RTI and Eastman Chemical Demonstrate Warm-Temperature Syngas Cleanup Technology

RTI International and Eastman Chemical Company (Eastman) have developed a novel warm-temperature technology package that provides a modular approach to the removal of various contaminants contained in syngas derived from coal and petroleum coke. All technology components operate at elevated syngas temperatures of 400 °F to 1,100 °F (about 200 °C to 600 °C), which eliminates the need to cool syngas to the ambient/sub-ambient conditions required by conventional, solvent-based cleanup technologies. This cooling results in significant loss of thermal efficiency, particularly in power production applications. Extensive field testing of various technology components was successfully completed at Eastman's Kingsport, Tennessee, gasification facility in 2008. This technology was developed with support from the National Energy Technology Laboratory of the U.S. Department of Energy (DOE).

RTI, in partnership with Eastman and DOE, has developed a novel technology package to remove various contaminants, including sulfur, ammonia, HCN, hydrogen chloride, heavy metals (Hg, As, Se, and Cd), and CO_2, from syngas produced from gasification of coal/petroleum coke at temperatures above 400 °F (about 200 °C). Removing these contaminants without cooling the syngas (as required by conventional cleanup technologies) results in significant thermal efficiency improvements for integrated gasification combined cycle (IGCC) power plants, as shown by an independent technoeconomic evaluation. This modular technology package can also meet the more challenging syngas cleanup requirements for production of chemicals and fuels from the syngas. Figure 1 shows a process flow diagram depicting integration of this modular syngas cleanup package within an IGCC plant.

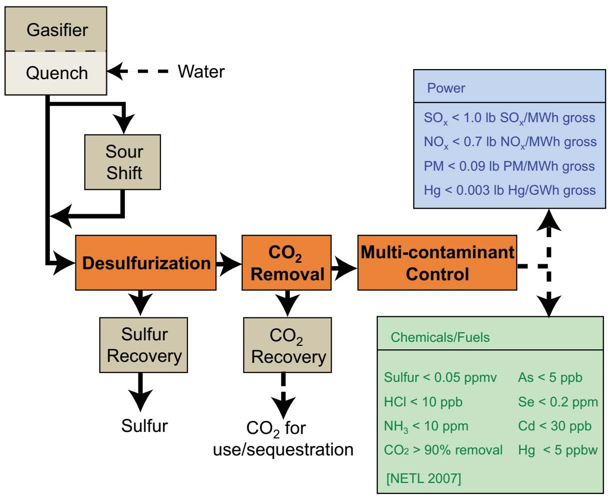

Figure 1. Integration of RTI-Eastman Syngas Cleanup Technology in an IGCC Plant

Warm-Temperature Syngas Cleanup Package for Power and Chemicals Production

The package comprises the following modular technology components (Figure 2):

- **Warm-Temperature Syngas Desulfurization Process (WDP)**—A synergistic integration of an attrition-resistant, fluidizable, and regenerable sorbent with a transport reactor design that allows continuous syngas processing in absorption reactor while achieving more than 99.9% sulfur (H_2S and COS) removal. Continuous sorbent regeneration in a regeneration reactor with an oxidant removes the sulfur from the sorbent as SO_2.
- **Direct Sulfur Recovery Process (DSRP)**—A fixed-bed catalytic process that selectively reduces SO_2 from the regenerator of the HTDP into elemental sulfur.
- **Warm-Temperature CO_2 Capture Process (WCCP)**—A regenerable sorbent-based process in which CO_2 is removed from hot syngas by reaction with a sorbent. During regeneration, the CO_2 captured by the sorbent is recovered as a high-purity CO_2 stream at higher pressures.

RTI is engaged in active development of this process under an ongoing DOE project and expects to move to pilot-plant demonstration within the next 18 months.

- **Warm-temperature fixed-bed sorbent processes** for removal of
  - Heavy metals (Hg, As, Se, Cd) by low-cost, disposable sorbents
  - Acid gases (HCl) by low-cost, disposable sorbents
  - Ammonia and HCN by regenerable adsorbents.

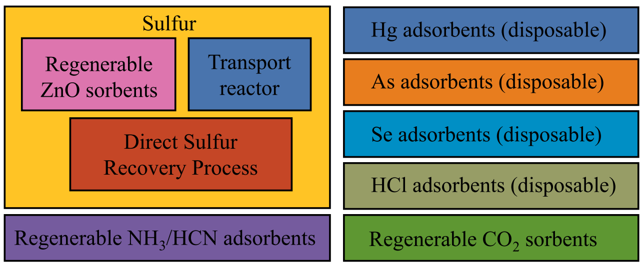

Figure 2. Warm-Temperature Syngas Cleanup Platform

For power production, the modular syngas cleanup package would consist of WDP, DSRP, and fixed-bed ammonia/HCN and Hg removal processes to achieve SO_x, NO_x, and Hg emissions significantly below the current specifications. With the addition of WCCP, the syngas cleanup package would be able to meet any future CO_2 regulations.

For chemical production applications, the overall layout of the syngas cleanup package remains the same (as shown in Figure 1), but the multi-contaminant removal process is optimized to achieve the more stringent contaminant requirements specifically for sulfur, HCl, Hg, As, Se, and Cd.

Warm-Temperature Syngas Desulfurization Process (WDP)

RTI and Eastman developed a new high-pressure dual-loop transport reactor design for WDP. This transport reactor offers the following advantages compared to a fixed-bed process:

- Continuous syngas desulfurization and sorbent regeneration using only two reactors
- Superior gas-solid contact, resulting in more efficient sulfur removal
- Thermally neutral operation and regenerator temperature control by heating incoming sorbent with exothermic regeneration heat
- Higher throughput due to high gas velocities, resulting in smaller reactor equipment for sulfur removal, and hence significantly lower capital cost.

Transport reactors have been used for several decades in the refining industry for fluid catalytic cracking. Therefore, significant design and operating experience exists for these reactors. RTI and Eastman have successfully leveraged this reactor technology for a higher-pressure operation for optimal integration within an IGCC process. The key process components are shown in Figure 3.

In a parallel development track to WDP, RTI developed a fluidizable, highly attrition-resistant, highly reactive desulfurization sorbent to meet the performance requirements of the WDP transport reactor. This sorbent incorporates zinc oxide as the active component for the desulfurization reaction and is very effective in desulfurizing syngas between 500°F and 1,000°F. Production scale-up of the sorbent material was conducted in collaboration with a major catalyst vendor. In extended pilot-plant tests, the desulfurization sorbent exhibited excellent physical strength and activity retention.

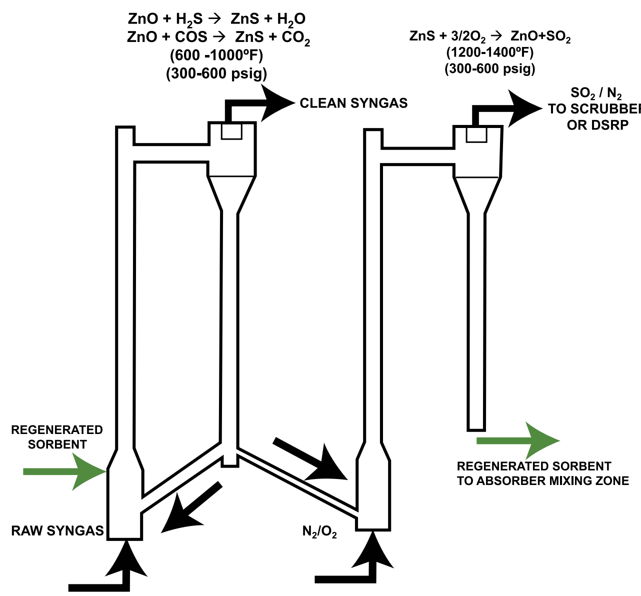

Figure 3. Transport Reactor System Design in WDP

Desulfurization Performance

The WDP pilot unit was operated for more than 3,000 hours using a syngas slipstream at Eastman's coal gasification facility in Kingsport. With an inlet syngas sulfur concentration between 7,000 and 10,000 ppmv, the effluent syngas sulfur concentration was consistently <10 ppmv (~99.9% sulfur removal efficiency) throughout testing, with <5 ppmv sulfur being consistently achieved at optimal operating conditions. The sorbent also effectively removed the COS present in syngas in addition to H_2S, as shown in Figure 4.

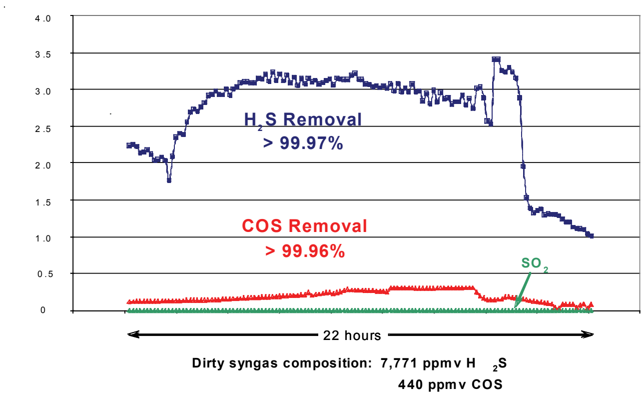

Figure 4. Typical H_2S and COS Removal Performance of WDP

Test Results from 3,000 Hours of WDP Pilot-Plant Operation		
Pressure, psig	300	600
Inlet Concentration, S ppmv	8,661	8,436
Effluent Concentration, S ppmv **Range**	5.9 0.4–9.3	5.7 3.3–18.1
S Removal, %	99.93	99.90

Operational Stability

Overall, more than 3,000 hours of successful testing of the WDP pilot plant (see Figure 5) with coal-derived syngas was completed, with the longest period of continuous operation being over 350 hours. In addition to demonstrating long-term stable operation of the WDP, this test also demonstrated thermally neutral operating conditions, established operating controls providing stable solids circulation and process performance, and identified and tested startup and shutdown protocols for a commercial system.

Direct Sulfur Recovery Process (DSRP)

RTI developed DSRP to treat the SO_2 generated during sorbent regeneration in WDP and achieve optimal thermal and process integration with WDP, which is not possible with the Claus process. DSRP, which has been demonstrated successfully at Eastman (see Figure 6), selectively reduces SO_2 into elemental sulfur at warm temperatures and pressures using a syngas slipstream over a fixed bed of molybdenum-based catalyst.

Figure 5. WDP Pilot Plant

Removal of Other Contaminants

In support of the warm-temperature syngas cleanup package, various sorbents were developed and tested for warm-temperature removal of heavy metals (Hg, As, Se, Cd), acid gases (HCl), ammonia, and HCN. In a bench-scale testing program, suitable sorbents for these contaminants were thoroughly evaluated. Fixed beds of the optimal sorbent candidates from bench-scale testing were integrated into the Eastman pilot-plant test. Results from this pilot-plant test demonstrated the effectiveness of these sorbents for the warm-temperature syngas cleanup technology package.

Figure 6. DSRP Pilot Unit

Economic Advantages

An independent, comprehensive, technoeconomic assessment of the warm-temperature syngas cleanup technology package developed by RTI and Eastman for power production was performed by Nexant, Inc. In this technoeconomic evaluation, Nexant compared the RTI-Eastman syngas cleanup technology package with a Selexol acid gas removal process in a state-of-the-art, 600 MWe IGCC conceptual plant incorporating the General Electric/Texaco gasifier. For both cases, cost estimates were developed for overall performance, as well as capital and operating and maintenance costs.

The comparison showed that integration of the RTI-Eastman warm-temperature syngas cleanup package can increase IGCC thermal efficiency by 3.6 points HHV, a relative improvement of 9.6% in power plant efficiency (see below). This increase in thermal efficiency is primarily due to the avoidance of process steam condensation. The estimated capital cost of the overall IGCC with warm-temperature syngas cleanup case was about 15% below that of the IGCC with conventional cleanup, resulting in an approximate 10% reduction in the overall cost of electricity. These results have been confirmed in a second independent study funded by DOE as part of DOE's evaluation of emerging technologies.

A similar technoeconomic evaluation of the warm-temperature syngas cleanup package meeting contaminant specifications for chemical/fuel production applications is being conducted with and without CO_2 capture.

	IGCC Base Case	IGCC with Warm Syngas	Improvement (%)
Imports/Feeds			
Coal Feed, STPD (AR)	5,467	5,467	
95% Oxygen, STPD	4,665	4,895	–4.9
99% N_2, STPD	7,024	3,959	43.6
Make Up Water, GPM	5,646	4,288	24.1
Exports or Products			
Electric Power, MW	585	641	9.6
Waste Water, GPM	2,798	1,085	61.2
Thermal Efficiency			
HHV%	37.6	41.2	9.6
LHV%	39.3	43.1	9.7

More Information

Markus Lesemann, PhD
Center for Energy Technology
+1.919.541.6246
mlesemann@rti.org

RTI International
3040 E. Cornwallis Road
Research Triangle Park, NC 27709-2194
www.rti.org

RTI-5907R2 0913