the ENERGY lab

High Efficiency Molten Bed Oxy-Coal Combustion with Low Flue Gas Recirculation

Background

The Advanced Combustion Systems (ACS) Program of the U.S. Department of Energy/National Energy Technology Laboratory (DOE/NETL) is aiming to develop advanced oxy-combustion systems that have the potential to improve the efficiency and environmental impact of coal-based power generation systems. Currently available carbon dioxide (CO_2) capture and storage technologies significantly reduce the efficiency of the power cycle. The ACS Program is focused on developing advanced oxy-combustion systems capable of achieving power plant efficiencies approaching those of air-fired systems without CO_2 capture. Additionally, the program looks to accomplish this while maintaining near zero emissions of other flue gas pollutants.

Oxy-combustion systems use high purity oxygen to combust coal and produce a highly concentrated CO_2 stream that can be more easily separated out of the flue gas. First generation oxy-combustion systems utilize oxygen from a cryogenic air separation unit integrated with a boiler system that represents current state-of-the-art air-fired boiler designs. These first generation oxy-combustion systems have demonstrated technology viability; however, further research is needed to develop advanced oxy-combustion systems to progress toward meeting the DOE carbon capture goals.

Oxy-combustion system performance can be improved either by lowering the cost of oxygen supplied to the system or by increasing the overall system efficiency. NETL targets both of these possible improvements through sponsored cost-shared research into pressurized oxy-combustion and chemical looping combustion (CLC). Through the two-phase Advanced Oxy-combustion Technology Development and Scale-up for New and Existing Coal-fired Power Plants Funding Opportunity Announcement, eight projects were recently chosen to begin Phase I. Under the 12 month Phase I effort, validation of the proposed pressurized oxy-combustion or CLC process will be accomplished through engineering system and economic analyses. Phase I projects will be eligible to apply for Phase II awards to develop and test the novel process components at the laboratory or bench scale.

Project Description

Gas Technology Institute (GTI) is leading a team to evaluate the potential of a novel pressurized oxy-combustion process based on a molten bed combustor. The molten bed combustor concept is derived from proven GTI engineering of a submerged combustion melting process. It is designed to maximize efficiency and minimize the cost of pressurized oxy-combustion by greatly reducing flue gas recirculation (FGR) while operating at elevated pressure. The unique combustion and heat transfer design employs a smaller and less expensive combustor and reduced gas-phase heat

PROJECT FACTS

Advanced Combustion Systems

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PARTNERS

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Reaction Engineering International
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PERFORMANCE PERIOD

Start Date	End Date
10/01/2012	09/30/2013

COST

Total Project Value
$1,000,000

DOE/Non-DOE Share
$800,000 / $200,000

AWARD NUMBER

DE-FE0009686

U.S. DEPARTMENT OF ENERGY

exchanger surface area. Decreasing the amount of FGR by up to 90 percent reduces capital cost and requires less maintenance. A small amount of flue gas is used for coal crushing and transportation to the burners. Exhaust gas handling and cleaning equipment will be reduced in size and cost. Cost savings are also realized from ash recovery as frit rather than micron-sized fines, which can be difficult to handle, and the potential exists to capture a large portion of the sulfur and mercury in stable forms in the molten slag.

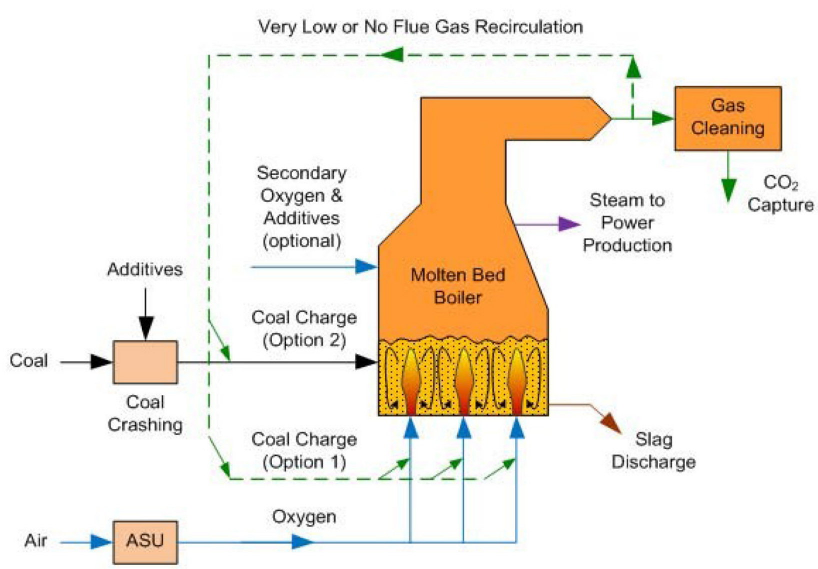
In this Phase I project, work will be focused on technical and economic analysis of a pressurized oxy-combustion power plant design based on the molten bed combustor and following NETL protocols with comparisons to a baseline supercritical steam power plant burning Illinois #6 bituminous coal. Engineering design and economic analyses will be carried out by GTI and Nexant. Oxy-coal burner testing and thermodynamic analyses will be conducted at Brigham Young University (BYU). Reaction Engineering International (REI) will address corrosion concerns and set up preliminary computational fluid dynamic (CFD) models for Phase 2 testing and scale-up. Cost sharing is being provided by the Illinois Clean Coal Institute and Infrastar Advisers, LLC.

Primary Project Goal

The project goal is to perform a techno-economic analysis of a pressurized oxy-coal power plant design based on the molten bed combustor to confirm that the design can lead to the DOE target of achieving 90 percent capture at less than a 35 percent increase in cost of electricity (COE).

Objectives

The project objective is to conduct engineering design and economic analyses of the pressurized, molten bed oxy-combustor including completion of oxy-combustion burner testing, mass and energy balance calculations, thermodynamic energy and exergy analyses, and corrosion assessment.



Block flow diagram for advanced technology case oxy-combustion, pressurized, molten bath, supercritical with CO_2 capture.

Planned Activities

- Engineering design and economic analyses calculations will be conducted using Aspen Plus® process modeling software. A strategy will be prepared for thermal integration and emission control using molten bed combustor material balance information. Thermal integration will utilize the GateCycle software package.
- An equipment list and cost estimates will be developed for each piece of equipment. Overall capital cost for the facility will be developed along with indirect costs, owner's costs, and the preparation of the COE calculations.
- Oxy-combustion burner testing will be conducted at the Burner Flow Reactor (BFR) located at BYU to obtain gas species, deposit compositions, heat flux, and flame temperature data.
- Thermodynamic energy and exergy analyses of the molten bed combustor based power plant will be conducted. Following an initial set of predicted gas species concentrations intended to guide the engineering analysis, a zero dimensional mass and energy balance model will be produced, including equilibrium calculations using a commercial equilibrium code (HSC Chemistry 7.0). A computer program will be written using commercial thermodynamic based software that considers the exergy destroyed in each process of the combustion stream and steam cycle.
- A corrosion assessment will be conducted to study the potential for high-temperature corrosion of heat exchanger and other surfaces from SO_2 and CO_2 concentrations.
- Computational fluid dynamics modeling will be used along with insight gained from the project results to create a first-generation conceptual design for scale-up to demonstration scale.

Accomplishments

Project awarded in September 2012.

Benefits

The unique approach of this molten bed oxy-combustion process offers potential benefits that may not be possible through modification of existing pulverized coal boilers. The design and development work accomplished for this new type of boiler will yield relevant technical and economic information of its advantages, including a plant efficiency increase of 4 percent, large reduction in FGR duct and equipment sizes, lower exhaust gas volume and less gas handling and cleaning equipment, reduction of boiler size by more than 50 percent, decreased convective path heat exchanger surface area and maintenance, near elimination of fine ash carryover into the exhaust gas, and recovery of ash/slag as aggregate instead of as micron-sized particulates.