United States
Environmental Protection
Agency

Industrial Environmental
Research Laboratory
Research Triangle Park NC 27711

Research and Development

EPA-600/S7-84-031 Apr. 1984

EPA

Project Summary

Evaluation and Demonstration of the Chemically Active Fluid Bed

R.E. Sommer, A.S. Werner, and Z. Kowszun

Results are reported on the operation of a 17-MW Chemically Active Fluid Bed (CAFB) demonstration unit, retrofitted to a natural gas boiler. The CAFB process gasifies high-sulfur, high-metals-content liquid and solid fuels. Residual oil, lignite, and bituminous coal were gasified separately or together between November 1979 and June 1981. Oil was gasified for 540 hours. A maximum continuous-rating test sustained 22 MW of electrical energy for 2 hours. Sulfur removal efficiencies of up to 90 percent were achieved during oil gasification. Lignite and bituminous coal were gasified for 42 hours: sulfur removal efficiencies of up to 70 percent were obtained. Design and operational areas which need to be upgraded were identified. Continuous monitors were used to measure boiler flue gas emissions of SO_2, nitrogen oxides (NO_x), CO, oxygen, CO_2, and opacity. Periodic manual emission tests were conducted for particulate, SO_2, and NO_x, using EPA reference methods. Emissions of these three criteria pollutants were generally lower than New Source Performance Standards for utility boilers, although occasionally excessive particulate and SO_2 emissions were observed. NO_x emissions were consistently lower than those from natural gas combustion. Potential multimedia impacts from the three major discharge streams from the CAFB (boiler flue gas, spent solids from the gasifier bed, and sulfur recovery system ash) were characterized using the phased approach to environmental assessments developed by EPA. Results of detailed chemical analyses and biological assays are reported.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Background

The Chemically Active Fluid Bed (CAFB) process was developed in the late 1960's by the Esso Research Center, Abingdon (ERCA), England, as a way to generate electrical energy from high-sulfur, high-metal, heavy fuel oil. In the CAFB process, oil or coal is fed continuously into a fluidized bed of lime maintained at 870°C. Air is preheated and fed to the gasifier in substoichiometric proportions. The fuel entering the gasifier is vaporized, oxidized, and cracked to produce a low-Btu low-sulfur gas which, after passing through cyclones to remove particulate matter, is burned in a conventional gas boiler. Sulfur contained in the oil initially forms various gaseous compounds which then react with the bed lime to yield solid calcium sulfide. Some of the fuel-bound trace elements are also bound to the bed stone. The sulfided lime is cycled to a regeneration unit where it is oxidized to produce calcium oxide (which is returned to the gasifier) and SO_2 (which is sent to a sulfur recovery unit).

During the early and mid-1970's, the process was demonstrated at a 2.9 MW pilot plant to provide energy efficiently from both liquid and solid fuels while simultaneously limiting emissions of SO_2, NO_x, vanadium, and nickel. Based on the successful pilot plant tests in England, the U.S. EPA and the Texas-based Central Power and Light Company (CP&L) commissioned Foster Wheeler Energy Corporation (FWEC) to construct a 17-MW demonstration plant in San Benito, TX. The agreement with CP&L, signed in

May 1975, provided for construction and operation of the demonstration plant. The contract with EPA (68-02-2106) covered engineering design, labor for start-up, fuels and feedstocks, and environmental monitoring. Design of the unit, based on the ERCA design and operating experience, was initiated in January 1975, and construction was completed in January 1979. The plant incorporated FWEC's proprietary sulfur recovery system, RESOX™. More than 130 contractors and subcontractors were employed during construction. A test program using heavy oil, lignite, and bituminous coal was conducted between October 1979 and June 1981.

This report describes the design, operation, and environmental aspects of the San Benito plant.

Plant Operation

Oil, lignite, and bituminous coal were gasified separately or together in the CAFB unit, which was retrofitted on the front end of a natural gas boiler, between November 1979 and June 1981. Eleven test runs were conducted during this period. Operating conditions and fuels employed for the runs are summarized in Table 1. Residual oil was gasified during the first four runs, totaling 343.5 hours of operation. The fifth gasification run was the longest and most successful. All three systems, the gasifier, regenerator, and RESOX™ reactor, were operational during the run. During the fifth run, oil (the primary feedstock) was gasified for 196 hours; however, lignite was introduced and gasified in combination with the oil for the final 3 hours of operation. During the second run, a maximum continuous-rating test sustained 22 MW of electrical energy on oil for 2 hours. Problems with the transfer of bed stone between the gasifier and regenerator limited regenerator operation during oil gasification to 213 hours. The RESOX™ sulfur recovery system was operated during oil gasification for 115 hours. Sulfur removal efficiencies of up to 90 percent were obtained.

West Texas lignite was gasified for 10.5 hours: problems with the coal feed system precluded additional operation. An eastern bituminous coal was gasified for 31.7 hours during the final four runs: again, coal feed problems caused premature termination of two of the runs. Throughout the final two runs, the boiler flames were strong and well-defined. A sulfur removal efficiency of 70 percent was achieved during the final run.

The following alterations would improve operation:

- More efficient cleanup of product gas entering the boiler. The single-stage cyclones at San Benito were, at times, inadequate.
- A sturdier, more reliable coal feed system. The coal feed system was very sensitive to coal physical properties and was prone to plugging under some conditions.
- A burnup cell for the carbon on the cyclone fines.
- More reliable rotary seals, valves, dampers, augers, and filters, to better withstand the severe conditions of CAFB operation.

Environmental Aspects

The demonstration unit was evaluated to determine its capability to control flue gas criteria pollutant emissions and to estimate potential multimedia pollution impacts. Continuous monitors were used by FWEC to measure SO_2, NO_x, CO, oxygen, CO_2, and opacity. In addition, periodic manual emission tests were conducted by FWEC for particulate, SO_2, and NO_x, using EPA

Table 1. *Summary of the 11 Gasification Runs Between December 1979 and June 1981*

Run	Dates	Hours of gasification	Fuels used	Regenerator operation	RESOX™ operation	Boiler load product gas	Comments
1	12/19/79- 12/20/79	32	Oil	No	No	4 MW - 6 hrs 9-10 MW - 28 hrs	
2	1/27/80- 1/31/80-	77.5	Oil	No	No	9-11 MW 14-15 MW 20-22 MW - 3 hrs	Maintained 22 MW for maximum continuous rating.
3	4/ 8/80- 4/14/80	144	Oil	No 3 hr	No	7.2-15 MW	
4	7/29/80- 8/ 1/80	90	Oil	Yes	Yes 17 hr	10.5 MW 72 hrs product/natural gas	First use of N_2 for material transfer between gasifers and regenerator.
5	9/24/80- 10/ 1/80	196	Oil Lignite, 2 hr	Yes	Yes	8.5 MW - product gas 2-hr coal provided 30% of 8.5 MW	During this run GCA performed environmental assessment
6	11/20/80- 11/25/80	79	Oil Lignite Oil/lignite	No	No	5- 6 MW	
7	12/ 9/80- 12/12/80	5.5	Oil Oil/lignite Lignite	Yes	No	9 MW 7.5 MW	The gasifier bed appeared to be releasing SO_2.
8	2/81	4	Lignite	Yes	No		Run aborted.
9	3/11/83- 3/12/83	10	Oil, 3 hr Oil/coal, 3 hr Coal, 4 hr	No	No	8.7 MW	Approximately 4.5 MW was from product gas.
10	6/ 5 - 6/ 6/81 6/ 7 - 6/ 8/81 6/ 9 - 6/10/81	19.5 17.5 19	Oil Oil, Oil/coal Oil, Oil/coal	Yes	No	9.0 MW	
11	6/22/81- 6/23/81	16	Oil, 3 hr Oil/coal, 5 hr Coal, 8 hr	No	No	4.8 MW - product gas 5.9 MW - natural gas	The bed from run 10 was reused in this run.

reference methods 5, 6, and 7, respectively. Potential multimedia environmental impacts were determined under a separate contract (68-02-2695) by GCA/Technology Division. This program, which followed protocols developed by EPA, characterized in detail the chemical composition of the three major streams discharged from the CAFB: boiler flue gas, spent lime sorbent, and ash from the sulfur recovery system.

The major environmental conclusions of the demonstration programs follow.

- NO_x emissions from the combustion of product gas generated by gasification of oil, lignite, or bituminous coal were consistently below 100 ng/J (0.233 lb/10^6 Btu) and were lower than NO_x emissions from natural gas combustion.
- During oil gasification, the sulfur removal efficiency (SRE) varied from 60 to 90 percent. The SRE decreased markedly as the gasifier bed temperature was raised above 870°C. Recycling of RESOX™ tail gas to the gasifier decreased SRE, probably as a consequence of steam and elemental sulfur entrained in the tail gas.
- Particulate emissions during oil gasification averaged 31.3 ng/J (0.073 lb/10^6 Btu) based on the results of five EPA Method 5 tests. Opacity was generally below 20 percent. However, the higher than anticipated elutriation rate of bed material from the gasifier resulted in excessive particulate buildup in the boiler. Periodically this material would be blown off the boiler tubes by increasing the gas flow to the boiler, resulting in momentary jumps in opacity.
- Particulate collected from the boiler flue gas showed neither appreciable toxicity nor any positive mutagenicity.
- Some mutagenicity was indicated by an Ames test on extracts of XAD porous polymer resin used to collect samples of gaseous organic compounds from the flue gas.
- Leachates collected from the spent stone and RESOX™ ash contained low metal and anion concentrations. Anion concentrations in both leachates were well below EPA Primary and Secondary Drinking Water Regulations.

Rebecca E. Sommer and Arthur S. Werner are with GCA/Technology Division, Chapel Hill, NC 27514; Z. Kowszun is with Esso Research Centre, Abingdon, Oxfordshire, OX136AE, England.

***Samuel L. Rakes** is the EPA Project Officer (see below).*

The complete report, entitled "Evaluation and Demonstration of the Chemically Active Fluid Bed," (Order No. PB 84-159 243; Cost: $19.00, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Industrial Environmental Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

☆ U.S GOVERNMENT PRINTING OFFICE, 1984 — 759-015/7640

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268