A Mechanistic Investigation of Nitrogen Evolution and Corrosion with Oxy-fuel Combustion

Dale R. Tree, Larry Baxter

Andrew Mackrory, Shrinivas Lokare

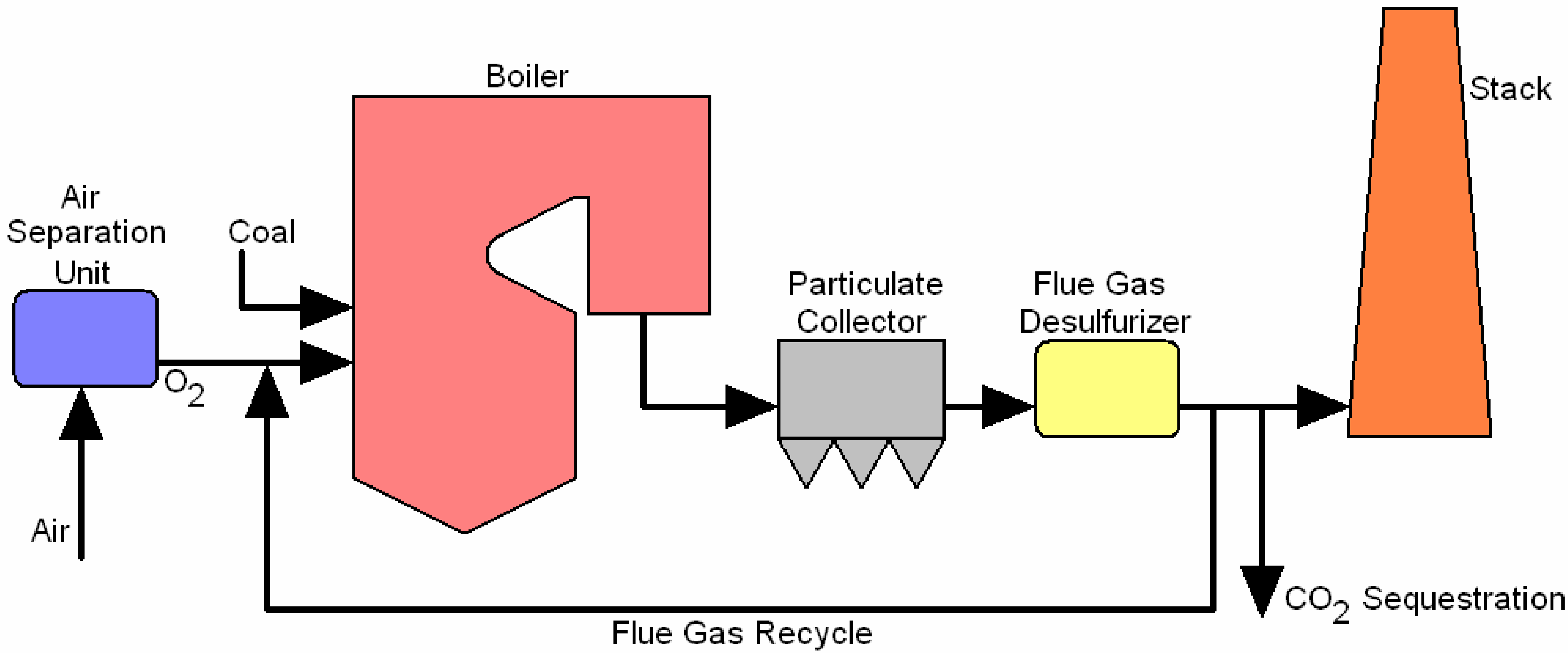
ACERC Conference

February 27-28, 2007

Introduction: NO_x Formation

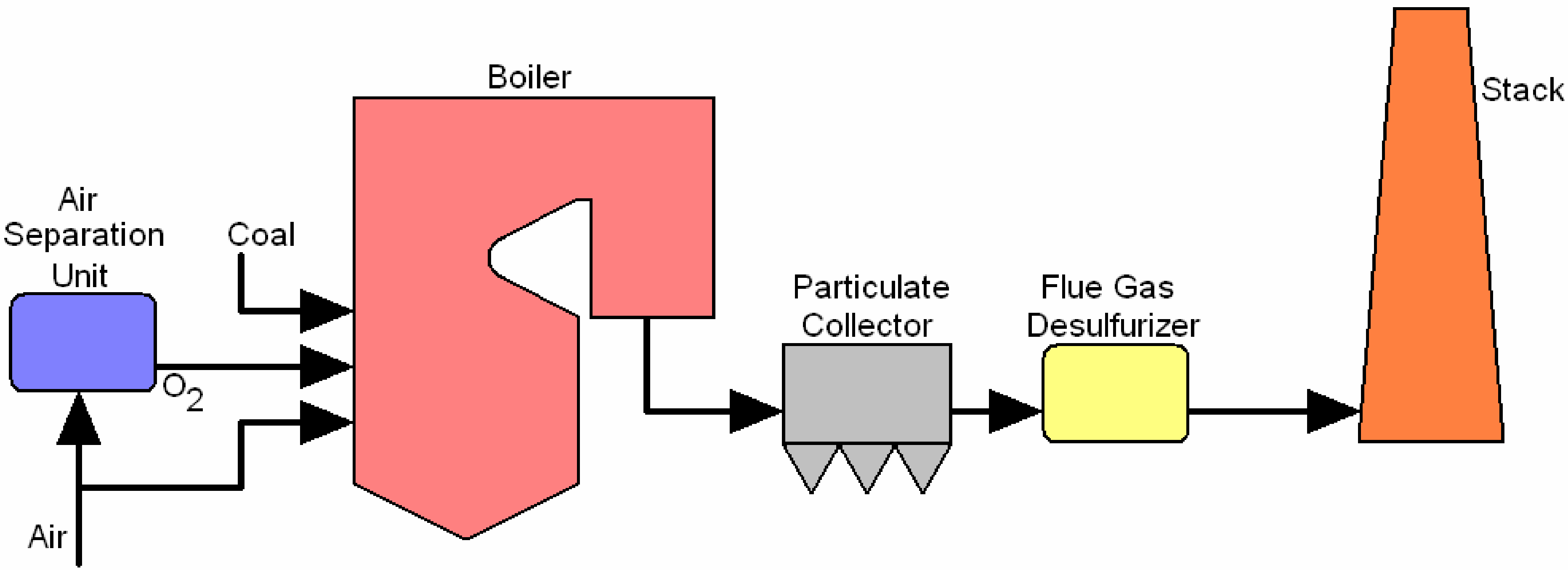
- Thermal NO_x – slowest forming, requires high T
- Prompt NO_x – quicker forming but slower than other combustion reactions
- Fuel-NO_x – like prompt-NO but N originates from fuel
  - Most of NO_x from coal combustion is fuel-NO_x (80%)

Introduction:
pc Oxy-fuel Combustion



O_2 Volume %: ~30%

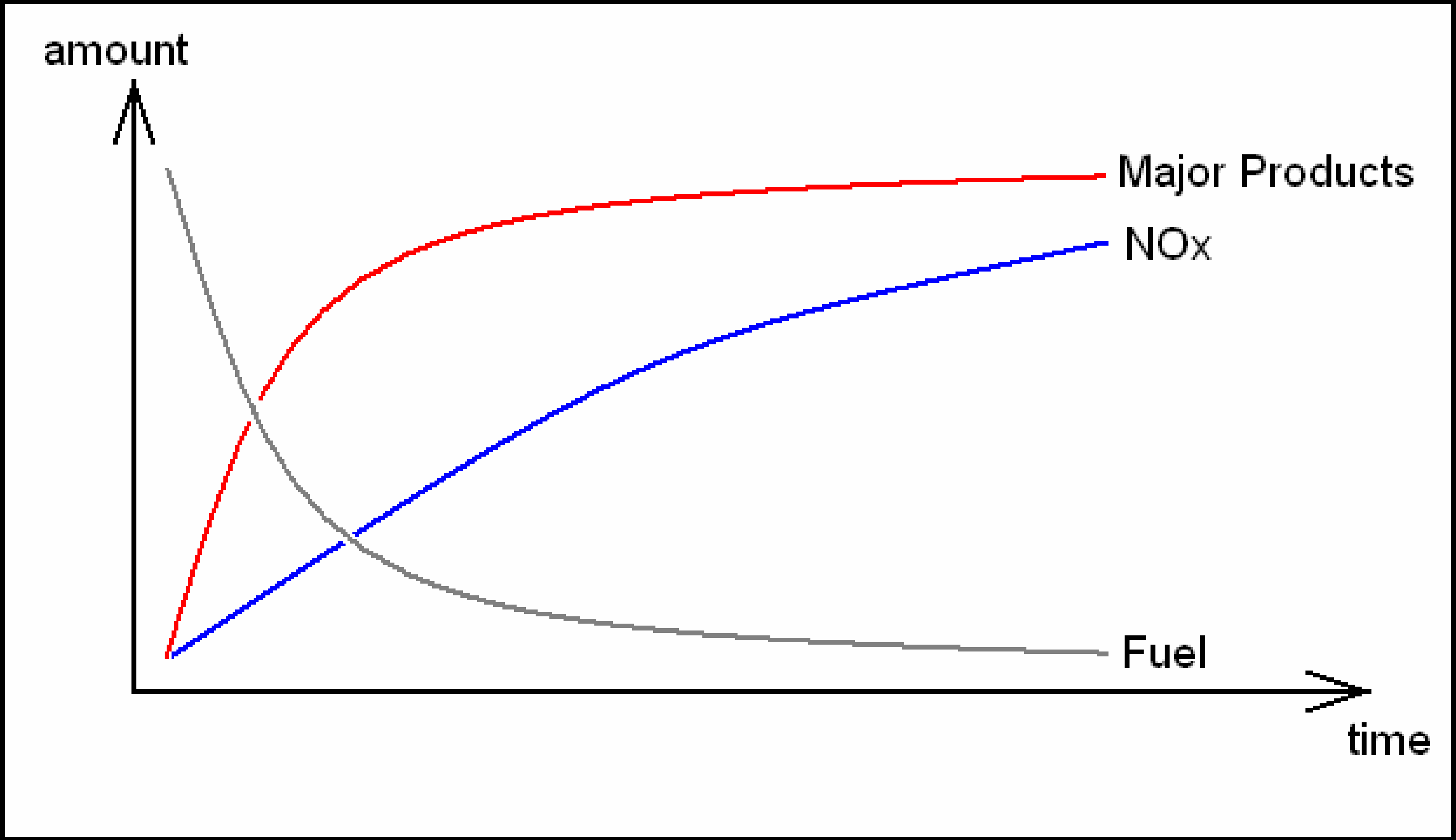
Introduction: pc O_2 Enhanced Combustion (OEC)



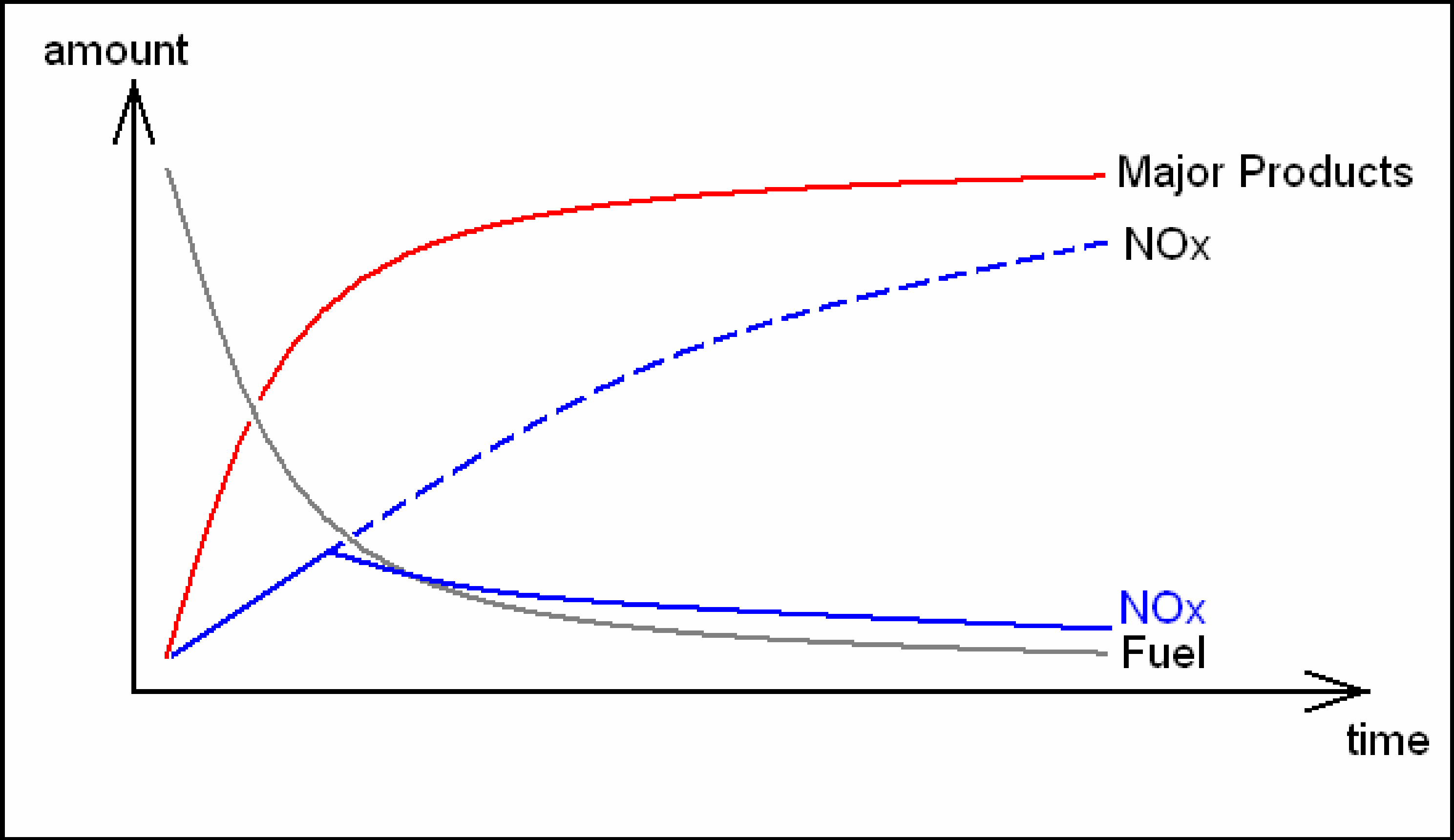
O_2 Volume %: 21.8 to 29% (in a fuel-rich stage only)

(US Patent # 6,957,955 Kobayashi, et al., 2005)

Oxygen Enhanced Combustion



Oxygen Enhanced Combustion



OEC and Oxy-fuel NO_x Comparison

Expected Common Features (relative to air):

- Higher O_2 concentration in fuel-rich region leads to:
  - Higher volatiles yield (lower char-N)
  - Shorter devolatilization period
  - Attached/Stable flame
- Longer residence times in fuel-rich zone:
  - More NO_X can be reduced
- Optimization is required

Introduction: OEC and Oxy-fuel NO_x Comparison

Differences:

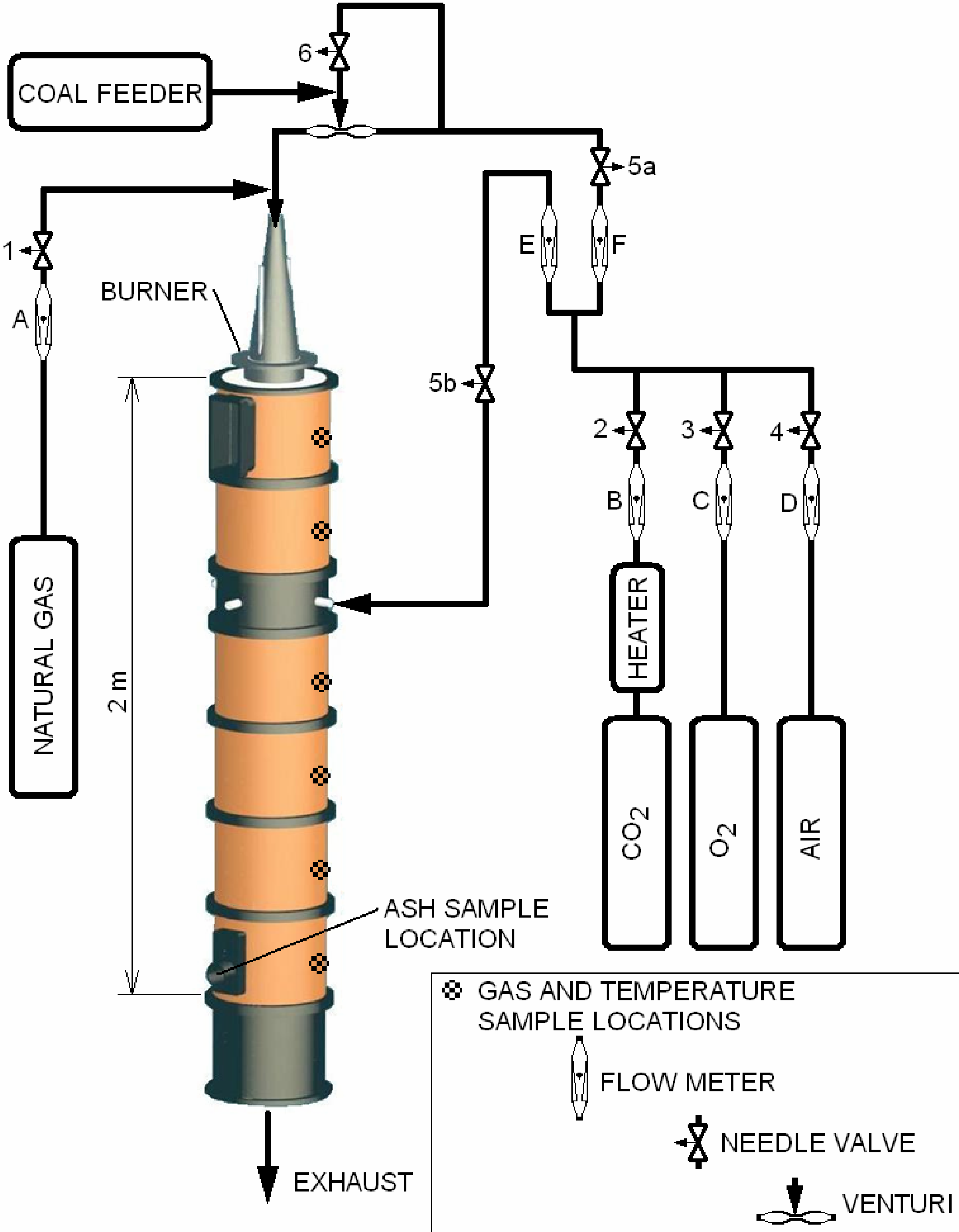
- OEC has (relative to Oxy-fuel):
  - High sensitivity to O_2 injection location
  - Large amounts of N2 (possibility of thermal and prompt NO_x)
- Only Oxy-fuel has:
  - Flue gas recycle (including NO_x)
  - Replacement of almost all N_2 with CO_2
    - Increased concentrations of corrosive species

Objectives

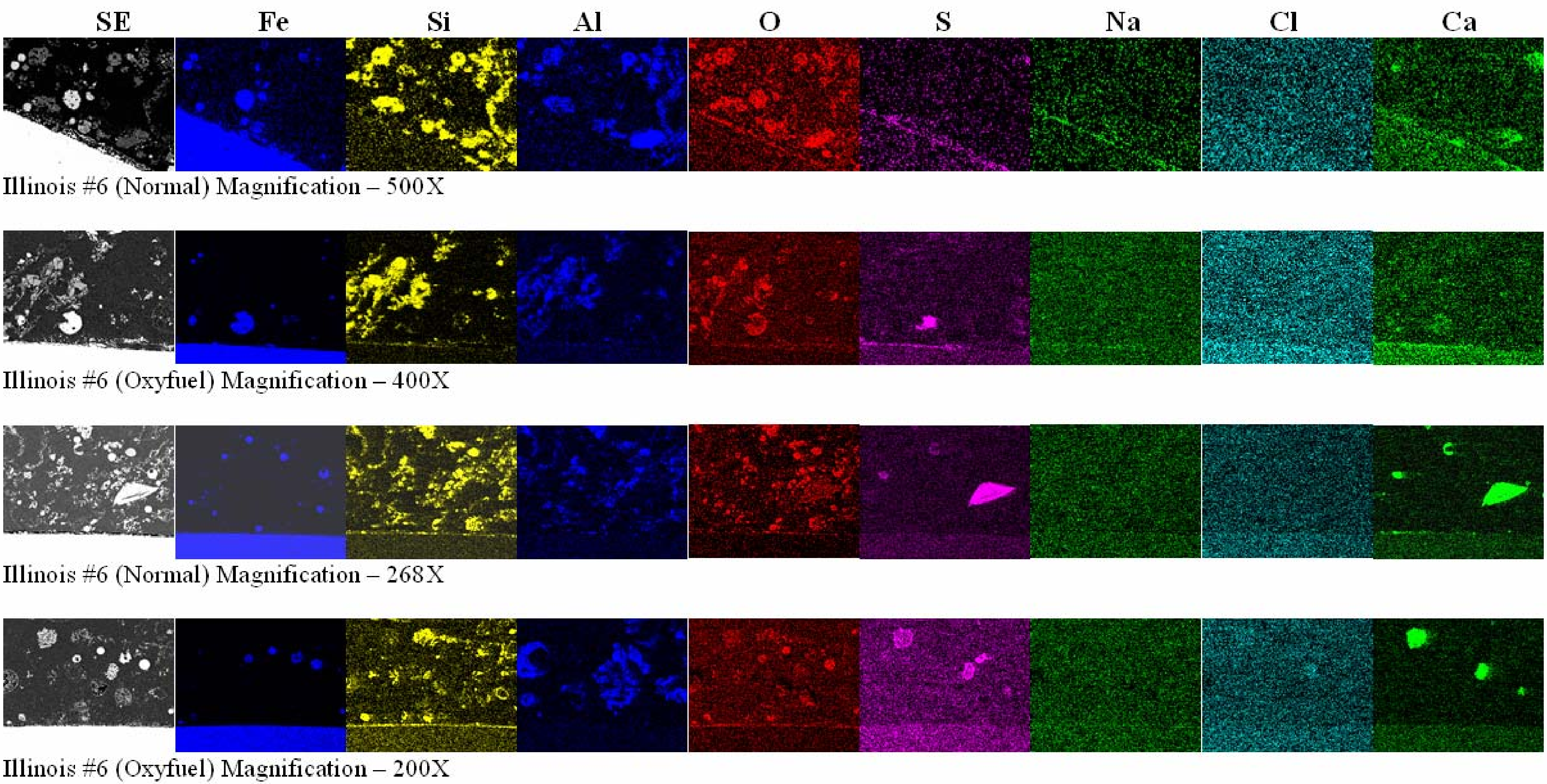
- Understand the mechanism(s) by which NO_x emissions are lowered in oxy-fuel combustion
  - leads to ability to optimize the process

- Measure indicators of corrosion tendency for oxy-fuel combustion relative to air

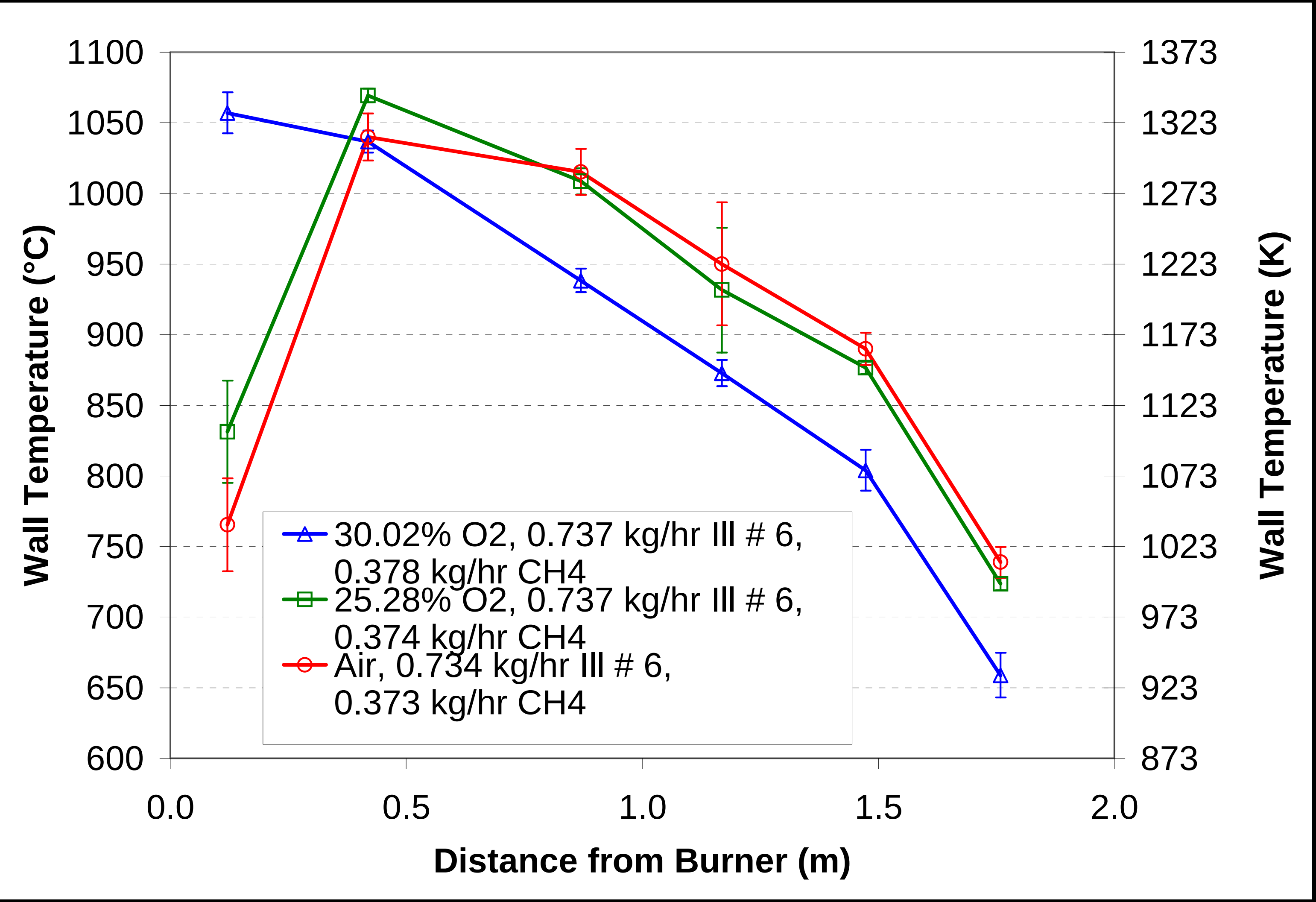
Equipment Setup



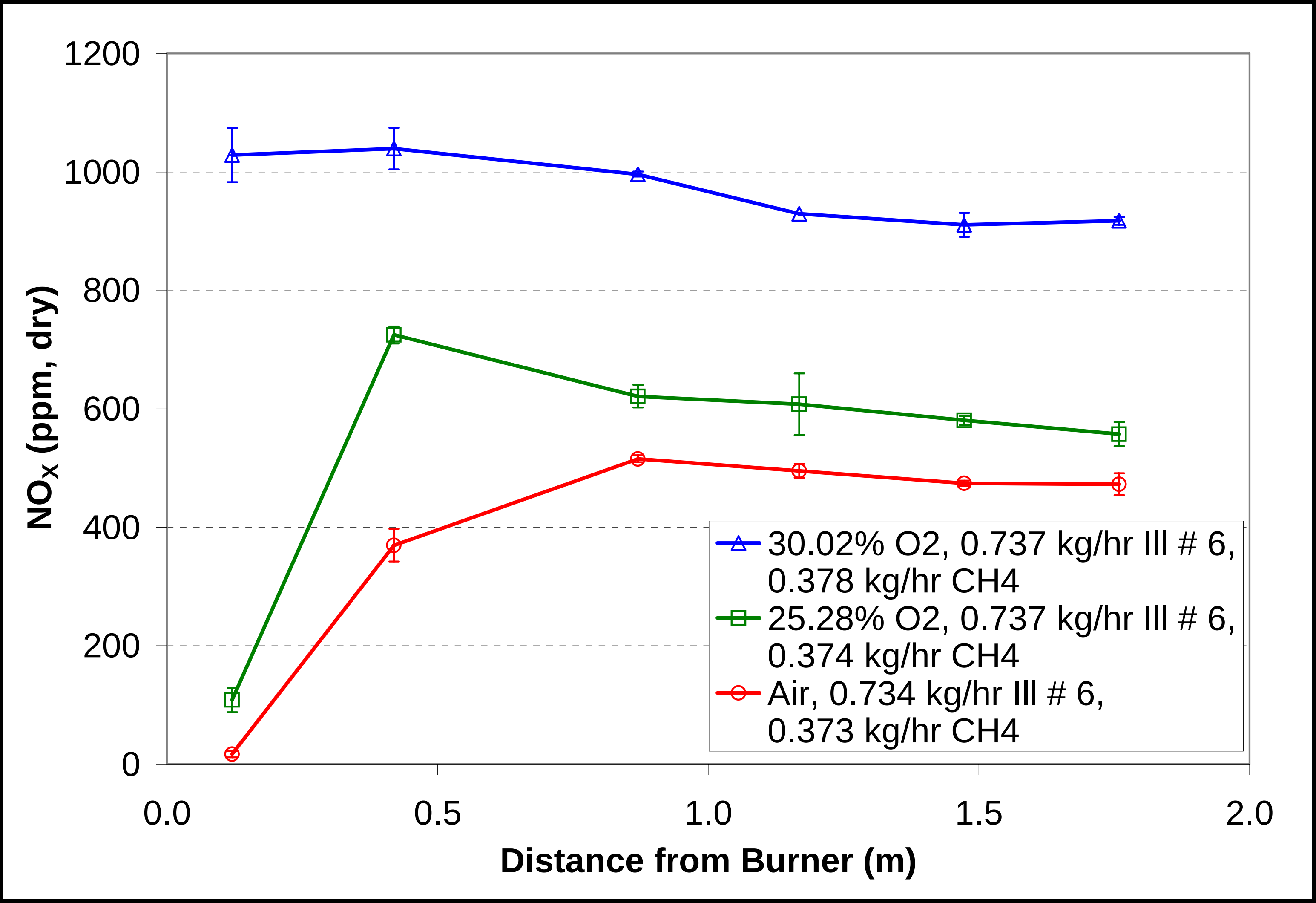
Preliminary Corrosion Results



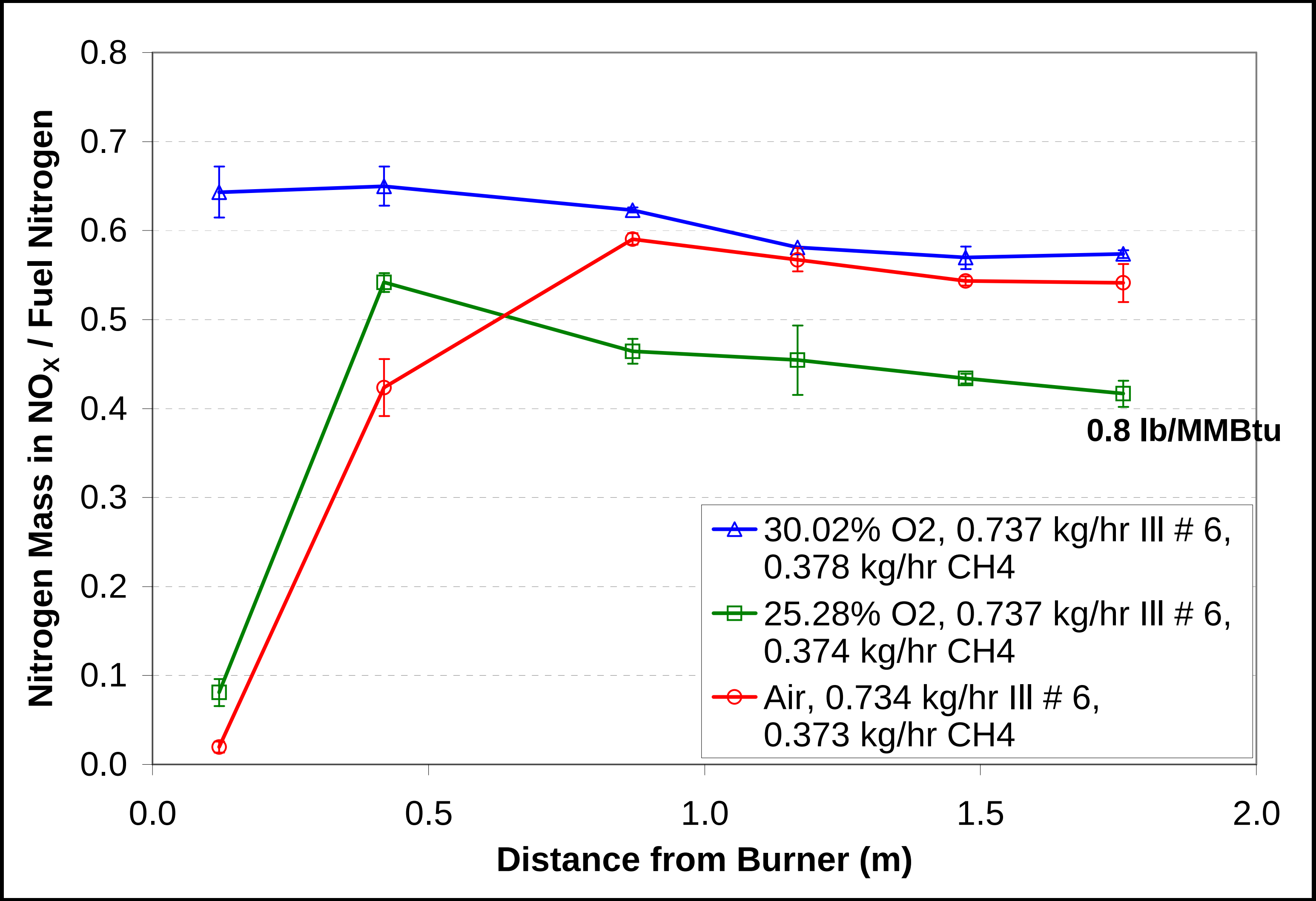
NO_x Results: Unstaged



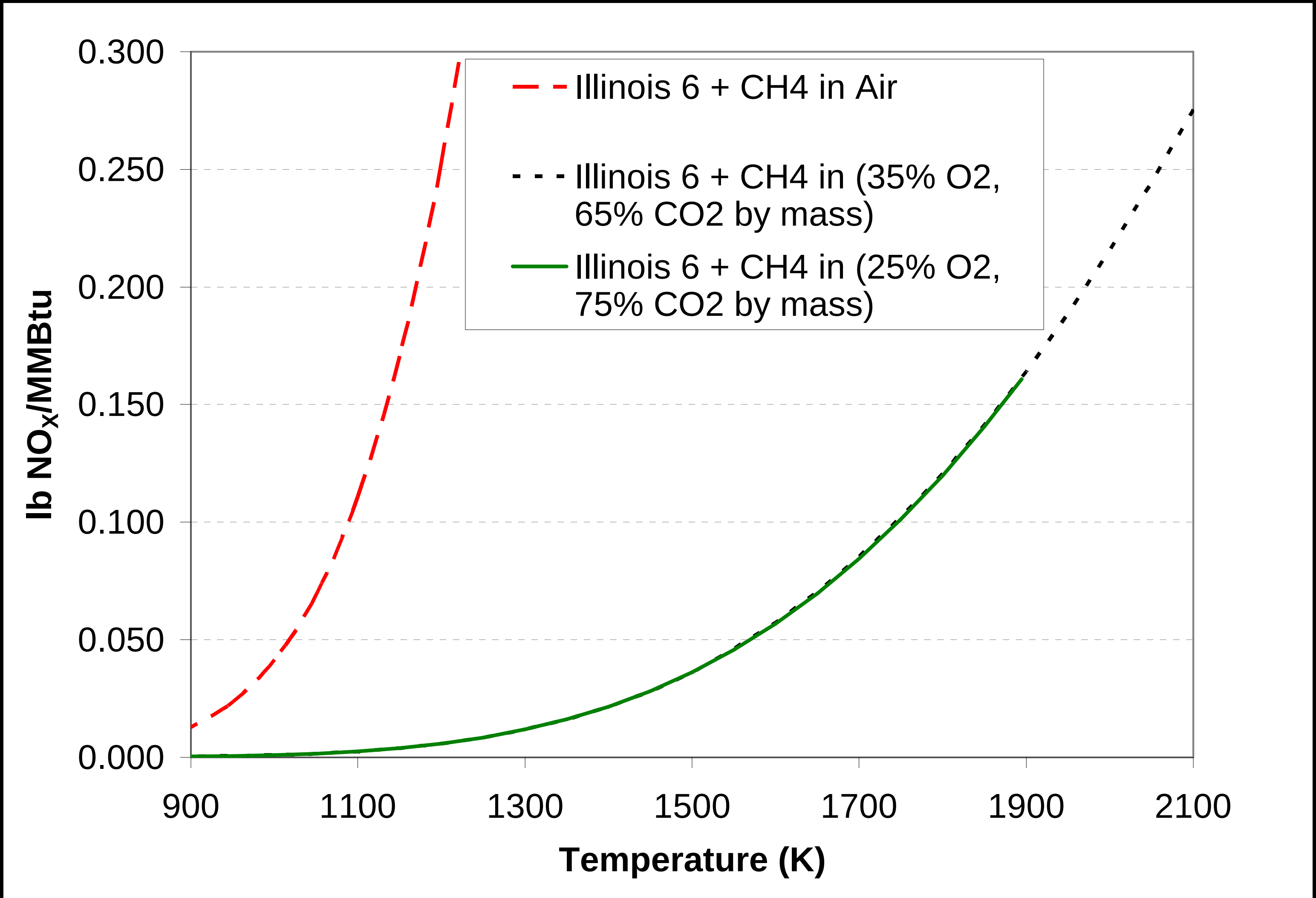
NO_x Results: Unstaged



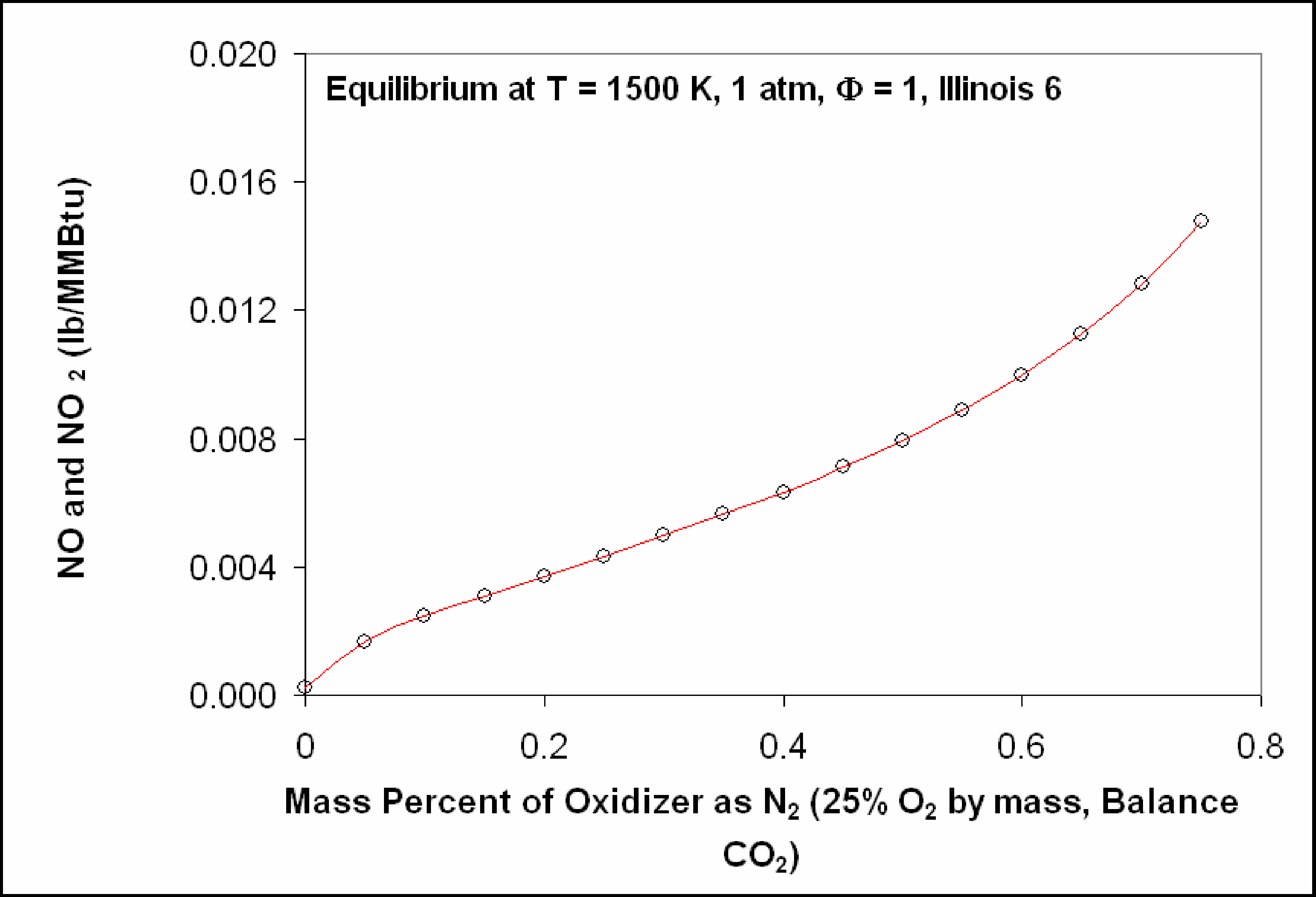
NO_x Results: Unstaged



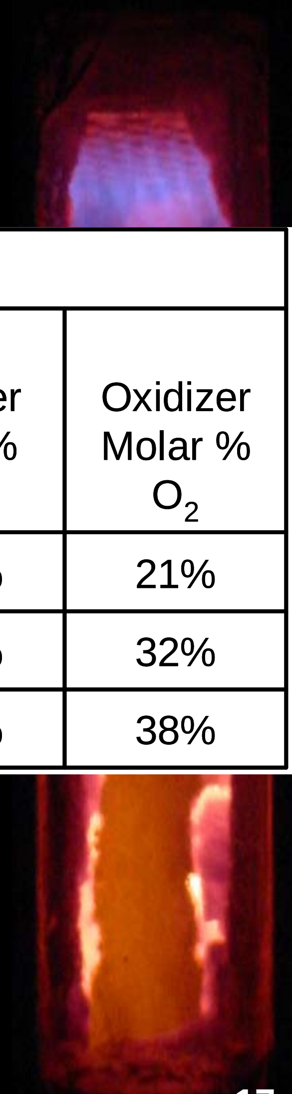
Equilibrium NO_x Trends



Equilibrium NO_x Trends

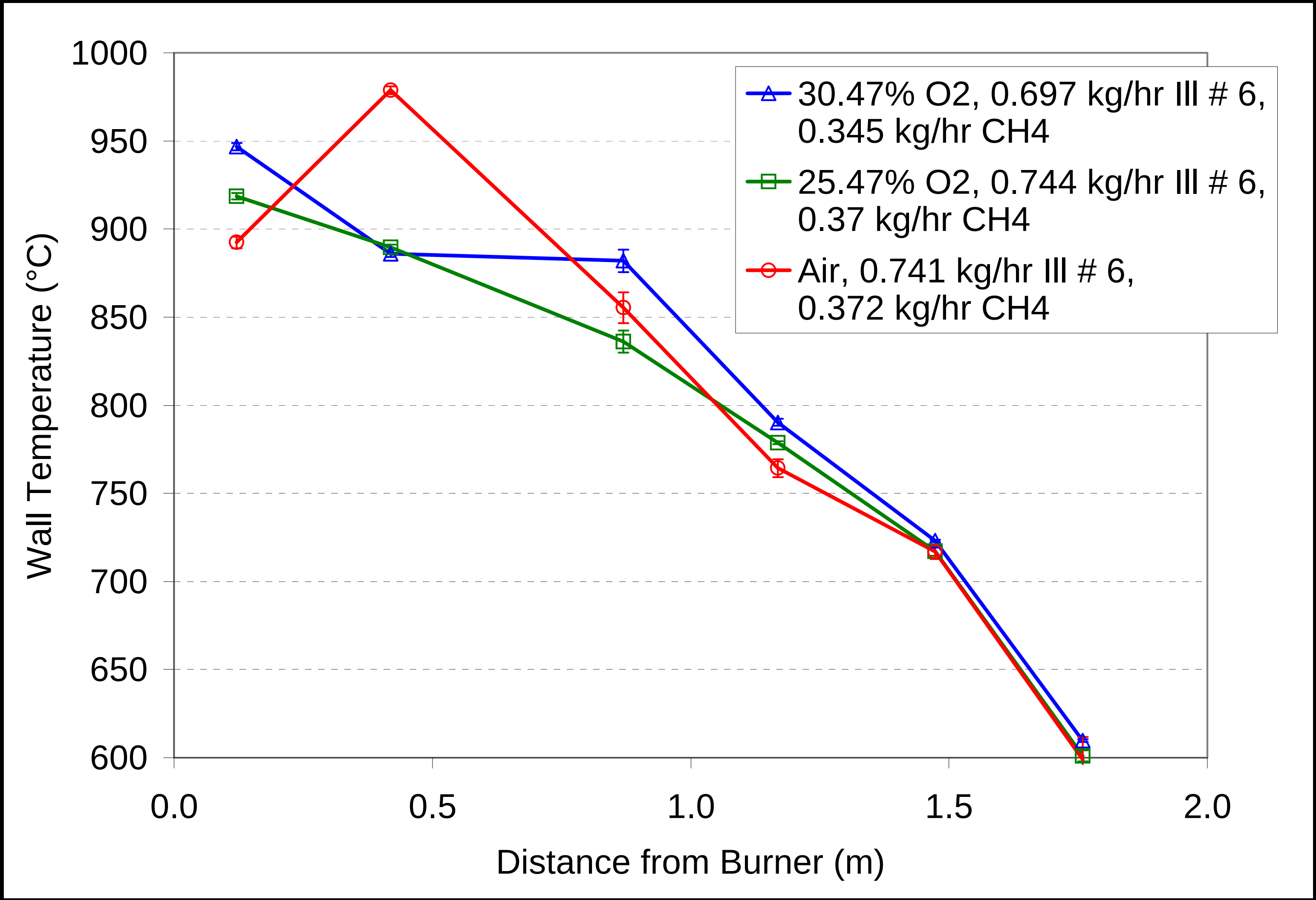


NO_x Results: Staged

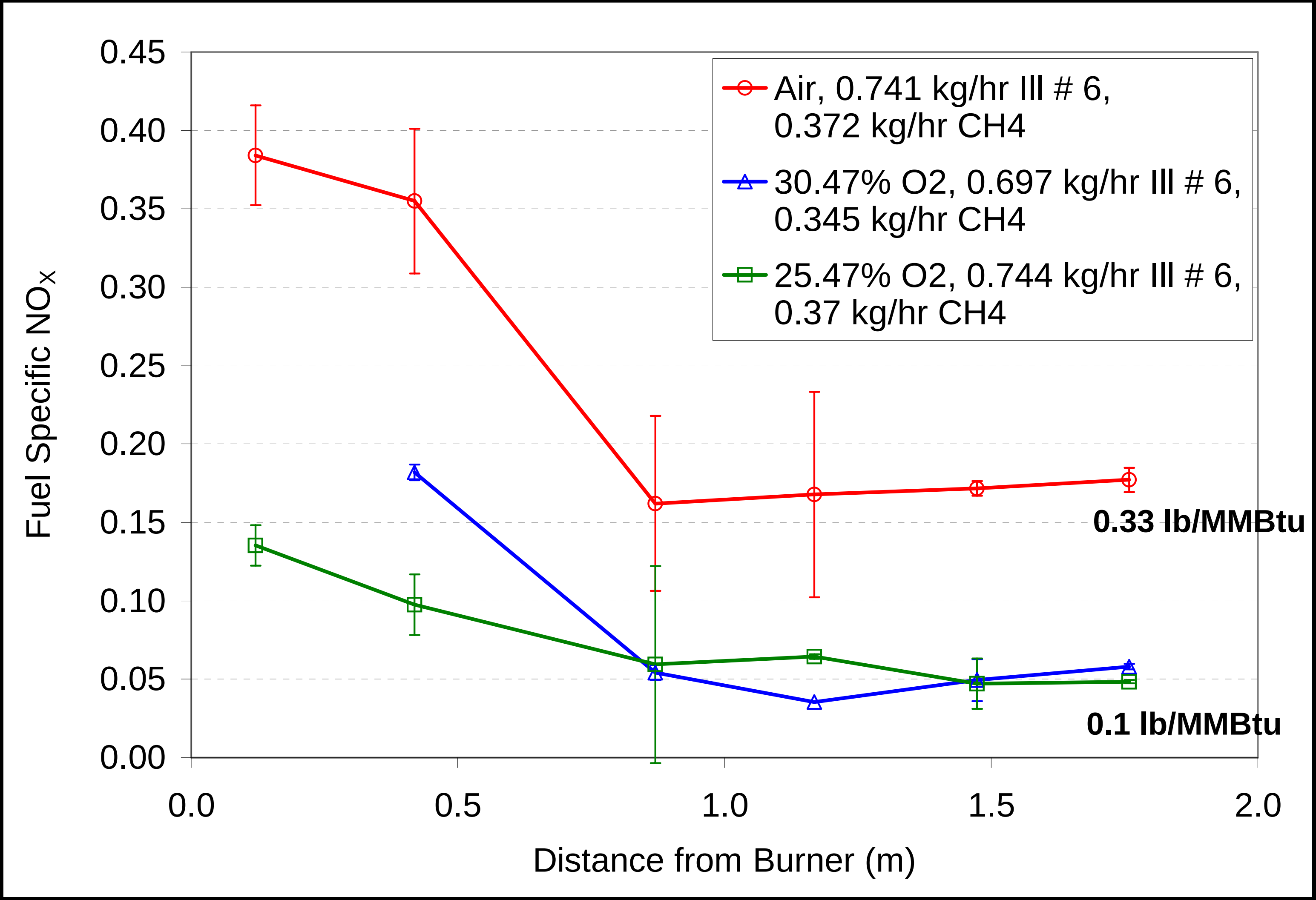


Total Mass Flow Rates (kg/hr)					Stoichiometry				
Coal	CH_4	Air	O_2	CO_2	Oxidizer to Burnout Section	Primary Stage SR	Sec. Stage SR	Oxidizer Mass % O_2	Oxidizer Molar % O_2
0.741	0.372	16.8	-	-	28%	0.75	1.05	23.3%	21%
0.744	0.370	-	3.886	11.37	28%	0.75	1.04	25.5%	32%
0.697	0.345	-	3.562	8.127	28%	0.73	1.02	30.5%	38%

NO_x Results: Staged



NO_x Results: Staged

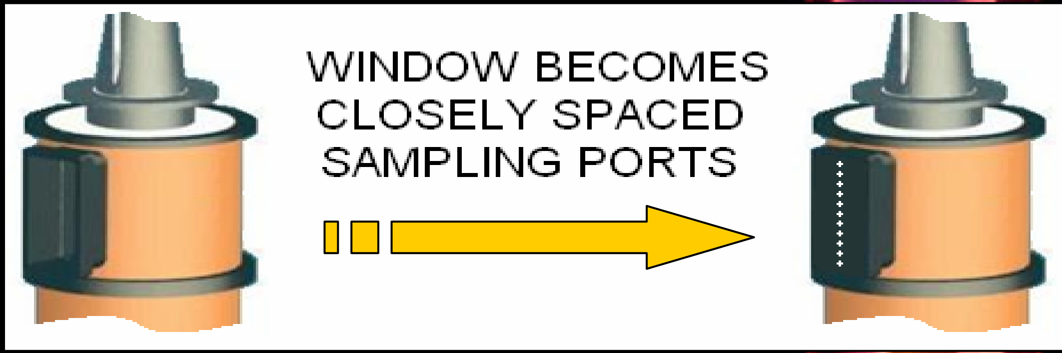


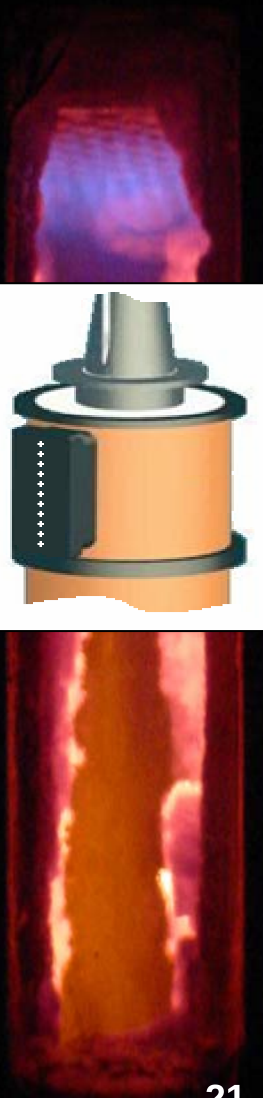
Summary

- Without staging, Oxy-fuel and Air combustion produce NO_x in large amounts
- With staging, Oxy-fuel produces lower NO_x
  - BUT: Recycle ratio must be optimized
    - Affects peak NO_x formation
    - Affects residence time

Planned Experiments (Subject to change)

- Devolatilization:
  - ~1cm resolution gas sampling near burner
    - O_2
    - NO_x
    - HCN, NH_3, CO
  - Doping of reactants (CO_2) with NO_x
  - Vary Φ, O_2/CO_2 ratios, depth of staging
  - OEC?





Planned Experiments (Subject to change)

- Corrosion:
  - Staged combustion of 3 coals
    - Illinois 6 (High Cl, S, K, Med Na)
    - PRB (High Na, Low Cl, S)
    - Pittsburgh 8 (High S, K, Med Cl, Low Na)
  - Mineral analysis of fly ash
  - SEM analysis of simulated superheater deposits

Acknowledgements

- We would like to thank the DOE, UCR program for the funding to do this work
- Air-Liquide for funding and technical support

Questions and Suggestions