+ million tons** of raw lignite.
  - Measurable efficiency improvement & emission reductions are being maintained on an ongoing basis.
  - Current system capacity is **>95%**.
  - Beneficial effects on plant operation, maintenance, & availability have been documented.
- **DryFining™** technology offers first cost and operating cost advantages and can be successfully integrated with IGCC and CTL.
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