1st Oxyfuel Combustion Conference, Cottbus, 2009

Development of Oxy-Burner Retrofit Principles for Existing Coal-Fired Utility Boilers

Andrew R. Fry, Bradley R. Adams, Marc A. Cremer
Reaction Engineering International

Jiefeng Shan
Siemens Environmental Systems & Services

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Presentation Outline

- Introduction
- University of Utah's 1.5 MW test furnace
- Existing low-NO_x burner and modeling results
- Motivation for new burner and design criteria
- Oxy-research burner initial and final design configurations and modeling results
- Oxy-research burner design specifics
- Summary

Program Overview

- **<u>Objective:</u>** ***Characterize and predict performance and operational impacts of oxy-combustion retrofit designs on existing coal-fired boilers***

- **Utilize multi-scale testing and theoretical investigations to develop:**
  - **Fundamental data that describe flame characteristics, waterwall corrosion, and ash properties (slagging, fouling) in oxy-firing**
  - **Validated mechanisms that describe impacts of oxy-combustion**
  - **Firing system principles (effects of oxy-burner design, flue-gas recycle)**

- **Incorporate validated mechanisms into CFD models and evaluate full-scale oxy-retrofit designs**

Experimental Overview

- **100 kW Oxy-Fuel Combustor (OFC) Tests**
  - **Ash Characterization and Deposition**
  - **Soot Evolution**
- **1.5 MW Pilot-Scale Furnace (L1500) Tests**
  - **Impacts of burner configuration on flame behavior**
  - **Heat Flux, Corrosion and Deposition**
  - **Flue Gas Chemistry**
- **Bench-Scale Optical Entrained Flow Reactor**
  - **Char Oxidation Kinetics**

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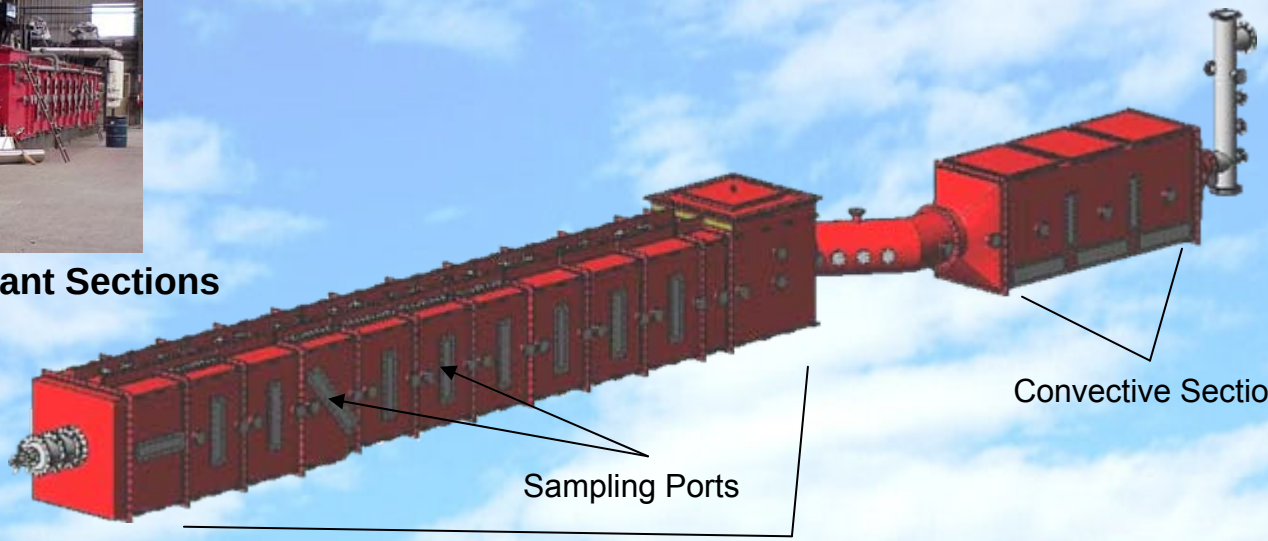
1.2 MW Pilot-Scale Furnace (L1500)

Air / FGR Train

Convective and Radiant Sections

Unique L1500 Capabilities:

- **Realistic Burner Turbulent Mixing Scale**
- **Realistic Radiative Conditions**
- **Realistic Time – Temperature History**



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1.2 MW Pilot-Scale Furnace Experiments

Experiments

Fuel, Oxygen and FGR Mixing in Burner

Corrosion, Radiation and Particle Deposition

Measurements

Flame Stabilization Location

Flue Gas Composition and Concentrations

Unburned Carbon in Ash

Temperature Profile

Real-Time Corrosion Rate Electrochemical Noise (ECN) Technology

Heat Flux

Deposition Rate

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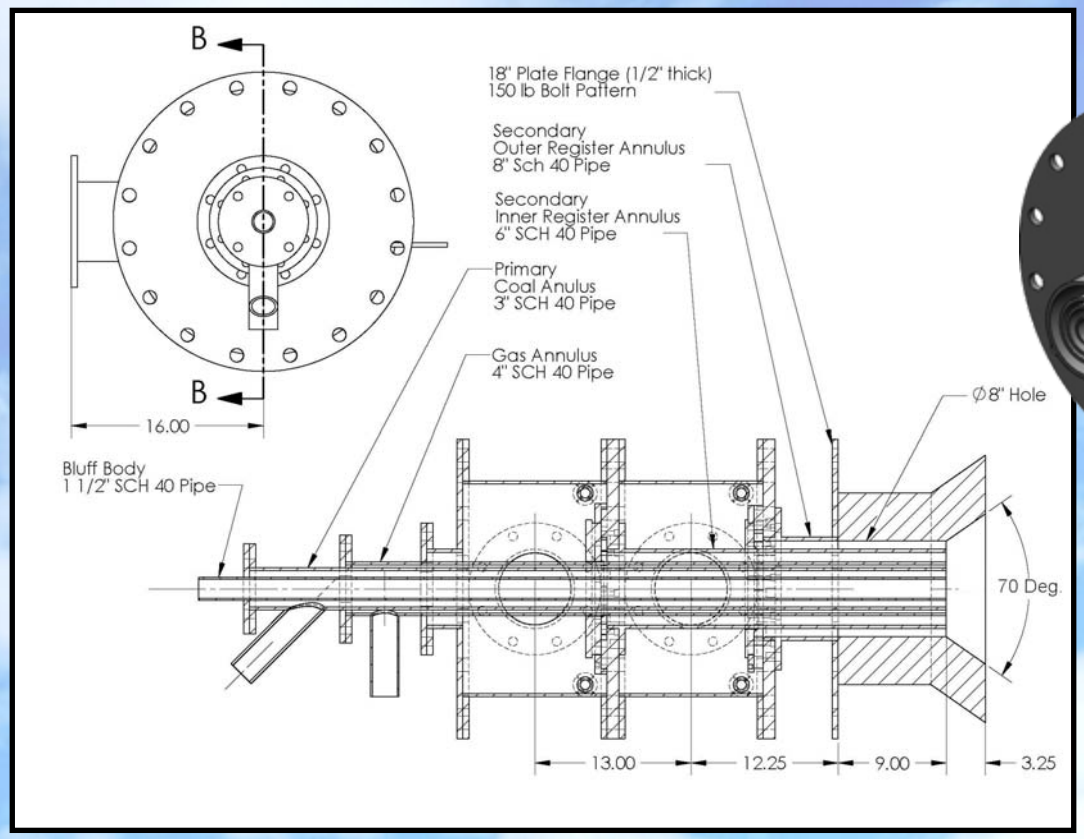
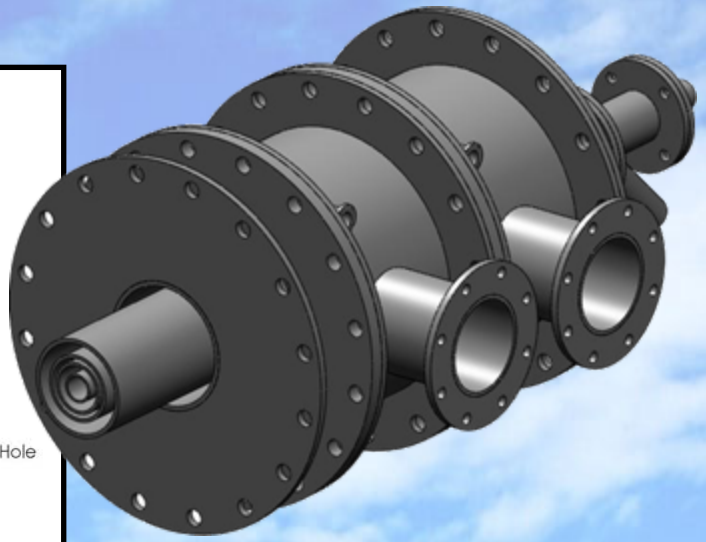
Existing Low-NO_x Burner (LNB)





- Dual register low-NO_x burner
- Designed for 1.5 MW firing rate

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Modeling Conditions for Existing LNB

OCC1,Cottbus

Operating Conditions

	LNB-A	LNB-O
Firing Rate (MW)	1.02	1.02
Fuel	Bit. Coal	Bit. Coal
Oxidizer	Air	O2 + FGR
Burner SR	0.9	0.9
Total Coal Flow (kg/s)	0.03523	0.03523
Total Coal Flow (lb/hr)	279.6	279.6
Primary Gas / Fuel	1.8	1.8
Primary Velocity (m/s)	20.5	14.4
Primary Velocity (ft/s)	67.2	47.2
Primary Flow (kg/s)	0.06342	0.06342
Primary Flow (lb/hr)	503.3	503.3
Inner Sec. Flow (kg/s)	0.06007	0.06656
Inner Sec. Flow (lb/hr)	476.8	528.3
Outer Sec. Flow (lb/hr)	0.18022	0.19968
Outer Sec. Flow (lb/hr)	1430.3	1584.8
Primary Feed O2 (vol %)	N/A	27.0%
Inner Sec. Feed O2 (vol %)	N/A	27.0%
Outer Sec. Feed O2 (vol %)	N/A	27.0%

Utah Bituminous Coal

Coal (As Fired)	
C (wt%)	71.31%
H (wt%)	5.04%
O (wt%)	10.14%
N (wt%)	1.28%
S (wt%)	0.57%
Ash (wt%)	8.66%
Moisture (wt%)	3.00%
Volatiles (wt%)	40.47
HHV (J/kg)	29.09
HHV (Btu/lb)	12517

Primary velocity for oxy-fired conditions is near coal layout velocity

O_2 Concentration in the Overall FGR/O_2 mixture = 27% (vol)

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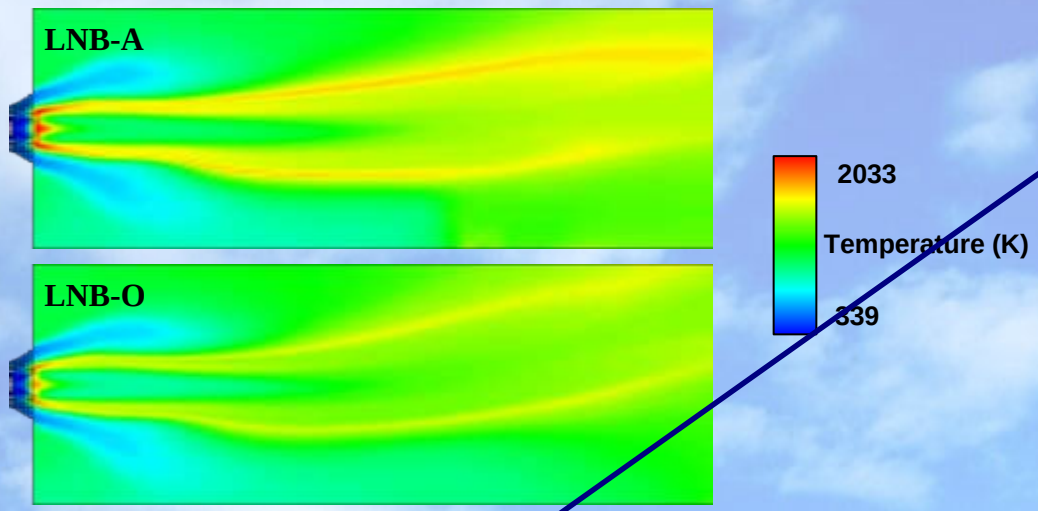
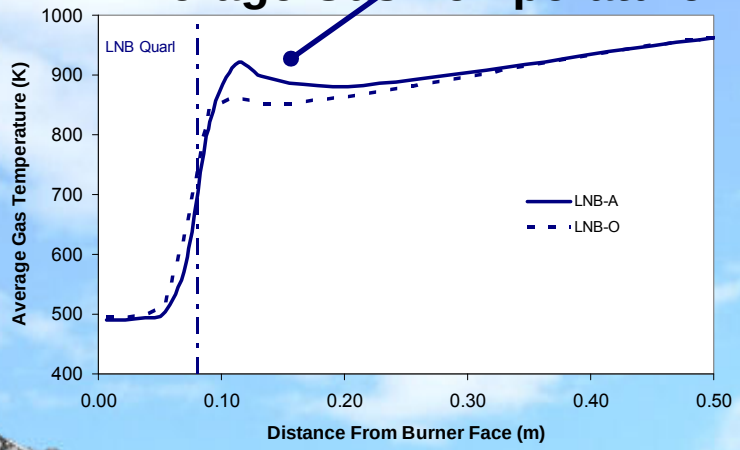
Predicted Gas and Particle Temperatures for the LNB



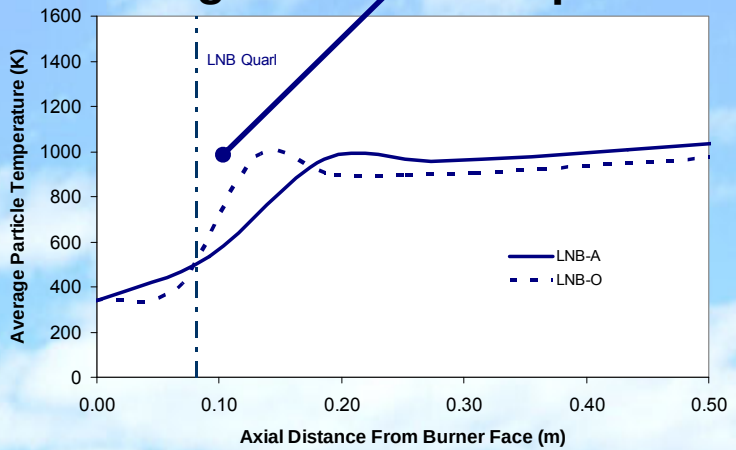
Average gas temperature is slightly lower for oxy-combustion in the burner region

Particles heat more quickly under oxy combustion conditions

Average Gas Temperature



Average Particle Temperature



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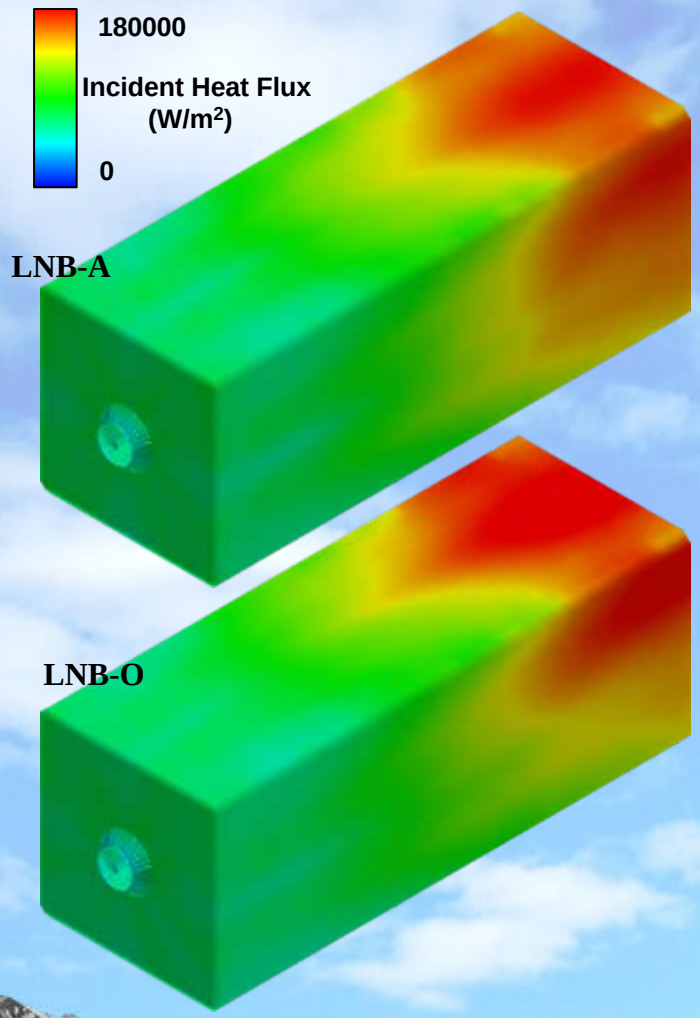
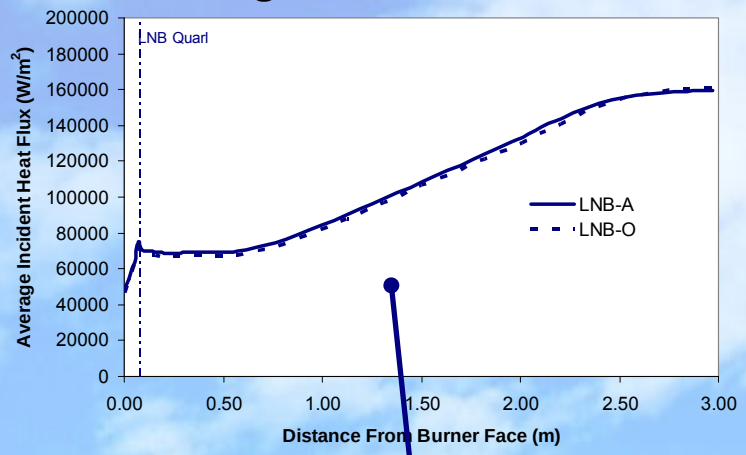
Predicted Incident Heat Flux for the LNB



Average Incident Heat Flux



Incident heat flux is nearly identical for air- and oxy-fired conditions

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Motivation for New Burner Design

- Existing burner was designed for a 1.5 MW firing rate
  - Velocities are low for the oxy-fired conditions, depending on conditions chosen
  - Flame will be stable and attached, almost independent of operating conditions
- Research burner must be able to handle various O_2 and FGR mixtures in each register, along with targeted O_2 injection in the primary and inner secondary
- REI and Siemens have developed a oxy-coal research burner, based on an existing Siemens full-scale burner design
  - Research burner will be used to test general combustion principles under air and oxy-fired conditions, relevant to most wall fired boilers

Goal and Approach

Goal: Stabilized flame at quarl exit

Condition was quantified by predicting flue gas and particle temperatures using CFD

Various design iterations were evaluated until the result was achieved

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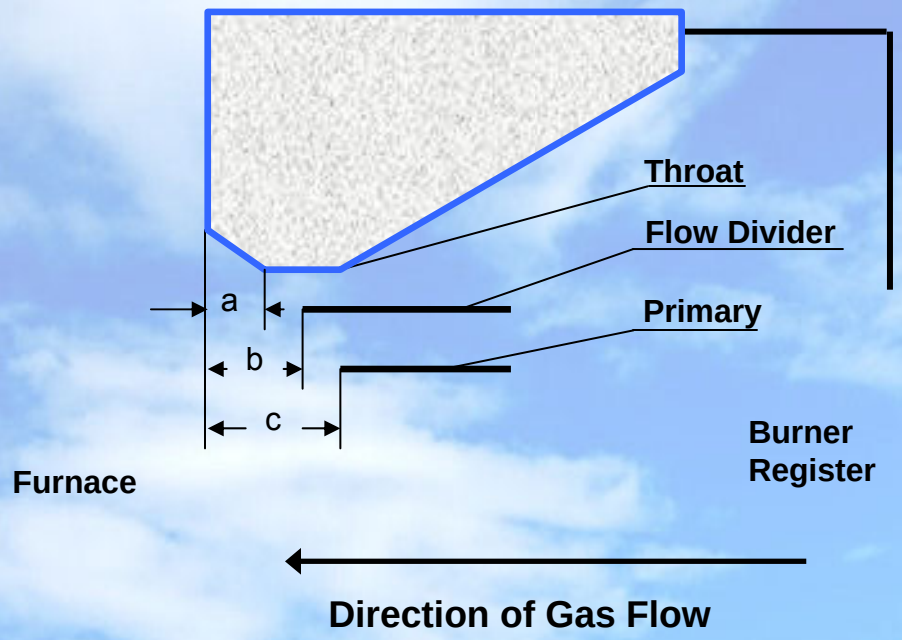
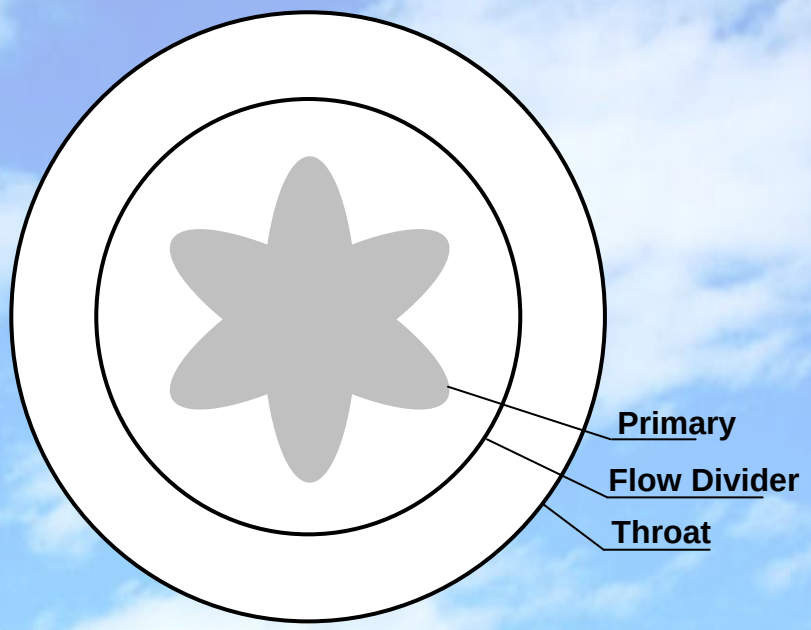
Initial Oxy-Research Burner (OXYI) Design Overview

Side View



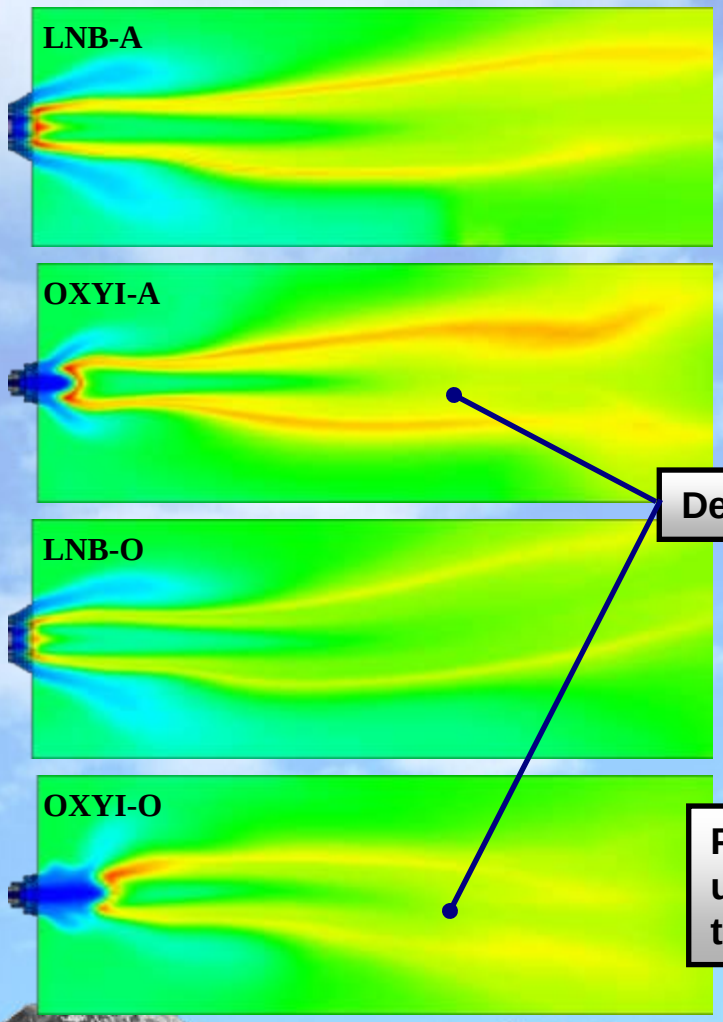
Front View

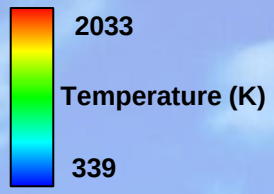


a	Quarl Depth
b	Divider Setback
c	Burner Setback

The oxy-research burner was initially designed by constant velocity scaling of the existing Siemens burner design

Comparison of Predicted Gas and Particle Temperatures for OXYI and LNB

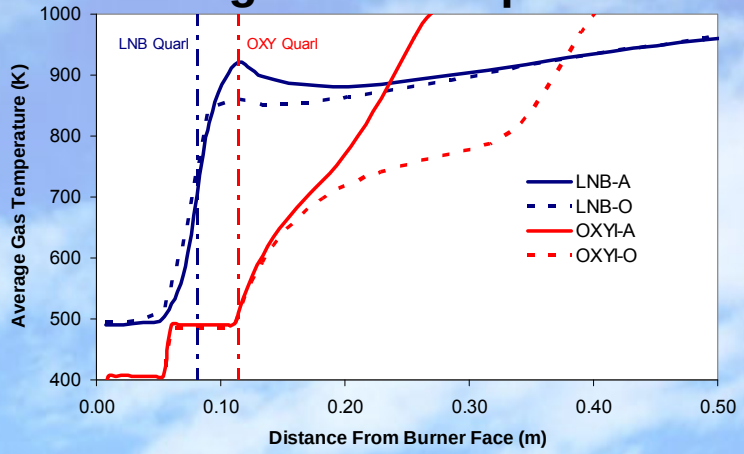




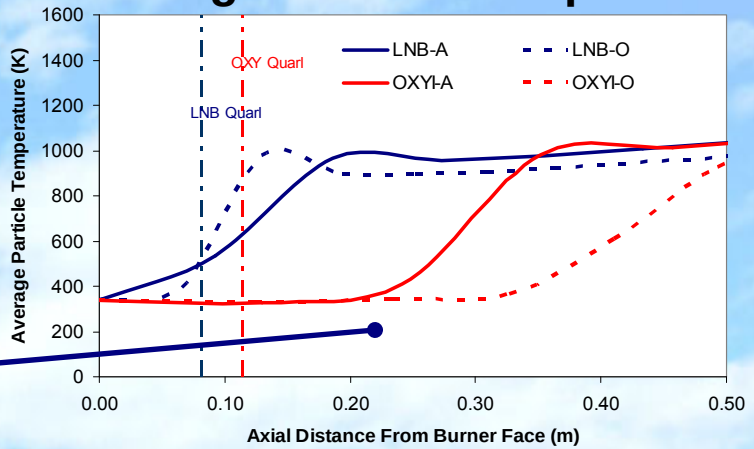
Detached flame

Particle heat-up is outside the quarl

Average Gas Temperature



Average Particle Temperature



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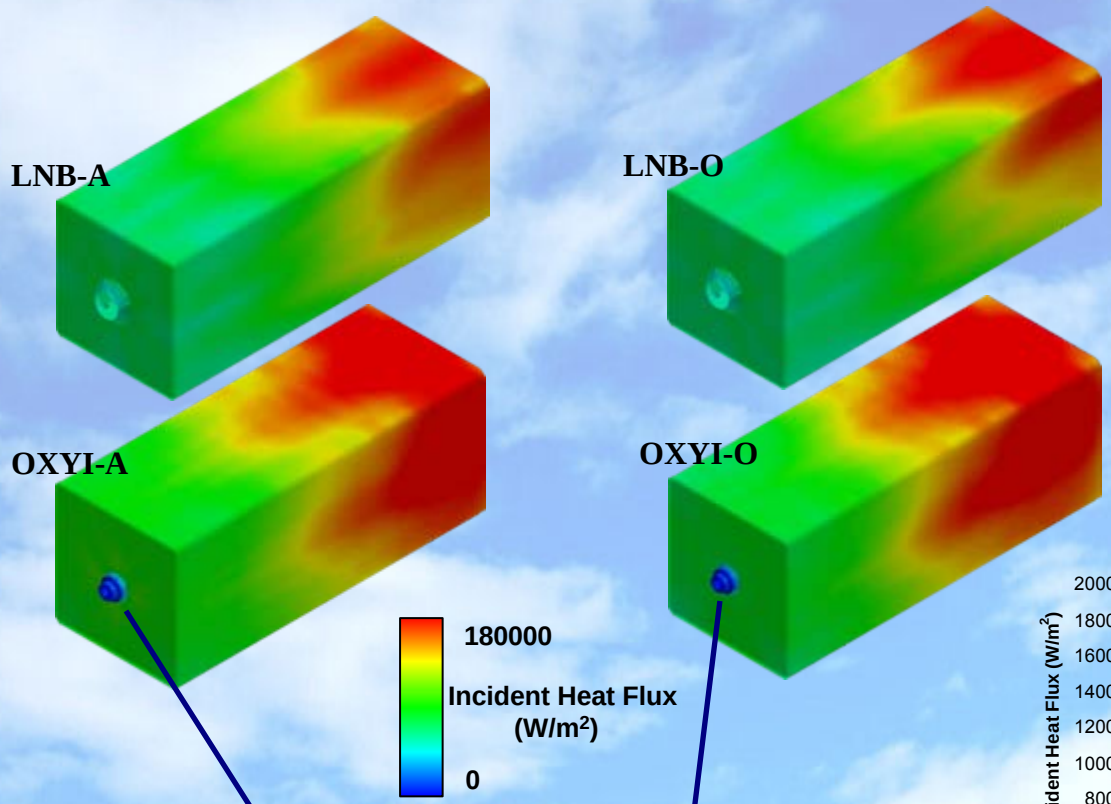
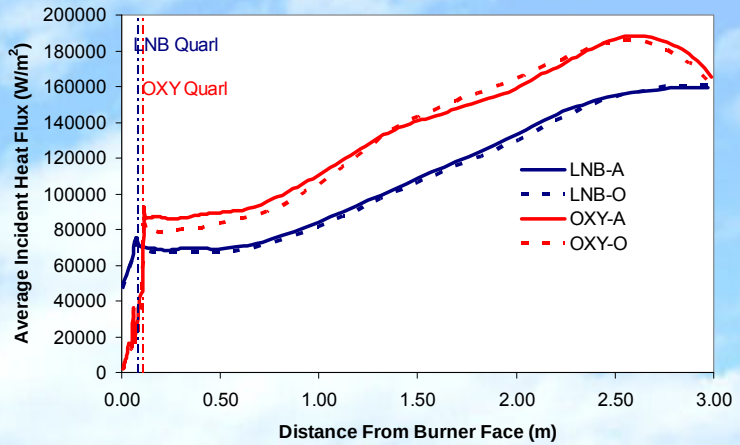
Comparison of Predicted Incident Heat Flux for OXYI and LNB



Increased heat flux for the oxy-combustion conditions

Limited heat flux into the OXYI quarl

Average Incident Heat Flux



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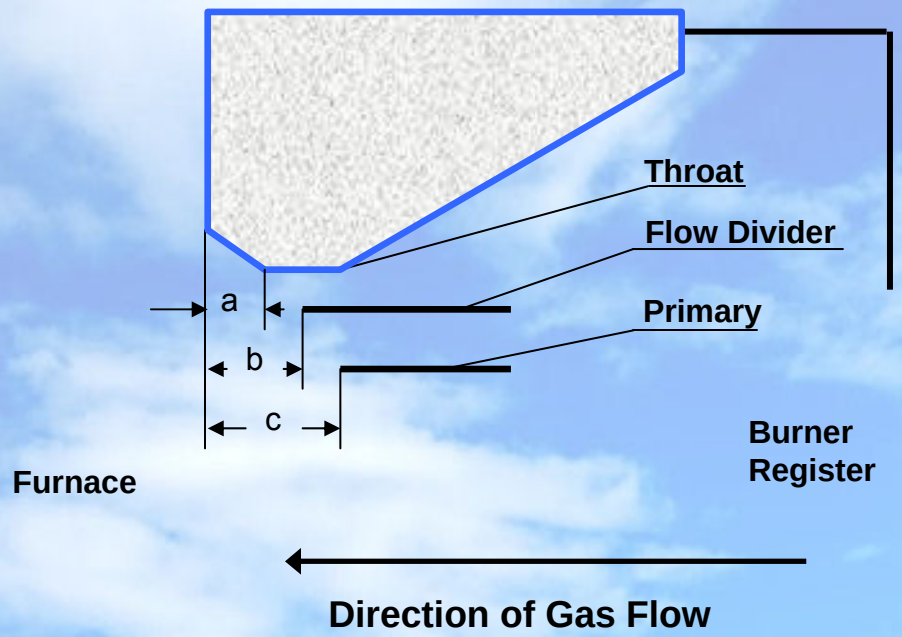
Modifications to the Oxy-Coal Research Burner

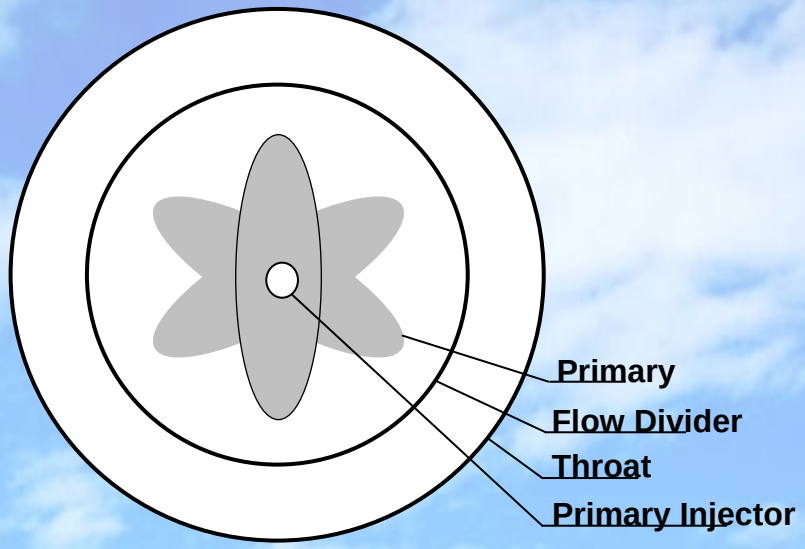
- Many iterations of redesign and modeling were performed ultimately resulting in the following modifications:
- Primary was redesigned with:
  - 15% reduction to the primary velocity
  - Concentric pipe for targeted oxygen injection
- Quarl was lengthened
- Burner setback was increased

Final Oxy-Research Burner (OXYF) Design Overview

Side View



Front View

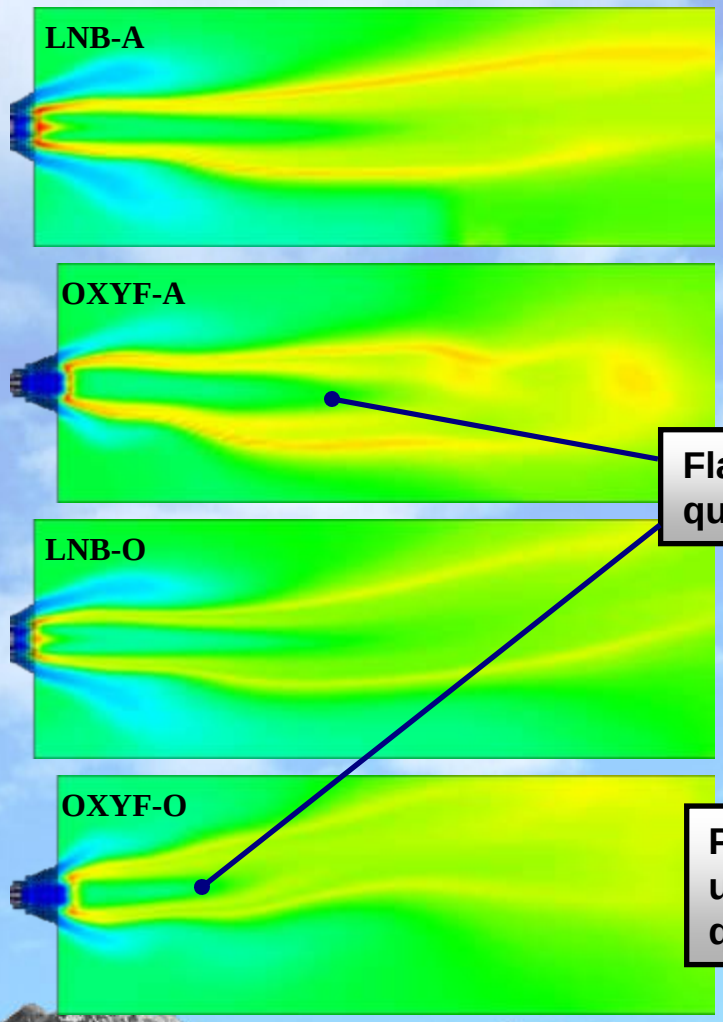


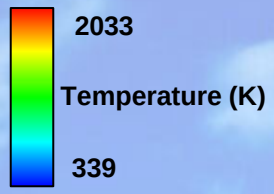
a	Quarl Depth
b	Divider Setback
c	Burner Setback

Nozzles for O_2 injection in the inner secondary are included, but not shown here or modeled

Modeling Comparison with Existing Burner

OCC1,Cottbus

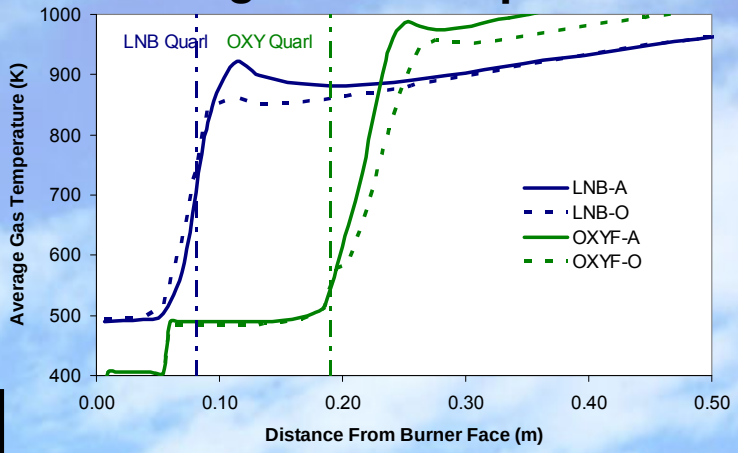




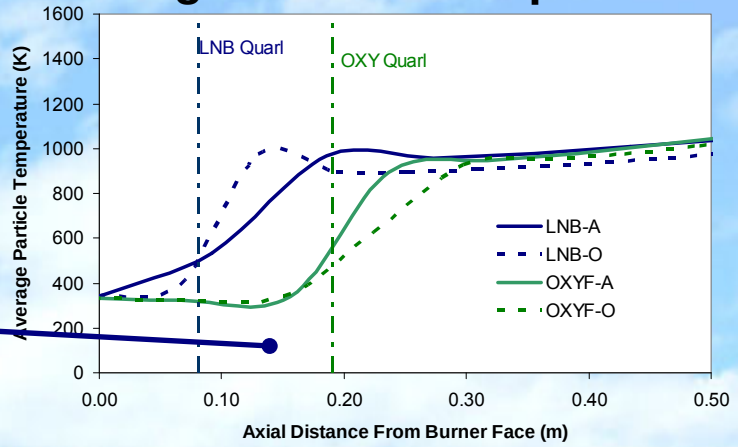
Flame attachment at quarl exit

Particle heat-up is inside the quarl

Average Gas Temperatures



Average Particle Temperatures



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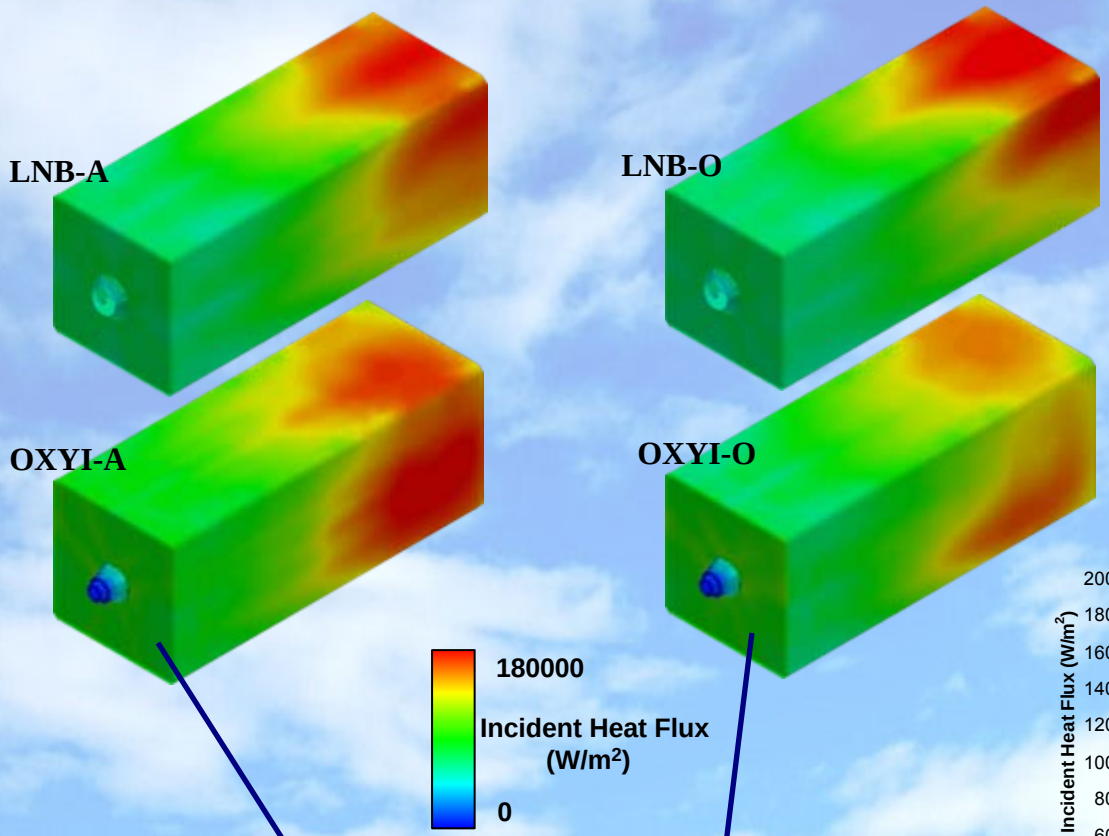
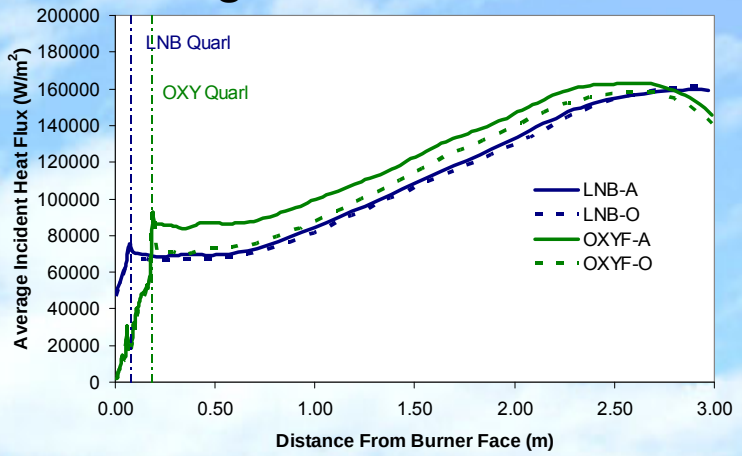
Modeling Comparison with Existing Burner

OCC1,Cottbus



Improved heat flux into the OXYF quarl

Average Incident Heat Flux



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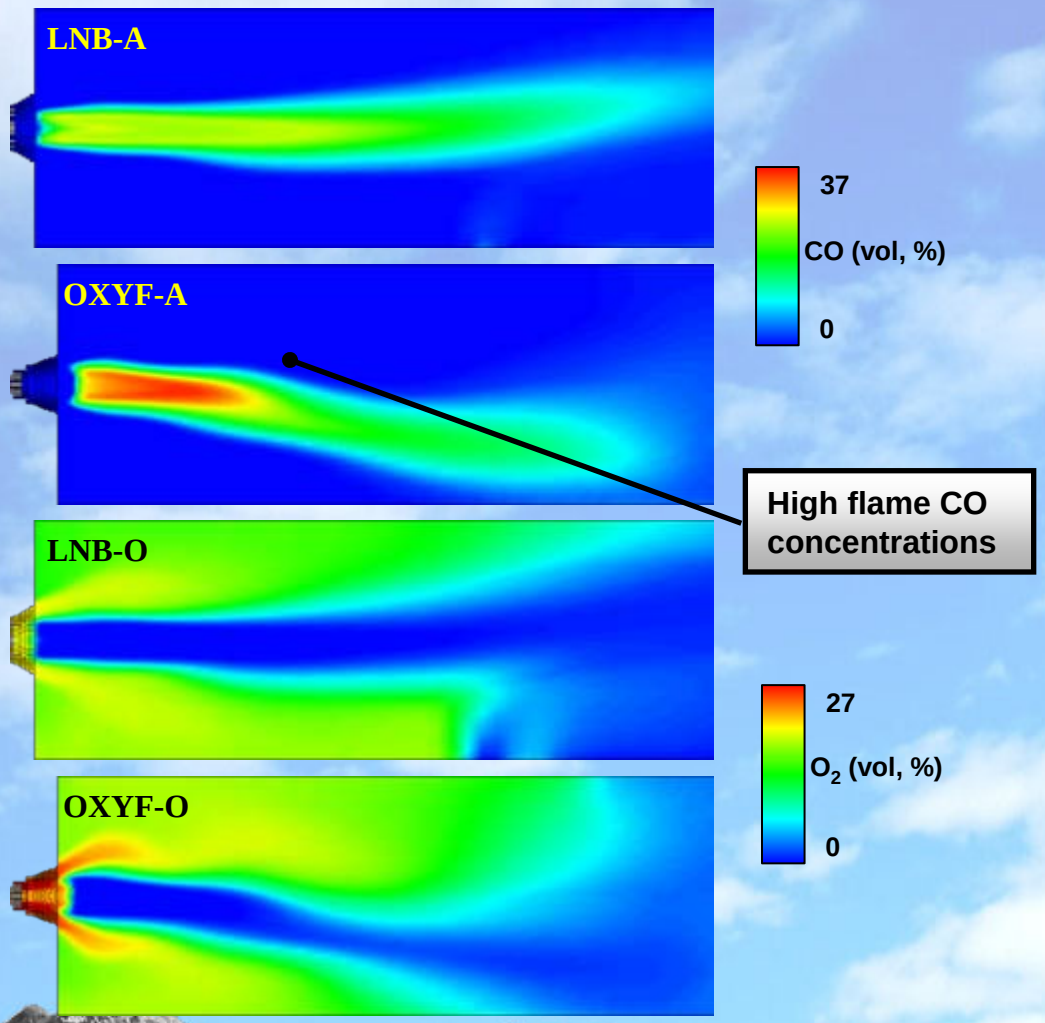
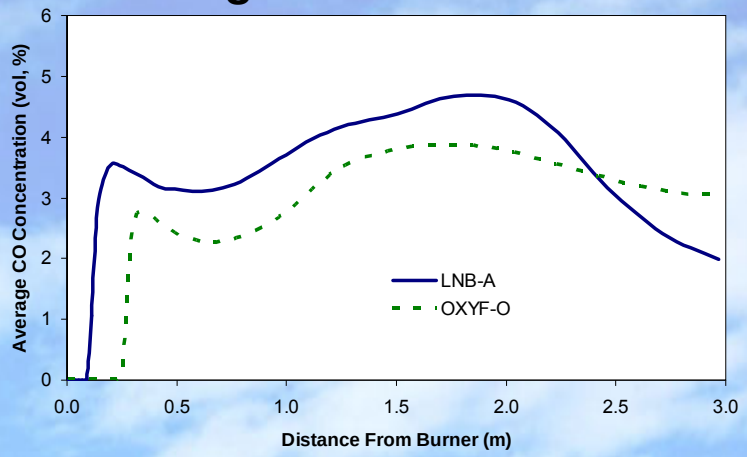
Comparison of Air-Firing (Existing Burner) and Oxy-Firing (Project Burner)

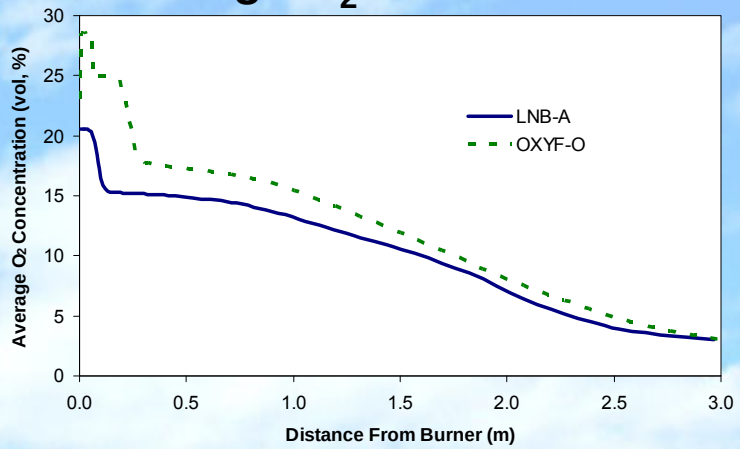
OCC1,Cottbus



Average CO Concentration



Average O_2 Concentration



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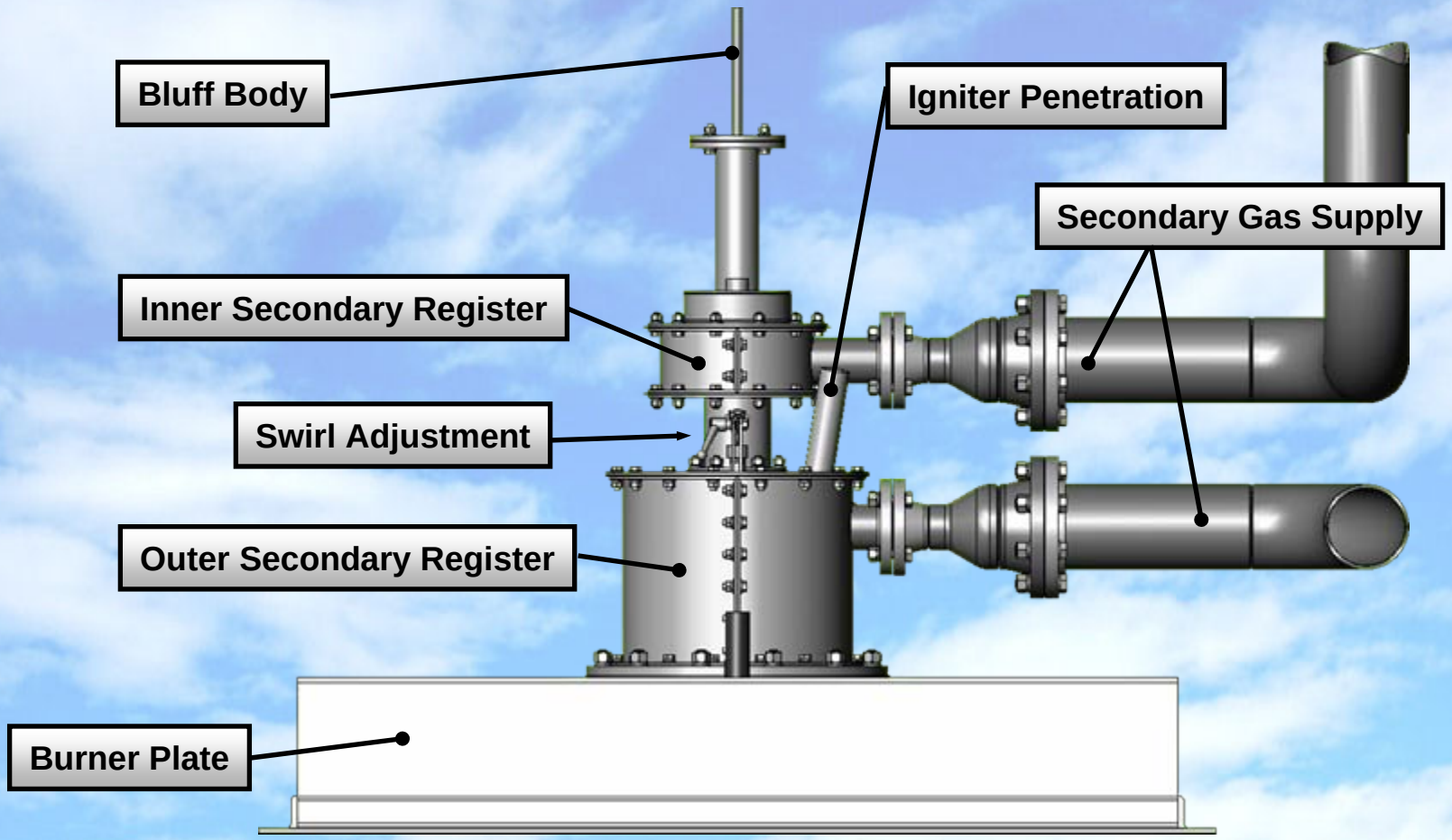
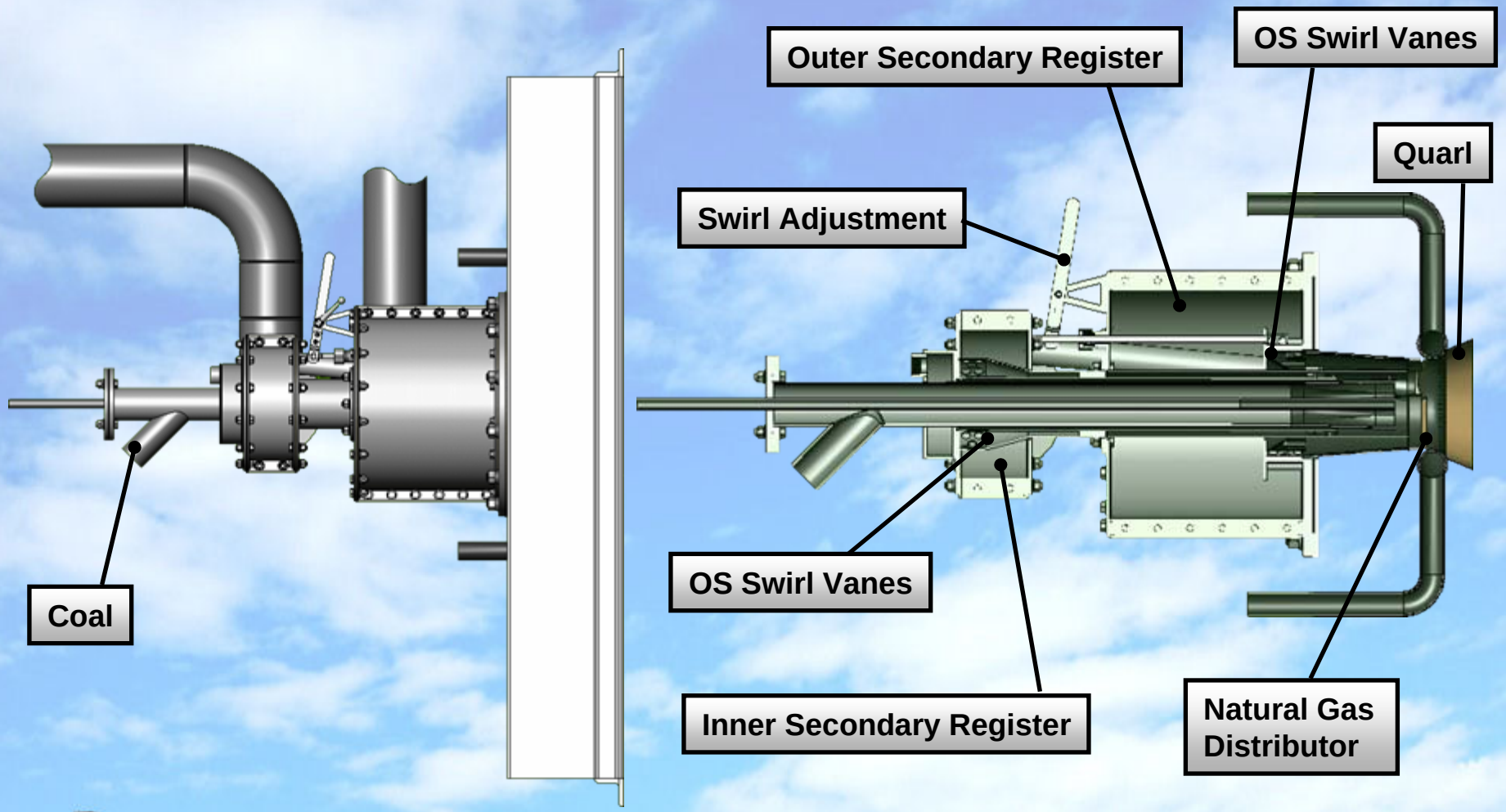
Oxy-Coal Research Burner Configuration



Oxy-Coal Research Burner Configuration

OCC1,Cottbus



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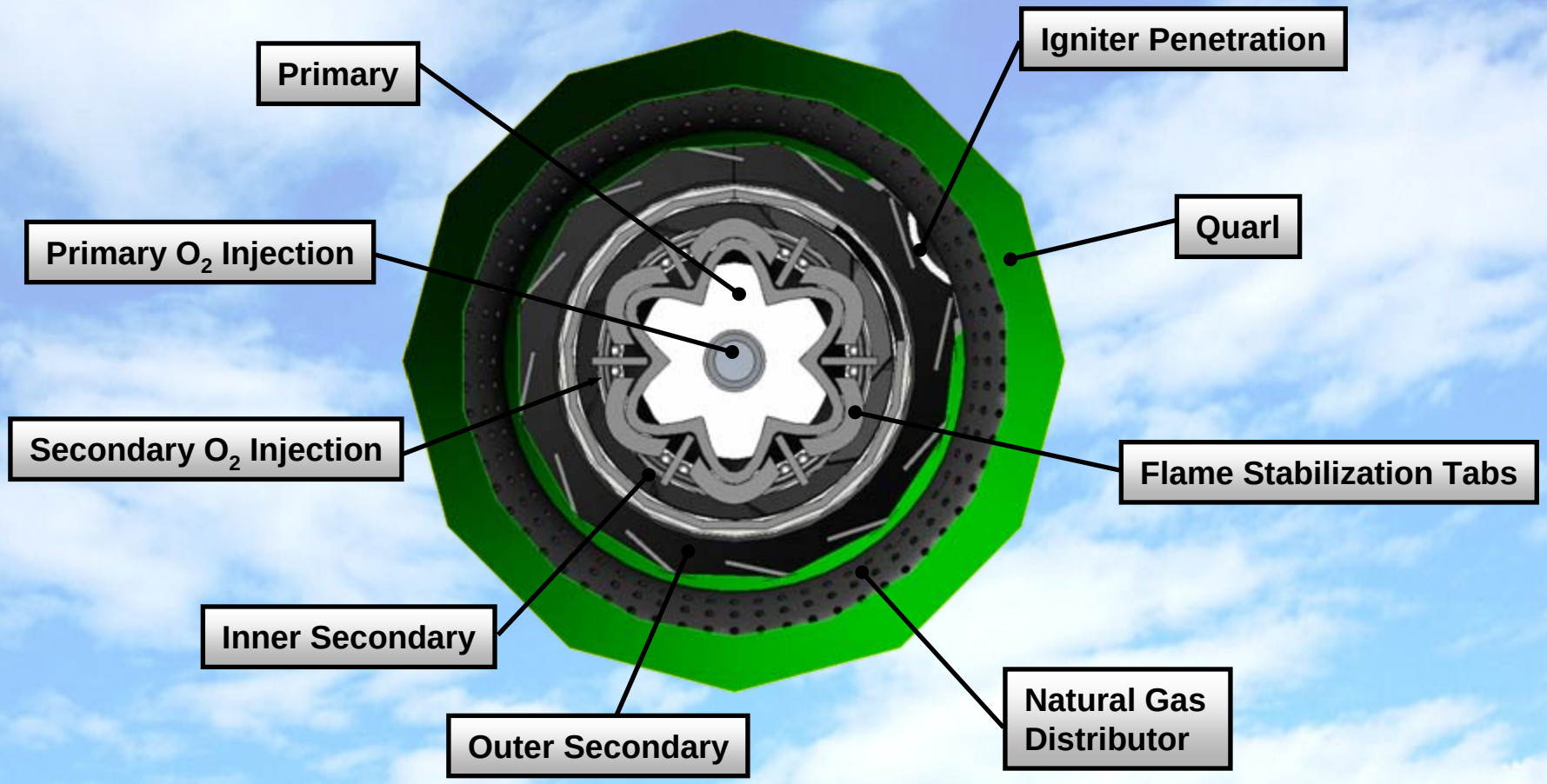
Oxy-Coal Research Burner Configuration



Summary and Conclusions

- Existing LNB was not ideal for our program
- Flame stabilization location can be evaluated using particle temperature profiles
- REI and Siemens have developed an oxy-research burner design that will provide
  - Ability to introduce O_2 and FGR into any register of the burner, at any mixture
  - O_2 injection in the Primary and Inner Secondary
  - Burner operating conditions → Flame behavior & Stabilization location

Acknowledgements

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- This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

- All figures containing results from CFD modeling were prepared using Intelligent Light's FieldView software.

Images By:

Intelligent Light FIELDVIEW

Questions?

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