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CONTROL OF ACID MIST EMISSIONS FROM FGD SYSTEMS

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CONTROL OF ACID MIST EMISSIONS FROM FGD SYSTEMS

ABSTRACT

Acid mist emissions can be a significant problem at power plants burning high-sulfur coal and using wet scrubbers for flue gas desulfurization (FGD). The acid mist, which is formed by condensation of sulfuric acid vapor within the scrubber system, can be a major contributor to particulate emissions. Since the acid mist is predominantly submicron in size, it avoids capture in conventional mist eliminator systems, and it scatters light very effectively. This can result in excessive visible emissions in some cases.

Improved control of acid mist emissions can be achieved by replacing or augmenting the conventional mist eliminators with a wet electrostatic precipitator (WESP). This paper describes a two-phased study performed to determine the degree of control that can be achieved with this approach. Phase I was a study of the electrical operation of a lab-scale WESP collecting an acid mist from a coal combustion pilot plant equipped with a spray chamber. The results of this study were used to develop and validate a computer model of the WESP. In Phase II, measurements were made at two utility scrubber installations to determine the loadings of acid mist, fly ash, and scrubber carryover. These measurements were used as input to the model to project the performance of a retrofitted WESP.

CONTROL OF ACID MIST EMISSIONS FROM FGD SYSTEMS

INTRODUCTION

Acid mists can be a major source of corrosion problems and visible emissions at power plants that burn high-sulfur coals and are equipped with wet flue gas desulfurization (FGD) systems. When flue gas is rapidly cooled in an FGD system, the SO_3 is condensed along with water vapor to form an ultrafine mist of sulfuric acid. The mist droplets are so small that they escape collection in the scrubber and the mist eliminators (MEs) (1). When discharged into the atmosphere, these fine droplets scatter and absorb light very effectively, sometimes resulting in excessive visible emissions. The presence of the acid mist in the flue gas can also be a contributing factor in excessive corrosion of the ducting and the stack liner downstream from the MEs. If a wet electrostatic precipitator (WESP) is used to replace or augment the MEs, the acid mist loading can be substantially reduced, along with the associated corrosion problems.

Under contract to the Department of Energy/Pittsburgh Energy Technology Center (DOE/PETC), Southern Research Institute investigated the use of a compact WESP to control acid mist emissions. The project was primarily directed toward acid mist emissions from wet FGD systems, although other sources of acid mist could be controlled by this approach. The goal of this investigation was to assess the improvement in acid mist control that was possible by using a WESP to replace or augment the existing MEs in an FGD system. The project was organized in two Phases. Phase I was initiated in August 1988 and completed in November 1989. It involved laboratory and pilot-scale studies of the WESP concept, along with the development of a WESP computer model. Phase II was completed in April 1991 and involved field measurements at utility FGD installations, projections of WESP performance, and development of a WESP demonstration plan.

PHASE I OBJECTIVES

The primary objectives of the Phase I effort were to (1) determine the ability of a compact WESP to collect the fine acid mist, (2) determine the effect of fly ash loading on mist collection efficiency, and (3) develop and validate a computer model of the WESP to help interpret test results and extrapolate results to full-scale applications. The second objective was included because the fly ash loading leaving the scrubber can vary widely, depending upon the performance of the upstream particulate control device. Also, a very high loading of submicron fly ash could adversely affect WESP performance by space charge suppression of the corona current.

PHASE I APPROACH

The approach used in Phase I of this project was to first fabricate a laboratory-scale WESP that could be used to determine the expected WESP fractional collection efficiency and provide data for validating a computer model of the WESP. Since it was anticipated that the volatile acid mist could present sampling difficulties, initial testing was done with a nonvolatile simulant oil, di-2-ethylhexyl sebacate (DES). A sketch of the WESP setup used for these tests is shown in Figure 1. After successful completion of these tests, the WESP was modified and connected to a pilot-scale combustion system to allow testing on an actual acid mist. The acid vapor was generated by firing either SO_2-doped natural gas or a combination of SO_2-doped natural gas with coal. This was done to allow testing of the WESP on the mist alone and the mist in combination with a fly ash loading typically encountered downstream from a scrubber. The acid mist was formed by passing the flue gas through a spray humidification chamber to simulate condensation in the scrubber system. A sketch of the modified WESP setup used in the pilot combustor tests is shown in Figure 2.

The data obtained from the tests with the DES and the actual acid mist were used to validate the computer model after each series of tests. The validated computer model was then used to make projections of WESP performance in a utility retrofit situation.

LABORATORY TESTS WITH SIMULANT OIL

The WESP setup used in these tests consisted of a tubular WESP made from a 1/8-inch diameter wire suspended along the axis of a 8-inch diameter galvanized metal tube. The energized length of wire was 3.5 feet. For the laboratory tests, air was drawn through the WESP system at a nominal flowrate of 100 cfm, resulting in a WESP specific collecting area (SCA) of about 74 ft^2/kacfm. This may be compared to a typical fly ash precipitator having an SCA of 250 to 350 ft^2/kacfm. Thus, these tests were designed to simulate a very compact WESP design.

The DES oil was atomized using a Sonic Development ST-47 nozzle operated at an air pressure of 88 psig and an oil pressure of 12 psig. This typically produced an aerosol with a mass mean diameter of about 4 μm. Although this is somewhat coarse for an acid mist, it provided an adequate concentration of submicron particles for reliable size-resolved efficiency measurements.

Collection efficiency as a function of particle size was determined from cascade impactor measurements made at the inlet and outlet of the WESP. Typical results obtained from these measurements are compared with the results of two alternate computer models, a current-specific model (2) and a current-seeking model (3), in Figure 3. For the particle size range resolved in these tests, the collection efficiency varied from about 97% for submicron particles to 99.8% for 10 μm particles. These results were extremely encouraging and showed good agreement with one of the two models initially considered.

The current-specific model was found to give better agreement with the WESP performance data, because it allowed input of both the applied voltage and the operating current. The current-seeking model predicts the current based on the applied voltage and the particulate space charge. The equation that is used for this is valid only in the region near corona onset (i.e., at relatively low voltage and current). The current-seeking model does not do a good job of predicting performance in this case since the actual voltage and current (60 kV and 270 $\mu A/ft^2$) are far from the region of corona onset (about 30 kV and near-zero current).

PILOT COMBUSTOR TESTS WITH ACTUAL ACID MIST

For these tests, the WESP was connected to a pilot-scale coal combustion facility equipped with a spray humidification chamber to serve as a source for the condensed acid mist. The acid mist was generated by firing SO_2-doped natural gas in the combustor and condensing the resulting acid vapor into a fine mist in the spray humidification chamber. Since this resulted in a saturated flue gas entering the WESP, it was necessary to make extensive modifications to the WESP setup to avoid electrical tracking along the high-voltage insulator. As shown in Figure 2, a hot-air purge system was installed to keep the high-voltage insulator dry, and a mist eliminator was added to prevent the carryover of large unevaporated droplets into the WESP. The hot purge air typically accounted for about half of the total gas flow through the WESP. Since the mist eliminator would collect mostly large particles, it had little effect on the acid mist fraction.

As in the laboratory tests, the size-dependent efficiency of the WESP was determined by cascade impactor measurements at the inlet and outlet of the WESP. Since the hot purge air was added downstream from the inlet sampling location, the inlet loadings had to be corrected for this dilution. Blank impactor runs were performed with each set of runs to ensure that no artificial weight gains resulted from flue gas interaction with the impactor substrate material. The impactor substrates were also acid washed to neutralize any alkaline sites that might adsorb SO_2 and cause a spurious weight gain.

Prior to each set of impactor runs, a measurement of the gas-phase SO_3 level by the controlled condensation method was made to assure constant conditions. To cover a range of acid mist concentration, two series of tests were conducted at nominal SO_3 levels of 25 ppm and 47 ppm. For these two series of tests, the average inlet mass loadings of acid mist were 8.6 mg/acm (0.0038 gr/acf) and 16.3 mg/acm (0.0071 gr/acf). These loadings were lower than expected for complete condensation of the acid, possibly due to removal of some of the acid vapor in the spray chamber. Nevertheless, the loadings showed the expected variation with SO_3 level. A summary of the test results is given below.

Test Parameter	Low SO_3	High SO_3
Initial SO_3 concentration, ppm	25	47
Inlet mass loading, mg/acm (gr/acf)	8.59 (0.0038)	16.3 (0.0071)
Inlet mass median diameter, μm	1.9	1.5
WESP applied voltage, kV	68	68
ESP current density, μA/ft^2	251	196
Specific collecting area, ft^2/kacfm	48.9	40.3
Collection efficiency, %		
Smaller than 1 μm	87.4 to 92.9	62.1 to 83.0
Smaller than 5 μm	88.5 to 93.0	71.4 to 91.8

These results show that the WESP is capable of good control efficiencies at an SO_3 level of 25 ppm. However, the WESP performance degrades at the higher SO_3 level of 47 ppm. Although this is partly attributable to a slight difference in the specific collecting area, the primary factor is the reduction in current density from 251 to 196 μA/ft^2, a reduction of 22%. This results from the increased particulate space charge and the concomitant suppression of corona current.

The space charge effect could be seen very dramatically in the voltage-current characteristics of the WESP, as illustrated in Figure 4. At an applied voltage of 50 kV, the operating current with no acid mist present was about 1.1 mA, compared to a current of about 0.4 mA with 25 ppm of SO_3 (8.6 mg/acm of acid mist). With 47 ppm of SO_3 (16.3 mg/acm of acid mist), the current was further reduced to about 0.35 mA at 50 kV. In actual practice, it may be possible to compensate for this effect to some degree by increasing the applied voltage. As shown in Figure 4, the voltage was actually increased to over 80 kV without sparkover, but this was not considered to be a realistic operating point for a commercial WESP.

It should be noted that all of the WESP testing with an actual acid mist was done with a much lower SCA than that used in the laboratory tests with the DES aerosol (40 to 49 versus 74 ft^2/kacfm). This was done to provide a more realistic simulation of a very compact WESP that could be retrofitted onto a scrubber. This difference in SCA, combined with the reduced current densities (196 to 251 versus 270 μA/ft^2), account for the lower collection efficiencies with the acid mist. The reduced current densities are a result of the space charge effect, which is more pronounced with acid mist due to the larger number of fine particles (1.5 to 1.9 versus 4 μm mass median diameter).

PILOT COMBUSTOR TESTS WITH MIST AND FLY ASH

Since a dramatic space charge effect was evident in the mist-only results, additional tests were conducted to examine any further degradation in WESP performance that might be caused by fine fly ash particles. This was accomplished by co-firing the SO_2-doped natural gas with a small quantity of coal to simulate the mass loading of fly ash in flue gas leaving a scrubber. The total thermal input into the combustor was maintained constant so there would not be a significant change in the temperature profile. With coal burned at a rate of 2 lb/hr and SO_2-doped natural gas fired at a rate of 970 cfh, the flue gas entering the spray chamber contained about 45 ppm of SO_3, and the inlet mass loading averaged about 27.6 mg/acm (0.012 gr/acf). This is comparable to recent measurements made by Flakt, Inc., at a scrubber installation of Seminole Electric, where an average loading of 28.8 mg/acm (0.0126 gr/acf) was reported (1).

Assuming that the ratio of the acid mist mass loading to the SO_3 level was the same as in the two mist-only tests, the inlet loading of acid mist may be estimated to be 15.6 mg/acm (0.0068 gr/acf). By difference, the inlet loading of fly ash is about 12.0 mg/acm (0.0052 gr/acf). With a coal containing 10% ash, this loading of fly ash would correspond to an upstream control efficiency (in the primary ESP or baghouse and scrubber) of about 99.7%, yielding a mass emission rate of about 0.013 lb/MMBtu, based on fly ash only. The total mass emission rate, including acid mist, would be about 0.03 lb/MMBtu. The total particulate mass would be composed of about 57% acid mist and 43% fly ash. Based on the measured mass median diameters (mmds) of the mist (1.5 μm) and the mist/fly ash combination (2.2 μm), the mmd of the fly ash is estimated to be 3.1 μm. This case is believed to be a reasonable simulation of a precipitator/scrubber installation operating in compliance with the 1979 NSPS (4). The results of this test are summarized below; the results of the high-SO_3 mist case are also included for comparison.

Test Parameter	Mist Only High SO_3	Mist Plus Fly Ash
Initial SO_3 concentration, ppm	47	45
Inlet mass loading, mg/acm (gr/acf)	16.3 (0.0071)	27.6 (0.012)
Inlet mass median diameter, μm	1.5	2.2
WESP applied voltage, kV	68	45
WESP current density, $\mu A/ft^2$	196	64
Specific collecting area, $ft^2/kacfm$	40.3	42.5
Collection efficiency, %		
Smaller than 1 μm	62.1 to 83.0	63.4 to 77.1
Smaller than 5 μm	71.4 to 91.8	65.1 to 77.6

Comparison of the mist-plus-ash case and the mist-only case shows a striking degradation of the electrical operating conditions with fly ash present. With fly ash in the system, it was not possible to maintain the same applied voltage that was used in the mist-only case. Intermittent sparking resulted in excessive tripping of the power supply and limited the applied voltage to about 45 kV. It may have been possible to operate at a higher voltage, but this would have required frequent resetting of the power supply, which may have compromised the outlet impactor data. In actual practice, the use of a spark-rate controller may partially alleviate this problem.

The presence of the fly ash appears to produce a larger performance degradation in the 1 to 5 μm size range than in the submicron size range. Since a very small mass fraction of the fly ash is submicron (typically less than 1 to 2%), it would not be surprising to see similar submicron collection efficiencies for the two cases, if the electrical operating conditions were similar. However, the degraded electrical conditions apparently limited the maximum submicron collection efficiency to 77.1%, compared to 83.0% for the mist only. For all particles smaller than 5 μm, the cumulative collection efficiency was reduced from a maximum of 91.8% to 77.6% with fly ash present.

PHASE II OBJECTIVES

The primary goal of the Phase II work was to refine the projections of WESP performance by using data from two utility FGD installations. This required SO_3 and particle size measurements, along with chemical analyses, to determine the loadings of acid mist, fly ash, and scrubber solids downstream from the two scrubbers. These measurements provided the data needed to project WESP performance using the computer model developed in Phase I. A secondary objective was to estimate the effect of the WESP on opacity relative to the baseline configuration (scrubber with ME only). Another major objective of Phase II was to develop plans for a follow-on demonstration of the WESP concept at utility sites, if warranted.

SITE SELECTION

The first task under Phase II was to select the test sites for the field measurements. It was preferred that the two sites have substantially different levels of SO_3 in the flue gas, so that the effect of acid mist loading could be examined. A high SO_3 concentration was desirable at one of the sites, so that the effects of space charge corona suppression could be further analyzed using the computer model. It was also considered desirable to avoid the selection of two sites with the same types of boilers, scrubbers, and MEs, so that the results would be applicable to a wider range of equipment types. Based on these considerations, two sites were ultimately selected.

Site 1 was a 700-MW, cyclone-fired unit equipped with a combination venturi/spray tower FGD system. The FGD system consisted of six scrubber modules, five of which were normally in operation. At the exit of each tower, the gas was discharged at a right angle and flowed horizontally through two vertical mist eliminators. Because of severe corrosion of the reheater tubes, the reheater had been removed, and the unit had been converted to wet-stack operation. The combination of a high sulfur content (3.2% nominal) and high iron content in the ash, along with the high-temperature cyclone firing, was reported to produce a very high SO_3 concentration at this site (5).

Site 2 was a 575-MW, pulverized coal-fired unit equipped with a venturi rod/spray tower FGD system. Each of the four scrubber modules was equipped with a horizontal mist eliminator mounted directly above the spray tower, so that the gas flow through the mist eliminator was vertically upward. Just above the mist eliminator was an in-line tubular reheater. Previous data obtained at this site (6) suggested that the SO_3 concentration would be lower than at Site 1, although the nominal coal sulfur content was about the same as at Site 1. The lower conversion of SO_2 to SO_3 at Site 2 is presumably associated with the different boiler type and the lower iron content of the ash.

SO_2/SO_3 DATA

Table 1 gives a summary of the SO_2 and SO_3 concentrations measured ahead of the scrubber at both sites. There is essentially no difference in the SO_2 concentrations measured at the two sites, but the SO_3 concentration is significantly higher at Site 1, for the reasons already discussed. If the reported amounts of SO_3 were completely condensed in the form of sulfuric acid (H_2SO_4), this material alone could account for a mass loading of about 0.03 gr/dscf at Site 1 or about 0.02 gr/dscf at Site 2. At Site 1, this would be sufficient to account for over 85% of the particulate mass measured at the ME outlet by the cascade impactors. At Site 2, it would be sufficient to account for about 70% of this mass. However, chemical analyses of the impactor samples (discussed later) reveal that the H_2SO_4 actually accounts for only 40 to 45% of the particulate mass at Site 1 and about 57 to 62% of the particulate mass at Site 2. This suggests that some of the SO_3 or sulfuric acid is removed in the scrubber and ME system.

To investigate the question of SO_3 removal across the scrubber, outlet SO_3 measurements were made at Site 2. To determine the amount of SO_3 removed, the sampling probe was heated to convert all of the H_2SO_4 back to SO_3. Measurements were also made with the probe at flue gas temperature (about 160°F after reheat) to verify that all of the SO_3 was condensed. These measurements confirmed that all of the SO_3 was condensed at this point (residual below the detection limit of 0.3 ppm) and that the amount of condensed H_2SO_4 was equivalent to an SO_3 concentration of 6 ppm. After correcting the inlet and outlet SO_3 concentrations to the same O_2 levels, the removal of SO_3 across the scrubber was calculated to be 28%. Allowing for this loss, the acid mist would be expected to account for about 61% of the outlet particulate mass at Site 1 and about 50% of the outlet particulate mass at Site 2. Chemical analyses of the impactor samples revealed 40 to 45% H_2SO_4 at Site 1 (about 16 to 20% less than calculated from the gas-phase SO_3 concentration) and 57 to 62% H_2SO_4 at Site 2 (about 7 to 12% more than calculated). The lower H_2SO_4 recovery at Site 1 may indicate that the SO_3 removal was higher than at Site 2 (removal measurements were made at Site 2 only). The slightly higher recovery at Site 2 could be attributable to other sulfates in the ash.

TOTAL AND SUBMICRON MASS LOADINGS

Particle size and mass loading measurements were made at both sites using University of Washington Mark V cascade impactors that were heated to avoid condensation within the impactor. At Site 1, these measurements were made at the ME inlet and outlet with either one or two MEs in place. This provided an analysis of the size-dependent collection efficiency of the MEs to compare to the projected performance of the WESP. Normally, the FGD system at Site 1 operates with two MEs in series. However, a WESP supplier (ABB Flakt, Inc.) recommended that one of the MEs be removed if a WESP were to be retrofitted. Therefore, measurements were made with both one and two MEs in place. Surprisingly, there was very little difference in the cumulative mass loadings measured with either one or both MEs in service. Therefore, only a single value is reported for the outlet mass loading.

At Site 2, measurements were made at the ME outlet and the reheater outlet. Only the ME outlet data are of interest for a WESP retrofit. It would not make sense to retrofit a WESP after the reheater, because the evaporation across the reheater would make the droplets finer and possibly more difficult to collect. These measurements were made at the request of the host utility to assist them in correlating the measured emissions with opacity.

Table 2 presents the average total and submicron mass loadings obtained at both sites at each sampling location. As expected, the mass loading was very large ahead of the MEs (13.7 gr/acf), and this mass was dominated by particles larger than 1 μm. The mass mean diameter (MMD) of this material was estimated to be 44 μm. Downstream from the MEs, the mass loading was much lower, and the particulate mass was predominantly submicron in size. The cumulative submicron mass loading was slightly higher at Site 1 than Site 2 (0.022 versus 0.021 gr/acf), although the cumulative submicron percentage was lower at Site 1 than Site 2 (87% versus 95%). Thus, Site 2 appears to have a finer distribution on the basis of submicron mass percentage, but it actually presents less challenging conditions for a WESP retrofit than does Site 1, because the absolute loading of submicron particles is lower at Site 2. This small difference in submicron mass translates into a large difference in the number concentration of submicron particles, which is critical in terms of space charge effects.

CHEMICAL COMPOSITION

The cascade impactor samples were analyzed to determine the weight percent of H_2SO_4, fly ash, and scrubber solids as a function of particle size. The analytical methods and procedures for calculating the weight percent of each component are detailed in the Phase II final report (7). To provide a sufficient quantity of sample for analysis, selected impactor stages were combined, yielding four size fractions: (1) larger than 8 μm, (2) 1 to 8 μm, (3) 0.1 to 1 μm, and (4) smaller than 0.1 μm. Figure 5 shows the H_2SO_4 content of the various size fractions from Site 1. As expected, H_2SO_4 content increases with decreasing particle size. At Site 2, this same trend was evident down to the 0.1 to 1 μm fraction, but the fraction smaller than 0.1 μm contained slightly less acid than the 0.1 to 1 μm fraction, as indicated below.

Size fraction, μm	H_2SO_4, Wt %	Scrubber Solids, Wt%	Fly Ash, Wt%
Less than 0.1	56.9	0.4	42.7
0.1 to 1	61.8	2.2	36.0
1.0 to 8	47.1	11.2	41.7
Larger than 8	27.3	72.7	0

WESP PERFORMANCE PROJECTIONS

The WESP computer model developed in Phase I was used to make performance projections for WESPs retrofitted at the two test sites discussed above. For the Site 1 projections, the mass loading and size distribution measured with one ME in place were used, since that configuration was recommended by a WESP supplier. For the Site 2 projections, the measurements made at the ME outlet were used. In each case, projections were made with two sets of electrical conditions, corresponding to the best and the worst conditions achieved in the Phase I pilot testing.

Electrical conditions	Predicted collection efficiency, %	
	Site 1	Site 2
45 kV and 72 nA/cm^2	84.9	97.5
60 kV and 114 nA/cm^2	90.2	98.7

The lower efficiencies for Site 1 are entirely attributable to the higher loading of fine particles and the resulting space charge effects. For both cases, the SCA was 50 ft^2/kacfm; the gas velocity was 20 ft/sec; and the tube length was 10 ft.

For Site 1, the baseline opacity, with both MEs in place, was 42 to 60% (as determined by a trained smoke reader after dissipation of the steam plume). The projected opacity after the WESP retrofit described above was 11 to 19% with the worst electrical conditions and 8 to 14% with the best electrical conditions. For Site 2, baseline opacity data were not available, but the projected opacity (after the WESP retrofit) was substantially lower than at Site 1 (1.5 to 3% with the worst electrical conditions and less than 1.5% with the best electrical conditions). These results strongly suggest that the WESP retrofit could maintain opacity below 20% at both of the sites investigated.

FOLLOW-ON DEMONSTRATION

Based on the results of Phase I and Phase II, a follow-on demonstration of the WESP concept appears to be justified. Therefore, preliminary planning for a follow-on demonstration has been undertaken. Two approaches have been considered: (1) Installation of a prototype WESP on a full-scale scrubber module and (2) construction of a smaller, mobile WESP demonstration unit that could be tested at various utility sites. Although the full-scale unit would be preferable in some respects, the ability to test a wide range of conditions is a key factor favoring the mobile unit. One possible embodiment of a mobile unit is shown in Figure 6. This unit would handle a gas flow of about 10,000 acfm at 125°F (about 5-MW equivalent) and would fit on a standard 40 to 50 ft trailer. The design would include provisions to test different types of discharge electrodes as well as different types of collecting tubes. Provisions would also be made for real-time monitoring of the gas flow, temperature, voltage, current, and opacity. Test parameters for the WESP demonstration program would include: coal type, SO_3/acid mist loading, fly ash and scrubber solids loadings, size distribution, scrubber type, ME type, electrode types, and cleaning methods and frequencies.

There is no definite source of funding for the WESP demonstration unit at this time. However, the Department of Energy, the Electric Power Research Institute, several utilities, and a major WESP supplier have expressed considerable interest in this concept. Recognizing the potential benefits to the utility industry and the potential market for WESP technology, the utilities and the WESP supplier have agreed in principal to share a portion of the project costs. During the initial portion of the proposed follow-on demonstration, an economic analysis of the WESP technology would also be done. This analysis would address existing WESP technology as well as various advanced concepts in discharge electrodes and materials of construction.

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Table 1.

Summary of SO_2/SO_3 Measurements

	Site 1	Site 2
Average SO_2 Concentration, ppm	2100	2200
SO_2 Concentration Range, ppm	2000 to 2260	2190 to 2210
Average SO_3 Concentration, ppm	19	11
SO_3 Concentration Range, ppm	13 to 25	9 to 13
Average SO_3-to-SO_2 Ratio	0.009	0.005
SO_3-to-SO_2 Ratio Range	0.0065 to 0.011	0.004 to 0.006

Table 2.

Total and Submicron Mass Loadings

	Mass Loading, gr/acf	
	Total	Submicron
Site 1 - ME Inlet	13.7	0.026 (0.2%)
Site 1 - ME Outlet	0.025	0.022 (87%)
Site 2 - ME Outlet	0.022	0.021 (95%)
Site 2 - Reheater Outlet	0.011	0.010 (91%)

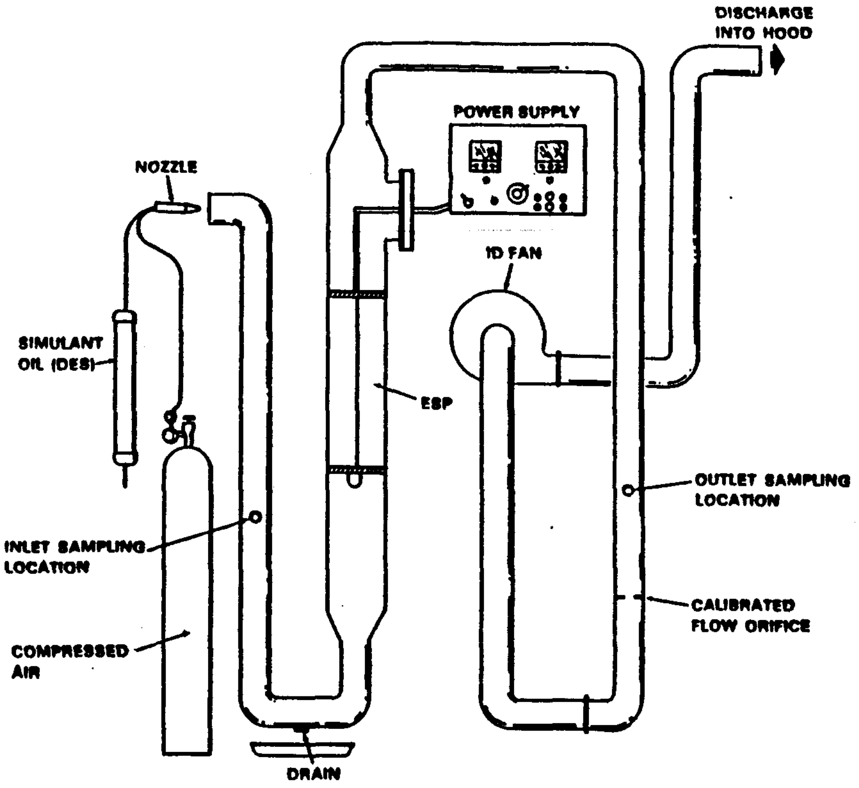

Figure 1. Sketch of WESP Setup Used in Laboratory Tests with Simulant Oil.

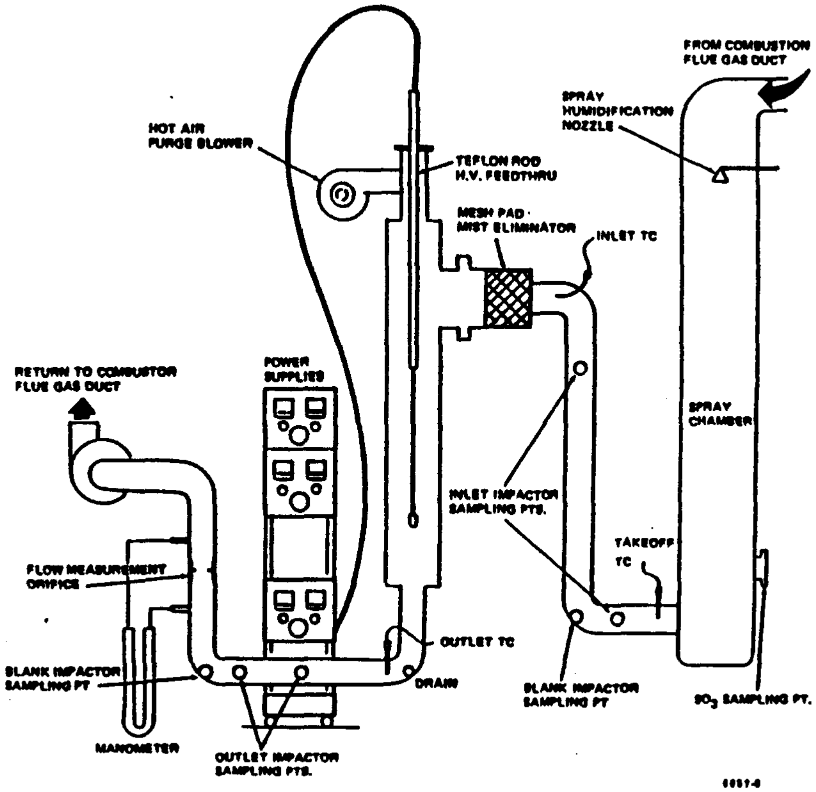

Figure 2. Sketch of Modified WESP Setup Used in Pilot Combustor Tests with Actual Acid Mist.

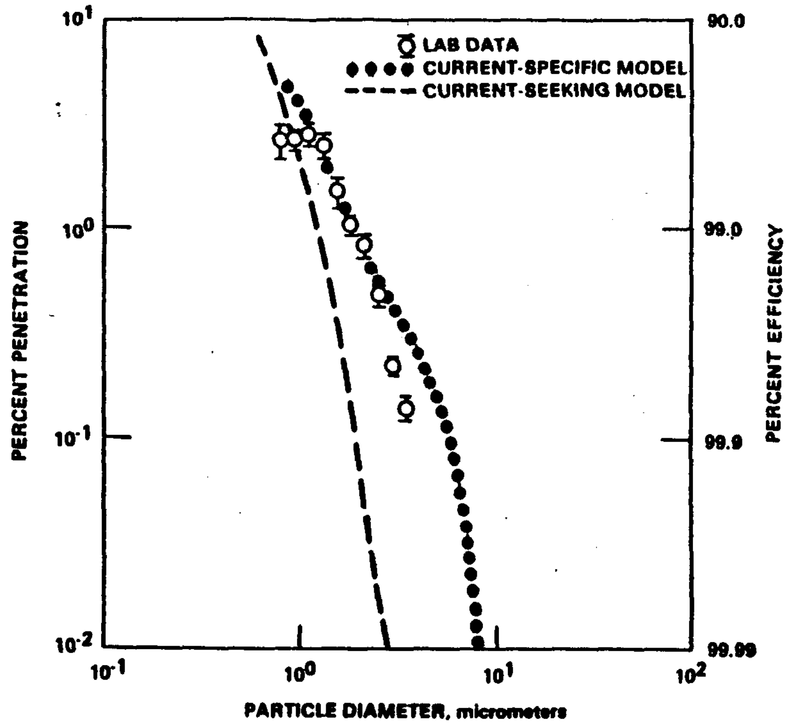

Figure 3. Comparison of WESP Fractional Collection Efficiency Measured Using Simulant Oil with Predictions of Two WESP Computer Models.

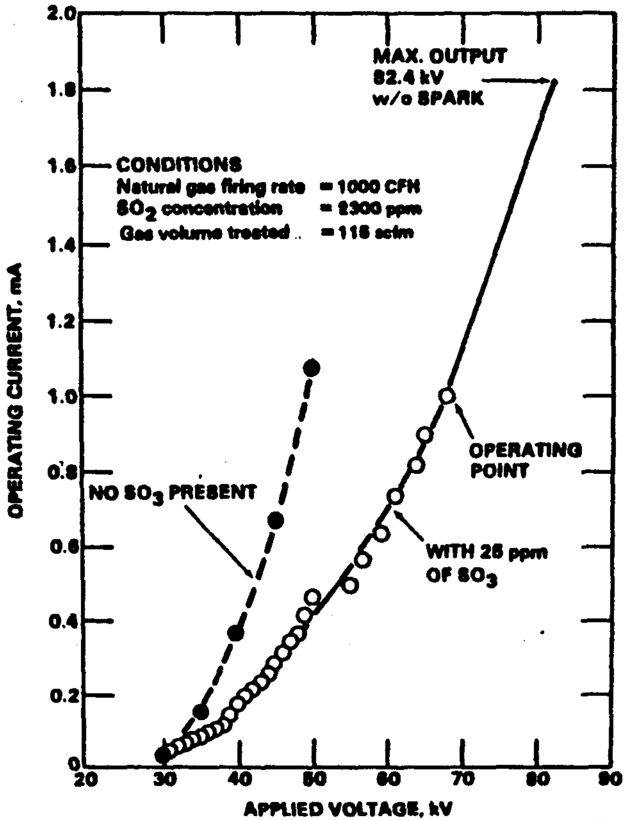

Figure 4. Comparison of WESP Voltage-Current Curves Obtained With and Without Acid Mist.

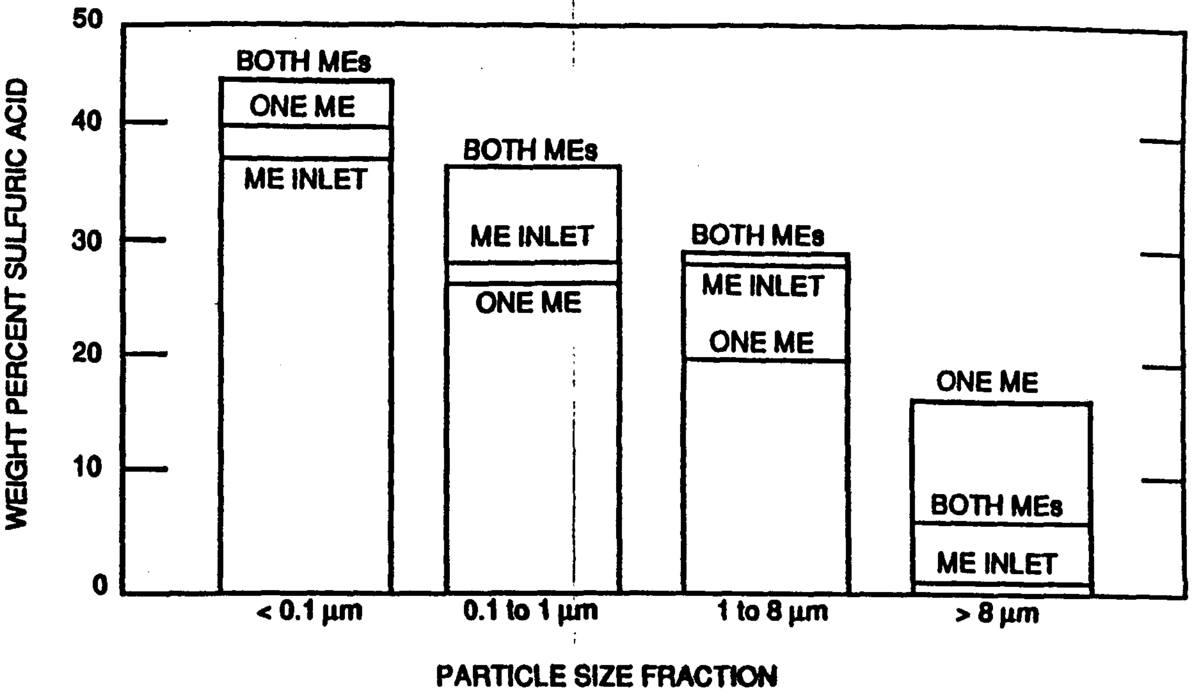

Figure 5. Sulfuric Acid Content of Particle Size Fractions at Site 1

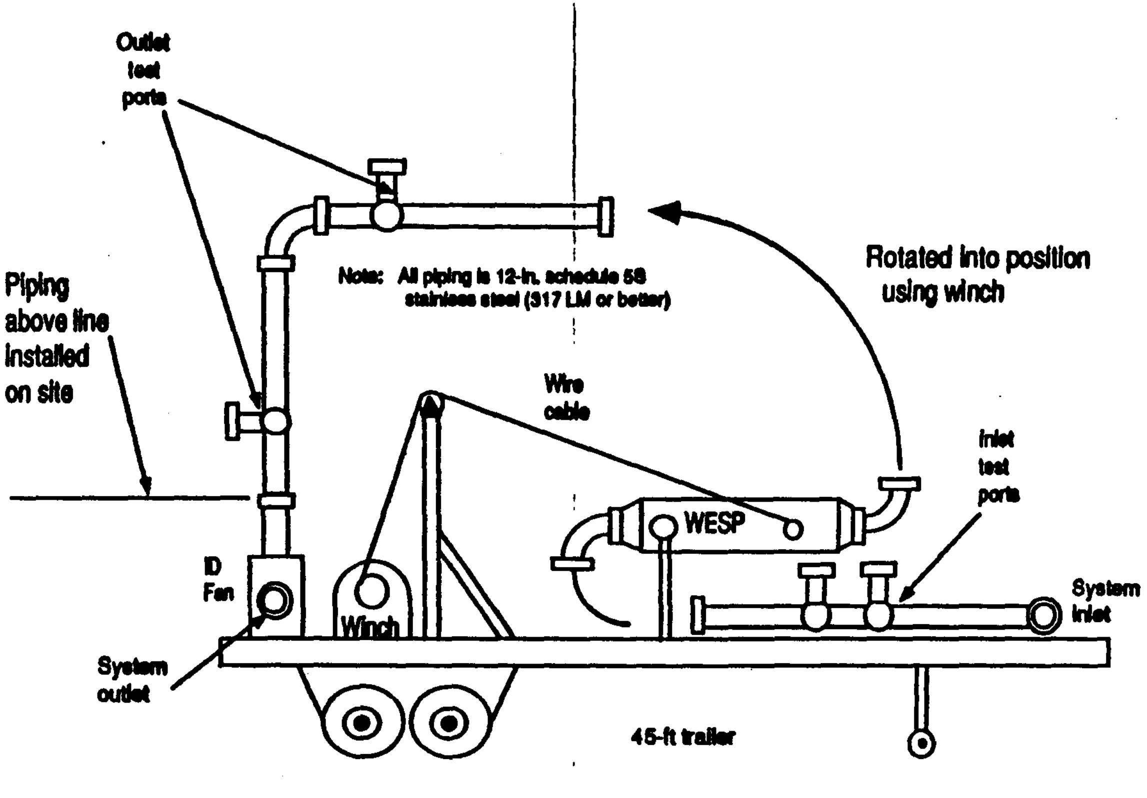

Figure 6. Sketch of Mobile WESP Pilot Unit for Demonstration Program