

2006 Environmental Controls Conference

Cost Effective Layered Technology for Ultra Low NOx Control

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The logo for Advanced Combustion Technology, Inc. (ACT) features the letters 'ACT' in a large, bold, red serif font. The letters are slightly shadowed, giving them a three-dimensional appearance.

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Blue Ridge Paper Products Boiler 4 NOx Emission Objective

- UNIT SIZE – 400,000 lb/hr 420 psig @ 730 F SH Steam
- UNIT TYPE: T-Fired, 12 burners, balanced draft
- FUEL – Eastern Bituminous Coal
- NOx : Base = 0.70 lb/mmBtu
- NOx : Reduced with layered technology < 0.15 lb/mmBtu (#6 oil)
- CO <200 ppm

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NRG Middletown Power, LLC

Unit #2 NOx Emission Objective

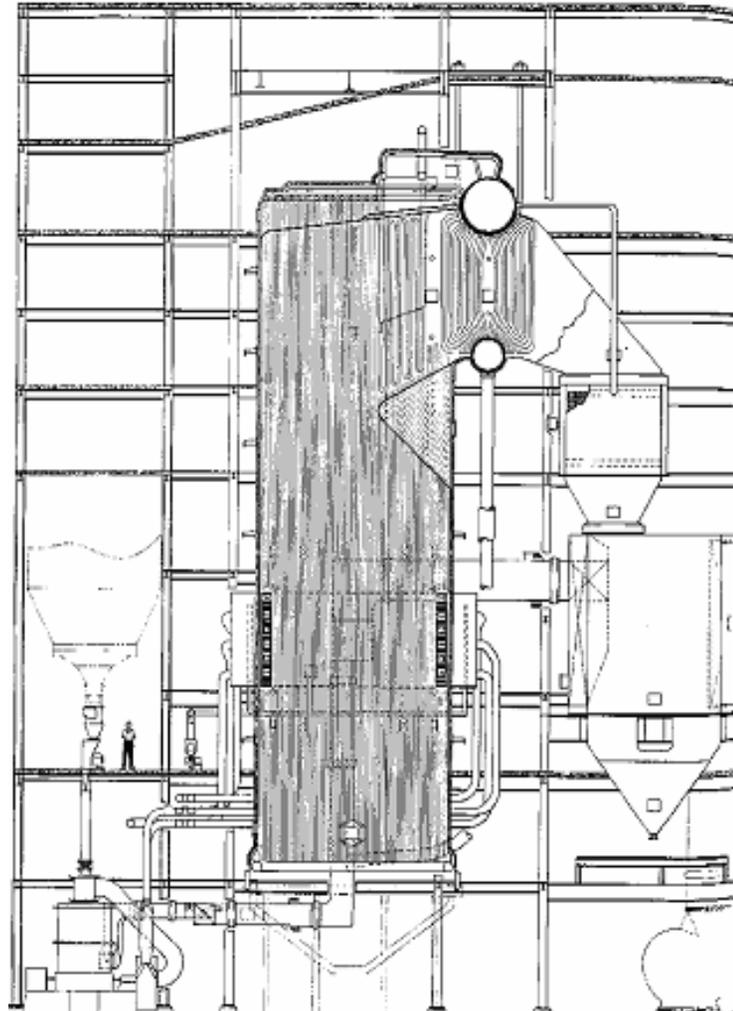
- UNIT SIZE – 125 Mwg, 1,900 psig @ 1005 F SH & RH Steam
- UNIT TYPE: Wall fired, 12 burners on 4 rows, balanced draft
- FUEL – #6 Oil & Natural gas (original coal fired design)
- NOx : Base = 0.39 lb/mmBtu (#6 oil)
- NOx : Reduced with layered technology < 0.12 lb/mmBtu (#6 oil)
- CO <200 ppm

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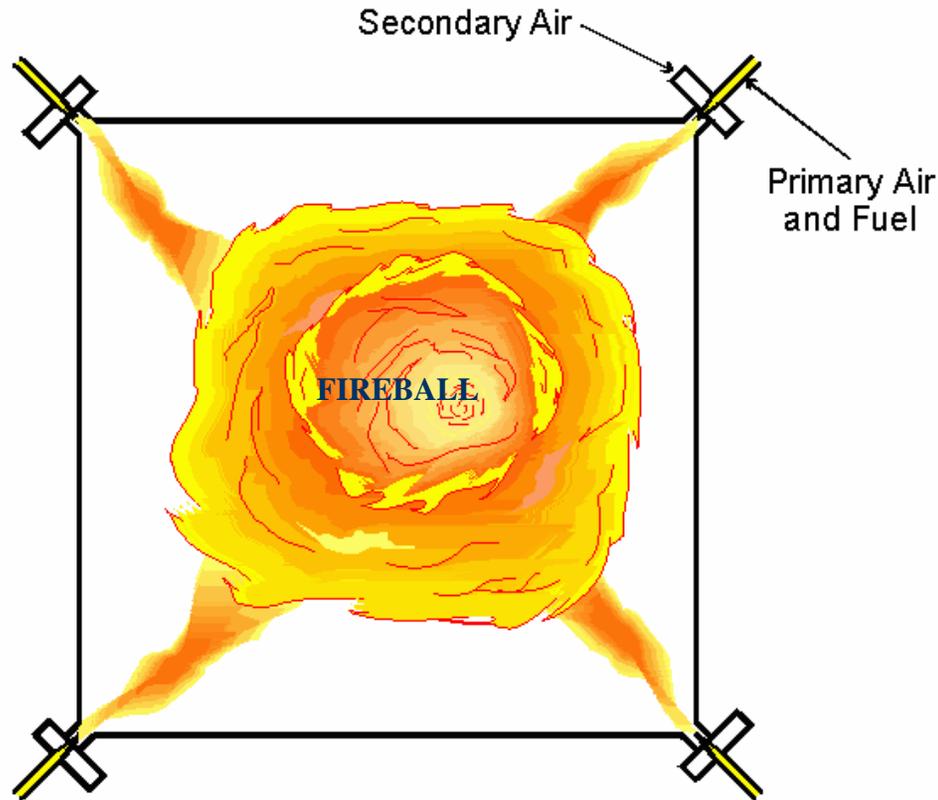
BLUE RIDGE PAPER BOILER 4 TANGENTIAL FIRED BOILER SIDE VIEW

- 400 Klb/hr Coal Fired Boiler
- 12 Burners
- Baseline NO_x of 0.7 lb/mmBtu



TANGENTIAL FIRED BOILERS

TANGENTIAL FIRED BOILERS UTILIZE FURNACE DYNAMICS TO ENHANCE COMBUSTION. NO_x REDUCTION THROUGH BURNER UPGRADES IS LIMITED.



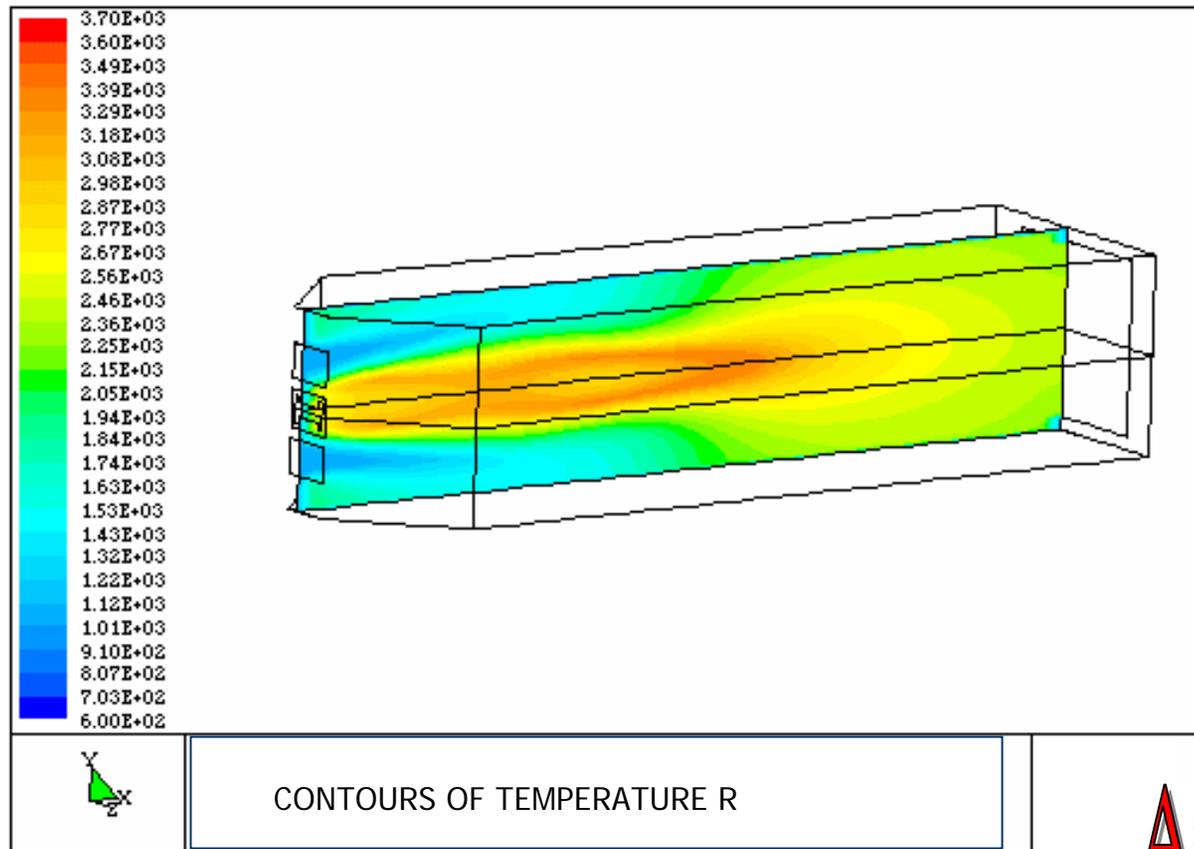
STRENGTH OF THE FIREBALL FORCES SOFA AIR TO THE SIDE WALLS. DISTRIBUTION OF AIR AND INJECTION VELOCITY COMPLETE MIXING IN THE UPPER FURNACE.

LOW NO_x BURNER DESIGN GOALS

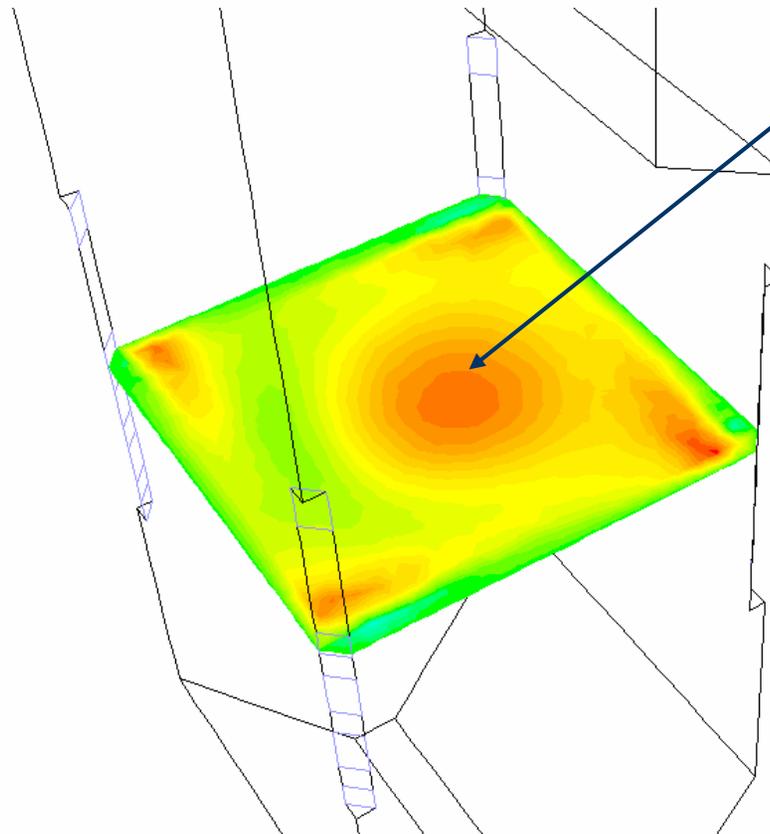
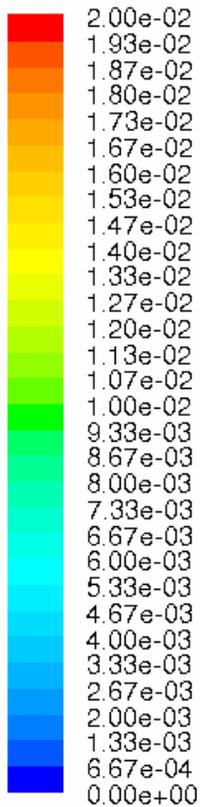
- STAGED COMBUSTION AT THE BURNER
- MINIMIZE IMPACT ON FLYASH LOI
 - BASELINE LOI <9%
- LIMIT CO EMISSIONS
- MAINTAIN OPACITY BELOW 15%
- DESIGNED TO ENHANCE OPERATION OF SOFA SYSTEM

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CFD MODEL OF LOW NO_x BURNER DESIGN



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DEVOLITIZE COAL IN
FURNACE CENTER TO
MAXIMIZE REDUCTION

Blue Ridge Paper Boiler 4 Furnace Model
Contours of CO Mole Fraction

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Phase 1 – Low NOx Burner Design

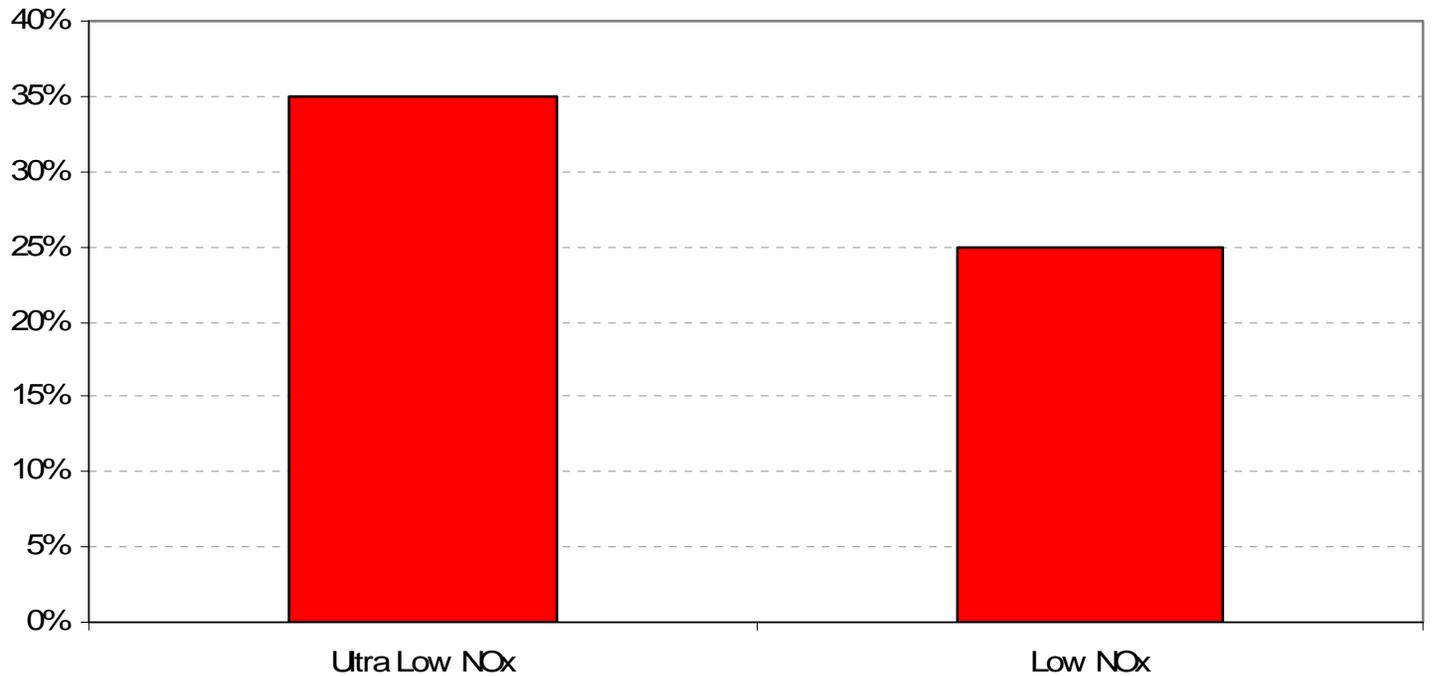


Ultra Low NOx
Fuel/Air Bucket



Low NOx Fuel/Air Bucket

Blue Ridge Paper Boiler 4 Fuel Air Bucket Analysis



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BLUE RIDGE PAPER BOILER 4 RESULTS LOW NO_x BURNER

- NO_x REDUCED FROM 0.7 lb/mmBtu to 0.5 lb/mmBtu
- FLYASH LOI < 10%
- CO EMISSIONS < 50 ppm

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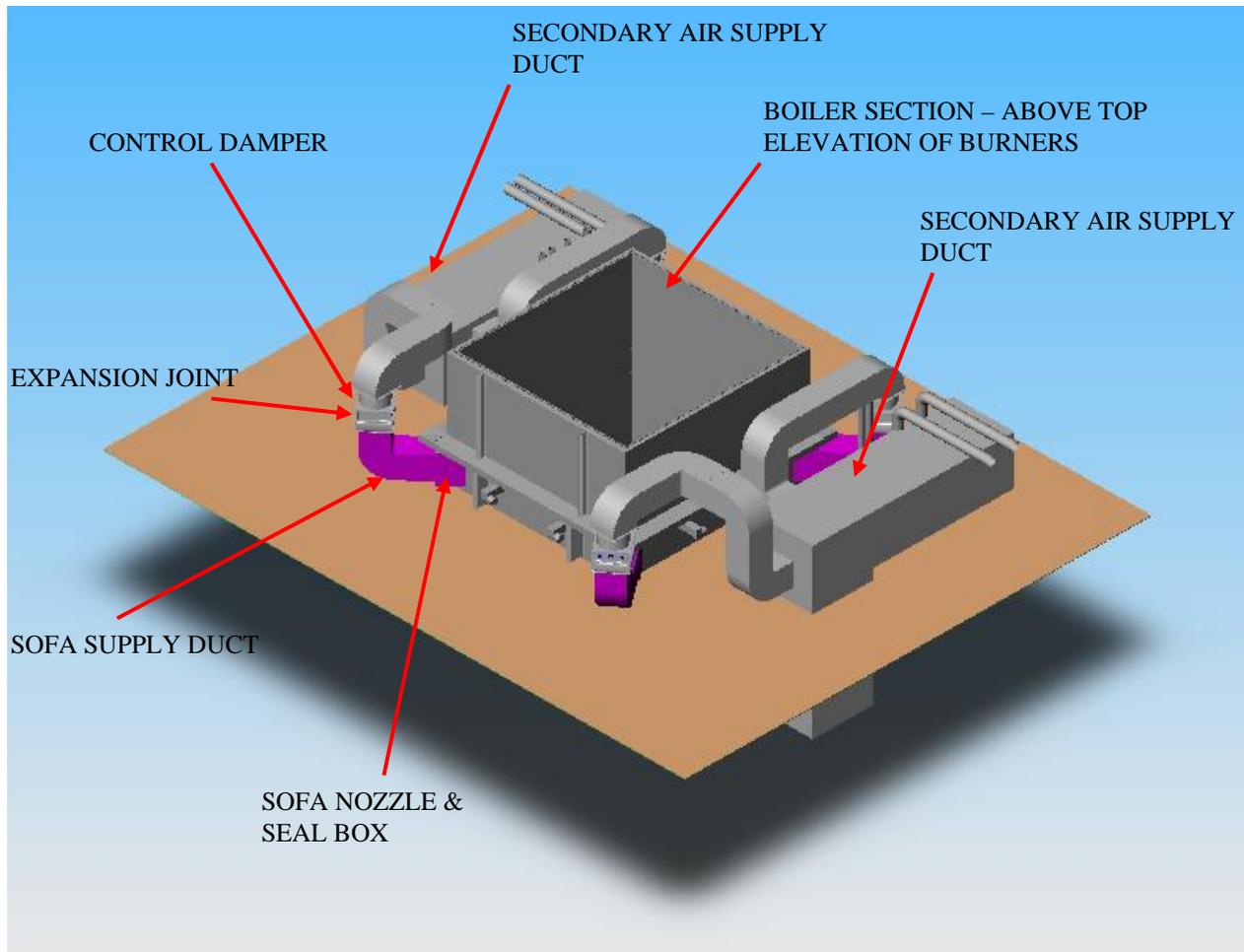
BLUE RIDGE PAPER BOILER 4 SOFA DESIGN GOALS

- SYSTEM DESIGNED FOR 15% COMBUSTION AIRFLOW
- FIXED PORT WITH EXIT VELOCITY OF 100 FT/S
- CONSISTENT OPERATION THROUGH THE LOAD RANGE
- PORT PLACEMENT TO DELIVER UREA TO PROPER TEMPERATURE WINDOW

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ACT SOFA LAYOUT

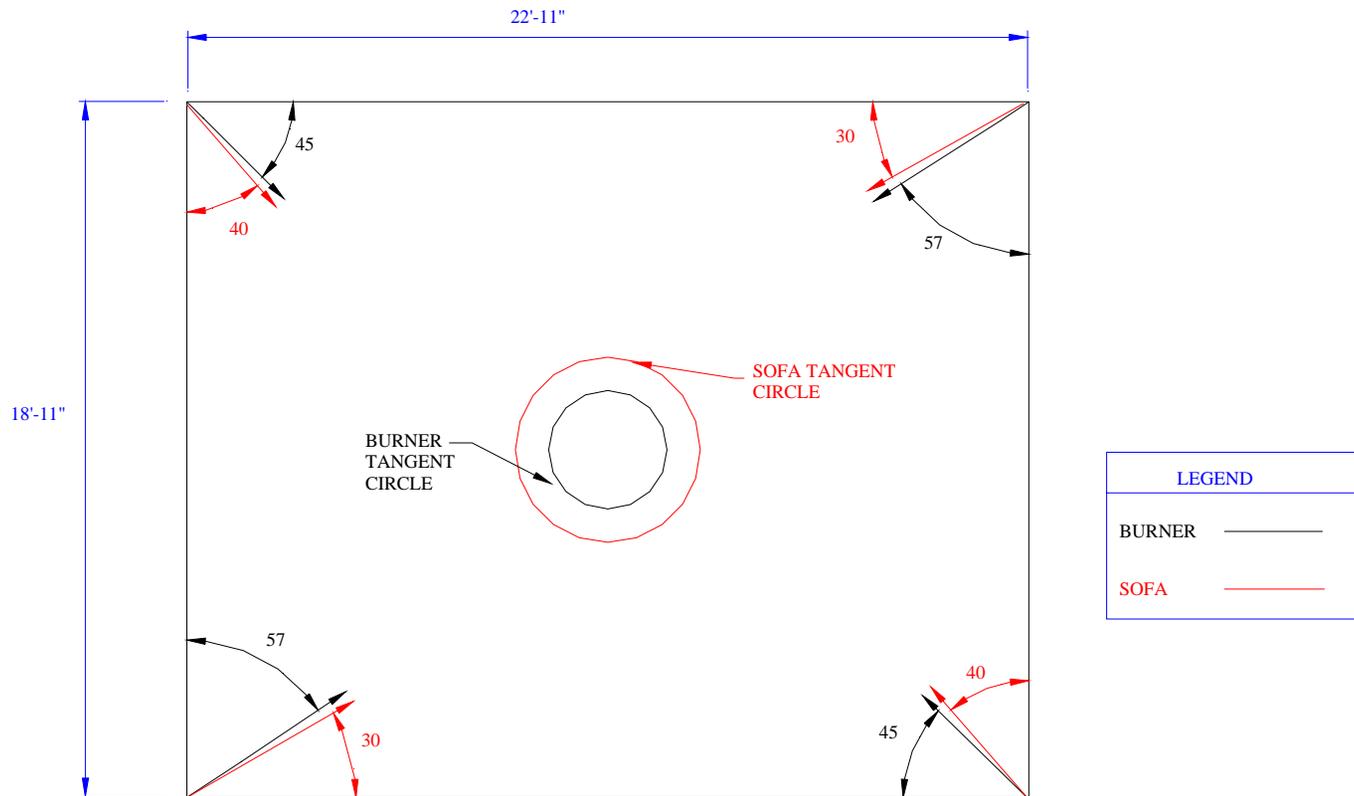


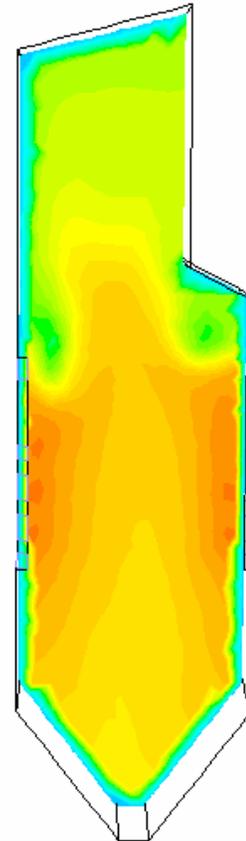
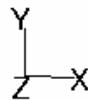
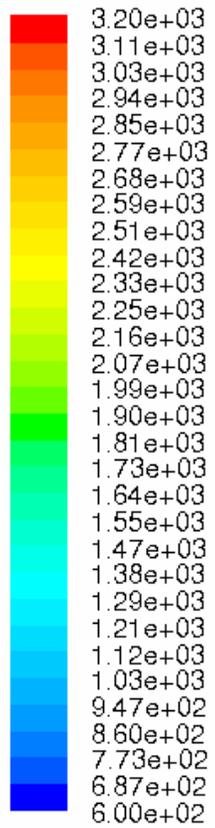
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BLUE RIDGE PAPER BOILER 4

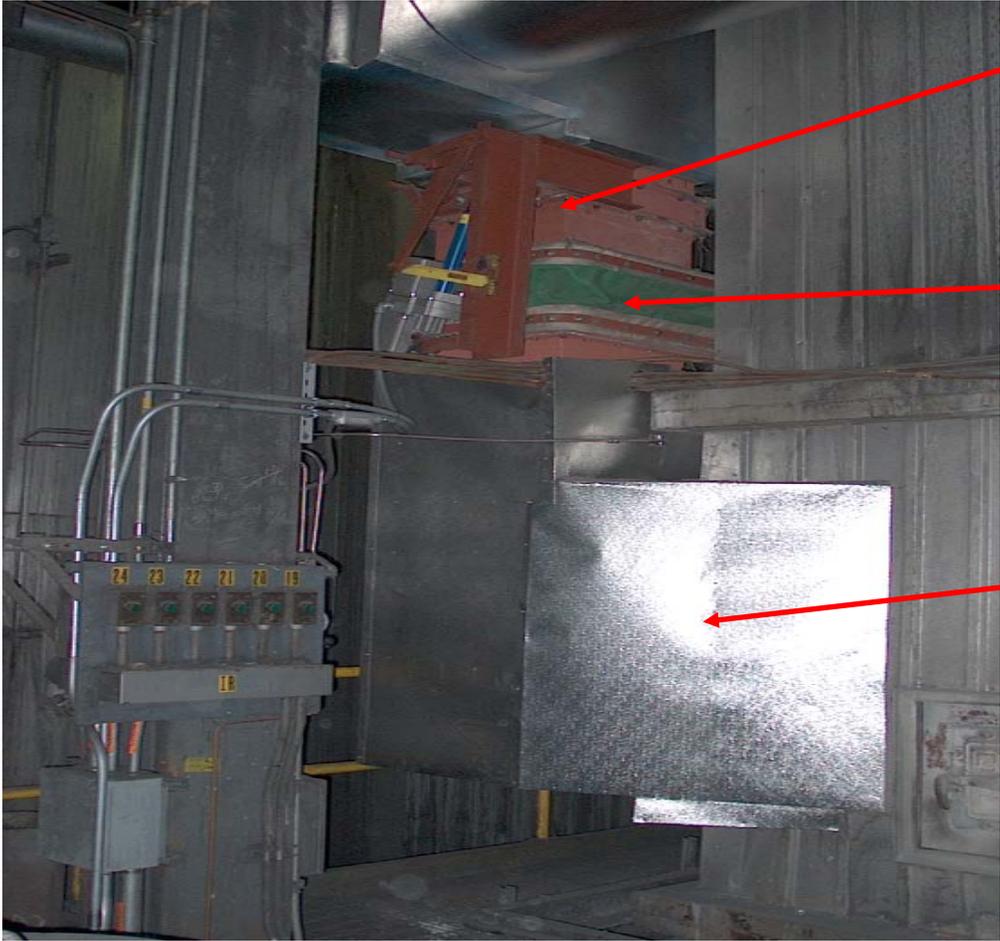
BURNER & SOFA INJECTION ANGLE





Blue Ridge Paper Boiler 4 Furnace Model
Contours of Static Temperature F

T-FIRED SOFA HARDWARE



DAMPER

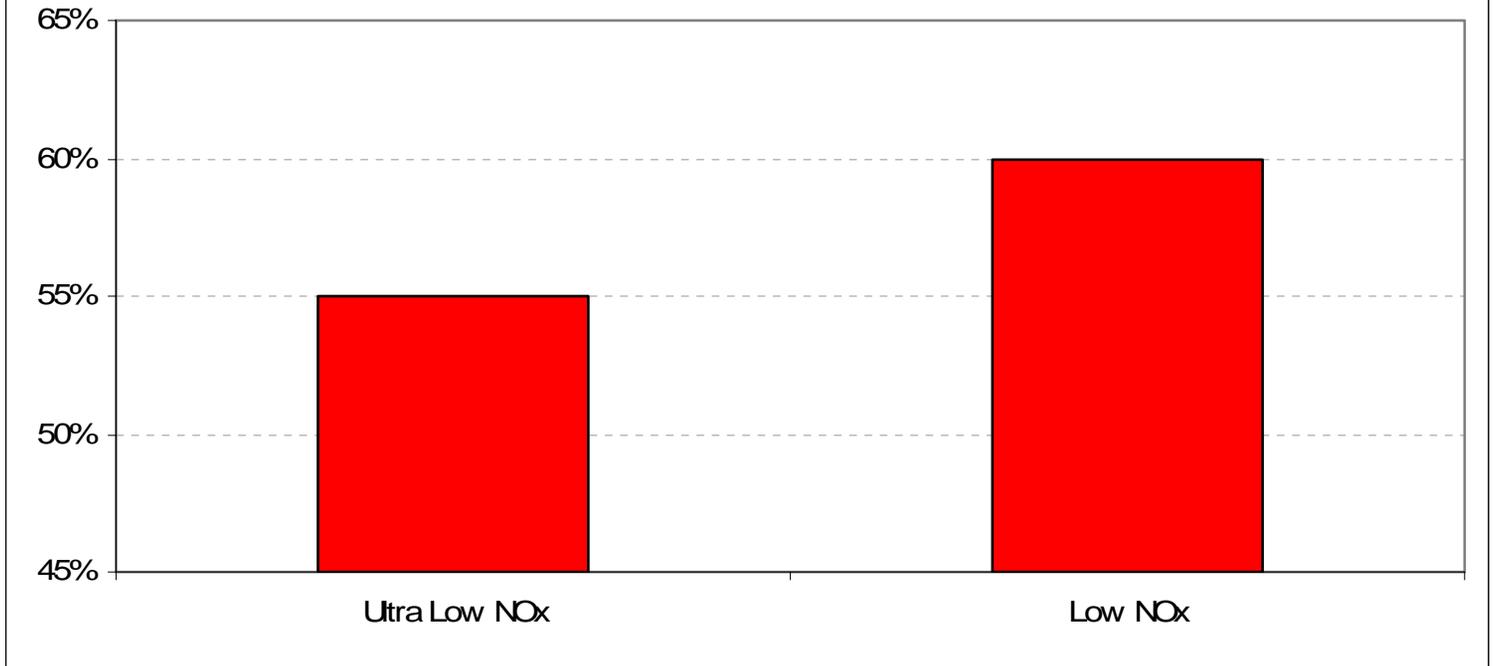
EXPANSION JOINT

SEAL BOX & NOZZLE

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**Blue Ridge Paper Boiler 4
Fuel Air Bucket Analysis
in Combination with SOFA**



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BLUE RIDGE PAPER BOILER 4 RESULTS LOW NO_x BURNER & SOFA

- NO_x REDUCED FROM 0.7 lb/mmBtu to 0.28 lb/mmBtu
- FLYASH LOI < 10%
- CO EMISSIONS < 50 ppm

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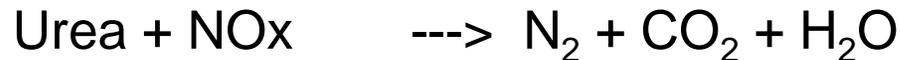
High Energy Reagent Technology (HERT) System Design Goals

- UREA INJECTION INTO A PORTION OF SOFA STREAM FOR INTERACTION WITH NO_x IN COMBUSTION FLUE GAS
- LOAD FOLLOWING CAPABILITY FROM 50% TO 100% LOAD RANGE
- UREA MECHANICAL ATOMIZER PRODUCES DROPLET SIZES RANGING 5 – 15 MICRONS
- HOT SOFA STREAM INTERACTS WITH FINE DROPLETS TO FORM VAPOR FOR ADDITIONAL COVERAGE
- MINIMIZE THE NUMBER OF INJECTORS REQUIRED

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HIGH ENERGY REAGENT TECHNOLOGY (SNCR)

- Typical reactions using ammonia or urea:

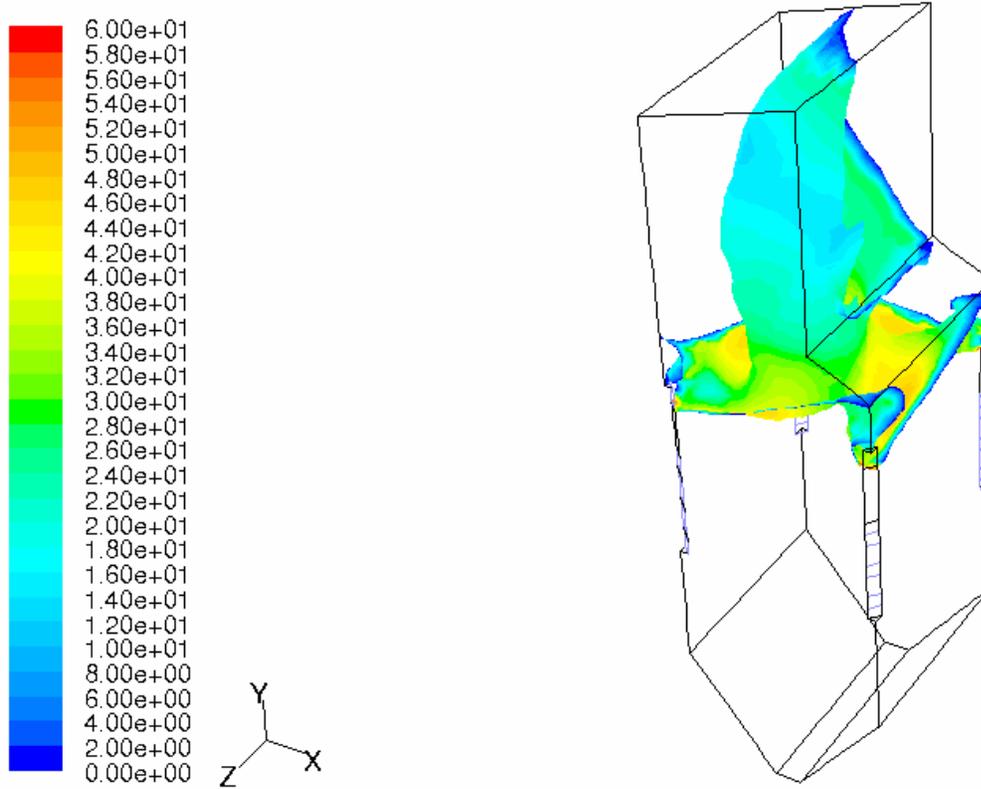


(must prevent excess injection of reagent)

- Optimum Reaction Temperature Range, 1,600 F to 2,100 F
- High Momentum Combustion Air Stream as Carrier for Urea Vapor

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Contours of Velocity Magnitude Urea and SOFA Flow Stream (ft/s)

HERT Test System

Portable test system used to determine NO_x reduction potential and permanent system design parameters



HERT INJECTOR



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BLUE RIDGE PAPER BOILER 4 RESULTS

HERT System

- NO_x REDUCED FROM 0.28 lb/mmBtu to < 0.15 lb/mmBtu with HERT
- Four high energy injectors utilized
- NH₃ Slip < 1 ppm
- No additional pressure part modification required for HERT injector

BLUE RIDGE PAPER BOILER 4

Layered Technology Results Summary

- NO_x reduced from 0.70 lb/mmBtu to less than 0.15 lb/mmBtu with LNB, SOFA & HERT
- Overall NO_x reduction greater than 78%
- Equivalent installed capital cost of \$25/kw

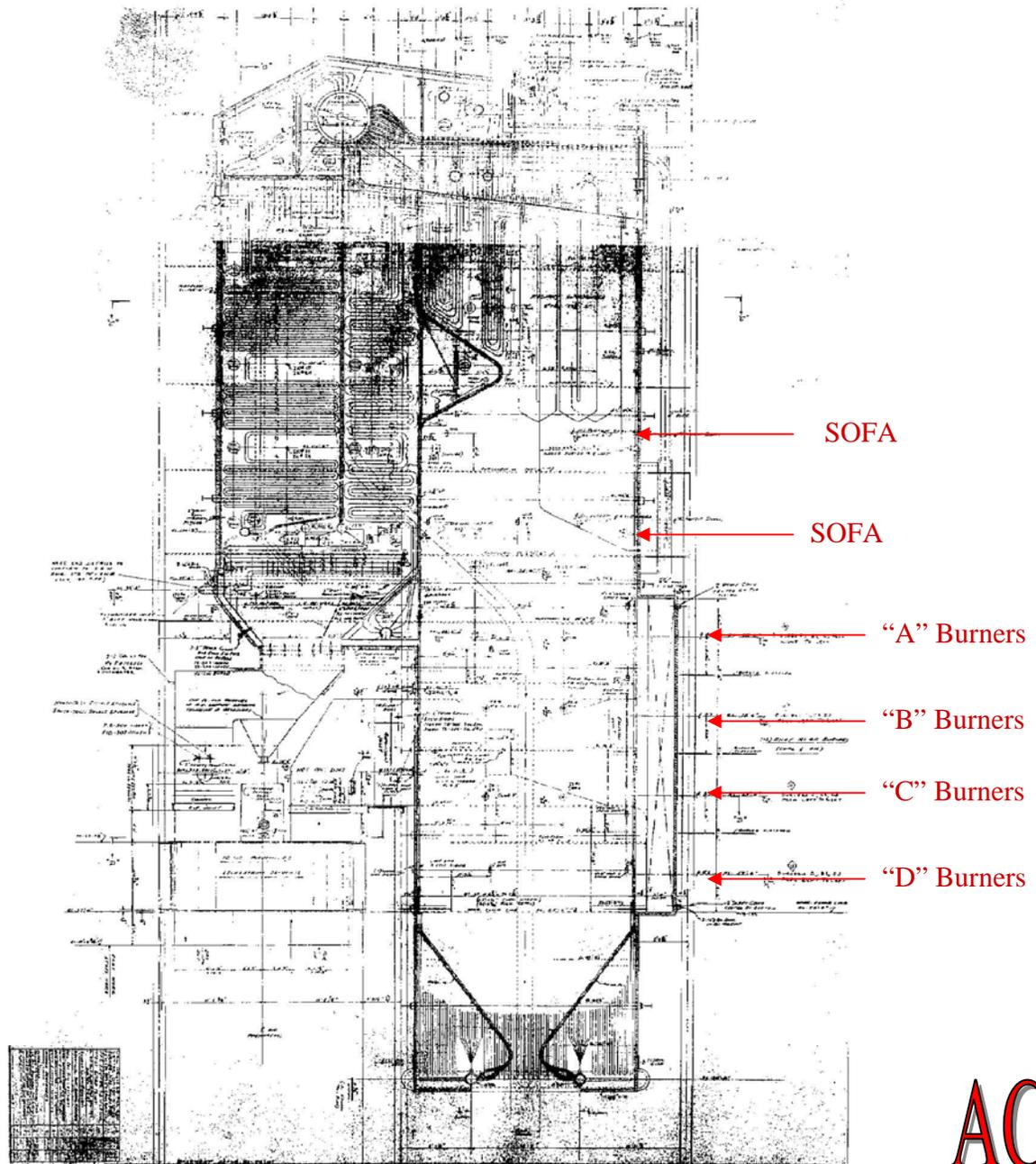
NRG Middletown Power, LLC

Unit #2 NOx Emission Objective

- UNIT SIZE – 125 Mwg, 1,900 psig @ 1005 F SH & RH Steam
- UNIT TYPE: Wall fired, 12 burners on 4 rows, balanced draft
- FUEL – #6 Oil (0.5% S) & Natural gas (original coal fired design)
- NOx : Base = 0.39 lb/mmBtu (#6 oil)
- NOx : Reduced with layered technology < 0.12 lb/mmBtu (#6 oil)
- CO <200 ppm

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Middletown Unit #2

NOx REDUCTION PHASES

- Separated Over Fire Air System Installed and Burners Modified – NOx from 0.39 to 0.28 lb/mmBtu with high opacity (15% to 20%)
- SOFA system modified and optimized
- #6 oil atomization converted from mechanical to steam
- Burners upgraded to ACT, Inc. Low NOx design
- Full load NOx at 0.22 to .19 lb/mmBtu with opacity below 7%
- HERT Testing performed and NOx reduced from 0.19 lb/mmBtu to < 0.12 lb/mmBtu with < 6.5 ppm NH3 slip

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ACT, Inc. OIL FIRED LOW NO_x BURNER DESIGN



MIDDLETOWN UNIT #2 RESULTS

HERT System

- Full load NO_x reduced from 0.19 lb/mmBtu to 0.118 lb/mmBtu with HERT
- Two high energy injectors utilized
- NH₃ Slip < 6.5 ppm
- No additional pressure part modification required for HERT injectors

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MIDDLETOWN UNIT #2

Layered Technology Results Summary

- NOx reduced from 0.39 lb/mmBtu to less than 0.12 lb/mmBtu with LNB, SOFA & HERT
- Overall NOx reduction nearly 70%
- Installed capital cost of \$7-10/kw

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Cost Effective Layered Technology for Ultra Low NOx Control Summary

- Significant NOx reductions possible with layered application of LNB, SOFA, & HERT
- Overall NOx reductions greater than 70%
- Relatively low installed capital cost
- Similar NOx reduction achieved with layered approach on 170 Mw wall fired boiler burning eastern bituminous coal

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