PROJECT facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Gasification Technologies

12/2007

Development of an Integrated Multi-Contaminant Removal Process Applied to Warm Syngas Cleanup

CONTACTS

Gary J. Stiegel
Gasification Technology Manager
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236
412-386-4499
gary.stiegel@netl.doe.gov

Jenny Tennant
Project Manager
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507
304-285-4830
jenny.tennant@netl.doe.gov

Howard Meyer
Principal Project Manager
Gas Technology Institute
1700 South Mount Prospect Road
Des Plaines, IL 60018
847-768-0955
howard.meyer@gastechnology.org

Description

The U.S. has more coal than any other country, and through gasification this coal can be converted into electricity, liquid fuels, chemicals or hydrogen. However, for coal gasification to become competitive enough to benefit the U.S. economy, and to help reduce our dependence on foreign fuels, gasification must cost less and be an ultra-clean technology. This project will make progress on both fronts by reducing the cost of coal syngas cleanup, and by cleaning syngas to at least these target levels:

Contaminant	Maximum After Cleanup
H_2S	50 ppbw
NH_3	0.1 vol%
HCl	1 ppm
Hg	5 ppbw
As	5 ppb
Se	0.2 ppm
Cd	30 ppb

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 both upstream (the gasifier) and downstream processes (turbine, chemical conversion, etc.). This requires temperature reductions to below 100 ºF and then reheating to downstream process temperature requirements, resulting in efficiency losses, and increased costs

PARTNERS

Gas Technology Institute
University of California, Berkeley

COST

Total Project Value
$2,124,713

DOE/Non-DOE Share
$1,366,591 / $758,122

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. This project is to develop two bulk sulfur removal processes:

1. The solvent-based high pressure University of California Sulfur Recovery Process (UCSRP-HP).

2. The CrystaSulf-DO process. The vision (outside this project) is that the CrystaSulf-DO bulk removal process will be used in concert with the CrystaSulf process to obtain near zero levels of sulfur.

Both technologies directly convert the H_2S in syngas into elemental sulfur at 285 to 300 °F; a significant difference is that the UCSRP is a solvent-based process, while the CrystaSulf-DO process uses a dry catalyst. The CrystaSulf-DO process is designed to work in concert with the CrystaSulf sulfur removal process, which was designed clean syngas from low sulfur coals to near zero emissions.

GTI will develop a second reaction loop to remove ammonia, Cl, Se, As, Cd and Hg, and will ingrate it in the same reactor with the UCSRP-HP so that the seven contaminants of greatest concern in coal-derived syngas can be removed in a single reactor.

A system study and economic evalution will be performed on both sulfur removal processes, comparing them to each other, to other technologies being developed, and to conventional cleanup technologies. The sulfur removal technologies will be integrated with the GTI ammonia, Cl, Se, As, Cd and Hg removal process.

This project will develop this concept until it is ready for pilot-scale demonstration. During Phase-I, extensive laboratory and bench scale experiments will be conducted to investigate the effect of temperature, pressure, flow rates and other important process parameters on contaminant removal efficiencies, solvent stability and to study the reaction kinetics, reactor hydrodynamics and metal-corrosion related issues.

The experiments will be conducted using simulated syngas in lab scale test units, and in a specially designed high-pressure, high-temperature reactor bench scale setup that will be capable of producing up to 20 lb/day elemental sulfur using the UCSRP-HP. The bench scale reactor is also capable of testing the GTI metal removal process. Data will be used to develop a computer simulation model that will later be used in the economic evaluation of the process to determine if further development is warranted, and if it is, to design a fully integrated pilot-scale demonstration unit for Phase-II work.

Primary Project Goals

The primary goals of this project are:

1. Test the feasibility of sulfur removal concepts at lab scale. Two sulfur conversion concepts will be tested: (1) The solvent-based high pressure University of California Sulfur Recovery Process - High Pressure (UCSRP-HP), and (2) the catalyst-based direct oxidation (DO) section of the CrystaSulf-DO process. It is anticipated that each process may need a polishing unit to meet the cooperative agreement maximum sulfur goal (50 ppbw), and that the CrystaSulf process will be used in concert with the CrystaSulf-DO process to obtain these ultra-clean levels.

2. Test the GTI trace-contaminant process feasibility at lab scale.

3. Expose the UCSRP-HP solvent and CrystaSulf catalysts to syngas with typical contaminants that may be present in the feed to a syngas cleanup reactor.

4. Investigate long-term solvent and catalyst stability.

5. Test the UCSRP-HP bench-scale unit with up to 20 lb/day sulfur production capacity to gather data for further verification of the process concept, measure contaminant removal efficiencies, determine reaction kinetics and optimize the process parameters for designing a pilot-scale demonstration unit for Phase-II study.

6. Develop Aspen-Plus based computer simulation models.

High pressure bench-scale test unit (design temperature of 450 °F, design pressure of 1000 psig).

Evaluate the economics of the UCSRP-HP and CrystaSulf processes, each combined with the GTI trace-contaminant cleanup process, applied to syngas cleanup for hydrogen production and for a 500 MWe coal-based IGCC power plant.

Accomplishments

The preliminary process concept for UCSRP-HP sulfur removal has been verified using a batch reactor at the Gas Technology Institute (GTI) and the results have been found to be promising.

One thousand hours of UCSRP-HP solution stability testing was successfully completed. These tests showed that the catalyst was stable, carbon steel is an acceptable material of construction, and 99.2 percent pure sulfur was formed.

At lab-scale, mercury removal to levels of less than 0.2 ppb was demonstrated.

UCSRP-HP tests on carbonyl sulfide (COS) removal show that 95 percent of COS (from 490 to 35 ppm) was removed, and simultaneously 99 percent of the H_2S (10 percent to 70 ppm) was removed, in a single stage reactor. The addition of SO_2 resulted in up to 99 percent of the COS being removed.

A new lab system was installed to study the conversion and separation of ammonia, chlorides, and selenium from a simulated syngas.

Shakedown tests of the bench-scale reactor are ongoing. This reactor will be used to test removal efficiencies of sulfur, NH_3 and HCl.

Benefits

The proposed processes are ideal for syngas multi-contaminant removal at 285 to 300 °F and at any given pressure (higher the better). Capital and operating costs are expected to be lower, compared to conventionally applied amine or physical solvent based acid-gas removal process followed by Claus/SCOT process. A economic evaluation of the UCSRP shows significant advantages (40 percent reduction in each of capital and operating cost) for the proposed scheme compared with conventional approaches (Claus plus SCOT tail gas treating). Additionally, testing done at GTI has shown negligible chemical consumption (including catalyst), unlike typical chemical costs of $300 - $1000 per ton sulfur removed found in competing processes.

ADDRESS

National Energy Technology Laboratory

1450 Queen Avenue SW
Albany, OR 97321-2198
541-967-5892

2175 University Avenue South
Suite 201
Fairbanks, AK 99709
907-452-2559

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4764

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4687

One West Third Street,
Suite 1400
Tulsa, OK 74103-3519
918-699-2000

CUSTOMER SERVICE

1-800-553-7681

WEBSITE

www.netl.doe.gov