the ENERGY lab

PROJECT FACTS

Existing Plants, Emissions & Capture

CANMET CO_2 Consortium - O_2/CO_2 Recycle Combustion

Background

The mission of the U.S. Department of Energy/National Energy Technology Laboratory (DOE/NETL) Existing Plants, Emissions & Capture (EPEC) Research & Development (R&D) Program is to develop innovative environmental control technologies to enable full use of the nation's vast coal reserves, while at the same time allowing the current fleet of coal-fired power plants to comply with existing and emerging environmental regulations. The EPEC R&D Program portfolio of post- and oxy-combustion carbon dioxide (CO_2) emissions control technologies and CO_2 compression is focused on advancing technological options for the existing fleet of coal-fired power plants in the event of carbon constraints.

Oxy-combustion, or burning of fuel in an atmosphere of nearly pure oxygen (O_2) to generate flue gas consisting primarily of CO_2 and water, has been established as a credible means to facilitate CO_2 capture from coal power plants. The economics of conventional oxy-combustion processes are currently limited by the parasitic power required for cryogenic O_2 production in conventional air separation units. A further limitation of oxy-combustion is the requirement that a portion of the CO_2 in the exhaust must be cooled and recycled in order to maintain the temperature in the combustion chamber within practical limits.

The CANMET Energy Technology Centre-Ottawa (CETC-O) has developed a world class pilot-scale research facility to perform advanced oxy-combustion research. The CanmetENERGY CO_2 R&D Consortium (Consortium), comprising national and international industry and government partners, was formed to pursue fundamental and pre-competitive research exploring the capture of CO_2 from fossil fuel power plants using O_2- enhanced combustion technologies. DOE provides funding to the Consortium through an agreement with the International Energy Agency Greenhouse Gas Program.

Description

The CanmetENERGY CO_2 R&D Consortium program started in 1994 with development of an advanced oxy-combustion pilot-scale research facility—the Vertical Combustion Research Facility (VCRF)—and has undergone eight successive phases

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PARTNERS

CanmetENERGY CO_2 R&D Consortium

PERFORMANCE PERIOD

Start Date	End Date
09/30/1999	12/31/2009

COMPLETED

COST

Total Project Value
$5,482,750

DOE/Non-DOE Share
$375,000 / $5,107,750

AWARD NUMBER

IEA-CANMET-CO_2

U.S. DEPARTMENT OF ENERGY

of R&D to help bring oxy-combustion, advanced power cycles, integrated multi-pollutant, and CO_2 capture technologies to a level of commercial acceptance.

The Consortium has reached Phase 9, development of the first-of-its-kind CO_2 capture and compression unit (CO_2CCU). This unit is capable of separating and compressing CO_2 from combustion flue gas streams for pipeline transport and storage. Part of this work involves studying CO_2 phase changes and the impact of impurities in the gas stream on the capture process. Other ongoing R&D activities include the modeling of advanced near-zero-emissions cycles (including supercritical and ultra-supercritical oxy-combustion plants with CO_2 capture), the development and testing of multi-pollutant control strategies, and testing and optimization of a novel multi-function oxy-fuel/steam burner.

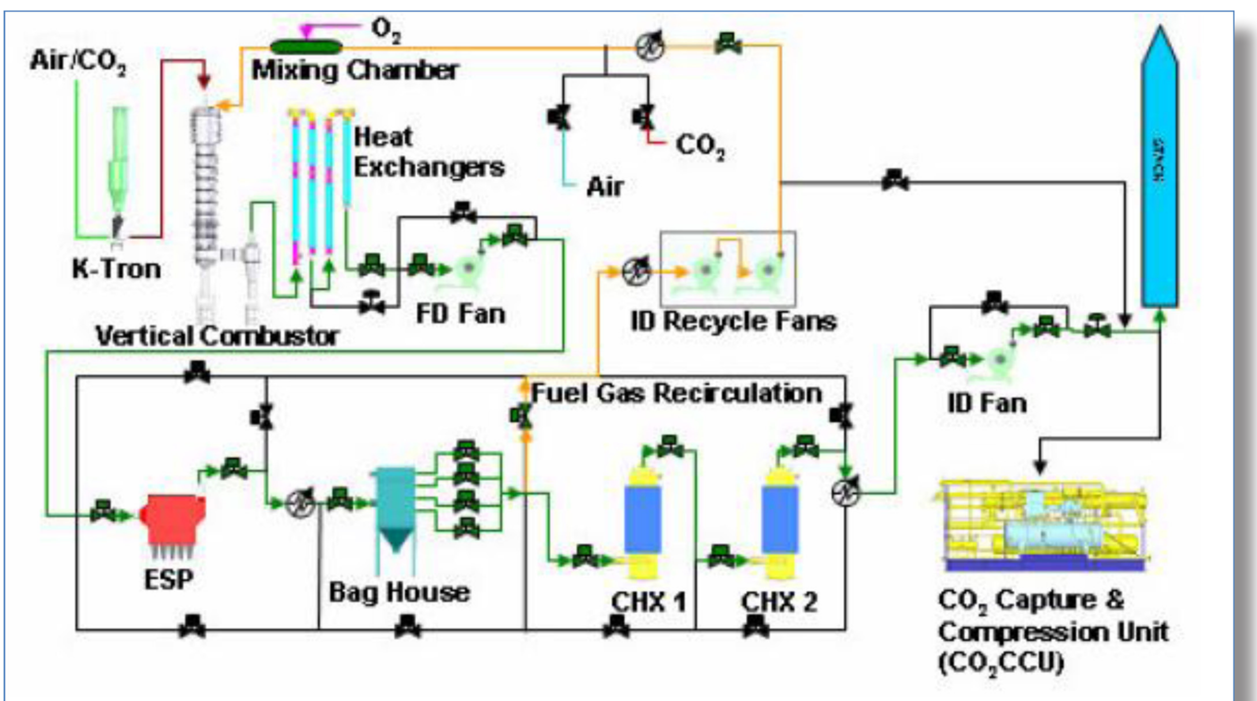
Project Goal

The project goal is to conduct research to further the development of oxy-combustion for retrofit to coal-fired power plants using a 0.3 megawatt thermal (MWth; 1 million Btu per hour) modular pilot-scale facility.

Objectives

The objectives of the Consortium Phase 9 program are to evaluate an expanded array of new technologies and process options for application in new, clean fossil power plants with CO_2 capture, including:

- Modeling and analysis of an advanced supercritical (ASC) oxy-combustion plant. The work also includes a cost analysis, impact of O_2 purity and O_2 partial enrichment, and overall process performance analysis.
- Performance testing of a pilot-scale CO_2CCU.
- Experimental investigation of CO_2 phase change at liquid and supercritical states in gas mixtures resulting from the oxy-combustion of fossil fuels.
- Testing and performance optimization of a novel multi-function oxy-combustion/steam burner.
- Development of an efficient mercury (Hg) removal process and analysis of multi-pollutant control strategies for oxy-combustion fired power plants.



Schematic of the Vertical Combustion Research Facility.

- Development of an advanced gas turbine cycle (100 MW class) for near-zero-emission combustion systems.

- Development of tools and processes for near-zero-emission advanced gas turbine cycle integrated with a solid-oxide fuel cell (SOFC).

Planned Activities

- Optimize the operation of the oxy-combustion combustion process with bituminous coal and a low rank coal at low excess oxygen conditions in both high and low purity oxygen streams using a new low nitrogen oxides (NO_x) burner, upstream sorbent injection for oxidized Hg removal, and variable flue gas recirculation rates to reduce in situ combustion generated pollutants. Simultaneously, evaluate the carbon burnout, ash formation properties, and convective and radiant heat transfer behavior in the furnace.

- Complete the development of an integrated multi-pollutant capture approach incorporating a fabric filter (or electrostatic precipitator) and a condensing heat exchanger system operating in a water condensing and/or sulfur oxide (SO_x) scrubbing environment to remove fine particulates, acid gases, and oxidized Hg. Synergies in the downstream gas cleaning approach with in situ pollutant reduction arising from the upstream oxy-fuel combustion process will also be explored.

- Develop an improved understanding of the phase behavior of CO_2 with minor impurities in the stream and evaluate its compressibility and performance in a purpose built CO_2 compression train.

- Undertake process modeling of oxy-combustion CO_2 capture power plant configurations based on these experimental findings.

Accomplishments

- A process model of an ASC oxy-combustion plant was developed using Aspen HYSYS for the air separation unit and the CO_2 capture and compression unit, and a CANMET code for the advanced super-critical boiler, balance-of-plant, and integrated pollution control.

- Based on the process model results, an Excel-based cost model was developed that determines the plant capital cost, levelized cost of electricity, and CO_2 avoidance cost, as well as performs sensitivity analyses. The methods and tools used to build the economic model include vendor quotes, costing software, scaled estimates from prior projects, and costing correlations from plant design references.

- A trailer mounted CO_2CCU unit was built, installed, and commissioned at the VCRF. Performance testing of the unit was conducted with synthetic flue gas mixtures and actual flue gas from the VCRF.

- A bench-scale CO_2 pressure cell was designed, built, and commissioned to study the phase behavior of various CO_2 gas mixtures at different pressure and temperature conditions. Preliminary testing was conducted on CO_2 and O_2 systems.

- Performance of a 4th generation novel burner design was tested in the VCRF to establish the operational envelope of the burner. Tests were performed with coal under oxy-combustion and oxy-steam conditions.

- The effectiveness of Hg removal processes for oxy-combustion power plants was tested.

- Performance of multi-pollutant control strategies was tested and evaluated. The electrostatic precipitator, baghouse, wet scrubber unit, and CO_2CCU were tested with different combustion and recycle conditions.

- Testing and evaluation of low-ash petcoke co-firing on performance and emissions, in both air and O_2-enriched environments, was performed.

Benefits

Pilot-scale R&D utilizing the VCRF and the CO_2CCU is a cost-effective means to obtain proof-of-concept results and provide valuable knowledge applicable to oxy-combustion coal-fired power plants with CO_2 separation, compression, and transportation, as well as with multi-pollutant control strategies. This research has important practical applications relating to CO_2 pipelines, material selection, and commercial design and implementation of these systems.