the ENERGY lab

PROJECT FACTS

Gasification Systems

National Carbon Capture Center — Water-Gas Shift Tests to Reduce Steam Use

Background

In cooperation with Southern Company Services, the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) established the National Carbon Capture Center (NCCC) at the Power Systems Development Facility (PSDF) in Wilsonville, Alabama. The center bolsters national efforts to reduce greenhouse gas emissions by developing cost-effective technologies to capture the carbon dioxide (CO_2) produced by fossil-fueled power plants.

The PSDF is a unique test facility. It is large enough to provide commercially relevant data, yet small enough to be cost effective and adaptable to testing a variety of emerging technology developments. The facility is a test bed capable of evaluating advanced technologies at multiple scales, thus allowing results to be scaled directly to commercial application. This capability gives the PSDF the flexibility to develop and demonstrate a wide range of advanced power generation technologies that are critical to developing highly efficient power plants that capture CO_2.

The carbon in coal-derived syngas is present primarily as carbon monoxide (CO) and CO_2, with some methane (CH_4). Solvent-based CO_2 capture processes do not remove CO. If CO is present when the synthesis gas (syngas) is combusted in a gas turbine, it will be converted to CO_2 during the combustion process and the CO_2 removal efficiency will thus be limited. To maximize CO_2 capture, the syngas is passed over a water-gas shift (WGS) catalyst in the presence of water to convert the CO to CO_2 and hydrogen (H_2) prior to the CO_2 removal step.

The NCCC is testing commercial WGS catalysts from multiple vendors in support of developing WGS reactor systems suitable for use in the power industry. This is a necessary step in reducing the cost of CO_2 capture from the syngas produced by coal gasification.

Project Description

The WGS reaction is a chemical reaction in which CO reacts with water vapor to form CO_2 and H_2. In petrochemical processing applications, the requirement for WGS systems is to maximize the production of H_2 by eliminating most of the CO. The excess steam also suppresses formation of CH_4, a contaminant in downstream processing stages. For power plant applications, however, acceptable CO_2 capture levels can be achieved with lower CO conversion and with some CH_4 formation, which allows the use of lower steam-to-CO ratios. This reduction results in a substantial increase in net electrical output. Thus optimization requirements differ between these applications.

To determine the feasibility of operating with steam-to-CO ratios lower than those historically proposed and guaranteed by suppliers, the NCCC is investigating the performance of WGS catalysts under a wide range of steam-to-CO ratios. A fixed bed of

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PROJECT DURATION

Start Date	End Date
10/01/2008	09/30/2013

COST

Total Project Value
$251,454,148

DOE/Non-DOE Share
$201,163,318 / $50,290,830

PROJECT NUMBER

NT0000749-NCCC-WGS

WGS catalyst exposed to a slipstream of sour syngas (i.e., some hydrogen sulfide is present) will be tested in a stainless steel vessel using gas analyzers to determine the inlet and outlet gas compositions. The vessel and the lines delivering the syngas are trace heated and insulated to maintain the required operating temperatures.

Goals/Objectives

The objectives of this project are to:

- Evaluate the performance of catalysts from different suppliers in support of developing WGS reactor systems suitable for use in the power industry.
- Determine the feasibility of operating with steam-to-CO ratios lower than those historically proposed and guaranteed by suppliers.
- Evaluate the benefits of lower steam to CO ratio.

Accomplishments

Nine test campaign runs have been carried out in support of CO_2 capture technology testing. Syngas was reliably produced with Powder River Basin sub-bituminous coal, lignite coal, or coal/biomass co-feed and was delivered to the syngas conditioning unit. Tests have been conducted on a number of advanced CO_2-absorbing chemical and physical solvents, various H_2- and CO_2-selective membranes, WGS catalysts, high-temperature mercury capture sorbents, and solid oxide fuel cells. Performance data thus generated have been used to validate laboratory data produced under ideal conditions and allow for engineering design for scale-up.

Figure 1. Power Systems Development Facility Wilsonville, Alabama.

Five different WGS catalysts have been evaluated to date. WGS catalyst tests reveal that steam-to-CO ratios can be reduced, resulting in an increase in the net power output of an integrated gasification combined cycle (IGCC) plant with CO_2 capture and a reduction in the cost of electricity. Evaluations of the impact of these test results for a commercial 500-megawatt (MW) IGCC power plant have shown that a reduction in the steam-to-CO molar ratio of 1.0 (from 2.6 to 1.6) corresponds to a substantial 40 MW increase in net electrical output. Several commercially available WGS catalysts have been tested, and the results are being provided to the manufacturers to aid them in specifying future WGS systems for IGCC plants incorporating CO_2 capture.

Benefits

Operating a WGS reactor that has been incorporated into a gasification power plant with high excess steam would have a significant impact upon net electrical output. Lower steam-to-CO ratios allow more steam for electricity generation, thereby increasing a plant's net electrical output. Other benefits include decreases in both CO_2 emissions and the total cost of electricity due to efficiency improvements.

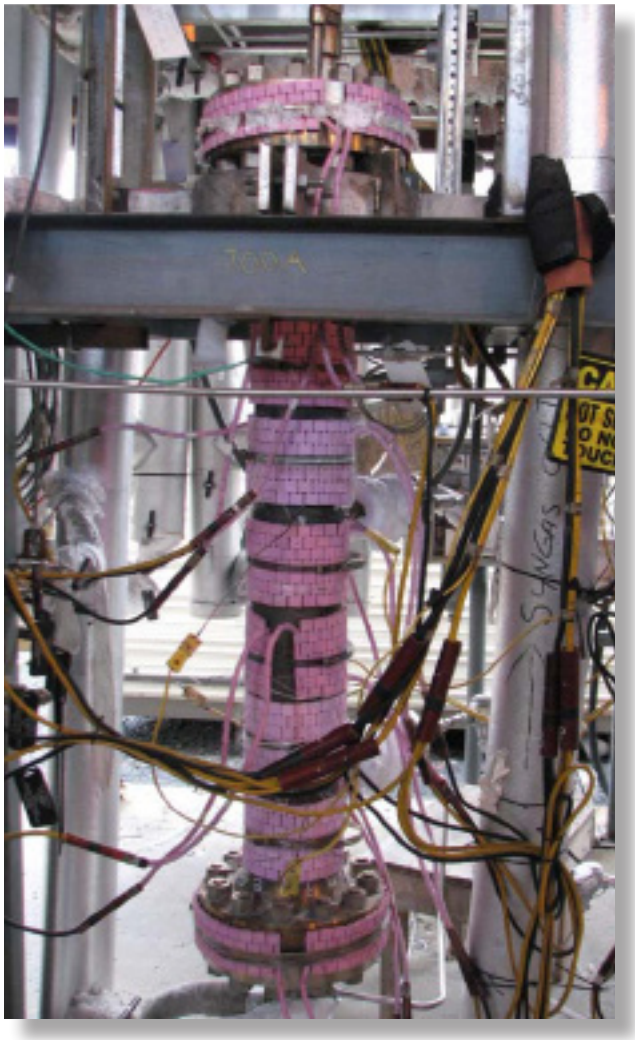

Figure 2. One of the vessels used for Water-Gas Shift testing.