CoalCONTROL™ – EMISSIONS REDUCTION THROUGH BURNER BALANCING

Harun Bilirgen, Edward Levy
REASONS FOR COAL-FLOW BALANCING

- Improved Performance and Reduced Emissions
  - Reduced Unburned Carbon
  - Lower CO
  - Improved Steam Temperature Control
  - Lower NOₓ
  - Improved ESP Performance

- Reduced Maintenance Costs
  - Lower Coal Pipe Erosion
  - Less Coal Pipe Plugging - Windbox Fires
  - Reduced Slag Buildup and Damage to Burner Tips
  - Reduced Localized Slagging and Waterwall Wastage
THE ERC APPROACH TO IMPROVED BOILER OPERATIONS

Emissions and Performance Optimization

Boiler Tuning and Correction of Maintenance Problems

Primary Air Balancing – Orifice Sizing

Coal-Flow Balancing – CoalCONTROL™
TYPICAL CoalCONTROL™
PROJECT STEPS

- Evaluate rifflers and burner lines.
- Perform unit performance and emissions baselining.
  Measure coal and PA flow imbalances.
  - Check measurement or collection location.
  - Review sample collection method.
  - Interpret data.
- Balance PA flow as needed.
- Design and fabricate CoalCONTROL™ devices.
- Install and test CoalCONTROL™.
- Provide combustion tuning after installation.
COAL-FLOW BALANCING
Balanced coal flow may not be best for optimum combustion. Optimal burner stoichiometry should be the objective.

Adjust combustion stoichiometry at the burner tip according to:
- Coal flow measurements.
- Flame characteristics.

Eliminate problems with individual burner air/fuel control:
- Fuel Rich – High CO, LOI, and Longer Flames
- Fuel Lean – High Flame Temperature at Burner Tip
- High Thermal NO$_x$
CoalCONTROL™ DESIGNS

- Current design is for mills with 2, 3, and 4-way pipe splits.
  - Coal distribution is heavily affected by inlet maldistribution.
  - Rifflers are used to improve coal flow distribution.

- Design in progress for pressurized vertical spindle mills
  - CFD modeling completed
  - Laboratory testing completed
  - Prototype field test in 2008
CoalCONTROL™ TECHNOLOGY FOR PIPES WITH SPLITS

- Dynamic coal flow control for two, three, and four-way splitters
- Negligible effect on Primary Air (PA) flow distribution
- Negligible additional pressure drop to existing systems
- Resistance to solid particle erosion
- Easy retrofit and cost effective
- U.S. patent Numbers: 6,789,488 and 6,966,508
CoalCONTROL™
HOW DOES IT WORK?
COAL FLOW BALANCING RESULTS WITH *CoaICONTROL™* – Neutral Position

- Adds a streamline body into the coal/air flow stream.
- Takes advantage of two-phase particle flow.
  - Air phase will flow along the body without separation.
  - Coal phase will separate from the body.
Moving the streamline bodies changes the coal flow distribution.

Changes in position doesn’t affect the primary air distribution.
COAL FLOW IMBALANCES AS A FUNCTION OF
FCE POSITION TWO-WAY SPLITTER

FCE: Flow Control Element
Additional Pressure Drop Due to FCE is Less than 0.8 Inches of Water

Balanced Coal Flow

CONTROLABILITY OF CoalCONTROL™
FIELD TEST RESULTS
# CoalCONTROL™ - 51 INSTALLATIONS

<table>
<thead>
<tr>
<th>STATION</th>
<th>CoalCONTROL™ CONFIGURATION</th>
<th>COAL IMBALANCE, %</th>
<th>BOILER SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FirstEnergy Sammis Plant Unit 3</strong></td>
<td>One 3-Way Controller</td>
<td>+14% to +17%</td>
<td>±4%</td>
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<tr>
<td><strong>Cogentrix Logan Station Unit 1</strong></td>
<td>Four 3-Way Controllers and Rifflers</td>
<td>+50% to -30%</td>
<td>±5%</td>
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<tr>
<td><strong>WE Energy Presque Isle Units 5&amp;6 (Babcock Power)</strong></td>
<td>Eight 2-Way Controllers</td>
<td>No Data</td>
<td>No Data</td>
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<tr>
<td><strong>New Energy Corporation (Babcock Power)</strong></td>
<td>Two 2-Way Controllers</td>
<td>No Data</td>
<td>No Data</td>
</tr>
<tr>
<td><strong>Smurfit Stone Container (Babcock Power)</strong></td>
<td>One 2-Way Controllers</td>
<td>No Data</td>
<td>No Data</td>
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<tr>
<td><strong>PPG Industries (Babcock Power)</strong></td>
<td>Three 2-Way Controllers</td>
<td>No Data</td>
<td>No Data</td>
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<tr>
<td><strong>New Installation – Shipping in April 2008 (Babcock Power)</strong></td>
<td>Sixteen 2-Way Controllers</td>
<td>No Data</td>
<td>No Data</td>
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<tr>
<td><strong>PSEG Mercer Station Unit 2</strong></td>
<td>Two 4-Way Controllers and Rifflers</td>
<td>25/25/25/25</td>
<td>Target: 20/30/30/20 Actual: 22/27/28/23</td>
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<tr>
<td><strong>AES Beaver Valley Unit 4</strong></td>
<td>Two 3-Way Controllers and Rifflers</td>
<td>+22% to -29%</td>
<td>±8%</td>
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<tr>
<td><strong>Conectiv Edge Moor Station Unit 3</strong></td>
<td>Twelve 2-Way Controllers</td>
<td>+33% to -26%</td>
<td>±5%</td>
</tr>
</tbody>
</table>
LOGAN GENERATING STATION
Four 3-Way *CoalCONTROL™* systems were designed, fabricated and installed on the Logan Generating Station's 245 MW front wall-fired unit.

The *CoalCONTROL™* systems replaced the existing 3-way coal distribution splits on the Foster Wheeler (FW) horizontal ball mills.
The ERC designed a combined coal-flow controller and riffler assembly.

Resistance to solid particle erosion was provided using Tungsten Carbide (WC) material.
FIELD RESULTS

The following were observed and measured improvements:

- Reduction in Fly ash LOI
- Reduction in CO emissions
- Reduction in SCR Ammonia injection rate
- More stable unit operations
IMPROVED COAL FLOW DISTRIBUTION
WITH CoalCONTROL™

Before CoalCONTROL™ Retrofit

After CoalCONTROL™ Retrofit
COAL BALANCE IMPROVEMENT USING CoalCONTROL™ – MILL 1

UNIT A - COAL FLOW IMBALANCES

Before Retrofit
After Retrofit

Coal Flow Imbalance [%]

A1 A2 A3 A4 A5 A6

Mill-1 Burner Lines
Coal Flow Variations in Burner B2
Before and After Lehigh Coal Flow Mechanism Installation

Time [Minutes]
Coal Flow Rate [%]

Before Installation
After Installation
REDUCTION IN CO EMISSIONS WITH CoalCONTROL™

CO Emissions - Before May 2004 Outage
(Before Riffler Retrofit)
Average O2 = 5.3 Percent
Average LOI = 25.0 Percent
Ammonia Injection Rate = 104 Gph

CO Emissions - After May 2004 Outage
(After Riffler Retrofit)
Average O2 = 4.6 Percent
Average LOI = 20.0 Percent
Ammonia Injection Rate = 80 Gph
REDUCTION IN LOI LEVEL IN FLY ASH WITH CoalCONTROL™

Fly Ash LOI Distribution - Before May 2004 Outage (Before Riffler Retrofit)
Average O2 = 5.3 Percent
Average LOI = 25 percent
Ammonia Injection Rate = 104 Gph

Fly Ash LOI Distribution - After May 2004 Outage (After Riffler Retrofit)
Average O2 = 4.6 Percent
Average LOI = 20 percent
Ammonia Injection Rate = 80 Gph
## CoalCONTROL™ BENEFITS SUMMARY

<table>
<thead>
<tr>
<th>Description</th>
<th>Units</th>
<th>Before Retrofit</th>
<th>After Retrofit</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Electrical Generation</td>
<td>MW</td>
<td>240.5</td>
<td>243.6</td>
<td>1.27</td>
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<tr>
<td>Average Flue Gas O₂ (Grid)</td>
<td>%</td>
<td>3.68</td>
<td>3.09</td>
<td>-0.59</td>
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<tr>
<td>Ammonia Inlet Flow</td>
<td>gph</td>
<td>106.84</td>
<td>88.04</td>
<td>-21.36</td>
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<tr>
<td>Stack NOₓ</td>
<td>ppm</td>
<td>83.26</td>
<td>78.86</td>
<td>-5.58</td>
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<tr>
<td>CEMS CO Monitor</td>
<td>ppm</td>
<td>86.21</td>
<td>76.68</td>
<td>-12.43</td>
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<tr>
<td>Heat Rate</td>
<td>Btu/kWh</td>
<td>10,187</td>
<td>10,098</td>
<td>-0.88</td>
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<tr>
<td>Average LOI in Fly Ash</td>
<td>%</td>
<td>24.9</td>
<td>20.3</td>
<td>-4.56</td>
</tr>
</tbody>
</table>

- Savings based on lower heat rate and reduced fly ash handling cost – $400,000 per year
- Payback in 5 months for CoalCONTROL™
MERCER GENERATING STATION
Designed and fabricated two *CoalCONTROL™* 4-Way rifflers and flow controllers for one mill.

Installation and coal flow adjustments – Adjusted *CoalCONTROL™* to achieve the specified coal distribution profile of $20/30/30/20$ percent of coal flow through each burner at each elevation.
PROJECT APPROACH

- Preliminary study was performed using the PSEG Energy Liaison Program (ELP) account.
  - CFD modeling – Pressure drop calculations and design improvement were done.
  - Contacted fabricators for cost estimates.
- Fabricated, installed and tested the CoalCONTROL™ technology.
- Future work – Installation of CoalCONTROL™ on the remaining mills.
CURRENT RIFFLER DESIGN AT MERCER

Stage 1: Two-Way Riffler
Stage 2: Two-Way Riffler
Four-Way Splitter

Flow

Long Radius Elbow

Four-Way Splitter

Stage 2: Two-Way Riffler
Stage 1: Two-Way Riffler
CFD MODELING OF THE EXISTING AND PROPOSED DESIGN

- Computed the pressure drop (dP) of the two designs
- Improve the proposed design to minimize dP
PRESSURE DROP (dP) COMPARISONS

- Lehigh Original Design: 10.55
- Mercer Current Design: 9.65
- Lehigh Modified Design: 4.75
PSEG MERCER STATION – 4-WAY CoalCONTROL™ ASSEMBLY

- Design and fabrication of two 4-Way CoalCONTROL™ riffler and flow controller assemblies was done in the Winter 2006.

- Installation and adjustments of CoalCONTROL™ to achieve the specified coal distribution profile was done in Spring 2007.
PSEG MERCER STATION – 4-WAY CoalCONTROL™ RESULTS

FURNACE 21

Unit Load ~ 320 MW
Coal = 100% Domestic
Lehigh CC = 100% Bias

Percent Coal Flow [%]

21-31 21-32 21-33 21-34
CONECTIV EDGE MOOR STATION
Station retrofitted a low NO$_x$ system. Vendor required balanced coal-flow distribution (±10%)

Designed and fabricated twelve (four primary and eight secondary) CoalCONTROL™ 2-way coal-flow control elements for four mills.

Installed and adjusted the CoalCONTROL™ elements to achieve the required coal-flow distribution.
PROJECT APPROACH

- Preliminary study used the Conectiv Energy Liaison Program (ELP) account.
  - Coal-flow element design.
  - Contacted fabricators for cost estimate.
- Fabricated, installed and tested the *CoalCONTROL™* technology.
LEHIGH CoalCONTROL™ INSTALLATION
LEHIGH CoalCONTROL™ CONTROLIBILITY

- SW Corner
- SE Corner

Graph showing the relationship between Coal Sample Weight (g) and Position of Flow Control Element (in).

- SW
- SE

Flow direction indicated by an arrow.
REAL TIME CONTROL OF COAL COMBUSTION

Specified coal flow bias between burners
- Windbox design
- Water wall tube temperature
- Slagging
- CO emission
CONCLUSIONS

- *CoalCONTROL™* has been tested in the field and has shown excellent results.
- Primary air flow distribution was not affected by coal flow changes.
- Reduced coal flow imbalances to less than ±10%.
- Minimal impact on pressure drop.
- Provides a useful tool for on-line combustion optimization.
ENERGY RESEARCH CENTER
For more information contact –

Dr. Harun Bilirgen

Telephone: (610) 217 0259
hab4@lehigh.edu