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CONFIGURATIONAL TESTING OF ELECTRON BEAM
IONIZATION FOR COAL FLY ASH PRECIPITATORS

Quarterly Report for the Period November 5, 1983—February 4, 1984

By
R. H. Davis

Work Performed Under Contract No. AC22-83PC60266

The Florida State University
Tallahassee, Florida

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QUARTERLY REPORT NO. 2

DOE Contract Number DE-AC22-83PC60266.

CONFIGURATIONAL TESTING OF
ELECTRON BEAM IONIZATION FOR
COAL FLY ASH PRECIPITATORS

For the Quarter

November 5, 1983 - February 4, 1984

Submitted by

The Florida State University
Tallahassee, Florida
32306

Principal Investigator

Dr. R. H. Davis
Department of Physics

(904) 644-2867
(904) 644-1767

Quarterly Report No. 2

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	
I. INTRODUCTION AND SUMMARY.....	1
II. ELECTRON BEAM PRECHARGING.....	3
A. Low Energy Electron Beam Precharger.....	3
B. Energy-Geometry Matched Precharger for Test Precipitator System.....	10
III. RESEARCH FOR EBP TECHNOLOGY.....	21
A. Free Electron Charging of Aerosol Particles..	21
B. SO ₂ Enhanced Resistivity Reduction with E-Beam.....	22
C. Investigation of E-Beam Effects on Resistivity.....	23
IV. LABORATORY PRECIPITATOR TEST SYSTEM.....	29
A. Wind Tunnel and Racetrack Modules.....	29
B. Monitoring Instruments and Data Acquisition System.....	29
C. Particles and Aerosol Generation.....	33
V. PRESENTATIONS AND PUBLICATIONS.....	35
A. Patent Disclosure on a Device to Enhance Radiation Dose.....	35
VI. PERSONNEL.....	35

ABSTRACT

DOE Contract Number DE-AC22-83PC60266

The energy-geometry matching condition reported in Quarterly Report No. 1 has been incorporated in the design of a Mark II precharger and construction is underway. By matching the energy and geometry, monopolar charging is assured by providing a charging zone outside the ionization zone. Particle charges greater than the Pauthenier limit were observed using a bi-electrode geometry. Either or both free electron charging or space-charge enhancement of the electric field may be responsible for the increase in charge above the theoretical limit for the average electric field. A separate experiment on free electron charging proceeded during this quarter and the progress is reported. To date the exhaustive experiments on resistance modification by simple electron beam irradiation have not provided evidence to support practical utilization. However, preliminary experiments do suggest that the presence of small amounts of SO_2 and the subsequent conversion of SO_2 by electron beam treatment may conductively coat high resistivity fly ash particles with a resultant reduction in resistivity. The status of the laboratory precipitator test system is reported along with the preparations for tests of the new Mark II precharger module. During this quarter a patent disclosure on a device to enhance radiation dose was submitted to the U.S. Department of Energy.

I. INTRODUCTION AND SUMMARY

Experiments with a bench-scale device show that electron beam ionization will produce superior aerosol particle charging in a bi-electrode geometry for which the electron energy is well matched to the electrode spacing. The requirement for energy-geometry matching was reported in Quarterly Report No. 1 and recognizes the necessity of avoiding ionization in the particle charging zone. The results of the bench-scale experiments are reported in Section II.A and the work on a new precharger (Mk. II) which will be installed in the Electron Beam Precipitator (EBP) test system is reported in Section II.B.

Several phenomena involving energized electrons are important research topics with regard to their utilization in particulate control technology. The status of the research projects is reported in Section III. Experiments to confirm the superior charging of aerosol particles by free electrons carried out by the Southern Research Institute group are underway. Substantial progress has been made, but new data suitable for comparison with the Southern Research Institute results is not available as yet. The possibility of reducing the resistivity of high resistivity fly ash by electron beam irradiation was revisited during this quarter. The evidence to date suggests that resistance reduction as a direct result of irradiation does not have a practical application but that there is a possibility of coating high resistivity fly ash particles with a conductive layer of SO_2 conversion products produced in electron beam treatment. Some SO_2 and NO_x are

present in the stack gas even when low sulfur coal is burned.

The status of the laboratory precipitator test system is reported in Section IV. Particular emphasis is placed on the modifications of the precharger module to accomodate the new energy-geometry matched precharger.

The work on radiation dose enhancement has been written up as a patent disclosure and this action is reported in Section V.

In summary, the development of an electron beam pre-charger advanced rapidly this quarter with the work on a new energy-geometry matched precharger. Extensive experiments on the direct modification of resistivity by electron beam bombardment were completed and the remaining promise for resistance modification apparantly lies in conductively coating the fly ash particles. The work on free electron charging is continuing because of its potential importance in practical applications. There were no visitors to the laboratory during this quarter. The personnel involved in the work reported here are listed in Section VI.

II. ELECTRON BEAM PRECHARGING

A. Low Energy Electron Beam Precharger

This quarter a low energy electron precharger was constructed and tested outside the wind tunnel. The low energy electron accelerator which was built last quarter was used to provide a source of low energy electrons (see Fig. II-1). The electron beam energy is variable between 0 and 90 KeV and the beam current can be adjusted between 0 and 10 μ A. The performances of the bi-electrode and tri-electrode configurations of the precharger (see Figs. II-2 and II-3) were evaluated by measuring the charge acquired by 1-3 μ m PSL particles using the q/a system described last quarter. In these measurements, the electron beam energy was adjusted so that the ionization zone (bipolar region of ionized air) was smaller than the electrode spacing. This avoids spurious ionization and establishes a monopolar charging region by separating the bipolar ions with the electric field.

In Figure II-4, the charging performance of the bi-electrode precharger is compared to the theoretical ionic charging theory for several average electric field strengths (voltage difference divided by electrode separation). The electrode separation is 15 cm, the electron beam energy is 90 KeV, and the beam current is 10 μ A. The 1 μ m diameter PSL particles received a charge which is much higher than that possible with normal ionic charging.

The increased charge may be caused by space-charge enhancement of the electric field or by free electron

diffusion charging or both. The space-charge enhancement of the electric field occurs primarily because of the existence of the bipolar plasma in the interelectrode volume effectively reduces the electrode separation and, to a lesser extent, because of the finite drift time in the monopolar region. Free electron diffusion charging occurs when the particles enter the region near the end of the electron beam path in air. This region contains a large number of free electrons which have not lost sufficient energy to become attached to O_2 molecules and form negative ions. Using 3 μm diameter particles the increase in charge was substantial, but not as great as for 1 μm particles. This suggests a decrease in diffusion charging efficiency with increasing particle size.

The charging performance of the tri-electrode precharger is compared to the ionic charging theory in Fig. II-5. The middle electrode is placed 5 cm and 10 cm, respectively, from the outer two electrodes, and the electron beam energy and current are 90 KeV and 10 μA . The electron beam ionizes the air in the 10 cm interelectrode gap, and the electric field extracts the negative ions and free electrons into the 5 cm interelectrode gap where particle charging occurs. The 1 μm diameter PSL particles received a somewhat higher value of charge than the theoretical limit, but not as high as the bi-electrode precharger values. Using the tri-electrode configuration greatly reduces the space-charge enhancement of the electric field, therefore the increased charge is probably caused by free electron charging only. Also the percentage of free electrons in the charging region in the tri-electrode

Low Energy Electron Accelerator

Figure II-1

BI — ELECTRODE E-BEAM PRECHARGER

Figure II-2

TRI-ELECTRODE E-BEAM PRECHARGER

Figure II-3

Particle charge using the Bi-electrode E-beam precharger

Figure II-4

Particle charge using the Tri-electrode E-beam precharger

Figure II-5

precharger is lower than in the bi-electrode precharger because the charging region is further from the end of the electron beam path.

These tests of the low energy electron beam precharger represent proof of concept and indicate that the precharger is extremely effective in charging a low concentration of 1-3 μm particles. The next step is to install the precharger in the wind tunnel and evaluate its performance for aerosols of medium and high concentrations.

B. Energy-Geometry Matched Precharger for Test Precipitator System

The transfer of successful precharger designs from preliminary testing outside the confines of the EPB racetrack to a more realistic situation within the wind tunnel represents the next major step in developing an operational particle charging system utilizing electron beam ionization. Several precharger arrangements, namely the bi-electrode and the tri-electrode rack systems, have been examined extensively to determine their effectiveness in separating the ion population produced by an electron beam. Proper geometry of the electrode racks and optimum e-beam energy and current are the two most important considerations when assessing the suitability of a certain precharger configuration for effective particle charging.

Section II.A of this report and sections in Quarterly Report 1 describe the initial results of the precharging

apparatus design and development. These experiments form the preliminary work needed to ascertain the basic parameters of electron beam precharging prior to transferring the technology to the wind tunnel. Earlier experimental results will be briefly reviewed here and progress towards applying a rack electrode precharge to the racetrack will be discussed.

1. Previous Experimental Results

The last contract was primarily concerned with designing and constructing a laboratory-scale precipitator test system which would be adaptable to a wide variety of experimental conditions.

The F.S.U. Electron Beam Precipitator Test System was subjected to a series of performance tests upon its completion. Among these were investigations of the air flow patterns through the system, and a thorough examination of the racetrack electronic monitoring devices. These tests were generally successful although the monitoring systems, especially the Climet optical particle counters, were found to have larger errors than expected, which must be taken into account when using these devices for diagnostic purposes. Our two Climet units always give somewhat different particle counts even when sampling the same gas stream, but initial difficulties obtaining quantitatively believable results have been overcome by internally adjusting the counting mechanisms. The other monitors and the data acquisition and analysis system are now functioning properly since the installation of a proper earth ground was completed.

Once the racetrack system was checked out, attention was focused on developing a working rack electrode particle precharger and a collection field downstream from the precharger. Any electrode arrangement to be used as an ion current separation device for charging particles must provide a high electric field while allowing an unimpeded flow of particle-laden gas to flow through the charging volume. A double rack precharger design (MK. I) was the first design tested. (See Fig. II-6) Each rack was composed of 9 - $\frac{1}{4}$ " thick by 11" high rods spaced at $1\frac{1}{4}$ " intervals. The racks were placed perpendicular to each other at a separation of 6" and the electron beam axis was aligned midway between the racks. Using a 1.2 MeV electron beam of 10 μ A primary current, a maximum ion current density of 54.3 mA/m^2 was obtained for an average electric field between the racks of 5 kV/cm. Since that time several new electrode configurations have proven more adept at charging particles effectively, and these will be discussed in a subsequent section.

The collecting section of the EBP can be operated as either a conventional high ion current, high electric field electrostatic precipitator or as a low current, medium to high field second stage collector of a two-stage ESP. High voltage wires of practically any diameter can be substituted for the present 1/10" diameter corona wires presently installed for testing. Within the collection module are two gas channels having three collecting fields each for a total of six. Wire-to-plate spacing is 3" and total SCA is 200.

At an applied corona wire voltage of 50 kV DC (6.5 kV/cm) the collector ion current was 28 mA (2.5 mA/m^2). Higher ion currents or electric fields can be produced with electrode geometry modifications.

Particle removal efficiency of the collector operating as a normal ESP was determined by injecting an aerosol of $1.1 \text{ }\mu\text{m}$ diameter polystyrene latex (PSL) spheres into the wind tunnel upstream from the collecting section. Climet optical particle counters sampled the gas stream before and after the collector and provided particle size and number data which resulted in a collection efficiency figure for various electric field values. At a corona wire voltage of 40kV (5.3 kV/cm) and an ion current density of 1.09 mA/m^2 the $1.1 \text{ }\mu\text{m}$ diameter particle collection efficiency was 99.6%. Using the Deutsch-Andersen equation, the number of electronic charges per particle (average) is found to be 285. In a two-stage configuration, however, the collector would be operated at a similar electric field but a lower ion current because the function of particle charging would be handled by an e-beam precharger upstream from the second stage.

To summarize, both the initial precharger (Mk. I) and the collector were tested to determine their electrical characteristics, and the collector was analyzed for its ability to remove fine particles from a gas stream. The results are in agreement with expectations and with earlier results obtained outside the racetrack.

The first tests of the Mk. I precharger operating on

a model aerosol (see Quarterly Report No. 1) uncovered a mismatch between the lowest available energy from the 3 MeV Van de Graaff accelerator and the precharger module geometry. Even the lowest beam energy was too large and produced spurious ionization which precluded the acquisition of a significant charge by the test particles. A low energy (~90 keV) electron accelerator was constructed of equipment at hand, but this energy is somewhat smaller than the optimum energy for the size of the precharger module.

2. Module Modifications for Mk. II Precharger

The precharging module as originally designed and constructed is a stainless steel cross-shaped unit having a working volume of 1 ft.³ (Fig. II-6). Two 1 ft.³ extensions of the working volume were provided to accommodate mechanical and electrical components required to collimate, diffuse, and measure the electron beam, which enters the module through one of the extensions. The original Mk. I double-rack precharger fit into the center of the module and actually filled most of the working volume. As previously mentioned, the new Mk. II precharger is smaller in size than the Mk. I version. This and a provision for higher voltages require a modification of the module.

Effecting these changes required turning the precharging module 90° and connecting one of the extensions directly to the southwest right-angle bend of the wind tunnel. The upstream monitoring module was removed to make room and monitor ports will be added to the precharging module upstream

PRECHARGING MODULE (Top)

Figure II-6

from the new working volume. A short, temporary piece of ducting was added to fill the gap between the precharging and transition sections (Fig. II-7).

3. Electrode/E-Beam Arrangement

Interior modifications to the precharging module revolve around a sub-duct or prosthesis which runs down the middle of the stainless steel precharging section. (See Fig. II-8) The square interior duct is 3 ft. long, has a cross section of 6" x 6", and has a small transition baffles on both ends. Narrower duct widths can be accommodated by sliding the moveable duct walls towards each other. Constructed of 3/4" thick PVC plate, the new precharging tube must be able to electrically insulate precharger rack voltages of 100 kV from the surrounding metal ductwork. A small extension of the sub-duct will accept the end of the new 100 keV electron source, which can be positioned in any desired location. Six rack electrode arrays, each composed of 3 - 1/4" thick stainless steel rods 5" high supported by PVC bases and caps, will delineate the ionization volume within the duct. The racks are moveable and can be used in any arrangement and number combination required. A stainless steel stopping plate forms the limit of the ionization zone opposite the e-beam tube entry. High voltage leads supply the racks and stopping plate with power.

Particles entering the old precharging module will be swept into the new duct where they will first be sampled by a particle counter. The aerosol then flows into a separated

Precharger Housing (Side View, $\frac{1}{8}$ scale)

Racetrack - Mounted Precharger (Top View)

Figure II-7

A Precharger Housing (Top View, $\frac{1}{4}$ scale)

Figure II-8

plasma region bounded by the racks and plate where particle charging occurs, as described in previous sections in this report. A second sampling station downstream from the charging region will accomodate the laser-based particle charge vs radius (q/a) instrument and also another particle counter. This counter can be moved downstream from the collector when precharger-collector particle removal efficiency data is needed. The new particle precharging prosthesis is designed for maximum flexibility of duct size and rack location in order to optimize beam energy-electrode geometry compatibility and to maximize the level of particle charge for the electrical and physical conditions in questions.

4. Experimental Plans

Design of the new precharger commenced this quarter and some construction work has begun. Experimental plans are now being formulated pending the outcome of the latest set of experiments involving the bi- and tri-electrode prechargers being tested outside the EBP. Several new developments, including the use of a pulsed power supply to energize the electrodes and the use of electrically enhanced dose will certainly influence the experimental program.

Fly ash or a monodisperse simulating medium such as Hydral will be resuspended and injected into the wind tunnel upstream from the precharger. Electron beam energy, current, and positioning and rack electrode voltage can be varied according to the specific conditions required. Gas velocity and humidity are controllable. Particle monitoring up- and downstream from the ionization volume and the optional

collector will produce collection efficiency data for each particle size in question. From the information gained in this small scale e-beam precharger, a scaled-up version will be designed, possibly requiring the construction of a larger precharging module housing. The performance of the Mk. II precharger on test aerosols will be discussed in future reports.

III. RESEARCH FOR EBP TECHNOLOGY

A. Free Electron Charging of Aerosol Particles

The Free Electron Particle Charger (FEPC) has been modified since the last quarterly report and is now under test. The design of the system is based on the system constructed at the Southern Research Institute (SRI) by J. DuBard's group. Experiments by DuBard's group showed free electron charging

1. to be more effective by a factor of 2 for 1 μm PSL particles than ionic charging.
2. to be linear in dependence on the particle radius.
3. to be anomalous in its dependence on the charging field.

The first tests showed that the cell is relatively free of oxygen. However, the alcohol used to re-suspend the PSL particles appears to be too electronegative and suppresses the charging characteristics.

The first experiments were with a DC charging field. Most of the PSL particles were precipitated for electric fields above 2.46 kV/cm. Following DuBard, the anode was switched over to an AC power supply. The results were less than anticipated. These results can not be taken to be conclusive since it now appears that the current on the anode probably was not measured accurately. Further work was done using a square-wave power supply, but these have not been repeated since finding the problem with current integration. Progress has been made towards obtaining reliable results which can be

compared with DuBard's data, but some further improvements are necessary:

1. Installation of a separate flush line to purge the cell independent of the FLAG to prevent back leaks into the FLAG.
2. Installation of a cold-trap to the input lines of the cell to remove any residual alcohol.
3. Installation of a new square-wave power source and more accurate meters on the anode and cathode.

When these improvements are completed the FEPC should be ready to operate at ten different charging fields (.82-8.2 kV/cm) with PSL particles from 1.091-3.0 μm in diameter. The next step would then be to operate using DES 2-diethylhetyl sebecate and later with fly ash. At present the above modifications are being made.

B. SO_2 Enhanced Resistivity Reduction with E-Beam

A preliminary experiment has been conducted on the modification of fly ash resistivity for particles suspended in air containing SO_2 , NO and NH_3 . It is expected that, if the mixture is treated by the electron beam, the fly ash surface will be coated by chemical products converted from SO_2 , NO and NH_3 . This will result in the decrease of the fly ash resistivity.

The reaction chamber shown in Fig. III-1 was used. Fly ash was inserted into the chamber and suspended in the sample gas by mixing with a fan. In order to compare the fly ash resistivity with and without the E-beam treatment, another

E-beam shielding cell was inserted inside the reaction chamber. Dry air was used. Concentration of SO_2 , NO and NH_3 were 1000, 1000 and 3000 ppm respectively.

An electron beam with 1.2 MeV energy and 10 μA beam current irradiated the chamber for 30 minutes. After the radiation suspended fly ash was collected on a filter. Resistivity of the fly ash without the treatment (sample #1), that exposed to the sample gas inside the shielding cell (sample #2), and that exposed to the sample gas and treated by the E-beam (sample #3) were measured in room air at 22°C and 30-60% relative humidity. Figure III-2 shows the time change of the resistivity (ratio to the sample #1) of sample #2 and #3. The resistivity dropped by a factor of 10 for the sample #2, and of more than 1000 for #3 at first. Then the resistivity gradually increased. After 18 hours, the resistivity of the sample #2 recovered and coincided with the value for sample #1. The resistivity of the sample #3 recovered after 24 hours, but stayed lower than that of #1 by a factor of 20.

These preliminary results suggest that the absorbed sample gas lowered the resistivity of the sample #2 but out-gased as the time elapsed so that the resistivity recovered. However, for the sample #3, the E-beam treatment made more stable chemical products which coated the fly ash surface and resulted in the lowering of the resistivity.

C. Investigation of E-Beam Effects on Resistivity

1. Parallel Plane Resistivity Cell

Reaction Chamber for the Resistivity Modification

Figure III-1

Time change of the resistivity ratio (ratio to the resistivity of non-treated flyash)

Figure III-2

The possibility of reducing the resistance of high resistivity fly ash by electron beam irradiation was further investigated this quarter in a series of experiments in a parallel plane geometry. The results to date using this geometry do not provide a basis for a practical application of resistance modification by irradiation. In addition to the results of the parallel plane experiments reported here, an extension of the experiment on resistivity reduction by coating particles with SO_2 conversion products (see Section III.B) is discussed.

A high resistivity fly ash (resistivity $> 10^{12} \Omega - \text{cm}$) was placed in a modified PTC-28 (ASME Power Test Code 28) resistivity test cell and experiments were performed with very low (approximately 0%) and 70% relative humidity. The sample was exposed to a 1.2 MeV electron beam of 10 μA intensity and for time durations which produce doses in the range of 1 Mrad to 2000 Mrad. No statistically significant changes in resistivity were observed as seen in the typical result in Fig. III-3. The conclusion is that direct modification of resistivity by irradiation with no additives is not occurring with this test cell.

However, the gases SO_2 and NO_x are produced to some degree even in the combustion of low sulfur coal and these gases might serve as "additives" in the electron beam modification of resistance through a conversion of the gases to conductive coatings on the fly ash particles. The first tentative results are reported in Section III.B. To further investigate this

RESISTIVITY MODIFICATION EXPERIMENT

Figure III-3

possibility, SO_2 was pumped through a fly ash layer during exposure to the electron beam in the resistivity cell. The resistivity did not change significantly. The experiment will be repeated to insure the validity of the results. The experiment reported in Section III.B in which fly ash and 1000 ppm SO_2 were blown through a precipitation cell with pulsed power delivered to the central electrode will be repeated. The application of pulsed power may play an unexpected role in the process.

Effort was spent on the design and construction of a resistivity cell for which the temperature could be varied from room temperature up to 300°C and the humidity could be varied from 0% to 20% by volume while a fly ash test layer is exposed to the electron beam. It appears that a cell based on a design from Research-Cottrell, Inc. could provide better control of both temperature and humidity. Such a cell will be constructed when time permits.

IV. LABORATORY PRECIPITATOR TEST SYSTEM

A. Wind Tunnel and Racetrack Modules

The FSU Electron Beam Precipitator test system and its components have been described in detail in previous reports and the entire system was reviewed in Quarterly Report No. 1. A schematic of the racetrack wind tunnel is shown in Fig. IV-1. As stated in Section II.B, the stainless steel precharging module was rotated 90° and moved upstream to a position adjacent to the southwest 90° bend. The first monitoring module was removed completely and a short temporary connecting piece will be inserted between the precharging and collector transition modules. Internal modifications to the precharging module will be required before the new precharger prosthesis can be fitted.

In addition to the precharger modification, the pulsed power supply which is being used in particle precharging and electron beam dose enhancement studies was moved to a new, semi-permanent location near the upstream humidity monitoring module and the northwest 90° turn. This supply delivers maximum 50 KV pulses at 60 Hz frequency for a duration of 300 ns to 1 μ s and can be used either by itself or imposed on top of a DC base potential. Continued developmental changes to the EBP test system will be described in future reports.

B. Monitoring Instruments and Data Acquisition System

Quantifying the various gas stream, particle, and precipitator parameters requires a complement of mechanical and

F.S.U. ELECTRON BEAM PRECIPITATOR TEST SYSTEM

Figure IV-1

electronic monitoring devices which can be remotely controlled or that have remote readouts. Climet optical particle counters give particle size and number information through a multi-channel analyzer (MCA) located in the accelerator control room. Hard wired to the MCA are two General Eastern relative humidity/temperature sensors located on module tops near the dehumidifier and downstream from the precipitator. These sensors are used with other experimental apparatus such as the fly ash resistivity measurement chamber for which a knowledge of moisture content is needed.

A bulk charge-to-mass (Q/M) sampler composed of a modified absolute filter holder connected to an electrometer has been tested and will be employed as a time-integrated particle charge measuring device for high loading EBP experiments. Single particle charge-to-radius (q/a) measurement using a laser-based AC oscillation field has been described in Quarterly Report No. 1 and is in daily use in precharger and FEPC development work. Monitoring voltage and current from many different sources is accomplished using several closed circuit TV camera systems with analog panel meters or digital multimeters. The digital multimeters, especially, have proven quite useful in measuring very small or wide ranging currents in the point-plane and plane-plane resistivity work.

A microcomputer-based data acquisition and analysis system is employed in the accumulation, storage and evaluation of all data taken during electron beam precipitator experiments.

Hardware presently interfaced to the microcomputer includes two 8" floppy disk drives, a Z10 video terminal, an Okidata 83 line printer and a UMAC-4000 Intelligent Measurement and Control System.

Recently, the group's Houston Instruments DMP-29 plotter was brought on line and a set of functional software was written to produce various graphical representations of experimental data. These include plotting on linear, semilog and log-log space. The advantages of this system include less time spent plotting data, greater accuracy and fewer errors in data handling (since everything can now be done on disk).

Last quarter the group acquired a copy of a cascade impactor data reduction program written by the Denver Research Institute (DRI). The program can be used to reduce raw impactor data (stage weight gains, etc.) to particle size distributions at a consistent set of particle sizes, and then combine multiple impactor runs and compare the results of the inlet and outlet samples to evaluate precipitator efficiency.

Although work on the conversion to BASIC-80 of this package is essentially complete, several modifications are being made to adapt it to the type of data accumulation employed by the EBP group. In addition, presentation of the results will soon be altered with the inclusion of a routine for accessing the pen-plotter and graphing differential distributions of particle sizes in log-normal space.

C. Particles and Aerosol Entrainment

A carefully chosen array of aerosol particles are necessary for the experiments designed to test precharger performance. As outlined in previous Quarterly Reports, three aerosol generators using different resuspension techniques will supply airborne test particles to a number of small bench scale experimental apparatus as well as to the large EBP wind tunnel. A Fluid Atomization Aerosol Generator (FLAG) has been used to generate a polystyrene latex (PSL) aerosol at relatively low concentrations for double rack precharger development studies outside the racetrack. The FLAG has also been employed in particle collection efficiency measurements for initial testing of the wind tunnel collector section when operated as a conventional ESP. The Free Electron Particle Charger (FEPC) is supplied by the FLAG because a well-controlled, monodisperse aerosol is needed for repeatable particle charging measurements. Several sizes of PSL particles have been injected into the cell and another particle type, 2 diethyl hexyl sebecate (DES) has been investigated for future use due to its ability to be atomized into a wide range of sizes.

Bench scale development of a successful rack electrode precharger has benefitted from the ease of operating the compact Wright Dust Feeder (WDF) at low or medium aerosol concentrations. Any powder or dust selected can be effectively resuspended for use in these studies, but Hydral, a monodisperse bulk powder, has proven most effective as a test particle in precharger performance experiments. In addition to its utilization in

precharger development, the WDF has served as a source of particles involving a study of the difference in electrical properties of mechanically versus electrically deposited ash layers. Several types of fly ash loaded into the WDF were subsequently precipitated onto the ground and center electrodes for electrostatically-packed ash resistivity measurements.

Fly ash and powdered reagents have been tested in both point-plane and plane-plane resistivity configurations in studies of the effect of electron beam bombardment on the electrical properties of the layer. A variety of ashes ranging from low to very high ($> 10^{12} \Omega - \text{cm}$) resistivity are available as well as pure aluminum oxide and silicon dioxide. Glass beads and powdered glass have been the subject of investigation in resistivity experiments involving several different geometric arrangements.

A third resuspension device, a fluidized bed featuring a sintered metal diffuser and a glass bead deagglomerating medium, has been tested and is ready for use when medium to high rates of resuspension are required.

V. PRESENTATIONS AND PUBLICATIONS

A. Patent Disclosure on a Device to Enhance Radiation Dose

A patent disclosure entitled "A Device to Enhance the Radiation Dose Delivered by Energetic Electrons by Means of Electric Field" has been submitted to the US Department of Energy Patent Office and to The Florida State University Patent Office in compliance with the contract.

VI. PERSONNEL

A. Investigators

Dr. Robert H. Davis	Principal Investigator
Mr. Wright C. Finney	Associate in Research
Dr. J. Sidney Clements	Assistant Research Scientist
*Dr. Akira Mizuno	Post-Doctoral Research Assistant

B. Graduate Students

Stephen J. Stout
David B. O'Hara

C. Part-time Student Assistants

George O. Winborne
Byron K. Ford

D. Part-time Secretary

Jeri L. Suarez

*On leave from Toyohashi University, Toyohashi, Japan