Oxy-Coal Combustion in a Small-Scale CFB

L. Bool and E. Eddings

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Goals

- **Praxair has core competencies in the main areas of oxy-coal combustion**
  - Air separation unit (ASU)
  - Oxy-fuel combustion
  - CO_2 purification unit (CPU)
- **Oxy-coal combustion is a significant potential market**
- **Understand key aspects of oxy-coal for carbon capture through**
  - Partnering with DoE and others to develop key components
  - Internally funded research to understand key fundamentals

Overview of Praxair Oxy-Coal Activities

PRAXAIR

- **First to use oxygen commercially in coal-fired power plants**
  - Provided key information on oxygen injection strategies and burner design for oxy-coal burners
- **Oxygen Transport Membrane Program**
- **CPU development**
- **Partner in Reaction Engineering International (REI) DOE Program "Characterization of Oxy-combustion Impacts in Existing Coal-fired Boilers"**

Experience and interest range from fundamentals to application engineering

Oxy-coal Retrofit at U. of Utah

- **Oxy-Coal Combustion Tests at University of Utah**
  - Pilot-scale (5 MBtu/hr) PC-fired with external FGR
  - Small-scale (0.6 MBtu/hr) CFB studies fired with external FGR
  - Bench-scale flame characterization in Oxy-Fuel Combustor (OFC)
- **Industrial gas supply**
  - Liquid CO_2 with vaporizer
  - 6000 gallon liquid O_2 supply with vaporizers
- **Flue gas recirculation**
  - Flue gas cooled with heat exchangers
  - Particulate removed with baghouse
  - Blower used for recirculation
  - Air infiltration minimized

Near Field Burner Studies

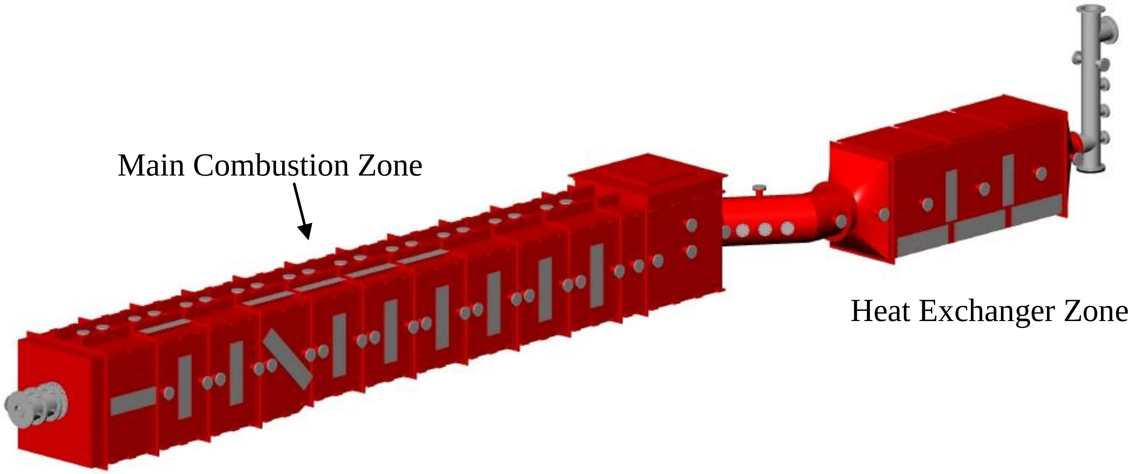
- **Model validation for potential application to new and retrofit situations**

- **Selected Praxair supported work**
  - Specially designed oxy-fuel combustor (~100 KW)
  - Effect of PO_2 in recycled flue gas on flame stabilization
  - Determine desired characteristics of a low emission, highly-stable, oxy-coal burner
  - Provide validation data for near-field aerodynamic simulations of well defined oxy-coal flames

PC Oxy-Coal Combustion Work

Pulverized Coal Pilot Scale Tests

- Existing L1500 furnace at University of Utah retrofitted to allow pulverized coal oxy-fuel combustion
- Effect of oxygen concentration and injection strategies on flame stability, pollutant formation and heat flux
- Support ongoing work under REI program

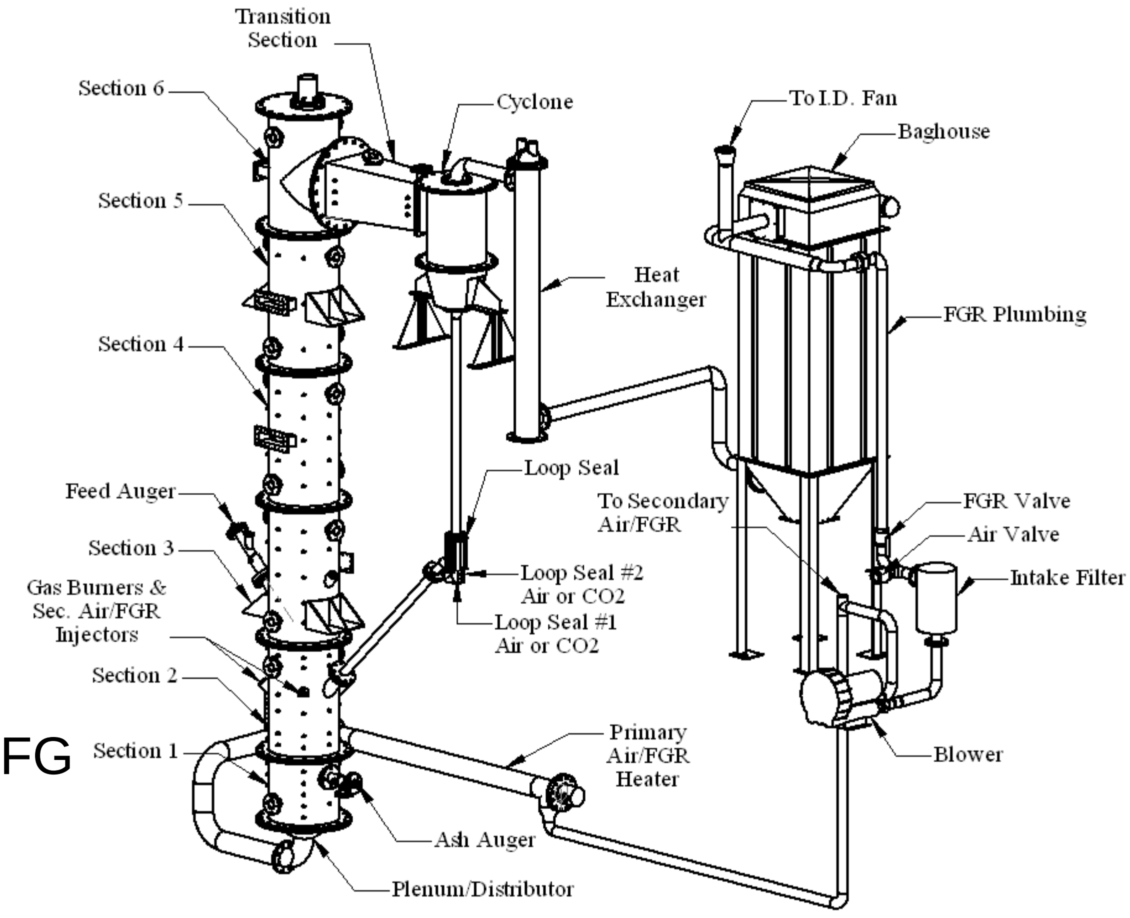


Small-Scale Studies – CFB

- **CFB work**
  - Operate CFB on air and oxy-recirculated flue gas
  - Understand impact of retrofit strategies on bed temperature, carbon burnout, other combustion parameters
  - Measure impact of oxy-coal on pollutant emissions
  - Understand operability of oxy-coal CFB

CFB

- **0.6 MMBtu/h**
- **21 ft long, 10 inch ID**
- **Heat removal**
  - In bed
  - Solids return line
  - Flue gas before baghouse
- **Flue gas recirculation**
  - Same blower for air and RFG
  - Flue gas recirculated after baghouse (wet)
  - Reheated to 600 F after O_2 mixing
  - Multiple oxidant streams



Retrofit Strategies - CFB

- **Constant O_2 concentration in flue**
  - Global stoichiometric ratio is lower than air-fired case
  - Oxidant flowrates decreased with increasing O_2 concentration in oxidant– reduce bed velocity
  - Fluidization/solids recirculation rates impacted?
- **Bed velocity constant**
  - Global stoichiometric ratio increases with O_2 concentration in the oxidant
  - Concentration in the flue increased O_2 with increasing O_2 concentration in the oxidant
  - 'wastes oxygen'
- **Alstom and Foster Wheeler have specific strategies for commercial retrofits/new builds**
  - Our study is based on fundamentals

CFB Operating Information

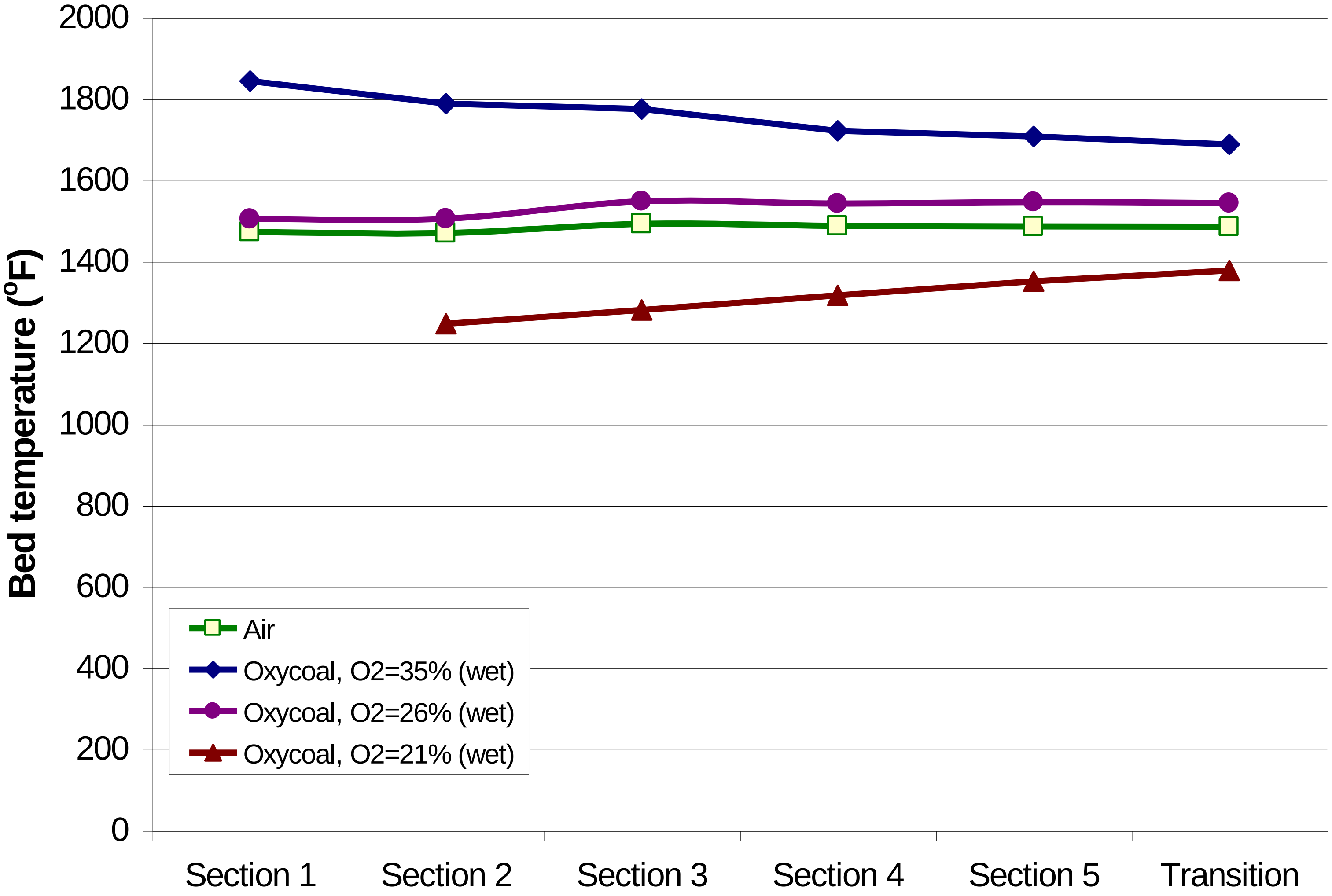
- **Several test campaigns completed**
  - wet flue gas recirculation
  - no SO2/NOx/CO cleanup before recirculation
  - O2 in flue maintained at 3 vol% (dry)

- **Quartz bed material used for current tests**
  - Fine enough to ensure solids recirculation

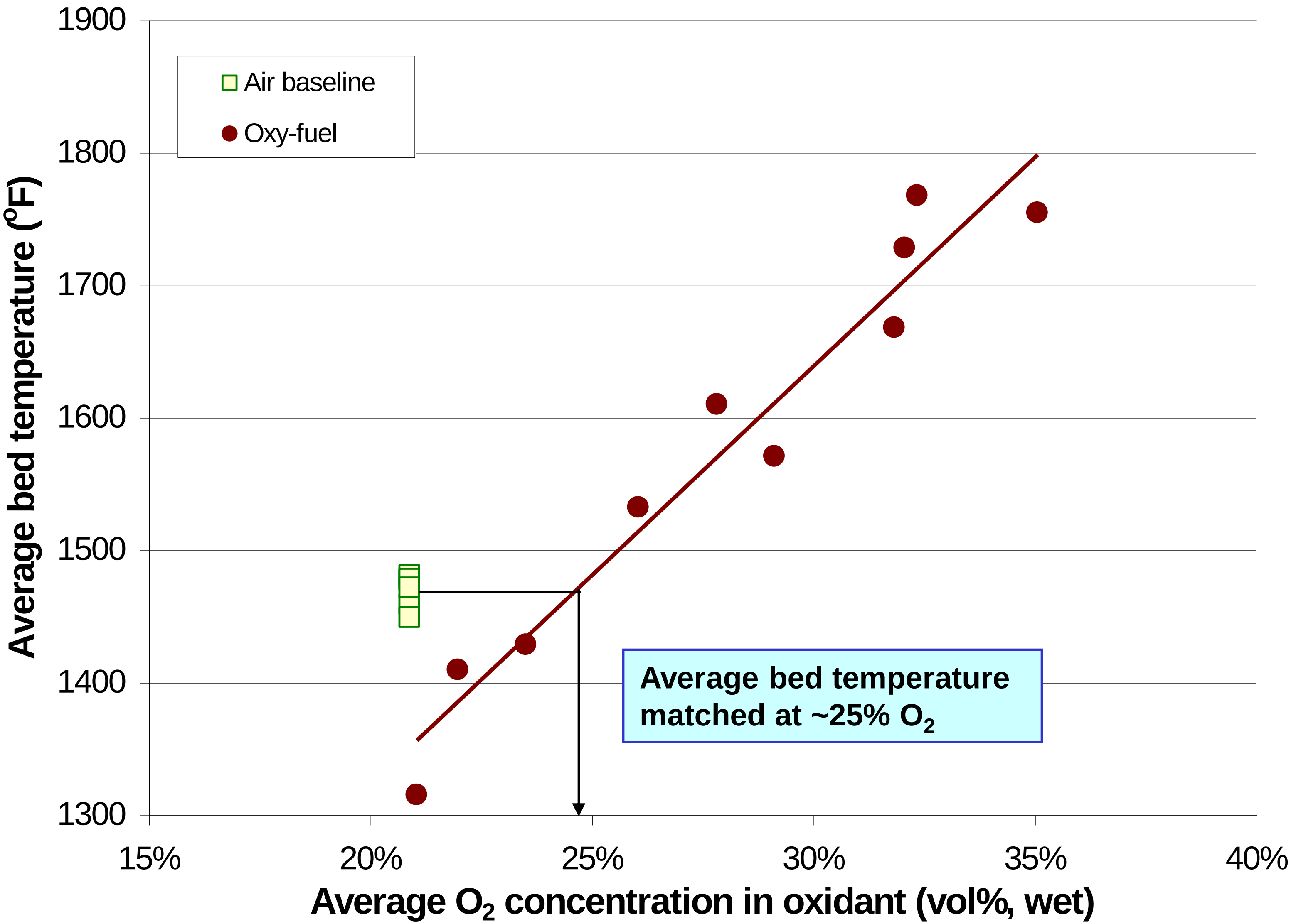
- **Utah bituminous coal used**
  - ~10.4% ash, 5% moisture
  - Ca/S ratio of 1.2

- **All data reported on WET O_2 concentration in oxidant**
  - Actual combustion environment based on wet concentration

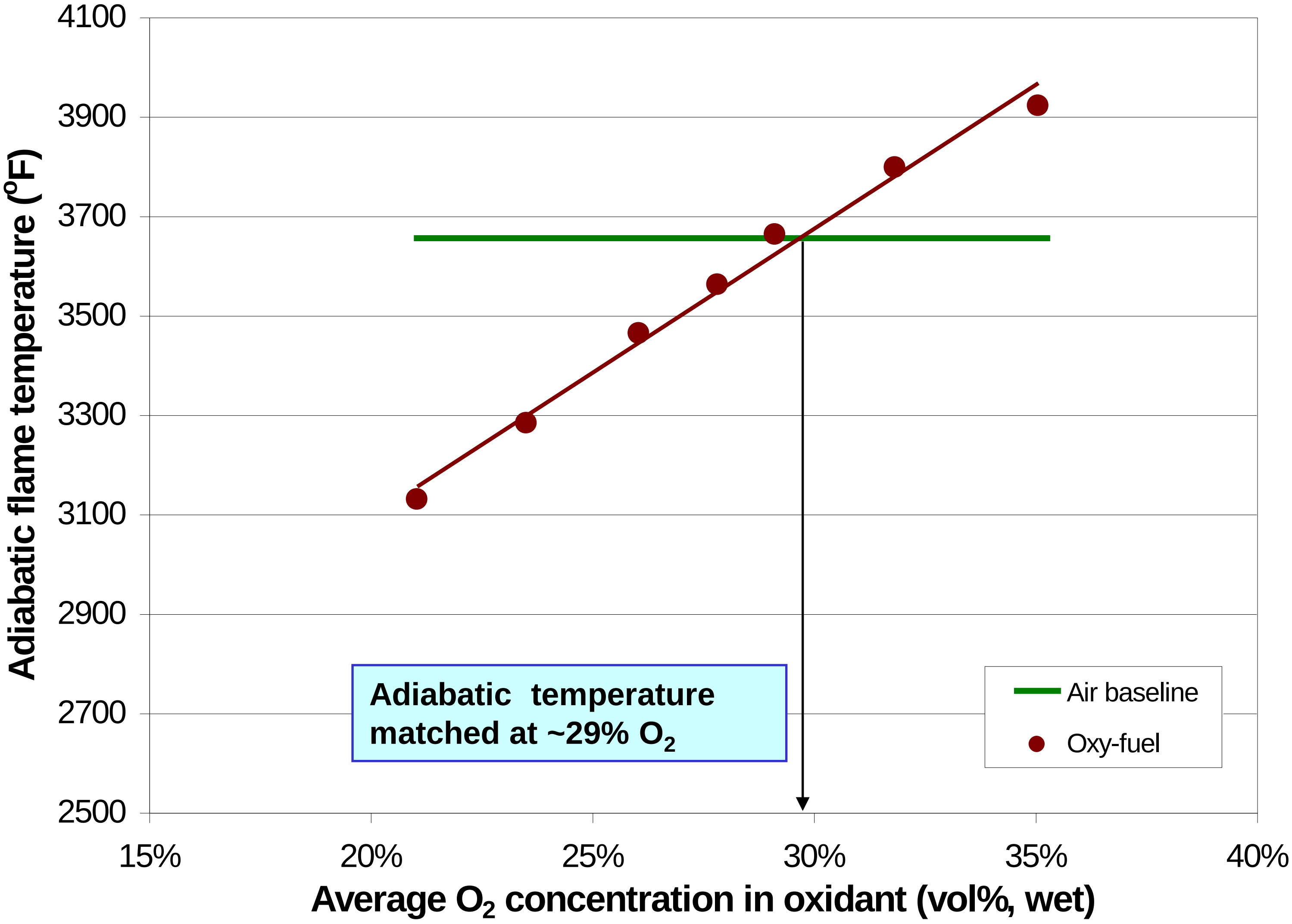
Typical Temperature Profiles



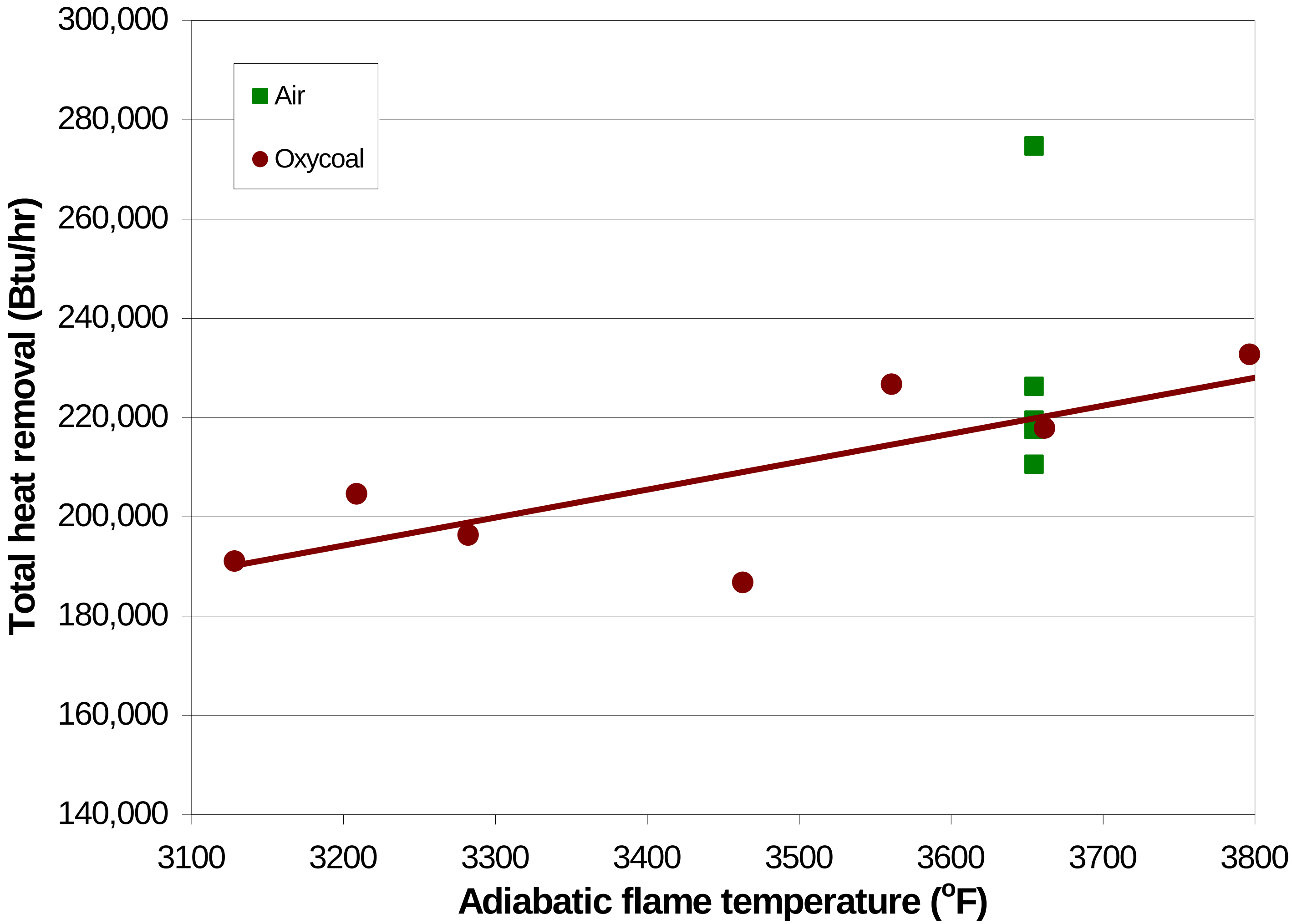
Bed Temperature with Oxy-Coal



Adiabatic Flame Temperature

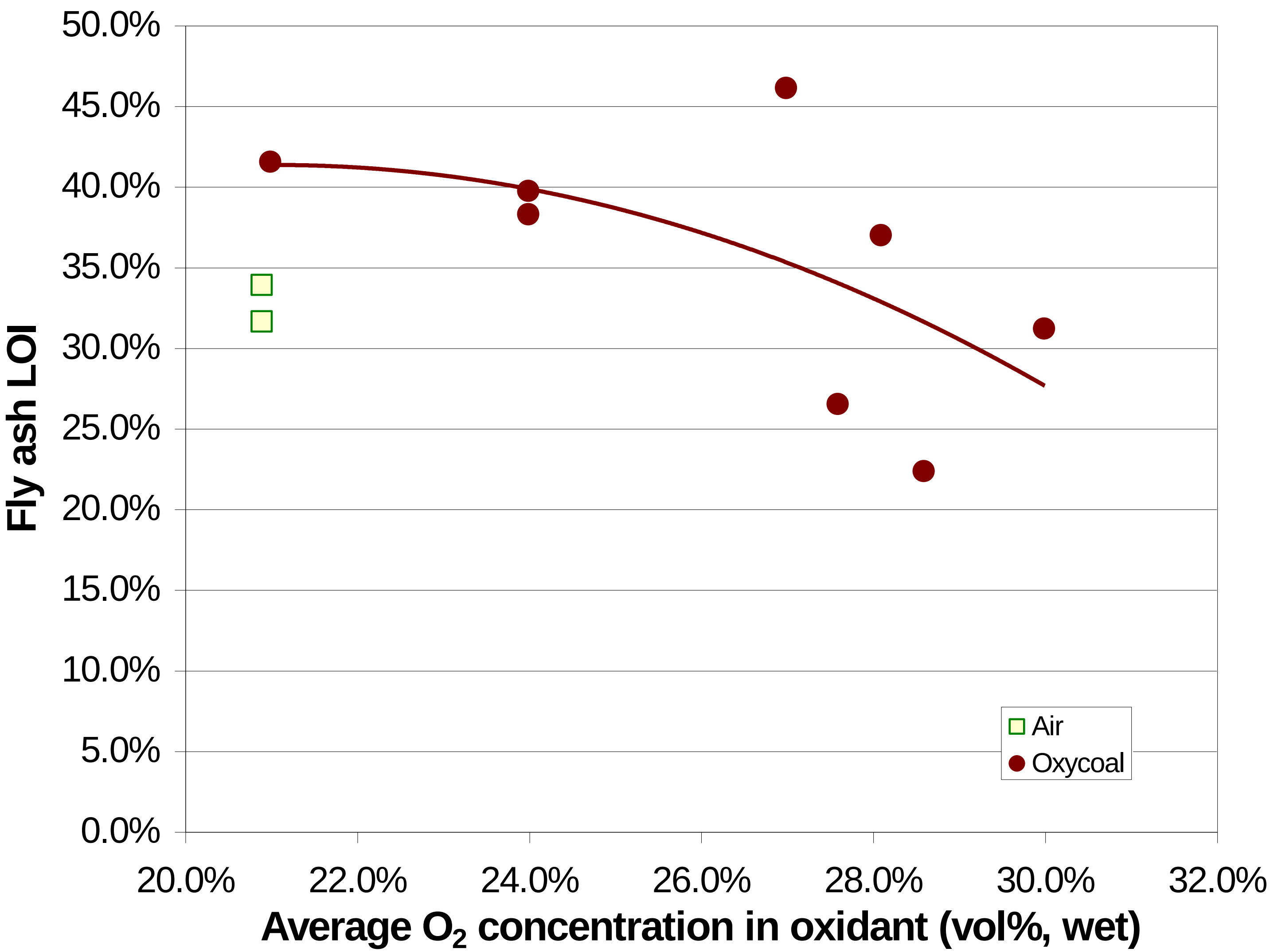


Heat Removal with Oxy-coal



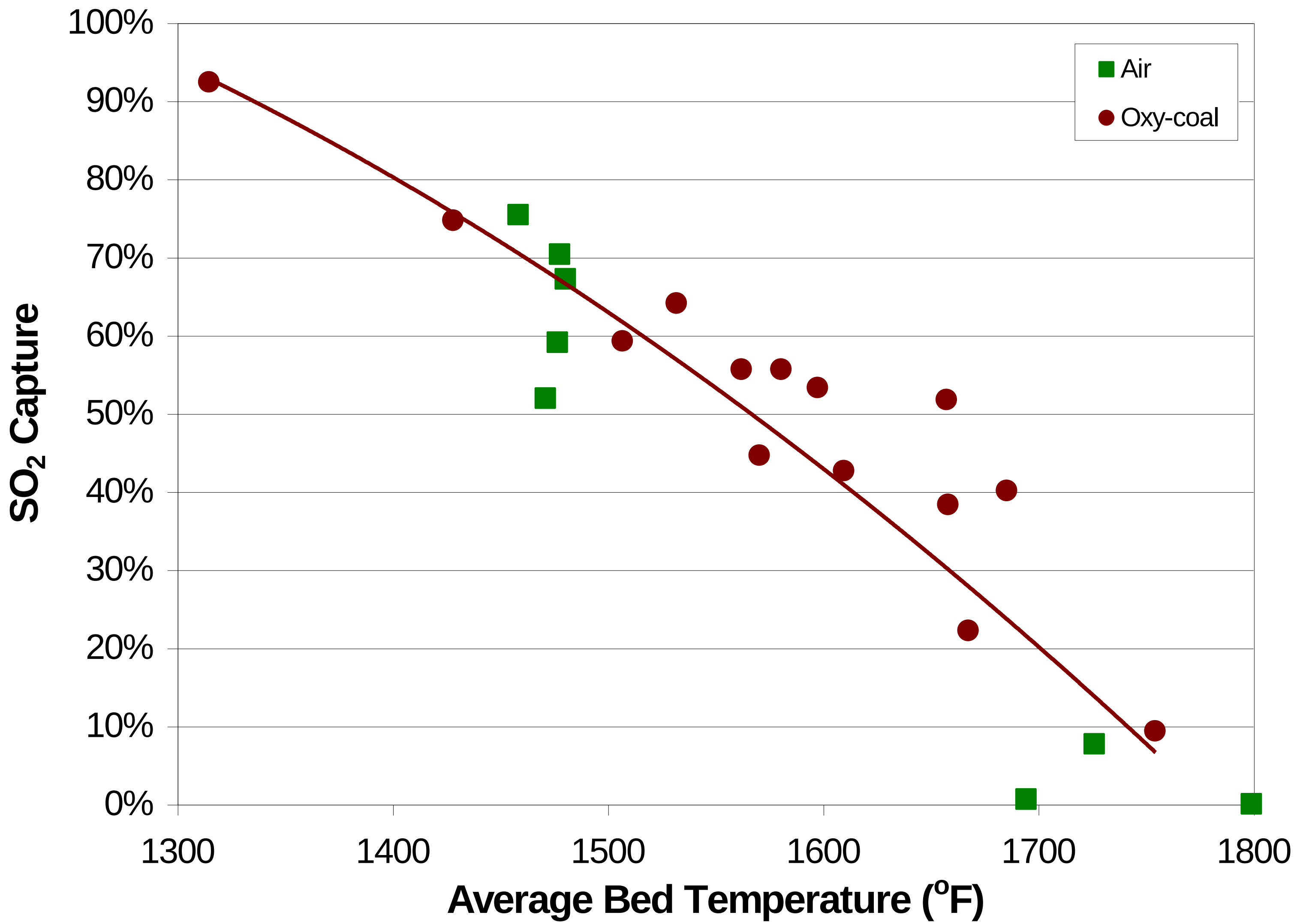
Total heat removal matched when adiabatic flame temperature is matched

LOI Results



50.0%
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
Fly ash LOI
20.0%
22.0%
24.0%
26.0%
28.0%
30.0%
32.0%
Average O2 concentration in oxidant (vol%, wet)
Air
Oxycoal

SO_2 Capture



100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
SO2 Capture
1300
1400
1500
1600
1700
1800
Average Bed Temperature (oF)
Air
Oxy-coal

Operating observations

- **Transition from air-firing to oxy-firing became routine**
  - Transition period ~ 15 minutes
- **Manual control of the system required careful attention due to the multiple recirculation loops**
- **Operating under slightly positive pressure precluded air infiltration in 'normal' leak points**
  - Air ingress likely due to leaks in the blower itself

Summary

- **Preliminary studies to operate oxy-coal firing of the CFB completed**
  - Constant O_2 in the flue
  - Constant velocity
- **CFB showed good operation on oxygen-enriched RFG**
  - Temperature controlled
  - Low air inleakage
- **Bed temperature proportional to oxygen concentration**
  - Matching adiabatic flame temperatures matched heat removal
- **Fly ash unburned carbon (LOI) slight oxygen concentration dependence**
- **Native SO_2 capture a function of temperature**
  - Additional experiments planned with lime addition
- **Additional work planned to evaluate strategies to optimize oxygen use**