Zonal* Combustion Optimization for Coal-Fired Boilers
McIlvaine Hot Topic Hour

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Boiler Optimization Services
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* Trademark of General Electric Company
Outline

> Principles of combustion optimization … how to obtain the optimum efficiency, availability and performance
> Available approaches
> GE’s Zonal combustion approach
  – Overview
  – Applicability
  – Capabilities
  – Limitations
  – Cost/Benefit
> Real world experience
Principles of Optimization
Combustion is a major contributor to coal-fired boiler performance losses

- High LOI
- Excessive Attemperation
- Excessive FEGT
- Delayed Combustion
- Local slagging
- Local corrosion
- Local hot spots
- High CO
- Increased excess O2
- High NOx
- High CO2
- Reduced efficiency

Coal Crushed
Coal Silos
Air Heater
ID Fan
Boiler
Combustion Monitors in Boiler
Backpass Boiler
Turbine Generator
Zonal TM
Coal-Fired Boiler

Poor Combustion
Typical burner-to-burner imbalance forces operation at high excess air levels.

Unique ability to detect combustion imbalance.
First step in improving combustion is to balance fuel-air distribution.

Tools and know-how to balance combustion
Balanced combustion avoids operating issues and allows operators to reduce excess air.

**Combustion Parameters**

- Efficiency
- \(O_2\)
- NOx
- UBC

**Air-Fuel Ratio**

- Low
- High

**Example Burner Array**

Confidence to operate at optimum.
Available Approaches
## Available combustion optimization approaches

<table>
<thead>
<tr>
<th>Approaches</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burner Coal Flow Balance</td>
<td>• Good practice</td>
<td>• Does not ensure uniform combustion</td>
</tr>
<tr>
<td></td>
<td>• Reduces air adjustments</td>
<td></td>
</tr>
<tr>
<td>Burner Air-Fuel Ratio Control</td>
<td>• Reasonably balances Burner A/F</td>
<td>• May not balance furnace A/F</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Limited accuracy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Expensive per burner system</td>
</tr>
<tr>
<td>Manual Economizer Gas Mapping</td>
<td>• Improves combustion when tuned</td>
<td>• Slow and imprecise mapping</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Operate blind between tunings</td>
</tr>
<tr>
<td>Furnace TDL Measurements</td>
<td>• Fast, path average conditions</td>
<td>• Lack spatial detail</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Poor CO detection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Data difficult to interpret</td>
</tr>
<tr>
<td>Optimizations (AI) Software</td>
<td>• Fast response</td>
<td>• Can drive unit into poor combustion zone</td>
</tr>
<tr>
<td></td>
<td>• Can handle complex operation</td>
<td></td>
</tr>
<tr>
<td>Zonal Combustion</td>
<td>• True combustion optimization</td>
<td>• Need operator and maintenance engagement</td>
</tr>
<tr>
<td></td>
<td>• Online operation benefits</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Synergies with coal balance and AI software</td>
<td></td>
</tr>
</tbody>
</table>
GE’s Zonal Combustion Approach
Zonal – foundation for success

Reliable sensors and equipment

Intuitive combustion information

Expert designs and implementation

Simplified operation & maintenance

a product of ecomagination™
Standalone tool for operator, I&C and engineers access

Operator Information
> Real-time O₂ & CO profiles
> Measurement trends

Maintenance Support
> Analyzer calibrations & drift checks
> Probe Blowback

Engineer Analytics
> Combustion average & imbalance
> Data historian
Zonal intuitive display

> Spatial information
> Intuitive color scheme
> Minimizes operator data overload

Color schemes:
- Red is bad (Low $O_2$, High CO)
- Green is good
- Blue is excessive (High $O_2$, no CO)
Zonal Combustion Monitoring System
Application targets:

> **Fired boilers**
  - Small to large size
  - Coal and natural gas

> **All firing configurations**
  - Wall, Tangential, Riley, & Cyclone
  - With or without LNB/OFA

> **Wide range of coals**
  - Ash up to 30%
  - Moisture up to 40%
  - Sulfur up to 4.0%

**Furnace**
- Incomplete combustion
- Significant stratification
- High fluctuations

**Backpass**
- Combustion complete
- Good tracing to burners
- Minimal air in-leakage

**Zonal Grid** (900-1,200°F)

**Post-Backpass**
- Poor flow distribution
- Poor tracing to burners
- Air in-leakage
Zonal Combustion System Costs and Benefits

Benefits
- Increase boiler performance and availability
- Improve fuel flexibility and emissions compliance
- Simplify and enhance boiler operation

Avoiding one forced outage can justify investment
Zonal Real World Experience
Zonal hardware installation

Analyzer Heads

Probe Support Sleeves

Electronic Assemblies

Probe Filter
Zonal is in excellent agreement with traditional O₂ ... higher resolution improves accuracy

Zonal is being used for air regulation control
Zonal: Mid-Western US front wall-fired boiler
As-Found Zonal Combustion Conditions

Normal O₂ Operation

> Plant O₂ average = 3.0%
> Zonal O₂ average = 3.8%
> Zonal O₂ variance +/- 1.4%

Reduced O₂ Operation

> Plant O₂ average = 2.5%
> Zonal O₂ average = 3.2%
> Zonal O₂ variance +/- 1.9%

Unknowingly operated at high excess O₂
Zonal: Western US tangential-fired boiler
As-Found Zonal Combustion Conditions

Normal O₂ Operation
> Zonal O₂ average = 3.6%
> O₂ Imbalance = +/- 0.9%
> CO average = 37 ppm

Reduced O₂ Operation
> Zonal O₂ average = 2.8%
> O₂ Imbalance = +/- 1.4%
> CO average = 150 ppm

Severe slagging at reduced excess O₂ operation
Zonal: Northern US opposed wall-fired boiler
As-Found Zonal Combustion Conditions

**Normal O₂ Operation**
- Zonal O₂ average = 3.5%
- Zonal O₂ variance +/- 1.7%
- CO average = <25 ppm

**Reduced O₂ Operation**
- Zonal O₂ average = 2.0%
- Zonal O₂ variance +/- 3.1%
- CO average = 400 ppm

Furnace wall corrosion drove need for high O₂ imbalance
Zonal: Mid-Western US front wall-fired boiler

Zonal CO Profiles

As Found Normal O₂
As Found @ Reduced O₂
Zonal Tuned @ Reduced O₂

Zonal provides ability to tune out poor combustion
Zonal: Western US opposed wall-fired Boiler
Combustion tuning

Opposed Fired Boiler

As Found

Tuned

O₂: 4.24 %
O₂ Dev.: 2.0
CO: 975 ppm

O₂: 4.23 %
O₂ Dev.: 0.99
CO: 548 ppm
Zonal: Western US opposed wall-fired boiler
Combustion tuning

Zonal improves understanding and operating behaviors
Western US tangential-fired boiler
Zonal Tuning Advisor results

Time series of Zonal sensor oxygen readings

Before

Tuning Advisor balanced boiler excess $O_2$

After

• $O_2$ average: 3.3%
• $O_2$ imbalance: +/- 1.0%
• CO: 34 ppm

Before

• $O_2$ average: 3.1%
• $O_2$ imbalance: +/- 0.3%
• CO: <25 ppm
Western US tangential-fired boiler
Zonal improved unit availability

> Zero slagging outages on Unit 1 after Zonal installed in August 2007

> In January 2009 O₂ was reduced on all 3 units to reduce NOx
  – Zero lost output on Zonal unit (Unit 1)
  – Lost output on other units increased

Unit 1 burns severe slagging western US coals
# GE Zonal System Installations

<table>
<thead>
<tr>
<th>No.</th>
<th>Site</th>
<th>Location</th>
<th>Boiler</th>
<th>MW</th>
<th>Grid</th>
<th>Service</th>
<th>Benefits</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>A-1</td>
<td>Utah, US</td>
<td>T-Fired</td>
<td>460</td>
<td>2x5</td>
<td>10/2007</td>
<td>Slagging, NOx, Efficiency</td>
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<tr>
<td>2</td>
<td>B-1</td>
<td>Denmark</td>
<td>Wall-Fired</td>
<td>380</td>
<td>2x6</td>
<td>6/2008</td>
<td>Excess O₂, NOx</td>
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<tr>
<td>3</td>
<td>C-1</td>
<td>UK</td>
<td>Wall-Fired</td>
<td>180</td>
<td>2x4</td>
<td>7/2008</td>
<td>NOx</td>
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<tr>
<td>4</td>
<td>C-2</td>
<td>UK</td>
<td>Wall-Fired</td>
<td>180</td>
<td>2x4</td>
<td>7/2008</td>
<td>NOx</td>
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<tr>
<td>5</td>
<td>D-1</td>
<td>Minnesota, US</td>
<td>Wall-Fired</td>
<td>80</td>
<td>2x4</td>
<td>1/2009</td>
<td>NOx, Slagging</td>
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<tr>
<td>6</td>
<td>E-3</td>
<td>Florida, US</td>
<td>Wall-Fired</td>
<td>380</td>
<td>3x4</td>
<td>12/2009</td>
<td>Excess O₂, Coal Flexibility</td>
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<td>7</td>
<td>F-7</td>
<td>Michigan, US</td>
<td>Wall-Fired</td>
<td>35</td>
<td>2x3</td>
<td>5/2010</td>
<td>NOx</td>
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<td>8</td>
<td>G-2</td>
<td>Colorado, US</td>
<td>Wall-Fired</td>
<td>350</td>
<td>3x5</td>
<td>1/2011</td>
<td>CO, NOx, Slagging</td>
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<tr>
<td>9</td>
<td>G-1</td>
<td>Colorado, US</td>
<td>T-Fired</td>
<td>350</td>
<td>3x5</td>
<td>5/2012</td>
<td>NOx, Slagging</td>
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<tr>
<td>10</td>
<td>H-1</td>
<td>Kentucky, US</td>
<td>Wall-Fired</td>
<td>425</td>
<td>3x5</td>
<td>8/2011</td>
<td>Coal Flexibility, NOx, Corrosion, Slagging</td>
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</tbody>
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