Oxyfired Supercritical CO₂ Cycles for Power Production: Focus on Corrosion

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Abstract

The Allam Cycle is a high-pressure, highly recuperative, oxygen-fired, supercritical CO₂ cycle that makes carbon capture part of the core power generation process. This cycle utilizes supercritical carbon dioxide as a high-pressure working fluid through a very compact high-pressure turbine. Cycle efficiencies are capable of reaching up to 47% on a higher-heating-value basis for a lignite feedstock while producing a near-sequestration-ready CO₂ stream requiring some O₂ reduction and dehydration (1). According to a recent study, the coal gasification-supercritical CO₂ cycle can offer a 25% to 50% increase in net cycle efficiency when compared to an integrated gasification combined cycle with 90% CCS (carbon capture and storage) (2).

A team consisting of the Energy & Environmental Research Center (EERC), 8 Rivers Capital, LLC (8 Rivers), and the North Dakota Industrial Commission (NDIC) Lignite Energy Council (LEC) is working to develop lignite-based Allam Cycle technology in support of an industry team comprising ALLETE, Inc., and Basin Electric Power Cooperative (BEPC). This work is building on the knowledge gained from development of the natural gas-fueled Allam Cycle while addressing challenges to coal-fired applications. The team is addressing potential technology barriers requiring further research and development for lignite-based applications. Potential barriers include corrosion, impurity management, gasifier selection, and syngas combustor design. This ongoing effort will develop knowledge to support the deployment of commercially viable low-carbon power generation technologies for the next generation of coal-fired power plants.

This paper reviews the Allam Cycle principles and also the challenges and opportunities of producing power with the Allam Cycle using North Dakota lignite. A major point of emphasis will be corrosion analysis. Several high-temperature and high-pressure dynamic corrosion evaluations were performed in the EERC’s corrosion system (Figure 1). Tests were performed on metal coupons and tubing to reduce risk and aid in the selection of materials of construction. From this work, it was determined that a flue gas containing high amounts of sulfur would not be easily manageable in areas where the system transitions in temperature below approximately 371°C (700°F). There is an extremely high probability for plugging to occur. Additionally, the acid gases that condense through this temperature transition produce acid with a pH below 1.0. With a reduction of sulfur in the gas stream, plugging is eliminated. The alloys tested at a pressure of 30 bar and 750°C all developed oxide layers which did afford some level of protection. Actual corrosion rates could not be determined because of the strong oxide layers that formed. Cross-sectional analysis was performed on each of the coupons to determine
the depth of corrosion, and sulfur species were observed to be penetrating in the grain boundaries. All alloys displayed good resistance under exposure to the tested gas conditions. Based on the information obtained to date, none of the alloys can be rejected as a viable candidate for use in a system under these conditions. Longer term pilot-scale testing is necessary to determine the long-term impacts and service life of components.

Figure 1. Dynamic corrosion system.

References
