John Zink Company, LLC

Low NOx Solutions for Industrial Boiler Applications

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John Zink Overview
John Zink Worldwide

Sales offices and independent representatives throughout the world

Research and Development Facility

- Largest combustion test facility in the world
- 14 Full-scale furnaces
  - 1 Dedicated to Duct Burners
  - 1 Dedicated to Boiler Burners
- 2 Lab-scale furnaces
- Flare testing pad
- Firing capabilities up to 150 MM Btu/hr
- Ability to blend and simulate a wide variety of liquid and gas fuel compositions
Tulsa Test Facility

Flare Pad

Furnace Pad

Fuel & Utility Supply

Office Building

Computational Fluid Dynamics Lab

State of the art CFD workstations

Flame Geometry

Furnace Heat Transfer
Market Segments Served

- Chemical/Petrochemical
- Pulp & Paper
- Food & Beverage
- Facilities, Universities, Hospitals
- Marine
- Manufacturing
- Independent Power Producers
- Utilities - Electric Generating Plants
Methods of NOx Formation

Thermal NO\textsubscript{x} (Zeldovich Mechanism) is a function of:

\[ [NO] = \int Ae^{-\frac{b}{T}} [N_2] \sqrt{[O_2]} dt \]

- Peak flame temperatures (> 2500 deg F) which breaks apart N\textsubscript{2} molecules
- Available oxygen to bond with and form NOx
- Time to allow the reaction to occur

~ 80% of the NOx from a natural gas burner

Methods of NOx Formation

Fuel NO\textsubscript{x} formed from nitrogen contained in the fuel

0% of NOx in natural gas firing (no FBN)
~ 50% of NOx in #2 oil firing (0.02% FBN)
~ 80% of NOx in #6 oil firing (0.30% FBN)
**Methods of NOx Formation**

Prompt NOx (Fenimore Mechanism) forms in sub-stoichiometric regions by:
- Rapid reaction of fuel radicals with atmospheric nitrogen
- HCN and NH$_3$ are formed as intermediate species
- Completed combustion causes these molecules to convert to NOx

~ 20% of NOx from a natural gas burner

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**Boiler Burner Design Considerations**

- Boiler type/design
  - Packaged
  - Field erected
    - Single burner
    - Multi-burner
- Burner Zone Heat Release (BZHR)
  - Furnace refractory
  - Combustion air temperature
- Fuel composition
  - Fuel bound nitrogen
  - Flame temperature
NOx Reduction Methods

- Flue gas recirculation (FGR)
  - Forced
  - Induced
- Steam or water injection
- Fuel-air staging
  - Staged combustion burner designs
  - Furnace staging
    - Over fire air (OFA)
    - NOx ports
- Gas fuel conditioning (FIR)
- Fuel-reburn
- Stack-end abatement
  - NSCR / SCR
  - SCONOx
  - LT O2

NOx Control Technology

![NOx Control Technology Graph](graph.png)

- Conventional Burners
- Staged Combustion
- Flue Gas Recirculation
- Advanced Low NOx Burner
- Ultra Low NOx Burner
Staged Combustion Burner Design

- Staged air enters flame to complete burnout
- Swirler imparts spin to primary air and creates recirculation zone

TODD Low NOx Burner Design Features

- Gas staging techniques
  - Gas injector design & orientation
- Oil staging techniques
  - Atomizer design & spray patterns
- Flame stabilization techniques
  - Swirler design & orientation
- Air staging
  - Primary, Secondary, & Tertiary Air locations and distribution
TODD Advanced Low NOx Burners

- Natural Gas / Propane
  - 20 to 30 ppm
- Refinery Gases
  - 20 to 50 ppm
- Amber 363 Oil (0.002 % FBN)
  - 30 to 40 ppm
- #2 Light Oil (0.02 % FBN)
  - 50 to 80 ppm
- #6 Heavy Oil (0.3 % FBN)
  - 200 to 300 ppm

TODD Ultra Low NOx Burner

- Reducing NOx Where It Starts
  - Rapid Mixing eliminates fuel rich regions that form prompt NOx
  - Use of FGR or Excess Air reduces peak flame temperatures that form thermal NOx
- By Incorporating
  - A radically different gas injection and mixing system
  - Proven burner geometry to maintain an extremely stable flame
TODD Products and Technologies

TODD Combustion Solutions

- Variflame™
- Variflame II™
- Dynaswirl-LN®
- RMB™
- COOL Technologies™
- LDRW Duct Burners
Variflame Single Burner Applications

- Industry leader for single burner applications
- Predictable performance
- NOx emissions as low as 25 ppm with FGR
- Low VOC, CO, and particulate emissions
- Capacity range: 30 to 400 million BTU/hr per burner
- High-combustion efficiency
- High turndown ratios: 8:1 on oil and 10:1 on gas

The New Standard in No-FGR Performance

The Variflame II is available for package boiler applications with burner heat inputs up to 150 million BTU’s per hour, and offers the following benefits:

- Sub-30 ppm NOx on natural gas without using FGR using COOLflame Technology
- Low NOx firing of light or heavy oils using COOLburn Technology
- Low CO, VOC, and Particulate emissions
- Superior flame stability
- No increase in flame length
Rapid Mix Burner

- **Guaranteed Ultra Low Emissions Performance**
  - Less Than 9 PPM NOx
  - Less Than 25 PPM CO
  - Less Than 3 PPM VOC
- Plus the added benefits of
  - Easy Installation and Start-up
  - Compact Stable Flame
  - No Moving Parts
  - Streamlined Permitting Tasks
  - Opportunities for Emission Reduction Credits
Rapid Mix Burner

- Applications
  - Packaged Boilers
  - Refractory Lined Air Heaters
  - Field Erected Boilers
  - Thermal Oil Heaters

- Features
  - Single burner heat inputs from 5 to 300 MMBtu/hr
  - Unison fired dual burners available for heat inputs up to 600 MMBtu/hr

Dynaswirl-LN
Multi-Burner Applications

- Heavy duty design for multiple burner applications. Stress relieved when required
- Predictable performance
- NOx emissions as low as 20 ppm with FGR, BOOS, or OFA
- Low VOC, CO, and particulate emissions
- Capacity range: 30 to 300 million BTU/hr per burner
- Low Excess Air Levels
COOL Technologies

COOLfuel™:
Gas Fuel Conditioning

COOLkits™:
Burner Modifications

COOLflow™:
Air Flow Modeling

COOLspray™:
Steam or Water Injection

COOLfuel

Fuel Gas Conditioning

• Introduction of flue gases or other inert gases into the fuel
• LOWERS THE HEATING VALUE OF THE FUEL
• The diluted fuel results in lower NOx
**COOLfuel**

Benefits of Fuel Dilution over conventional FGR.

- Adding the flue gases to the fuel has a greater effect on NOx reduction than adding them to the combustion air.
- Lower flue gas flows are required to achieve the same amount of NOx reduction.

**COOLspray**

Injection of Steam or Water for NOx Reduction

- Lowers the peak flame temperature.
- Reduces thermal NOx formation.
- Impacts system efficiency = higher operating costs.
- Still economical when compared to SCR or other back-end cleanup.
- Effectiveness dependant on injection method (fuel, air, flue gas).
- Water injection effectiveness dependant on droplet size.
COOLkits

Low NOx Burner Modifications

- Custom designed components for installation into existing air registers
- Incorporates poker and swirler designs similar to those found in TODD’s Variflame and Dynaswirl-LN burners

COOLflow

Air flow is one of the most significant contributors to Combustion Performance and COOLflow modeling takes out the guess work

- Evens airflow distribution
- Improves air and FGR mixing
- Reduces vibration
- Increases capacity
- Lowers NOx, CO, & other emissions
- Lowers the amount of excess air required
- Increases efficiency
LDRW Duct Burner Assembly

Case Studies
Rapid Mix Burner Retrofit Case Study

- 100,000 lb/hr D-type package boiler
- Natural gas fired
- Ambient combustion air
- 23 - 28% FGR
- NOx less than 8.5 ppm across entire load range
- CO less than 1 ppm across entire load range
- Excess O2 of 3.2 to 4.0%
- Boiler capacity increased to 110,000 lb/hr

COOLfuel

165 MW tangentially fired utility boiler retrofit (CS 117)

Boiler Type: Combustion Engineering
Boiler Size: 165 MWe
Steam Flow: 1,200,000 PPH
Burner Type: CE Tilting Tangential
# Burners/Boiler: 40
Heat Input: 40 MMBtu/hr
Comb. Air Temp: 540 deg F
Fuel: Natural Gas
NOx - base: 132 ppm
COOLfuel NOx: 33 ppm
**COOLfuel + COOLSpray Combo**

Refinery Power Plant Retrofit (CS 117)
- Boiler Type: Riley
- Steam Flow: 140,000 PPH
- Burner Type: John Zink LCF
- # Burners/Boiler: 5
- Heat Input: 40 MMBtu/hr
- Comb. Air Temp: 440 deg F
- Fuel: Refinery Gas (40% H2 by volume)
- NOx - baseline: 400 - 450 ppm
- COOLfuel NOx: 70 ppm (~83% reduction)
- COOLSpray NOx: 22 ppm (~95% reduction)
- NOx @ max steam usage: <7 ppm (~98% reduction)

**COOLflow**

Real Models = Real Results (CS 108 & CS 112)
- 1/12 scaled replica of the combustion air & FGR system for a 330 MW Utility Boiler in Northern California
- 24 Burners & 12 Over Fire Air (OFA) Ports
- FGR supplied by 4 airfoil spargers
- Improved airflow distribution from +/- 16% to +/- 7.5%
- Increased FGR flow by 5%
- Increased OFA flow from 8 to 12%
- Along with the new Dynaswirl-LN burners this reduced NOx from 73 to 36 ppm
Now Available!

“The John Zink Combustion Handbook is a welcome addition to combustion literature...”
- Chemical Engineering Magazine, July 2001

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Developing Clean Air Solutions for Planet Earth