NOx Emission Control Options for ICI Boilers

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Fuel Tech is an integrated technology company providing advanced engineering solutions to enable clean efficient energy.
Fuel Tech at a Glance

- Air Pollution Control – Capital Projects
  - NO$_x$OUT® Products:
    - SNCR, ASCR, and ULTRA
  - Low NOx Burner and Overfire Air Systems
- FUEL CHEM® – Specialty Chemical Programs
  - Boiler Efficiency and Availability Improvements
  - Slag and Corrosion Reduction
  - Control of SO$_3$ Emissions
- Technology solutions - Advanced Engineering
Fuel Tech’s Global Activities

Office Locations: Warrenville, IL; Stamford, CT; Milan, Italy; Beijing, China

Countries where Fuel Tech does business: USA, Belgium, Canada, China, Chile, Columbia, Czech Republic, Denmark, Dominican Republic, Ecuador, France, Germany, Italy, Jamaica, Mexico, Poland, Portugal, Puerto Rico, Romania, South Korea, Spain, Taiwan, Turkey, United Kingdom, Venezuela
NOx Emissions Controls

- **Combustion Controls**
  - Low-NOx Burner (LNB) Retrofit
  - Over Fire Air (OFA)

- **Post-Combustion Controls**
  - Selective Non-Catalytic Reduction (SNCR)
  - Selective Catalytic Reduction (SCR)
  - Advanced SCR
NOx Emissions Controls

- Combustion Controls
  - Low-NOx Burner (LNB) Retrofit
  - Over Fire Air (OFA)

- Combustion Control Examples
  - Burner Replacements
  - OFA Design and Installation
  - Combustion Optimization and Testing
**Burner Case History**

- **Trigen Syracuse Boilers 1, 2, 3**
  - Three 200,000 lb/hr B&W WF Boiler Eastern Bit Coal
    - Engineer, model and supply
    - Eight burners and OFA System
  - Baseline NOx 0.50 lb/mmBtu
  - NOx reduced 25% to 0.33 lb/mmBtu

### CASE HISTORY

<table>
<thead>
<tr>
<th>CLIENT</th>
<th>Trigen – Syracuse Boilers 1, 2 &amp; 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLANT NAME</td>
<td>Trigen – Syracuse Boilers 1, 2 &amp; 3</td>
</tr>
<tr>
<td>APPLICATION</td>
<td>Three (3) - 200,000 lb/hr Babcock &amp; Wilcox Wall Fired Boiler required combustion improvement and NOx reduction under the EPA Section 126 petition.</td>
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<tr>
<td>PROJECT SCOPE</td>
<td>Engineer, model, supply and start-up burner optimizations and to reduce NOx emissions 25% and flyash LOI 25% from existing baselines</td>
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<tr>
<td>BOILER DATA</td>
<td></td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Babcock &amp; Wilcox</td>
</tr>
<tr>
<td>Type</td>
<td>Natural Circulation Boiler</td>
</tr>
<tr>
<td>Capacity</td>
<td>200,000 lb/hr</td>
</tr>
<tr>
<td>Steam Conditions</td>
<td>850 PSIG, 850°F SH</td>
</tr>
<tr>
<td>Fuels</td>
<td>Eastern Bituminous Coal</td>
</tr>
<tr>
<td>Burners</td>
<td>Eagle Air Low NOx type</td>
</tr>
<tr>
<td>Firing Arrangement</td>
<td>Front Fired 3 wide x 2 high</td>
</tr>
<tr>
<td>Overfire Air</td>
<td>Four (4) ports on the front wall and Four (4) ports on the rear wall</td>
</tr>
<tr>
<td>Baseline Emissions</td>
<td>NOx - 0.50 lb/mmBtu, CO - &gt;1000 ppm, Flyash LOI &gt; 35%</td>
</tr>
<tr>
<td>Final Emissions</td>
<td>NOx - 0.33 lb/mmBtu, CO - &lt;500 ppm, Flyash LOI &lt;25%</td>
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</table>

**DESCRIPTION AND PERFORMANCE**

Trigen-Syracuse (TS) owns and operates Boilers 1, 2 & 3 to supply steam for generation and process use. TS had a desire to improve combustion and reduce NOx following a Low NOx burner retrofit by Eagle Air (EA). During the burner retrofit by EA eight (8) Over Fire Air (OFA) ports were added.

Fuel Tech conducted a Computational Fluid Dynamics (CFD) model of the existing burners and OFA system. It was determined the OFA ports were not effective and they were plugged. Each of the four (4) burners were upgraded with Fuel Tech’s Low NOx swirlers, Coal Distribution Disk, Low NOx coal nozzle and Approach Cone.

NOx emissions were reduced from a baseline of 0.50 lb/mmBtu to 0.30 lb/mmBtu. Flyash LOI was also reduced from greater than 35% to less than 25% with a 50% reduction in CO emissions.
Burner Case History

- Mead Corporation Boiler 8
  - 360,000 lb/hr CE WF Boiler burning Eastern Bituminous Coal
  - Engineer, model and supply burner modifications and Over-Fire Air System
  - Baseline NOx 0.86 lb/mmBtu
  - NOx reduced 55% to 0.36 lb/mmBtu
ARE, Inc. Boiler C
- 300,000 lb/hr CE WF
Boiler burning Eastern Bituminous Coal
- Engineer, model, supply and start up six (6) burner upgrades
- NOx baseline 0.80 lb/mmBtu
- NOx reduced by 60% to 0.35 lb/mmBtu
Burner Case History

- **BP Whiting Refinery**
  - Five (5) 475,000 lb/hr WF units
  - Engineer, model, supply and start up six (6) burner upgrades
  - NOx baseline 0.52 lb/mmBtu
  - NOx reduced by 90% to 0.04 lb/mmBtu

**CASE HISTORY**

<table>
<thead>
<tr>
<th>CLIENT</th>
<th>BP REFINING</th>
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</thead>
<tbody>
<tr>
<td>PLANT NAME</td>
<td>BP Whiting Refinery</td>
</tr>
<tr>
<td>APPLICATION</td>
<td>Five (5) 475,000 lb/hr Foster Wheeler Wall Fired Boiler required NOx reduction under the EPA Consent Degree</td>
</tr>
<tr>
<td>PROJECT SCOPE</td>
<td>Engineer, model, supply and start-up burner upgrades to reduce NOx emissions 90% to 0.04 lb/mmBtu.</td>
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</table>

- **Manufacturer** Foster Wheeler
- **Type** Natural Circulation Boiler
- **Capacity** 475,000 lb/hr
- **Steam Conditions** 900 PSIG, 900°F SH
- **Fuels** Natural Gas/Refinery Gas
- **Burners** 6 GEA circular register
- **Baseline NOx** 0.52 lb/mmBtu
- **Final NOx** 0.04 lb/mmBtu

**DESCRIPTION AND PERFORMANCE**

BP Refining owns and operates Boiler house 3 with five (5) Foster Wheeler natural gas and refinery gas fired boilers. As part of an EPA Consent Decree, they needed to reduce NOx to less than 0.04 lb/mmBtu from a baseline of 0.52 lb/mmBtu. Fuel Tech’s burner upgrades were selected as the most cost effective technology to reduce NOx to the lowest possible level. Baseline testing determined the CO emissions were less than 50 ppm. The design was required to limit flyash to less than 400 ppm with no impact on combustion performance.

Burners are located in three (3) rows of two (2) burners. Burner upgrades included the addition of a Low NOx Swirler, Gas Pokers and Shrouds. An Induced Fuel Gas Recirculation (IFGR) and Over Fire Air (OFA) systems were installed for additional reductions.

Secondary airflow was balanced utilizing Fuel Tech’s combustion air testing technology. The existing secondary air shrouds were set to balance airflow to each burner to within ±5% of boiler mean.

NOx was reduced to less than 0.04 lb/mmBtu over the load range while maintaining CO emissions less than 400 ppm.
OFA System Installed above Windbox
T-Fired Low NOx System w/SOFA

T-Fired Low NOx Burner (LNB) & Separated Over Fire Air (SOFA) System

T-Fired Low NOx Burner (LNB)
Corner Windbox
Coal To Gas/Low NOx Gas Conversions
Coal Flow Balancing
- ASME Coal Sampling Probe
- Dirty Air Flow Testing

Secondary Air Flow Balancing

Combustion Air Testing
- Startup and Optimization

Fly Ash Sampling
- UBC/LOI Determination
**NOx Emissions Controls**

- **Combustion Controls**
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  - Over Fire Air (OFA)

- **Post-Combustion Controls**
  - Selective Non-Catalytic Reduction (SNCR)
  - Selective Catalytic Reduction (SCR)
  - Advanced SCR
Post Combustion Controls

Selective Non-Catalytic Reduction (SNCR)

**Urea**

$$2\text{NO} + \text{NH}_2\text{-CO-NH}_2 + \frac{1}{2}\text{O}_2 \Rightarrow 2\text{N}_2 + \text{CO}_2 + 2\text{H}_2\text{O}$$

**Ammonia**

$$2\text{NO} + 2\text{NH}_3 + \frac{1}{2}\text{O}_2 \Rightarrow 2\text{N}_2 + 3\text{H}_2\text{O}$$
SNCR Technology Overview:

- **In-furnace, Post-combustion Control**
  - Injection of Aqueous Urea Droplets
  - 25 – 70% NOx Reduction
  - Many Injection Options:
    - Compressed Air
    - Mechanical
    - Multiple Nozzle Lances – Water Cooled
  - Package Boilers to Utility Boilers
  - Effective on All Fuels and Blends
SNCR Process Application

- Computational Fluid Dynamics
- Chemical Kinetics Model
- Injection Model
Urea Injector Inside Boiler
Process Design Methodology

- Carefully Target the Injection Zone
  - CFD Modeling
  - Field Assessments / Demonstrations

- Understand the Chemistry
  - Urea and ammonia Mechanisms
  - Ammonium Bisulfate Formation

- Refer to Experience Database
  - More Than 540 Applications
  - More Than 100 Utility Furnaces
<table>
<thead>
<tr>
<th>Electric Utilities</th>
<th>Refinery Process Furnaces</th>
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<tbody>
<tr>
<td>Wood-fired IPPs / CoGen Plants</td>
<td>CO Boilers</td>
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<tr>
<td>TDF Plants</td>
<td>Petrochemical Industry</td>
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<tr>
<td>Pulp &amp; Paper</td>
<td>CoGeneration Package Boilers</td>
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<tr>
<td></td>
<td>Municipal Solid Waste</td>
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<tr>
<td></td>
<td>Process Units</td>
</tr>
<tr>
<td>Grate-fired</td>
<td>Steel Mills</td>
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<tr>
<td>Sludge Combustors</td>
<td>Cement Kilns</td>
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<td>Recovery Boilers</td>
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<tr>
<td>Wellons Boilers</td>
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<tr>
<td>Cyclones</td>
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</tbody>
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Fuels

- Coal – Bituminous, PRB, Lignite
- Oil – #2 and #6
- Natural Gas
- Refinery Gases (High CO)
- Municipal Solid Waste
- Tire Derived Fuel
- Wood
- Sludge
Boiler Types

- Utility Boilers
  - T-fired, Wet Bottom, Front-wall Fired, Cyclone, Tower
- Circulating Fluidized Bed
- Bubbling Fluidized Bed
- Stoker, Grate Fired
- Incinerators
- Industrial
• **Temperature** – 1600°F to 2200°F (Process Dependent)
• **Residence Time** – 0.2 Seconds to 2.0 Seconds
• **Background Gas Composition** – CO, O₂, NOx
• **NOx Reduction** – Baseline and Target
• **Reagent Distribution** – Access and Penetration
**NOxOUT SNCR for GALVANIZING FURNACE**

*0.5 to 1.5 Seconds of Residence Time*

- Heat Input = 63.1 MMBTU/hr
- Estimated Flue Gas Flow = 13,956 SCFM
- Baseline NOx = 242 ppmd@4.3% O₂
- Baseline NOx = 0.32 lb/MMBTU, 20.3 lb/hr
- Controlled NOx = 0.209 to 0.097 lb/MMBTU
- NOx Reduction = 35% to 70%
- Ammonia Slip = 10 ppm – 20 ppm
- Required Injection Temperature = 1,750 - 1,850 °F
- Injection CO Limit = 100 ppm
- NOxOUT® LT Reagent = 5 GPH to 10 GPH
NOxOUT® SNCR PROCESS SCHEMATIC
Post Combustion Controls

- Selective Catalytic Reduction (SCR)
  - NH₃ and NO React over a Catalyst
  - Very High Reductions / Utilization Possible
  - Products are N₂ and H₂O
  - 600F to 700F typical Catalyst Temperature

- Limitations
  - Capital Cost Modifications
  - Poisons and High Dust Issues
  - Temperature Limits: SO₃ formation
  - Pressure Drop
SCR CATALYST DESIGN PARAMETERS

- Flue Gas Flow Rate
- Flue Gas Temperature at Catalyst
  - Conventional Catalyst - 800F
  - Zeolite Based Catalyst – 1000F
- Flue Gas Composition
  - NOx, SO2, O2, and Particulate Loading
- NOx Reduction Requirement
- Ammonia Slip Limit
- Pressure Drop Constraints
**NOxOUT Industrial SCR Experience**

- **Gas Fired Commercial System No. 1**
  - Heat Input, MMBTU/hr = 99.0
  - Estimated Flue Gas Flow = 173,977 lb/hr
  - Baseline NOx = 547 ppmd@3% Oxygen
  - Controlled NOx = 55 ppmd@3% Oxygen
  - NOx Reduction = 90%
  - Ammonia Slip = 15 ppm
  - Required Injection Temperature = > 850 °F
  - Required Catalyst Temperature = 600 - 720°F
  - NOxOUT® LT Consumption = 16 GPH
NOxOUT Industrial SCR Experience

**Gas Fired Commercial System No. 2**

- Maximum Heat Input, MMBTU/hr = 117
- Flue Gas Flow Rate = 137,000 lb/hr
- Uncontrolled NOx = 223 ppmd@7.37%O₂
- Controlled NOx = 22.3 ppmd@7.37%O₂
- NOx Reduction Guaranteed = 90%
- Ammonia Slip at Stack, < 15 ppm
- Temperature at Point of Injection = > 850 °F
- Temperature at Catalyst Face = 600 - 750 °F
- NOxOUT® LT Consumption = 12.0 GPH
ASCR<sup>TM</sup> - Advanced SCR

- A Synergistic Layering of NOx Control
- Fully Engineered SCR Reactor
  - Best Available Flow Mixing
  - Uniformity of Gases at Catalyst Face
- Upstream NOx Control
  - Combustion / Post-Combustion
  - Reduced NOx at SCR inlet
- Less Required Catalyst
- Reduced Risk and BOP Impact
**Gas Fired Commercial System – page 1**

- Furnace Heat Input = 48 MMBTU/hr
- Flue Gas Flowrate @ SNCR = 48,725 lb/hr
- Flue Gas Flowrate @ SCR = 117,600 lb/hr
- NOx Baseline = 0.30 lb/MMBtu, (87 ppmd@15 % O2)
- Controlled NOx = 0.043 lb/MMBtu, (13 ppmd@15% O2)
- Overall ASCR Reduction = 85%
Gas Fired Commercial System – page 2

- SNCR NOx Reduction = 75%
  (87ppm => 22ppm)
- SCR Reduction = 41%
  (22ppm => 13ppm)
- Overall ASCR Reduction = 85%
- Catalyst Size = 1.0 Cubic Meter
- Temperature at Injection = 1,650 °F
- Temperature at Catalyst = 650 - 700 °F
Fuel Tech Steel Industry Experience

- Previous List Includes Nucor Steel Experience
- Multiple Plant Locations
  - Berkeley, South Carolina
  - Crawfordsville, Indiana
  - Hickman, Arkansas
- Paper from Previous ICAC Conference in 2002
  
NOxOUT ULTRA®

- Urea to Ammonia Conversion
  - Non-Hazardous Reagent for SCR
  - Avoids Ammonia Hazard Permitting
- Low Capital and Operating Cost
  - Built on Proven Fuel Tech Technologies
- 50 Commercial Installations
- From 5 lb/hr to 1300 lb/hr Ammonia Demand
NOx Emission Control Summary

- Utilize Optimal Technology Suite
- All Proven Commercial Products
- Customized Solution to Reduce Risks
- Balanced to Reduce Costs
  - Capital vs. Operation Costs
  - Variations in Fuel and Capacity
- Best Possible Performance
  - NOx Reduction
  - Secondary Impacts (BOP)
NOx Emission Control Options for ICI Boilers

QUESTIONS?

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