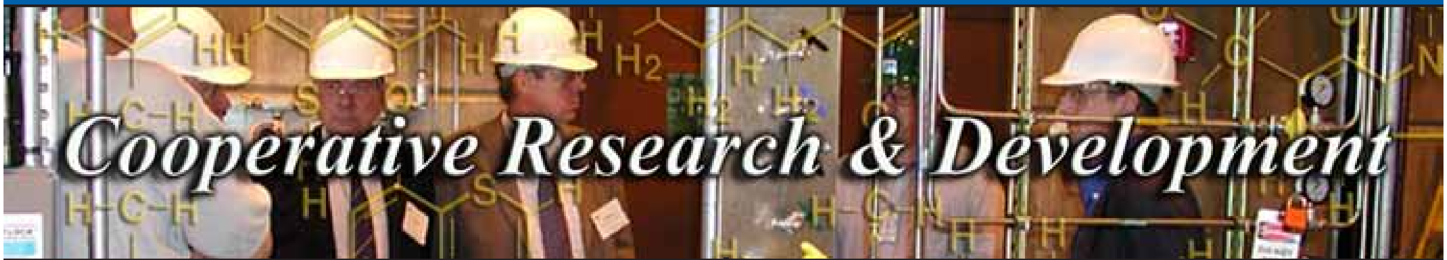
U.S. Department of Energy • Office of Fossil Energy
National Energy Technology Laboratory



Successes

Novel Oxygen Supply Process for Oxycombustion Applications

Advanced Research

To support coal and power systems development, NETL's Advanced Research Program conducts a range of pre-competitive research focused on breakthroughs in materials and processes, coal utilization science, sensors and controls, computational energy science, and bioprocessing—opening new avenues to gains in power plant efficiency, reliability, and environmental quality. NETL also sponsors cooperative educational initiatives in University Coal Research, Historically Black Colleges and Universities, and Other Minority Institutions.

Accomplishments

- ✓ **Process improvement**
- ✓ **Cost reduction**
- ✓ **Greater efficiency**
- ✓ **Innovative materials**

NETL

Description

The University of Wyoming's Western Research Institute (WRI), Laramie, has successfully completed a two-year jointly sponsored research project with BOC/The Linde Group, Murray Hill, New Jersey, to develop a pilot-scale test facility and perform operational testing of an innovative process for oxygen production and supply to oxy-fuel combustion (oxycombustion) boilers using recycled flue gas. The research was co-sponsored by the U.S. Department of Energy's Office of Fossil Energy (DOE-FE) and administered by the Advanced Research program at DOE's National Energy Technology Laboratory (NETL).

Oxycombustion is a viable approach to control pollutants such as nitrogen oxides (NO_X), implement carbon management, and provide potentially enhanced mercury sorption during the combustion of pulverized coal. In an oxy-fuel combustion-based power plant, oxygen rather than air is used to burn a fossil fuel such as coal, which results in a highly pure exhaust stream that can be captured at relatively low cost and stored in a variety of ways. Oxycombustion is a promising technology to capture greenhouse gases including carbon dioxide (CO_2) at existing coal-fired power plants.

The key requirement to making the oxycombustion power plant an option for the electric utility industry is a significant reduction in the cost of supplying oxygen. No commercial oxycombustion power plants are operating yet, due mainly to the high cost of producing oxygen using current methods, primarily cryogenic technology. Research is under way on a number of options to advance technologies that will both cost-effectively produce oxygen, and enable plant operators to utilize that oxygen for advanced oxycombustion. These projects are expected to help advance the timeline to commercialize oxycombustion technology.

BOC, the world's second largest industrial gas company, has developed a novel high-temperature sorption-based technology referred to as the Ceramic Autothermal Recovery (CAR) process, which is used to produce oxygen that is supplied to oxycombustion boilers with flue gas recycle. This technology is based on sorption and storage of oxygen in a fixed bed that contains mixed ionic and electronic conductor materials. The process uses the mineral perovskite to absorb oxygen and subsequently release it in a circulating fluidized bed. The oxygen then is stored and used to replace combustion air in a conventional pulverized coal (PC) boiler by partial pressure reduction using a sweep gas such as hot recycled flue gas or steam. In a cyclical process, air is passed through one bed to allow sorption and storage of oxygen and steam, while hot flue gas is passed through the other bed to release the stored oxygen for use in the boiler. The recirculated flue gas that results from this process is rich in CO_2, making it easier to capture and sequester.

One key requirement to validate the CAR process was the design and testing of a pilot-scale process development unit (PDU), which could be integrated with a coal-fired boiler and operated at pilot scale to identify and resolve issues.

Objectives

The overall objective of this research was for WRI to work with BOC to develop, fabricate, integrate, and evaluate BOC's CAR system with a simulated PC boiler using CO_2/flue gas recirculation to moderate the temperature. Specific objectives included:

- Construction by BOC of a CAR PDU capable of producing 10 standard cubic feet per minute (scfm) of oxygen using recirculated flue gas provided from the 250,000 Btu/hour WRI Coal Combustion Test Facility as the sweep gas (a gas used to purge a constituent separated from solid sorbent or to regenerate the solid sorbent);
- Integration of the pilot-scale CAR with the test facility;
- Determination of the operability of the CAR system when integrated with the test facility; and
- Determination of combustion and heat transfer characteristics of the combined system during operation.

Project Duration

Start Date
10/01/04

End Date
09/30/06

Cost

Total Project Value
$0

DOE/Non-DOE Share
$0 / $0

Industrial Partner

Co-Sponsor
BOC/The Linde Group
100 Mountain Avenue
Murray Hill, NJ 07974-2082
800-262-4273 or 908-464-8100
USweb-inquiries@boc.com

Accomplishments

The CAR PDU was designed and fabricated at BOC in Murray Hill, New Jersey. The unit then was shipped to WRI in Laramie, Wyoming, where the site had been prepared by installing air, carbon dioxide, natural gas, nitrogen, computer, electrical, and infrastructure systems. Staff from BOC travelled to WRI and assisted with installation and shakedown testing. The programmable logic control (PLC) system was turned on, and communications between the control computer and PLC were checked. Shortly after initial testing of component functionality, and after minor alterations and hardware adjustments, all systems were found to be within operational parameters. Eventually, online computer access was established so that BOC staff could monitor the unit remotely. System components are shown in Figures 1 & 2.

Figure 1. CAR PDU in place at WRI

Initial PDU experiments consisted of flowing air into both sides of the absorption systems, and using air heaters to warm the bed temperatures to about 750 °F. At that point, combustible methane was introduced at a low concentration (2–3 percent by volume) to ramp up the bed to operational temperatures. The two beds were tested individually to operational temperatures, up to about 1,650 °F. Temperatures of 1,470–1,650 °F in the bed are necessary to maintain proper temperatures when cycling begins. The cyclical process was tested with gases flowing alternatively from the top and then the bottom of the beds. During the tests, the PDU operated as expected with respect to flow, pressure, and heat. The PDU advanced to the point at which oxygen production testing could begin, and integration with the test facility could occur.

Figure 2. Compressors and Carbon Dioxide Unit at WRI

In preliminary tests, the system produced about 11 percent oxygen in a 40–50 scfm CO_2 stream, as shown in Figure 3. Many conditions affecting this concentration still must be optimized, including CO_2 flow rate, bed temperature, bed temperature uniformity, ceramic volume, ceramic material absorption capability, cycle times, and methane concentration. The CAR PDU will continue to be used to test all of these variables before moving to a commercial-scale unit.

Oxycombustion tests then were conducted with the testing facility to measure performance of the PDU under a CO_2/oxygen flow at 21 percent CO_2 and 27 percent oxygen. Flow rates were adjusted during the tests to keep the total mass flow constant regardless of the coal or oxygen/air condition. Three different coals were used for this testing: bituminous coal, subbituminous coal, and lignite. CO_2 and oxygen for the tests came from thermally insulated flasks to simulate operation when integrated with the CAR PDU.

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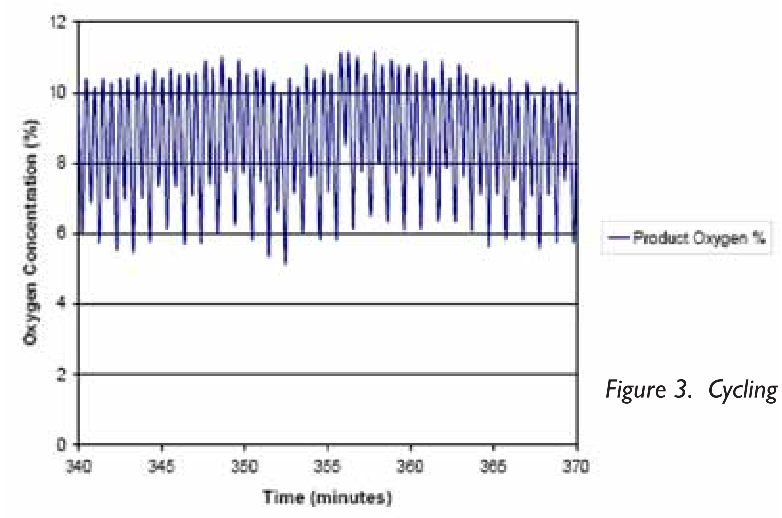

Figure 3. Cycling bed oxygen production

The oxycombustion tests were very successful and yielded heating and combustion data that will be used when the CAR PDU is integrated with the test facility. Conclusions drawn from these preliminary tests include:

- The 21 percent oxygen/CO_2 mixture did not match the thermal performance of air-blown operation, leading to lower overall temperatures throughout the furnace. The 27 percent oxygen/ CO_2 mixture did very closely match the thermal properties of the furnace during operation, as predicted by modeling.
- Most pollutant levels were reduced during oxycombustion operation under 27 percent oxygen/ CO_2 flow, including sulfur dioxide (SO_2), NO_X, and mercury species.

The team received funding under a separate contract to continue development of the CAR process, so the joint development effort described above was discontinued. It is the goal of all jointly sponsored research projects to lead to further demonstrations under other funding. In that regard, this project met its goal and advanced the CAR technology farther along the path to commercialization.

States and Localities Impacted

Laramie, WY

Murray Hill, NJ

Benefits

Coal is expected to continue to be a dominant fuel source for existing power plants. As electricity generation and use continue to grow, reducing carbon emissions by capturing and storing CO_2 from those plants is vital. Reducing the cost and technical risk of oxycombustion technology will help move the nation closer to cleaner, more efficient power generation from coal, the nation's most abundant fossil fuel resource.

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