Large scale oxy-fuel systems: The role of laboratory combustor research.

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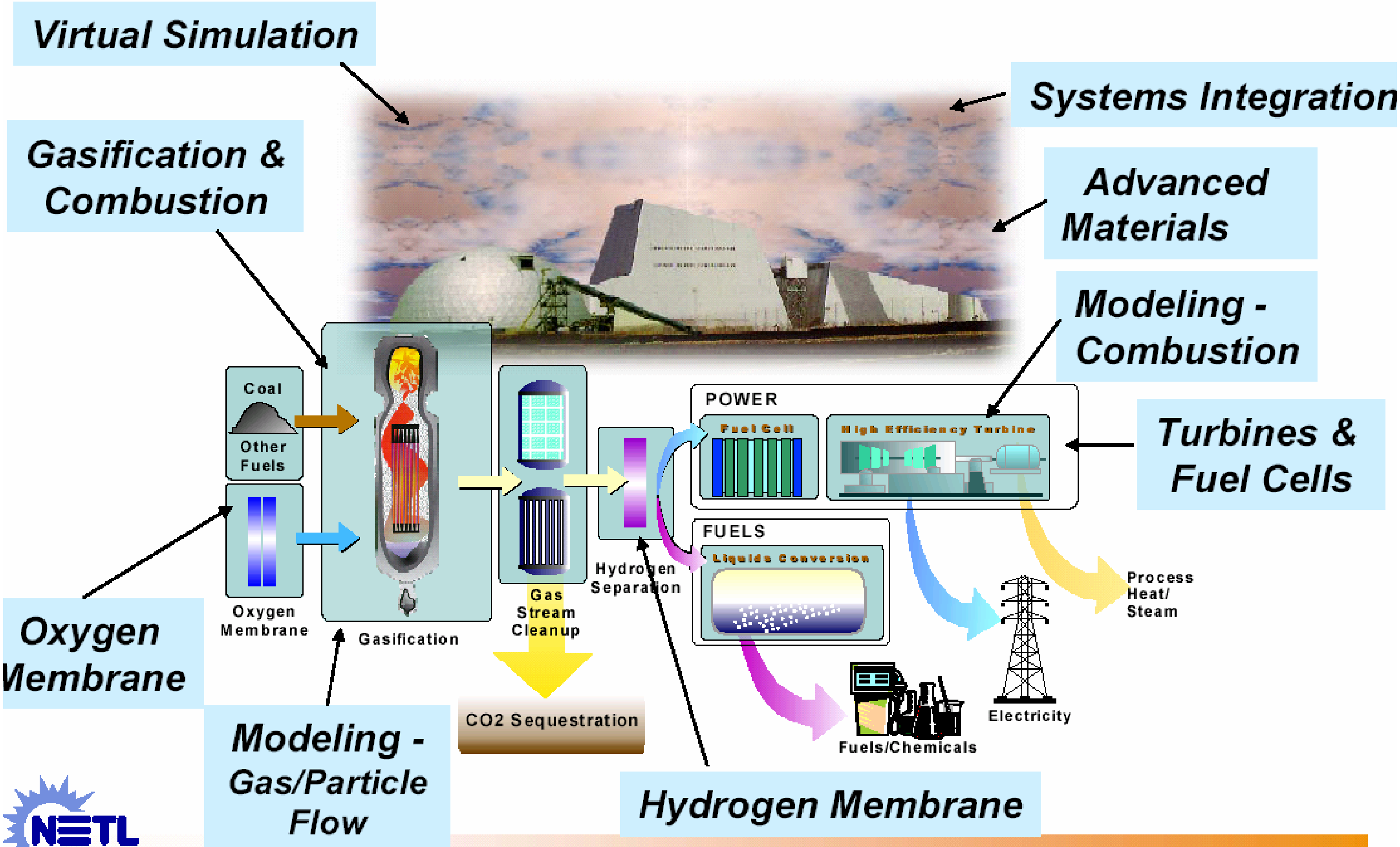
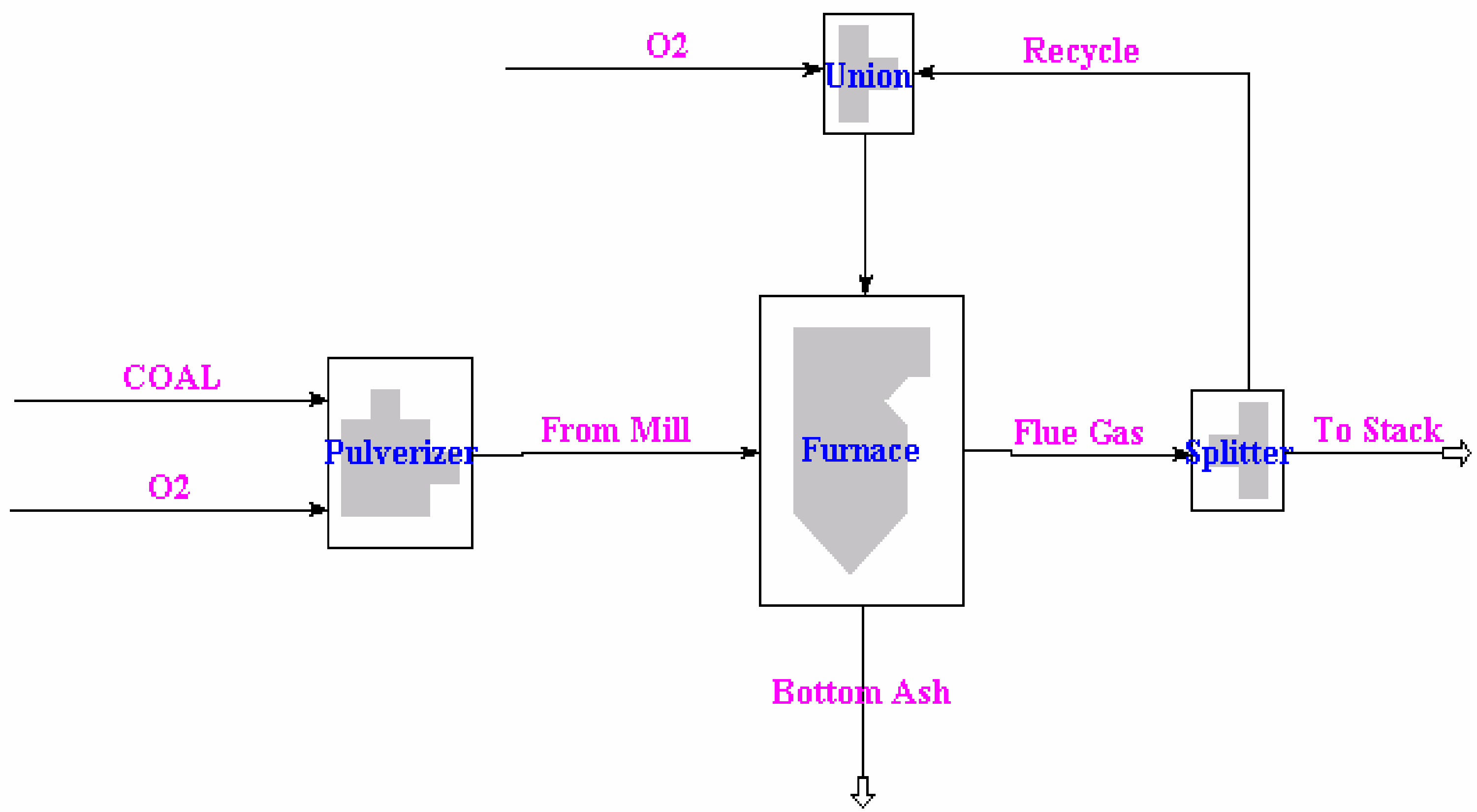
Vision 21

Project Activities Contribute to the Near-Zero Emission Energy Plant



Combustion: Schematic of oxygen fired PC furnace with CO_2 recycle (*Sarofim et al, 2004*)



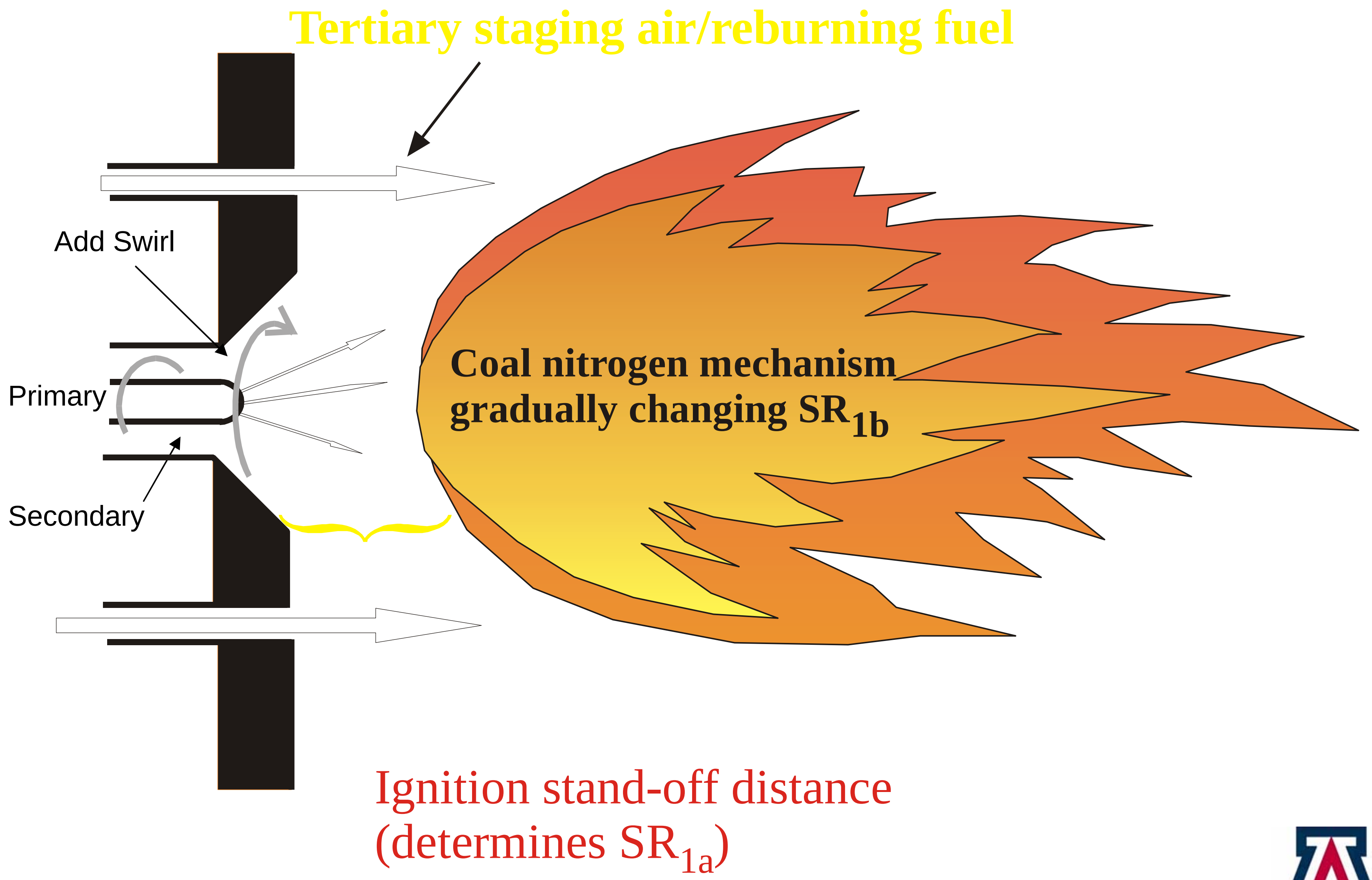
Oxyfuel combustion issues

- Recycle gas volume
- Where to withdraw recycle gas
- Heat transfer
- Flame stability
- Ignition
- NO_x, SO_x, Hg

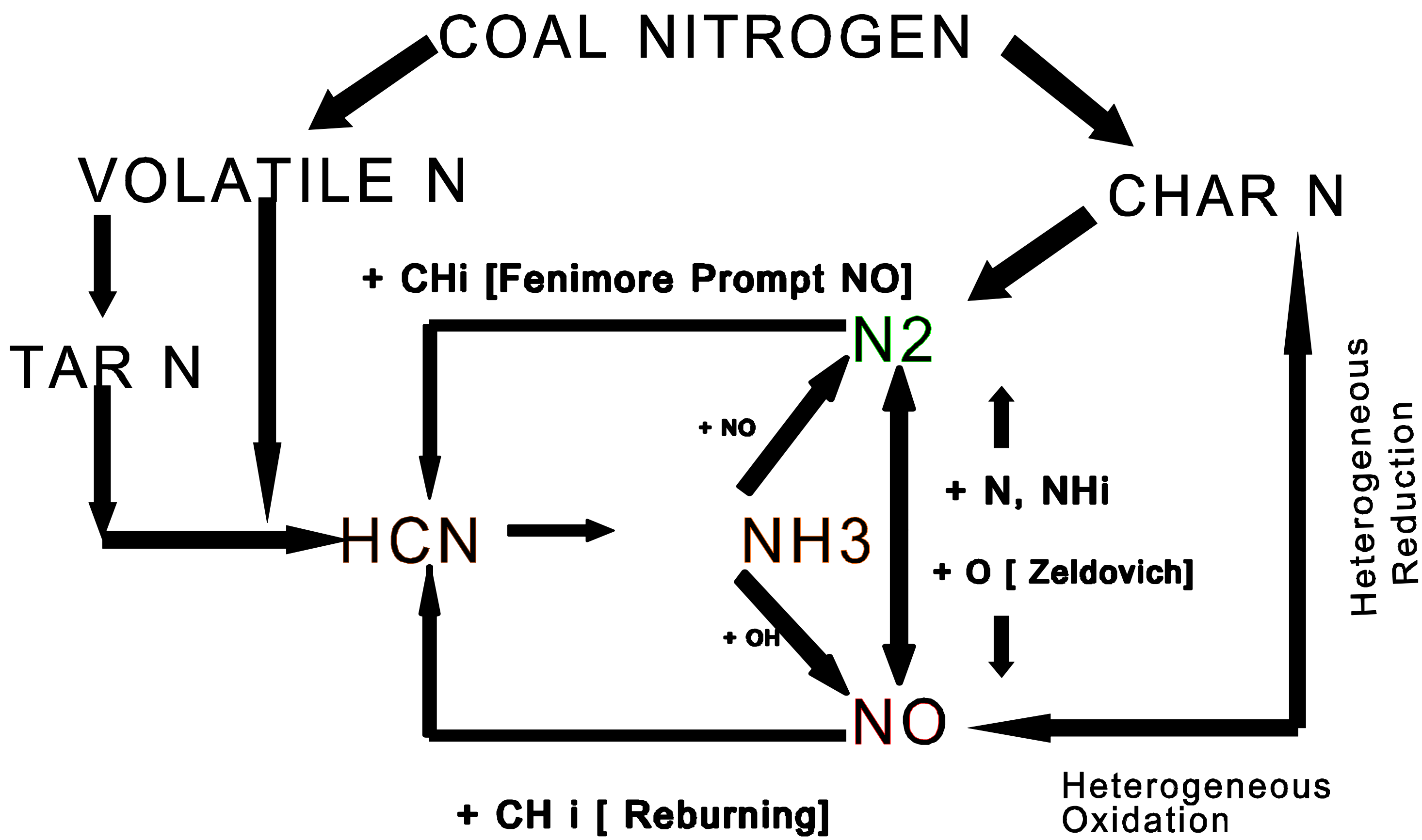
Related research on laboratory combustors:
Kinetic and aerodynamic issues

- Studies on two down fired laboratory furnaces each firing ~2kg/h coal.
  - Model A: reactor mode for kinetic issues.
  - Model B: axial diffusion flame mode for coupled aerodynamic issues.
- O_2 enrichment and staged combustion of pulverized coal (Kinetic issues: Model A)
- Effects of O_2 enrichment on pulverized coal axial diffusion flames (Coupled aerodynamic issues: Model B)
  - Flame attachment
  - NOx

Wall-Fired Burner



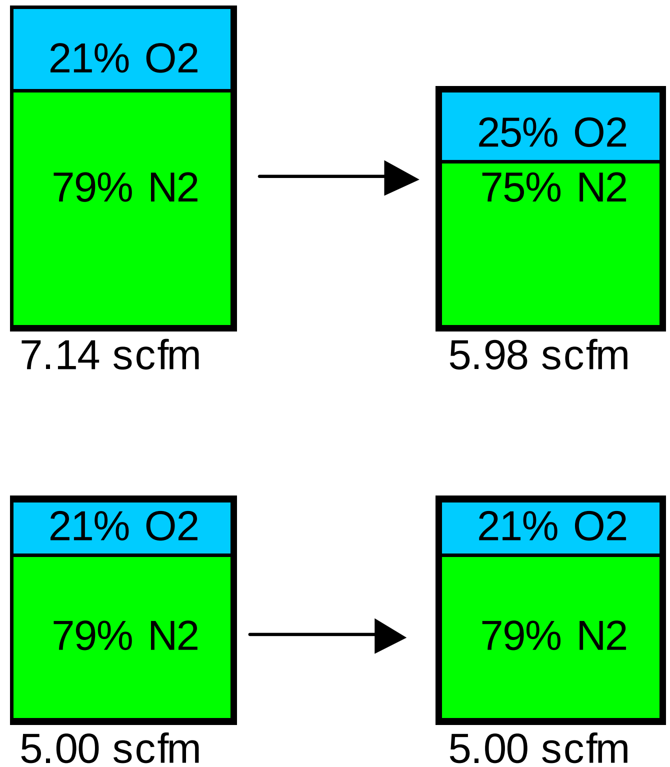
Fuel NO_x pathways



Oxygen enrichment in staged combustion

2 kg/h coal

- First Stage
  - Remove 10% of the total air
  - Replace 10% O_2 removed in first stage
- Second Stage
  - No change
  - All air removed in first stage

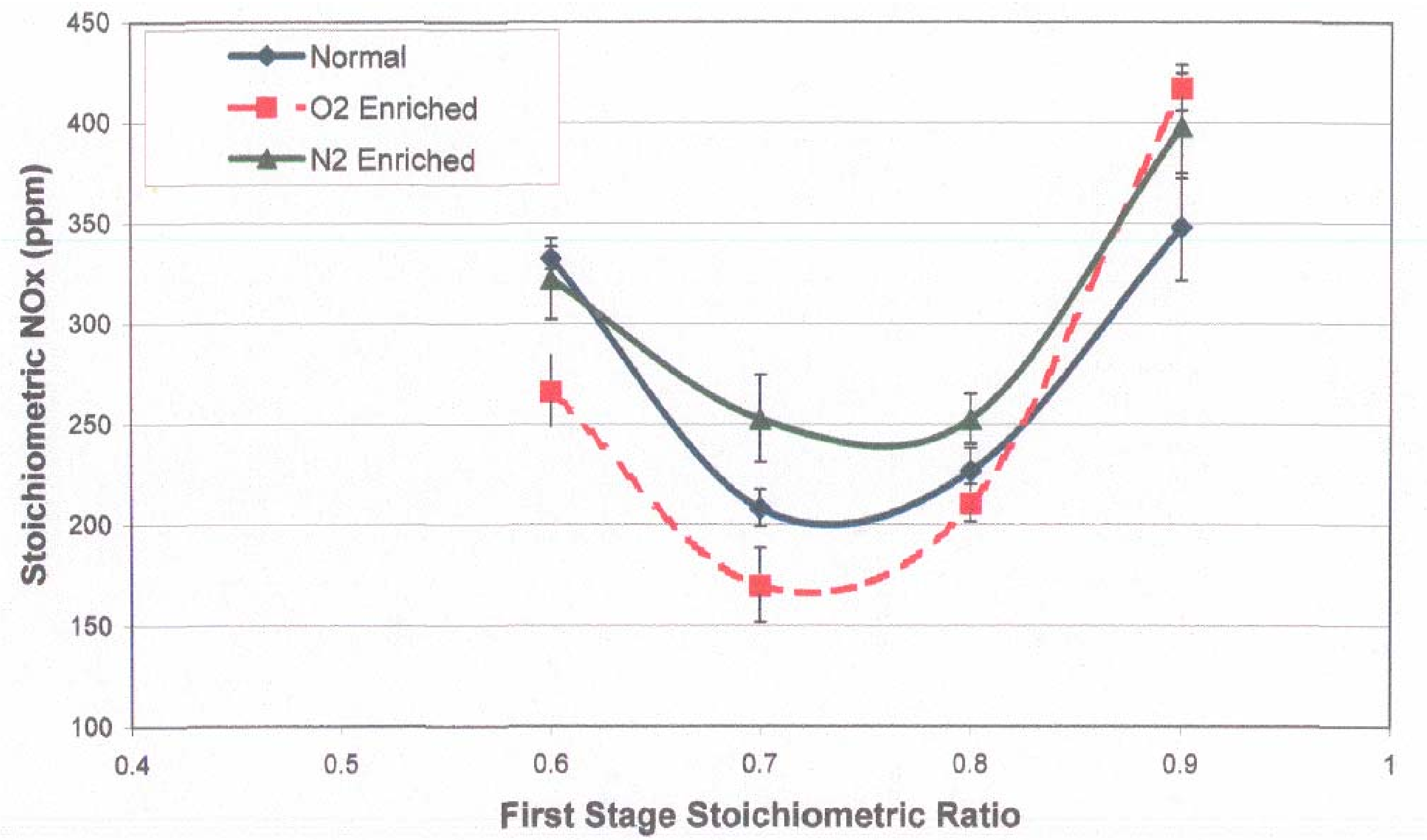


12.14 scfm 11.22 scfm

Flows are from a stoichiometric ratio of 1.2 overall, 0.7 in first stage.

O_2 enrichment and coal N *kinetic issues*: Exhaust NO_x after staged combustion of pulverized coal vs SR in the first stage.

SR_{PRIM} varied; $SR_{EXHAUST}$= 1.2. Fixed staging location.



O_2 enrichment and *flame aerodynamic* issues: Questions addressed using Model B laboratory combustor.

(Greg *Ogden, Ph.D dissertation, University of Arizona, 2002)*

- What impact do near-burner aerodynamics have on flame detachment and how can it be measured?
- What effect does oxygen partial pressure in the **transport stream** have on flame stability, flame detachment and NO_x?
- How do coal fines affect combustion stability and pollutant emissions?

Project Motivation

- Flame attachment is a critical variable for optimum performance of low NO_x burners for pulverized coal combustion
- Need to promote formation of fuel-rich combustion zone
  - Fuel-N devolatilization
  - Reduction to N_2

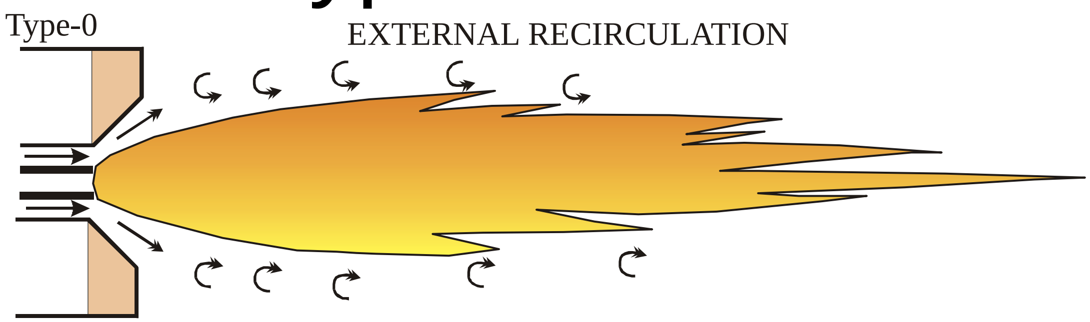
Approach

- Whereas, under well mixed conditions, oxygen enrichment and firing micronized coal are known to:
  - Increase combustion intensity, flame temperatures
  - Increase both Fuel and Thermal NO_x
- Under diffusion mixed conditions, oxygen enrichment of **only** transport air and/or increasing fines content of regular coal
  - Should promote coal ignition and flame attachment
  - Reduce premixing
  - Reduce NO_x

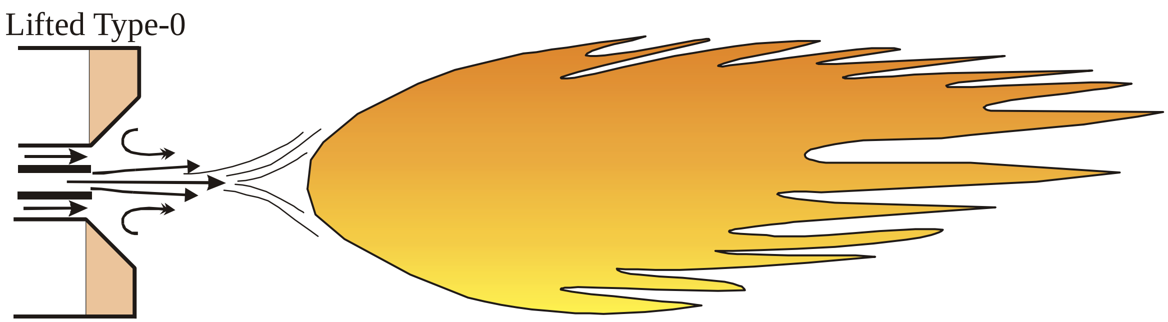
Approach-Cont'd

- Restrict to coaxial flames
  - Type 0 Flames
    - no secondary air swirl
    - No internal recirculation zone
- Represents corner fired boilers and cement kilns
  - Well defined aerodynamically
  - Flame standoff distance has been identified as key parameter for NO_x emissions in cement kilns

Type 0 Flames



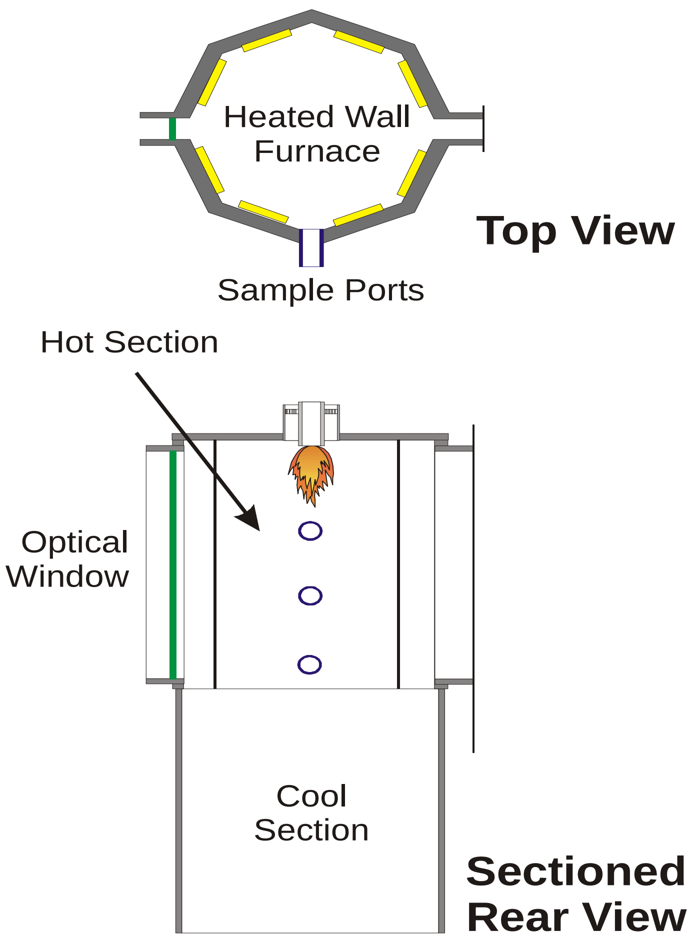
ATTACHED DIFFUSION FLAME



PARTIALLY PREMIXED FLAME

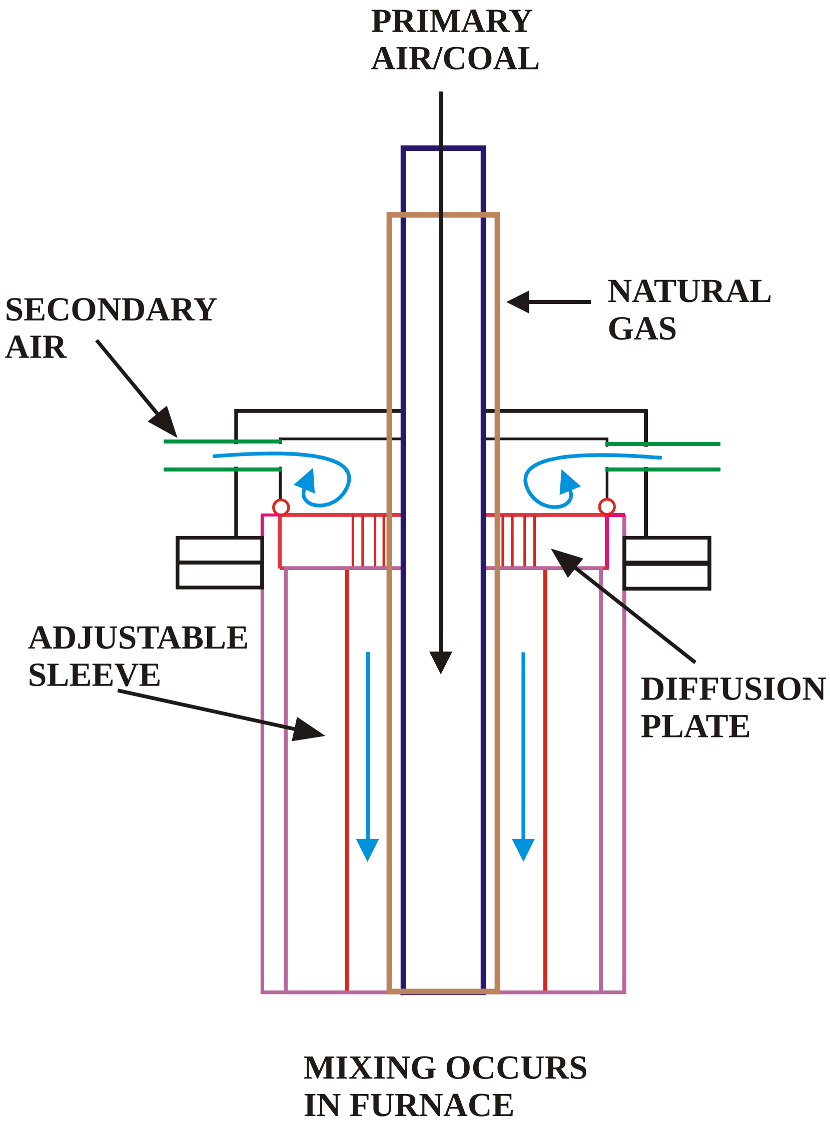
Furnace Layout

Laboratory Furnace Details



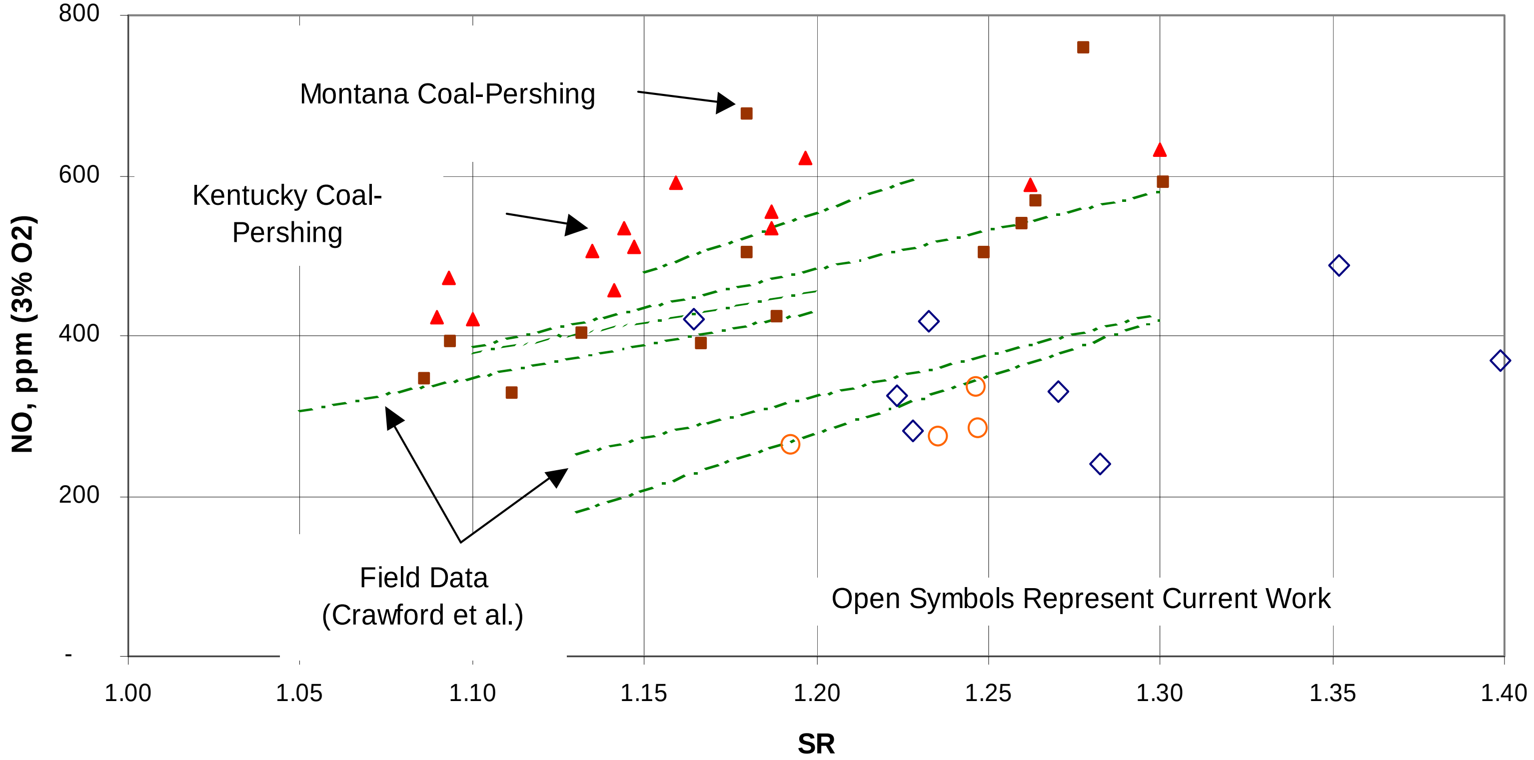
- 18" ID hot wall furnace
  - Designed for "near flame" analysis
  - lightweight refractory
  - Air preheater
- 3' Hot section
  - Multi-zone ceramic heaters wall temperatures to 1,300 K
  - Full length quartz window for flow visualization studies
  - 4 stationary sampling ports

Axial Burner



- Removable sleeves
  - –Velocity is controllable
    - Fuel
    - Combustion air
  - –Maintain constant momentum at different secondary air temperatures
  - –Independently control velocity and momenta
- Supplemental gas injection if reqd.

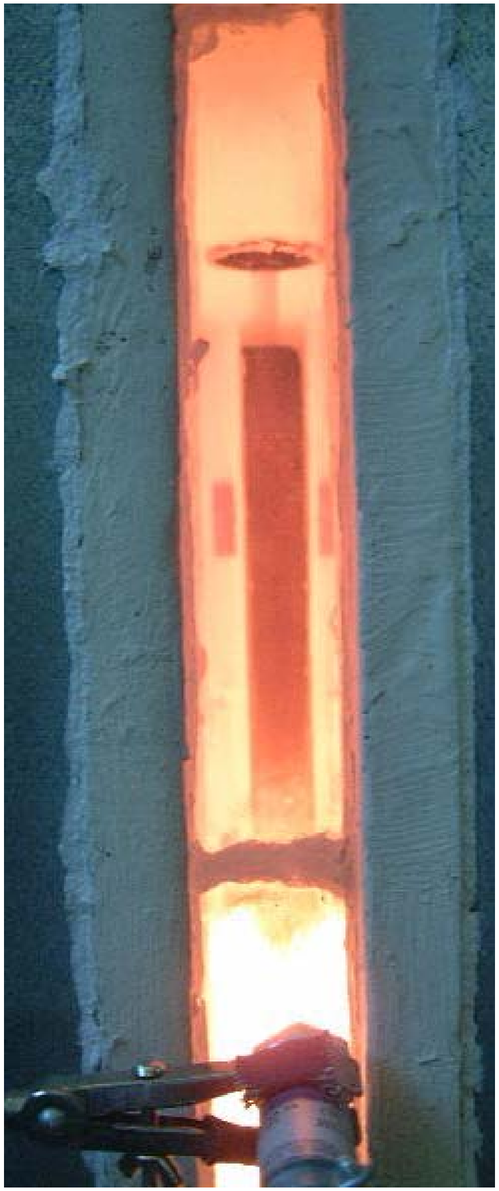
Furnace Validation



Oxygen Enrichment

- Varied transport air oxygen partial pressure (Po_2)
  - 20-29% via O_2 enrichment
  - 13% via N_2 dilution
- Furnace wall temperature
  - 750° & 900°C
- General operating conditions
  - 2 kg/hr Utah coal, 1.2 SR overall
  - 450°C air preheat
  - V_c ~31.2 to 32.5 fps

Attached

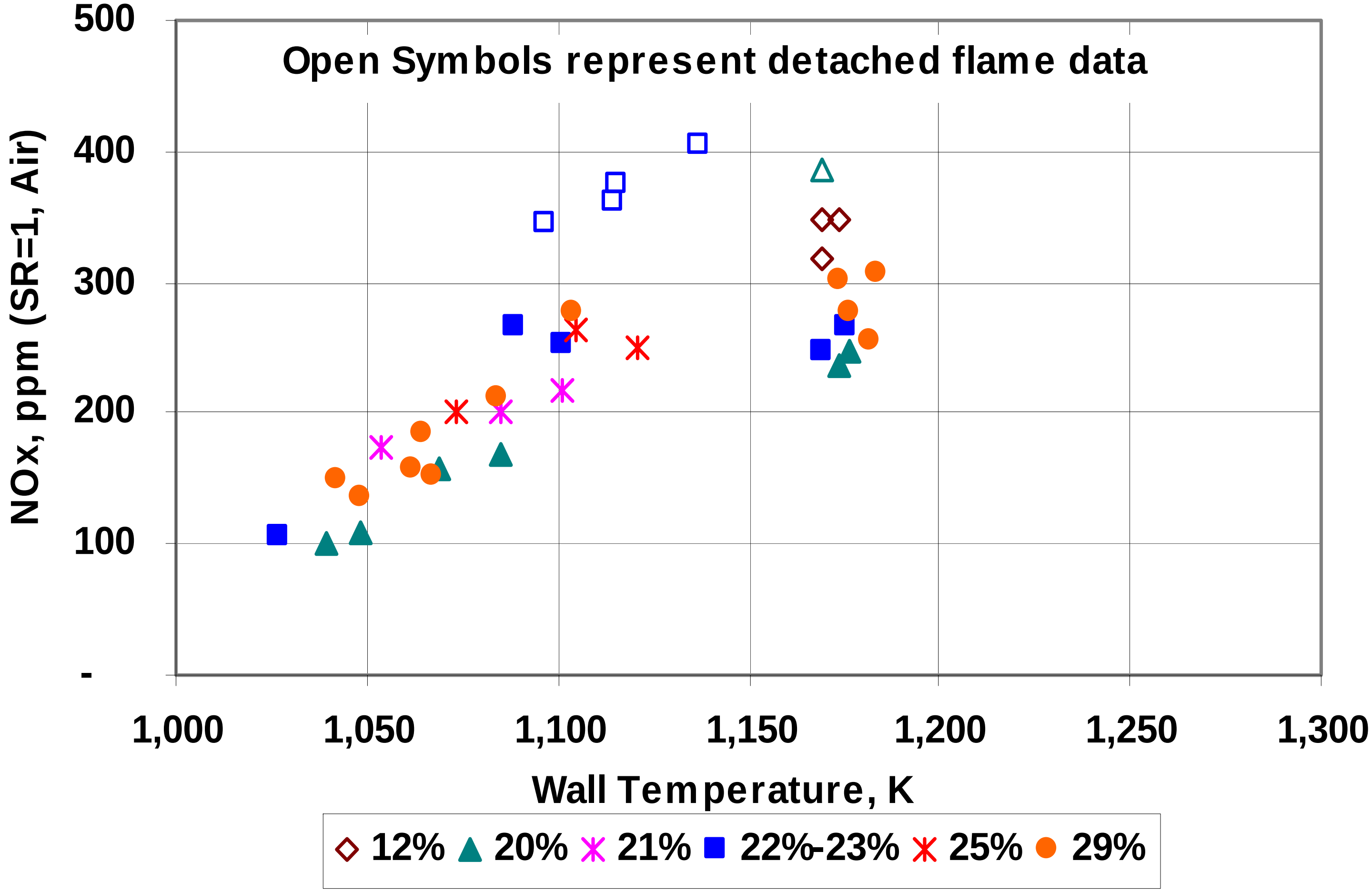


Detached

Coal stream

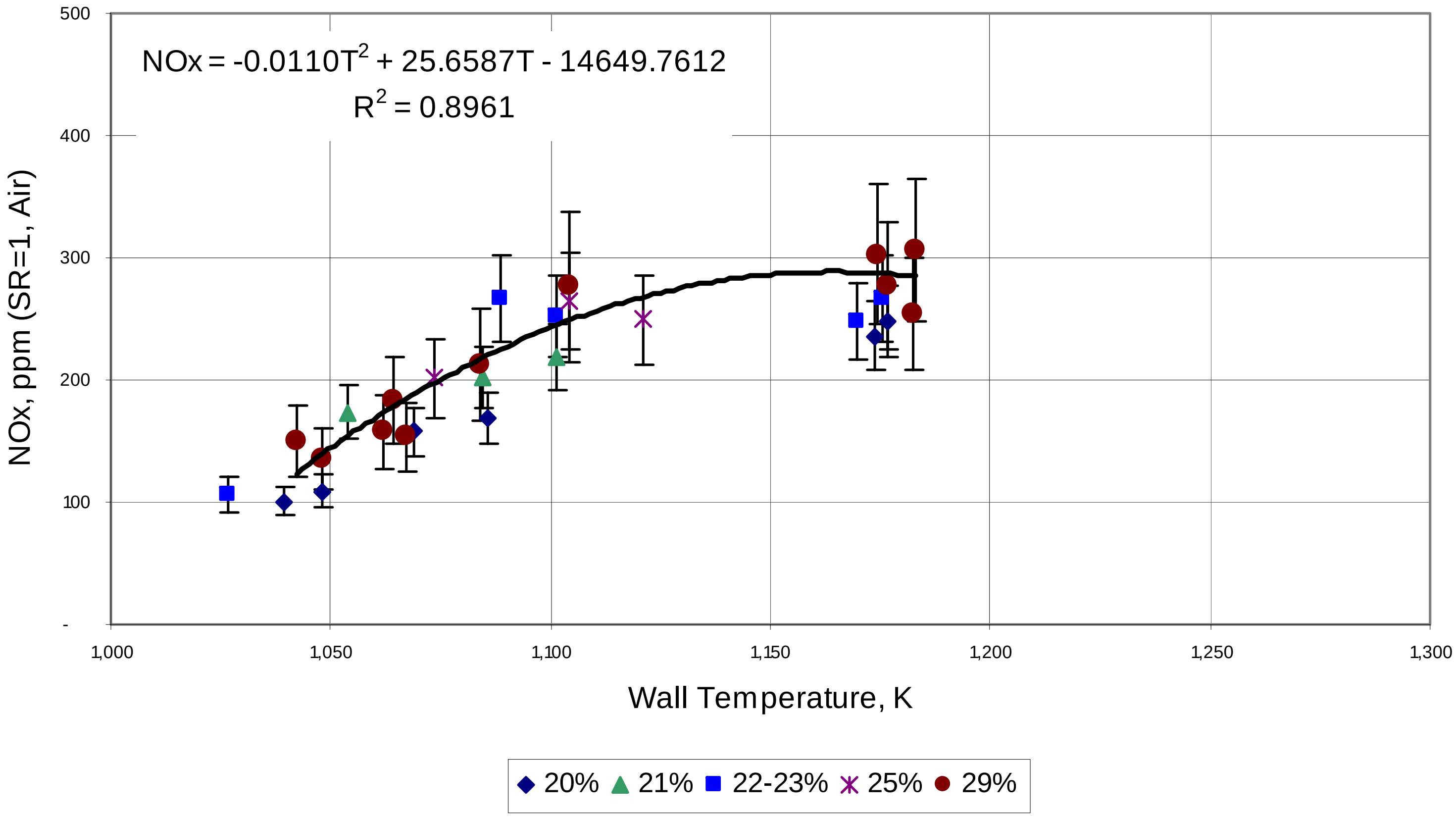
Flame Detachment

NO_x Emissions Data



Subtle P_{O2} Effects

Temperature Effect on NO_x Attached Flames

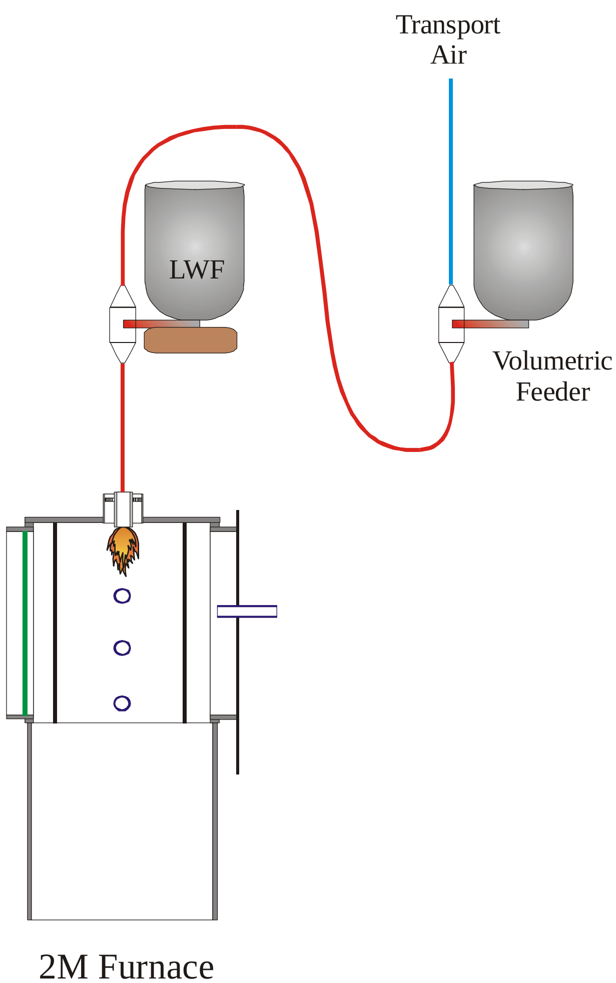


Coal Fines

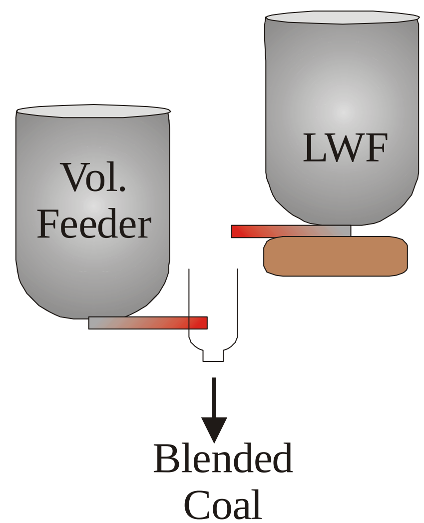
- Investigate impact of fines fraction for a normal PC distribution
  - Fines-d_p <10 microns
  - 0, 15% (base), 23% and 31% fines
  - 825 & 925°C walls
  - 21 & 29% transport air oxygen

Feeding Fines

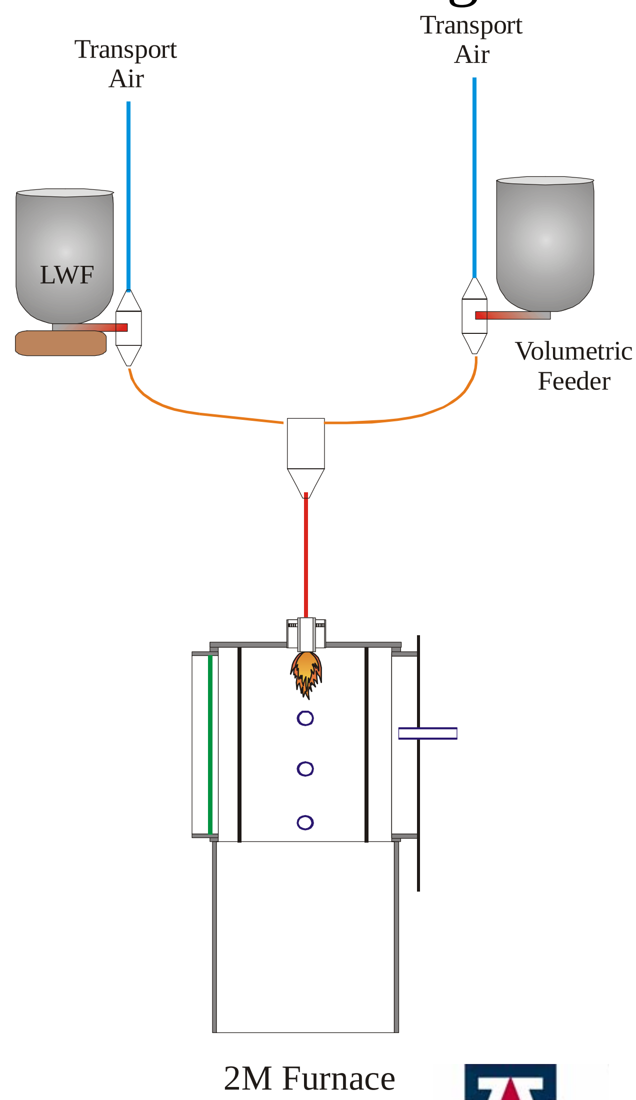
Initial Setup

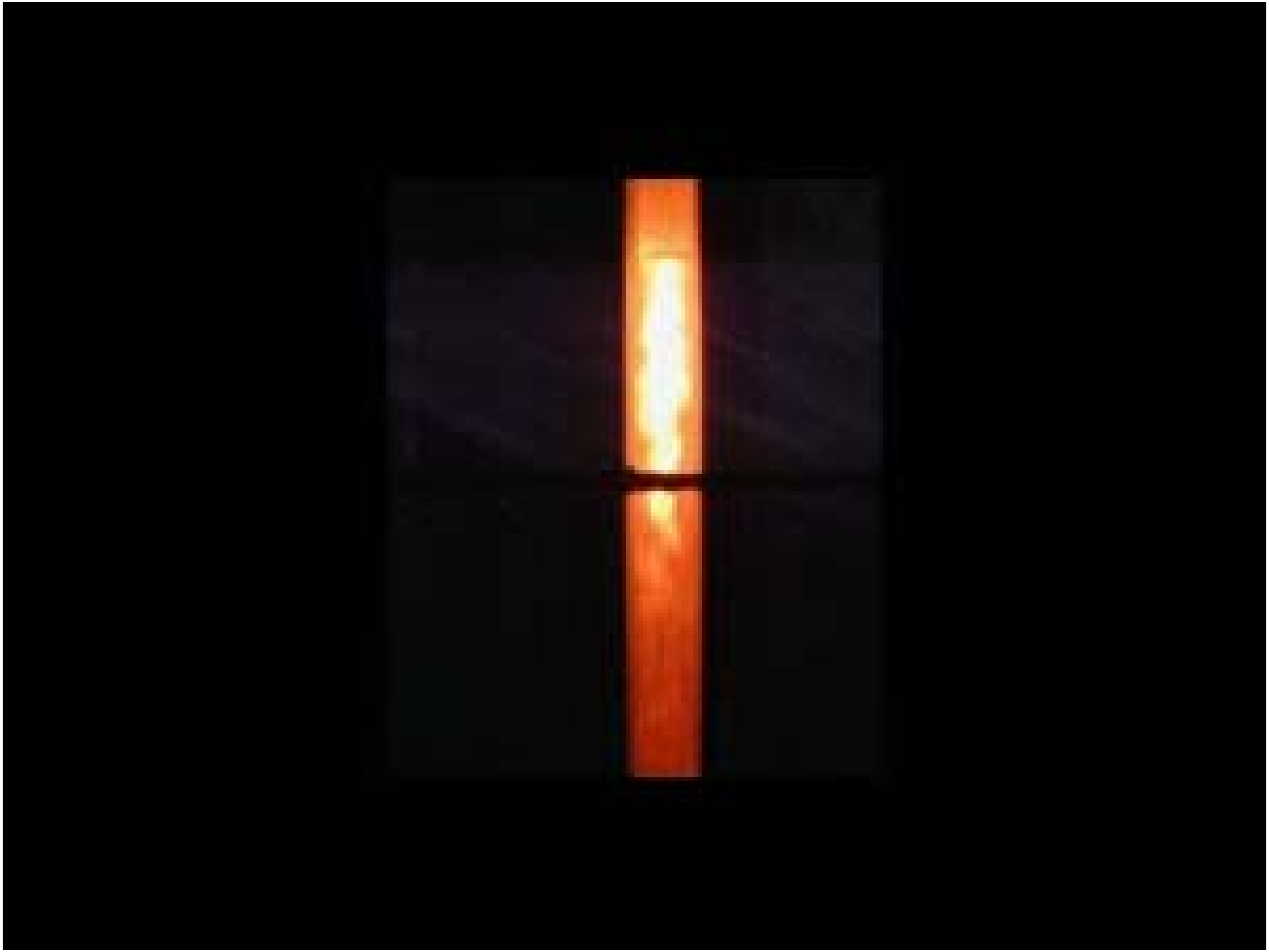


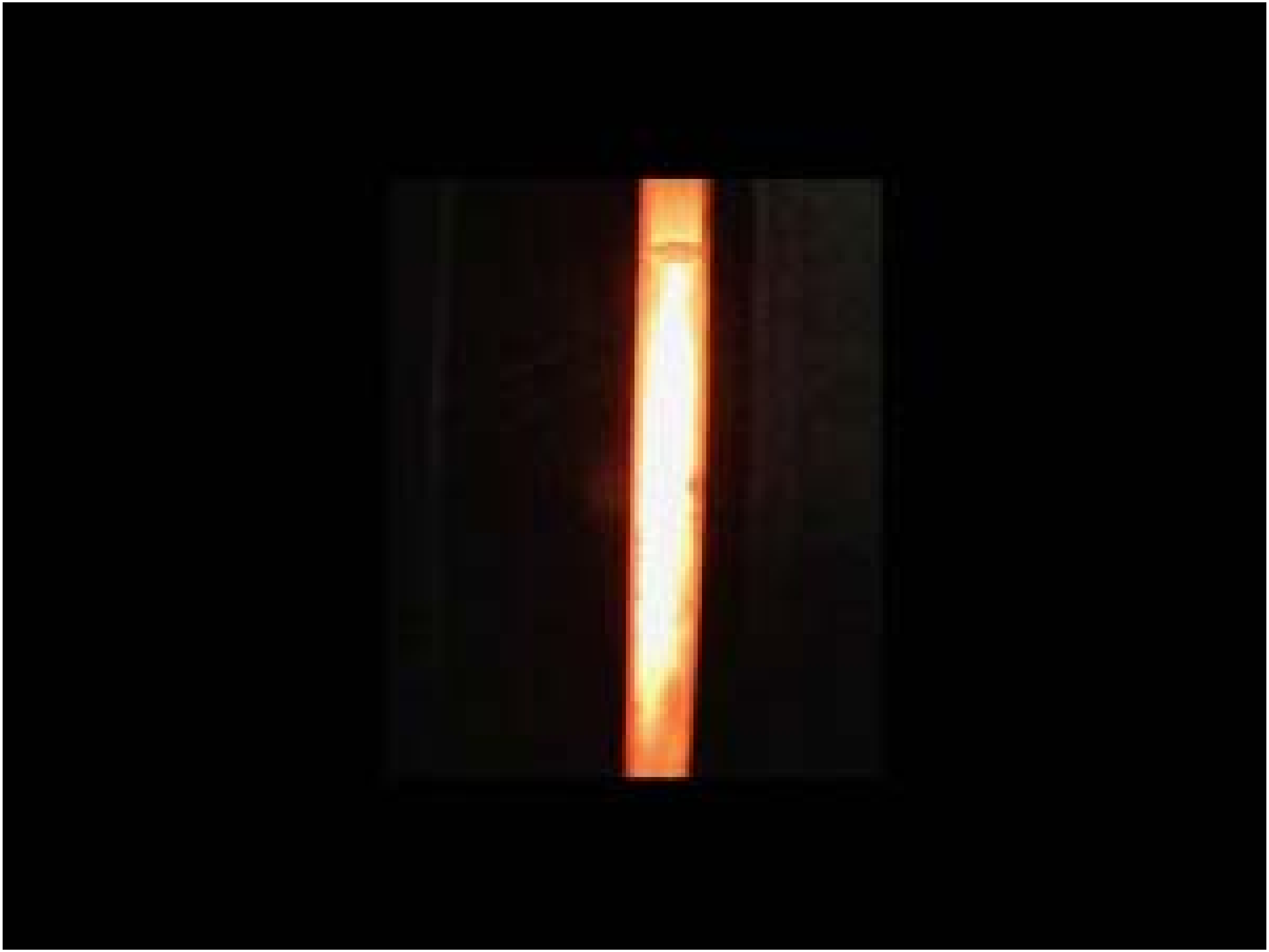
Blending



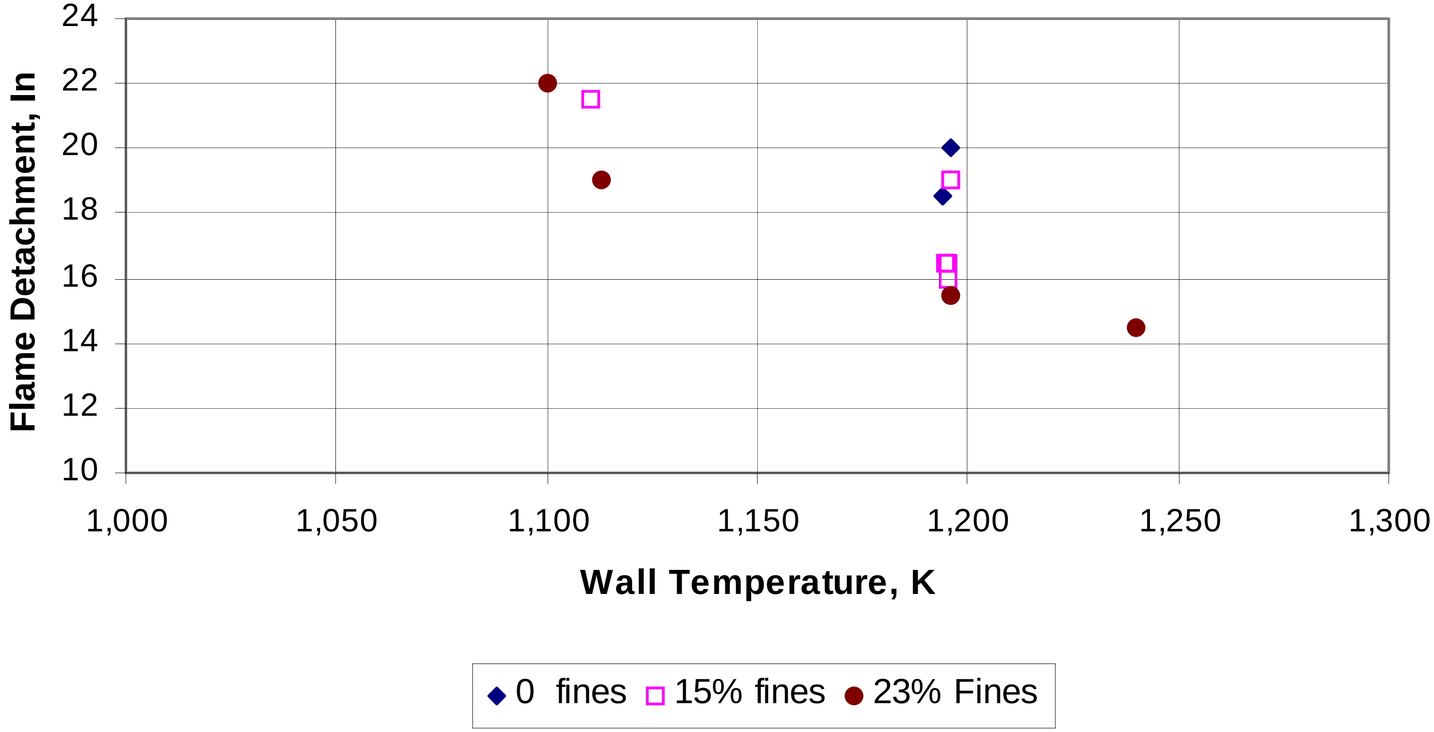
Co-Feeding





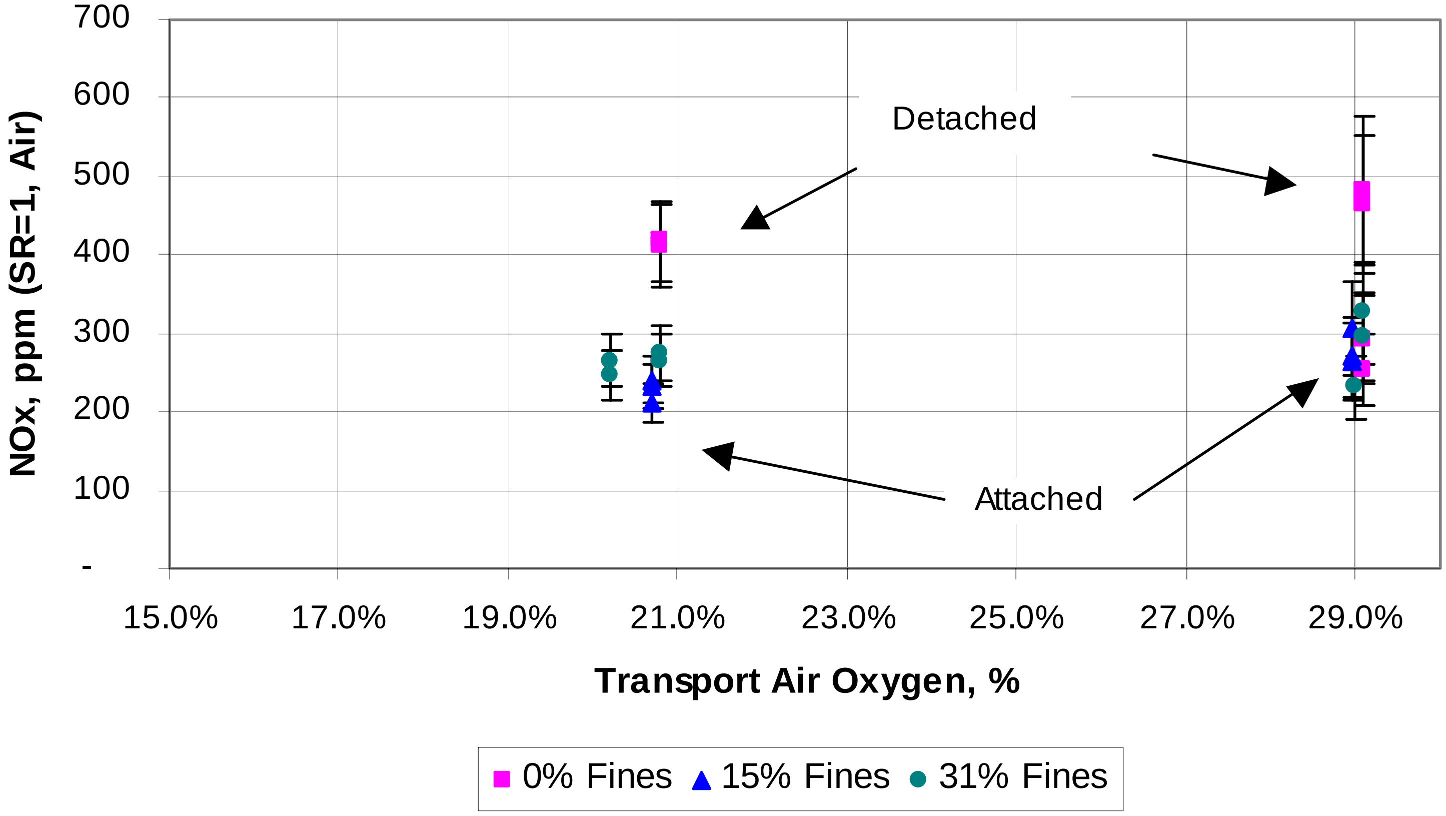


Fines Reduce Flame Detachment

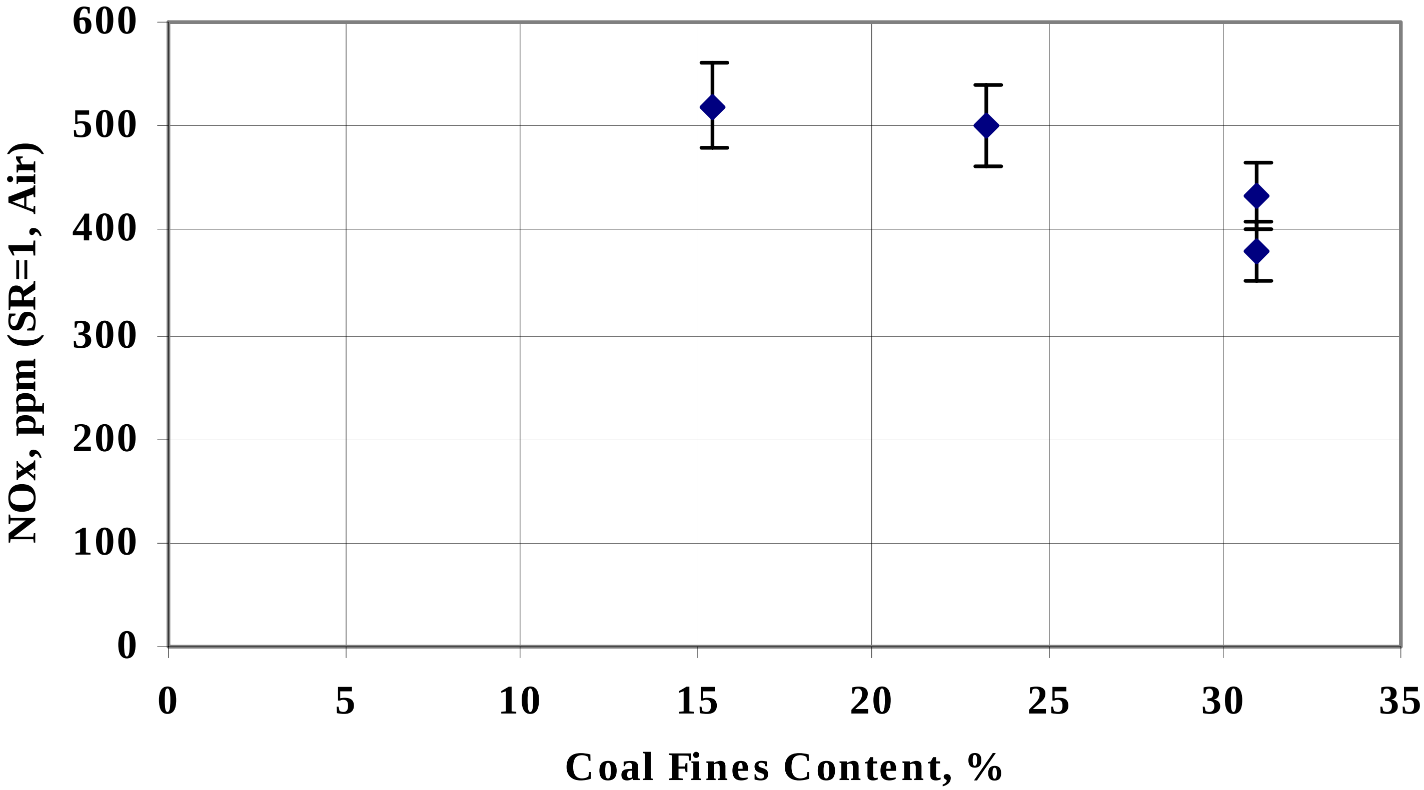


21% Transport Air Oxygen

NO_x vs. Transport Air Oxygen



Fines vs. NO_x (attached flames)



Co-Feeding Base coal and Fines

Conclusions: Model B furnace

- Demonstrated the utility of the 2m laboratory combustor (Model B) in examining near-flame combustion phenomena.
  - Full-length quartz window
  - Electrically heated walls
  - Axial burner
  - Allows for *systematic adjustment* and evaluation of individual parameters

Conclusions (Model B furnace) -Cont'd

- NO_x emissions reduced through flame attachment
  - Up to 64% reduction
- Promote flame attachment by increasing
  - Transport air Po_2
  - Fines
  - Wall temperature

Conclusions (Model B furnace)-Cont'd

- For always-attached flames
  - Po_2 and fines had only slight effect on NO_x
- For always-detached flames
  - Increasing fines reduced flame detachment
  - Po_2 and fines had only slight effect on overall NO_x
- Slight increases in both fines and Po_2 promoted flame stability
  - Attached otherwise detached flames
  - Produced stable detached flames

Acknowledgements

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