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ELECTROSTATIC PRECIPITATION OF CONDENSED ACID MIST

THIRD QUARTERLY TECHNICAL PROGRESS REPORT

March 1 to May 31, 1989

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ELECTROSTATIC PRECIPITATION OF CONDENSED ACID MIST

1. INTRODUCTION

1.1. Technical Background

This project addresses the acid mist that is formed by condensation of sulfuric acid vapor in flue gas from coal-fired utility boilers. An acid mist can be formed whenever the flue gas temperature approaches the prevailing acid dew point. This commonly occurs when the gas is subjected to rapid adiabatic cooling in a wet scrubber system for flue gas desulfurization. Acid mists can also sometimes result from unexpected temperature excursions caused by air inleakage, load cycling, and start-up operations.

Most of the acid mist that is formed in a wet scrubber system escapes collection in the scrubber (1). This is a result of the extremely fine droplet size in the acid mist, which allows the mist droplets to follow the gas streamlines around the droplets of scrubber slurry, thereby avoiding collection by inertial impaction or interception.

Acid mists can sometimes constitute a significant portion of the total particulate emissions from power plants burning high-sulfur coals. Complete condensation of 10 ppm of acid vapor produces a condensed acid mass loading of about 0.02 gr/dscf or 0.03 lb/MMBtu, equivalent to the total allowable mass emissions under the revised (1979) New Source Performance Standards (2).

In some states, the mass emission sampling protocols allow exclusion of the acid mass from the total particulate sample (cf 3). Even in these cases, the acid mist can be a limiting factor due to its effect on opacity. The acid mist droplets are predominantly in the size range of 0.1 to 1 μm (4), where light scattering is very efficient. In some cases, the droplet size distribution seems to be concentrated in the 0.4 to 0.5 μm range, near the wavelength of blue light, giving the plume a bluish tint (5). Due to these considerations, it may be necessary to reduce acid mist emissions even when their contribution to the total particulate mass is relatively small.

A wet electrostatic precipitator (WESP) is the best control option for acid mist. The mist would blind a fabric filter and attack glass fiber fabrics. A wet ESP is required because the acid would quickly corrode the plates in a conventional dry ESP. The wet ESP also offers the advantages of no rapping reentrainment and no sensitivity to fly ash resistivity. Therefore, this program has been structured around the use of a compact, wet ESP to control acid mist emissions.

1.2. Project Objectives

The purpose of this project is to develop and demonstrate a compact, wet electrostatic collector for condensed acid mist in power plant flue gas. In order to accomplish this goal, several objectives must be met.

1. A laboratory-version of the WESP must be fabricated.

2. The WESP performance must be optimized through laboratory tests with a non-volatile simulant aerosol having a size distribution similar to the acid mist.

3. The WESP concept must be proven by demonstrating adequate collection of actual acid mist in a pilot coal combustion facility under conditions simulating a full-scale power plant burning high-sulfur coal.

4. A computer model of the WESP process must be developed to assist in the process optimization, interpretation of test results, and extrapolation to full scale.

5. Utility participation must be solicited in a follow-on demonstration of the WESP concept at a full-scale power plant.

1.3. Project Structure and Scope

The project is organized in two phases. Phase I, which is scheduled for September 1988 to September 1989, involves the WESP fabrication, laboratory and pilot combustor testing, and computer modeling. Phase II, which is scheduled for September 1989 to September 1990, involves the solicitation of a utility demonstration site, preliminary site measurements, and planning for the demonstration test program. The execution of Phase II is contingent upon successful completion of Phase I. Only Phase I has been funded at this time. Therefore, only the Phase I work will be addressed in this discussion.

Phase I is organized in five tasks, with two of the tasks having subtasks as follows:

Task 1. Work Plan Preparation

Task 2. Hardware and Software Development

Subtask 2.1. Prototype ESP fabrication

Subtask 2.2. ESP model development

Task 3. Laboratory Testing

Subtask 3.1. Preparation of auxiliary systems

Subtask 3.2. Tests of collection efficiency

Task 4. Pilot Combustor Testing

Task 5. Phase I Reporting

2. TASK 1 - WORK PLAN PREPARATION

The project work plan was submitted to DOE in September 1988. After presentation and discussion of the plan at the project kickoff meeting, the plan was approved by the DOE project manager. All details of the work breakdown structure, schedule, cost plan, management plan, and key personnel assignments are given in the work plan.

3. TASK 2 - HARDWARE AND SOFTWARE DEVELOPMENT

3.1. Subtask 2.1. - Prototype ESP Fabrication

The prototype WESP system was described in detail in the first quarterly report. Subsequent modifications were described in the second quarterly report. Figures 1 and 2 show a sketch and a photograph of the system as originally assembled. No additional modifications were made this quarter.

3.2. Subtask 2.2 - ESP Model Development

No further work was performed on the cylindrical geometry ESP model pending the collection of laboratory data. These data are needed to determine which of the three existing models is most applicable to the prototype WESP.

4. TASK 3 - LABORATORY TESTING

4.1. Subtask 3.1 - Preparation of Auxiliary Systems

The auxiliary systems for mass train and impactor sampling were described in the first quarterly report. The second quarterly report discussed the subsequent relocation of the outlet sampling port and flow measurement orifice to accommodate system modifications.

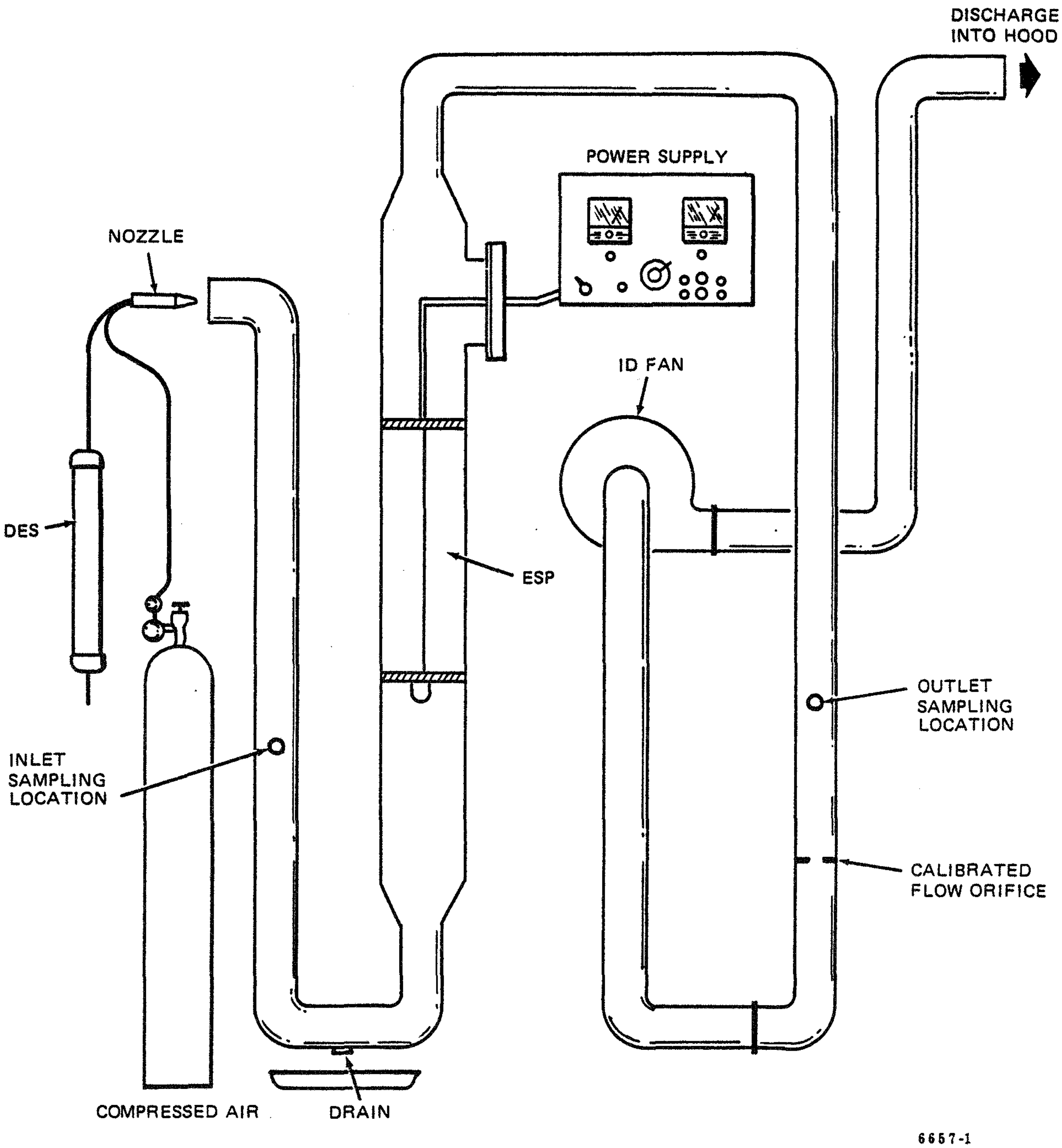

Figure 1. Sketch of Prototype ESP System.

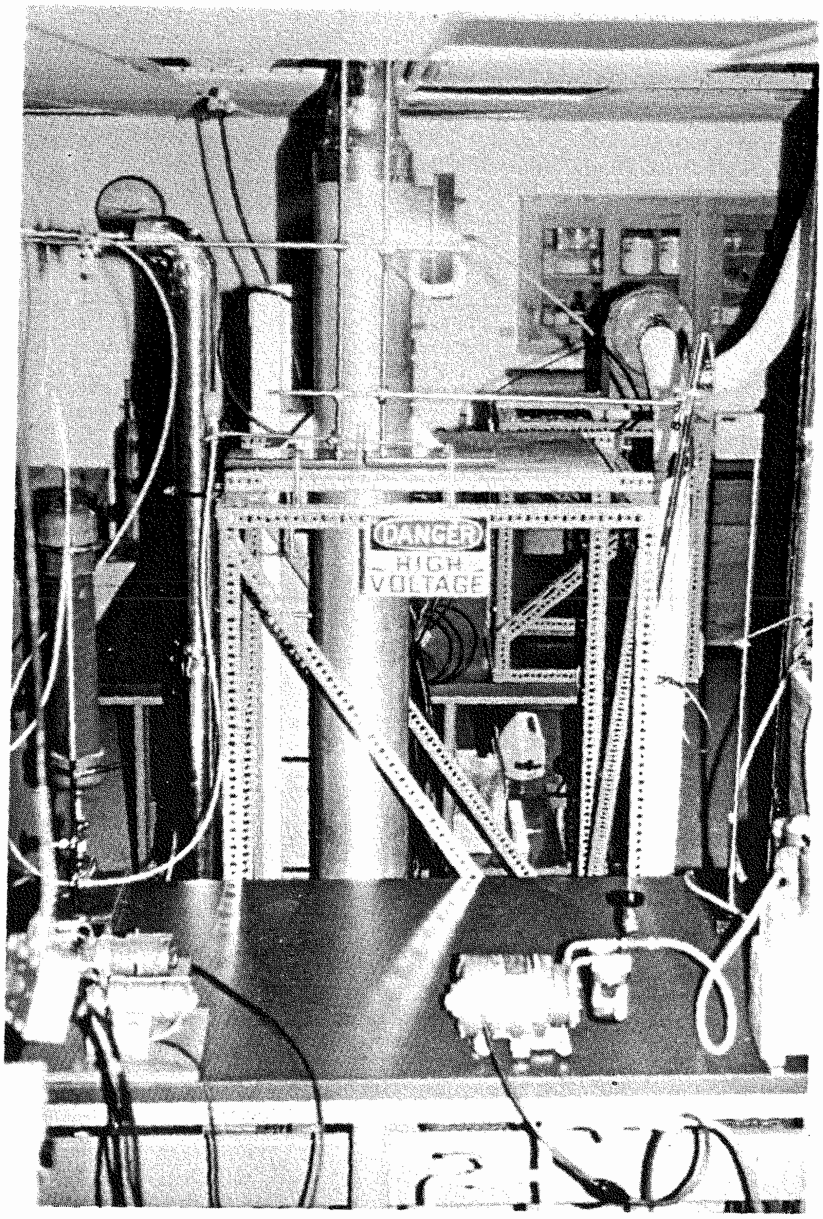

Figure 2. Photograph of the Prototype ESP System.

As discussed in the last quarterly report, the type of impactor used at the outlet was switched from a low flowrate Brink impactor to a high-flowrate University of Washington impactor. This allowed both impactors to be run for the same time period without over-loading any of the impactor stages. This was the setup used for the tests conducted this quarter.

4.2. Subtask 3.2 - Tests of Collection Efficiency

Collection efficiency tests were continued this quarter. Collection efficiency as a function of particle size was determined by cascade impactor measurements using Brink impactors at the inlet and University of Washington impactors at the outlet. The two impactors were run simultaneously for a period of 4 hours of steady-state ESP operation. Four sets of inlet and outlet runs were obtained. During all runs, the ESP was operated at maximum power input (60 kV and 2 mA). The air flow through the system was maintained constant at about 100 acfm. Atomizing air and DES pressures at the nozzle were maintained at 88 psig and 10 psig.

Excellent electrical operating conditions were achieved in the laboratory ESP, in that the 60 kV applied voltage resulted in a current density of 270 microamps/ft^2 (about 5 to 10 times higher than that of a typical dry ESP). Although these conditions do not represent an optimum use of electrical power, the relatively high values of charging and collecting fields produced in the precipitator would be expected to result in high values of collection efficiency. Analysis of the impactor data confirmed this expectation in that overall collection efficiency ranged from a low of 98.76% to a high of 98.92%.

Figure 3 shows the inlet and outlet cumulative mass loading curves. A comparison of the two curves over the particle size range resolved by the impactor reveals that 1) for the lower limit of particle size resolution, the cumulative loading at the outlet is lower than that at the inlet by a factor of about 16, and 2) for the upper limit of size resolution, the difference is a factor of about 60. Thus, for all particle sizes resolved by the impactors, the overall collection efficiency is 98.3%. The true overall collection efficiency is higher due to the large loading of droplets beyond the upper limit of impactor size resolution.

Figure 4 shows the fractional collection efficiency curve generated from the impactor data. As expected, the curve shows a strong dependence on particle size. Over the range of impactor size resolution, the efficiency varies from about 97.4% to 99.77%. This indicates excellent removal of the fine droplets expected to occur in an acid mist.

5. TASK 4 - PILOT COMBUSTOR TESTING

Work on this task may be delayed due to conflicts with field test activities. At the present time, however, this does not appear to put the planned project completion date in jeopardy.

6. TASK 5 - PHASE I REPORTING

All monthly status and cost management reports have been submitted on schedule. The project is proceeding within schedule and budget.

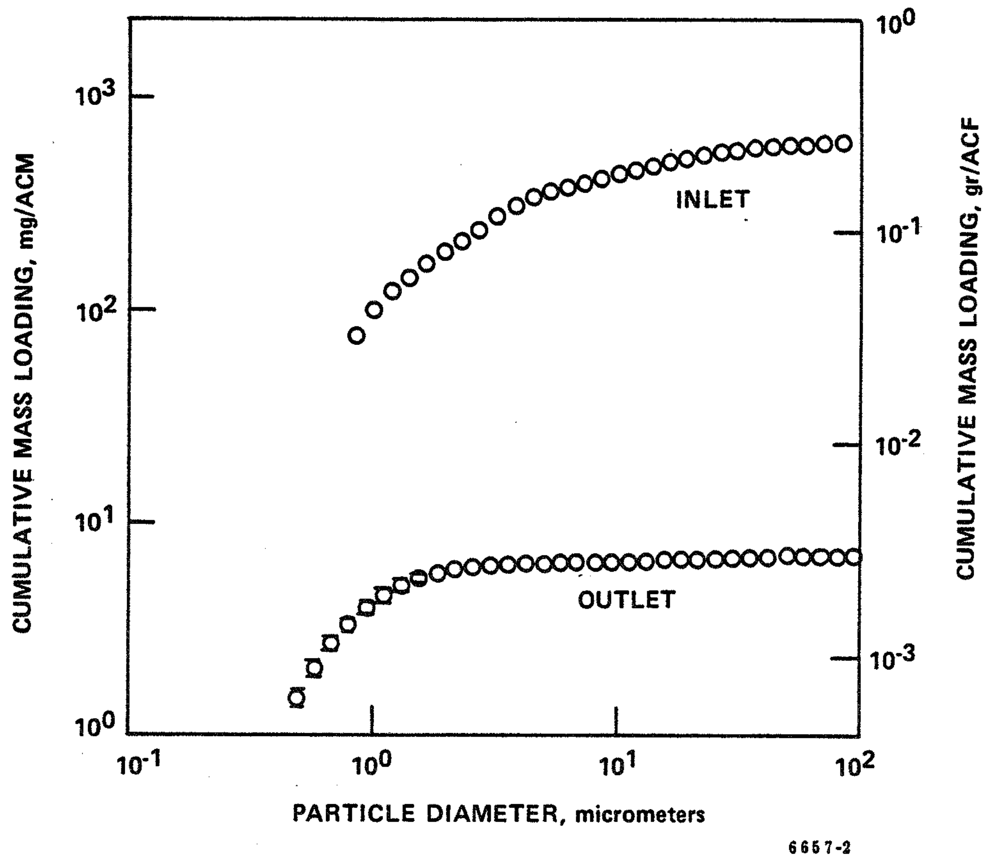

Figure 3. Comparison of Cumulative Mass Loading Curves Obtained at WESP Inlet and Outlet.

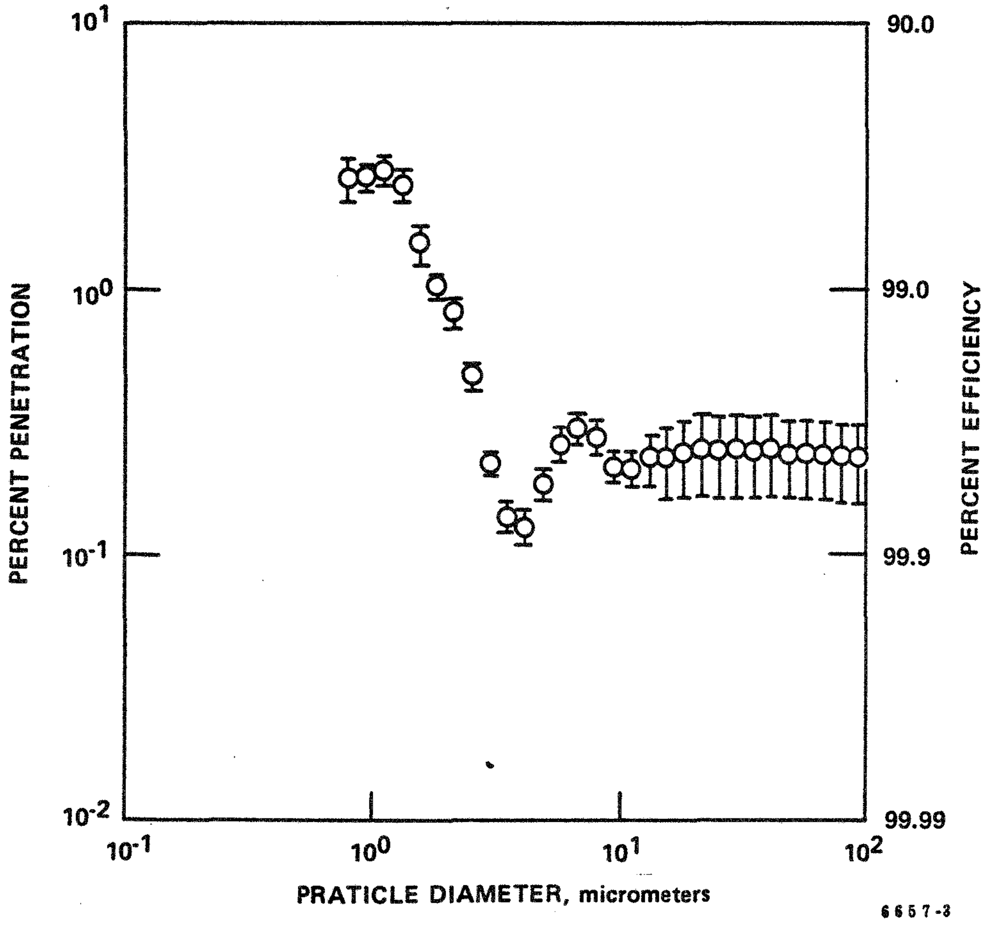

Figure 4. Fractional Collection Efficiency Curve Determined from Inlet and Outlet Impactor Runs.

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