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CATALYTIC FABRIC FILTRATION FOR SIMULTANEOUS NO_x AND PARTICULATE CONTROL

*Quarterly Technical Progress Report
January 1 through March 31, 1993*

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CATALYTIC FABRIC FILTRATION FOR SIMULTANEOUS NO_x AND PARTICULATE CONTROL

1.0 INTRODUCTION

The University of North Dakota Energy and Environmental Research Center (EERC); Owens-Corning Fiberglas Corporation (OCF); and Stearns-Roger, a division of United Engineers & Constructors (UE&C) are conducting research to develop a catalytic fabric filter for simultaneous NO_x and particulate control. Funding for the project is being provided by the U.S. Department of Energy/Pittsburgh Energy Technology Center (DOE/PETC), Consolidated Edison Company of New York Inc. (Con Edison), and the Empire State Electric Energy Research Corporation (ESEERCO). OCF is providing catalyst-coated bags, fabric samples, and technical support as a cost share.

The DOE/PETC funding was secured as a result of a competitive award from the DOE/PETC Advanced NO_x Control program. The objective of this program is to develop advanced concepts for the removal of NO_x from flue gas emitted by coal-fired utility boilers, or for the control of NO_x formation by advanced combustion modification techniques. Funded projects are required to focus on the development of technology that significantly advances the state of the art using a process or a combination of processes capable of reducing NO_x emissions to 60 ppm or less. The concept must have successfully undergone sufficient laboratory-scale development to justify scaleup for further evaluation at the pilot scale (not to exceed 5 MW_e in size). Other requirements include production of a nonhazardous waste or a salable by-product. The concept should have application to both new and retrofit coal-fired systems and show the potential for a 50% cost savings when compared to a commercial selective catalytic reduction (SCR) process capable of meeting the 60-ppm NO_x emission limit.

The EERC approach to meeting the program objective involves the development of a catalytic fabric filter for simultaneous NO_x and particulate control. The idea of applying either permanent or throwaway catalysts to a high-temperature fabric filter for NO_x control is not new (1-4). However, advances at OCF have shown that a high-activity catalyst can be applied to a high-temperature woven glass cloth resulting in a fabric filter material that can operate at temperatures higher than the maximum operating temperatures of commercially available, coated glass fabric. The NO_x is removed by catalytic reduction with ammonia to form nitrogen and water. The catalyst employed at this time is vanadium/titanium, but the exact catalyst composition and the unique method of applying the catalyst to high-temperature glass fabric are the property of OCF (5). Other catalyst options are being evaluated by OCF in order to improve catalyst performance and minimize catalyst cost.

Bench-scale experimental results have shown that over 90% NO_x removal can be achieved, the catalyst/fabric has promising self-abrasion characteristics, and the potential exists for substantially reduced cost when compared with conventional SCR/fabric filtration technology (6, 7). However, development of the technology requires further evaluation of air-to-cloth ratio effects, ammonia slip, SO₂ oxidation to SO₃, temperature cycling, catalyst-coated fabric preparation, fuel impacts, fabric cleaning (reverse-gas versus pulse-jet), catalyst life (poisoning and resistance to erosion), and filter performance/life (particulate control, differential pressure, and durability).

2.0 SCOPE OF WORK

The specific approach being used to address these issues is represented by the following:

- Task 1—Program Definition
- Task 2—Design and Construct Test Unit
- Task 3—Experimental Program and Data Reduction
- Task 4—Conceptual Design and Economic Evaluation
- Task 5—Test Unit Removal

Task 1, Program Definition, required preparation of a Project Management Plan. This document contains a detailed scope of work, project schedule, and project budget; identifies key project personnel; and presents an appropriate QA/QC plan for the project. Task 2, Design and Construct Test Unit, was divided into three subtasks. Subtasks 2.1 and 2.2 involved the detailed design of the test facility on which the experimental program was performed, the construction of the test facility, and an operational shakedown of the system prior to initiating the experimental effort. Subtask 2.3 involved preparation of the catalyst-coated fabric filters that are being evaluated in the experimental effort.

Task 3, Experimental Program and Data Reduction, has four subtasks. Subtask 3.1, Fundamental Testing, is intended as a support effort to the primary experimental test plan. This effort should supply information needed to understand the process mechanism thoroughly, allow screening of additional fabric samples, address the issue of catalyst poisoning, and generally support the pilot-scale effort. Subtask 3.2, Process Testing/Reverse-Gas System, is intended to evaluate process performance in a pilot-scale reverse-gas fabric filter, identify and optimize important process variables, and provide data for a conceptual design. Subtask 3.3, Process Testing/Pulse-Jet System, will evaluate process performance in a pilot-scale pulse-jet fabric filter. Subtask 3.4, Fabric Durability Testing/Pulse-Jet System, will evaluate catalyst-coated fabric durability/performance for up to 12,000 hours in a slipstream pulse-jet baghouse.

Based on the results of Task 3, a technical and economic assessment of the catalytic fabric filter concept will be completed in Task 4, Conceptual Design and Economic Evaluation. Task 5, Test Unit Removal, requires the identification of all major test facilities, equipment, and instruments and hardware, and their condition, ownership, and proposed disposition.

The EERC is the primary contractor for the project and is responsible for the management/direction of all technical and administrative project activities. The EERC has specifically performed all work associated with Task 1 and Subtasks 2.1 and 2.2 and will perform Tasks 3 and 5.

OCF performed and/or supervised all work associated with Subtask 2.3, including manufacturing the "S" glass fabric, coating the fabric, and manufacturing the filter bags for the reverse-gas and pulse-jet systems. This effort, as well as technical support, is being provided by OCF as a cost share to the project.

UE&C, as a subcontractor to the EERC, provided technical support for Task 1 and is currently working on Task 4. EERC personnel involved in the Task 3 effort and OCF personnel will provide input to UE&C Task 4 activities.

The project schedule is based on a project start date of October 1, 1990, and assumes a project duration of 36 months. Therefore, the planned project completion date is September 30, 1993. As of March 31, 1993, planned experimental activities for Subtasks 3.2 and 3.3 have been completed. Bench-scale experimental work associated with Subtask 3.1 is continuing, and some additional bench-scale work is planned in support of Subtasks 3.2 and 3.3. Operation of the slipstream baghouse at the UND Steam Plant (Subtask 3.4) is expected to resume in mid-April. Task 4 activities were initiated in February.

3.0 GOALS AND OBJECTIVES

The overall objective of this project is the development of a catalyst-coated fabric filter for simultaneous NO_x and particulate control. The catalyst-coated fabric filter must provide high removal efficiency of NO_x and particulate matter. An acceptable bag and catalyst life must be demonstrated, and process economics must show a significant cost savings when compared to a commercial SCR process and conventional particulate control. Specific goals include the following:

- Reduce NO_x emissions to 60 ppm or less
- Demonstrate particulate removal efficiency of >99.5%
- Demonstrate a bag/catalyst life of >1 year
- Control ammonia slip to <25 ppm
- Show that catalytic fabric filtration can achieve a 50% cost savings over conventional fabric filtration and SCR control technology
- Determine compatibility with SO₂ removal systems
- Show that the concept results in a nonhazardous waste product

Specific project activities during the past quarter (January through March 1993) were to include the following:

- Continue Subtask 3.1 - Fundamental Testing
- Continue Subtask 3.2 - Process Testing/Reverse-Gas System
- Continue Subtask 3.4 - Fabric Durability Testing/Pulse-Jet System
- Initiate Task 4 - Conceptual Design and Economic Evaluation

4.0 ACCOMPLISHMENTS

4.1 Subtask 3.1 - Fundamental Testing

Early this past quarter, it was necessary to modify the four bench-scale reactors in order to correct a leakage problem that had developed as a result of temperature cycling. The lightweight clamped flanges were replaced with bolted flanges to eliminate the leakage problem. Following completion of the modifications, bench-scale experiments resumed. Results from the experiments were poor due to system contaminants identified by the Fourier transform infrared (FTIR) analyzer. Over a period of weeks, the sources of contamination were identified and eliminated. The primary source was the reactors themselves. Although the rebuilt reactors were heated with a torch and wiped clean, small quantities of cutting oil residue apparently remained. As a result, hydrocarbons and sulfur were observed in the product gas from the reactors. The contamination was eliminated by washing the reactors with a series of solvents and then operating the reactors at temperature for several hours with a continuous gas purge consisting of 4 vol% oxygen with a nitrogen balance.

Attempts were made to use more than a half-dozen gasket materials that were vendor-rated to 800°F. All of the commercial gasket materials tested off-gassed carbon dioxide and hydrocarbons, making it impossible to determine ammonia slip using the FTIR analyzer. In one case, a high-temperature gasket material containing graphite was observed to consume oxygen from the gas stream, resulting in high levels of carbon dioxide. As a result, the EERC Project Manager elected to use aluminum o-rings made in the EERC machine shop to seal the reactors. The reactors can be sealed adequately, and use of the aluminum o-rings has eliminated the off-gas products that were interfering with the FTIR spectra.

At this time, it appears that all of the product gas contamination problems observed have been corrected, the mass flow controllers are working properly, and the rebuilt reactors seal properly. Most of the bench-scale experiments completed this past quarter will have to be repeated due to the problems previously discussed. Since the availability of the FTIR analyzer is limited as a result of three individual projects making use of the instrument, some experiments will be performed using other methods for determining ammonia slip. The catalyst deactivation experiments planned as part of this effort have been delayed in order to complete some bench-scale fabric tests planned as a support activity for 100- and 500-hr pilot-scale tests. Completion of the catalyst deactivation experiments is not anticipated before late May.

4.2 Subtask 3.2 - Process Testing/Reverse-Gas System

Subtask 3.2 activities this past quarter included completion of routine reporting requirements, reviewing data resulting from the 500-hr pulse-jet test completed in December 1992, preparation of two papers, and scheduling the next project review meeting. Data from the 500-hr pulse-jet test was summarized in the Quarterly Technical Progress Report for the period October through December 1992. In addition, the results are the focus of two papers initiated this past quarter. The first paper was requested by DOE-PETC and briefly summarizes project activities in the past year. A draft of the paper was mailed April 2, 1993, for review by DOE-PETC personnel. The paper will be presented at the Ninth Annual Coal Preparation, Utilization, and Environmental Control

Contractors' Conference, to be held July 19-22, 1993, in Pittsburgh, PA. Once review comments from DOE-PETC have been received and addressed, copies of the paper will be mailed to all project participants.

The second paper, entitled "Pilot-Scale Evaluation of a Catalyst-Coated Fabric Filter for Simultaneous NO_x and Particulate Control in a Pulse-Jet Baghouse," is due in mid-April for inclusion in the proceedings of the EPRI/EPA 1993 Joint Symposium on Stationary Combustion NO_x Control. The paper presents the results (NO_x reduction, ammonia slip, SO₂ to SO₃ conversion, baghouse particulate emissions, and baghouse differential pressure) of the 500-hr pulse-jet test completed in December 1992. The paper will be presented at the symposium the week of May 23-27, 1993, in Miami Beach, Florida. Copies of this paper will be distributed to project participants at the project review meeting on April 29, 1993.

As a result of telephone conversations with project participants, the next project review meeting has been scheduled for April 29, 1993, at the EERC. The purpose of the meeting will be to review the results of the 500-hr pulse-jet test completed in December and preliminary results from UE&C's work associated with Task 4. The EERC Project Manager will contact project participants prior to the meeting to identify specific questions the project participants may have that need to be addressed during the meeting. A representative from ABB Environmental Systems is expected to attend the project review meeting.

The EERC Project Manager plans to conduct some additional bench-scale experiments using fabric samples from filter bags used during the 100- and 500-hr pilot-scale tests as well as from two bags used during the performance/durability test at the UND Steam Plant. Evaluating these fabric samples in the bench-scale system should determine the differences in catalyst-coated fabric reactivity as well as the effect of exposure to flue gas as a function of time.

The experimental approach will involve selecting one bag from each of the five pilot-scale pulse-jet test periods (three 100-hr and two 500-hr tests) and one new bag that has not been exposed to flue gas. Two bags have been removed, representing 840 and 1642 hours of flue gas exposure, from the pulse-jet baghouse at the UND Steam Plant. Three fabric samples will be cut from each bag, representing the top, middle, and bottom of each bag. Since the bench-scale experimental system consists of four reactors, each set of four experiments will include three fabric samples removed from individual bags and one sample of non-coated fabric. The non-coated fabric sample will represent a blank. Fabric samples collected from the new bag will be heat-treated at 700°F for 4 hours before testing. Each fabric sample will be evaluated in the bench-scale system at a temperature of 650°F, an air-to-cloth ratio of 3 ft/min, and an ammonia/NO_x molar ratio of 0.8, resulting in 24 individual data sets (NO_x reduction and ammonia slip). Key measurements will include inlet and outlet NO_x concentrations and ammonia slip. Depending on the results of the initial bench-scale experiments, additional experiments may be proposed.

The planned bench-scale experiments will be completed in the next quarter. The initial series of experiments to be completed includes baseline tests and fabric tests using fabric samples collected from one bag removed from the pulse-jet baghouse after completion of the last 500-hr test and the two bags removed from the pulse-jet baghouse

at the UND Steam Plant. It is anticipated that these experiments will be completed prior to the project review meeting scheduled for late April. The planned pilot-scale experimental activities outlined in the original scope of work have been completed. Remaining activities will include routine reporting, preparation of papers and/or journal articles, additional bench-scale experimental work as previously described, and, possibly, some additional fabric analytical characterization.

4.3 Subtask 3.3 - Process Testing/Pulse-Jet System

Performance of the three 100-hr pulse-jet tests planned for this subtask were completed in July 1992, and the 500-hr test was completed in August 1992. Results were presented at a project review meeting in October 1992 and were summarized in the Quarterly Technical Progress Report for the period July through September 1992. Subtask 3.3 activities have been completed, with the exception of final reporting activities and the preparation of any papers or journal articles deemed appropriate.

4.4 Subtask 3.4 - Fabric Durability Testing/Pulse-Jet System

Operation of the baghouse slipstream system at the UND Steam Plant did not resume this past quarter as anticipated, but the required modifications were initiated in March. On November 22, 1992, operation of the slipstream baghouse was discontinued due to installation of a new flue gas duct on the steam plant boiler. Unfortunately, installation of the new flue gas duct required relocation of the slipstream baghouse. It was only necessary to move the baghouse a few feet, but modifications to the inlet and outlet piping were required. Numerous delays were encountered due to an unplanned steam line move, the planned tie-in of a new stack, and scheduling problems with the subcontractors on-site.

Modifications to the baghouse inlet and outlet piping were completed in March. In the process of completing this activity, it was discovered that a catwalk would be required to provide safe access to the top of the baghouse. In addition, during the course of working on the Steam Plant boiler, the subcontractors on-site had cut the conduit in two places through which all the thermocouple leads were run, requiring replacement of the thermocouple wire and some conduit. Other items to be completed prior to resuming operation of the baghouse include reinstalling power to the ID fan and panel board, verifying the data acquisition system, and precoating the bags with ash prior to initiating flue gas flow from the stoker-fired boiler. Completion of the additional repairs and other items identified will take roughly two weeks. Therefore, the slipstream baghouse should be operating by mid-April. The impact of these activities at the UND Steam Plant has been the loss of nearly 5 months of operation and a cost of about \$15,000.

Even if the operation of the slipstream baghouse at the UND Steam Plant were continuous from now through December 1993, 12,000 hours of operating time would not be achieved. In order to achieve 12,000 hours of operating time, it would be necessary to operate the baghouse through June 1994 and secure the uncommitted portion of the original project budget.

The boiler from which the slipstream baghouse draws flue gas will operate through May 1993. Therefore, the potential exists to operate the baghouse for an additional 1000 hours through May, if baghouse operation resumes in mid-April as anticipated. It is

possible that the boiler may operate most of the summer; therefore, additional operating hours could be accumulated in the summer of 1993. Sufficient funding is available to operate the slipstream baghouse through August 1993, if project sponsors feel that continued operation is warranted. Therefore, roughly 4200 hours of total operating time could be accumulated.

4.5 Task 4 - Conceptual Design and Economic Evaluation

UE&C is working on the conceptual design and economic evaluation. The EERC Project Manager has asked UE&C personnel to present preliminary results of their Task 4 activities at the project review meeting scheduled for April 29, 1993.

5.0 KEY PERSONNEL STAFFING REPORT

Table 1 presents planned versus actual workhours for key EERC personnel involved in the Catalytic Fabric Filtration project through March 1993. Workhours reported for Mr. Robie of UE&C represent hours invoiced through February 1993.

TABLE 1
Planned Versus Actual Workhours
for Key Project Personnel Through March 1993

Key Personnel	Planned Hours	Actual Hours	Percentage of Total Available Workhours Used
Greg F. Weber	1818	1608	88
Dennis L. Laudal	2776	1073	39
Chris Robie	309	34	11

6.0 REFERENCES

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