John Zink Company, LLC

TODD® Combustion

Low NOx Solutions for Industrial Boiler Applications

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Director - North American Sales

Table of Contents

John Zink Overview

John Zink Company

- TODD® Combustion
  - Industrial & Utility Boiler Burners
  - Duct Burners
- John Zink®
  - Process Burners
  - Flares
  - Vapor Control
  - Thermal Oxidizers
  - Refractory
  - Rental Equipment
- Gordon-Piatt™
  - Commercial & Industrial Boiler Burners
- Support & Resources
  - Global Operations
  - Origination
  - R&D Test Center
  - Manufacturing
  - Parts & Service
  - Customer Education

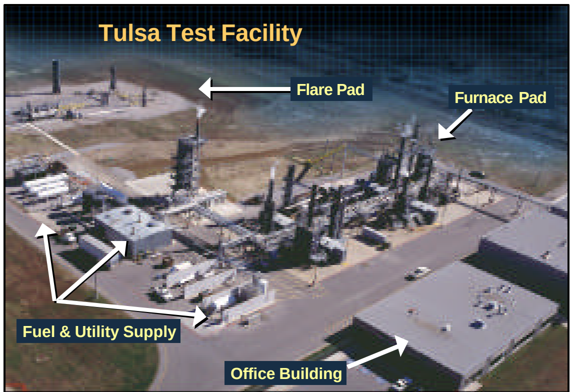
John Zink Worldwide

Sales offices and independent representatives throughout the world

Research and Development Facility

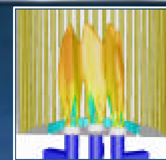
- Largest combustion test facility in the world
- 14 Full-scale furnaces
  - 1 Dedicated to Duct Burners
  - 1 Dedicated to Boiler Burners
- 2 Lab-scale furnaces
- Flare testing pad
- Firing capabilities up to 150 MM Btu/hr
- Ability to blend and simulate a wide variety of liquid and gas fuel compositions

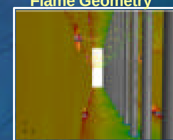
Tulsa Test Facility



Computational Fluid Dynamics Lab

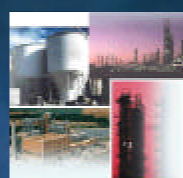

State of the art CFD workstations


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



TODD Combustion

Boiler Burner NOx Formation Fundamentals

Methods of NOx Formation

Thermal NO_x (Zeldovich Mechanism) is a function of:

$$[NO] = \int A e^{-\frac{b}{T}} [N_2] \sqrt{[O_2]}\, dt$$

- Peak flame temperatures (> 2500 deg F) which breaks apart N_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_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

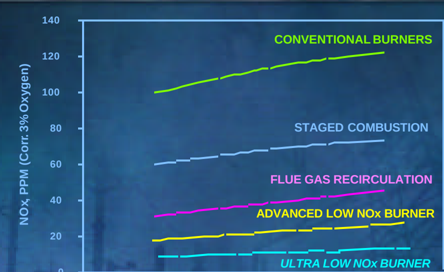
Boiler Burner Design Considerations

- 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

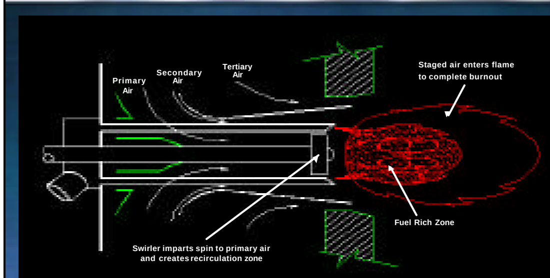
NOx Reduction Methods

- 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 re-burn
- Back-end cleanup
  - NSCR / SCR
  - SCONOx
  - LTO

NOx Control Technology

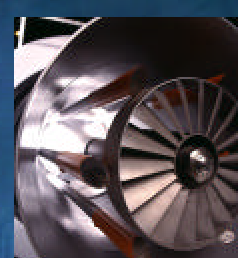


Staged Combustion Burner Design



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

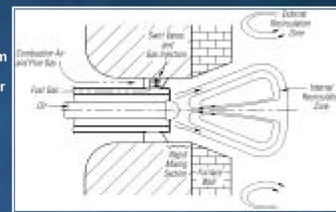


TODD Advanced Low NOx Burners

- 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

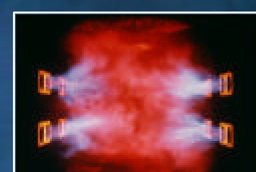
- Reducing NOx Where It Starts
  - Rapid Mixing eliminates fuel rich regions that form prompt NOx
  - Use of FGR or Excess Air reduces peak flame temperatures that form thermal NOx
- By Incorporating
  - A radically different gas injection and mixing system
  - Proven burner geometry to maintain an extremely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



TODD Products and Technologies

TODD Combustion Solutions

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



Top View, 400MWe Utility Boiler

Variflame Single Burner Applications

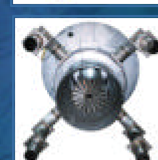
- Industry leader for single burner applications
- Predictable performance
- NOx emissions as low as 25 ppm with FGR
- Low VOC, CO, and particulate emissions
- Capacity range: 30 to 400 million BTU/hr per burner
- High-combustion efficiency
- High turndown ratios: 8:1 on oil and 10:1 on gas

Variflame II™

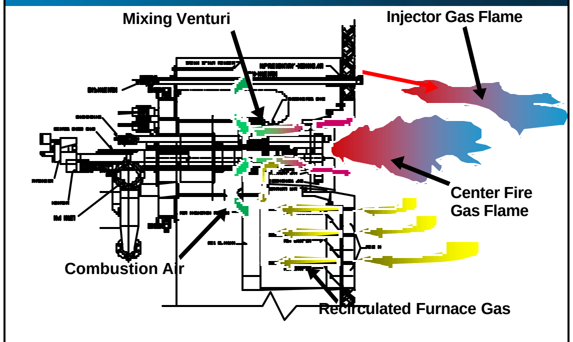
The New Standard in No-FGR Performance

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-30ppm NOx on natural gas without using FGR using COOL *flame* Technology
- Low NOx firing of light or heavy oils using COOL*burn* Technology
- Low CO, VOC, and Particulate emissions
- Superior flame stability
- No increase in flame length



Variflame II Principle of Operation



Rapid Mix Burner

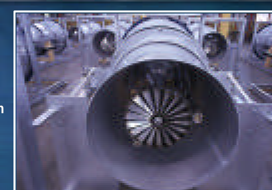
- *Guaranteed* Ultra Low Emissions Performance
  - Less Than 9 PPM NOx
  - Less Than 25 PPM CO
  - Less Than 3 PPM VOC
- Plus the added benefits of
  - Easy Installation and Start-up
  - Compact Stable Flame
  - No Moving Parts
  - Streamlined Permitting Tasks
  - Opportunities for Emission Reduction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



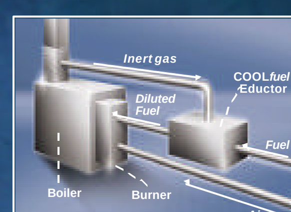
COOL Technologies

COOL*fuel*™:
Gas Fuel Conditioning
COOL*kits*™:
Burner Modifications
COOL*flow*™:
Air Flow Modeling
COOL*spray*™:
Steam or Water Injection

COOL*fuel*

Fuel Gas Conditioning

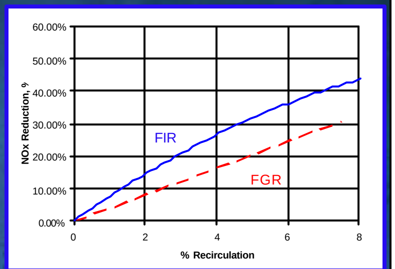
- Introduction of flue gases or other inert gases into the fuel
- Lowers the heating value of the fuel
- The diluted fuel results in lower NOx



COOL*fuel*

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



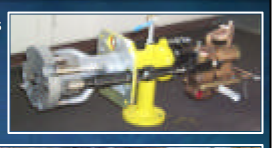
COOL*spray*

Injection of Steam or Water for NOx Reduction

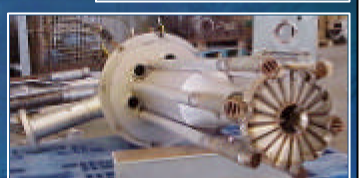
- Lowers the peak flame temperature
- Reduces thermal NOx formation
- Impacts system efficiency = higher operating costs
- Still economical when compared to SCR or other back-end cleanup
- Effectiveness dependant on injection method (fuel, air, flue gas)
- Water injection effectiveness dependant on droplet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

COOL*kits*

Low NOx Burner Modifications



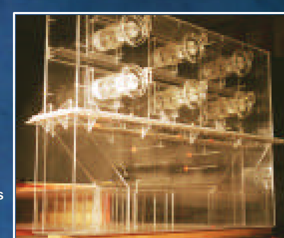
- Custom designed components for installation into existing air registers
- Incorporates poker and swirler designs similar to those found in TODD's Variflame and Dynaswirl-LN burners



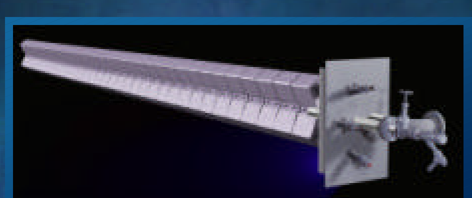
COOL*flow*

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



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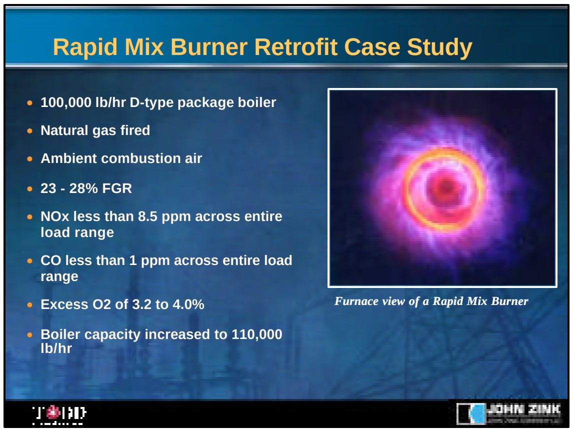
Case Studies


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
Furnace view of a Rapid Mix Burner
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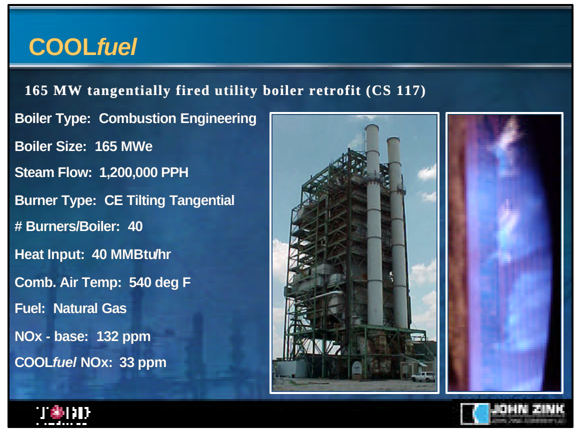
COOLfuel
165 MW tangentially fired utility boiler retrofit (CS 117)
Boiler Type: Combustion Engineering
Boiler Size: 165 MWe
Steam Flow: 1,200,000 PPH
Burner Type: CE Tilting Tangential
Burners/Boiler: 40
Heat Input: 40 MMBtu/hr
Comb. Air Temp: 540 deg F
Fuel: Natural Gas
NOx - base: 132 ppm
COOLfuel NOx: 33 ppm
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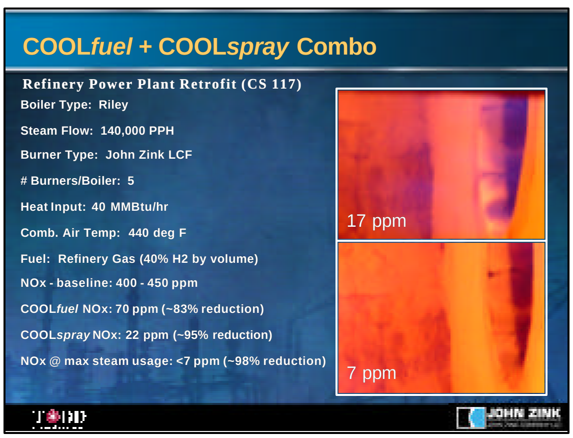
COOLfuel + COOLspray Combo
Refinery Power Plant Retrofit (CS 117)
Boiler Type: Riley
Steam Flow: 140,000 PPH
Burner Type: John Zink LCF
Burners/Boiler: 5
Heat Input: 40 MMBtu/hr
Comb. Air Temp: 440 deg F
Fuel: Refinery Gas (40% H2 by volume)
NOx - baseline: 400 - 450 ppm
COOLfuel NOx: 70 ppm (~83% reduction)
COOLspray NOx: 22 ppm (~95% reduction)
NOx @ max steam usage: <7 ppm (~98% reduction)
17 ppm
7 ppm
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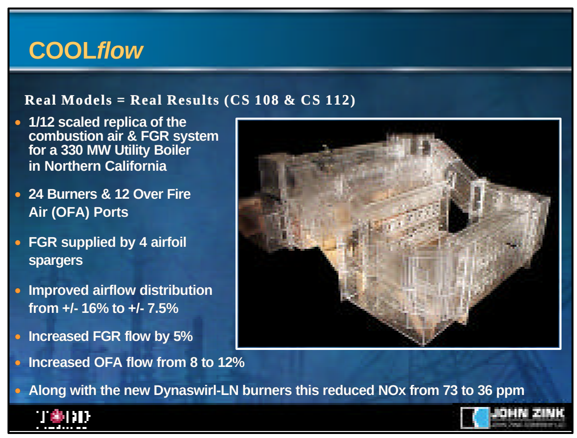
COOLflow
Real Models = Real Results (CS 108 & CS 112)
1/12 scaled replica of the combustion air & FGR system for a 330 MW Utility Boiler in Northern California
24 Burners & 12 Over Fire Air (OFA) Ports
FGR supplied by 4 airfoil spargers
Improved airflow distribution from +/- 16% to +/- 7.5%
Increased 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
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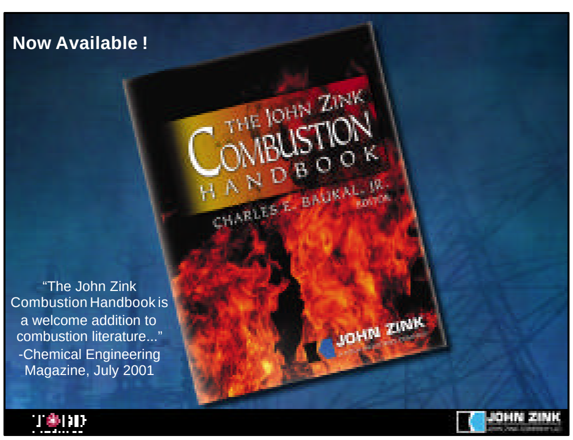
Now Available !
THE JOHN ZINK COMBUSTION HANDBOOK
CHARLES E. BAUKAL, JR.
EDITOR
JOHN ZINK
"The John Zink Combustion Handbook is a welcome addition to combustion literature..."
-Chemical Engineering Magazine, July 2001
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Developing Clean Air Solutions for Planet Earth
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