the ENERGY lab

PROJECT FACTS

Carbon Capture

# Investigation on Flame Characteristics and Burner Operability Issues of Oxy-Fuel Combustion

## Background

Fundamental and applied research on carbon capture and storage (CCS) technologies is necessary to allow the current fleet of coal-fired power plants to comply with existing and emerging environmental regulations. These technologies offer great potential for mitigating carbon dioxide ($CO_2$) emissions into the atmosphere without adversely influencing energy use or hindering economic growth.

Deploying these technologies in commercial-scale applications requires a significantly expanded workforce trained in various CCS technical and non-technical disciplines that are currently underrepresented in the United States. Education and training activities are needed to develop a future generation of geologists, scientists, and engineers who possess the skills required for implementing and deploying CCS technologies.

The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL), through funding provided by the American Recovery and Reinvestment Act (ARRA) of 2009, manages 43 projects that received more than $12.7 million in funding. The focus of these projects has been to conduct carbon capture and geologic storage training and support fundamental research projects for graduate and undergraduate students throughout the United States.

## Project Description

NETL has partnered with the University of Texas at El Paso (UTEP) to investigate the characteristics of oxy-fuel combustion (oxy-combustion) flames and assess their impact on the operability of oxy-combustion systems. The examination of fundamental flame characteristics data and related burner operability parameters is essential for the design and development of oxy-combustion systems for new coal-fired power plants and the retrofit of existing power generation units. In an oxy-combustion system, coal is combusted in an enriched oxygen environment using pure oxygen ($O_2$) diluted with recycled $CO_2$ or water vapor ($H_2O$), resulting in a flue stream consisting of only $CO_2$ and $H_2O$ (Figure 1). Oxy-combustion is promising for CCS applications because $H_2O$ can be condensed out of the $CO_2/H_2O$ stream to produce a relatively pure $CO_2$ end product for capture. Oxy-combustion and subsequent $CO_2$ capture is currently being considered by the DOE's Carbon Capture Program as having the potential to meet the goal of 90 percent $CO_2$ capture without increasing the cost of electricity by more than 35 percent.

UTEP will measure fundamental flame characteristics of oxy-combustion utilizing flat flame, nozzle, and counter-flow burners on two different fuel streams: natural gas ($CH_4$) and coal-derived synthesis gas [syngas consisting of hydrogen ($H_2$) with carbon monoxide (CO)]. The important characteristics to be examined are flame radiation, radiative heat release rate, burning velocities, flammability, and flame

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## PARTNERS

None

## PROJECT DURATION

| Start Date | End Date |
|---|---|
| 12/01/2009 | 05/30/2013 |

## COST

**Total Project Value**
$299,991

**DOE/Non-DOE Share**
$299,991/$0

American Recovery and Reinvestment Act (ARRA) Funded.

## PROJECT NUMBER

DE-FE0002402

shapes. Project researchers will systematically investigate the effects of fundamental flame characteristics on operability issues (blowout and flashback) of oxygen-fired combustors. Blowout refers to a condition where the flame lifts off from the anchoring point and is ultimately blown out of the combustor, and flashback is a condition in which the flame propagates upstream against the gas stream into the burner tube, causing serious hardware damage and increasing pollutant emissions.

A successful outcome for the project will not only improve fundamental understanding of oxy-combustion processes, but also provide critical experimental data for the validation of modeling tools. Project research is being conducted primarily by graduate students to provide them with an opportunity to receive training and experience with technical concepts related to CCS, and help cultivate the workforce required to implement CCS technologies on a commercial scale.

## Goals/Objectives

The main project goals are to investigate oxy-combustion flame characteristics, assess their impact on the operability of oxy-combustion systems, and train UTEP students in the field of oxy-combustion. The project objectives are to develop (1) a flame characteristics data set (flammability, flame radiation, radiation heat release factor, laminar and turbulent burning velocities, flame lift-off, and flame blowout); and (2) a burner operability-parameter data set (blowout, heat-flux contour, and flashback limit) for oxy-combustion.

## Accomplishments

- As of September 2012, six students had accumulated 6,082 training related hours under the program.
- The experimental setups for flat flame and tubular burner systems were developed, modified, and validated for oxy-combustion operation. A boiler system was designed and installed in the experimental setup to allow analysis and characterization of the effect of additive recirculated $H_2O$.
- Experimental measurements of radiative heat release rates of oxy-combustion flames and the subsequent effects of recirculated $CO_2$ to the oxy-combustion conditions were evaluated.
- Flame stability experiments were conducted and the results analyzed to determine the effect of $CO_2$ and $H_2O$ diluents, the percentage of $O_2$ in the fuel-oxidizer mixture at various velocities, and the recirculation ratio of $H_2O$ diluents. Testing with various fuel compositions and different burner diameters was performed to provide insight into the effect of diluent recirculation ratios on flame stability in realistic operating conditions.
- Testing was conducted for flame velocity and thermal diffusivity. The effect of diluents on flashback and blowout behavior was determined, and correlations between the diluents and the burner diameter were identified.
- Flow field visualization was performed to capture the turbulence characteristics of various oxy-combustion mixtures. The velocity fluctuations, turbulence intensities, and local propagation velocities along the combustion chamber were determined.
- The experimental setup was modified to conduct measurements of spectral radiation from $CH_4/O_2$ and syngas/$O_2$ flames with diluents of $H_2O$ and $CO_2$.
- Investigation was initiated on the turbulence flow field of premixed syngas/air flames, $CH_4/O_2$ flames, and syngas/$O_2$ flames in a laboratory-scale burner.

## Benefits

The project will make a vital contribution to the scientific, technical, and institutional knowledge needed to establish frameworks for the development of commercial-scale CCS. Improved fundamental flame characteristics and related burner operability parameters are essential for designing and developing future oxy-combustion systems for new power plants and retrofitting existing power generation units to facilitate large-scale CCS. Oxy-combustion data attained through research are critically needed to validate and improve the fidelity of modeling tools to optimize oxy-combustion systems. Furthermore, this research opportunity provides the historically under-represented groups at UTEP with an opportunity to participate in advanced carbon capture research.

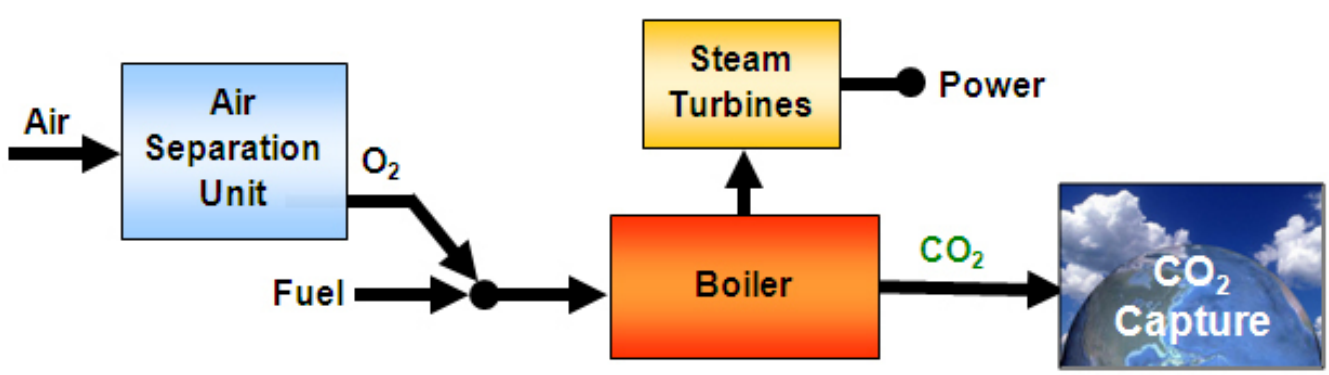


*Figure1. Schematic describing the basic oxy-combustion process.*