the ENERGY lab

PROJECT FACTS

Gasification Technologies

Development of an Integrated Multicontaminant Removal Process Applied to Warm Syngas Cleanup for Coal-Based Advanced Gasification Systems

Background

The U.S. has more coal than any other country, and it can be converted through gasification into electricity, liquid fuels, chemicals, or hydrogen. However, for coal gasification to become sufficiently competitive to benefit the U.S. economy and help reduce our dependence on foreign fuels, gasification costs must be reduced and its effectiveness as an ultra-clean technology must be demonstrated. Achieving these aims will require that sulfur-containing species, as well as other emissions contaminants, be reduced to parts-per-million (ppm) or in some cases parts-per-billion (ppb) levels, while keeping the technology competitive. This project has made progress on both fronts by reducing the cost of coal synthesis gas (syngas) clean-up and by cleaning syngas to specified target levels.

Contaminant	Maximum After Cleanup
hydrogen sulfide (H_2S)	50 parts-per-billion by weight (ppbw)
ammonia (NH_3)	0.1 percent by volume
hydrogen chloride (HCl)	1 ppm
mercury (Hg)	5 ppbw
arsenic (As)	5 ppb
selenium (Se)	0.2 ppm

Project Description

Conventional syngas clean-up technologies use low-temperature or refrigerated solvent-based scrubbing systems such as MDEA, or physical solvents (i.e., Rectisol, Selexol, Sulfinol)—processes that operate at temperatures below those of both upstream (the gasifier) and downstream (turbine, chemical conversion, etc.) processes. This requires temperature reductions to below 100 degrees Fahrenheit (ºF) and then reheating to downstream process temperature requirements, resulting in efficiency losses and increased costs for plant integration. The development of multi-contaminant cleanup systems that can be matched to the elevated temperature and pressure conditions of gasification processes is, therefore, of critical importance.

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PARTNERS

CrystaTech Inc.
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PROJECT DURATION

Start Date
06/01/2005

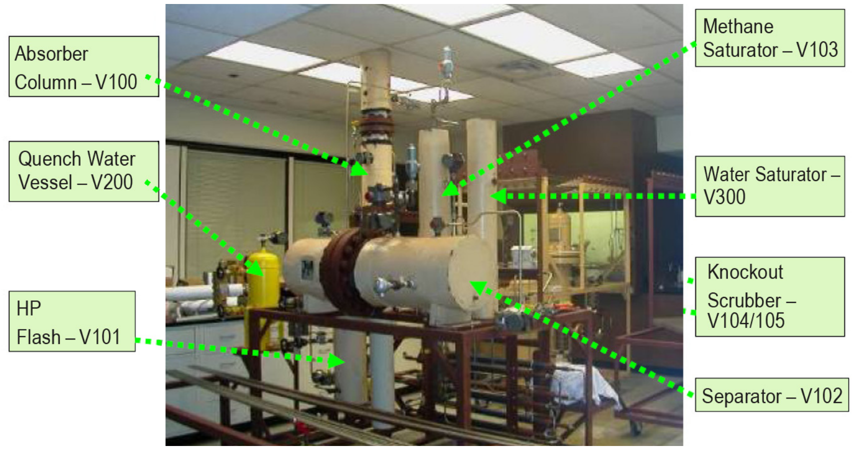
End Date
11/30/2010

COST

Total Project Value
$2,248,632

DOE/Non-DOE Share
$1,490,510 / $758,122

Two sulfur conversion concepts were tested in the laboratory under this project, the solvent-based, high-pressure University of California Sulfur Recovery Process – High Pressure (UCSRP-HP) and the catalytic-based, direct oxidation (DO) section of the CrystaSulf-DO process. This latter process was designed to work in concert with the CrystaSulf® Sulfur Removal process, which cleans syngas produced from low sulfur coals to near zero emissions. Both technologies directly convert the hydrogen sulfide (H_2S) component of syngas into elemental sulfur at temperatures from 285 to 300 °F.



Bench Scale Unit

Gas Technology Institute (GTI) has developed a second reaction loop to remove ammonia (NH_3), chlorine (Cl), selenium(Se), arsenic (As), cadmium (Cd), and mecury (Hg), and has integrated it in the same reactor with the UCSRP-HP so that these seven contaminants of greatest concern in coal-derived syngas can be removed in a single reactor.

During Phase I, extensive laboratory and bench scale experiments were conducted to investigate (1) the effect of temperature, pressure, flow rates, and other important process parameters on contaminant removal efficiencies; (2) solvent stability; and (3) reaction kinetics, reactor hydrodynamics, and metal-corrosion related issues.

The experiments were conducted using simulated syngas in lab-scale test units, and in a specially designed high-pressure, high-temperature reactor bench-scale setup capable of producing up to 20 pounds per day (lb/day) of elemental sulfurusing the UCSRP-HP. The bench-scale reactor was used to also test the UCSRP-HP for the removal of trace, non-sulfur contaminants, including ammonia, hydrogen chloride, and heavy metals. Data from the tests was used in the development of Aspen-Plus®-based computer simulation models, in which the economics of the UCSRP-HP and CrystaSulf-DO processes were evaluated for a nominal 500 MWe, coal-based, IGCC power plant with carbon capture.

Goals/Objectives

The primary goals of this projectwere to:

- Test the feasibility of sulfur removal concepts at lab scale.
- Test GTI trace-contaminant process feasibility at lab scale.
- Expose the UCSRP-HP solvent and CrystaSulf-DO catalysts to syngas, with typical contaminants that may be present in the feed, to a syngas cleanup reactor.
- Investigate long-term solvent and catalyst stability.
- Test the UCSRP-HP bench-scale unit with up to 20 lb/day sulfur production capacity.
- Develop Aspen Plus® based computer simulation models.
- Evaluate the economics of the UCSRP-HP and CrystaSulf-DO processes.

Accomplishments

- The CrystaSulf-DO lab-scale reactor was modified and tested for acceptable performance and the commissioning of the bench-scale unit was completed.
- The preliminary process concept for UCSRP-HP sulfur removal has been verified using a batch reactor at GTI and the results were found to be promising.
- One thousand hours of UCSRP-HP solution stability testing were successfully completed; demonstrating that the catalyst was stable, carbon steel is an acceptable material of construction, and 99.2 percent pure sulfur was formed. At lab scale, Hg removal to levels of less than 0.2 parts per billion (ppb) was demonstrated.
- UCSRP-HP tests on carbonyl sulfide (COS) removal show that 95 percent of COS and 99 percent of the H_2S were simultaneously removed in a single stage reactor. Also solvents testing showed 97 to 99 percent removal of Se and As.
- CrystaSulf candidate catalyst "D" was successfully tested for 100 hours.
- Aspen-Plus®-based computer simulation models of the UCSRP-HP and CrystaSulf-DO processes were completed, and used to prepare preliminary process design evaluations.

Benefits

An economic evaluation of the UCSRP-HP shows significant advantages (40 percent reduction in both capital and operating costs) for the proposed scheme compared with conventional approaches (i.e., Claus plus SCOT tail gas treating). Additionally, testing done at GTI has shown negligible chemical consumption (including catalyst). The UCSRP-HP process has the potential to reduce the cost of power generation by about 8 to 10 percent relative to the conventional cold gas cleanup schemes involving the Selexol acid gas removal process.