UTILIZATION OF PARTIALLY GASIFIED COAL FOR MERCURY REMOVAL

Final Technical Report

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Abstract

In this project, General Electric Energy and Environmental Research Corporation (EER) developed a novel mercury (Hg) control technology in which the sorbent for gas-phase Hg removal is produced from coal in a gasification process in-situ at a coal burning plant. The main objective of this project was to obtain technical information necessary for moving the technology from pilot-scale testing to a full-scale demonstration.

A pilot-scale gasifier was used to generate sorbents from both bituminous and subbituminous coals. Once the conditions for optimizing sorbent surface area were identified, sorbents with the highest surface area were tested in a pilot-scale combustion tunnel for their effectiveness in removing Hg from coal-based flue gas. It was determined that the highest surface area sorbents generated from the gasifier process (~600 m^2/g) had about 70%-85% of the reactivity of activated carbon at the same injection rate (lb/ACF), but were effective in removing 70% mercury at injection rates about 50% higher than that of commercially available activated carbon. In addition, mercury removal rates of up to 95% were demonstrated at higher sorbent injection rates.

Overall, the results of the pilot-scale tests achieved the program goals, which were to achieve at least 70% Hg removal from baseline emissions levels at 25% or less of the cost of activated carbon injection.

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Executive Summary

In this project General Electric Energy and Environmental Research Corporation (EER) developed a novel mercury (Hg) control technology in which sorbent for Hg removal is produced from coal in a gasification process in-situ at a coal burning plant. The main objective of this project was to obtain technical information necessary for moving the technology from pilot-scale testing to a full-scale demonstration. The goal of the program was to achieve at least 70% Hg removal above baseline at 25% or less of the cost of activated carbon injection.

In the project, a pilot-scale gasifier was used to produce sorbents for use as a substitute for activated carbon. The gasifier operating conditions that were varied included temperature, air-to-fuel ratio, and particle residence time. Based upon studies using two bituminous coals and one subbituminous coal, it was observed that the optimum gasifier operating conditions to generate high surface area sorbent were somewhat dependent on the parent coal characteristics. For bituminous coal, the highest surface area sorbents were generated at gasifier temperatures between 1,400 to 1,600°F, stoichiometric ratios between 0.4 to 0.6, and residence times between 1.0 to 1.5 seconds. For subbituminous coals, residence times between 1.5 to 2.5 and stoichiometric ratios between 0.6 to 0.7 provided the highest surface area sorbents. Under optimal conditions with the pilot-scale gasifier, the maximum sorbent surface area achieved with a subbituminous coal was over 600 m^2/g, which was 225% greater than the highest surface area achieved with the first bituminous coal tested.

Selected sorbent materials were tested in a pilot-scale combustion tunnel for effectiveness in removal of Hg from coal-fired flue gas. When firing bituminous coal, the gasifier-generated sorbent had a reactivity between 70% and 85% of the reactivity of activated carbon at the same injection rate (in terms of lb/ACF). The sorbents were capable of reaching 70% mercury removal at injection rates approximately 50% higher than that for a standard activated carbon. In addition, mercury removal rates of up to 95% were demonstrated at higher sorbent injection rates.

Preliminary economic analyses performed for a bituminous coal-fired boiler equipped with an ESP indicate that the new process would have a total cost of mercury control (in terms of $/lb of mercury removed) between 80%-85% lower than that of activated carbon depending upon the level of mercury control required. Overall, the results of the present study met the project goals of 70% Hg removal above baseline at 25% or less of the cost of activated carbon injection.

1.0 Introduction

In this project General Electric Energy and Environmental Research Corporation (EER) developed a novel mercury (Hg) control technology in which the sorbent for Hg removal is produced from coal in a gasification process in-situ at a coal burning plant. The main objective of this project was to obtain technical information necessary for moving the technology from pilot-scale testing to a full-scale demonstration. The goal of the program was to achieve at least 70% Hg removal above baseline, at 25% or less of the cost of activated carbon injection.

The program consisted of pilot-scale testing to determine the optimum conditions for maximizing the surface area of sorbents produced from the gasifier process and to determine the effectiveness of the produced sorbents in removing mercury from coal-fired flue gases.

This report summarizes the results of the project and contains seven sections. Section 2.0 describes the technical approach to the project. Section 3.0 describes the experimental set up for the pilot-scale gasifier and combustion tunnel. Section 4.0 discusses the test results obtained with the gasifier to identify the optimum conditions for generation of high surface area sorbent. Section 5.0 discusses the results of tests performed to evaluate the mercury removal performance of the gasifier-generated sorbents. Section 6.0 summarizes the results of the preliminary economic analysis prepared for the technology. Section 7.0 summarizes the key findings of the project.

2.0 Technical Approach

The project scope of work was designed to evaluate major aspects of the novel in situ gasifier technology and was divided into the following four major tasks.

- Task 1 – Experimental Facility Preparation,
- Task 2 – Gasification Process Optimization,
- Task 3 – Mercury Removal Optimization, and
- Task 4 – Management and Reporting.

The experimental facilities, which consisted of the gasifier and Boiler Simulator Furnace (BSF), were set up and prepared for the program in Task 1. This task included verifying the performance of the equipment and selecting coals for the test program. The objective of Task 2 was to optimize the coal gasification process to maximize reactivity of the sorbent. In the experiments, sorbent carbon content and surface area were used as an indicator of sorbent reactivity towards Hg removal. Several coals were evaluated in Task 2 for sorbent production including bituminous and subbituminous coals.

In Task 3, sorbents selected in Task 2 were injected upstream of an electrostatic precipitator (ESP) fed with flue gas from the BSF, which is a 300 kW combustion tunnel. The sorbent performance was evaluated with respect to sorbent injection rate and was compared to a typical activated carbon. Task 4 consisted of project management and reporting and was executed throughout the project.

3.0 Experimental Set Up

The experimental facilities used in this project consisted of a pilot-scale gasifier and the Boiler Simulator Furnace (BSF). The facilities are described in the following.

3.1 Pilot-Scale Gasifier

A schematic of the solid fuel gasifier is shown in Figure 3-1. The gasifier is constructed from stainless steel and its inner walls are refractory lined. Heat required for solid fuel gasification is supplied by the combustion of natural gas in air. The auxiliary section of the gasifier has an internal diameter of 20 cm. Solid fuel is injected into the gasification section, which has an internal diameter of 30 cm. Nitrogen or air can be used as a transport media for the solid fuel. The gas-phase temperature profile in the gasification zone is measured using several thermocouples located along the axis. Ports located near the exit of the gasifier allow gas and solid samples to be taken and analyzed.

Shakedown tests were conducted with the gasifier to characterize its performance. The goals of these tests were to verify the operability of all of the gasifier components and to ensure that gasifier was capable of operating continuously for several hours. Figure 3-2 shows the gasifier with control panel installed near the BSF. Auxiliary heat for the

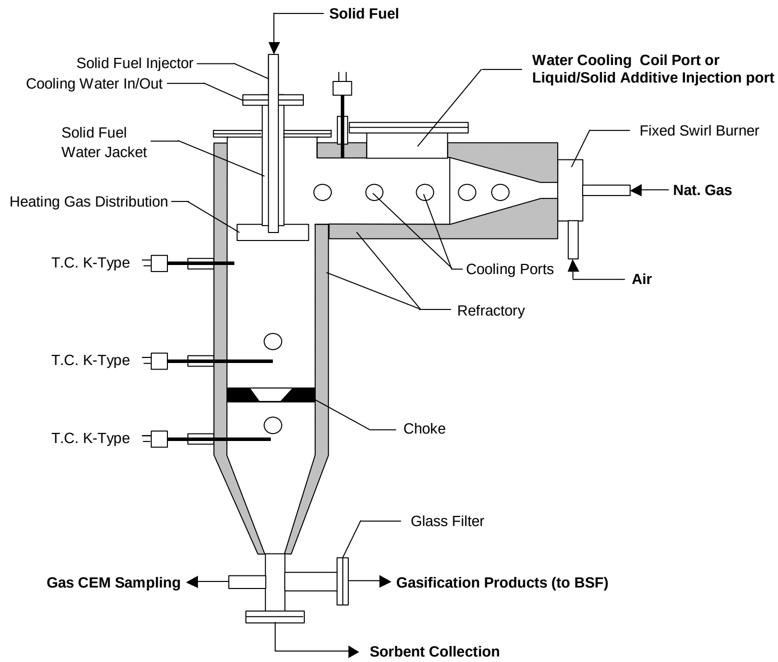

Figure 3-1. Schematic of Pilot-Scale Gasifier.

gasifier is generated by natural gas, which is injected into horizontal section of the gasifier. Coal is injected in the top part of the gasifier and partially gasified coal (sorbent) is collected from the bottom.

Figure 3-2. Photograph of Pilot-Scale Gasifier.

3.2 Boiler Simulator Furnace

To evaluate the effectiveness of the sorbents generated from the gasifier, sorbent injection tests for mercury removal were carried out using GE's Boiler Simulator Facility (BSF). The BSF is a 300 kW (1.0 MBTU/hr) down-fired combustion research facility designed to simulate the thermal characteristics of a utility boiler. A photograph of the BSF is shown in Figure 3-3. The BSF consists of a combustion tunnel followed by a convective pass simulator. A variable-swirl diffusion burner with an axial fuel injector was used to simulate the approximate temperature and gas composition of a commercial burner in a full-scale boiler. Numerous ports located along the axis of the facility permitted access for supplementary equipment such as overfire, additives injectors and sampling probes.

Figure 3-3. Photograph of BSF facility.

The BSF was configured by using cooling rods in the convective pass to match the residence time-temperature profile and furnace exit gas temperature typical for coal fired units. The BSF was fired on natural gas overnight and on coal during the day.

The BSF is equipped with an electrostatic precipitator (ESP) and pulse-jet fabric filter for particulate matter control and a wet scrubber for SO_2 control. The ESP was used for this test program. The ESP is a plate type unit with three electric fields, each measuring 3 feet by 4.5 feet. An individual transformer rectifier supplies power to each field. Each field contains two gas passages comprised of three parallel collecting panels. The gas passage width is set at four inches. The Specific Collection Area (SCR) of the ESP is 450 ft^2/1000 ACFM. Flue gas treatment time in ESP is about 10 seconds.

During the tests, the BSF was operated on a bituminous coal to generate flue gas typical of a coal-fired boiler. Sorbent was injected into the convective pass upstream of the ESP. Mercury measurements with and without sorbent injection were made using an Ohio Lumex CEM-IRM 915 or using the carbon trap sampling method. Samples were extracted after the ESP. A continuous emissions monitoring system was used to monitor flue gas concentrations of O_2, CO, CO_2, SO_2, and NO_X.

4.0 Gasification Process Optimization

The objective of the gasification process is to partially gasify the coal to generate a byproduct sorbent that can be used for mercury removal. In a full-scale installation, the sorbent would be separated from the gas stream and injected into the boiler flue gas either upstream or downstream of the air preheater. The low-Btu gas generated from the process would then be fired in the boiler for energy recovery. The process could be implemented on a continuous basis or sorbent could be generated and stored for subsequent use.

One of the objectives of this program was to determine the optimum conditions for the gasification process that would maximize the sorbent surface area whilst maintaining high carbon content in the sorbent. The primary variables that were investigated were:

- Coal Type – bituminous or subbituminous,
- Gasification Residence Time, which was varied by changing the depth of the solids injector,

- Gasification Stoichiometric Ratio, which was adjusted by changing the combustion air flow rate, the coal flow rate, and the transport gas flow rate and composition.

- Gasification Temperature, which was adjusted by changing the auxiliary burner heat input.

For the experiments, the coal transport gas was either air or a blend of air with nitrogen or argon. By varying the composition of the transport gas, it was possible to control the overall stoichiometric ratio to the test set point, while maintaining a consistent firing rate.

The partially gasified coal samples collected from the gasifier were sent out for two types of analysis: carbon content and surface area. The surface area analysis was a multi-point analysis using nitrogen gas. The results are provided as either BET or Langmuir surface area (m^2/g). In some cases, the surface area was too large to be measured by the BET method. Therefore, a Langmuir data reduction method was used to calculate the surface area. Overall, the Langmuir surface area results are considered to be more accurate.

Sorbents were generated from the three coals presented in Table 4-1. The coals tested included two bituminous coals and one subbituminous coal. The bituminous coals are typical of bituminous coals from the Eastern United States. The subbituminous coal is typical of subbituminous coals mined in the central United States and Canada.

TABLE 4-1. COALS SELECTED FOR GASIFIER TESTS

Parameter	Units	Bituminous Coal #1	Bituminous Coal #2	Subbituminous Coal
Carbon	wt. %	69.12	66.94	48.06
Hydrogen	wt. %	4.67	4.74	2.95
Nitrogen	wt. %	1.43	1.32	0.52
Sulfur	wt. %	1.35	0.63	0.18
Oxygen	wt. %	6.30	10.52	15.81
Ash	wt. %	9.66	7.17	12.48
Moisture	wt. %	7.47	8.68	20.00
		100.00	100.00	100.00
Higher Heating Value	Btu/lb	12,114	11,806	7,975

For Bituminous Coal #1, experiments were performed based a full factorial design test matrix to examine the impacts of gasifier firing rate (or gasification temperature), stoichiometric ratio, and residence time on the surface area and carbon content of the generated sorbent. Data obtained with the first coal were used to develop an optimized test matrix for Bituminous Coal #2. Finally, a limited set of data was obtained under optimal conditions with the subbituminous coal. A summary of the experimental data can be found in Appendix A.

4.1 Bituminous Coal #1 Sorbents

The sorbents generated from the gasifier were evaluated for carbon content and surface area. Figure 4-1 and Figure 4-2 show the impacts of the gasifier stoichiometric ratio and residence time on the sorbent surface area. For the results shown in these figures, the sorbent carbon content ranged from 62% to 72%, with an average of 67%.

In Figure 4-1, sorbent surface area is plotted against stoichiometric ratio for selected ranges of gasifier residence time. In this report, stoichiometric ratio (SR) is defined as the ratio of the actual moles of air available to the moles of air required for complete combustion of the fuel. A stoichiometric ratio of one implies that there is sufficient air to complete combustion of the fuel. As shown in the figure, there is a strong dependence of

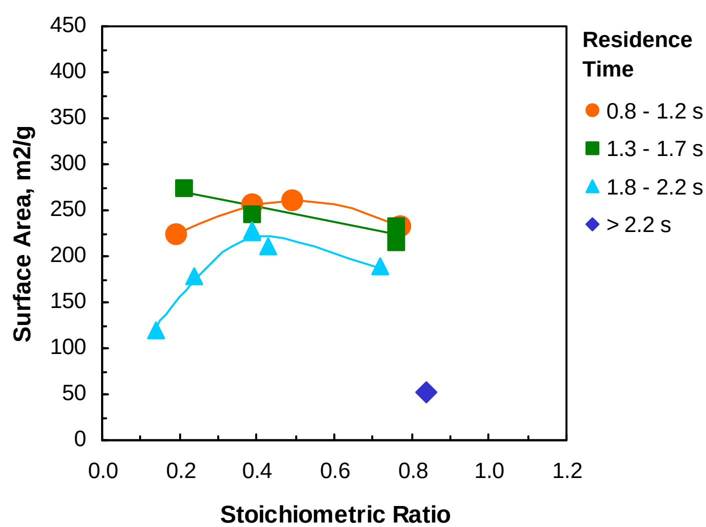

Figure 4-1. Impact of stoichiometric ratio on Bituminous Coal #1 sorbent surface area.

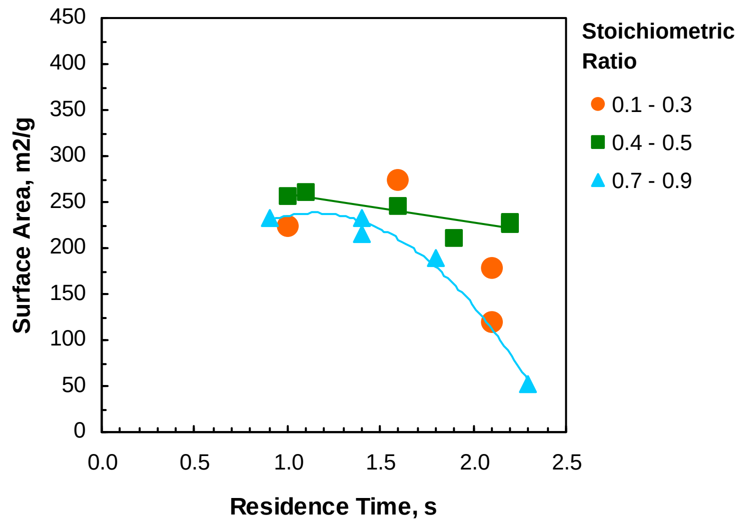

Figure 4-2. Impact of residence time on Bituminous Coal #1 sorbent surface area.

the sorbent surface area on the gasifier SR. For this bituminous coal, at longer residence times (> 2.2 seconds), the dependence is more pronounced than at shorter residence times. Overall, the optimal SR appears to be in the range of 0.4 to 0.6.

In Figure 4-2, sorbent surface area is plotted against gasifier residence time for selected ranges of stoichiometric ratio. As shown in the plot, optimal residence times for this coal are in the range of 1.0 to 1.5 seconds. As residence time increases, sorbent surface area decreases. Overall, the maximum surface area achieved with Bituminous Coal #1 was 260 m^2/g, which was obtained with stoichiometric ratios in the range of 0.4 to 0.5 and gasifier residence times of one second.

4.2 Bituminous Coal #2 Sorbents

Prior to testing with Bituminous Coal #2, the solids injector on the gasifier was modified to improve feeding of the solids into the high temperature gasifier environment. As a result of the modification, the testing with this coal also included operation of the gasifier at higher heat inputs. Figure 4-3 and Figure 4-4 show the impacts of the gasifier stoichiometric ratio and residence time on the sorbent surface area generated from Bituminous Coal #2. For the results shown in these figures, the sorbent carbon content ranged from 72% to 81%, with an average of 77%.

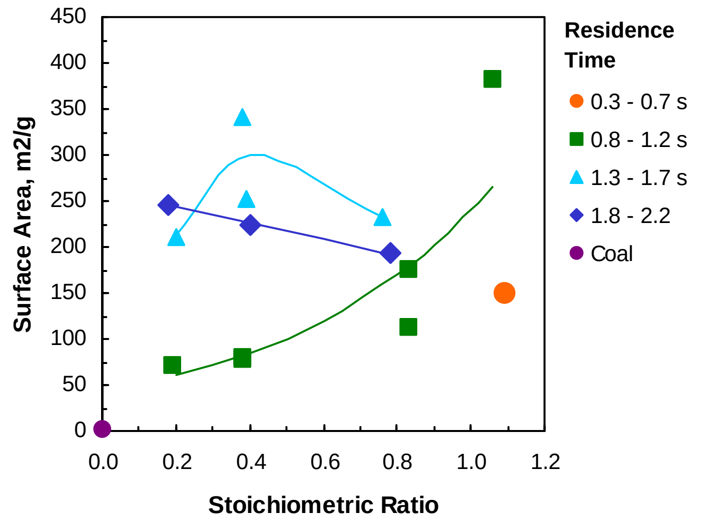

Figure 4-3. Impact of stoichiometric ratio on Bituminous Coal #2 sorbent surface area.

In Figure 4-3 sorbent surface area is plotted against stoichiometric ratio for selected ranges of gasifier residence time. For this bituminous coal, and at residence times below 0.7 and above 1.3 seconds, the data trends are similar to those observed with Bituminous Coal #1 and show an optimal stoichiometric ratio near 0.4. The data collected at residence times between 1.3 to 1.7 seconds shows anomalous behavior. This was due to the low gasifier temperatures (~1,300°F) experience for the tests performed at SR < 0.4.

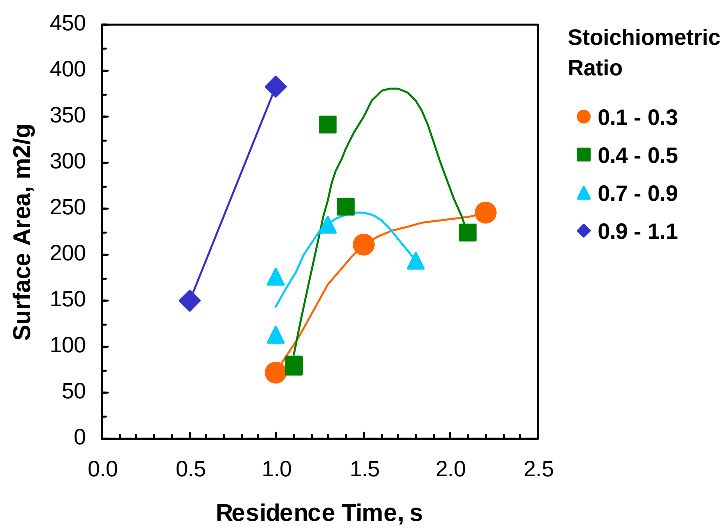

Figure 4-4. Impact of residence time on Bituminous Coal #2 sorbent surface area.

Figure 4-3 also shows that the surface area of the parent (un-gasified) coal had a value of approximately 2 m^2/g. Comparison of the surface area of the coal with the sorbents shows that the gasifier process is effective in generating a higher surface area sorbent.

In Figure 4-4 sorbent surface area is plotted against gasifier residence time for selected ranges of stoichiometric ratio. For these tests, the optimal residence time appears to be between 1.25 and 1.50 seconds when the gasifier SR was greater than 0.3. At low stoichiometric ratios (<0.3), increasing the residence time resulted in an increase in sorbent surface area, which is different from the trend observed with Bituminous Coal #1.

As noted above, the gasifier temperature also impacted sorbent surface area. Figure 4-5 shows the impact of the average gasifier temperature on the sorbent surface area generated for Bituminous Coal #2. The data are separated according to gasifier residence time. As shown in the figure, the optimum gasification temperature was in the range of 1,450 to 1,600°F. The minimum gasification temperature appears be in the range of 1300°F for generation of high-surface area sorbents.

4.3 Subbituminous Coal Sorbents

For the subbituminous coal, testing focused on the evaluation of particle residence time and stoichiometric ratio. For these tests, particle residence times of up to 2.5 seconds and

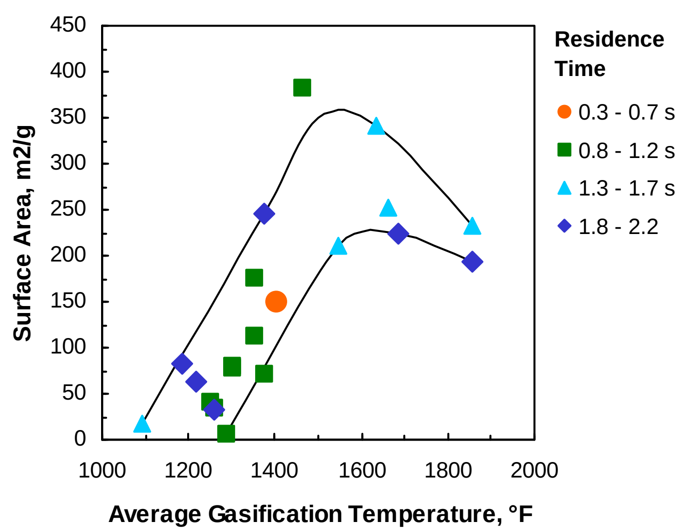

Figure 4-5. Impact of temperature on Bituminous Coal #2 sorbent surface area.

stoichiometric ratios up to 1.0 were evaluated. Figure 4-6 and Figure 4-7 show the impacts of the gasifier stoichiometric ratio and residence time on the sorbent surface area generated from the subbituminous coal.

In Figure 4-6, sorbent surface area is plotted against stoichiometric ratio at a fixed gasifier residence time. For this coal, highest sorbent surface areas were obtained when the gasifier was operated at a stoichiometric ratio of approximately 0.6 and residence time was between 1.5 to 2.5 seconds. At the shortest residence time tested (0.5 seconds), the sorbent surface area was trending upwards even at a stoichiometric ratio of 1.0.

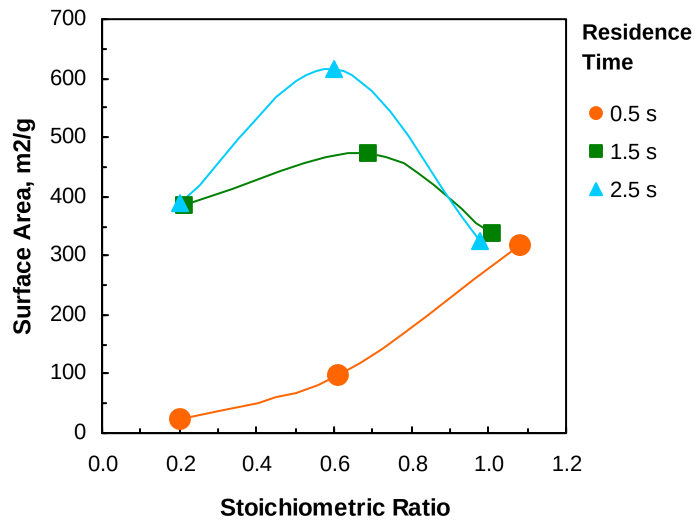

Figure 4-6. Impact of stoichiometric ratio on subbituminous coal sorbent surface area.

In Figure 4-7 sorbent surface area is plotted against gasifier residence time for selected ranges of stoichiometric ratio. At stoichiometric ratios near 1.0, the sorbent surface area was roughly constant at approximately 325 m^2/g. For intermediate stoichiometric ratios (~0.20), the highest surface area was obtained for a residence time between 1.5 to 2.5 seconds. At low stoichiometric ratios (~0.65), sorbent surface area increased as residence time was increased, with a surface area of 615 m^2/g being achieved at 2.5 seconds.

Based upon the tests performed in this program, the subbituminous coal yielded sorbents with the highest surface areas. Figure 4-8 compares the maximum surface areas achieved

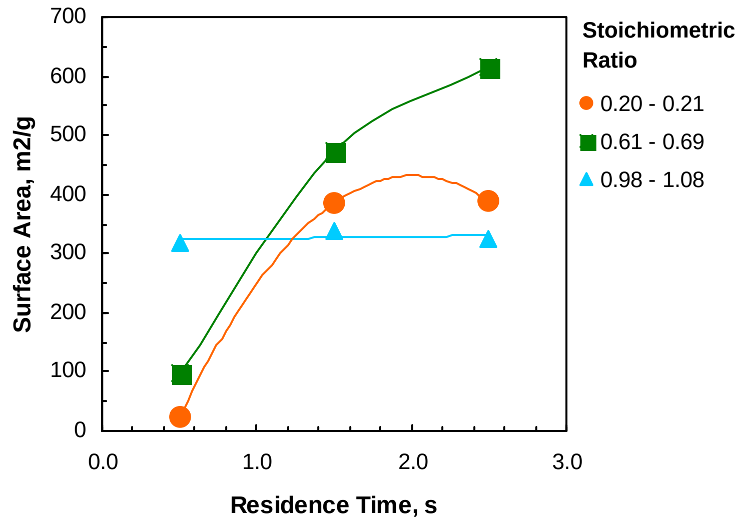

Figure 4-7. Impact of residence time on subbituminous coal sorbent surface area.

with the three coals tested. In this figure, the maximum surface area for sorbents generated from each coal is plotted against the parent coal carbon content on a dry, ash free basis. Generally speaking, the lower the carbon content, the higher the volatile matter in the coal. The results compare fairly well suggesting that higher volatile coals should produce more reactive sorbents in the gasification process.

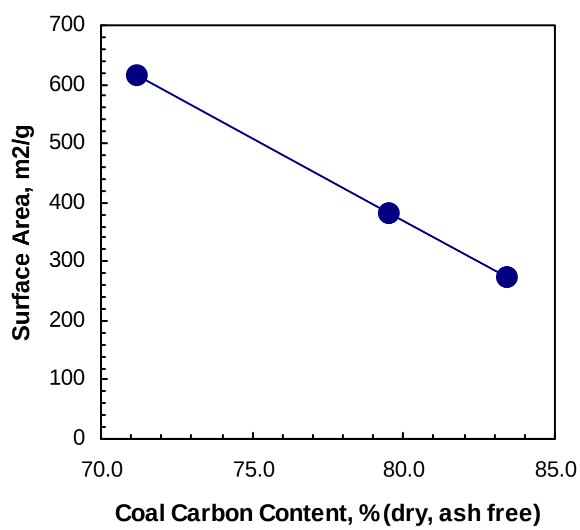

Figure 4-8. Impact of coal carbon content on maximum sorbent surface area.

4.4 Sorbent Shelf Life

As mentioned earlier, the gasification process could be used to generate sorbents in a continuous generation and injection process or to generate sorbents for storage and subsequent injection. For this second option, the ability of the generated sorbent to retain its surface area over long periods of time is important.

Figure 4-9 shows the impact of storage time or shelf life on the sorbent surface area. The sorbents were generated with Bituminous Coal #2. For these sorbents, surface area was maintained after five months of storage. This result indicates that the second option is highly feasible depending upon the specific plant requirements.

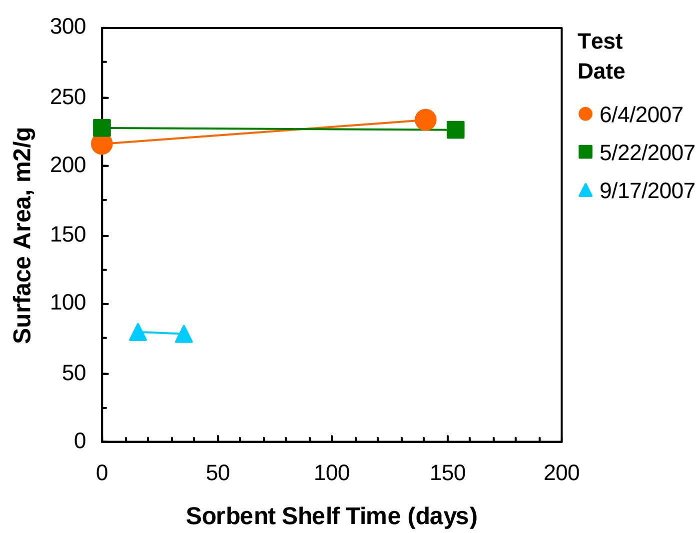

Figure 4-9. Impact of sorbent storage duration on surface area.

5.0 Mercury Removal Optimization

Testing was performed using the BSF to characterize the sorbent reactivity towards mercury removal. In these tests, the BSF was fired on an Eastern bituminous coal and selected sorbents generated from the gasification process were injected upstream of the ESP. Mercury measurements were made at the ESP outlet. Results are summarized in Appendix B.

Figure 5-1 shows the results of mercury removal testing performed with sorbents having surface areas between approximately 500 to 600 m^2/g. For comparison, mercury removal tests were also performed with a commercially available activated carbon (Norit Darco HG). Figure 5-1 shows that the sorbents generated from the gasification process had 70 to 85% of the reactivity of activated carbon at the same injection rate (in terms of lb/ACF). The figure also shows that the gasification-generated sorbents were capable of reaching 70% mercury removal at injection rates approximately 50% higher than that for the standard activated carbon. In addition, mercury removal rates over 80% were achievable with sorbents generated from the novel gasification process.

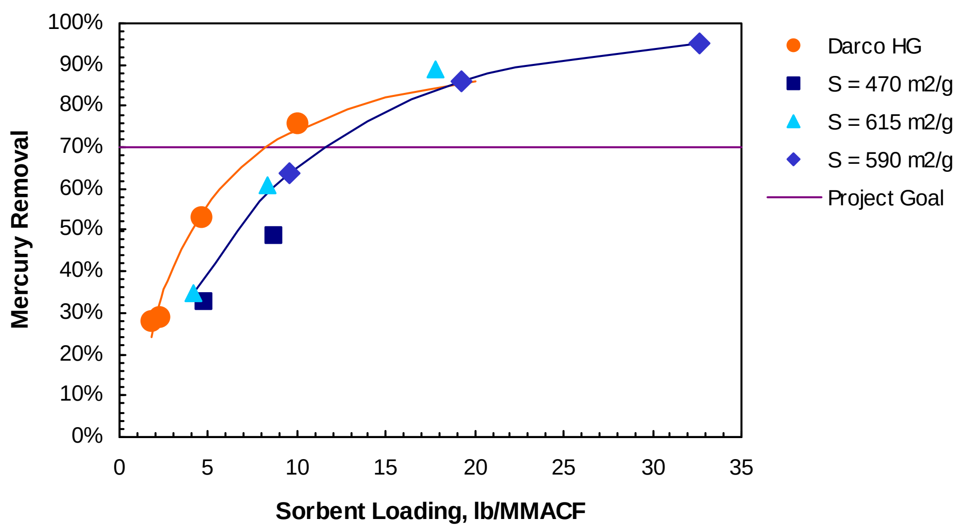

Figure 5-1. Gasification-generated sorbent mercury removals.

6.0 Preliminary Economic Assessment

While detailed economic analysis was outside the scope of the project, a preliminary economic assessment has been performed for the gasification process. For this analysis, it was assumed that the unit would fire bituminous coal and be equipped with an ESP. A capital cost of $2 million was assumed for the cost of retrofit of an on-line gasifier. Figure 6-1 compares the cost of mercury removal (in $/lb of Hg removed) to that of activated carbon at three assumed control levels. The costs for activated carbon injection were taken from previous DOE work.

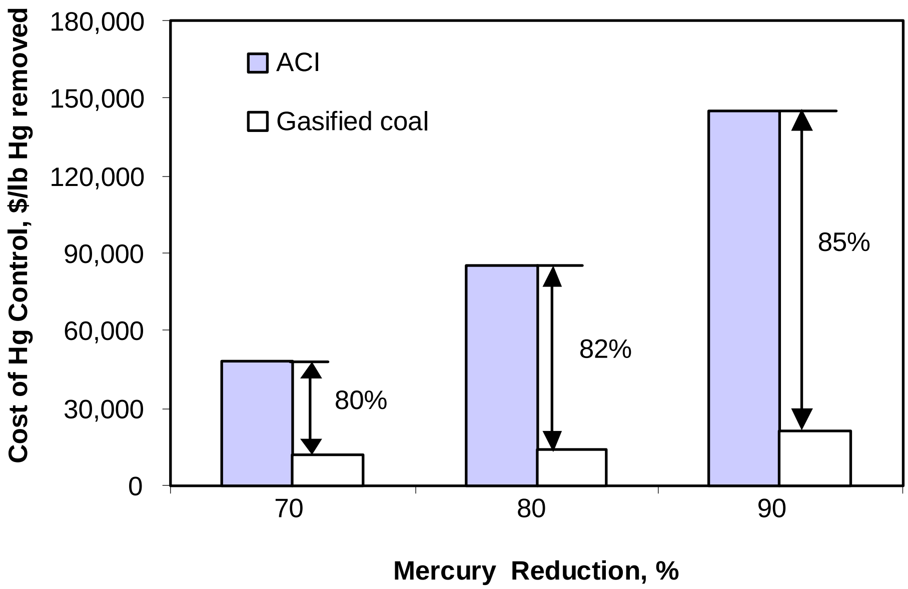

Figure 6-1. Preliminary economic evaluation of gasification process.

As can be seen in Figure 6-1, the economics for the gasification process compare favorably to activated carbon injection. At the project control level goal of 70%, the gasification system is estimated have a control cost only 20% of that of activated carbon. Even though the sorbent requirements are higher, the low cost of the parent material keeps the total control cost low.

7.0 Conclusions and Recommendations

The overall objectives of this project were to evaluate the process conditions needed to optimize the reactivity of sorbent generated from the gasification process. The results from this project will support further scale up and development of the technology.

The results of the experimental program show that subbituminous coals can be used to generate sorbents with surface areas of over 600 m^2/g. Bituminous coals produce sorbents with about half that surface area. Optimum gasification conditions need to be tailored to the specific coal. For bituminous coal, the highest surface area sorbents were generated at gasifier temperatures between 1,400 to 1,600°F, stoichiometric ratios between 0.4 to 0.6, and residence times between 1.0 to 1.5 seconds. For subbituminous coals, residence times between 1.5 to 2.5 and stoichiometric ratios between 0.6 and 0.7 provided the highest surface area sorbents.

Selected sorbent materials were tested in a pilot-scale combustion tunnel for effectiveness in removal of Hg from coal-fired flue gas. When firing bituminous coal, the gasifier-generated sorbent had a reactivity between 70% and 85% of the reactivity of activated carbon at the same injection rate (in terms of lb/ACF). The sorbents were capable of reaching 70% mercury removal at injection rates approximately 50% higher than that for a standard activated carbon. In addition, mercury removal rates of up to 95% were demonstrated at higher sorbent injection rates.

Preliminary economic analyses performed for a bituminous coal-fired boiler equipped with an ESP indicate that the new process would have a total cost of mercury control (in terms of $/lb of mercury removed) between 80%-85% lower than activated carbon depending upon the level of mercury control required. Overall, the results of the present study confirm that the project goals of 70% Hg removal above baseline at 25% or less of the cost of activated carbon injection.

Based upon the success of the pilot-scale program, the following next steps for development of the gasification process technology are recommended:

- Pilot-scale experiments should be performed to evaluate the potential for brominating the gasifier-generated sorbents. This would extend the overall applicability of the technology to all coal types.
- Based upon the required sorbent injection rates, a design for a full-scale gasifier should be developed. The gasifier should be designed for integration into a typical coal-fired power plant and for potential use for sorbent generation and storage. The design should be used to confirm the process economics and cost effectiveness.
- A more detailed economic assessment should be performed to validate the results of the preliminary assessment.
- A full-scale demonstration of the technology should be performed.

Appendix A - Gasifier Data Summary

TABLE A-1. GASIFIER TEST DATA SUMMARY

Test No.	Firing Rate Gasifier NG (Btu/hr)	Coal Type	SR Gasifier Air/Coal	Firing Rate Gasifier Coal (Btu/hr)	Coal Transport Gas	Average Gasification Temperature (°F)	Gasifier Residence Time	Carbon Content (%)	BET Surface Area (m^2/g)	Langmuir Surface Area (m^2/g)
1-1	67,300	Bit. #1	0.84	14,800	Ar		2.3		46.9	51.7
1-2	80,000	Bit. #1	0.15	50,100	N2		2.0	72.08	14.6	
1-3	80,000	Bit. #1	0.05	145,400	N2		1.9	72.02	24.7	
1-4	80,000	Bit. #1	0.43	80,000	Ar/Air		1.9	68.41	210.8	210.8
1-5	80,000	Bit. #1	0.14	46,600	N2	1669	2.1	71.39	106.0	119.2
1-6	87,500	Bit. #1	0.24	47,245	Ar/Air	1649	2.1	67.55	178.5	178.5
1-7	80,000	Bit. #1	0.39	44,600	Ar / Air	1662	2.2			226.7
1-8	80,000	Bit. #1	0.39	44,600	Ar / Air	1662	2.2	67.48		227.8
1-9	80,000	Bit. #1	0.39	44,000	Ar / Air	1616	1.6	64.01		246.3
1-10	80,000	Bit. #1	0.49	36,000	Ar / Air	1664	1.1	64.49		259.8
1-11	80,000	Bit. #1	0.72	44,700	N2 / Air	1818	1.8	64.51		188.5
1-12	80,000	Bit. #1	0.39	59,800	N2	1605	1.0	64.28		257.5
1-13	80,000	Bit. #1	0.76	41,900	N2 / Air	1750	1.4	63.26	148.4	216.0
1-14	80,000	Bit. #1	0.76	41,900	N2 / Air	1750	1.4			233.3
1-15	80,000	Bit. #1	0.77	41,400	N2 / Air	1788	0.9	62.60	159.8	232.4
1-16	80,000	Bit. #1	0.21	39,500	N2 / Air	1522	1.6	68.72	184.4	274.7
1-17	80,000	Bit. #1	0.19	42,900	N2 / Air	1507	1.0	68.60	149.6	223.7
2-1		Bit. #2	0.00				0.0	71.97	2.4	2.4
2-2	80,000	Bit. #2	0.76	41,800	N2 / Air	1855	1.3	73.90		233.1
2-3	80,000	Bit. #2	0.78	41,000	N2 / Air	1856	1.8	78.05		192.8
2-4	80,000	Bit. #2	0.40	40,500	N2 / Air	1685	2.1	79.25		224.0
2-5	80,000	Bit. #2	0.18	44,300	N2 / Air	1373	2.2	74.79		245.5
2-6	80,000	Bit. #2	0.19	40,800	N2 / Air	1187	1.9	70.87		81.7
2-7	80,000	Bit. #2	0.39	40,800	N2 / Air	1217	1.8	69.97		63.1
2-8	80,000	Bit. #2	0.40	40,200	N2 / Air	1094	1.3	70.36		18.1
2-9	90,000	Bit. #2	0.19	43,700	N2 / Air	1257	1.6	71.70		32.2
2-10	100,000	Bit. #2	0.20	39,200	N2 / Air	1249	1.1	76.11		41.4
2-11	100,000	Bit. #2	0.43	37,500	N2 / Air	1260	1.0	74.65		35.8
2-12	100,000	Bit. #2	0.83	38,800	N2 / Air	1350	1.0		112.0	112.0
2-13	100,000	Bit. #2	0.83	38,800	N2 / Air	1350	1.0	77.39		176.7
2-14	120,000	Bit. #2	0.38	42,000	N2 / Air	1634	1.3	81.28		342.3
2-15	110,000	Bit. #2	0.20	40,800	N2 / Air	1544	1.5	80.16	211.2	211.2
2-16	110,000	Bit. #2	0.19	41,500	N2 / Air	1288	1.1	75.26	5.8	5.8
2-17	120,000	Bit. #2	0.19	42,000	N2 / Air	1377	1.0	75.86	71.8	71.8
2-18	120,000	Bit. #2	0.38	42,200	N2 / Air	1302	1.1		78.9	78.9
2-19	120,000	Bit. #2	0.38	42,200	N2 / Air	1302	1.1	75.93	80.2	80.2
2-20	120,000	Bit. #2	1.06	37,900	Air	1461	1.0	75.43		383.5
2-21	120,000	Bit. #2	1.09	36,600	Air	1404	0.5	74.24	150.9	150.9
2-22	120,000	Bit. #2	0.39	61,100	N2 / Air	1662	1.4	78.34		252.0

TABLE A-1. GASIFIER TEST DATA SUMMARY

Test No.	Firing Rate Gasifier NG (Btu/hr)	Coal Type	SR Gasifier Air/Coal	Firing Rate Gasifier Coal (Btu/hr)	Coal Transport Gas	Average Gasification Temperature (°F)	Gasifier Residence Time	Carbon Content (%)	BET Surface Area (m^2/g)	Langmuir Surface Area (m^2/g)
3-1	120,000	Subbit.	0.21	39,000	N2 / Air		1.5			385.7
3-2	120,000	Subbit.	0.61	39,200	N2 / Air		0.5			98.2
3-3	120,000	Subbit.	0.69	35,000	N2 / Air		1.5			474.1
3-4	90,000	Subbit.	0.60	40,000	N2 / Air	1653	2.5			615.2
3-5	120,000	Subbit.	1.08	37,000	Air		0.5			318.1
3-6	120,000	Subbit.	1.01	40,000	Air		1.5			337.0
3-7	90,000	Subbit.	0.98	40,800	Air		2.5			325.7
3-8	120,000	Subbit.	0.20	40,000	N2 / Air		0.5			23.3
3-9	90,000	Subbit.	0.20	40,000	N2 / Air		2.5			387.7
3-10	90,000	Subbit.	0.43	56,500	N2 / Air		2.4			593.4

Appendix B - Mercury Removal Results

TABLE B-1. MERCURY REMOVAL TEST DATA SUMMARY

Coal	Run	Sorbent	Sorbent Surface Area (m^2/g)	ESP Outlet (°F)	Loading (lb/MMACF)	O_2 (%)	Hg-T (ug/m^3)	Hg-T (3% O_2) (ug/m^3)	Hg Reduction
Bit. #1	Baseline	-		223	-	4.3	4.66	5.02	-
Bit. #1	1	Darco HG		223	1.75	4.2	3.39	3.63	28%
Bit. #1	Baseline	-		236	-	3.9	6.06	6.38	-
Bit. #1	2	Darco HG		238	4.62	4.0	2.83	3.00	53%
Bit. #1	Baseline	-		235	-	4.2	6.20	6.64	-
Bit. #1	3	Darco HG		238	10.00	4.1	1.48	1.58	76%
Bit. #1	Baseline	-		247	-	4.3	6.74	7.27	-
Bit. #1	4	Darco HG		248	2.27	4.2	4.82	5.17	29%
Bit. #1	Baseline	-		233	-	4.2	5.74	6.15	-
Bit. #1	1	Gasifier 01-11-08-1	474.1	234	4.69	4.2	3.82	4.09	33%
Bit. #1	Baseline	-		235	-	4.0	6.12	6.48	-
Bit. #1	2	Gasifier 01-11-08-1	474.1	235	8.70	4.0	3.14	3.33	49%
Bit. #1	Baseline	-		256	-	4.8	5.35	5.95	-
Bit. #1	1	Gasifier 01-14-08-1	615.2	256	4.17	4.8	3.47	3.86	35%
Bit. #1	Baseline	-		258	-	4.9	5.68	6.35	-
Bit. #1	2	Gasifier 01-14-08-1	615.2	258	8.37	4.9	2.19	2.45	61%
Bit. #1	Baseline	-		257	-	5.3	5.36	6.15	-
Bit. #1	3	Gasifier 01-14-08-1	615.2	257	17.83	5.3	0.61	0.70	89%
Bit. #1	Baseline	-		258	-	5.5	5.47	6.36	-
Bit. #1	1	Gasifier 07-22-08-1	593.4	258	32.62	5.5	0.30	0.35	95%
Bit. #1	Baseline	-		252	-	5.1	4.56	5.16	-
Bit. #1	2	Gasifier 07-22-08-1	593.4	252	9.60	5.1	1.66	1.88	64%
Bit. #1	Baseline	-		256	-	5.2	5.22	5.95	-
Bit. #1	3	Gasifier 07-22-08-1	593.4	256	19.20	5.2	0.71	0.81	86%