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ELECTROSTATIC PRECIPITATION OF CONDENSED ACID MIST

Phase II Final Report for the Period January 18, 1990–April 18, 1991

By
Robert S. Dahlin

April 1991

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ABSTRACT

This report deals with the second part (Phase II) of a two-phased study of the control of acid mist emissions using a compact, wet electrostatic precipitator (WESP). The goal of the study was to determine the degree of acid mist control that could be achieved when a compact WESP was used to replace or augment the mist eliminators in a flue gas desulfurization (FGD) system. Phase I of the study examined 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 computer model to project the performance of retrofitted WESPs at both of the utility test sites.

The Phase I results showed that excellent electrical operating conditions could be achieved, but very high loadings of acid mist or fine fly ash tended to degrade electrical operation because of space charge suppression of the corona current. Measurements made at the utility sites under Phase II showed that the mass loading of total particulate matter exiting the mist eliminators was within the range of 0.022 to 0.025 gr/acf, and 87 to 95% of this material was submicron in size. Acid mist accounted for 40 to 57% of the total particulate mass, while fly ash and scrubber solids accounted for 40 to 55% and 1.0 to 3.4%. Impactor samples from both test sites showed an increase in acid content with decreasing particle size, down to a size of 0.1 μm. At one of the sites, the acid content continued to increase with smaller sizes below 0.1 μm; at the other site, the acid content appeared to level off below 0.1 μm.

Projections of WESP performance suggest that a compact WESP (SCA=50 ft^2/kacfm) could collect 84.9 to 98.7% of the material exiting a single-stage mist eliminator and maintain stack opacity below 20%. The primary factor limiting WESP performance appears to be the suppression of corona current by the space charge associated with high loadings of acid mist and fine fly ash. A 10% difference in submicron particulate mass between the two test sites resulted in a degradation in collection efficiency from 97.5% to 84.9%. This would produce an increase in opacity from 1.5 to 3% to 11 to 19%, depending upon the optical properties of the mist/ash aerosol.

The results of Phase II suggest that a WESP would provide an effective means of controlling acid mist emissions from utility FGD systems. However, this suggestion is based on data from only two test sites. There are also a number of factors that this study has not addressed. These include the effects of various scrubber types and mist eliminator configurations, coal type, alternate designs of discharge and collecting electrodes, materials of construction, and cleaning methods and frequencies. In view of the encouraging results obtained in Phase II and the remaining questions concerning WESP performance, the next logical step in the WESP development program is a demonstration. This report includes specific recommendations for such a demonstration.

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William J. Page	-	Cascade impactor sampling
Dave W. Smith	-	Laboratory chemical analysis
Marvin R. Steele	-	SO_2/SO_3 measurements
Thomas A. White	-	Cascade impactor sampling

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1. INTRODUCTION

1.1. Technical Background

This project addresses the problem of acid mist 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 startup operations.

Most of the acid mist 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/MBtu, 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, however, the acid mist can be a limiting factor because of 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). Because of 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 was to investigate the potential for improved control of acid mist by using a compact, wet electrostatic collector to replace or augment the mist eliminators used with utility FGD systems. To accomplish this overall goal, the following secondary objectives were established:

1. Fabricate a versatile, laboratory-scale WESP for investigating electrical operating characteristics.

2. Verify proper operation of the laboratory unit through initial tests with a non-volatile surrogate aerosol having a size distribution similar to that of acid mist.

3. Demonstrate the feasibility of the WESP concept by achieving adequate collection of acid mist in a pilot coal combustion facility under conditions simulating a full-scale power plant burning high-sulfur coal.

4. Develop a computer model of the WESP process to assist in process optimization, interpretation of test results, and extrapolation to full scale.

5. Perform field measurements of the mass loading and size distribution of acid mist, fly ash, and scrubber solids to provide a reliable basis for projecting WESP performance in utility applications.

6. Make computer projections of WESP performance and size requirements to serve as a basis for the design of a prototype WESP.

7. Solicit utility participation in a follow-on demonstration of the WESP prototype at a full-scale power plant.

Objectives 1-4 were satisfied under Phase I of the contract. Objectives 5-7 apply to the effort under Phase II, which is the subject of this report.

1.3. Project Structure and Scope

The project was organized in two phases. Phase I, which was initiated in September 1988 and completed in November 1989, involved the WESP fabrication, laboratory and pilot combustor testing, and computer modeling. Phase II, which was initiated in January 1990 and completed in April 1991, involved the solicitation of utility test sites, preliminary site measurements, and planning for the demonstration test program. All of the Phase I work was summarized in the Phase I Final Report (6), which was reviewed and approved by DOE. Only Phase II work is addressed in this discussion.

Phase II was organized in four tasks as follows:

Task 6.	Site Selection
Task 7.	Site Measurements
Task 8.	Computer Modeling and Demonstration Plan
Task 9.	Phase II Reporting

2. TASK 6 - SITE SELECTION

Through a contact at the Electric Power Research Institute (EPRI), three potential test sites were initially identified. These sites were the Merom Station of Hoosier Energy, the Big Bend Station of Tampa Electric, and the Widows Creek Station of the Tennessee Valley Authority (TVA). Another potential site, the Sherburne Station of Northern States Power, was identified in a letter received from one of the utility's project engineers. In February 1990, phone calls were made to the appropriate utility personnel to solicit their participation. All of the individuals contacted expressed an interest in participating. The phone calls were followed up with letters that briefly described the proposed testing and test schedule. Copies of the Phase I Final Report were sent along with the letters. These were reviewed by the appropriate management personnel in each utility. Preliminary data on the potential test sites were compiled from the PEDCo FGD Survey (7). A summary of these data is given in Table 1. The utility contacts are listed below.

Joe Kominski	Tampa Electric	P.O. Box 111 Tampa, FL 33601	(813) 228-4111
John Lehto	Northern States Power	414 Nicolett Mall Minneapolis, MN 55401	(612) 337-2049
John Lytle	Tennessee Valley Authority	1101 Market Street Chattanooga, TN 37402	(615) 751-2798
Paul Reynolds	Hoosier Energy	P.O. Box 908 Bloomington, IN 47402	(812) 876-2021

After initial discussions with John Lytle of TVA, it was decided that the Paradise Plant would be superior to the Widows Creek Station, since the Paradise Plant had a definite problem with acid mist emissions. Also, TVA had

Table 1. Potential Test Sites For WESP Project (Data from PEDCo FGD Survey)

Utility name	Hoosier Energy	Northern States Power	Tampa Electric	Tenn. Valley Authority	Tenn. Valley Authority
Plant name	Merom	Sherburne County	Big Bend	Widows Creek	Paradise
Unit number	1	1	4	7	2
Location	Sullivan, Indiana	Becker, Minnesota	Tampa, Florida	Stevenson, Alabama	Drakesboro, Kentucky
Capacity, MW	490	750	475	575	700
Coal type	Bituminous	Subbituminous	Bituminous	Bituminous	Bituminous
% Sulfur	3.5	0.8	3.5	3.7	3.2
% Ash	16.0	Data not available	Data not available	17.0	10.0
Scrubber type	Mitsubishi cocurrent packed tower	Sherco bubbling jet reactor	Research-Cottrell	Combustion Engineering	TVA venturi/spray tower
No. of scrubbers	4	10	Data not available	4	6
Gas flow, ACFM	1,850,000 @ 280°F	Data not available	Data not available	Data not available	2,150,000 @ 300°F
L/G ratio, gal/kACF	42.3	Data not available	Data not available	Data not available	85.0
Ca/S ratio	Data not available	Data not available	Data not available	Data not available	Data not available
Slurry solids, %	Data not available	Data not available	Data not available	Data not available	8
Start-up date	8/82	3/76	1/85	9/81	12/83
Regulatory status	12/71 NSPS	12/71 NSPS	6/79 NSPS	12/71 NSPS	12/71 NSPS
Design efficiency, %	90	90	90	80 (upgraded to 90)	84
Mist eliminator type	Horizontal, up-flow	Two-stage vertical	Data not available	Horizontal, up-flow	Vertical M.E./ Horizontal gas flow
Reheat, ΔT, °F	50	Data not available	Data not available	50	50

already requested Southern Research Institute (SRI) to conduct a more extensive test program at Paradise to investigate alternate solutions to the problem. Based on the suitability of the plant as a test site and the fact that SRI was already planning to be on site for the TVA-sponsored testing, the decision was made to select Paradise as one of the test sites for this project.

The SRI Project Manager visited the Paradise Plant in March 1990 and was met by John Lytle and George Munson from TVA Headquarters in Chattanooga. The Unit 2 scrubber appeared to offer an ideal test site since the reheater was being removed, and there was adequate space for measurements before and after the mist eliminators. TVA installed 48 4-in. ports on both sides and the top of the mist eliminator entrance and exit. After some delays caused by an outage and conflicts with other testing, the Paradise field test was performed on July 16 to 24, 1990.

The Sherburne County (Sherco) Station of Northern States Power (NSP) was initially selected as the site of the second field test, largely because of the interest expressed by the utility and their willingness to share some of the test costs. However, further discussions with NSP revealed that the emissions at Sherco were primarily composed of fine fly ash, rather than acid mist. Since this project was directed specifically at acid mist, the Sherco site was ruled out. The Merom Station and the Big Bend Station were subsequently ruled out, largely because of insufficient interest on the part of the utilities involved. After further discussions between SRI, the Department of Energy (DOE), and TVA, it was decided that the Widows Creek Station was the best site for the second test, both in terms of the site characteristics and the cooperation provided by TVA.

The SRI Project Manager visited the Widows Creek Station in January 1991 and was met by John Lytle and George Munson from TVA headquarters. After inspection of the site, it was agreed that the Unit 7 scrubber was appropriate for the proposed tests. Both Units 7 and 8 are equipped with scrubbers, but only the Unit 7 scrubber has the conventional up-flow mist eliminator design. The Unit 7 boiler is a pc-fired unit, as opposed to the cyclone-fired boiler at Paradise. The Widows Creek field test was performed on March 5 to 8, 1991.

3. TASK 7 - SITE MEASUREMENTS

3.1. Test Plans and Procedures

3.1.1. Paradise Unit 2

As mentioned previously, the first field test was conducted at the Paradise Plant on July 16 to 24, 1990. Particle size measurements were made with University of Washington (UW) Mark V impactors (heated to avoid condensation on the walls), and SO_3 measurements were made by the controlled condensation technique. The impactor measurements were made upstream and downstream of the mist eliminators (ME) at the locations shown in Figure 1. The SO_3 measurements were made in the common duct at the inlet of the FGD system.

The schedule that was followed at the Paradise site is given below.

Sunday	7/15	Travel
Monday	7/16	Set Up Equipment
Tuesday	7/17	Impactors at ME Outlet with Both MEs in Place
Wednesday	7/18	Same as Above
Thursday	7/19	Impactors at ME Inlet
Friday	7/20	Same as above
Saturday	7/21	Impactors at ME Outlet with Only 2nd ME in Place
Sunday	7/22	Impactors at ME Outlet with Only 1st ME in Place
Monday	7/23	Take Down Equipment and Travel

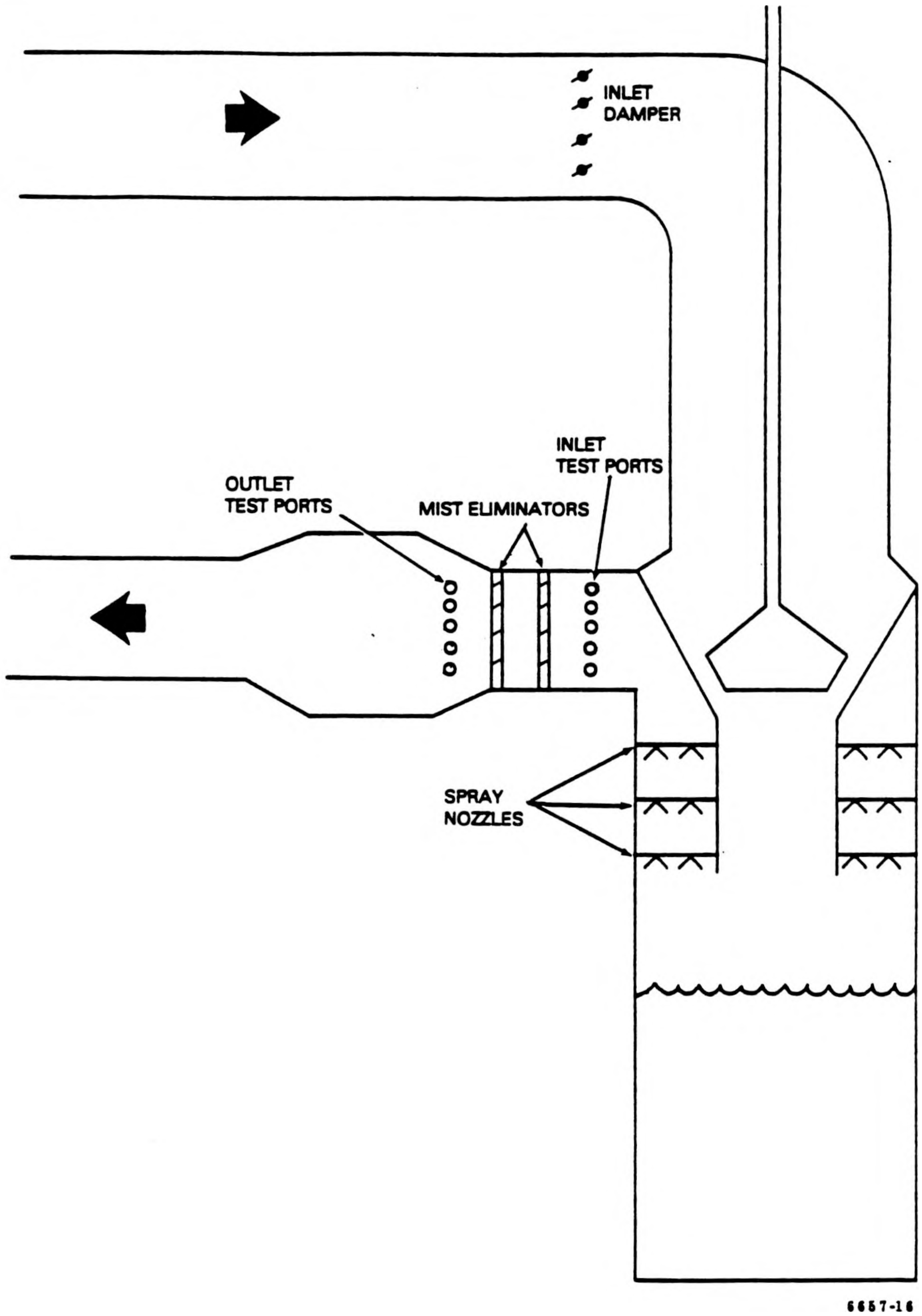


Figure 1. Sketch of Paradise Scrubber Module Showing Locations of Inlet and Outlet Test Ports

As indicated above, the original test plan was expanded to include tests with one of the mist eliminators removed. This was done to simulate the condition recommended by Asea Brown Boveri (ABB) Environmental, Inc. for installation of a WESP. Since the two mist eliminators were of slightly different design, separate tests were conducted with each one. In order to make this approach possible, plant personnel removed the specified mist eliminator during the night shift.

3.1.2. Widows Creek Unit 7

The second field test was performed at Widows Creek Unit 7 on March 5-8, 1991. Particle size and SO_3 measurements were made by the same techniques used at Paradise. Impactor measurements were made at the mist eliminator (ME) outlet and the reheater outlet. SO_3 measurements were made at the scrubber inlet and the reheater outlet. TVA personnel also made simultaneous impactor measurements at the scrubber inlet for their use in analyzing scrubber operation. Since an analysis of scrubber operation is beyond the scope of this project, the TVA measurements will not be addressed here. They will be analyzed, and the results will be reported to TVA separately.

The schedule that was followed at the Widows Creek site is given below.

Tuesday	3/5	Travel and Set Up Equipment
Wednesday	3/6	Impactors at Reheater Outlet
Thursday	3/7	Impactors at ME Outlet
Friday	3/8	Take Down Equipment and Travel

This test plan was much less ambitious than the Paradise plan, but still provided the data needed to project WESP performance.

3.2 SO_3 Measurements

3.2.1. Paradise Unit 2

SO_3 concentrations were measured at the scrubber inlet to determine the amount of condensed acid mist that could potentially be formed. As shown in Table 2, the measured values varied from 13 to 25 ppm, corresponding to equivalent mass loadings of 0.023 to 0.044 gr/scf, or mass emission rates of 0.043 to 0.083 lb/MBtu. This range of mass loadings accounts for only 0.1 to 0.2% of the total mass loading measured at the mist eliminator inlet. However, it could account for virtually all of the mass at the outlet of either one or both mist eliminators.

It should be noted that the SO_3 concentration declined during the last two days of testing. There was no change in the coal sulfur content or ash composition that would explain the lower SO_3 levels on these days. However, the flue gas oxygen content was slightly lower (4.9 to 5.1% versus 5.2 to 5.8% for the preceding four days), which could have produced less conversion of SO_2 to SO_3. This is the most likely explanation, since the SO_2 level remained essentially constant throughout the test period (relative standard deviation = 3.7%).

Table 2. Paradise Unit 2 SO_3/SO_2 Data
(All Measurements in Common Scrubber Inlet Duct)

Date	Flue Gas Temperature, °F	O_2, %	H_2O, %	SO_2 ppm	SO_3 ppm
7/17/90	292	5.6	8.5	2082 2087 2052	22 21 19
7/18/90	298	5.2	8.7	2171 2174 2255	19 19 17
7/19/90	292	5.2	9.9	2139 2140	23 24
7/20/90	294	5.8	8.6	2018 1996	25 20
7/21/90	292	4.9	8.8	2009 2009 2002	18 17 15
7/22/90	288	5.1	8.9	2109 2159 2126	15 14 13
AVERAGE	293	5.3	8.9	2096	19

3.2.2. Widows Creek Unit 7

As shown in Table 3, SO_3 concentration at the scrubber inlet varied from 9 to 13 ppm at Widows Creek Unit 7. This corresponds to an equivalent mass loading of 0.016 to 0.023 gr/scf, or a mass emission rate of 0.030 to 0.043 lb/MBtu. This potential loading of acid is about 40 to 60% lower than that measured at Paradise, although the SO_2 concentrations are very similar (2200 ppm at Widows Creek versus 2100 ppm at Paradise). The lesser conversion of SO_2 to SO_3 at Widows Creek may be associated with the difference in boiler types (pc-fired at Widows Creek versus cyclone-fired at Paradise). It cannot be explained by differences in excess O_2, since the O_2 level was higher at Widows Creek (6.6% versus 5.3%). As was the case at Paradise, the amount of SO_3 present at Widows Creek was sufficient to account for almost all of the particulate mass exiting the mist eliminators.

At Widows Creek, SO_3 measurements were also made at the reheater outlet in order to estimate the amount of SO_3 collected in the FGD system. Since virtually all of the SO_3 is converted to H_2SO_4 aerosol in the scrubber system, it was necessary to make the reheater outlet measurements at both the flue gas temperature (to quantify any remaining SO_3 vapor) as well as the standard operating temperature of 550°F (where the H_2SO_4 aerosol would be converted back to SO_3 vapor). These measurements, also given in Table 3, show that about 28% of the SO_3 was removed by the scrubber (after correction for O_2), and the remaining SO_3 was completely converted to H_2SO_4 aerosol (i.e., less than 0.3 ppm SO_3 vapor detected at flue gas temperature).

Table 3. Widows Creek Unit 7 SO_3/SO_2 Data (Measurements at Scrubber Inlet and Reheater Outlet)

Date	3/6/91				3/7/91					
Location	Scrubber Inlet				Reheater Outlet					
Run Number	1	2	3	4	1	2	3	4	5	6
Flue gas temp., °F	298	299	298	303	139	139	138	139	140	141
Probe and filter holder temperature, °F	550	550	550	550	550	550	550	550	140	141
SO_3 concentration, ppm	9	11	12	13	6	6	6	5	<0.3	<0.3
SO_2 concentration, ppm	2199	2187	2212	2195	134	117	114	112	107	113
O_2 concentration, %	6.6				10.5-11.0					
H_2O concentration, %	7.8				9.2					

3.3. Impactor Run Conditions and Velocity Profiles

3.3.1. Paradise Unit 2

Impactor runs were performed at two sampling locations (mist eliminator inlet and outlet) and with three different mist eliminator configurations (both MEs in place, only the second ME in place, and only the first ME in place). Tables 4-7 give a list of the impactor runs performed at each location and ME configuration. Each set of runs constituted a traverse of the entire duct cross section, with one exception. Only the east side of the duct was traversed during the outlet runs with only the second ME in place. This set of runs was abbreviated because the design of the first ME would be preferred for a WESP retrofit.

Since the duct was 26 ft wide, it was necessary to traverse from both sides. Each run consisted of a four-point traverse within a given port, beginning at a point near the duct centerline and traversing toward the duct wall. This procedure was repeated for each port on each side of the duct. Prior to each set of runs, gas velocity measurements were made at the same traverse points. The locations of the traverse points and the corresponding gas velocities are given in Figures 2-7. The velocities at the four traverse points within a given port were averaged to determine the impactor sampling velocity to be used. Thus, a given impactor run was isokinetic with the average gas velocity encountered during the traverse. However, the sampling was highly anisokinetic at certain traverse points because of the highly non-uniform velocity profiles (see Figures 2-7).

Table 4. Description of Impactor Runs Performed at Paradise Mist Eliminator Outlet with Both Mist Eliminators in Place

Date	Start time	Run No.	Substrate Set No.	Port No.	Run time, min	Sampling Rate, acfm
7/17/90	1228	PAR2MEO-1	235	1E	60	0.364
7/17/90	1428	PAR2MEO-2	233	2E	60	0.292
7/17/90	1710	PAR2MEO-3	234	3E	60	0.302
7/17/90	1755	PAR2MEO-4	236	4E	60	0.387
7/17/90	2000	PAR2MEO-6	238	5E	60	0.305
7/18/90	1300	PAR2MEO-13	245	1W	60	0.333
7/18/90	1328	PAR2MEO-14	246	3W	60	0.270
7/18/90	1505	PAR2MEO-9	241	2W	60	0.349
7/18/90	1655	PAR2MEO-11	243	4W	44	0.382
7/18/90	1745	PAR2MEO-12	244	5W	44	0.399

Table 5. Description of Impactor Runs Performed at Paradise Mist Eliminator Inlet						
Date	Start Time	Run No.	Substrate Set No.	Port No.	Run Time, min	Sampling Rate, acfm
7/19/90	0930	PAR2MEI-1	248	1W	16	0.324
7/19/90	1058	PAR2MEI-2	247	2W	16	0.317
7/19/90	1213	PAR2MEI-3	249	3W	16	0.306
7/19/90	1300	PAR2MEI-4	250	4W	16	0.326
7/20/90	0915	PAR2MEI-6	252	1E	16	0.393
7/20/90	0955	PAR2MEI-7	253	2E	16	0.406
7/20/90	1055	PAR2MEI-8	254	3E	16	0.310
7/20/90	1125	PAR2MEI-9	255	4E	16	0.310

Table 6. Description of Impactor Runs Performed at Paradise Mist Eliminator Outlet with Second Mist Eliminator in Place (East Side Only Tested)

Date	Start Time	Run No.	Substrate Set No.	Port No.	Run Time, min	Sampling Rate, acfm
7/21/90	1018	PAR2MEO-13	257	1E	44	0.342
7/21/90	1217	PAR2MEO-14	258	2E	36	0.330
7/21/90	1240	PAR2MEO-15	259	5E	36	0.262
7/21/90	1437	PAR2MEO-16	260	3E	36	0.287
7/21/90	1615	PAR2MEO-18	262	4E	36	0.313

Table 7. Description of Impactor Runs Performed at Paradise Mist Eliminator Outlet with First Mist Eliminator in Place

Date	Start Time	Run No.	Substrate Set No.	Port No.	Run Time, min	Sampling Rate, acfm
7/22/90	1029	PAR2MEO-19	264	3E	36	0.327
7/22/90	1050	PAR2MEO-20	263	5E	36	0.263
7/22/90	1314	PAR2MEO-21	266	4E	36	0.270
7/22/90	1242	PAR2MEO-22	265	1E	36	0.279
7/22/90	1454	PAR2MEO-24	268	2E	36	0.312
7/22/90	1603	PAR2MEO-25	269	2W	36	0.280
7/22/90	1630	PAR2MEO-26	270	1W	36	0.303
7/22/90	1735	PAR2MEO-27	271	3W	36	0.230
7/22/90	1753	PAR2MEO-28	272	4W	36	0.401
7/22/90	1855	PAR2MEO-29	273	5W	36	0.291

TOP

PORT / POINT	4	3	2	1	1	2	3	4	PORT
1W	21.2	15.5	13.1	17.6	19.9	18.6	16.1	16.1	1E
2W	25.6	18.6	11.7	13.1	20.3	16.6	11.0	13.8	2E
3W	26.3	22.0	20.3	22.7	21.6	23.5	9.3	7.2	3E
4W	25.6	15.5	18.6	17.6	17.6	12.5	8.3	5.9	4E
5W	28.2	18.6	15.5	15.5	13.3	9.7	0.0	0.0	5E

WEST SIDE 16 ft

EAST SIDE

BOTTOM

26 ft

Numbers indicate velocity in ft/sec.

Average velocity = 16.1 ft/sec
Standard deviation = 6.49 ft/sec
Relative standard deviation = 40.3%
Calculated flowrate = 401,900 acfm

Figure 2. Velocity Profile at Paradise Mist Eliminator Outlet with Both Mist Eliminators in Place.

TOP

PORT	POINT 4	3	2	1	℄ 1	2	3	4	
1W	32.7	29.9	27.3	23.5	32.8	35.8	34.4	35.8	1E
2W	32.6	28.1	24.9	24.2	33.9	35.4	38.6	35.4	2E
3W	31.6	30.5	23.5	21.1	25.7	20.4	24.3	34.9	3E
4W	25.6	19.4	11.7	9.3	8.3	14.4	15.6	22.0	4E

WEST SIDE — 10 ft 8 in.

EAST SIDE

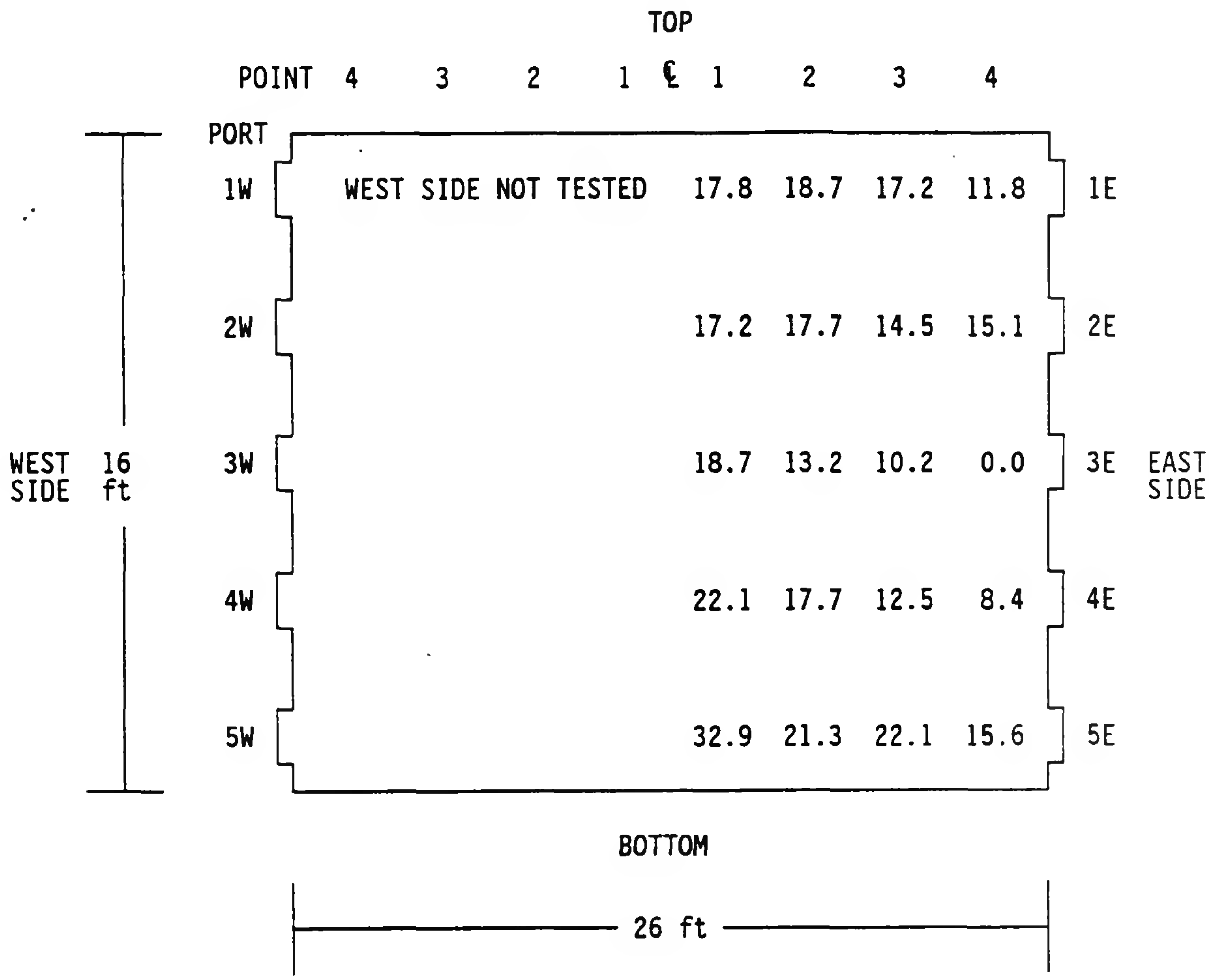
BOTTOM

26 ft

Numbers indicate velocity in ft/sec.

Average velocity = 26.4 ft/sec
Standard deviation = 8.26 ft/sec
Relative standard deviation = 31.3%
Calculated flowrate = 439,200 acfm

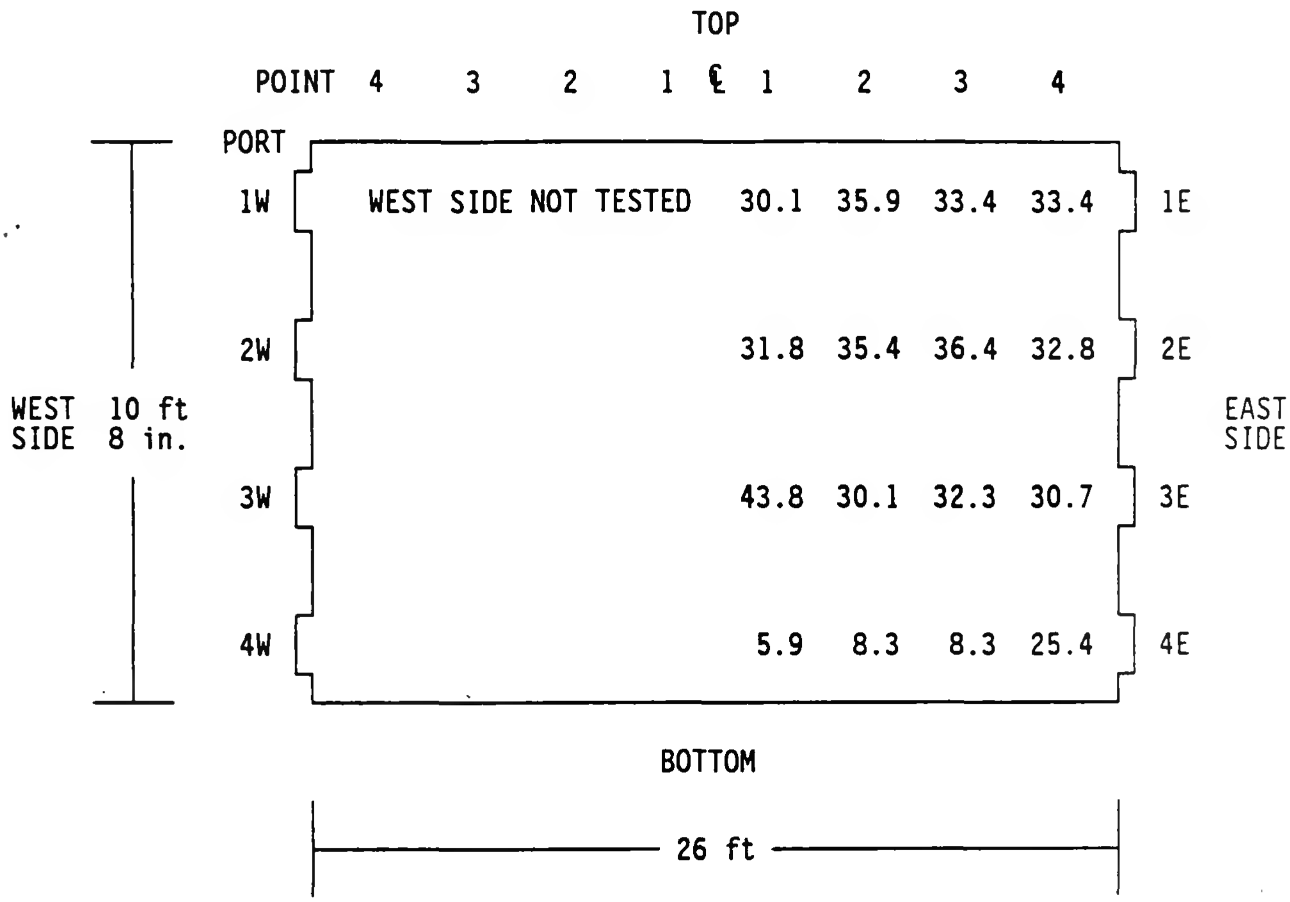
Figure 3. Velocity Profile at Paradise Mist Eliminator Inlet with Both Mist Eliminators in Place.



Numbers indicate velocity in ft/sec.

Average velocity = 16.2 ft/sec
Standard deviation = 6.50 ft/sec
Relative standard deviation = 40.1%
Calculated flowrate = 404,400 acfm (assuming west side has same average velocity as east)

Figure 4. Velocity Profile at Paradise Mist Eliminator Outlet with Second Mist Eliminator in Place (East Side Only Tested).



Numbers indicate velocity in ft/sec.

Average velocity = 28.4 ft/sec
Standard deviation = 11.07 ft/sec
Relative standard deviation = 39.0%
Calculated flowrate = 472,500 acfm (assuming west side has same average velocity as east)

Figure 5. Velocity Profile at Paradise Mist Eliminator Inlet with Second Mist Eliminator in Place (East Side Only Tested).

TOP

PORT \ POINT	4	3	2	1	℄ 1	2	3	4	
1W	17.7	13.2	13.2	14.4	15.6	13.8	11.8	11.8	1E
2W	28.3	24.3	22.0	22.8	20.4	10.2	0.0	0.0	2E
3W	25.0	22.8	19.5	15.6	20.9	28.9	29.5	32.8	3E
4W	25.7	16.7	19.5	17.7	13.2	20.4	31.2	32.9	4E
5W	30.6	25.0	22.8	22.0	19.6	13.2	0.0	5.9	5E

WEST SIDE 16 ft

EAST SIDE

BOTTOM

26 ft

Numbers indicate velocity in ft/sec.

Average velocity = 18.8 ft/sec
Standard deviation = 8.51 ft/sec
Relative standard deviation = 45.3%
Calculated flowrate = 469,200 acfm

Figure 6. Velocity Profile at Paradise Mist Eliminator Outlet with First Mist Eliminator in Place.

TOP

PORT \ POINT	4	3	2	1	1	2	3	4	
1W	33.9	19.5	23.6	22.1	32.8	35.4	35.9	36.4	1E
2W	35.4	29.5	27.0	25.0	33.4	34.4	36.8	32.8	2E
3W	31.2	30.6	25.0	22.1	20.4	18.7	22.8	34.4	3E
4W	25.7	22.1	16.7	8.3	8.3	20.4	25.0	25.7	4E

WEST SIDE 10 ft 8 in.

EAST SIDE

BOTTOM

26 ft

Numbers indicate velocity in ft/sec.

Average velocity = 26.6 ft/sec
Standard deviation = 7.70 ft/sec
Relative standard deviation = 28.9%
Calculated flowrate = 442,600 acfm

Figure 7. Velocity Profile at Paradise Mist Eliminator Inlet with First Mist Eliminator in Place.

The relative standard deviations of the gas velocity distributions are summarized below:

	ME Inlet	ME Outlet
Both MEs in Place	31.3%	41.3%
First ME in Place	28.9%	45.3%
Second ME in Place	39.0%	40.1%

The flow distribution was obviously poor ahead of the mist eliminators, and it was made even worse by the mist eliminators. Remedial measures (e.g., addition of a perforated plate) would be required to improve the flow distribution prior to installation of a WESP.

3 3.2. Widows Creek Unit 7

Impactor runs were performed at two sampling locations (reheater outlet and mist eliminator outlet). The mist eliminator outlet runs served to provide data for the projection of WESP performance. The reheater outlet runs were not useful in this regard, since it would not make sense to install a WESP after a reheater. These runs were performed primarily to judge the effect of reheat on the mass loading and particle size distribution. This information may also assist TVA in correlating Widows Creek opacity data with emissions.

Tables 8 and 9 give a list of the impactor runs performed at each location. At the reheater outlet, each run comprised a traverse of one-half of the duct cross-section (4 out of 8 ports, 4 points per port). The four runs effectively

Table 8. Description of Impactor Runs Performed at Widows Creek Reheater Outlet

Date	Start Time	Run No.	Substrate Set No.	Port No.	Run Time, min	Sampling Rate, acfm
3/6/91	1400	WCRHO-01	352	1-4	64	0.393
3/6/91	1402	WCRHO-02	353	5-8	64	0.345
3/6/91	1446	WCRHO-03	359	1-4	240	0.393
3/6/91	1648	WCRHO-04	360	5-8	240	0.345

Table 9. Description of Impactor Runs Performed at Widows Creek Mist Eliminator Outlet

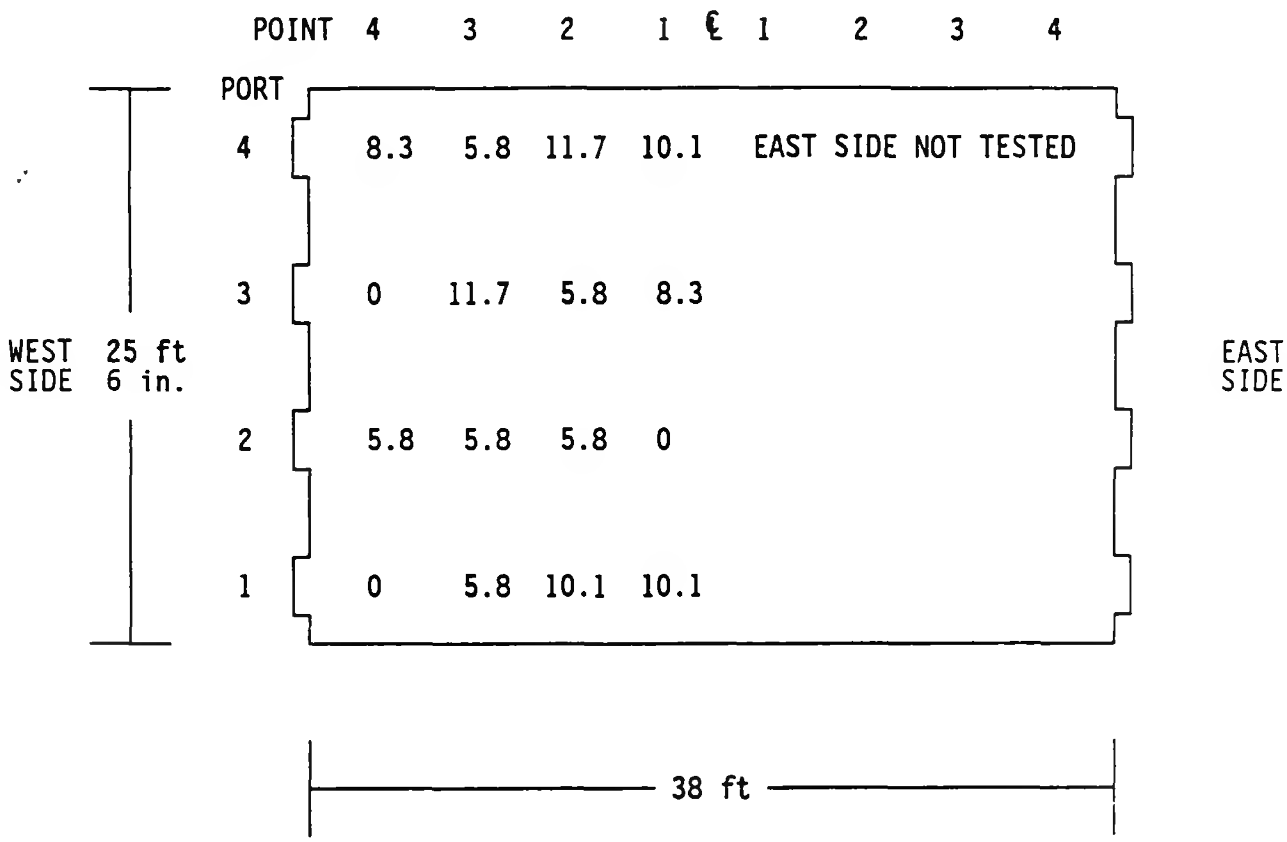
Date	Start Time	Run No.	Substrate Set No.	Port No.	Run Time, min	Sampling Rate, acfm
3/7/91	1230	WCMEO-01	363	1	240	0.398
3/7/91	1254	WCMEO-02	364	3	240	0.394
3/7/91	1738	WCMEO-03	366	2	240	0.274
3/7/91	1755	WCMEO-04	367	4	240	0.302

traversed the entire duct twice. Prior to these runs, gas velocity measurements were made at the same traverse points. Locations of the traverse points and their corresponding gas velocities are given in Figures 8 and 9. At the reheater outlet, the velocities at the 16 traverse points within a given side of the duct were averaged to determine the impactor sampling velocity to be used. At the mist eliminator outlet, an average velocity was calculated for each port, since a separate impactor run was performed in each port. At this sampling location, only one side of the duct was accessible, and the sampling probes were not quite long enough to reach the centerline. Therefore, slightly less than one-half of the duct was actually traversed. There was a highly non-uniform velocity profile at this location, as indicated in Figure 8. The relative standard deviations of the gas velocity distributions at the ME outlet and the reheater outlet were 59.2% and 11.5%.

3.4. Impactor Results

3.4.1. Paradise Unit 2

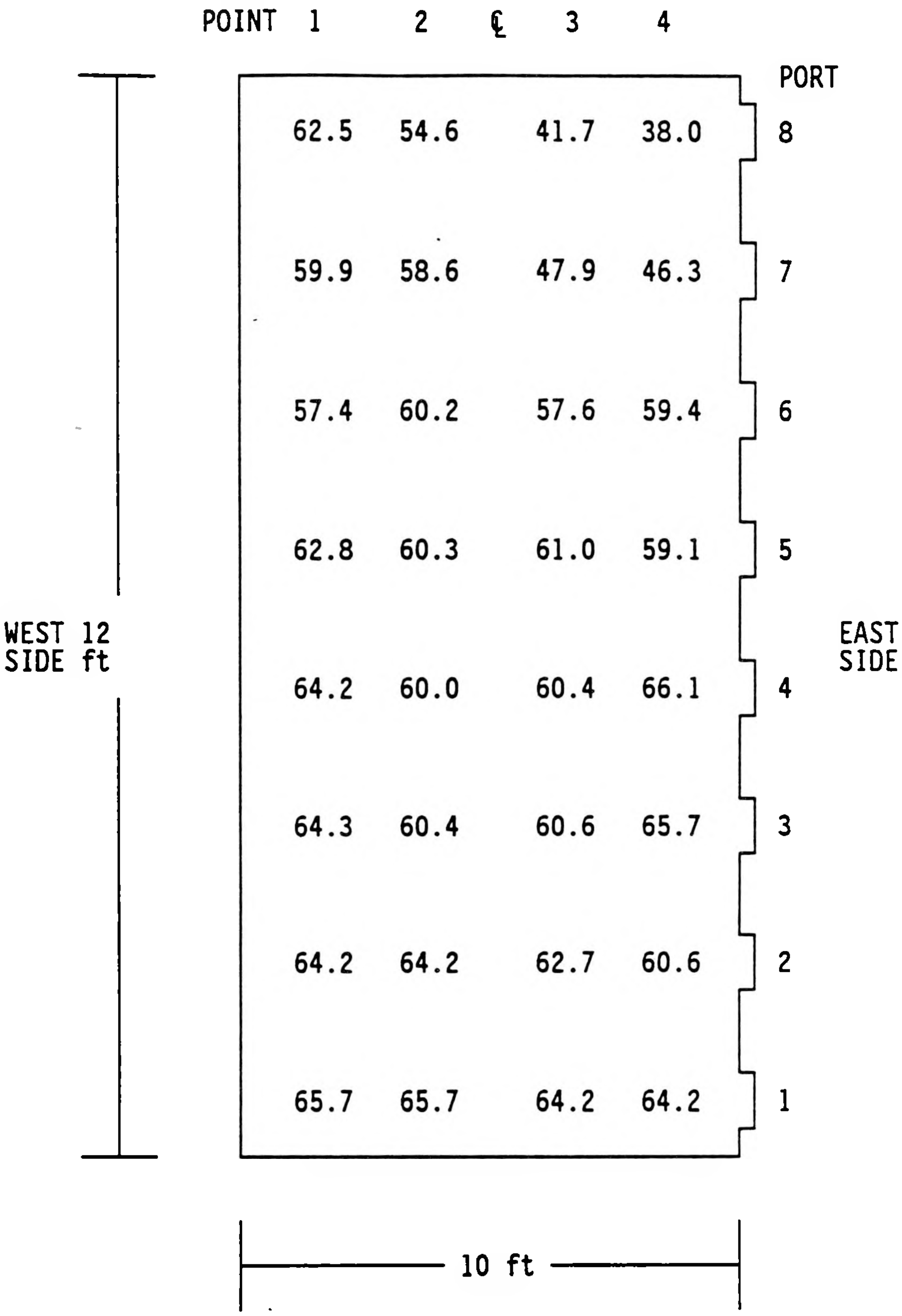
Table 10 gives the average total mass loading and mass median diameter (MMD) for each set of impactor runs. As expected, the particulate mass loading ahead of the mist eliminators was extremely high (13.7 gr/acf). This material was predominantly large droplets of scrubber carryover, resulting in a relatively large MMD (44 μm). Downstream from the mist eliminators, the mass loading was greatly reduced (0.025 gr/acf) and the MMD was much smaller ($\leq$0.1 μm). This result suggests that the mist eliminators were very effective in removing the entrained scrubber droplets and most of the fly ash. With only the first mist



Numbers indicate velocity in ft/sec.

Average velocity = 6.6 ft/sec
Standard deviation = 3.9 ft/sec
Relative standard deviation = 59.2%
Calculated flowrate = 383,700 acfm (assuming east side has same average velocity as west)

Figure 8. Velocity Profile at Widows Creek Mist Eliminator Outlet (West Side Only Tested).



Numbers indicate velocity in ft/sec.

Average velocity = 59.4 ft/sec
Standard deviation = 6.8 ft/sec
Relative standard deviation = 11.5%
Calculated flowrate = 427,700 acfm (assuming west side has same average velocity as east)

Figure 9. Velocity Profile at Widows Creek Reheater Outlet

Table 10. Summary of Average Mass Loadings and MMDs Measured at Paradise Mist Eliminator (ME) Outlet and Inlet

Test Location	Number of Runs	Average Mass Loading (Total)				Mass Median Diameter (MMD), μm
		gr/acf	mg/acm	gr/dscf	mg/dscm	
ME Outlet/ Both MEs In	10	0.0252	57.7	0.0346	79.2	0.067
ME Inlet/ Both MEs In	8	13.71	31,360	18.90	43,250	44.1
ME Outlet/ Second ME In	5	0.0265	60.7	0.0373	85.3	<0.067
ME Outlet/ First ME In	10	0.0249	57.1	0.0348	79.7	0.104

Calculated ME collection efficiencies (total):
Both MEs: 99.817% Second ME: 99.803% First ME: 99.816%

eliminator in place, the calculated collection efficiency was virtually identical to that obtained with both mist eliminators in place (99.816 versus 99.817%). However, the performance of the second mist eliminator alone may have been slightly worse (99.803%). This suggests that it may be possible to reduce system pressure drop by removing the second mist eliminator without any increase in particulate mass loading.

Figure 10 shows the average cumulative mass loading curves from the four sets of impactor runs. These results show that all four sets of impactor runs produced essentially identical particle size distributions for particles smaller than about 6 μm. For particle sizes larger than about 6 μm, only the inlet distribution is significantly different because of the large amount of scrubber carryover. These larger particles (or droplets) account for over 99% of the inlet particulate mass. On a number basis, however, they make up less than 0.01% of the particles. By virtue of their low number density, these large particles would make a very small contribution to particulate space charge within a WESP. Furthermore, there is no statistically significant difference in the fine particle concentrations obtained at the inlet or at the outlet with either one or both mist eliminators in place. This suggests that the potential for suppression of the corona current by particulate space charge is independent of the location of the WESP and the number of mist eliminators in service. In terms of space charge effects, there is nothing to be gained by using one or more mist eliminators ahead of the WESP. The use of at least one mist eliminator may still be required, however, if the scrubber solids would otherwise tend to form tenacious deposits on discharge or collecting electrodes. The use of one mist eliminator ahead of the WESP has been recommended by ABB Environmental, Inc. (8).

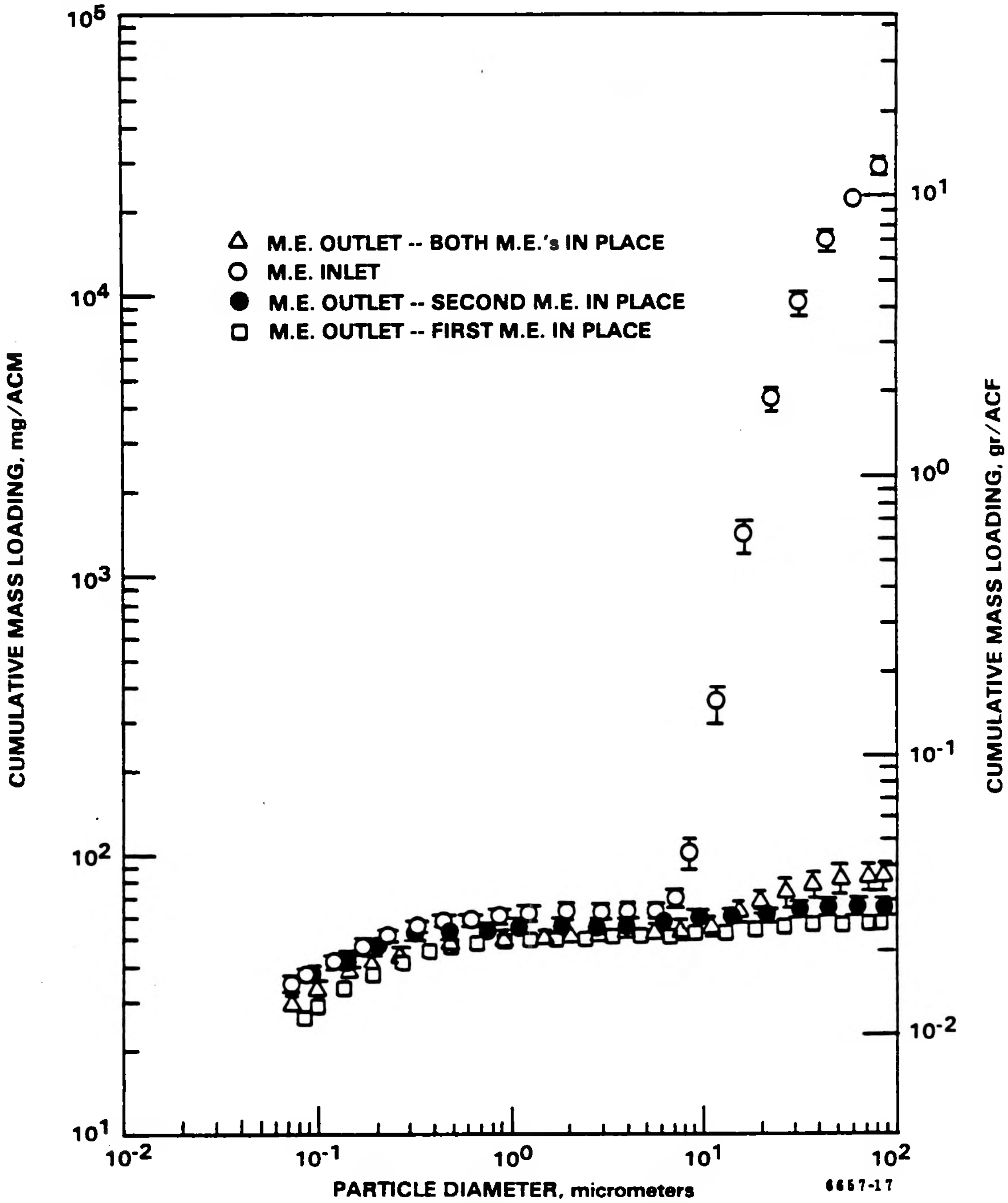


Figure 10. Cumulative Mass Loading Curves Obtained at Paradise Mist Eliminator Inlet and Outlet with Various Mist Eliminator Configurations

3.4.2. Widows Creek Unit 7

Table 11 gives the average total mass loading and MMD for each set of impactor runs. The loadings are somewhat lower than those obtained at Paradise, which is consistent with the lower amount of SO_3. Comparison of the ME outlet and reheater outlet data suggests that about one-half of the material leaving the MEs is evaporated in the reheater. Comparison of the cumulative mass loading curves, shown in Figure 11, suggests that this is entirely the result of the evaporation of extremely fine material that would be collected only on the impactor back-up filter. This produces the uniform reduction in cumulative mass indicated in Figure 11. There is no change in the mass concentration of particles larger than about 0.1 μm.

In terms of the mass percentage in the submicron size range, the Widows Creek size distribution appears to be somewhat finer than the Paradise size distribution (95% versus 87%). However, the submicron mass loading is actually higher at Paradise. The percentage is higher at Widows Creek only because the total mass loading is lower.

3.5. Chemical Analysis of Impactor Substrates

3.5.1. Paradise Unit 2

The impactor catches from each set of runs were combined and analyzed to determine the relative amounts of sulfuric acid, fly ash, and scrubber solids that

Table 11. Summary of Average Mass Loadings and MMDs Measured at Widows Creek Mist Eliminator (ME) Outlet and Reheater Inlet						
Test Location	Number of Runs	Average Mass Loading (Total)				Mass Median Diameter (MMD), μm
		gr/acf	mg/acm	gr/dscf	mg/dscm	
ME Outlet	4	0.0216	49.3	0.0286	65.4	<0.062
Reheater Outlet	4	0.0111	25.3	0.0160	36.7	<0.062

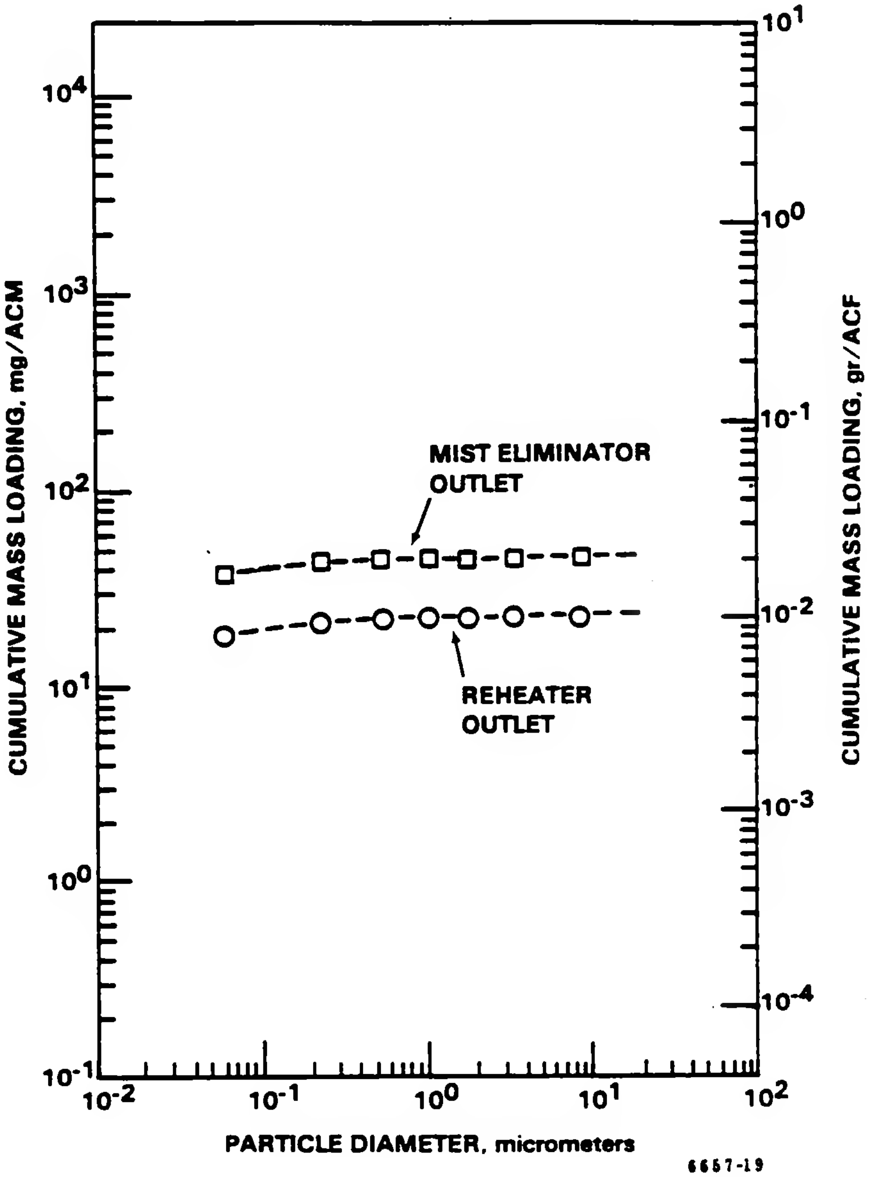


Figure 11. Cumulative Mass Loading Curves Obtained at Widows Creek Mist Eliminator Outlet and Reheater Outlet

were present. Selected stages were combined in order to provide an adequate amount of sample for reliable analysis. The combined impactor substrates were extracted in deionized water, and the extracts were analyzed for calcium and sulfate. From the calcium content, the corresponding percentage by weight of scrubber solids, expressed as $CaSO_4$, was calculated. The amount of sulfate corresponding to the $CaSO_4$ was subtracted from the total sulfate, and the difference was ascribed to sulfuric acid. In the case of the inlet large particle fraction, the water content was determined independently. The remaining material was assumed to be fly ash.

Table 12 gives the results of the analytical procedure described above. With respect to sulfuric acid, the results show the expected trend of increasing concentration with decreasing particle size. Only the size fraction larger than an 8 μm showed a major difference between the H_2SO_4 contents of the inlet and outlet samples. The inlet sample contained virtually no H_2SO_4 in the fraction larger than 8 μm, while the outlet samples obtained with one ME and with both MEs in place contained 17.2% and 5.8%, respectively. This may be the result of the collection of a small portion of the acid mist in the ME, followed by reentrainment in the form of larger droplets. The results suggest that there may be a lesser amount of this type of reentrainment when both mist eliminators are in place.

With respect to the scrubber solids, the loading in the inlet fraction larger than 8 μm may seem low (2.3%); however, the total mass of this fraction is about 38,100 mg, compared to 18.4 mg for the outlet sample with one ME in place and 176 mg for the outlet sample with both MEs in place.

Table 12. Chemical Analysis of Paradise Impactor Stages

Impactor Stages	PC +1	2-4	5-7	BUF
Approximate Size Range, μm	>8	8-1	1-0.1	<0.1
Wt% H_2SO_4				
Inlet	0.1	29.5	28.7	38.3
Outlet with 1st M.E.	17.2	20.5	27.3	42.0
Outlet with Both M.E.s	5.8	30.7	38.3	45.0
Wt% $CaSO_4/CaSO_3$				
Inlet	2.3	43.9	7.1	3.4
Outlet with 1st M.E.	24.5	20.4	4.4	3.0
Outlet with Both M.E.s	1.4	16.7	4.1	1.9
Wt% Fly Ash				
Inlet	9.7	26.6	64.2	58.3
Outlet with 1st M.E.	58.3	59.1	68.3	55.0
Outlet with Both M.E.s	92.8	52.6	57.6	53.1

Notes:
PC = precutter
BUF = back-up filter
Inlet PC+1 sample contained 87.9% water; all other samples were dry.

The actual mass of scrubber solids in the fraction smaller than 8 μm in each sample is given below:

Inlet	880 mg
Outlet with first ME	4.5 mg
Outlet with both MEs	2.5 mg

Thus, the first mist eliminator removed about 99.5% of the large (larger than 8 μm) scrubber solids, while both mist eliminators in combination removed about 99.7%.

In general, fly ash appears to account for at least half of all the solid particulate matter, except in the 1 to 8 μm fraction of the inlet sample. This exception appears to be due to the high loading of scrubber solids in this particular fraction. These particles may be the result of fines in the limestone used in the scrubber slurry, or they may result from attrition within the scrubber circuit.

In the submicron size fractions, which tend to make the greatest contribution to opacity, the particulate mass is composed primarily of fly ash (53 to 68%) and sulfuric acid (27 to 45%), with a very small amount of scrubber solids (1.9 to 3.4%). It should be noted that some of this sulfuric acid may be condensed on the surface of fly ash particles and may react to form metal sulfates. These sulfates may have a variety of colors and may absorb light accordingly. Some of the acid may also be present as separate droplets of pure H_2SO_4 with corresponding waters of hydration. Impurities in the acid may also give these droplets a wide variety of colors and corresponding light absorption. Thus, the refractive index of this material may include a significant imaginary component. This can have a major effect on opacity when the particles are very fine, as they are in this case.

3.5.2. Widows Creek Unit 7

The same procedure described above was used to analyze the Widows Creek impactor stages. Only the ME outlet samples were subjected to this analysis, since this would be the location of a WESP retrofit. The results are summarized in Table 13. The values determined for the pre-cutter/stage 1 composite (PC + 1) were not reliable because of residual sulfate that was left in the substrate after acid washing. For the other stages, this correction is negligible because the sample mass is so much greater than the mass of residual sulfate. Therefore, the analyses of the other composites are reliable. They show that the particles smaller than about 8 μm are primarily composed of acid (47% to 62%) and fly ash (36% to 43%), and the scrubber solids are largely confined to particle sizes above 8 μm. There is a trend toward increasing acid concentration with decreasing particle size down to a size of 0.1 μm. However, below 0.1 μm the acid content appears to level off or possibly decrease slightly (61.8% in the 0.1 to 1 μm fraction and 56.9% in the fraction smaller than 0.1 μm fraction). The explanation for this result is not clear. Nevertheless, it is clear that acid mist accounts for a significant portion of the fine particle emissions.

Table 13. Chemical Analysis of Widows Creek Impactor Stages

Impactor Stages	PC +1	2-4	5-7	BUF
Approximate Size Range, μm	>8	8-1	1-0.1	<0.1
Wt% H_2SO_4	27.3	47.1	61.8	56.9
Wt% $CaSO_4/CaSO_3$	72.7	11.2	2.2	0.4
Wt% Fly Ash	0	41.7	36.0	42.7

Notes:
PC = precutter
BUF = back-up filter
Inlet PC+1 sample contained 87.9% water; all other samples were dry.
The values for the PC+1 stages are suspect because of a relatively large blank correction necessitated by the presence of a relatively large amount of residual sulfate on these substrates.

4. TASK 8 - COMPUTER MODELING AND DEMONSTRATION PLAN

4.1. Computer Modeling

4.1.1. Paradise Unit 2

The particle size data described earlier were used to make projections of WESP performance for two cases. Case 1 was a wire-pipe WESP with a tube diameter of 8 in., tube length of 10 ft, and gas velocity of 20 ft/sec. The nominal specific collection area (SCA) for this case was 50 ft^2/kacfm. Case 2 was a wire-plate WESP designed especially for the ducting at the Paradise site as shown in Figure 12. For Case 2, both a two-field and a three-field WESP were considered. The latter unit would require modification of the existing ducting as illustrated in Figure 12. Each field contained 40 plates, spaced 8 in. apart, with a depth in the direction of flow of 5 ft. The gas velocity, based on the measured gas flow rate, was 16 ft/sec. The corresponding SCAs for the two-field and three-field units were 31 and 47 ft^2/kacfm. Thus, a three-field wire-plate unit would be required to achieve an SCA comparable to that of the generic wire-pipe case.

For the modeling of both cases, the input size distribution was based on the impactor measurements made after the first mist eliminator only. This size distribution was selected because there was very little collection in the second mist eliminator, the design of the first mist eliminator was considered to be superior to the design of the second one, and most FGD systems are equipped with only one mist eliminator.

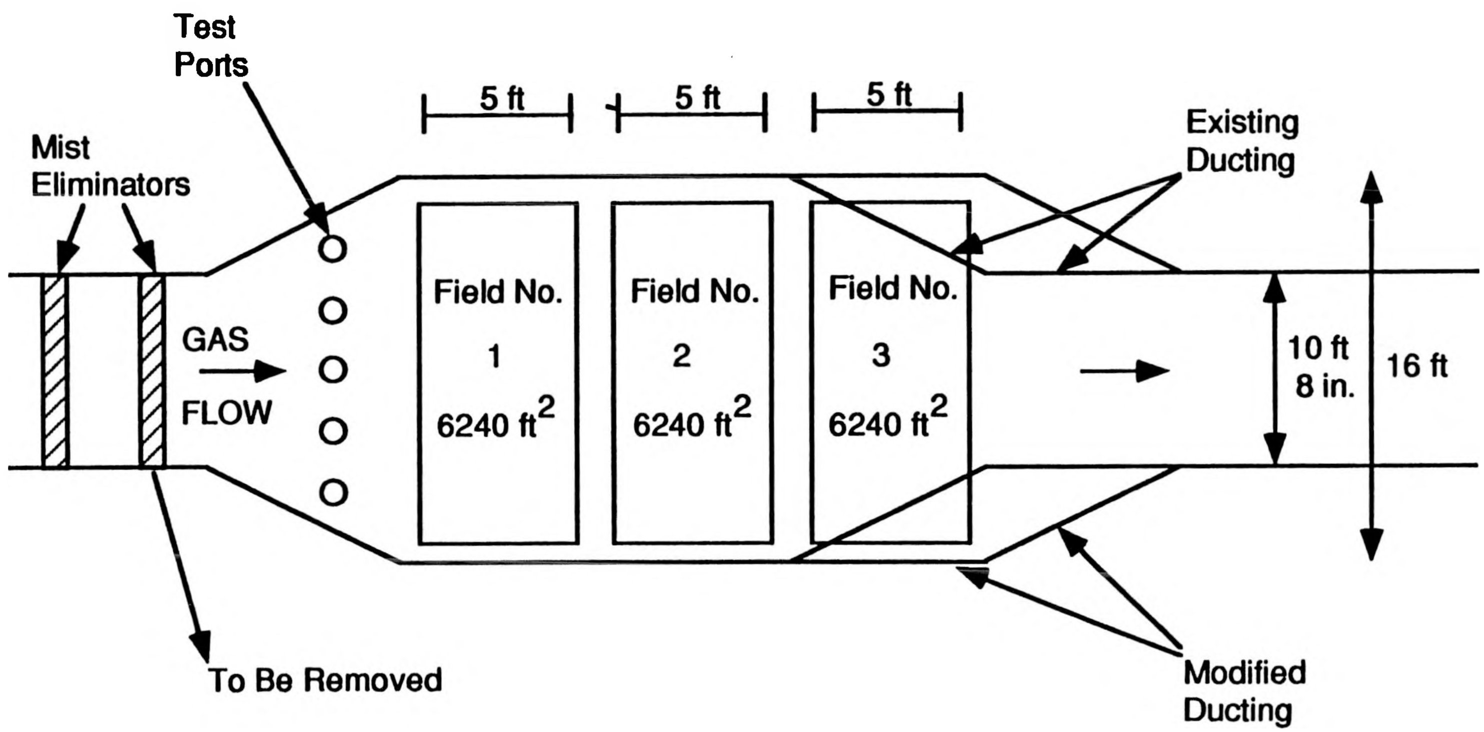


Figure 12. WESP Retrofit for Paradise Scrubber Module

For the wire-pipe case (Case 1), WESP performance was predicted using the current-specific model described in the Phase I Final Report. For the wire-plate case (Case 2), the SRI/EPA ESP Model was used without the standard correction for rapping reentrainment. In both cases, the predicted outlet size distribution was used to project stack opacity. The opacity projections were made with an in-house model assuming a range of refractive index from 1.5 - 0.1i to 1.8 - 0.2i. This range of values was used since the correct refractive index is not known and would be difficult to determine. However, this range establishes an upper and lower limit for the expected opacity.

For each case, two different sets of electrical conditions were also modeled. This was done to take into account the varying degrees of corona suppression that might be encountered at various sites. The specified range of conditions was consistent with the range of operating conditions achieved during the pilot WESP tests under Phase I. A summary of the modeling results is given below. For reference purposes, the range of opacity predicted using the inlet size distribution was 42 to 60%.

Case No.	Geometry	No. of Fields	SCA, ft^2/kacfm	Voltage, kV	Current Density, nA/cm^2	Predicted Efficiency, %	Predicted Opacity, %
1	Pipe	1	50	45	72	84.9	11-19
				60	114	90.2	8-14
2	Plate	2	31	45	72	73.7	18-29
				60	114	85.8	11-19
		3	47	45	72	84.2	12-20
				60	114	92.8	6-11

The results suggest that a relatively compact (10-ft tube length) wire-pipe unit could reduce the stack opacity to below 20% even with the worst electrical operating conditions considered here. It should be noted that this result was obtained with a very fine inlet size distribution (mmd = 0.1 μm). Therefore, it appears likely that this level of performance could be achieved at other sites.

The results for Case 2 suggest that a wire-plate unit with a comparable SCA could achieve a performance level similar to that of the wire-pipe unit. However, the space limitations at Paradise are such that a three-field unit would be required. This may not be the case if the duct cross-section could be expanded to allow the use of taller plates. However, structural interferences would not allow this kind of modification at Paradise. The use of the relatively short (16-ft) plates requires that the total length of electrical fields be 15 ft. This produces an SCA of 47 ft^2/kacfm.

It is emphasized that the wire-plate case simulated here is site-specific. The space available for a retrofit of this type will probably vary from site to site, which will dictate the size of the unit that can be installed. It should also be emphasized that a wire-plate unit would be considered only in those instances where the mist eliminators and reheater are in a vertical configuration (horizontal gas flow), a relatively unusual situation. For example, a recent summary of FGD process descriptions prepared by PEDCo (9) revealed that only 3 out of the 24 units surveyed had a mist eliminator section with horizontal gas flow. The most common configuration is a direct mounting of the mist eliminators and reheater on top of the scrubber with upward gas flow. In general, the mist eliminators and reheater occupy at least the same cross-sectional area as the scrubber tower. Calculations given in our Phase I Final Report (6) showed that a wire-pipe WESP with an SCA of 50 ft^2/kacfm and tube length of 10 ft could be installed in this location provided that the duct diameter is at least 15 ft. This would be the case at most scrubber installations.

4.1.2. Widows Creek Unit 7

The retrofit of a WESP to the mist eliminator outlet at Widows Creek was modeled using the same approach described above for the Paradise case, except that only a wire-pipe case was considered. The wire-plate case was not examined because it would be difficult to implement in the up-flow orientation at Widows Creek. A one-field WESP with an SCA of 50 ft^2/kacfm and a two-field WESP with an SCA of 100 ft^2/kacfm were modeled using the same electrical conditions used for the Paradise modeling. The results are summarized below.

No. of Fields	SCA, ft^2/kacfm	Voltage, kv	Current Density[2] nA/cm^2	Predicted Efficiency, %	Predicted Opacity, %
1	50	45	72	97.5	1.5-3
		60	114	98.7	<1.5
2	100	45	72	99.4	0.4-0.8
		60	114	99.7	<0.4

These results suggest that better WESP performance is achievable with the Widows Creek size distribution than with the Paradise size distribution, even though the former distribution contains a larger percentage of submicron particulate mass. Although the Widows Creek distribution contains a higher percentage of submicron mass, the actual mass loading of submicron particles is about 10% lower than at Paradise. The mass percentage is higher only because the total mass loading is lower. (The mass percentage is determined by dividing the absolute mass concentration by the total mass concentration.) This relatively small difference in fine particulate mass translates into a significant difference in collection efficiency (97.5% versus 84.9% with an SCA of 50 ft^2/kacfm). The larger number of fine particles in the Paradise size distribution leads to greater suppression of the corona current by space charge.

4.2. Demonstration Plan

A logical follow-on to this project would be the demonstration of the WESP concept at a series of utility FGD installations. Provision for this follow-on activity was made by preparing a WESP demonstration plan, which is described below.

Originally, two approaches to the plan were considered. The first was based on the installation of a full-scale WESP on one of the Paradise scrubber modules (gas flow equivalent to 140 MW). The second approach was based on a portable, pilot WESP that could be tested at a number of different sites. The first approach offers the advantages that: (1) the technology could be demonstrated at full scale; (2) there would be no concern about the representativeness of the treated flue gas, which can be a problem with a slipstream approach; and (3) TVA has expressed considerable interest in this approach and is willing to co-fund the demonstration. The disadvantages of this approach are relatively high cost and relatively little flexibility to vary test conditions.

The second approach, using a portable unit, offers the advantage of much greater testing flexibility. The unit could be transported to various sites, thus providing a range of coal types, acid mist loadings, fly ash loadings, scrubber types, and mist eliminator configurations. A unit that is designed to be transported by a tractor-trailer rig could probably be sized for a flue gas flow of up to 10,000 acfm. This size would correspond to less than 3% of the flow rate through one of the Paradise scrubber modules (about 400,000 acfm). Using a device of this scale could lead to questions about how well the 3% slipstream represents the full gas flow in terms of mass loading and particle size. Of course, such questions can be addressed by conducting comparative impactor measurements in both the full-scale ducting and the slipstream. Although there is no current prospect for co-funding the portable WESP, its capital cost should be much less than that of the full-scale demonstration unit. However, testing costs may be somewhat higher with the portable unit because of the transportation costs and costs of connecting and disconnecting the unit at various sites. This differential in testing costs would certainly not be high enough to offset the savings in capital cost. Therefore, the portable unit seems to offer a more cost-effective approach.

A final decision on the approach to the WESP demonstration has not been made, but all of the information available thus far tends to favor the use of a portable unit. We have done some preliminary planning relative to the features of such a unit and how it would be used. The following is a list of some desirable features:

1. The unit should fit on a standard trailer (40 to 50 ft in length) and be low enough to fit under highway overpasses.

2. A wire-pipe geometry is probably preferred because of the prevalence of upflow mist eliminator configurations.

3. The power supplies should be sized so that they will not limit the electrical conditions that can be achieved.

4. Intermittent spray capability should be provided to clean the wires and pipes when necessary.

5. The ability to test different types of corona wires (e.g., plain wires of various diameters, barbed electrodes, disks on wires, and auger-type electrodes) should be incorporated.

6. The ability to test different types of collecting pipes (e.g., fiberglass-reinforced plastic, various acid-resistant alloys, plastic-coated steel, and high-temperature plastics) should be incorporated.

7. Adequate straight runs of inlet and outlet ducting should be provided for good flow distribution at sampling points and through the WESP.

8. An opacity monitor should be included to provide a real-time indication of performance.

9. A flow meter should be included to provide a real-time indication of flue gas flow rate through the unit.

10. All major operating parameters (e.g., gas flow, temperature, pressure, voltage, current, and opacity) should be automatically recorded by a dedicated data logger system.

11. The system should include a separate control trailer with visual displays of all major operating parameters and computer facilities for analyzing the operating data.

12. Part of the control trailer should be reserved for assembly, disassembly, and storage of sampling equipment (e.g., mass trains and impactors).

In addition to the requirements enumerated above, the pilot unit should use tubes that are the same size as those used in full-scale WESP units (nominal diameter of 8 in. and length of 10 ft). This means that the total height of the unit, including allowances for the high-voltage insulator supports and inlet and outlet transitions, would be well over 15 ft. This height may not allow the unit to pass under certain highway overpasses. To circumvent this problem, it may be necessary to design a "collapsible" unit, such as that shown in Figure 13. In this design, the WESP can be transported in a horizontal position and then placed in its vertical operating position after arriving on site. As indicated in Figure 13, some of the overhead piping would have to be assembled on site. Therefore, the piping should be as lightweight as possible. The 12-in., Schedule 5S pipe suggested in Figure 13 weighs about 21 lb/ft. If

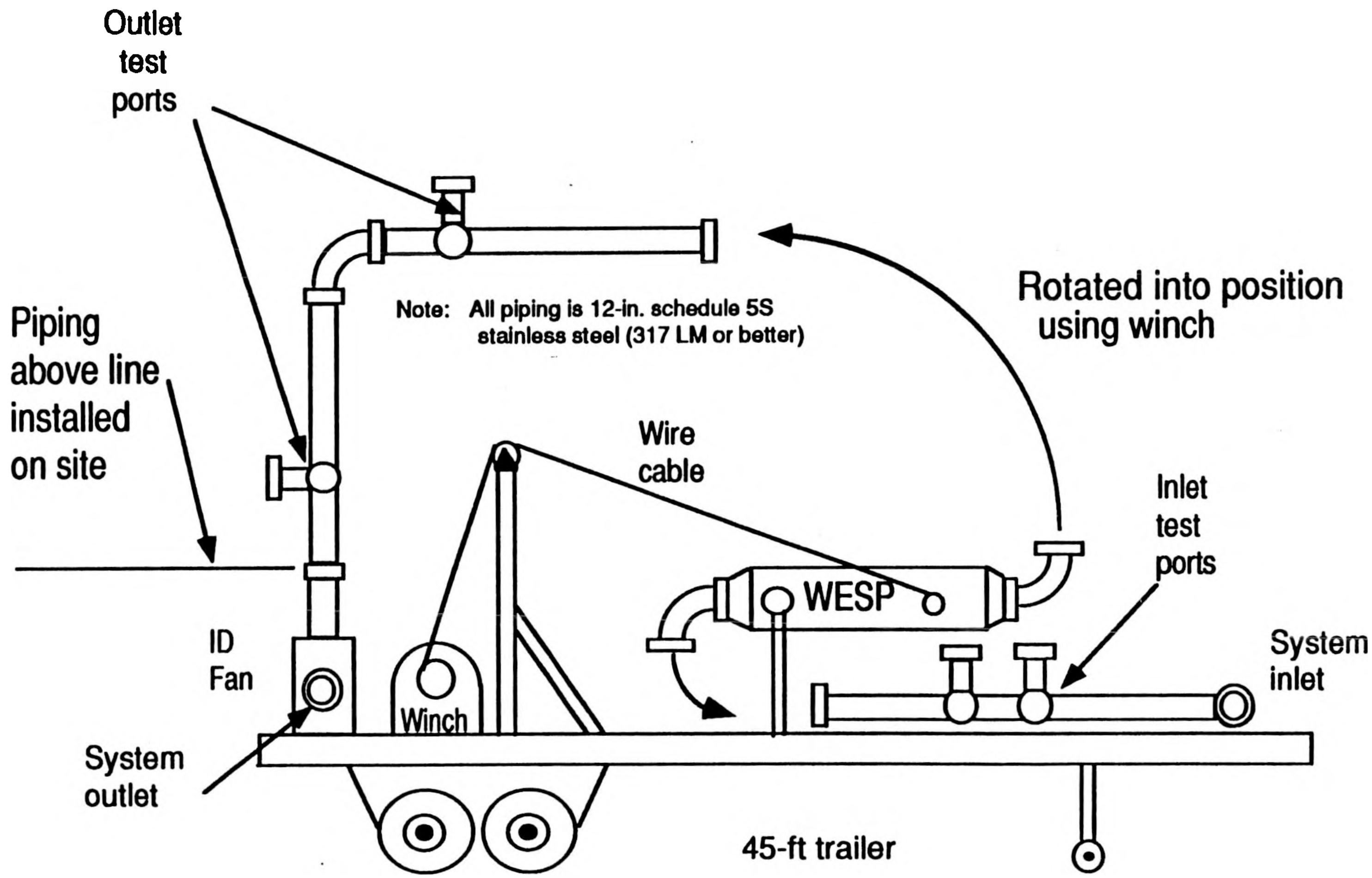


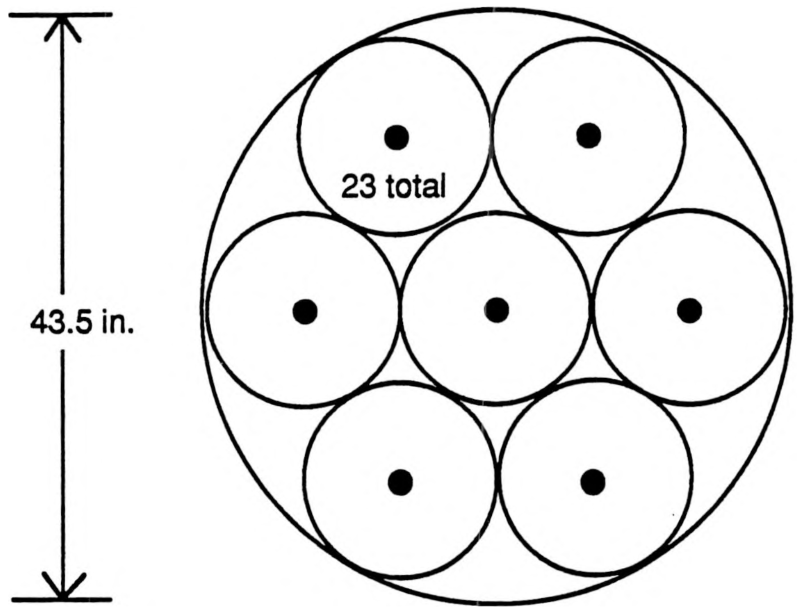
Figure 13. Preliminary Sketch of WESP Pilot Unit for DOE Demonstration Program (Note: Power Supplies, Controls, and Data Logger Located in Separate Trailer)

the length of each piece of pipe is limited to 4-5 ft, the on-site assembly should not require the use of heavy equipment.

As indicated in the sketch, the pilot unit should have its own induced-draft (ID) fan to draw the desired flue gas flow from the power plant duct. A throttling valve or damper (not shown in sketch) should be provided to control the flow through the pilot unit. The inlet and outlet piping should be designed to provide a straight run of at least 8 diameters ahead of the sampling ports. Of course, all piping and fittings should be made of a corrosion-resistant alloy. TVA and ABB have suggested 317LM stainless steel, which is a low-carbon, high-chromium, high-nickel steel, with a molybdenum content of about 3.5%. It is very similar to the 20 alloys that are the most widely used in sulfuric acid service. Hastelloy and Inconel may also be suitable in this application, but they are somewhat more expensive.

Although not shown on the sketch, it would be necessary to heat trace and insulate all of the system piping. Appropriate temperature controllers would be used to maintain the piping at the temperature of the flue gas leaving the scrubber (typically about 125°F). The liquid and solids that collect on the WESP tube walls would be drained into a tank (also not shown), which would be connected to the bottom WESP transition section during on-site assembly. An isolation valve would be provided so that the tank could be disconnected and drained into a scrubber slurry tank or dumped into the plant's ash pond.

A cross-sectional view and further specifications of the pilot WESP are given in Figure 14. Based on a design gas velocity of 20 ft/sec and flow of 10,000 acfm, it is possible to provide an SCA of almost 50 ft^2/kacfm using an array of



SPECIFICATIONS

Overall diameter	43.5 in.
Tube diameter	8 in.
Design gas flow	10,000 acfm
Design gas velocity	20 ft/sec
Tube length	10 ft
No. of tubes	23
Total collecting area	483 ft^2
Specific collecting area	49 ft^2/kacfm

Figure 14. Cross-Sectional View and Specifications of Pilot WESP

23 8-in. tubes as shown. The overall diameter would probably be somewhat larger than the 43.5 in. shown to allow for the space occupied by the tube sheet and the wall thickness of the tubes and shell. The high-voltage bus and feedthrough would be located in the top transition section above the tube array. This configuration may require a somewhat larger transition section than that indicated in the sketch.

A test plan for the portable WESP should address the following key variables:

1. Coal type
2. Concentration of SO_3 and acid mist in flue gas
3. Loadings of fly ash and scrubber solids
4. Size distribution of acid mist and particles
5. Scrubber type
6. Mist eliminator type (and number)
7. Gas velocity
8. Type of discharge electrode
9. Type of collecting electrode
10. Electrode cleaning method and frequency

Obviously, a large number of tests will be required to adequately address all of the parameters listed above. Therefore, a carefully designed test plan will be essential to the success of the WESP demonstration.

5. TASK 9 - PHASE II REPORTING

All monthly status and cost management reports were submitted on schedule. A technical paper discussing Phase I results was also prepared and presented at the DOE/PETC Contractors Conference on August 6-9, 1990. Technical papers discussing the Phase II results are planned for the DOE/PETC Contractors Conference on July 15-18, 1991; the Ninth Particulate Control Symposium on October 15-18, 1991; and the EPRI/EPA/DOE 1991 SO_2 Control Symposium on December 3-6, 1991.

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