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ENHANCING THE USE OF COALS BY GAS REBURNING-SORBENT INJECTION

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Prepared by
Energy and Environmental Research Corporation
18 Mason
Irvine, California 92718

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1.0 SUMMARY

The objective of this project is to evaluate and demonstrate a cost effective emission control technology for acid rain precursors, oxides of nitrogen (NO_x) and sulfur (SO_x), on two coal fired utility boilers in Illinois. The units selected are representative of pre-NSPS design practices: tangential and cyclone fired. Work on a third unit, wall fired, has been stopped because of funding limitations. The specific objectives are to demonstrate reductions of 60 percent in NO_x and 50 percent in SO_x emissions, by a combination of two developed technologies, gas reburning (GR) and sorbent injection (SI).

With GR, about 80-85 percent of the coal fuel is fired in the primary combustion zone. The balance of the fuel is added downstream as natural gas to create a slightly fuel rich environment in which NO_x is converted to N_2. The combustion process is completed by overfire air addition. SO_x emissions are reduced by injecting dry sorbents (usually calcium based) into the upper furnace. The sorbents trap SO_x as solid sulfates that are collected in the particulate control device.

This project is conducted in three phases at each site: (1) Design and Permitting, (2) Construction and Startup, and (3) Operation, Data Collection, Reporting and Disposition. Technology transfer to industry is accomplished through the formation of an industry panel. Phase I of the project commenced on June 5, 1987 and concluded on May 15, 1989. It included five tasks as follows:

Task 1 - Project Management
Task 2 - Process Design
    Subtask 2.1 - Host Site Characterization
    Subtask 2.2 - Process Specification
Task 3 - Project Engineering
Task 4 - Environmental Reports, Permitting Plans and Design
Task 5 - Technology Transfer

In Phase AII at Hennepin, Task 1 - Project Management coordinated the completion of the startup work and wrap up of all contractual issues prior to the close out of Phase AII at the end of September 1991.

In Phase CII at Lakeside, Task 1 - Project Management, Project management activities continued throughout the quarter. A Participants Committee meeting was held in March at the GRI facilities to discuss the current status of the project and the application for the project extension and additional matching funds.

Close coordination was maintained at both sites with host representatives. Some of the coordination meetings were attended by representatives of DOE, GRI and ENR.

In Phase AII at Hennepin, Task 2 - Construction and Startup, All remaining funds and budgeted restoration dollars have been transferred to Phase AIII, thus completing all activities for Phase AII.

In Phase CII at Lakeside, Task 2 - Construction and Startup, Mechanical, electrical and ash handling construction activities have been completed. The current effort involves checkout of equipment prior to startup.

Phase AIII at Hennepin - Testing, Data Collection, Reporting and Disposition proceeded in parallel with the completion of the Phase AII activities. Gas reburning runs were made that indicate as high as 77% reduction in NO_x emission using about 18% gas. Gas Reburning - Sorbent Injection test results indicated as high as 62% reduction in SO_2. These results are significantly higher than the project emission reduction goals of 60% NO_x and 50% SO_2 and provide a wide safety margin for maintaining the 60% and 50% emission reductions during long term routine testing.

Phase CIII at Lakeside, Task 2 - Technology Demonstration, All test equipment has been set up to measure and record test data. Testing will commence following system startup.

Key Words

SO_x	Ash	Emission
SO_2	Coal	Control
NO_x	Gas	Boiler
NO	Sorbent	Precipitator (ESP)
Pond	Construction	Flue Gas
Startup	Instrumentation	Contracts
CEMS	Industry Panel	Ducts
Reburning	Injection	
Humidification	BPMS	

2.0 INTRODUCTION

Clean Coal Technology implies the use of coal in an environmentally acceptable manner. Coal combustion results in the emission of two acid rain precursors: oxides of sulfur (SO_x) and oxides of nitrogen (NO_x). This clean coal technology project will demonstrate a combination of two developed technologies to reduce both NO_x and SO_x emissions: gas reburning and calcium based dry sorbent injection. The demonstrations will be conducted on two pre-NSPS utility boilers representative of the U.S. boilers which contribute significantly to the inventory of acid rain precursor emissions: tangentially fired and cyclone fired units. (A demonstration on another representative boiler type, wall fired, has been stopped because of funding limitations.)

Gas reburning is a combustion modification technique that consists of firing 80-85 percent of the fuel corresponding to the total heat release in the lower furnace. Reduction of NO_x to molecular nitrogen (N_2) is accomplished via the downstream injection of the remaining fuel requirement in the form of natural gas (which also reduces the total SO_x emissions). In a third stage, burnout air is injected at lower temperatures in the upper furnace to complete the combustion process without generating significant additional NO_x.

Dry sorbent injection consists of injecting calcium based sorbents (such as limestone, dolomite, or hydrated lime) into the combustion products. For sulfation of the sorbent to $CaSO_4$, an injection temperature of about 1230 °F is optimum, but calcium-sulfur reactions can also take place at lower temperatures. Thus, the sorbent may be injected at different locations, such as with the burnout air, at the exit from the superheater, or into the ducting downstream of the boiler with H_2O added for humidification. The calcium sulfate and sulfite products are collected together with unreacted sorbent by the particulate collection device, usually an electrostatic precipitator or bag filter.

The specific goal of this project is to demonstrate NO_x and SO_x emission reductions of 60 percent and 50 percent, respectively, on two coal fired utility boilers having the design characteristics mentioned above. Host Site Agreements have been signed by EER and utility

companies in the State of Illinois: Illinois Power Company (Test Site A, Hennepin Unit 1, 71 MW_{net} tangentially fired boiler in Hennepin), Central Illinois Light Company (Test Site B, Edwards Unit 1, 117 MW_{net} front wall fired boiler in Bartonville), and City Water Light and Power (Test Site C, Lakeside Unit 7, 33 MW_{net} cyclone fired boiler in Springfield). (As discussed above, GR-SI demonstrations are now planned only at sites A and C.)

Co-funding for this project is provided by the Gas Research Institute (GRI) and the State of Illinois Department of Energy and Natural Resources (ENR)--the other Funding Participants. GRI and ENR are responsible for funding approximately one-third and one-sixth, respectively, of the total project costs.

To achieve the objectives of the project, it is being conducted in the following three phases at each host site.

Phase I: Design and Permitting
Phase II: Construction and Startup
Phase III: Operation, Data Collection, Reporting and Disposition

Phase I of the project was conducted in parallel for test sites A, B and C over a period of 22 months, starting in June 1987. During the period of May 15-August 15, 1989, Phase AII-A pre-engineering overlap work was conducted on the tangentially fired site A. After continuing negotiations with the host of site A, a Host Agreement Modification was signed on January 19, 1990. Phase AII-B (the balance of the Construction and Startup work) was resumed immediately, and essentially completed during the third quarter of 1991. Also, GR and GR/SI optimization testing was done at Hennepin, while Phase CII Construction and Startup work continued at Lakeside.

During the past quarter the principal objectives of the work performed were as follows:

A. Hennepin Unit 1

1. Continue standard project management activities of preparation of deliverables, coordination of the project team's activities, and reporting events and issues to the project sponsors on a timely basis.
2. Operate as many hours as possible under GR/SI long term conditions. Based on IP's typical daily cycle, the boiler will be between 40MW and 70MW about 12 hours per day, Monday through Friday. Allowing for process startup, lineout and shutdown, it is estimated that 10 - 11 hours per day of testing can be achieved on most days if no unusual equipment problems are experienced.
3. Gradually begin to turn over the responsibility for GR/SI operation and maintenance to IP. In order to make this transition smoothly, some additional training will be necessary. A meeting on January 14, 1992 to discussed the turnover. The overall objectives of the long term testing phase is to demonstrate that the GR/SI process can be operated successfully by the utility without constant direction by EER.
4. Fine tune GR/SI process control as necessary to improve ease of operation.
5. Measure N_2O emissions using a continuous analyzer.
6. Measure resistivity of ash entering the ESP under GR/SI operating conditions.

B. Lakeside Unit 7

1. Continue project management activities.
2. Complete mechanical, electrical, and ash handling subcontractor activities.
3. Complete startup activities.
4. Mobilize for Phase CIII testing.

3.0 PROJECT DESCRIPTION

Within the three phases of the project, the following tasks will be performed to demonstrate the cost effective control of NO_x and SO_x emissions from pre-NSPS coal fired utility boilers:

Phase I: DESIGN AND PERMITTING

Task 1 - Project Management

- Coordination of all Participant and subcontractor efforts
- Coordination with the host sites
- Planning and scheduling all tasks
- Monitoring all technical efforts
- Keeping DOE, GRI, and ENR fully informed of project status
- Continual review of relevant ongoing technical developments

Task 2 - Process Design

Subtask 2.1 - Host Site Characterization

- Establishment of the condition of each host site, including field evaluations.

Subtask 2.2 - Process Specification

- Preparation of GR-SI process designs, aiming at 60% and 50% reduction in NO_x and SO_x, respectively.
- Continuing bench scale tests to define key process parameters.

Task 3 - Project Engineering

- Preparation of site specific detailed engineering designs, construction plans and schedules, cost estimates, startup plans and Phase III test plans.

Task 4 - Environmental Reporting, Permitting, Plans and Design

- Preparation of relevant environmental data for obtaining NEPA approval.
- Preparation of Environmental Monitoring Plan.
- Assistance to host sites in obtaining environmental permits.

Task 5 - Technology Transfer

- Formation of an Industry Panel for technology transfer.
- Arrangement of Panel meetings on (1) process design and (2) detailed engineering design and plans for Phases II and III.

Phase II: CONSTRUCTION AND STARTUP

Task 1 - Project Management

- Continuation of Phase I project management activities.
- Arrangement of project review meetings at approximately the 40 and 90 percent completion points for each site.

Task 2 - Installation and Checkout

- Installation of the emission control and auxiliary equipment.
- Checkout of functional operation of all components.

Task 3 - Technology Transfer

- Continuation of technology transfer activities initiated in Phase I.
- Meetings with Industry Panel to review installations and plans.

Task 4 - Restoration

- Decision on disposition of test equipment if project is discontinued: to be retained by host sites or removal and restoration work.

Phase III: OPERATION, DATA COLLECTION, REPORTING AND DISPOSITION

Task 1 - Project Management

- Continuation of Phases 1 and 2 project management activities.
- Conducting final project review at conclusion of project.

Task 2 - Technology Demonstration

Subtask 2.1 - Optimization Testing

- Evaluation of effects of process variables on emission control performance.
- Determination of operating conditions for optimum overall performance.

Subtask 2.2 - Evaluation of Alternative Coals and Sorbents

- Evaluation of performance of alternative coals and sorbents:
  - High and medium sulfur coals, with consideration of cleaned and run-of-mine coals.
  - Selection of sorbents from high calcium and dolomite limestones, hydrated limestones and limes.

Subtask 2.3 - Long-Term Testing

- Operation of GR-SI equipment under optimized conditions for approximately one-year duration at each host site.
- Measurement of emission control system performance.
- Determination of boiler impacts.

Task 3 - Evaluation of Demonstration Results

- Analysis of test data.
- Preparation of guideline manuals for application of GR-SI technology, including design recommendations, cost projection and comparisons with competing technologies.

Task 4 - Restoration

- Disposition of GR-SI equipment installation:
  - To be retained by host site or removal and restoration work.

Task 5 - Technology Transfer

- Continuation of technology transfer activities from Phases I and II.
- Meeting with Industry Panel at one host site to review results obtained there and plans for other two host sites.
- Meeting with Industry Panel at completion of project.

4.0 PROJECT STATUS

4.1 Task 1 - Project Management

Monthly and other reporting activities were fulfilled according to the reporting requirements of the Cooperative Agreement.

Work Progress was monitored continuously. Coordination with IP took place at monthly meetings in Hennepin and by telephone. The project co-funders were apprised of progress and development through telephone conferences and meetings.

Activities were coordinated to complete Phase CII construction and startup and mobilize for Phase CIII testing. A project review meeting with the project co-funders was held at the GRI facility on March 18, 1992.

4.2 Task 2 - Installation and Startup

Hennepin - Installation and Startup activities were officially completed September 30, 1991.

Lakeside - All mechanical, electrical and ash handling construction has been completed. Checkout activities are continuing to be followed shortly by startup. The boiler has operated successfully using the newly installed Westinghouse WDPF control system and sootblowers. Startup problems with the FGR and OFA duct systems had been resolved through modifications of the duct routing and support systems. A successful test run of the boiler was performed following connection of GR/SI related equipment. This test was performed to verify that there would be no detrimental effects on normal boiler operation.

4.2.1 Contracts

Hennepin - A local electrical/mechanical contractor has provided support as needed during the operation/testing phase of the project.

Lakeside - No new contracts were awarded during the quarter.

4.2.2 Construction CPM Scheduling

Hennepin - None.

Lakeside - All construction activities have been completed. Phase CII is currently estimated to be 95% complete.

4.2.3 Construction Drawings

Hennepin - All construction drawings are complete. As-built installation documentation is 98% complete and should be completed early in the second quarter, 1992.

Lakeside - All construction drawings have been completed and released. Preparation of as-built drawings is currently underway.

4.2.4 Equipment Purchasing

Hennepin - Purchase orders for materials and services were placed during this quarter. The purchases were largely intended to provide replacement parts for "wear" items and consumables such as calibration gas, lime, and CO_2.

Lakeside - Minor items are being purchased in support of testing.

4.2.5 Miscellaneous

Hennepin - Meetings between Illinois Power and EER were held at Hennepin on an as needed basis during the past quarter.

Lakeside - The test probes currently being used for monitoring boiler emissions have been found to become obstructed during operation of the sorbent injection. A test of a redesigned probe is planned at Hennepin in support of the CWLP project. Failure of this test could result in a delay of sorbent injection startup.

4.2.6 Testing

Hennepin - The following were completed during this quarter:

1. As a direct result of the IP - EER meeting on January 14, 1992, IP has gradually assumed more and more of the operation and maintenance functions of GR/SI. EER continues to closely monitor operations, plus handles the data acquisition and emissions monitoring with the BPMS/CEMS.
2. The majority of this quarter's operation was with GR/SI operation under load following (dispatch) control. In general, the project goals of 60% and 50% NO_x and SO_2 reduction continue to be met under these load swinging conditions. Sorbent Injection operation was maintained about 80% of the time Gas Reburn was operating.
3. Ash resistivity measurements were performed under GR/SI conditions by Dr. Marlin Anderson, an ESP consultant. Preliminary indications are that GR/SI ash with humidification has resistivity in the low to mid 10^{11} ohm-cm range at 250 °F and in the mid 10^{10} ohm-cm range at 180 - 190 °F. Results obtained with GR only last July showed resistivity in the mid 10^{10} range at 315 - 330 °F without humidification. Thus it appears that humidification at Hennepin is effective in bringing GR/SI ash resistivity into a suitable range for proper ESP performance.

4. Continuous N_2O emissions were monitored over a three week period. Very low levels were observed under a variety of operating conditions (baseline, GR, and GR/SI). The maximum value seen was 4 ppmv with almost all data between 0.5 and 2.0 ppmv corrected to 3% O_2. These results are in good agreement with those normally seen in PC fired boilers.

5. Slagging and fouling observations and measurements were also carried out this quarter. Furnace video recordings, heat fluxes and thermal performance studies were performed. While detailed evaluation of results is still underway, it appears that the sootblowing program developed during long term testing can control deposition of material in the furnace and convective pass. Longer operating times will be studied to confirm these observations and better define the deposition characteristics.

Lakeside - The test equipment was mobilized during the last quarter in support of startup and subsequent testing operations. This included the test trailer, sampling equipment, and supporting materials.

A discussion was held with CWLP to determine the demand on the boiler over the next year and a half. This information will be used to refine the test schedule while accommodating available boiler time. The unit will be available for testing through August 1992 after which it will be down for three months.

4.3 Technology Transfer

An Industry Panel meeting was held in Denver, Colorado on March 31 - April 1, 1992.

5.0 PLANNED ACTIVITIES

During the next quarter (January through March, 1992) the following work is planned.

A. Hennepin Unit 1

1. Continue standard project management activities of preparation of deliverables, coordination of the project team's activities, and reporting events and issues to the project sponsors on a timely basis.
2. Continue long term load following operation with increasingly longer operating periods.
3. Complete evaluation of preliminary Fouling/slagging studies.
4. Perform ESP performance characteristics under GR/SI, GR, and baseline conditions.
5. Measure SO_3 concentrations in flue gas during GR/SI operations.
6. Perform a short term comparison of Marblehead lime with Linwood lime. These alternate sorbent data are useful to both the Hennepin and Lakeside projects.

B. Lakeside Unit 7

1. Continue project management activities.
2. Complete checkout and startup activities.
3. Complete all Phase CII activities.
4. Complete 50% of the parametric tests in support of optimization testing.

6.0 REPORT DISTRIBUTION LIST

The number in parentheses ( ) indicates the total number of copies submitted.

6.1 Funding Organization Distribution

6.1.1 U.S. Department of Energy

Mr. Harry J. Ritz (2)
PETC Technical Project Manager
Mail Stop 920-L
U.S. Department of Energy/PETC
P.O. Box 10940
Pittsburgh, PA 15236

Mr. John Augustine (1)
Contracting Specialist
AD-21, Mail Stop 921-165
U.S. Department of Energy/PETC
P.O. Box 10940
Pittsburgh, PA 15236

Mr. Douglas Uthus (1)
HQ Program Manager
FE-22, 3E-042, Forrestal
U.S. Department of Energy
Washington, DC 20545

Office of Patent Counsel (1)
U.S. Department of Energy
9800 South Cass Avenue
Argonne, IL 60439

Department of Energy (3)
Office of Technology Transfer
Mail Stop 58-105
U.S. Department of Energy/PETC
P.O. Box 10940
Pittsburgh, PA 15236

Dr. S.N. Roger Rao (1)
Burns and Roe Technical Group Manager
P.O. Box 18288
Pittsburgh, PA 15236

Mr. Charles Drummond (1)
Mail Stop 920-L
U.S. Department of Energy/PETC
P.O. Box 10940
Pittsburgh, PA 15236

Mr. George G. Weth (1)
Senior Program Manager
Office of Clean Coal Technology
FE-24, C-177
U.S. Department of Energy
Washington, DC 20545

Dr. C. Lowell Miller (1)
Associate Deputy for Clean Coal
Office of Clean Coal Technology
FE-24, C-178
U.S. Department of Energy
Washington, DC 20545

6.1.2 Gas Research Institute

Mr. John Pratapas (10)
Gas Research Institute
8600 West Bryn Mawr Avenue
Chicago, IL 60631

6.1.3 Illinois Department of Energy and Natural Resources

Mrs. Carol Rowe (2)
Illinois Department of Energy and Natural Resources
325 West Adams Street
Springfield, IL 62706

6.2 Host Utility Distribution

6.2.1 City Water Light and Power

Mr. James Rechner (6)
Electric Division Manager
City Water Light and Power
Municipal Building
Springfield, IL 62757

6.2.2 Illinois Power Company

Mr. T. J. May (6)
Illinois Power Company
500 South 27th Street
Decatur, IL 62521

6.2.3 Central Illinois Light Company

Mr. James F. Wittmer (1)
Central Illinois Light Company
300 Liberty Street
Peoria, IL 61602

END

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