the ENERGY lab

PROJECT FACTS

Project No: FWP-2012.03.03 Task 5

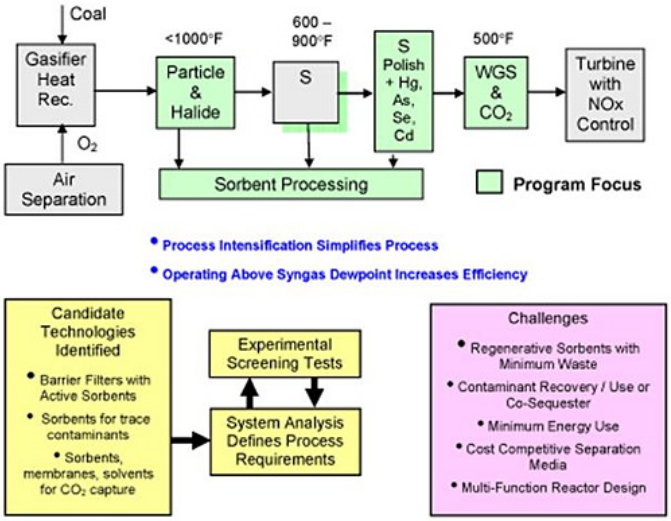
Performer: NETL Office of Research and Development

Advanced Energy Systems - Gasification Systems

Warm Gas Cleanup

Project Description

Work on warm gas clean-up is focused on testing and developing palladium (Pd) sorbents to capture the trace metals selenium (Se), phosphorus (P), arsenic (As), mercury (Hg), antimony (Sb), and cadmium (Cd) from coal-derived syngas. A laboratory-scale packed-bed reactor is used to test the capacity of the Pd sorbent for Hg, As, Se, P, and Cd from simulated flue gases at temperatures between 400 and 700 degrees Fahrenheit (°F). The performance of the Pd sorbents is being examined at larger scales via testing in bench-scale packed-bed reactors. Additional larger-scale tests using slipstreams of actual coal gas will continue at the National Carbon Capture Center (NCCC), and pilot-scale testing at NCCC will focus on the use of smaller loadings of Pd as well as longer exposures to slipstreams of dirty syngas. A detailed cost analysis for the use of Pd-based sorbents in trace contaminant capture has been developed and will be used for guiding the future application and development of the sorbents. Low-cost sorbents for trace contaminant capture will also be tested at laboratory through pilot scales.



2nd Generation IGCC Plant Gas Cleaning Technology

Program Background and Project Benefits

Gasification is used to convert a solid feedstock, such as coal, petcoke, or biomass, into a gaseous form, referred to as synthesis gas or syngas, which is primarily hydrogen and carbon monoxide. With gasification-based technologies, pollutants can be captured and disposed of or converted to useful products. Gasification can generate clean power by adding steam to the syngas in a water-gas-shift (WGS) reactor to convert the carbon monoxide to carbon dioxide (CO_2) and to produce additional hydrogen. The hydrogen and CO_2 are separated—the hydrogen is used to make power and the CO_2 is sent to storage, converted to useful products or used for enhanced oil recovery. In addition to efficiently producing electric power, a wide range of transportation fuels and chemicals can be produced from the cleaned syngas, thereby providing the flexibility needed to capitalize on the changing economic market. As a result, gasification provides a flexible technology option for using domestically available resources while meeting future environmental emission standards. Polygeneration plants that produce multiple products are uniquely possible with gasification technologies. The Gasification Systems program is developing technologies in three key areas to reduce the cost and increase the efficiency of producing syngas: (1) Feed Systems, (2) Gasifier Optimization and Plant Supporting Systems, and (3) Syngas Processing Systems.

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Duration
Award Date: 10/01/2011
Project Date: 09/30/2014

Cost
Total 2013 Project Value: $171,634

Performer website: NETL Office of Research and Development

Syngas processing research and development underway emphasizes technologies that can be efficiently integrated into the plant, optimized with the temperature and pressure requirements of other systems, and meet product delivery specifications. A major cost element in gasification plants is converting raw syngas into a pure and specific gas used to create the plant's target product suite. High-hydrogen, low-methane, ultraclean syngas is versatile and can be used for power production with CO2 capture, fuels or chemicals production, and for many polygeneration applications. The technologies being developed are focused on high-efficiency processes that operate at moderate to high temperatures and clean syngas of all contaminants to the extremely low levels needed for chemical production—often significantly lower than the U.S. Environmental Protection Agency (EPA) required levels for power plants.

This NETL Office of Research and Development (ORD) project is developing palladium sorbents at lab and pilot-scale for capture of trace metals (mercury, arsenic, selenium, phosphorus, antimony, and cadmium) from integrated gasification combined cycle (IGCC) plants to meet or exceed EPA's standard limits for contaminants, and to avoid poisoning of downstream process elements such as catalysts and fuel cell electrodes. ORD is also developing a novel warm-gas reactor to allow for capture in one step to reduce the process footprint, costs, and complexity; and increase the certainty of the final disposition of the trace elements. A benefit of removing contaminants at elevated temperatures (up to 550°F) is preserving the higher thermal efficiency of the IGCC system.

Project Scope and Technology Readiness Level

This project will develop industry-ready technology for moderate-to-high temperature coal-derived synthesis gas (syngas) cleanup and potentially address proposed EPA mercury rules. The objectives are to meet both DOE and EPA targets for trace contaminant capture from coal gasification while preserving the high thermal efficiency of the IGCC system, and to develop sorbents capable of removing mercury, arsenic, selenium, phosphorus, antimony, and cadmium contaminants from high-temperature (up to 550 °F) syngas.

The Technology Readiness Level (TRL) assessment identifies the current state of readiness of the key technologies being developed under the DOE's Clean Coal Research Program. In FY 12, this project was assessed a TRL of 2.

The TRL assessment process and its results including definition and description of the levels may be found in the "2012 Technology Readiness Assessment- Analysis of Active Research Portfolio".

Accomplishments

- Work to characterize and estimate the cost of a trace Hg removal system using Pd sorbents in syngas cleanup configurations for integrated gasification combined cycle (IGCC) plants has been completed. The system utilizes the Research Triangle Institute (RTI) International warm gas cleanup technology for sulfur removal from raw syngas and bulk trace contaminant removal. Warm gas clean-up enjoys a theoretical thermal efficiency advantage over cold gas clean-up of approximately three percent. The RTI technology removes sulfur and heavy metals from gasification syngas at high temperatures, eliminating the need for cooling and expensive heat recovery systems, increasing thermal efficiency and reducing capital and operating costs compared to conventional contaminant removal technology. The preliminary results are very promising for use of the sorbent as a polishing step to ensure close to 100 percent removal of the trace contaminants.
- Development of a cheaper alloy sorbent for trace contaminant removal, and several inexpensive base metal oxide and sulfide sorbent candidates have been identified in collaborations with Carnegie Mellon University (CMU). NETL-CMU efforts will provide insight into the mechanism of sorbent removal of trace contaminants leading to improved sorbent formulations.
- The team has conducted lab-scale tests to demonstrate online detection of syngas contaminants Hg, P, As, and Se.
- A study has been completed on the sorption of mercury, arsenic, and selenium from warm syngas on materials coated with palladium and low cost mixtures of palladium with other metals. Palladium was found to be an outstanding material for cleanup of the gases in a commercial syngas environment, while low cost mixtures of elements were determined to selectively remove limited amounts of some, but not all, targeted gases.
- There have been six pilot-scale tests conducted to date of the palladium sorbent with Southern Company and Johnson Matthey at the NCCC. Using a ten pound bed of palladium on alumina beads in a slipstream of real syngas, each test has shown near 100% removal of mercury, arsenic, and selenium at 500F and elevated pressures over extended periods of time (typically several weeks). The fifth test was the most challenging long-term exposure of palladium to slipstreams, the sorbent was exposed to syngas for 1,011 hours (over 42 days) at 500°F, a pressure of 180 psig, and a space velocity of 1,704 hr-1. The NETL sorbent removed nearly 100 percent of the mercury present within the syngas, with no breakthrough observed. The last test in March 2014 demonstrated use of a thermally regenerated sorbent.
- Palladium-based sorbents are currently among the most promising candidates for high-temperature capture of mercury, arsenic, selenium, phosphorus, and the other trace elements from syngas. Studies were made of a solid electrolyte technique applicable for determining the thermodynamic activity of hydrogen on a palladium surface under syngas conditions (gas composition and temperature). This technique, called solid electrolyte potentiometry (SEP) will be used to study the interactions of fuel gas constituents such as hydrogen sulfide, carbonyl sulfide, arsine, hydrogen selenide, mercury, phosphine, water, carbon monoxide, and hydrogen with palladium.