Understanding the complexities of enhanced oxygen, high temperature pulverized coal char combustion

Ethan S. Hecht ehecht@sandia.gov

Christopher R. Shaddix crshadd@sandia.gov

Combustion Research Facility, Sandia National Laboratories, Livermore, CA 94550

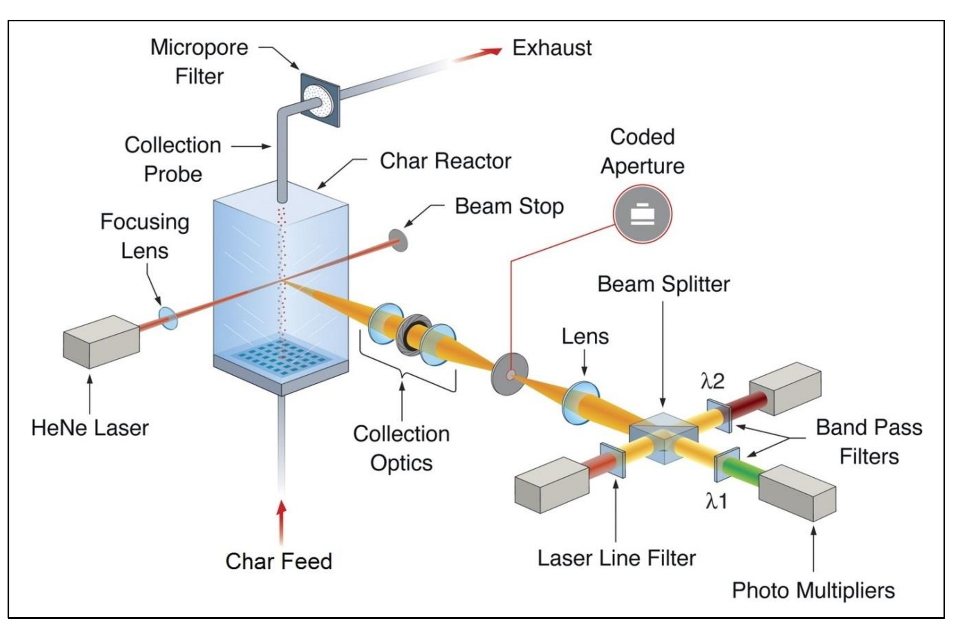
Motivation

Magnetohydrodynamic (MHD) power generation requires four essential components: a working fluid with sufficient ion conductivity, a channel for the fluid to flow in, a magnet, and load circuitry. One means of generating a suitable working fluid is to combust pulverized coal at high temperatures (2000-3000K) and seed the fluid with an alkali metal. These high combustion temperatures can be achieved by reacting the pulverized coal in a high concentration of oxygen. We have historically studied pulverized coal combustion in high concentrations of oxygen in the context of oxy-combustion of coal with carbon capture and storage. We have accurately measured ignition delays and have extensively studied char combustion and gasification kinetics under oxygen enriched conditions. We are currently extending this work to understand the effect of pressure on oxyfuel combustion. The observations and understanding we have of enhanced oxygen, high temperature pulverized coal char combustion can aid in the design of working fluid production for MHD power generation. Further, the experimental platforms we have are well-suited to extend this physical basis to even higher temperature conditions, and understand the implications of changing the combustion conditions to achieve suitable working fluid properties.

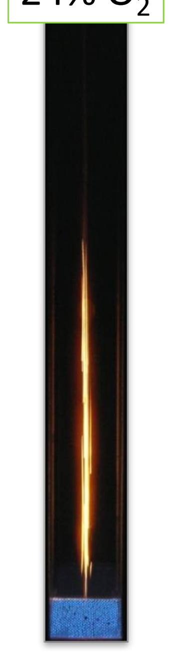
Two experimental platforms are used to study pulverized coal char combustion

- Both allow particle collection (for burnout measurements) and in-situ, individual particle temperature measurements

Char Combustion Laboratory

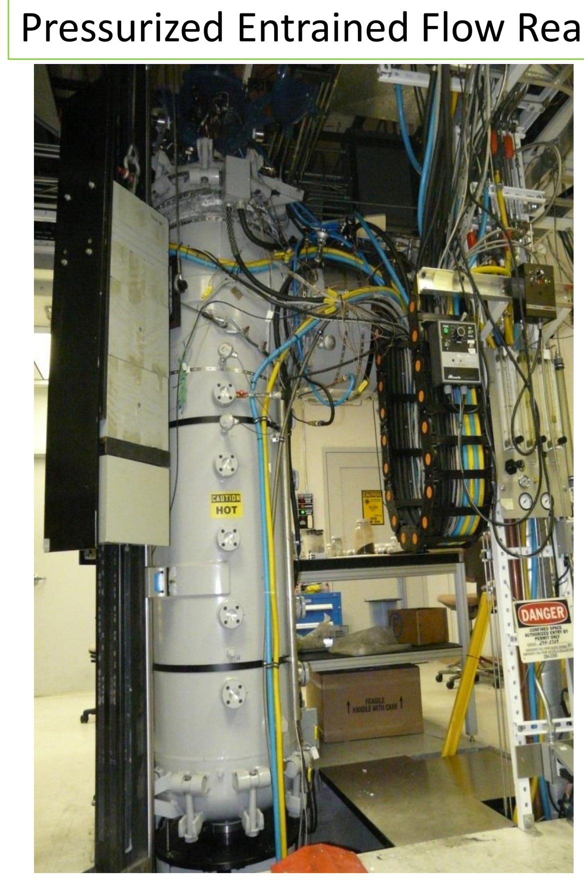


24% O_2

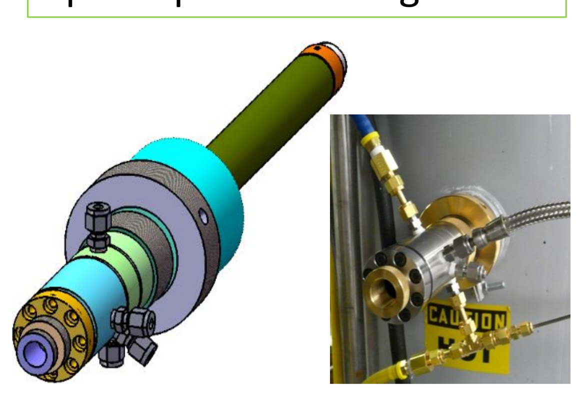


60% O_2

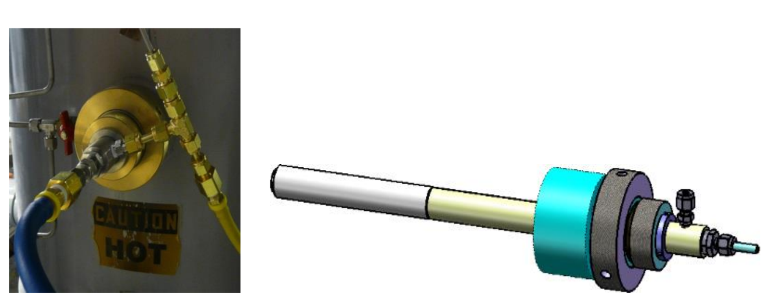
Pressurized Entrained Flow Reactor



optical probe cooling sheath

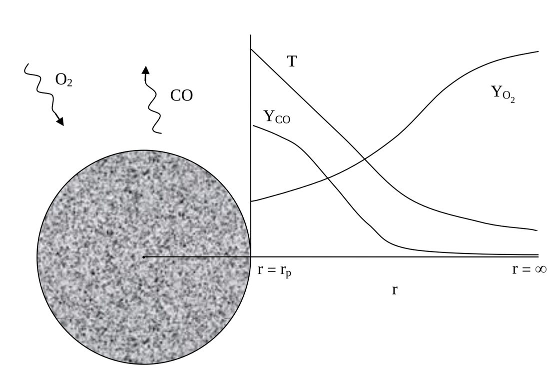


cold surface probe



Models of varying complexity are used to interpret experimental results and guide experimental design

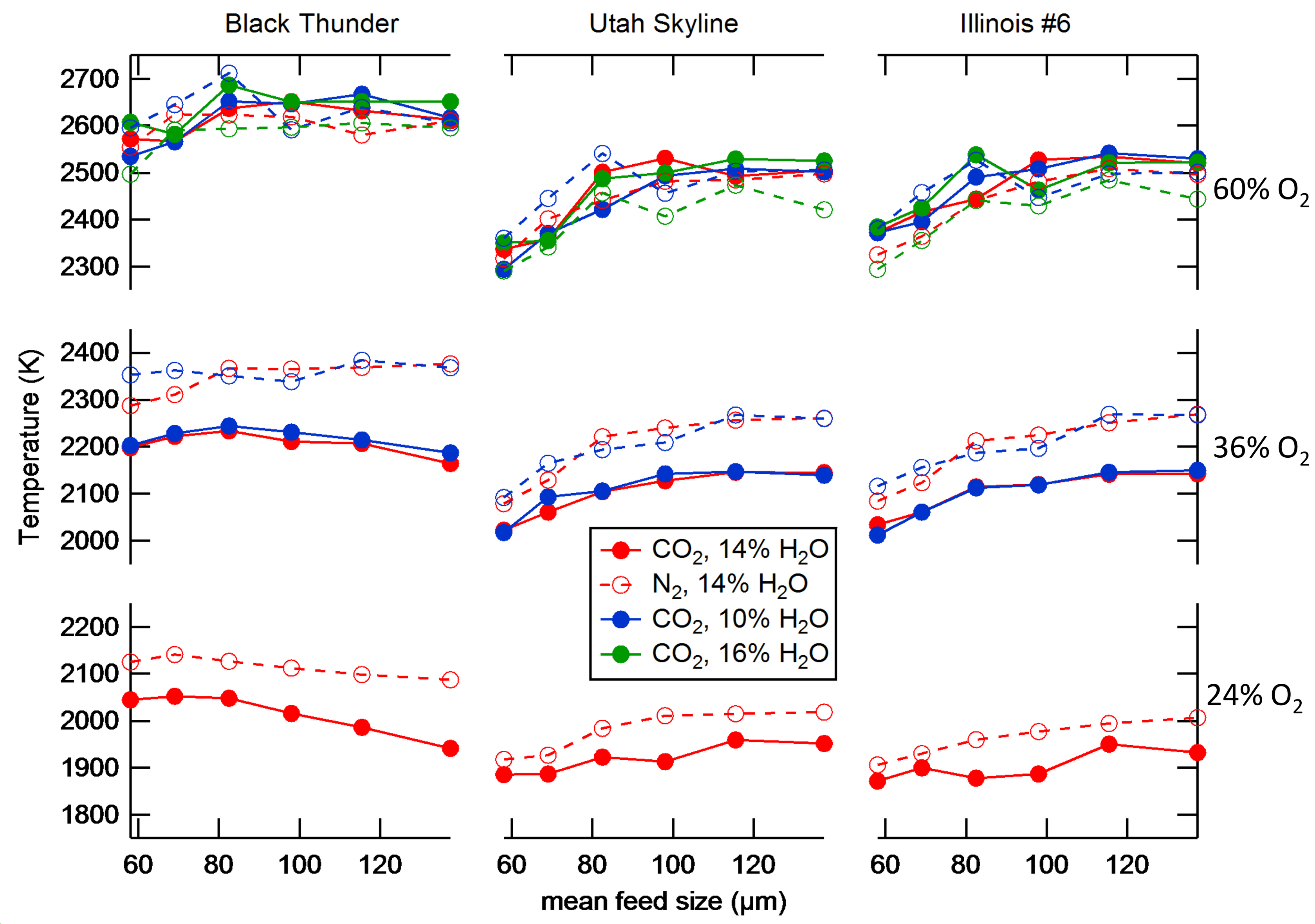
Single-film:
- No gas phase reactions
- Can include steam and CO2 gasification reactions



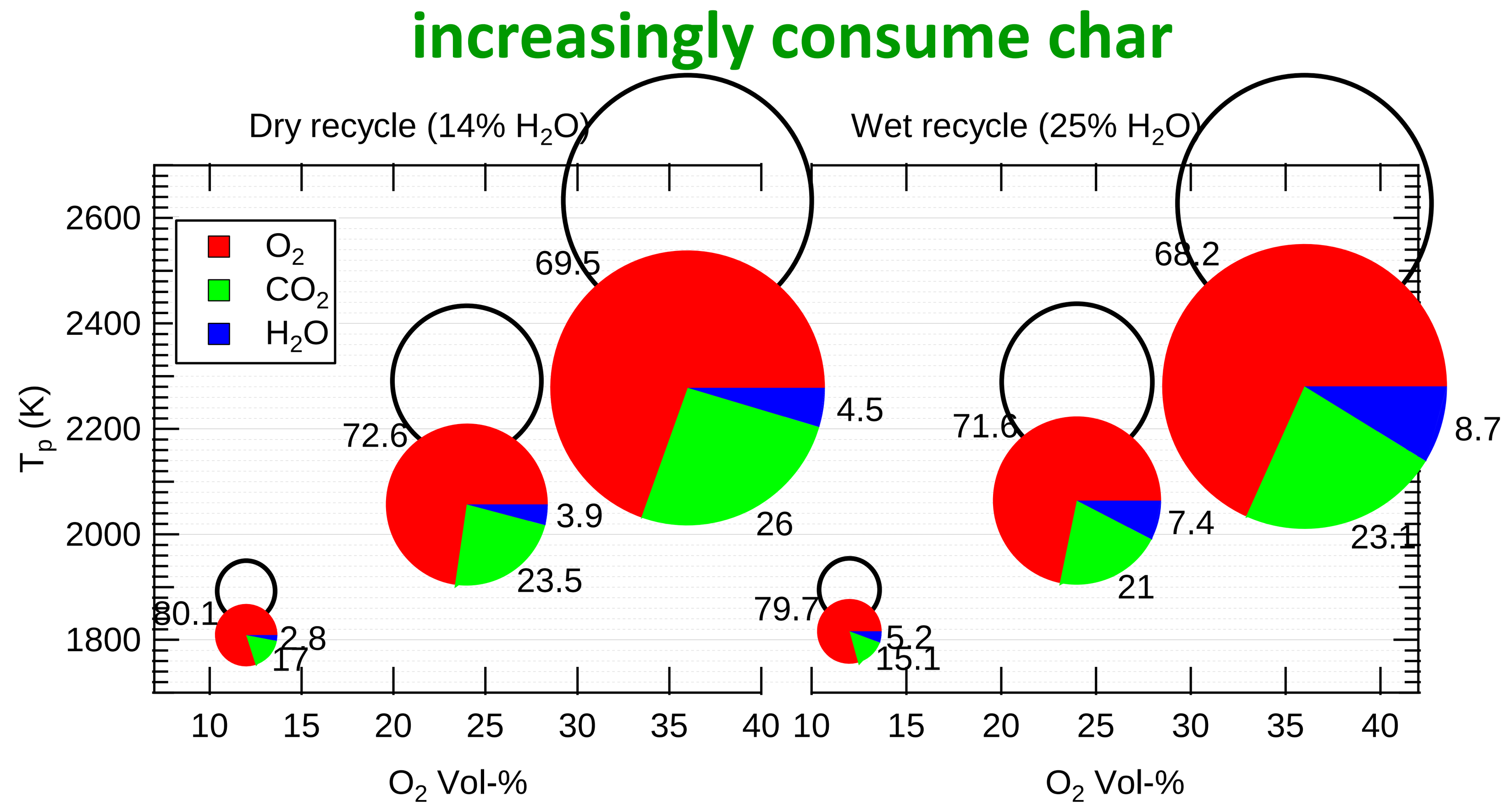
Continuous film (SKIPPY):
- Detailed gas phase and heterogeneous chemistry
- Validates use of single-film model

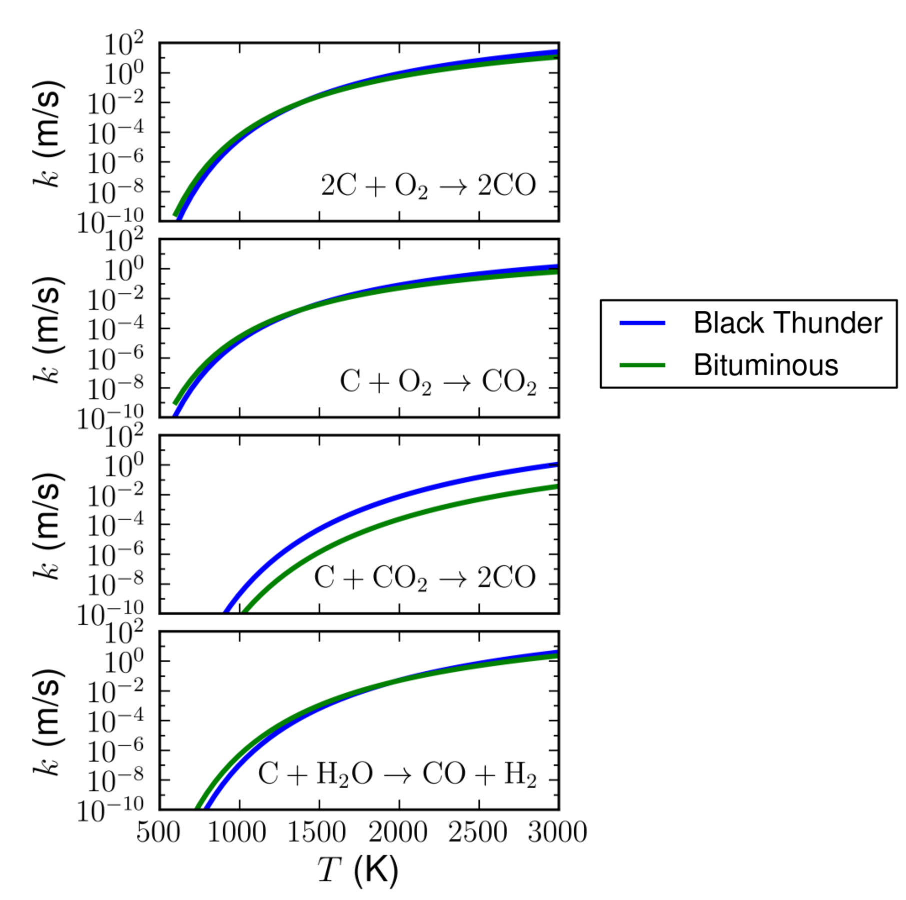
Reaction	A (g/cm² s)	E (kJ/mol)
Heterogeneous oxidation:		
(R1) C_s + O_2 => CO + O_s	3.3E+15	167.4
(R2) O_s + 2C(b) => CO + C_s	1.0E+08	0.
(R3) C_s + O_2 => O_2_s+ C(b)	9.5E+13	142.3
(R4) O_2_s + 2C(b) => C_s + CO_2	1.0E+08	0.
CO_2 gasification reaction:		
(R5) C_s + CO_2 => CO + O_s + C(b)	variable	251.0
Steam gasification reaction:		
(R6) C_s + H_2O => H_2 + O_s + C(b)	variable	222.8

Low rank coal chars burn hotter under high oxygen concentration conditions



At high temperatures, gasification reactions increasingly consume char





Conclusions

- high temperature pulverized coal combustion can be achieved with elevated oxygen concentrations (oxyfuel combustion)
- accurate measurement of char particle temperatures during oxyfuel combustion experiments is necessary to determine the balance of oxidation and gasification reactions that together determine the char burning rate
- a single-film models that accounts for oxidation and gasification reactions is generally accurate enough for oxyfuel combustion modeling
- experimental facilities at the Combustion Research Facility at Sandia National Labs are well suited to study oxyfuel combustion

Acknowledgements

This material is based upon work supported by the U.S. DOE National Energy Technology Laboratory's Cross-Cutting Research Program, managed by Susan Maley. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.