REINHOLD ENVIRONMENTAL Ltd.

2017 NOx-Combustion-CCR Round Table Presentation

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Modifications to Existing Overfire Air Systems for Improved NO_x Control

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February 28, 2017

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Outline

- Approach to Cost-effective Compliance Solutions
- ROFA System Description
- Application of CFD Engineering
- Results
  - 380 MW unit
  - 500 MW unit
- Summary

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Layered Approach for Emissions Compliance

Primary Measures

- Combustion Tuning
- Low-NO_x Burners
- Over-fire Air
- Boiler Optimizer

Critical Step: Minimize boiler outlet NO_x emissions

Secondary Measures

- SNCR
- SBS
- LoTOx

Trim to compliance limits

Flexible, cost-effective alternatives to SCR

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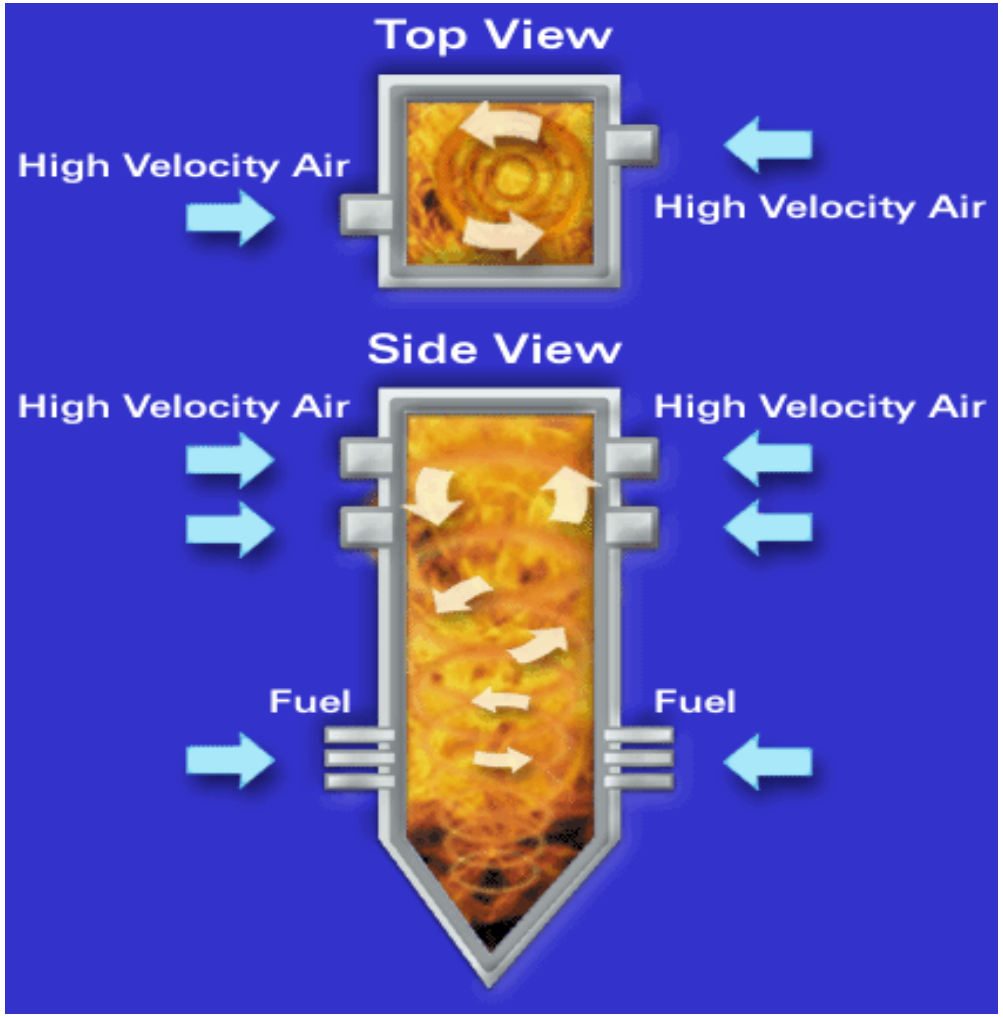
ROFA® (Rotating Opposed-fire Air)

- Method of staging combustion using boosted secondary air to create turbulence in the upper furnace for improved flue gas mixing resulting in optimum NO_x reduction, CO and LOI
- System designed based on actual furnace readings, flue gas traverses and vast experience utilizing CFD engineering
- Implemented in conjunction with burner/secondary air modifications



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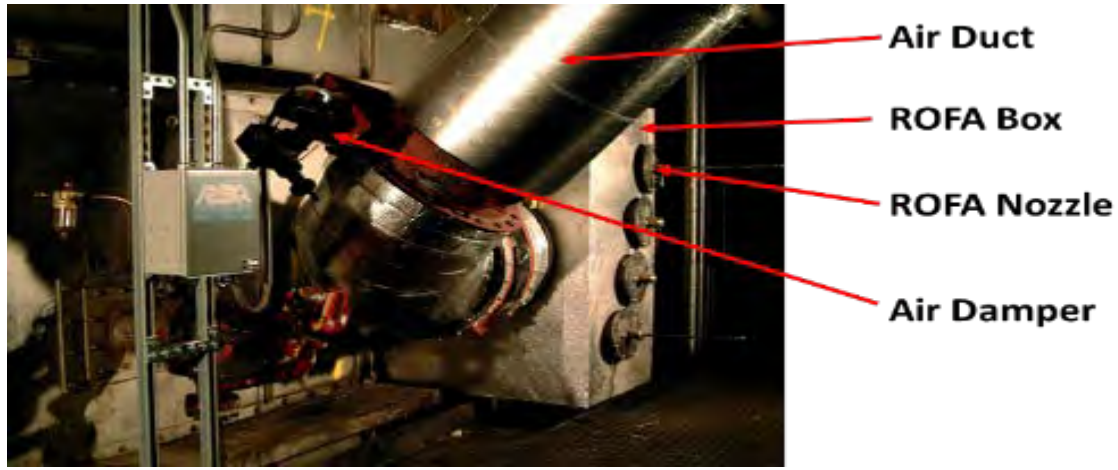
System Design

Major equipment list

- Boosted fan
- Ductwork / expansion joint
- ROFA boxes
- Modulated dampers
- Secondary air nozzles
- Electrical and I&C



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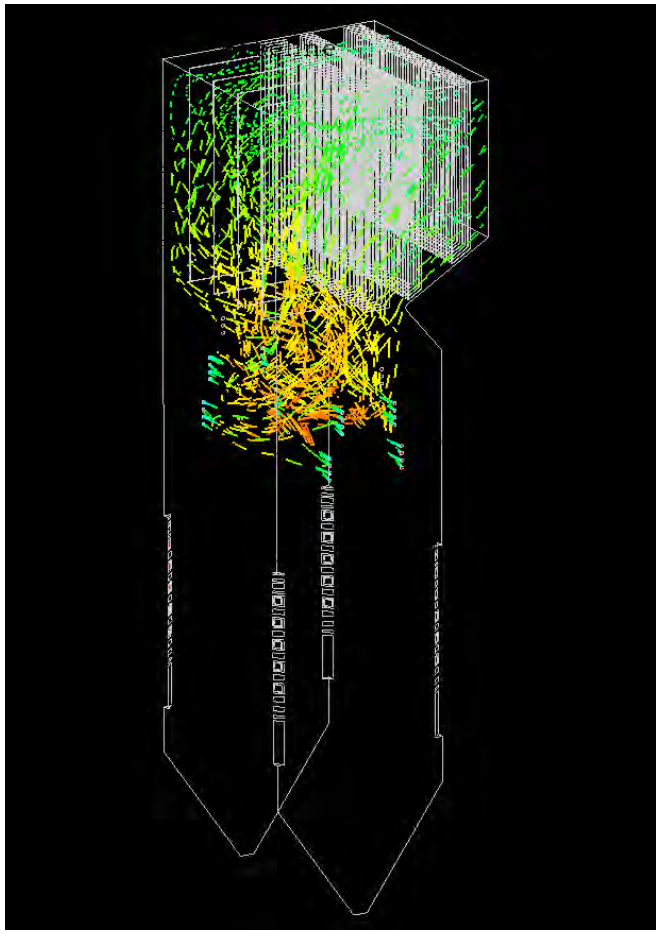
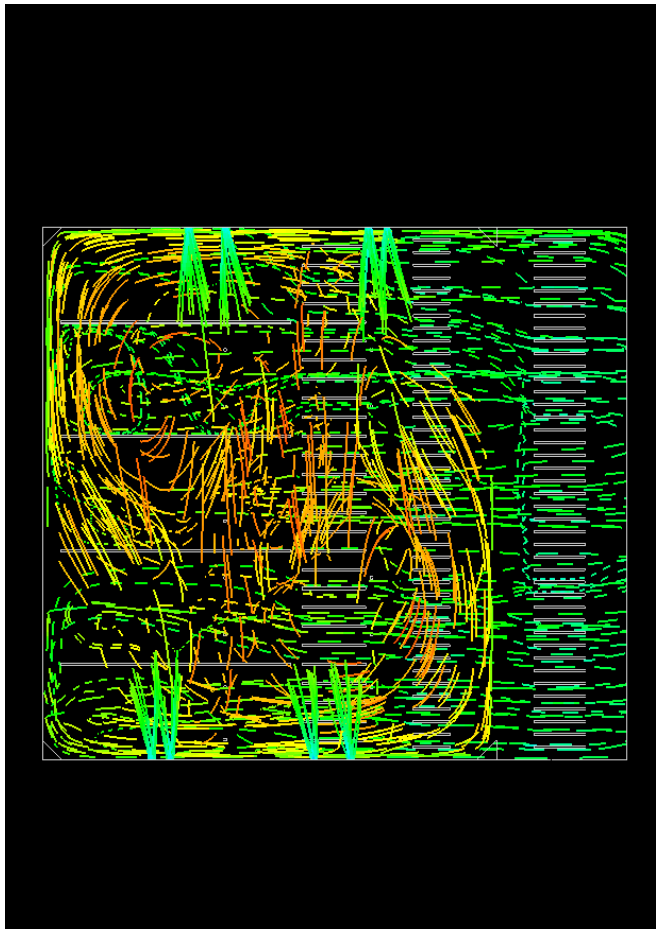
CFD Engineering to Improve Combustion Quality

- CFD-assisted placement of injection boxes utilizing actual furnace data
- Multiple air nozzles to ensure maximum flue gas coverage
- Better mixing due to energy imparted to flue gas
- Increased residence time for more complete combustion



Streamlines



Air Jets (Plan View)

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Improved Combustion Allows for Deeper Staging

- Better mixing of air and fuel in upper furnace reduces CO and LOI
- Allows for operation with decreased excess oxygen, resulting in lower heat rate
- Sustained NO_x reduction performance at reduced load
- Modifications to secondary air nozzles
  - Manage windbox/furnace ΔP
  - Maintain oxygen concentration along walls
- No evidence of increased water wall tube wastage

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380MW Unit

- Tangentially-fired tower boiler
- Bituminous coal
- CCOFA and SOFA previously installed
  - Adjustable yaw
  - Fixed tilt
  - Design for 20% TAF for overfire air system
  - Reduced to ~13% TAF to avoid tube wastage
- Baseline NO_x: 0.32-0.36 lb/MMBtu

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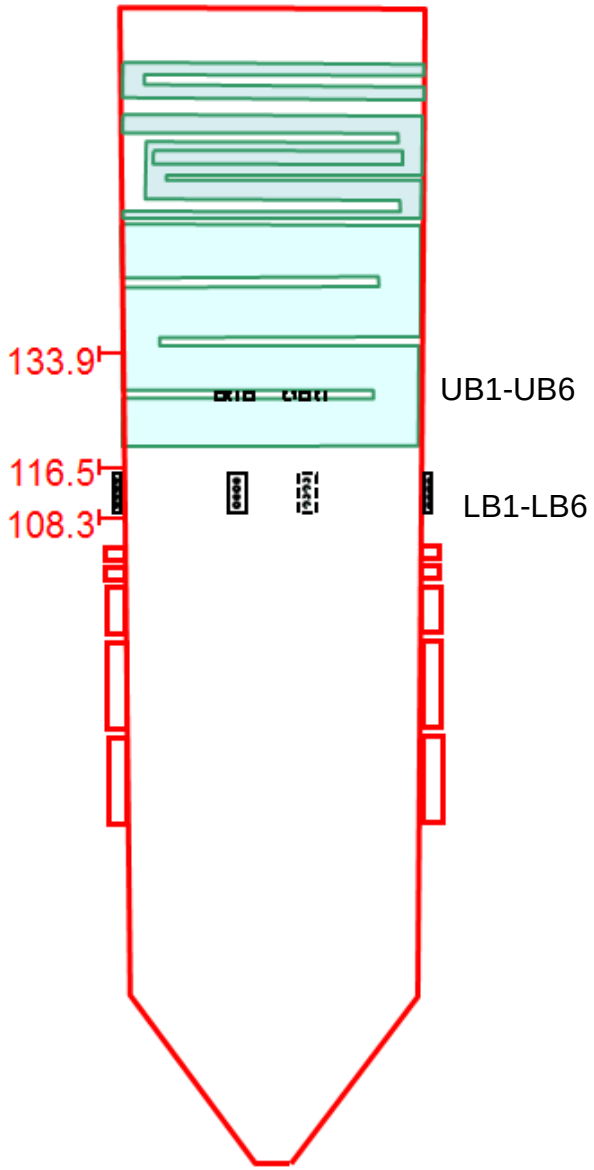
380MW Unit - Modifications

- Retained CCOFA, but modified nozzles
  - Smaller cross-section to increase velocity
  - Allow for horizontal directional adjustment
- Removed SOFA
- Modifications to secondary air nozzles
- Implemented two levels of ROFA nozzles
  - Six ports at SOFA elevation; used two of the existing SOFA penetrations on front and rear walls
  - Six additional ports, three each in side walls, located 16 feet above SOFA elevation
- ROFA TAF = 30%



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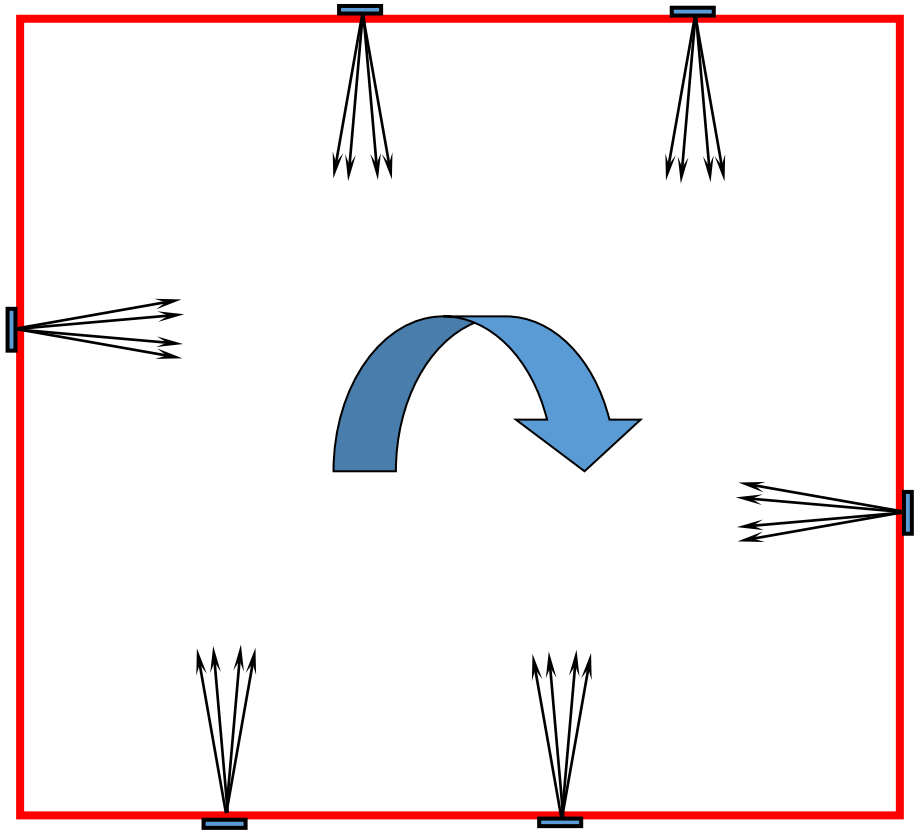
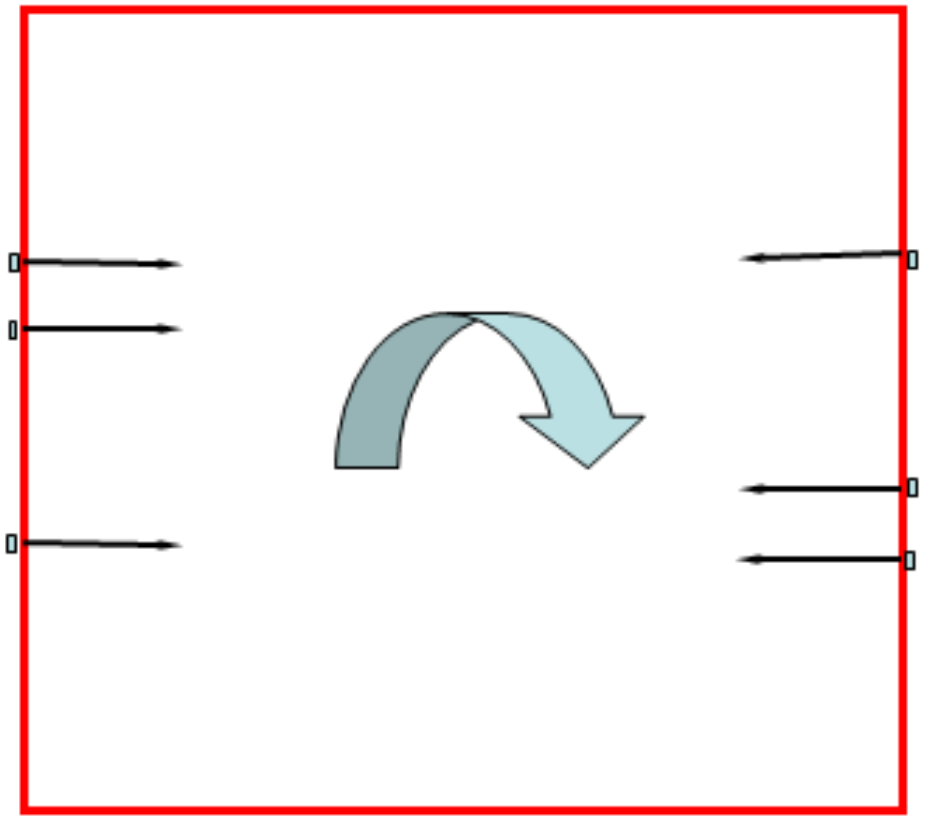
380 MW Unit - Schematic of ROFA port locations

Rear Wall



Front Wall
Lower Elevation

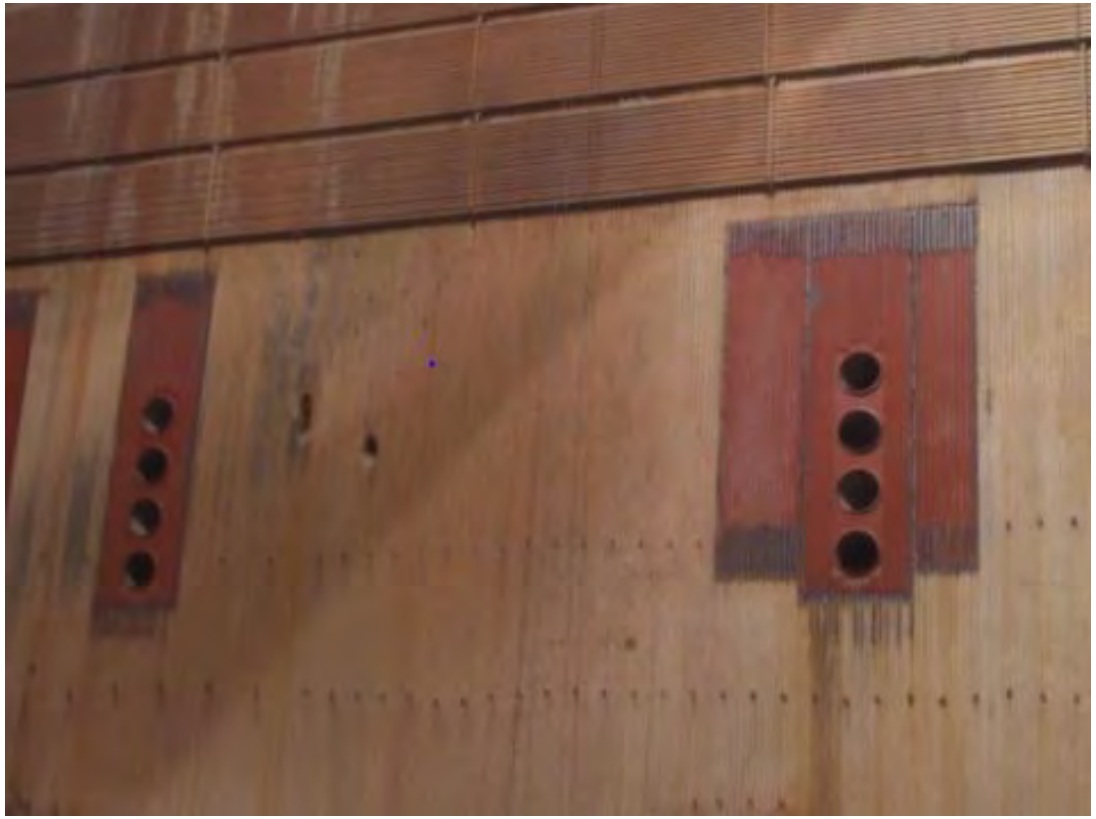
Rear Wall



Front Wall
Upper Elevation

380 MW Unit - Installation

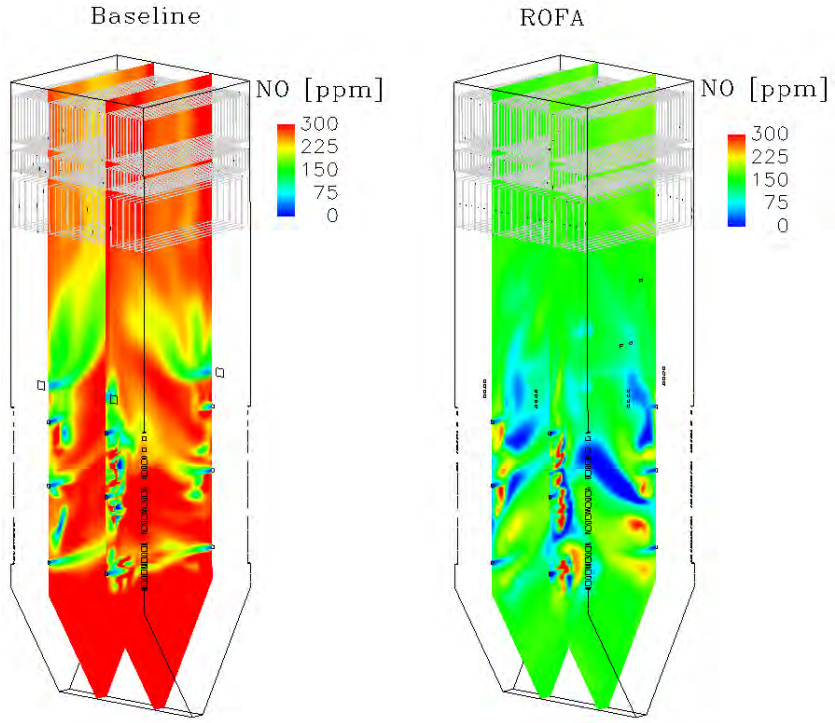
ROFA Ducting



Lower Level Nozzles in Furnace

380MW Unit - Results

- 44% NO_x reduction (from ~0.32 lb/MMBtu)
  - 0.18 lb/MMBtu at full load
  - 0.14 lb/MMBtu at 210 MW
- CO < 50 ppm
- LOI: 3.5%
- Excess oxygen decreased from 3.8% to 2.7%
- 0.7% decrease in net unit heat rate
- Demonstrated ability to handle significant fuel variability



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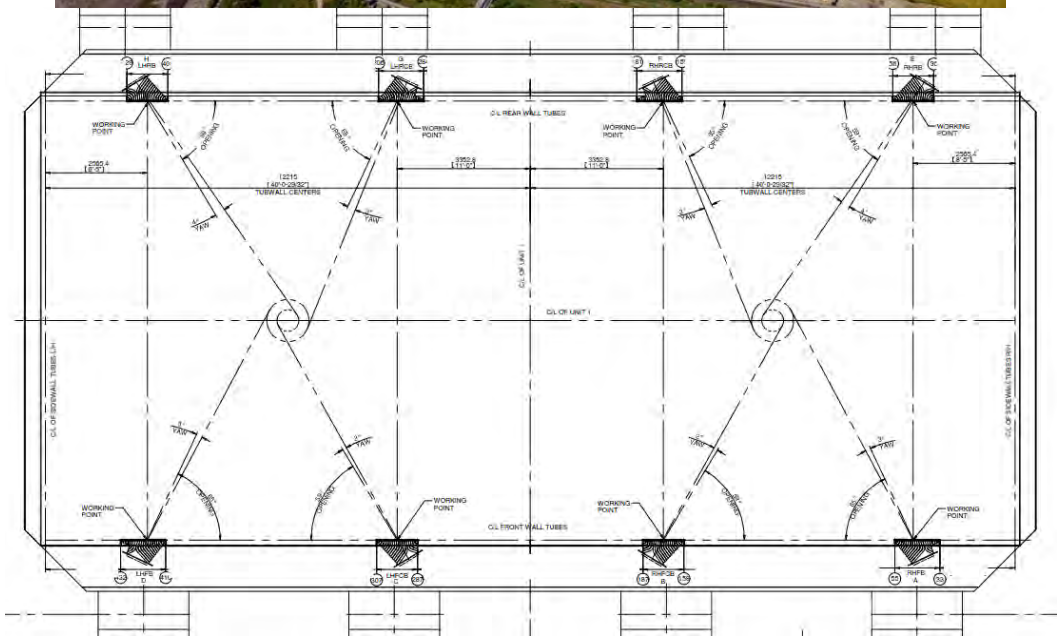
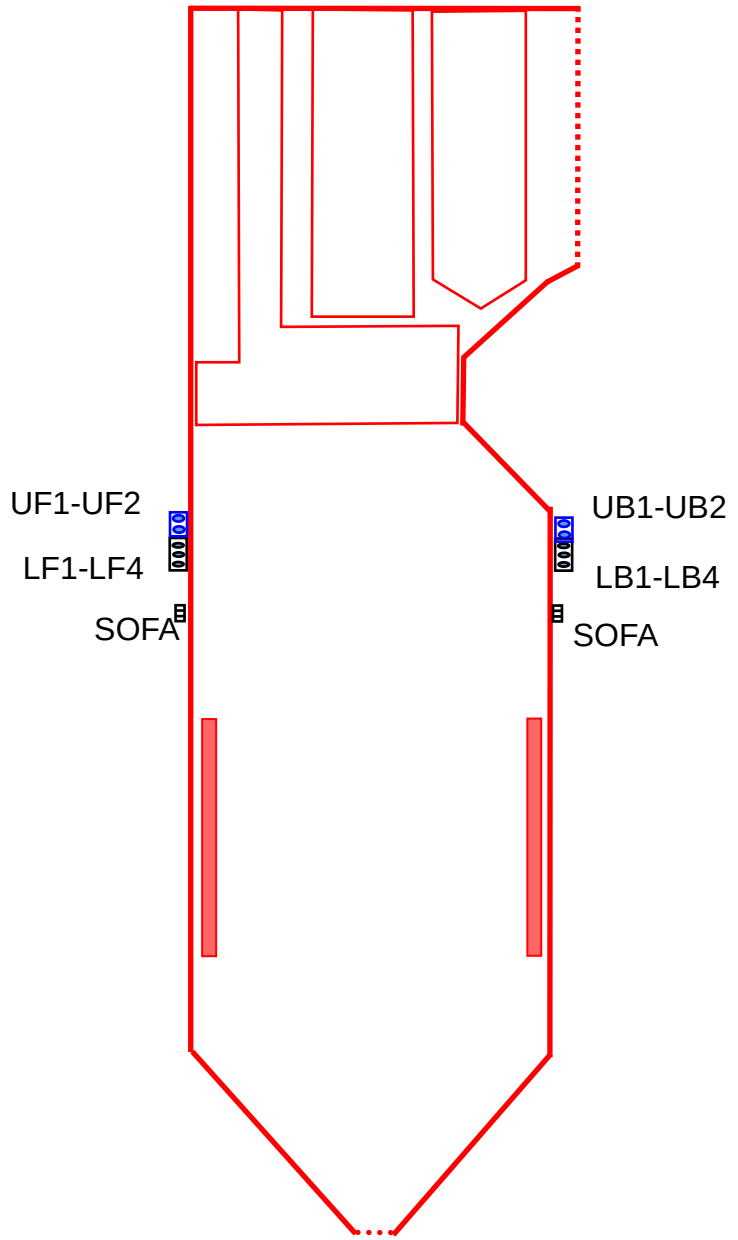
500MW Unit

- Tangentially-fired twin-furnace
- Variety of international coals
- CCOFA and SOFA previously installed
  - Two CCOFA nozzles at each corner, injecting 4% of TAF
  - Two SOFA ports on front and rear wall of each furnace, injecting 8% of TAF
- Baseline NO_x: 0.33 lb/MMBtu at full load with both CCOFA and SOFA in service
- SOFA typically out of service to avoid high dust levels, resulting in high-NO_x operating mode
- Elevated baseline CO (700ppm) and LOI (14%)



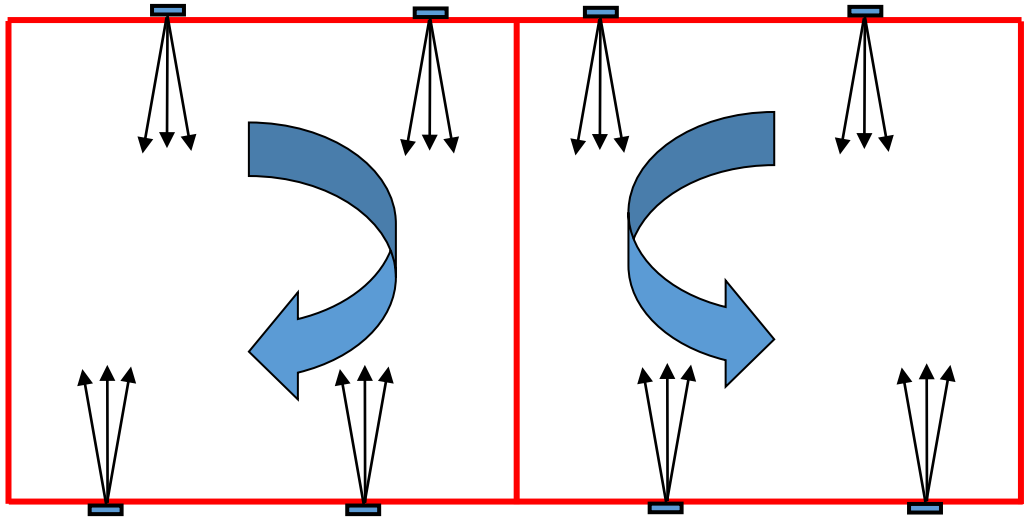
500MW Unit - Modifications

- ROFA ports located at two levels
  - 4 ports each furnace, located 8 feet above SOFA elevation
  - 2 ports each furnace, located 16 feet above SOFA elevation
- Incorporated CCOFA and SOFA into overall NO_x control system
- Modifications to secondary air nozzles
- ROFA TAF = 25%



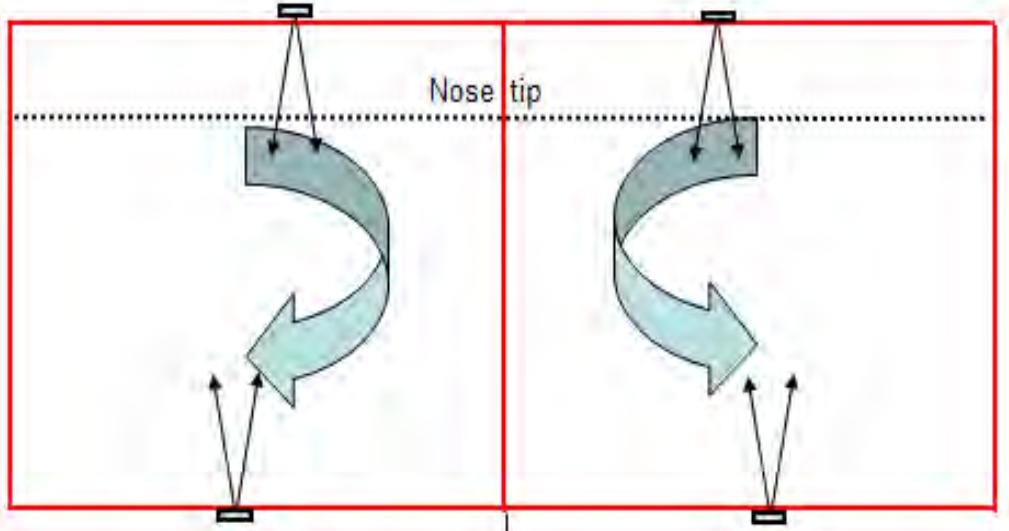
500MW Unit – Schematic of ROFA Port Locations

Rear Wall



Front Wall
Lower Elevation

Rear Wall



Front Wall
Upper Elevation

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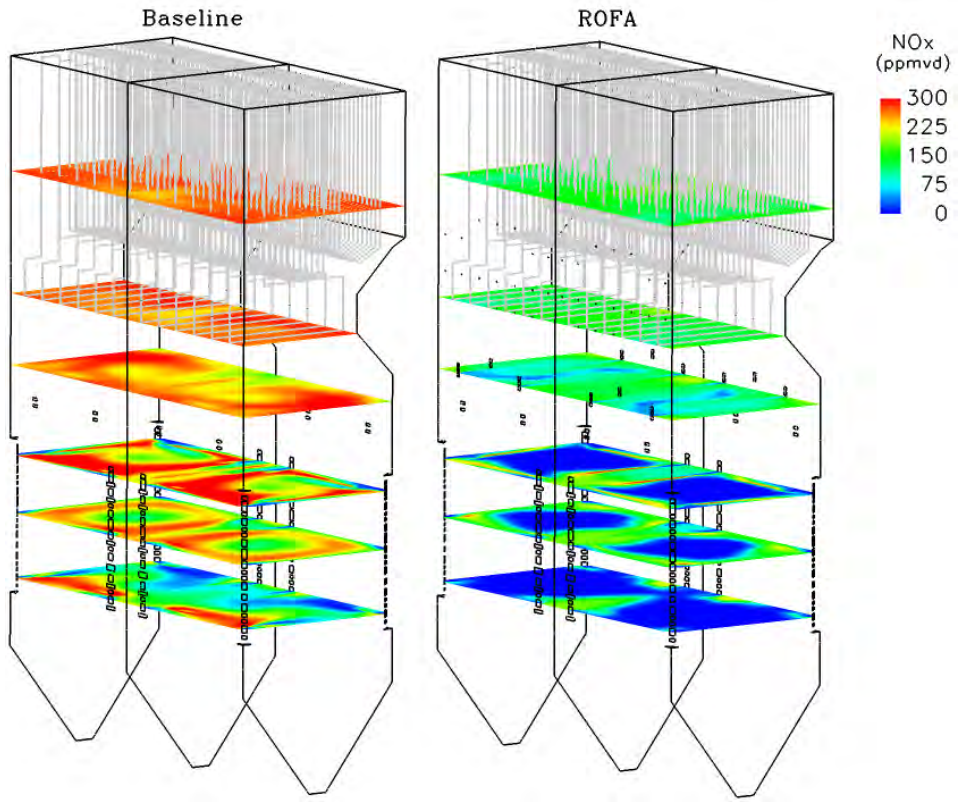
500MW Unit - Results

- 39% NO_x reduction (60% from “SOFA-off”)
- Performance test results at full load
  - NO_x: 0.20 lb/MMBtu
  - CO decreased to 150 ppm
  - LOI decreased to 8.2%
- Minimal change in boiler efficiency
- Demonstrated ability to handle significant fuel variability
- Utilized SNCR to achieve IED compliance



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Summary

- ROFA system has been applied to boilers with existing CCOFA and SOFA
- Achieved ~40% additional NO_x reduction
- Effectively managed CO and LOI
- Maintained or increased boiler efficiency
- Reduction in NO_x formation enables implementation of secondary measures for regulatory compliance solution
- Helps create opportunity to avoid SCR