



Nitrogen Evolution in Oxy-fuel Combustion

Experiments and Modeling

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Presentation Overview

- Background
- Objective
- Hypotheses
- Methods
 - Experimental
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- Results and Discussion
- Conclusions
- Future Work

Background



- Oxy-fuel is a promising technology for CO₂ sequestration
- Pilot scale tests show an unexpected reduction in NO_x emissions
- Early research suggests that reduction of recycled NO_x is the dominant mechanism (Okazaki and Ando, 1997) but...
- ...the mechanisms behind this reduction are not yet understood (Sarofim, 2007).

Objective



 Determine the cause(s) of NO_x reduction in oxy-fuel combustion and thereby understand how NO_x reduction might be maximized

Hypotheses



- Near-elimination of thermal- and prompt-NO_x
- More attached flame
- Elevated NO concentrations
- Reduction of recycled NO_x in the fuel-rich zone
- Temperature increases
- Increased residence time in fuel-rich regions
- Equilibrium considerations
- Reduced NO formation from char
- Enhanced heterogeneous reburning
- Increased importance of gasification reactions

Experimental Method



For results shown:

- Coal and O₂ flow is constant
- Diluent is changed (N₂ or CO₂)
- Oxy-fuel mixtures:
 - 25% O₂ by mass
 - 30% O₂ by mass
 - (32 and 37 vol.% respectively)
- 29% of oxidizer to burnout stage
 - SR₁ = 0.76
 - SR₂ = 1.05





Computational Model





Series network of CSTR's \approx Plug flow reactor (1-D)

Homogeneous NO_x mechanisms:

Thermal

Prompt

Fuel

 Advanced reburning

Software: Cantera with MATLAB

NO Sampling Issues



NO Sampling Issues



Measured NO_x Concentration



Nitrogen Conversion



Equilibrium NO_x





Modeling: NO_x Formation in Air



Volatiles-N Release



Predicted Volatile-N Release



Predicted Nitrogen Conversion



Fuel Rich NO Predictions



CO Near Burner



Equilibrium CO





CO Downstream from Burner



N_2 vs. CO_2





Conclusions



• Oxy-fuel can produce lower NO levels without recycling

•NO destruction rates appear faster in oxy-fuel

Modeling traditional NO mechanisms predicted known trends:

- Suppression of NO formation by recycled NO
- Destruction of almost all recycled NO
- •BUT... did not predict the results seen here

High CO levels exist in the reducing zone of oxy-fuel flames

- Thermal dissociation of CO₂ is only a partial explanation
- Gasification of char by CO₂ is another possible source (suggested by wall temperature data)

A possible mechanism for enhanced NO reduction in oxy-fuel is NO reaction with CO on the char surface

- •Char components can act as catalysts (e.g. Ca)
- Probably coal-type dependent
- •Char reactions were not modeled

Future Work





Recent Improvements:

- Simpler coal feed system
- Additional sampling ports
- Secondary air preheating
- Air-cooled probe
- New stoichiometry:
 - $SR_1 = 0.75$ (unchanged)
 - SR₂ = 1.2 (previously 1.05)

Future Work



Future Experiments:

- Stage 1: High spatial resolution NO, O₂, CO data with 3 coals
 - identify peak NO levels and size of reducing zones, study coal-type dependence, close N balance with fly ash samples
- Stage 2: Dope reactants with NO
 - determine effects of NO recycling
- Stage 3: Measure HCN, NH₃, CO₂, SO₂, SO₃, and other species by FTIR
- Stage 4: Collect simulated superheater ash deposits
 - look for indicators of altered corrosion tendencies in oxy-fuel combustion



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Questions?

