Quarterly Progress Report

Project No. DE-FC26-05NT42304

Lovelace Biomedical and Environmental Research Institute
Albuquerque, NM

Health Effects of Subchronic Inhalation of Simulated Downwind Coal Combustion Emissions

Quarter 3

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1. Executive Summary

This Report describes progress during the third calendar quarter of project DE-FC26-05NT42304 "Health Effects of Subchronic Inhalation of Simulated Downwind Coal Combustion Emissions". The project was initiated on February 3, 2005. The first quarterly report described progress through April 2005. The second report described progress through July 2005. This third report describes progress through October 2005.

The purpose of this project is to conduct a comprehensive laboratory-based evaluation of selected respiratory and cardiac health hazards of repeated, subchronic (up to 6 months) inhalation of simulated key components of "downwind" emissions of coal combustion. This project is being performed as an integral part of a joint government-industry program termed the "National Environmental Respiratory Center" (NERC), which is aimed at disentangling the roles of different physical-chemical air pollutants and their sources in the health effects associated statistically with air pollution. The characterization of the exposure atmosphere and the health assays will be identical to those employed in the NERC protocols used to evaluate other pollution source emissions.

The project has two phases, each encompassing multiple tasks. Guidelines for the composition of the exposure atmosphere were set by consensus of an expert workshop. The capability to generate the exposure atmosphere, and pilot studies of the comparative exposure composition using two coal types, will be accomplished in Phase 1. In Phase 2, the toxicological study will be conducted using one of the coal types tested in Phase 1. This project provides 50 % support for the work in Phase 1 and 20% support for the work in Phase 2.

During this reporting period (May-July, 2005), the project was in Phase 1, Task 1, and progressed satisfactorily according to the overall schedule. The sequence of certain of the subtasks has differed from the original estimate, as opportunities for progress from week to week have shifted from subtask to subtask, but the project is not only at its planned stage, but has also made advance progress on certain tasks planned for later completion. Technical and logistic challenges are being met, and no serious obstructing issues or problems have arisen. We are still estimating that the project will continue as scheduled.

Work during the reporting period focused on three subtasks: 1) completing the assembly of the generation system in preparation for generating coal emissions; 2) resolving personnel allocations for refining the system and conducting the generation trials and exposures; and 3) obtaining the coals to be used in preliminary trials beginning in September. Progress on these subtasks is summarized below:

- *The construction of the generation system was completed in an initial configuration. We are now ready to begin burning coal.*
- *A newly-recruited doctoral-level aerosol scientist was assigned to manage the daily operation of the laboratory.*
- *Arrangements were completed for UND/EERC to receive and process shipments of two coal types.*

In addition, advantage was taken of the availability of technical personnel to assemble the dilution/distribution and exposure system, a subtask under Phase 2, Task 1 originally scheduled for May-June 2006.

2. Results of Work During Reporting Period

a. Approach

The general approach taken in this project has not changed from that described in the application. The approach to Phase1, Task 1, involves: 1) collecting information on the use of drop-tube furnaces for laboratory-scale coal combustion; 2) collecting information on potential coal types and resources for obtaining coal and processing it for use in the laboratory; 3) finalizing a design for the drop-tube furnaces to be used in this project; obtaining processed coal; 4) obtaining, installing and testing the furnaces; 5) developing and testing the coal aerosol generator; 6) assembling the emissions generation/modification system; and 7) confirming system operation by generating coal emissions. The work is then to proceed to Phase 1, Task 2: conducting iterative generation trials with PRB coal in an attempt to meet the target ratios of particulate and non-particulate components at target total particle mass concentrations.

The last progress report described progress toward accomplishment of item 6, and associated staffing and coal acquisition activities. In addition, we reported progress on assembly of the systems for diluting and distributing the different concentrations and exposing animals, which were completed out of sequence and well ahead of schedule.

We have now completed items 6 and 7, and have begun Phase 1, Task 2, as was scheduled for this quarter. Overall, the project is on schedule.

1) Assembly of Generation/Mixing and Exposure Systems

The last quarterly report described the assembly and design of the generation system less the sulfate generator. In brief, the system consisted of two electric furnaces and coal aerosol generators, buffer chambers to receive the output from the furnaces and a sulfate generator, a mixing/aging chamber, and a dilution/exposure system. At the time of the last report, this system was complete with the exception of the sulfate generation system, which had not yet been assembled. Progress beyond that point is described below.

Coal Generation System

The coal aerosolizing system, consisting of the syringe pump and the test-tube containing coal, was optimized for consistent delivery of coal aerosol into the furnace. The system was optimized in terms of the flow rate of coal and the speed of test tube upward movement in the syringe pump to deliver a uniform concentration of coal. The flow rate of the coal delivery line is now set at 1.0 L/min and combustion air is delivered at 15 L/min

We decided to begin storing the coal overnight in an oven prior to its use the next day, as per the suggestions of EPA. EPA's experience, validated by our own, is that warming the coal overnight in the oven to reduce moisture makes the coal much easier to aerosolize, thus producing a more consistent delivery to the furnace. The coal for the next day's generation is now kept overnight in the oven at 95°C.

The adequacy of the coal generation system was checked by burning PRB coal and measuring particle concentration downstream in the buffer tank, which is interposed between the furnace and the mixing/aging chamber. Fairly uniform concentrations over multiple hours were achieved, indicating that the coal aerosolization and combustion system could be operated in a stable manner. The concentrations achieved in the buffer chamber during the initial stability trials ranged from 700-900 $\mu g/m^3$, which will be adequate.

Changes to the Introduction of Coal Aerosol and Combustion Air Into the Furnace

During the initial operation of the main furnaces, we found that the stainless steel inlet tube at the top of the furnace melted. We ran tests with thermocouples at various places in the furnace and found that the "conditioning zone" at the top of the main furnace was only 200°C cooler than the hot zone (which was 1400°C). We shortened the SS tube, which alleviated the problem. The SS tube now runs only in the conditioning zone followed by the ceramic tube in the heating zone.

In addition, a smaller electric furnace was installed to pre-heat the combustion air to about 600°C before it enters the main furnace. The new set-up, shown in Figures 1 and 2, now operates satisfactorily.

Figure 1. Small electric furnace for pre-heating combustion air

Figure 2. Main furnace with pre-heat furnace at upper left

Change in Size of the Buffer Tanks

The size of the two buffer tanks upstream from the mixing/aging chamber has been reduced. These tanks receive flows from the furnace and the sulfate generator, and enhance the stability and "controllability" of the diluted flows that enter the mixing/aging chamber. We started with buffer tanks consisting of 55 gal drums, but found that this large volume gave an unnecessarily long lag-time for changing inputs to the mixing/aging chamber. We replaced the drums with 30 L stainless steel tanks (Figure 3), which improved system responsiveness. Subsequent tests using a DustTrak aerosol monitor confirmed a reduced residence time of about 1 minute.

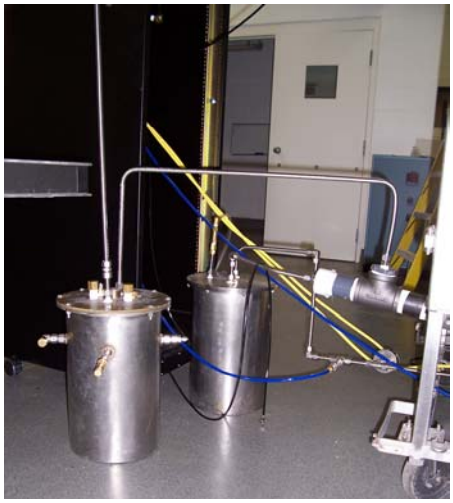

Figure 3. New 30 L stainless steel buffer tanks

Characterization of PRB Coal Emissions in New Buffer Tank

The effluent from combustion of PRB coal was characterized by sampling it from the buffer tank during a generation trial. The cyclone between the furnace and the buffer tank was removed for this test to gain an understanding of the entire size distribution of the aerosol. The initial results are presented in Table 1. The bimodal particle size distribution is illustrated in Figure 4.

Table 1. PRB coal emissions in buffer tank (without cyclone)

Particles	
PM mass concentration	2.1 mg/m^3
$PM_{1.0}$	33% of total PM
Peaks of bimodal size	0.17 and 3.66 μm
Gases	
NO	5.6 ppm
NO_2	1.6 ppm
CO	Zero (good combustion)
CO_2	1125 ppm
SO_2	800 ppb

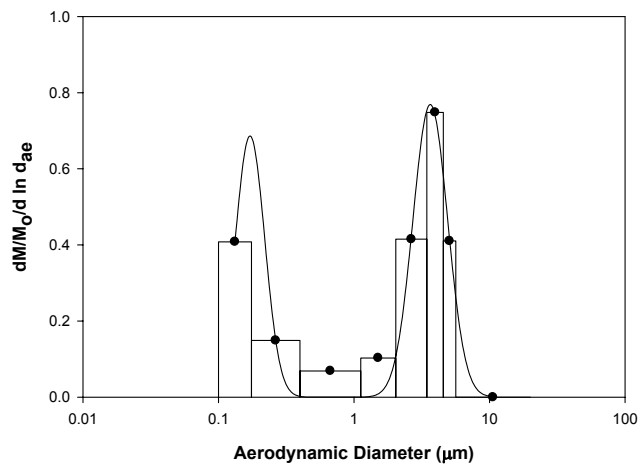

Figure 4. Bimodal size distribution of particles in buffer tank

Installation of the Sulfate Generation System

The sulfate generation system has been constructed, installed, and connected to the mixing/aging chamber via one of the 30 L buffer chambers. The system (Figure 5) consists of a liquid reservoir (for the diluted sulfuric acid stock solution), a nebulizer, a diffusion drying section, and a cooled nucleation section. The diffusion dryer is lined with silica gel, and the nucleation section is cooled by circulated ethylene glycol. Initial trials indicate that the system works adequately, and is now ready for fine-tuning.

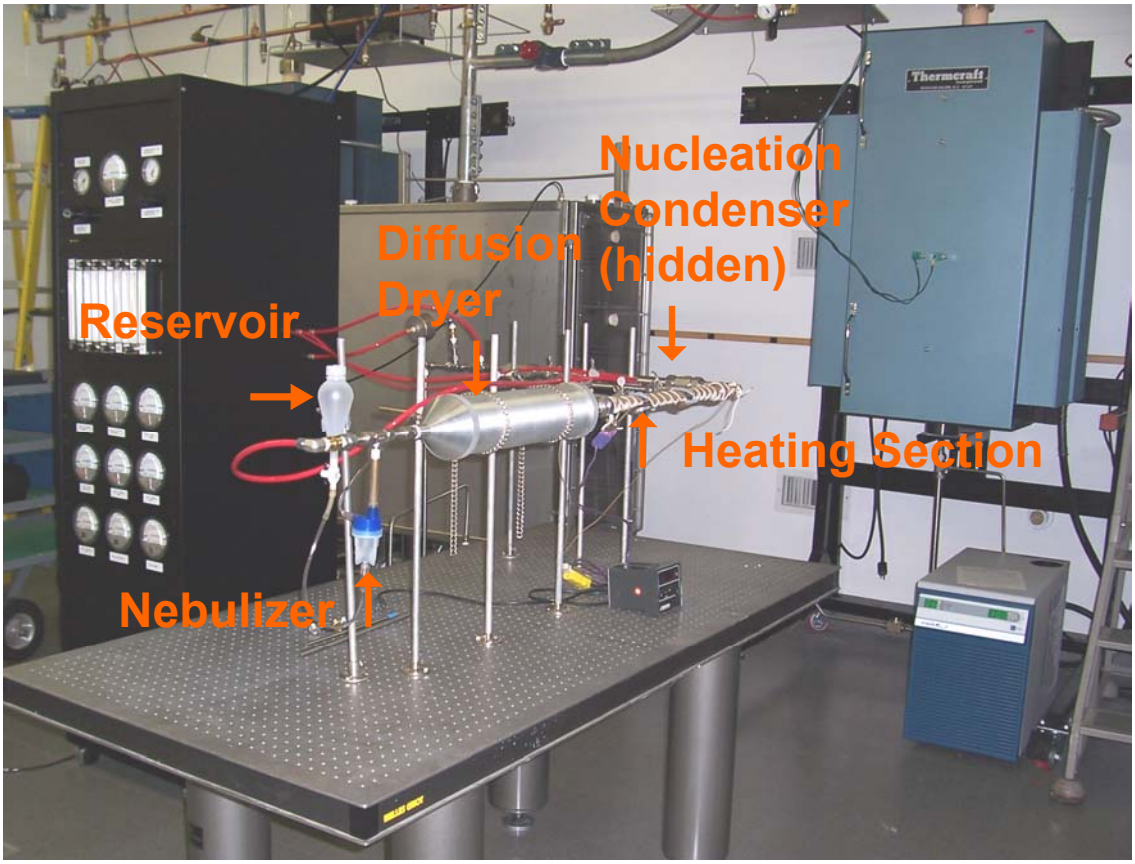

Figure 5. Sulfate generation system

2) Procurement of Study Coals

Decisions regarding the sources for the two coal types to be used were described in earlier reports. Logistics were put into place to obtain coals from the Black Thunder Mine in Campbell County, Wyoming (Powder River Basin [PRB] coal) and the Jones Fork blending/processing plant in Knott County, Kentucky (Central Appalachian Low Sulfur [CALS] coal). An agreement was reached with UND/EERC for obtaining the two coals, processing by grinding and mixing, conducting partial chemical analysis, packaging under nitrogen, and shipping to LRRI.

During this reporting period, both coals were obtained by UND/EERC. The CALS coal was obtained first, and has now been processed and shipped to LRRI. The PRB coal has now also been obtained by EERC and is now being processed. We had originally planned to use coal from the Black Thunder mine, which until recently was the largest single source of PRB coal. Because of some coordinating difficulty, it appeared that Black Thunder coal might not be available, and coal from another PRB source would be used. Recently,

however, EERC overcame the difficulties and obtained Black Thunder coal. It is now being dried in preparation for grinding.

The experimental schedule calls for generating PRB coal first, followed by LSCA coal. While the study PRB coal is being processed, generation trials are underway using PRB coal obtained from EPA. This coal was from the same source as our study coal, and was also processed by EERC. The following summarizes recent progress and results.

b. Results and Discussion

The only data results produced to date are those described above. There are no other specific technical results or data to report during this quarter. The project will produce additional preliminary results during the next quarter from the iterative PRB combustion trials.

c. Conclusions

The project continues to appear technically feasible and should progress as planned and according to schedule. We are on track on the overall schedule, and have embarked on iterative generation trials with PRB coal. As noted above and in the last report, the animal exposure system was constructed approximately a year ahead of schedule. This will be very useful, because it will allow the generation trials to determine the composition and component ratios in the actual exposure chambers at the final exposure concentrations, rather than just at the outlet of the mixing chamber.

3. Milestones

The milestones pertinent to this reporting period have been met. Phase 1, Task 1 "Assemble Drop-Tube Furnace and Emissions Modification System" has been completed. Of course, modifications to the system will continue to be made during the ongoing generation trials. Phase 1, Task 2 "Conduct Iterative Generation/Modification Trials Using PRB Coal", is underway, as scheduled. We see no reason at this time that it should not be completed as scheduled (end of CY 2005).

4. Cost and Schedule Status

a. Cost Status

DOE expenses as of 10/31/05:	$ 168.092.48
LRRI cost share as of 10/31/05:	$ 33,618.50
Other cost share as of 10/31/05:	$ 134,473.98
Total expenditures as of 10/31/05:	$336,184.96

b. Schedule Status

The project is on schedule. We see no reason at this time that Phase 1, Task 2 "Conduct Iterative Generation/Modification Trials Using PRB Coal", should not be completed as scheduled (end of CY 2005).

5. Significant Accomplishments

Significant accomplishments were described in detail above. In summary, we have:

- Completed assembly of the generation/modification system
- Received the processed CALS coal and obtained the PRB coal for processing
- Begun generation trials with PRB coal

6. Problems, Delays, and Corrective Actions

We have not encountered any problems or delays that have obstructed progress significantly.

7. Technology Transfer Activities

There have been no technology transfer activities or issues to date. It is not anticipated that this project will generate any intellectual property or technical advances that will raise technology transfer issues. The product of this project is explicitly information on the health effects of exposure to modified coal emissions, and that information is to be communicated to the scientific community, public, and other stakeholders through peer-reviewed, open literature publications.