ZoloBOSS: Laser-based Sensor for Real-time Combustion Optimization

Better Measurements, Better Results
Combustion Optimization Principles

1. **Measure** the right constituents, at the right place
2. **Correlate** constituent profiles to manipulated variables
3. **Balance:** manipulate variables to balance combustion
4. **Optimize:** safely lower excess $O_2$ to optimize combustion
Balanced Combustion ➔ Optimized Combustion

- Balanced combustion (Temp, O₂ & CO) is better combustion
- Balanced combustion permits safe operation at lower excess O₂
- Lower excess O₂ ➔ increases efficiency (heat rate)
- Lower excess O₂ ➔ lowers NOx rates
- Subject to constraints on CO and slagging
Maintaining Furnace Balance Is Difficult

- Traditional measurement sensors/locations are not adequate
  - “The right amount of ingredients don’t make a good cake”
  - Proper air/fuel at each burner is important but may not mean optimized combustion
- Natural process variations will lead to local imbalances in furnace
  - 80% of combustion problems occur in 20% of furnace – but where??
  - CO increases exponentially, Slag/fouling hot spots, NOx with high O₂
- Permanent measurement is needed to maintain performance
  - One-time tuning is only good for a short period
  - Conditions change over time: loads, fuels, operators

Air/Fuel Measurements
- Good for burner performance
- Not indicative of overall combustion

Back Pass Measurements
- Limited info on local furnace conditions
- Typically point measurement only
- Good for overall O₂ control
- Good for overall CO monitoring

In-furnace Measurements
- Critical for in-furnace balancing
- Identifies localized combustion issues
- Permanent measurement maintains optimal combustion
The Solution: The ZoloBOSS System

- **Measure the Right Things**
  - Uses TDLAS to simultaneously measure Temperature, $O_2$, CO & $H_2O$

- **Measure in the Right Place**
  - Real-time measurement directly in the furnace

- **Measure all the time**

- **Multiple measurement paths**
  - Generate two-dimensional images or profiles

Better Measurement, Better Results
Typical ZoloBOSS Layout

- Slotted Opening in Membrane
- Port Rodder
- SensAlign Heads installed on front wall

3/8 " x 3 "
(9.5 x 76mm)
Slot

SensAlign Head w/ Port Rodder
SensAlign™ Head
Typical ZoloBOSS Layouts

Wall-fired

- Elevation below nose arch
- Orthogonal Grid
- Paths above each LNB column
- Paths near side walls
- Optional: SH/RH paths

Grid

T-fired

- Elevation below nose arch
- Orthogonal Grid
- Typical: 5x5 or 6x6
- Optional: SH/RH paths

Single Paths
Combustion Optimization

**Measure**
- Plant data
- Furnace data

**Center/Balance**
- Balance/Center Temperature
- Balance O₂
- Balance CO

**Optimize**
- Manipulate Air/Fuel bias
- Reduce Excess O₂

**Correlate**
- Parametric Tests
- Model-based
- Rules-based
- Neural-net based

**Results:**
- Improve Heat Rate
- Lower Emissions: NOx & CO₂
- Minimize Slag
- Increase Fuel Flexibility

**Develop Relationships**
- Manual Balancing
- Operator control
- Combustion Optimizer
Center Combustion: Why?

- Centered Combustion = Balanced combustion
- Goal = Centered Combustion (fireball)
  - Fireball center is a compass to direct combustion manipulations

![Contour Plot for B_ZoloTemp_StdDev](image)

- Closer to center: Lower StDev, More balanced
- Further away from center: Higher StDev, Less balanced
Fireball Centering for T-Fired Furnace (1)

- 660 MW T-fired Furnace
- Supercritical conditions
- 6 x 6 ZoloBOSS Grid
- Parametric testing produced “rules” for centering fireball
- ZoloBOSS readings 180° out of phase of burner locations due to flame swirl.

ZoloBOSS readings 180° out of phase of burner location due to spiral flow of flue gas
### Closed-loop Combustion Optimization (2)

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<th>Optimization Objective</th>
<th>Operational Adjustments</th>
<th>Performance Improvement</th>
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<td><strong>Fireball Centering</strong></td>
<td>Secondary Auxiliary Air • Corner &amp; levels (A-F)</td>
<td>• Improved heat transfer • Reduced slagging • Improved boiler efficiency</td>
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<tr>
<td><strong>O₂ Balancing</strong></td>
<td>SOFA • Corner &amp; layers (I-IV)</td>
<td>• Improved boiler efficiency • O₂ too high = efficiency loss • O₂ too low = efficiency loss</td>
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<tr>
<td><strong>Combustion Balancing</strong> (Temp, O₂ and CO)</td>
<td>Secondary Boundary Air • Corner &amp; levels (A-F)</td>
<td>• Improved heat transfer</td>
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<tr>
<td><strong>O₂ Reduction</strong></td>
<td>O₂ Set Point</td>
<td>• Lower flue gas flow ➔ Lower dry gas losses ➔ Improved boiler efficiency</td>
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#### Fireball Centering

By modifying Secondary Auxiliary Air

#### O₂ Balancing

By modifying SOFA

#### Combustion Balancing

By modifying Secondary Boundary Air
Optimizer Control w/ Balancer

- **Balancer Off**
  - Optimizer can not lower $O_2$ → CO increases and hits limit

- **Balancer On**
  - Optimizer lowers $O_2$ from 3.6% to 2.85%
  - CO stays within limits
  - NOx Reduced by 14%
  - Efficiency Improvement = 0.49%
700MW Twin Tangential-fired Boiler

Plant Objectives:
• Maintain NOx at <100ppm
• Maintain CO at <200ppm
• Maintain SH and RH temperatures at >1000 F

Problem:
• CO & NOx targets met with optimizer
• Steam temps generally below 1000F

Solution:
• In-furnace measurement with ZoloBOSS
• Balance furnace combustion
1. Equilibrate East and West Furnace.

Overall Results

• Emissions:
  – NO\textsubscript{x} ↓ by 5% (78 to 74ppm); Maintained CO limits < 200ppm

• Steam Temps:
  – Superheat ↑ 6.4F; Reheat ↑ 18.0F; (SH split - 0.1F, RH Split of 6.6F)

• Auxiliary Power:
  – ↓ 2.4 MW

• Heat Rate:
  – Total Heat Rate Reduction \sim 0.9%
Summary

Optimized combustion requires:
- Real-time, in-furnace measurement data
- Combustion must be balanced before optimization

Balanced / Optimized combustion leads to:
- Improved heat rate (efficiency)
- Enhanced availability
- Greater fuel flexibility
- Decreased emissions
- Minimize slagging
Questions?

- Please visit our website at www.zolotech.com
- Thank you for your time and your interest!

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