CDCL Process – Ohio State University

Project Title:

Coal Direct Chemical Looping Retrofit to Pulverized Coal Power Plants for In-Situ CO_2 Capture

Technology Area:	**Technology Maturity:**
Chemical Looping	Sub-pilot, ~25-kWth

Primary Project Goal:

Design, build, and test a sub-pilot scale (25-kWth) coal direct chemical looping (CDCL) facility.

Technical Goals:

- Evaluate the reactivity, recyclability, and physical strength of different iron oxide (Fe_2O_3)-based oxygen (O_2) carrier particle compositions.
- Determine optimum fuel reactor operating conditions to gasify coal char using O_2 carrier particle.
- Operate integrated sub-pilot system for a minimum of 50 continuous hours with the optimal O_2 carrier.
- Determine the fate of nitrogen oxide (NO_X) and sulfur via integrated system testing.
- Conduct techno-economic analysis of the CDCL process.

Technical Content:

Researchers at Ohio State University (OSU) are developing a one-step CDCL process to produce electric power and high-purity carbon dioxide (CO_2) in retrofit power plant applications. While preliminary tests with the bench-scale reactor have shown 90 to 95% coal char conversion and >99% volatile conversion, the primary focus of this project is to identify the optimal O_2 carrier chemical composition and conduct integrated, continuous CDCL testing at the sub-pilot (25-kWth) scale.

As shown in Figure 1, the CDCL system consists of a fuel reactor and a combustor. The moving-bed fuel reactor utilizes a countercurrent gas-solid contacting pattern to maximize the conversion of the Fe_2O_3-based O_2 carrier, as it releases O_2 to facilitate the conversion of pulverized coal to CO_2 and water. The combustor, an entrained-flow reactor, uses air to pneumatically transport the O_2 carrier back to the fuel reactor, while re-oxidizing the O_2 carrier and generating a significant amount of heat. A portion of the heat generated in the combustor is used for steam generation via the high-temperature exhaust gas, while the remainder is carried to the fuel reactor by the hot regenerated particles to supply the heat required for coal conversion.

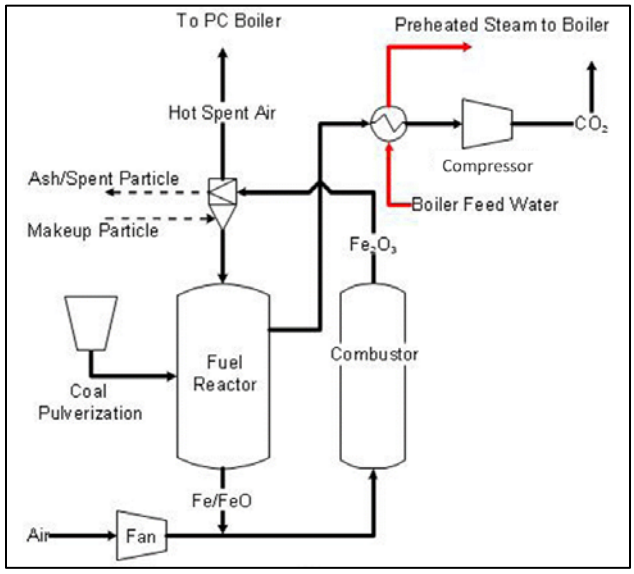

Figure 1: CDCL Process Flow Diagram

The O_2 carrier consists primarily of Fe_2O_3 based on earlier tests that showed an

acceptable O_2 capacity and no loss of activity during more than 100 redox cycles in a thermogravimetric analyzer (TGA) test. To optimize the reactivity, recyclability, and physical strength of the Fe_2O_3-based O_2 carrier for the CDCL process, OSU researchers evaluated the performance of six support materials (aluminum oxide [Al_2O_3], titanium dioxide [TiO_2], magnesium oxide [MgO], silicon dioxide [SiO_2], bentonite, and kaoline) and two promoters (cerium oxide [CeO_2] and zirconium oxide [ZrO_2]) using a TGA and a fixed-bed reactor. These initial screening experiments were used to select the 10 most reactive and recyclable particle compositions, which were subjected to additional reactivity and physical strength tests. These 10 particles were tested to measure their reactivity with coal char in an inert environment and their tolerance to carbon deposition using TGA. The particles were then pelletized for further evaluations, such as pellet strength and reactivity, using a fixed-bed. After eliminating pellets with unacceptable strength and reactivity, the five most promising Fe_2O_3-based composite O_2 carrier particles were identified.

Bench-scale (2.5-kWth) testing of the five most promising O_2 carrier particle compositions in a moving-bed reactor will be used to determine the optimal O_2 carrier particle composition for the CDCL process. Continuous bench-scale tests will be conducted for at least 15 hours.

Using the sub-pilot scale (25-kWth) testing unit shown in Figure 2, the integrated CDCL process will be evaluated during a minimum of 50 hours of continuous operation with the optimal O_2 carrier particle composition. During testing, OSU researchers will monitor the composition of outlet gases (including CO_2, sulfur dioxide [SO_2], and [NO_X]), attrition of the O_2 carrier, and the ash separation effectiveness of the cyclone system.

To quantify the performance and potential benefits of the CDCL process, detailed modeling and a techno-economic analysis of the system will be conducted by CONSOL Energy.

Figure 2: Sub-Pilot Scale (25-kW$_{th}$) CDCL Unit

Technology Advantages:

An air separation unit is not required for O_2 production and CO_2 separation simultaneously takes place with the coal conversion. Additionally, the CDCL process is a versatile technology that can produce power, syngas, or hydrogen (H_2), while offering fuel flexibility.

R&D Challenges:

In addition to scale-up issues, challenges associated with the CDCL process include solids handling and transport; O_2 carrier capacity, reactivity, and attrition; slow reaction rates between the O_2 carrier and coal char; and ash management.

Results To Date/Accomplishments:

- Tested the base O_2 carrier particle with the standard protocol.
- Identified initial five O_2 carrier particles.
- Constructed the bench-scale reactor system for additional O_2 carrier optimization tests.
- Initiated construction of the sub-pilot scale system.
- Developed a cold model for the CDCL fuel reactor to study the contacting patterns of O_2 carrier and pulverized coal.

Next Steps: OSU will complete moving-bed testing of the candidate O_2 carriers, conduct continuous bench-scale testing for at least 15 hours, perform integrated CDCL testing at the sub-pilot scale for at least 50 continuous hours, and complete a techno-economic analysis. Final test results will not be available until the December 2011 project completion date.	
Available Reports/Technical Papers/Presentations: Presentation: Annual NETL CO_2 Capture Technology for Existing Plants R&D Meeting, March 24-26, 2009, in Pittsburgh, Pennsylvania.	
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