Optimization of Pressurized Oxy-Combustion with Flameless Reactor

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 design. These first generation oxy-combustion systems have demonstrated technology viability; however, further research is needed to develop advanced oxy-combustion systems to meet 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

Unity Power Alliance, in collaboration with their partners, will examine a novel pressurized oxy-combustion technology with potential for increasing process efficiency and reducing emissions and costs associated with CO_2 capture and compression. This project will advance the state of the art in oxy-combustion technology by laying the groundwork for development of a pilot-scale oxy-combustion facility operating at very high pressure (up to 70 bar) with a heat recovery steam generator (HRSG) inlet temperature of 700 °C (current technology is at 605 °C) using a flameless combustion

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PARTNERS

ThermoEnergy Corporation
ITEA SpA
Massachusetts Institute of Technology
Georgia Institute of Technology

PERFORMANCE PERIOD

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

COST

Total Project Value
$1,514,709

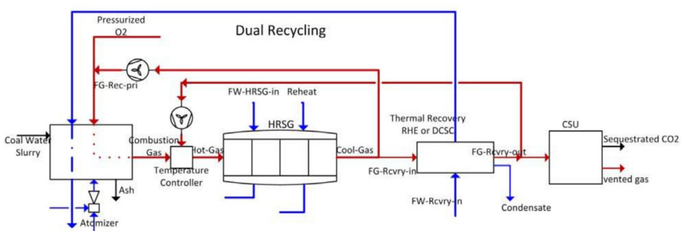
DOE/Non-DOE Share
$1,000,000/$514,709

AWARD NUMBER

DE-FE0009478

reactor. The system is expected to achieve an approximately 10 percent efficiency improvement over oxy-combustion at atmospheric pressure, reduce costs associated with CO_2 compression, and avoid the need for costly and energy-intensive flue gas treatment.

The use of high pressure is expected to reduce the cost of electricity (COE) by improving generation efficiency through higher heat transfer rates, recycling of high temperature condensate, and by reducing capital and operating expenses associated with pressurizing the emitted CO_2. In addition to the efficiency benefits, the capture of CO_2 at higher pressure would enable nearly 100 percent CO_2 capture and would cause the power cycle to generate more water than it consumes (the system would be “net water positive”). Condensate could be recycled for use in preparation of the coal-slurry feedstock, significantly reducing the water demands of the system.



Pressurized oxy-combustion power cycle with dual flue gas recycling

In contrast to a conventional coal combustion furnace, flameless combustion approximates the conditions of an isothermal chemical reactor in which temperatures remain uniform and constant throughout the reaction process. This highly-efficient, carefully controlled reaction promotes complete combustion of coal at high temperatures with negligible generation of airborne particulates or hazardous pollutants. The majority of the pollutants that are normally released in flue gas are instead permanently entrained in a vitrified or glass-like slag. As a result, the use of a flameless reactor mitigates the need for costly and energy intensive flue gas treatment.

In Phase I, the project will encompass two independent research efforts: (1) computer modeling and optimization of pressurized oxy-combustion with a flameless reactor, and (2) design, construction, and testing of a 100 kilowatt (kW) bench-scale flameless reactor.

Primary Project Goal

The goal of this project is to optimize the pressurized oxy-combustion technology utilizing the flameless reactor and advanced HRSG, while capturing and compressing CO_2 at a greater than 90 percent rate with no more than a 35 percent increase in COE.

Objectives

The specific objectives of this project are to (1) identify the optimum operating pressure, flue gas recycling method, and oxygen purity level for flameless pressurized oxy-combustion to improve overall system efficiency and minimize COE; (2) confirm the fate of sulfur, oxides of nitrogen, particulate matter, and mercury and other pollutants through bench-scale testing of a high-pressure flameless reactor with the goal of substantially reducing or eliminating emissions of these pollutants; (3) confirm that the system design can achieve net water positive conditions and near zero level discharge of wastewater; and (4) confirm, through modeling and bench-scale testing, that a flameless pressurized oxy-combustion system can be built and operated with improved overall efficiency and the capability to achieve DOE goals.

Planned Activities

- Develop a model capable of determining the optimal process cycle configuration, examining operating performance and efficiency as a function of pressure in the range of 5–70 bar, and selecting among three alternatives for recycling of flue gas: wet, dry, or dual recycling.
- Design a 100 kW bench-scale testing unit and testing program to prove flameless reactor (combustor) technology at pressures up to 70 bar.
- Construct, install, and commission the 100 kW bench-scale reactor at GA Tech’s Carbon Neutral Energy Solutions facility.
- Conduct bench-scale testing with bituminous, sub-bituminous, and lignite coals at pressure ranges from 5–50 bar to confirm/determine operating conditions which support a flameless reaction.
- Complete a Phase I technology engineering design and economic analysis and a Phase I technology gap analysis.

Accomplishments

- Project awarded in September 2012.

Benefits

The pressurized oxy-combustion technology with flameless reactor has the potential to contribute to securing a power generation role for coal in a future CO_2-constrained economy by achieving the DOE goals of a minimum of 90 percent CO_2 capture with compression to 2,200 pounds per square inch and a 35 percent or less increase in COE, while concurrently increasing overall plant efficiencies. The use of flameless technology will mitigate or even eliminate the need for flue gas treatment, because most of the pollutants that are normally emitted in flue gas will be entrained in vitrified slag formed in the flameless reactor. The vitrified slag is expected to have a lower cost of disposal than conventional coal combustion residuals, because vitrification has been shown to eliminate leaching issues. As a result, the slag can be safely landfilled or sold for beneficial uses.

NETL