Oxy-Coal Combustion at Washington University in St. Louis

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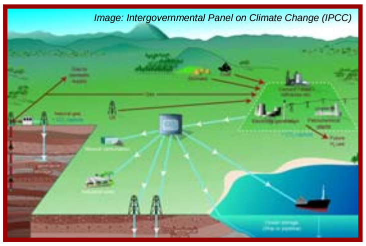
Motivation

- In 2004 coal accounted for 26% of total world energy production and is projected to increase 74% by 2030 (EIA, International Energy Outlook 2004)
- Coal combustion accounts for 50% of U.S. electricity production with more than five hundred ½ GW power plants
- The U.S. has sufficient coal reserves to meet the country's electricity demands for the next 150 years
- Coal combustion is the second largest fuel source of energy related carbon dioxide (CO_2) emissions (behind oil), but produces more CO_2 per unit energy than oil or natural gas
- CO_2 is the largest contributor to the greenhouse effect, understood to cause global warming

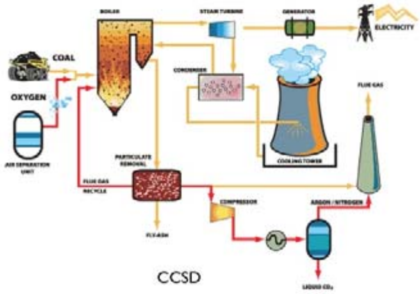
Carbon Capture and Sequestration (CCS)

- Carbon capture and sequestration is currently the most feasible short term solution for reducing atmospheric CO_2 emissions
- Potential CO_2 storage sites include underground geological formations, ocean depths greater than 1000 meters, and in minerals formed by reacting CO_2 with naturally occurring magnesium and calcium
- Cost efficient CO_2 capture by direct compression requires concentrated exhaust gases



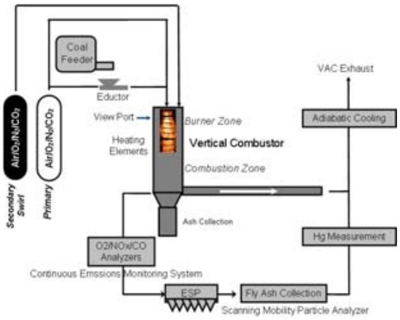
Oxy-Coal Combustion

- Oxy-coal combustion involves using a concentrated O_2 stream as the oxidizer in place of air
- The exhaust gases can be recirculated to control temperature and carry the heat through the system
- Benefits of oxy-coal combustion include 95% CO_2 by volume in the exhaust gas as opposed to the 10-20% found in conventional air-fired combustion, 70% reduction in NOx emissions and 27% reduction in SOx emissions, and improved pollutant capture efficiency due to reduced flue gas volume



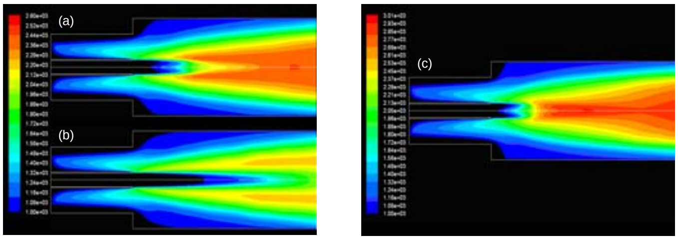
Experimental

- A combustion system capable of self-sustaining, unpiloted coal burning at thermal outputs as low as 500 W and as high as 50 kW has been designed and constructed at Washington University in St. Louis
- Flame stability in oxy-combustion has been quantified experimentally as a function of inert type and oxygen concentration in the primary oxidizer (PO) and secondary oxidizer (SO)



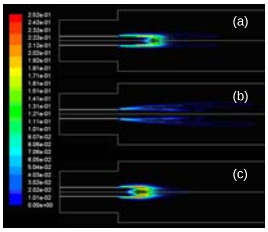
Modeling

- Fluent software was utilized to model the experimental system and better understand the effects of temperature and volatile reaction rates on flame stability

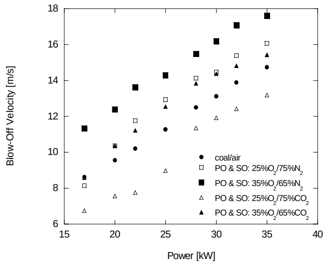


Temperature profiles (above) and volatile reaction rate (below) for (a) PO: 21% O_2, SO: 21% O_2 (b) PO: 6% O_2, SO: 35% O_2 (c) PO: 35% O_2, SO: 35% O_2 with N_2

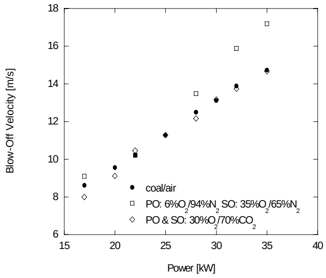
- Cases (a) and (b) have similar near burner temperature profiles even though case (b) has a cool region extending farther axially into the flame
- Case (c) results in much higher temperatures overall as indicated by the change in scale
- Relative to Case (a), Case (b) results in reduced volatile reaction rates that extend farther downstream of the burner exit while Case (c) results in increased rates occurring nearer to the burner exit



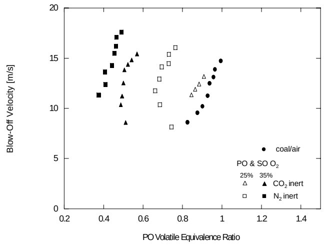
Experimental Results



The figure above demonstrates that overall, an increase in O_2 concentration improves flame stability while replacing N_2 with CO_2 results in reduced flame stability.



The air-fired flame and the 30%-O_2/70%-CO_2 flame have similar blow-off velocity limits. The flame with 6% O_2 in the PO and 35% O_2 in the SO also has comparable blow-off velocity limits suggesting the potential for reduced NOx due to the removal of O_2 from the high temperature region of the flame without sacrificing flame stability.



Blow-off velocities as a function of equivalence ratio (computed based on PO O_2 and complete volatile release) appear nearly independent of coal feed rate and flames with higher temperatures due to elevated O_2 concentrations remain stable under leaner conditions.

Acknowledgements

DOE/UCR, DNR, AmerenUE