Ultra-low Emission Products and Applications

Agenda

• Who is Cleaver-Brooks?
• NO$_x$ formation and issues
• Low NO$_x$ burner design
  – FGR
  – Steam injection
  – Mixing
  – CFD and other modeling techniques
• Cleaver-Brooks design
• Application/projects
• Challenges
Cleaver-Brooks
Family of Brands

- Cleaver-Brooks Packaged Boilers
  - Commercial Watertube Boilers
  - Firetube Boilers
- Nebraska Boiler
  - Industrial Watertube Boilers
- Industrial Combustion
- NATCOM

Cleaver-Brooks
Product Development

- Development Center in Milwaukee, WI
- Total System Focus
  - Boilers
  - Burners
  - Controls
- Integration and Optimization
  - Maximize Efficiency and Reliability
  - Minimize Emissions
Low-$\text{NO}_x$ Burners

- Impact on Boiler System
  - Additional Equipment
  - Impact on Performance
  - Safety Concerns
  - Compliance Uncertainty
  - Burner / Boiler Incompatibility

NO$_x$ Formation

- Types
  - Thermal NO$_x$
  - Fuel NO$_x$

- Conditions
  - Nitrogen and Oxygen
  - Temperature
  - Time
**NO\textsubscript{x} Formation**

- Temperature Dependent

![Diagram showing NO\textsubscript{x} formation with temperature and flame temperature axes]

**NO\textsubscript{x} Conditions**

- Nitrogen and Oxygen
  - Fuel Bound Nitrogen in Liquid Fuels
  - Oxy-Fuel Combustion
- Flame Temperature
  - Formation over 2600 F
  - NO\textsubscript{x} increases as Temperature Increases
- Residence Time
  - Controlled by Mixing and Furnace Geometry
Low Emissions Window

Practical NO\textsubscript{x} Issues

- Regulated Levels
  - very small concentrations
- Accurate Measurement
  - Equipment and Methodology
  - Continuous vs. Sampling
- Operator Training
Control Technologies

• Pre-Combustion
  – Fuel Selection
  – Oxygen vs. Combustion Air

• Post-Combustion
  – Catalytic NO\textsubscript{x} Reduction

• Reduction at the Source
  – Boiler/Burner/Controls design

Low-NO\textsubscript{x} Burner Design

• Premix Design
  – Near ‘Perfect’ Mixing
  – Surface Combustion
  – NO\textsubscript{x} emission < 10 PPM possible
  – Air/Fuel Mixing Equipment affects System Size

• Nozzle Mix Design
  – Traditional Burner Concept
  – Typical NO\textsubscript{x} emissions 25-50 PPM due to local Hot-spots
Low-NO$_x$ Burner Design

- NO$_x$ Reduction
  - Flue Gas Recirculation
  - Steam Injection
  - Mixing
  - Modeling

Flue Gas Recirculation
Flue Gas Recirculation

• Effective in Lowering the Flame Temperature
• NO$_x$ < 9 PPM
• Recirculation of up to 40% of Exhaust Gas
• Burner Changes Required to Maintain Combustion Stability

%FGR vs. NO$_x$ Reduction
Steam Injection - HyperMix

- Lowers Flame Temperature
- Less Effective than FGR
- Lower Capital Expenditure than FGR
- 1-2% of Total Steam Produced
- Requires minimal Burner Modifications
- Promotes mixing

Mixing Power

- Options
  - Air pressure (fan horsepower is expensive)
  - Fuel pressure (usually 5-10 psig is available and is ‘free’)
  - Other sources (ex. Steam)
- Total mixing power = summation of the above
Zones

AIR
Axial air zone
Center core air zone
Swirler air zone

GAS
Stabilizer gas injection zone
Staged gas injector zone
Main gas injector zone

STEAM
Hypermix

Computational Fluid Dynamics (CFD)

- Optimize Burner Flame Pattern and Furnace Temperature Distribution
Furnace Temperature Profiling

Exhaust Velocity Streamlines
Iso-Temperature Profile

Products and Applications

- **Watertube**
  - Commercial (1.5 - 12 mm BTU/hr)
  - Industrial (10,000 - 300,000 pph)

- **Firetube**
  - 100 to 1500 hp
ProFire NTH
(1.5 - 14.5 mm BTU/hr)

ProFire NTD
(12.6 - 37.8 mm BTU/hr)
ProFire NTS
(37.8 - 63 mm BTU/hr)

Baxter Healthcare  Burbank  500 HP  Firetube
Patton State Hospital Patton  500 HP  Firetube
Eisenhower Medical Center Palm Springs  (4) 300 HP  Firetube
Boeing Aerospace Long Beach  (2) 400 HP  Firetube
See's Candies Los Angeles  167 HP  Watertube
1000 Fremont Bldg Alhambra  239 HP  Watertube

12 PPM NOx JOBS
### 12 PPM NOx JOBS

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<td>Nor Cal Beverage Company</td>
<td>Anaheim</td>
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<td>UCSD Cancer Center</td>
<td>La Jolla</td>
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### 9 PPM NOx JOBS

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<td>Clement Pappas Company</td>
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<td>J. D. Heskell Company</td>
<td>Fontana</td>
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Challenges

- Simplify Set-up and Maintenance
- Feedback and Control
  - Parallel Positioning
  - Oxygen Trim
  - Boiler NO\textsubscript{x} Emission
- Further Integration of Burner and Boiler
- Regulations

Clearfire Boiler New from Cleaver Brooks
Thank You