the ENERGY lab

PROJECT FACTS

Advanced Combustion Systems

Solid-Fueled Pressurized Chemical Looping with Flue-Gas Turbine Combined Cycle for Improved Plant Efficiency and CO_2 Capture

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 (ASU) 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). Chemical looping combustion conducts the oxidation and reduction reactions in separate reactors, allowing the capture of concentrated CO_2 and requiring no ASU. 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.

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PARTNERS

WorleyParsons
Southeast University
Süd-Chemie Inc.

PERFORMANCE PERIOD

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

COST

Total Project Value
$755,300

DOE/Non-DOE Share
$599,687/$155,613

AWARD NUMBER

FE0009469

U.S. DEPARTMENT OF ENERGY

Project Description

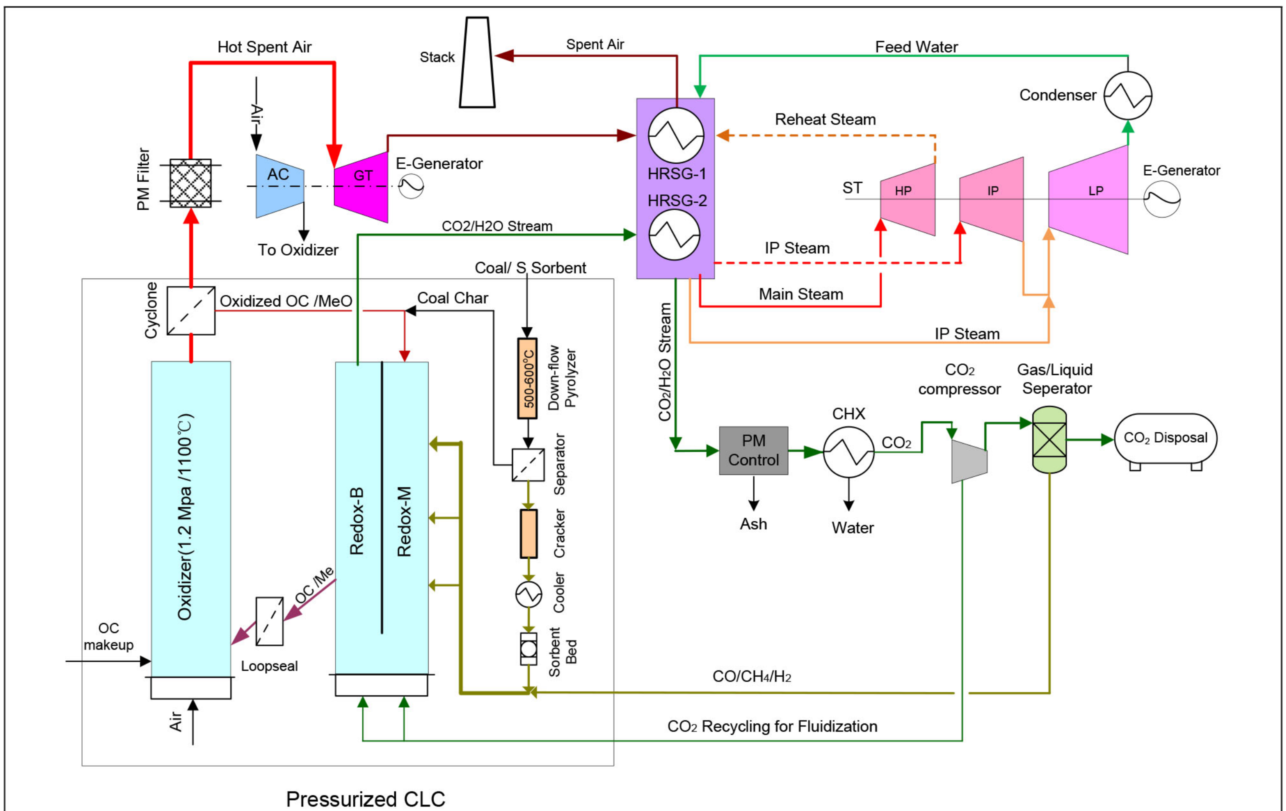
The University of Kentucky Center for Applied Energy Research (CAER) is developing a heat-integrated coal-based combined cycle for power generation using a pressurized chemical looping combustor (PCLC). The PCLC system may achieve an overall plant thermal efficiency of approximately 48 percent [lower heating value (LHV)] by passing the high-temperature flue gas through a gas turbine for electricity generation and a heat recovery steam generator (HRSG) for supercritical steam production used to drive a conventional steam cycle.

The PCLC system contains an oxidizing reactor, in which oxygen from air is selectively fixed into an oxygen-carrier structure, and a reducer reactor in which coal is burned by the oxygen carrier. The PCLC will generate two gas streams: (1) a high-temperature, high-pressure, alkali-free, clean gas stream from the oxidizer used to drive a gas turbine followed by a HRSG, and (2) a small-volume CO_2-enriched stream from the reducer for sequestration. Advantages of the PCLC system include lower power requirements for compression of the enriched CO_2 stream, reduced reactor size due to elevated operation pressure, and significant reduction to cost of electricity (COE) of a commercialized CLC power plant by using a relatively high-performance and cost-effective iron-based oxygen carrier. The PCLC system holds potential to meet DOE's target of limiting the energy penalty with no more than a 35 percent increase in the COE, while capturing at least 90 percent of the CO_2 released during the combustion of fossil fuels.

A design basis and final design package will be developed in Phase I. The major equipment will be sized using data obtained from previous thermogravimetric analyses and bench- and pilot-scale apparatuses operated at CAER and Southeast University (SEU), respectively. The data will be used to determine suitable reaction kinetics, oxygen carrier make-up rate, carbon slip ratio between air and fuel reactor, as well as temperature and pressure profiles along the reactors. A rate-based Aspen Plus® process model will be built for the heat-integrated combined cycle to provide the necessary stream table for technical analysis. A detailed process design basis and engineering flow chart with appropriately sized equipment will be provided for an economic analysis of a commercial-scale PCLC system.

Primary Project Goal

The primary project goal is to develop an innovative design for a pressurized chemical looping combustion process and validate its application to solid fuels, resulting in a higher efficiency alternative technology for electricity generation with CO_2 capture and a cost-effective means to control emissions.



The PCLC process under development

Objectives

Objectives of Phase I are to (1) gather critical process parameters for design of the equipment needed to complete the integration of the PCLC subsystem into a power generation plant; (2) perform Aspen Plus simulations of the process; (3) conduct a cost and economic analysis of the PCLC process as applied to solid fuels; and (4) conduct a technology gap analysis.

Planned Activities

- Collect and analyze data obtained from CAER and SEU to determine basic design parameters.
- Complete a preliminary process design for a 200 kW_{th} pilot-scale facility, including major equipment sizing and energy and mass balances.
- Perform Aspen Plus simulations of the heat-integrated combined cycle process.
- Determine detailed sizing of the selected reactor configuration.
- Perform a preliminary technical and economic analysis of the proposed process design to be implemented at commercial scale based on existing laboratory and pilot test data.
- Perform a comparative financial analysis to compare the PCLC CO_2 capture technology to state-of-the-art coal-fired generation technologies.
- Complete a technology gap analysis to identify all research needs required to fully develop the technology for commercial use.

Accomplishments

- Project awarded in September 2012.

Benefits

Key potential benefits from this investigation include the provision of a higher-efficiency alternative technology for electricity generation with CO_2 capture; a cost-effective means to control emissions such as sulfur, mercury, and trace metals; and deep reductions in nitrogen oxide formation due to coal-free combustion of the oxygen carrier to generate steam.