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EFFECTS OF E-SO_x TECHNOLOGY ON ESP PERFORMANCE

by

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ABSTRACT

The E-SO_x Process has been evaluated at Ohio Edison's Burger Station. Adequate SO_2 removal and acceptable particulate emission levels from the electrostatic precipitator (ESP) are the prime objectives of this investigation. This report describes limited ESP performance testing under both baseline and E-SO_x conditions. The ESP data collected under E-SO_x conditions, which give the required 50% SO_2 removal, show evidence of ESP performance dominated by factors not represented in existing versions of precipitator performance models. Analyses of particle size fractions from impactor stages revealed that the relative calcium content of the finer size fractions increased from inlet to outlet. From these analyses and other considerations, it appears that the factors which dominate under the conditions tested are a combination of instantaneous reentrainment of low resistivity ash/sorbent particles and deagglomeration of slurry residues within the precipitator. These observations may be important to other sorbent injection processes as well as E-SO_x. Improvement of the gas velocity and temperature distributions at the ESP inlet improved the ESP performance, but the performance was still dominated by the reentrainment process and was therefore lower than mathematical model predictions.

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FIGURES

FIGURES (continued)

TABLES

UNIT CONVERSION TABLE

TO CONVERT FROM	TO	MULTIPLY BY
in.	cm	2.54
ft	m	0.3048
ft^3	m^3	0.02832
lb	g	453.6
gr	g	0.06480
lb/ft^3	g/m^3	1.602×10^4
gr/ft^3	g/m^3	2.288
ft^3/min	m^3/sec	0.000472
°F	°C	5/9 (°F-32)
$ft^2/kacfm$	$m^2/(m^3/sec)$	0.19685
lb/MMBtu	ng/J	430
$\mu A/ft^2$	nA/cm^2	1.08
ft/sec	m/sec	0.3048

SECTION 1

INTRODUCTION

Process Description

The E-SO_x process involves removal of sulfur oxides prior to the inlet of an electrostatic precipitator (ESP) with an aqueous spray of an alkaline material. The entering fly ash and resultant particulate matter are then removed in the ESP. A research program to develop and demonstrate the process has been performed under the sponsorship of the U.S. EPA, the Ohio Coal Development Office, and the Babcock & Wilcox Company.

Slaked lime slurry without the use of recycled material has been the source of alkalinity for experiments performed to date. Pebble lime was transferred pneumatically from tank trucks to a storage bin, and the lime was then slaked and placed in a slurry tank. The slurry was metered and injected into a spray chamber through two B & W Mark 4 nozzles. Dilution water was added with the slurry prior to reaching the nozzle, depending on the calcium to sulfur ratio and approach to saturation desired. At the exit of the spray chamber and ahead of the ESP are two rows of Droplet Impingement Devices (or DIDs) which are temperature-controlled pipes to prevent entry of large wet particles into the ESP. The flue gas and uncollected particulate matter which exited the ESP were returned to the main ductwork ahead of the main unit's ESP. Figure 1 presents a schematic of the E-SO_x pilot facility.

Pilot ESP Description

The ESP installed at the E-SO_x facility is EPA's pilot transportable ESP (TEP) which was originally installed at Public Service Company of Colorado's Valmont station. The pilot ESP was disassembled at Valmont and reassembled at the Burger station. Personnel of B & W's Alliance Research Center supervised the reassembly of the TEP and operated the pilot system during the test programs. Figure 2 shows the E-SO_x transition and ESP arrangement installed at the Burger station.

The ESP consists of four electrical fields in the direction of gas flow, and each field is preceded by a cooled pipe precharger of Denver Research Institute design. Each field consists of six gas passages, 9 in.* wide, 12 ft high, and 70 in. deep. This results in a total collection area of 3360 ft^2. The discharge electrodes are 0.25 in. in diameter, 9 in. apart, and are held in a rigid frame. The discharge frames and collecting plates are rapped with a drop hammer type of rapping system. All collecting plates in a section or all discharge wires in a section are rapped at once when a rap is called for during the rapping cycle.

*Readers more familiar with metric units may use the conversion table at the end of the report front matter.

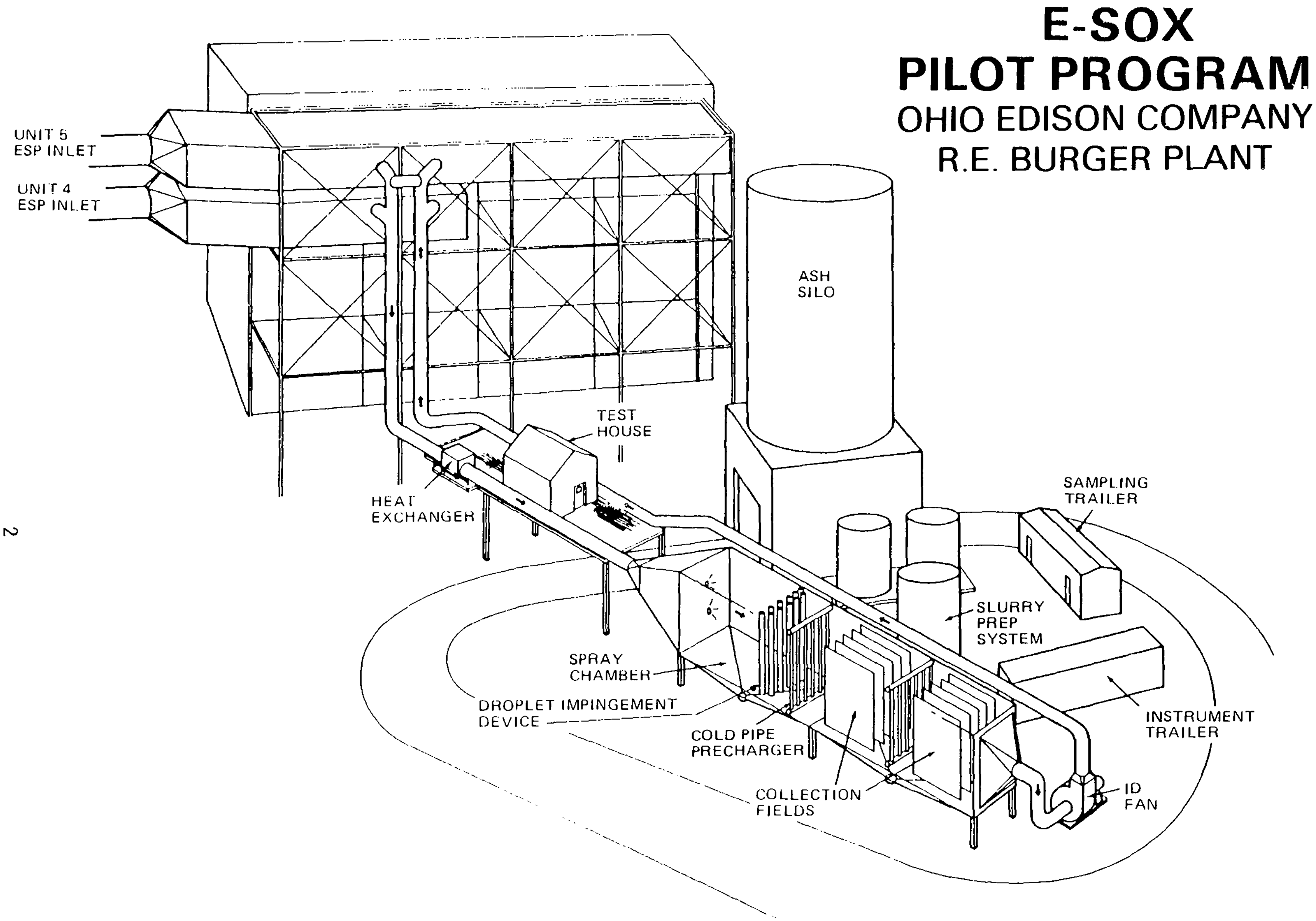

Figure 1. E-SOX Pilot Facility Schematic

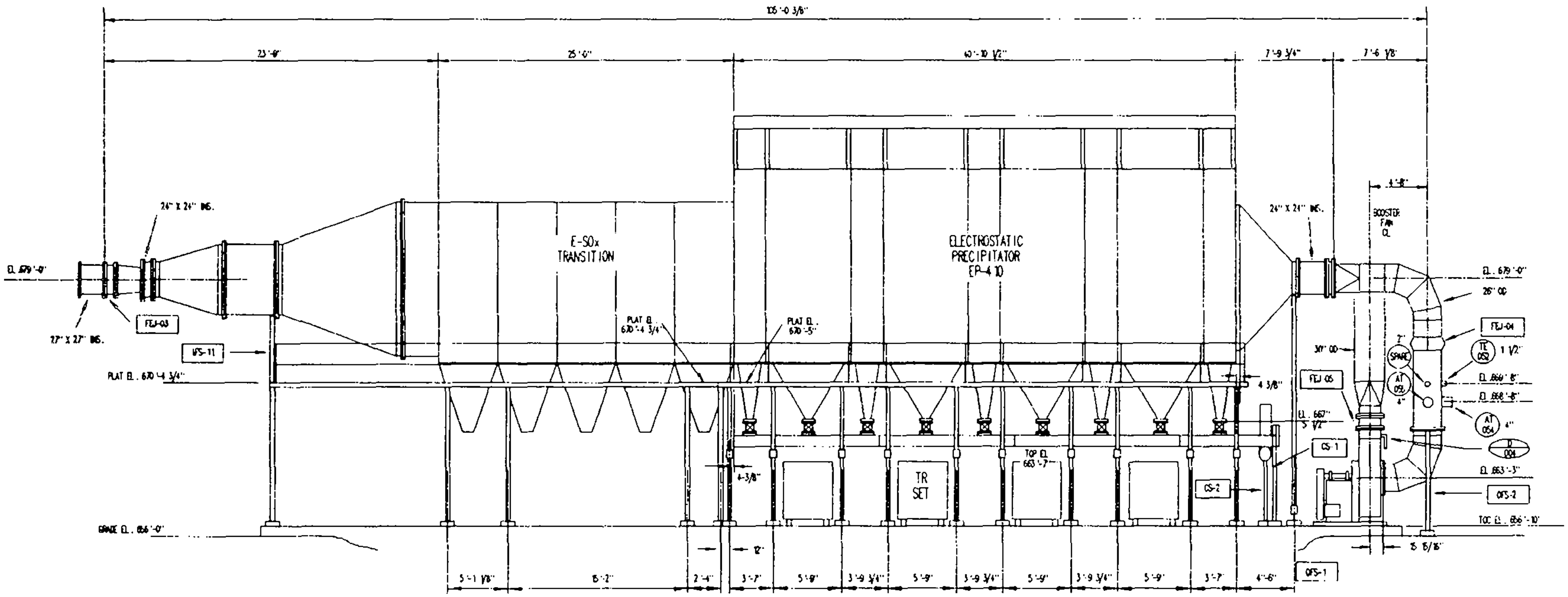

Figure 2. E-SOX Transition and TEP Elevation

Ash collected in the precharger sections or collector fields is discharged from the individual hoppers into a screw conveyor by a rotary valve. The ash is then transported to a storage bin for disposal. Ash from the transition section is also removed by screw conveyors, but placed in a different storage bin.

E-SO_x Test Program

The E-SO_x pilot facility was operated and maintained by personnel from B & W's Alliance Research Center. The B & W test program included evaluations of: spray nozzles, SO_2 removal efficiency at various stoichiometric ratios and approaches to saturation temperature, the Droplet Impingement Device, and equipment performance during long term operation of the process. Results from this work will be reported elsewhere.[1]

Southern Research Institute (SRI) was responsible for testing the ESP under "baseline" and "E-SO_x" conditions and for evaluating the performance of the precipitation process. These particulate characterization measurements and ESP performance analyses are the subject of this report.

SECTION 2

ESP PERFORMANCE AND PARTICULATE CHARACTERIZATION MEASUREMENTS

Precipitator Performance

The ESP, the fly ash, and fly ash/sorbent mixtures were characterized by measuring:

- Inlet and outlet mass concentrations
- Inlet and outlet mass vs particle sizes with cascade impactors
- Real-time outlet mass concentration trends with an Environmental Systems Corporation P5A mass emissions monitor
- Secondary voltage-current relationships and operating points
- Inlet velocity traverses
- Inlet and outlet temperature traverses
- Laboratory and in situ resistivity
- Chemical analysis of bulk and size-fractionated samples
- Ash cohesivity and Bahco particle size

Baseline measurements were performed without the DID array, whereas the sorbent injection tests necessarily were performed with the DID array present. In addition to preventing penetration of large, moist particles into the first field of the ESP, the DID array was designed to minimize gas velocity non-uniformity due to flow disturbances caused by the sorbent injection nozzles.

Emissions caused by rapping systems in pilot-scale ESPs are usually not representative of full-scale systems. Therefore, the test program was conducted with rapping systems de-energized during the time period that outlet measurements were underway. Rappers were energized between tests to avoid excessive electrode buildups. This testing strategy allowed the overall and particle size dependent efficiencies to be compared with the "no rap" projections of the mathematical model, as will be discussed later.

Tables 1 and 2 present results from particulate mass concentration measurements under baseline and slurry injection conditions, respectively. Voltage-current relationships for these test conditions are presented in Figures 3, 4, and 5, and average electrical operating points are given in Table 3. Figure 6 illustrates the changes in the signal from the outlet mass monitor as average temperature was increased from 160 to 180°F at the inlet. The decrease in "noise" due to non-rapping emission spikes is apparent as temperature was increased. The actual decrease is larger than illustrated, because the 180°F segment is recorded on a

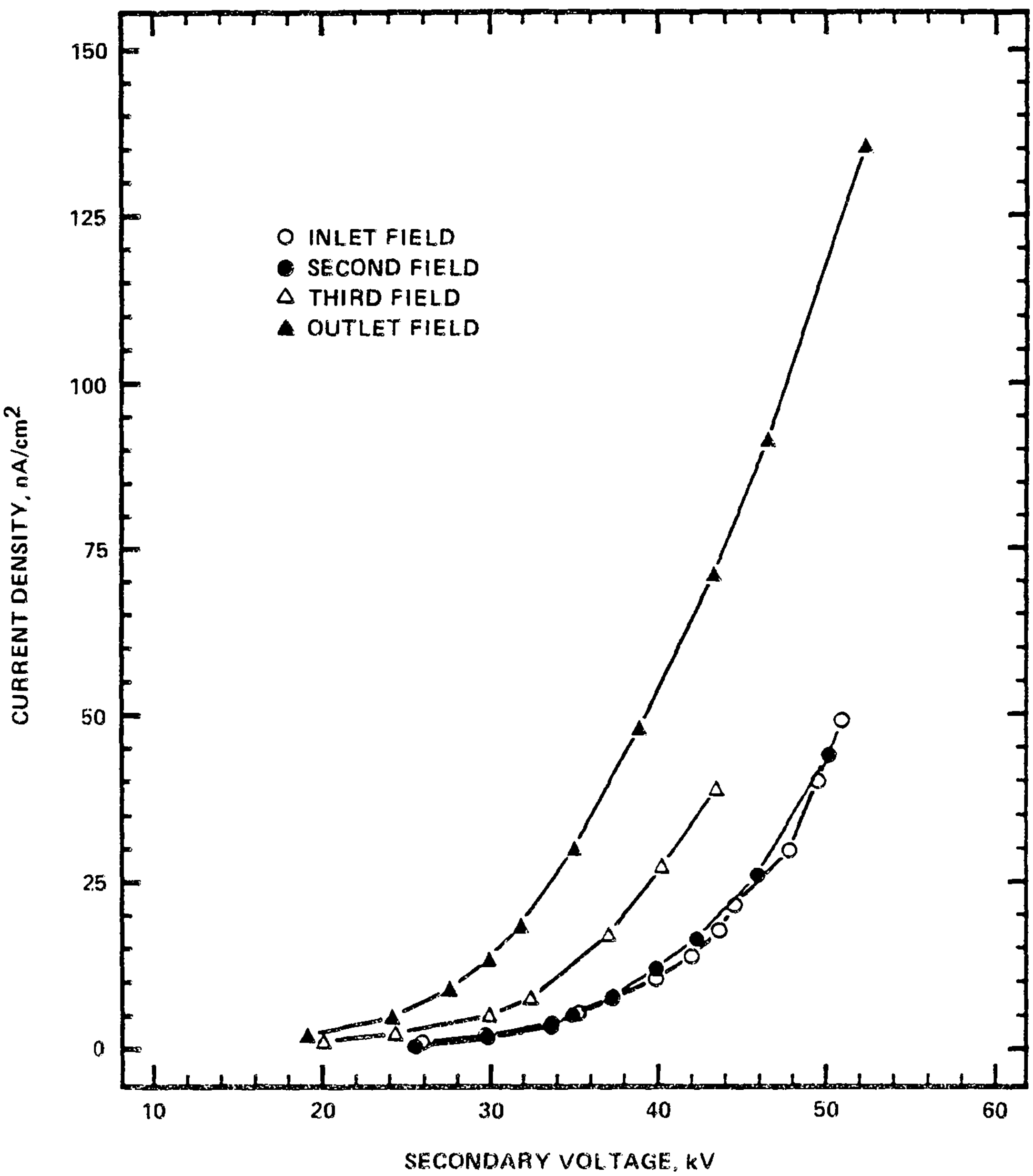

Figure 3. EPA Pilot-ESP Voltage-Current Curves E-SOX Baseline Test, 6/25/89

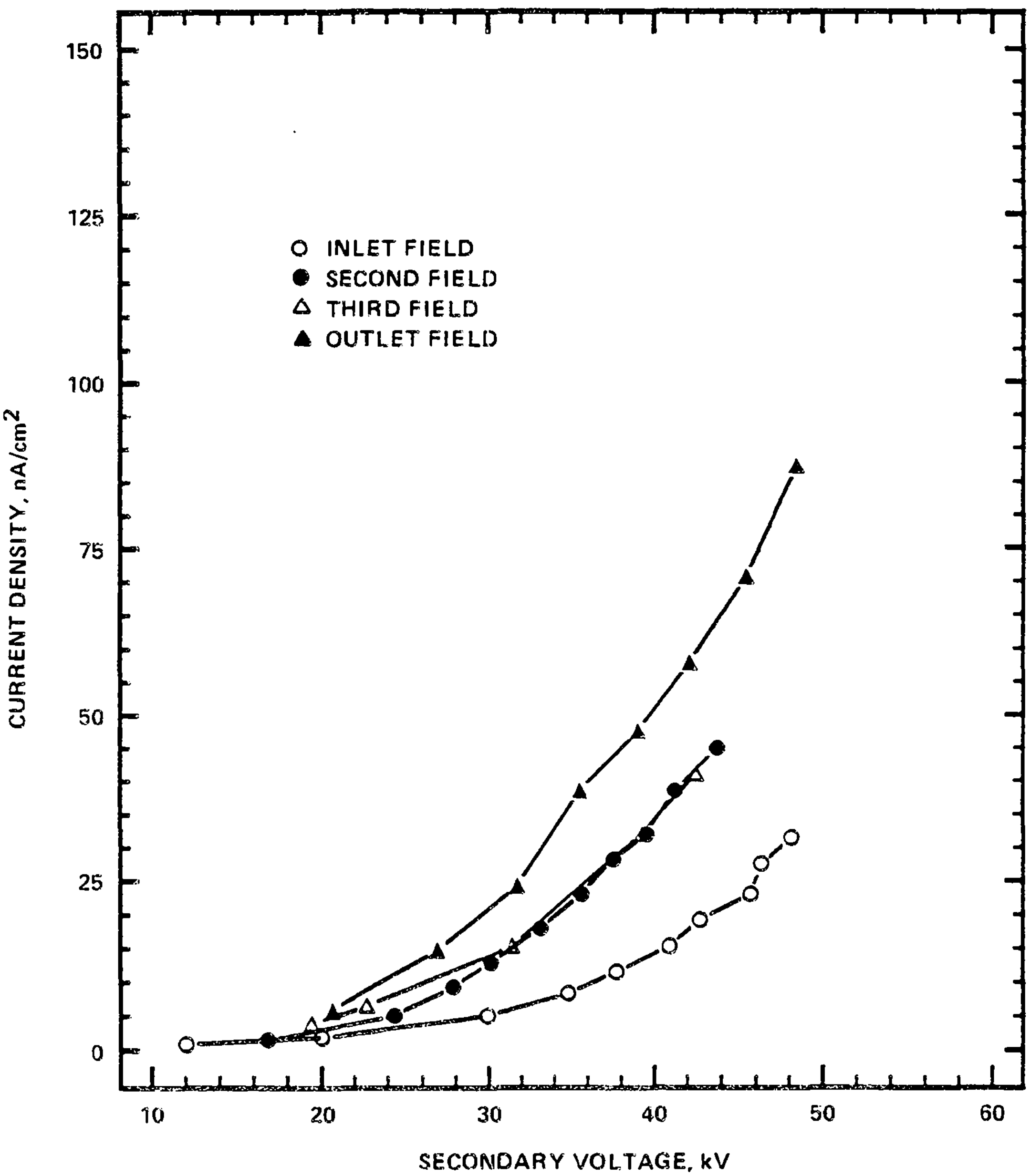

Figure 4. EPA Pilot-ESP Voltage-Current Curves E-SOX Slurry Test, 10/25/89, 160 °F

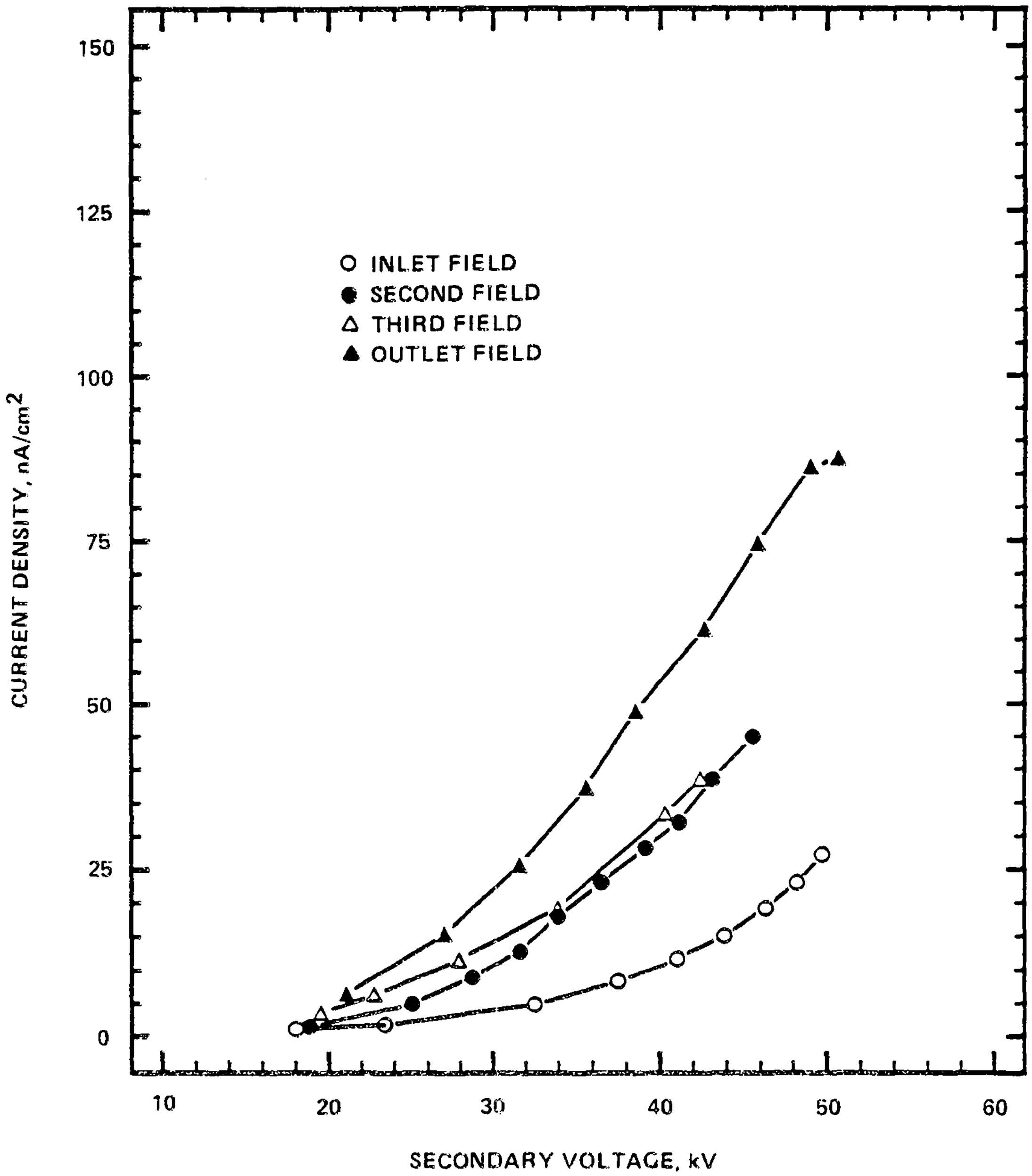

Figure 5. EPA Pilot-ESP Voltage-Current Curves E-SOX Slurry Test, 10/25/89, 180 °F

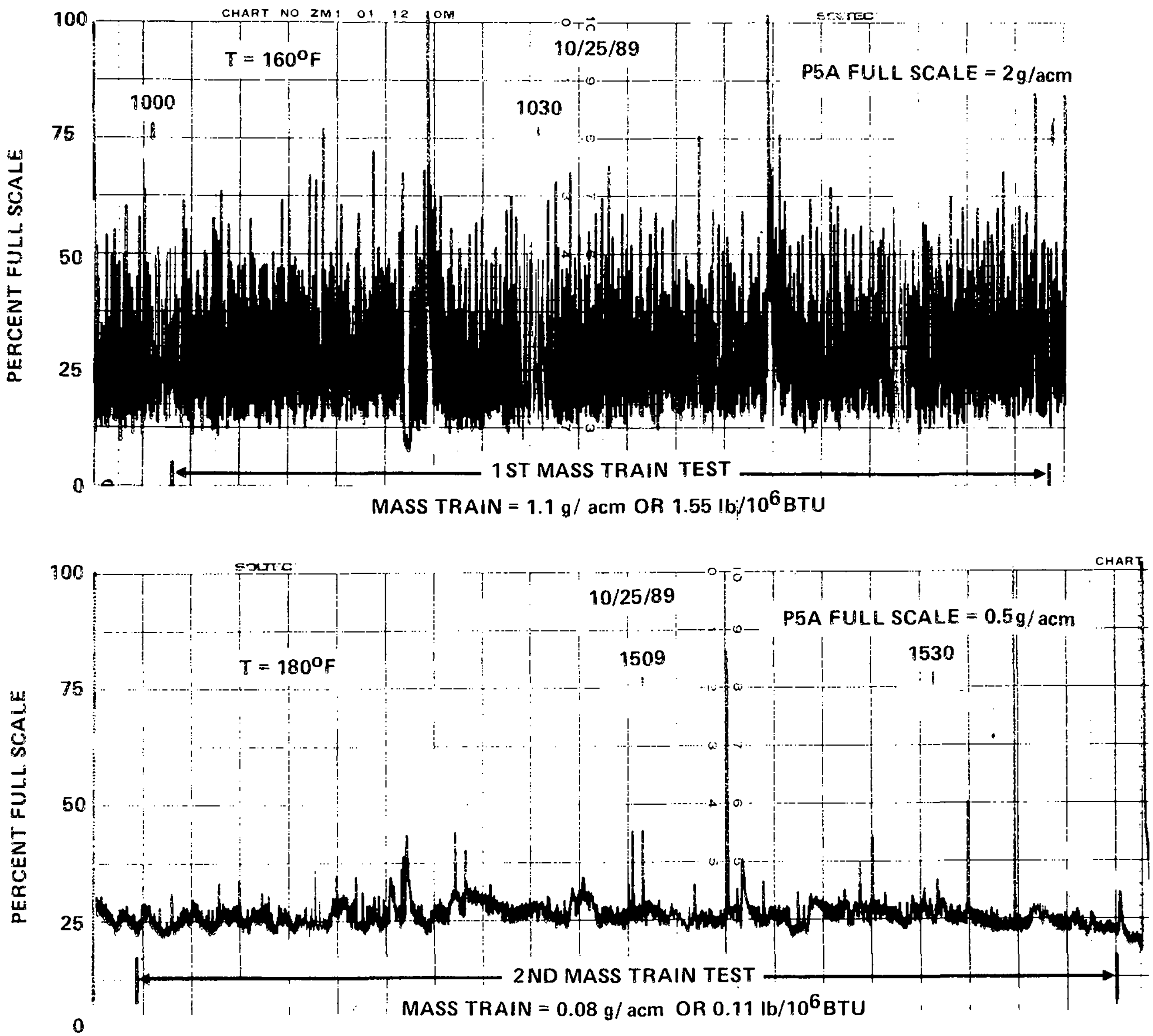

Figure 6. Strip Chart Recording of P5A Output

Table 1

PILOT ESP RESULTS
MASS MEASUREMENTS, BASELINE

	6/24/89	6/26/89
SYSTEM INLET		
Temp., °F	308	315
gr/scf	4.199	4.018
lb/MMBtu	9.258	8.296
DSCFM	8553	9017
OUTLET[a]		
Temp., °F	276	277
gr/scf	0.0045	0.0033
lb/MMBtu	0.012	0.008
EFFICIENCY[b], %	99.87	99.90
SCA, ft^2/kacfm	231	215
OMEGA K, cm/sec	97.1	112.7

[a]No Rapping
[b]Based on lb/MMBtu

Table 2

PILOT ESP RESULTS
MASS MEASUREMENTS, E-SOX CONDITIONS

	10/22/89	10/25/89	
POST DID INLET			
Temp., °F	170	160	180
gr/scf	3.891	3.891[a]	3.891[a]
lb/MMBtu	7.867	7.867	7.867
DSCFM	9267	8493	8493
OUTLET[b]			
# of Runs	2	1	1
Start Time	1116	1002	1430
End Time	1527	1110	1546
Temp., °F	175	162	184
gr/scf	0.1288	0.6352	0.0464
lb/MMBtu	0.313	1.552	0.113
EFFICIENCY[c], %	96.02	80.27	98.56
SCA, ft^2/kacfm	257	287	278
OMEGA K, cm/sec	20.5	4.7	32.9

[a]Inlet Data of 10/22/89 Used
[b]No Rapping
[c]Based on lb/MMBtu

Table 3

AVERAGE ELECTRICAL OPERATING CONDITIONS

Condition	Average Voltage, kV	Average Current Density, nA/cm^2
Baseline, 6/25/89, 281°F	46.1	56.2
E-SOX Slurry, 10/25/89, 180°F	45	48.9
E-SOX Slurry, 10/25/89, 160°F	42.9	50.6

scale with a maximum of 0.5, whereas the 160°F segment was recorded with a maximum scale reading of 2.0.

ESP performance changed from excellent under baseline conditions (0.012 or 0.008 lb/MMBtu out) to unacceptable (0.113 to 1.55 lb/MMBtu out) with slurry injection. Note that inlet data for slurry conditions were obtained downstream of the DID array in a low velocity region, and therefore the efficiency data in Tables 1 and 2 are not directly comparable. Average process conditions on 10/22 and 10/25 were as follows: Ca/S ratio = 1.44; SO_2 removal = 48.5%; and the estimated total mass loading of dried, partially sulfated sorbent and fly ash was 10.2 gr/scf. Using this estimate as a basis, the mass train traverse in the low velocity region recovered about 38% of the total mass.

"Omega K" values in Tables 1 and 2 represent an ESP performance parameter that provides a semi-quantitative means of comparing performance under various conditions.[2] As points of reference, omega k values of full scale ESPs collecting ash downstream of spray dryers have been reported to range from 27 to 62 cm/sec. The recent paper by Durham, et al.[3] provided data on the Shawnee TVA ESP Spray Dryer pilot plant which indicated omega k values ranging from 32 to 53 cm/sec. Thus, the highest efficiency "no-rap" data from the E-SO_X system at 180°F indicate a performance parameter in the lower portion of the range reported for spray dryer applications.

The decrease in outlet emissions measured by the mass train with increasing temperature on 10/25/89 is confirmed by the P5A trace shown in Figure 6. This trend toward higher emissions at lower operating temperatures was observed at earlier times in the test program, and proved to be a reproducible phenomenon. The large spikes appear to represent non-rapping reentrainment occurring on a massive scale at the lower temperatures.

A related observation concerns the appearance of rapping spikes on the P5A output which coincides with rapping of the DID array. This rapping process is expected to produce relatively large particles which would be charged and be driven to the collecting electrodes quickly with the observed voltages and currents. However, large rapping spikes were observable at the outlet with a time lag corresponding to the gas transit time between the DID array and the P5A sampling point. This observation indicates that a large fraction of the sorbent/ash mixture is instantaneously and repeatedly reentrained by electrical forces as it travels through the electrical fields.

The electrical operating points in Table 3, and the voltage-current curves in Figures 3 through 5, reveal no anomalies which would explain the extremely high outlet emissions with sorbent injection. As will be shown in a subsequent discussion of observed vs predicted performance, the measured voltages and currents indicated that very high electrical migration velocities and collection efficiencies would be predicted under both baseline and slurry conditions. It is also of interest to note that a significant change in voltages and currents did not occur as temperature was increased from 162 to 181°F, although mass emissions decreased by a factor of 13.7.

An extensive trouble shooting effort was performed during the test program in an attempt to locate possible mechanical problems that might be responsible for the excessive particulate emissions with slurry injection.

Specifically:

- Hopper fluidizing air was turned off and on;
- The ash removal screw conveying system was turned off and on;
- Nozzles and the DID array were periodically cleaned both on line and while the system was down for short-term repairs; and
- Voltages were held to values below those which would cause excessive sparking during the test periods.

The above items related to mechanical issues did not result in a reduction in outlet emissions; excessive sparking did, however, increase outlet emissions. Also, the No. 4 precharger was energized and de-energized, with no apparent effect on the outlet mass monitor.

Overflowing hoppers are one source of emissions which could not be directly ruled out by observation. However, the ash removal system was monitored to ensure that it was operating. Furthermore, the reproducible change in outlet emissions with temperature is not explainable by hopper overflow since the lower emission data were obtained later during the same test day.

In view of potential flow disturbances due to the presence of sorbent injection nozzles and the DID array, temperature traverses were conducted during the test program. A velocity traverse with air flow was also performed after the test program with the perforated plate downstream from the DID array in an uncleaned condition. Tables 4 and 5 illustrate the inlet temperature distribution on October 25 when the average inlet temperatures were 160 and 180°F, respectively. Table 6 contains the inlet velocity traverse. Note that high velocity and low temperature areas coincide near the bottom of the ESP. This combination of conditions, where reentrainment by electrical forces is greatest in the region of highest velocity, would be expected to exacerbate the ESP performance problems. Also, during the test program, an average temperature of 155°F was obtained from a traverse at the outlet of the fourth field of the ESP, while the average inlet temperature was 173°F. As expected, the lowest outlet temperatures occurred near the bottom of the ESP.

The test program data clearly indicated that operation in the 180°F region improved ESP performance. However, operation at temperatures far above the adiabatic saturation point is not an acceptable solution for excessive particulate emissions because of the adverse effects on SO_2 removal.

Particulate Characterization

Figure 7 contains cumulative inlet size distributions obtained by impactors at the E-SO_X pilot facility, and Figure 8 illustrates baseline and E-SO_X size-dependent efficiencies obtained from impactor data. Also shown on Figure 8 are

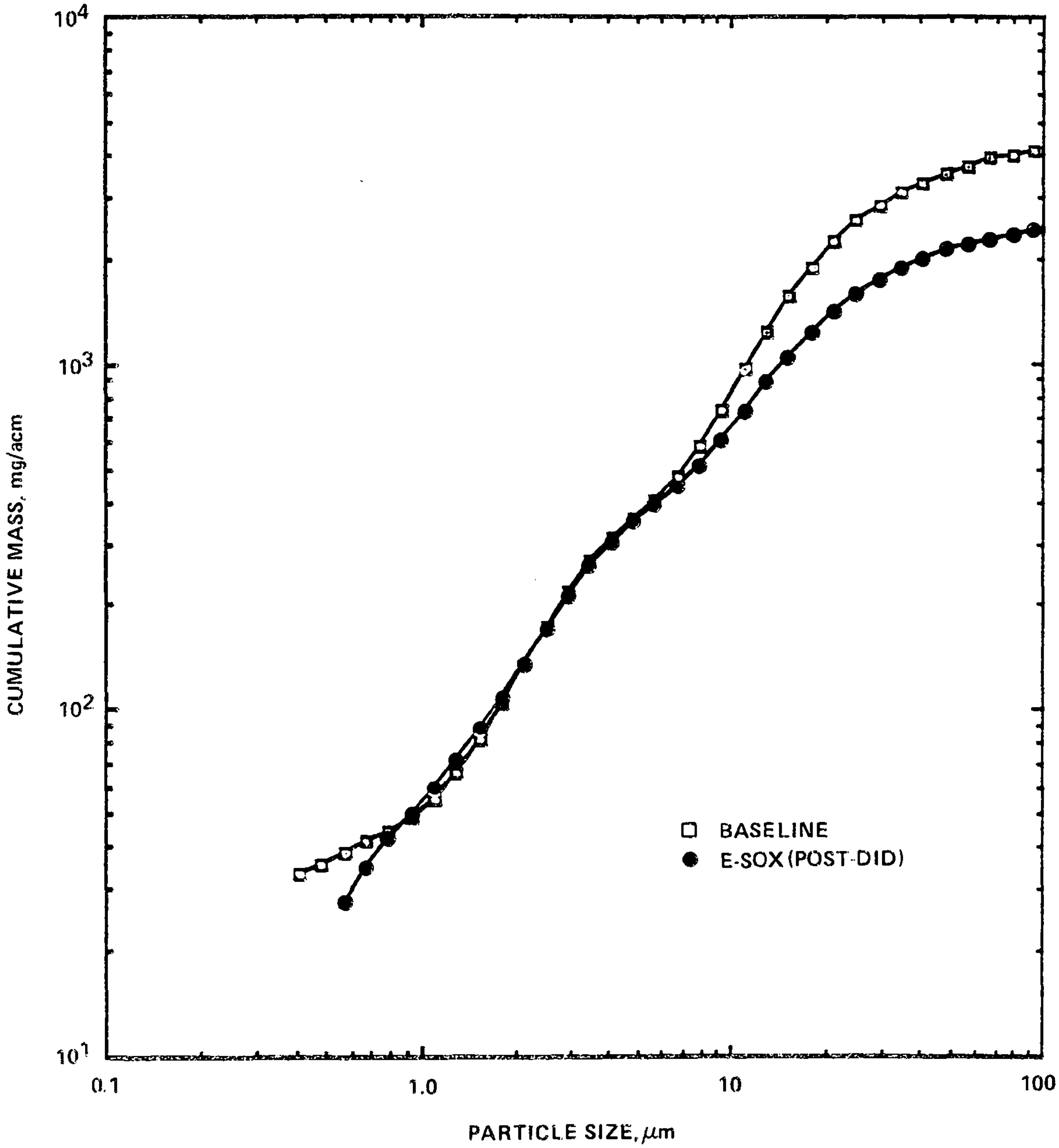

Figure 7. Inlet Cumulative Mass vs. Particle Size for Baseline and Post-DID E-SOX Conditions

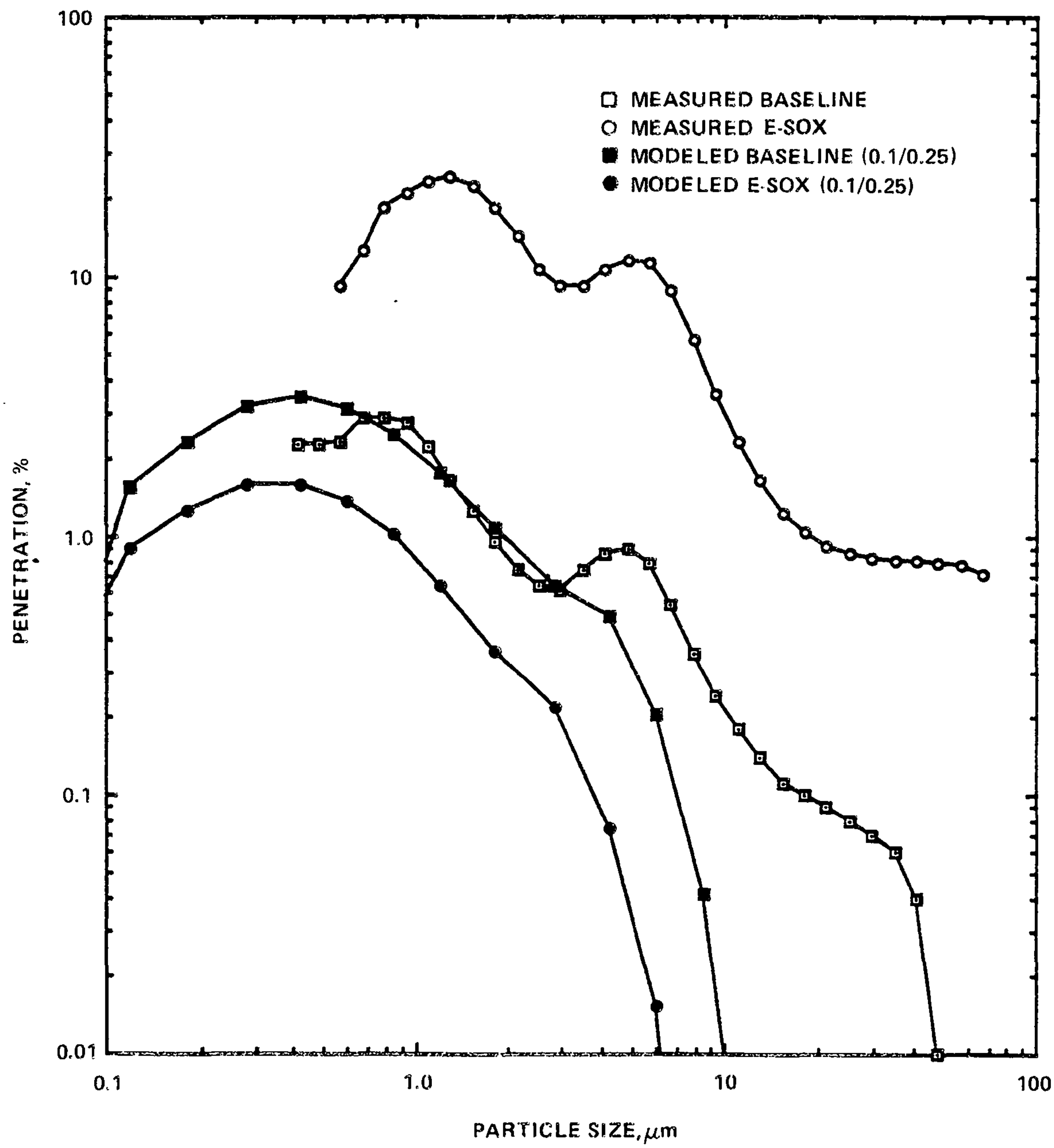

Figure 8. Measured and Modeled Penetration vs. Particle Size, E-SOX Demonstration Tests

Table 4

TEMPERATURE DISTRIBUTION AT ESP INLET
AVERAGE INLET GRID TEMPERATURE EQUALS 160°F

	Position One °F	Position Two °F	Position Three °F	Position Four °F
Top Row	172	175	176	177
Third Row	168	165	164	164
Second Row	157	153	156	150
Bottom Row	148	147	147	146

GRID IS VIEWED IN DIRECTION OF GAS FLOW

Table 5

TEMPERATURE DISTRIBUTION AT ESP INLET
AVERAGE INLET GRID TEMPERATURE EQUALS 180°F

	Position One °F	Position Two °F	Position Three °F	Position Four °F
Top Row	195	186	190	196
Third Row	187	182	184	187
Second Row	176	171	172	175
Bottom Row	173	166	165	172

GRID IS VIEWED IN DIRECTION OF GAS FLOW

Table 6

GAS FLOW MEASUREMENTS AT PILOT ESP INLET
VELOCITIES IN FEET PER MINUTE

	Position One ft/min	Position Two ft/min	Position Three ft/min	Position Four ft/min
Top Row	388	275	335	400
Third Row	385	235	245	325
Second Row	282	205	230	465
Bottom Row	655	520	455	640

GRID IS VIEWED IN DIRECTION OF GAS FLOW

1) Perforated Plate Uncleaned From Operability Test
2) Mass Gas Flow 44,000 lb/hr, Temp. 98°F
3) Grid Average is 378 ft/min.

ESP model projections for baseline and E-SO_x conditions. These projections include the effects of 10% sneakage and reentrainment with a gas velocity standard deviation of 0.25. The model projections will be discussed later. Total mass loadings obtained with the impactor traverses are presented in Table 7.

If it is assumed that each slurry droplet produces one agglomerated particle upon drying, a size distribution can be estimated for dried and partially sulfated sorbent. Figure 9 contains an estimated size distribution of the dried sorbent downstream of the DID array that was supplied by B & W.[4] A Bahco-derived size distribution of ash/sorbent mixture obtained from the ESP hopper is also provided on Figure 9.

The impactor data in Figure 7 indicate no significant difference in total inlet loading between the E-SO_x and baseline conditions in the size range resolved by the impactors (below about 8 μm diameter). An examination of the dried agglomerate size distribution in Figure 9 reveals that only 15% of the slurry residue would be expected to consist of particles 8 μm in diameter and smaller, which is consistent with the lack of increase that was observed in this size range by inlet impactors. The low total mass loading obtained with the impactors under E-SO_x conditions results from the fallout and impaction which occur in the spray chamber and on the DID array, and from the difficulties in obtaining a representative total mass sample in the low velocity region behind the DID array.

A comparison of the baseline and E-SO_x fractional efficiency curves in Figure 8 indicates a large drop in efficiency under E-SO_x conditions across the entire size range. Total average mass loading obtained with the outlet impactors on 10/20 and 10/23 at 170°F (Table 7) is similar to that obtained with the mass trains at 180°F on 10/25 (0.0497 vs. 0.0464 gr/scf). It is of interest to note that the penetration ratio of E-SO_x to baseline conditions at 3 μm diameter is similar to the results of Durham[3] for the Shawnee spray dryer ESP (13 for E-SO_x and 10 for Shawnee).

A comparison of the ESP model projections with baseline data in Figure 8 shows good agreement between model projections and measured results. In contrast, the E-SO_x measured data exhibit a large decrease in efficiency instead of the increased performance projected by the ESP model. This indicates that ESP performance with sorbent is dominated by factors which are not represented in the existing model. All of the model projections are "no rap" cases, since the pilot ESP rapping system was not energized during sampling.

Penetration vs particle size curves such as those in Figure 8 are calculated by taking the ratio of outlet to inlet particle mass in a given size interval. However, the dried slurry residue is an agglomeration of smaller particles which originated from the lime slaking process, and the potential exists for deagglomeration to occur in the ESP. It has been hypothesized that slurry agglomerates could be broken apart due to internal forces arising from the relatively high values of charge acquired by particles in the interelectrode region. These forces must overcome the cohesive forces between the individual particles. The ID fan upstream of the outlet sampling ports would not be expected to provide sufficient shear forces to deagglomerate particles in the size range of interest. If deagglomeration or decrepitation did occur, the

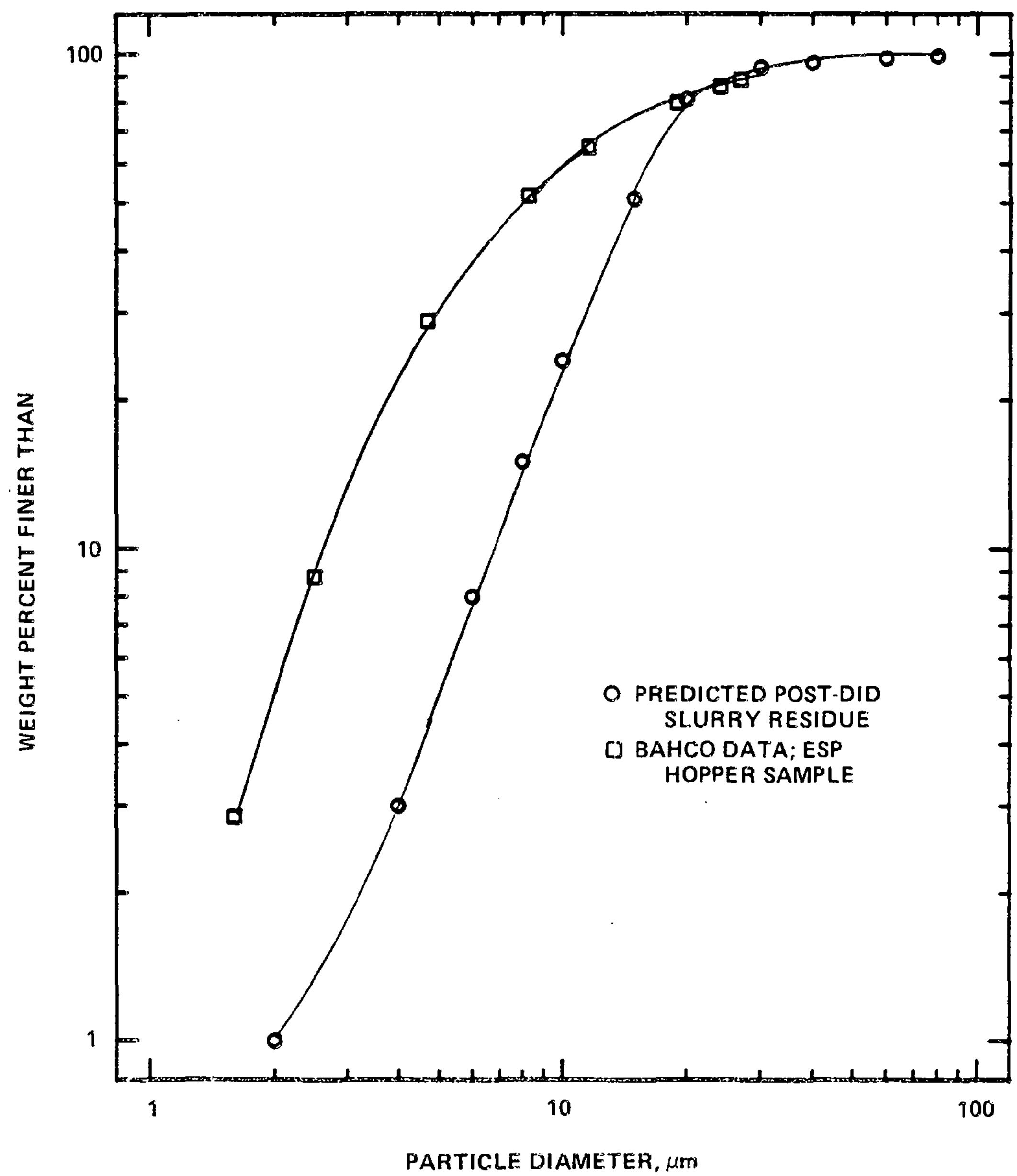

Figure 9. Bahco and Predicted Slurry Residue Size Distribution

Table 7

PILOT ESP IMPACTOR DATA, BASELINE

Date	Inlet 6/25 & 6/27	Outlet 6/25
Mass Loading		
gr/acf	1.7834	0.0034
gr/scf	3.0160	0.0053
Avg. Temp., °F	306	270
Avg. MMD, μm	19.9	5.1
Avg. SCA, ft^2/kacfm	208	

PILOT ESP IMPACTOR DATA, E-SOX CONDITION

Date	System Inlet 10/20	ESP Inlet 10/23	Outlet 10/20 & 10/23
Mass Loading			
gr/acf	2.163	1.114	0.0372
gr/scf	3.405	1.567	0.0497
Avg. Temp., °F	264	170	170
Avg. MMD, μm	21	17	4.3
Avg. SCA, ft^2/kacfm	272		

fractional efficiency curves would represent the net of the collection and decrepitation processes.

Evidence that a significant degree of slurry residue decrepitation did occur is presented in Figures 10 and 11. These figures contain plots of the signal ratio of calcium to iron and calcium to silicon from an energy dispersive X-ray (EDX) analysis of inlet and outlet impactor substrate samples. There is a large change in the relative amounts of calcium to iron and silica from the inlet to the outlet. This change is consistent with the hypothesis that slurry residue agglomerates were broken apart, so that the relatively fine, calcium-rich particles dominate the smaller size fractions in the outlet samples.

Photomicrographs of outlet impactor stages 4 and 6 are presented in Figure 12 for baseline and E-SO_X conditions. Also illustrated is a large agglomerate captured in the cyclone stage of the inlet impactors. The outlet stages illustrate that the impactors were classifying the sampled particles, and no evidence of gross reentrainment of larger particles from the upper stages was observed. If reentrainment occurred in the impactors to a significant degree, the change in composition with impactor stage could not be attributed to compositional differences as a function of particle size.

Further evidence that deagglomeration of slurry residue can occur is given in Figure 9, in which it can be observed that a Bahco size distribution of a sample obtained from the ESP hoppers contains more fine particles on a relative basis than the estimated slurry residue distribution entering the ESP. Figure 13, which provides composition of the Bahco size fractions as a function of particle size, illustrates that the finer size fractions are dominated by calcium-rich material.

Chemical analyses of samples collected from several points in the system are contained in Table 8, and coal compositions of representative samples are presented in Table 9. It is of interest to note that the outlet sample composition is very similar to that obtained at the ESP inlet. This observation provides further evidence that the slurry droplet residues were not retained in the ESP as predicted. Since the agglomerated slurry residue has a small fraction of fine particles, theoretical collection efficiency vs particle size relationships predict that the ESP would selectively collect the slurry residue so that the outlet particle mass would contain a significantly smaller fraction of calcium compounds.

Reliable values for the electrical resistivity of sorbent/ash mixtures are difficult to obtain with standard methods. The in situ point-plane resistivity probe has been reported to selectively reentrain low resistivity sorbent particles,[3] and this process is likely to have biased data obtained with the probe during this test series. In addition, samples collected at various points in the system at different times during the slurry injection test program exhibited significantly different resistivity vs temperature curves, as Figure 14 illustrates. The laboratory data were obtained using a modified procedure that was adapted for samples containing calcium sorbents.[5]

An examination of the in situ and laboratory data for 10/24 and 10/25 (Figure 14) indicates resistivity values in the 10^{10} to 10^{11} ohm-cm range at 160-180°F, which

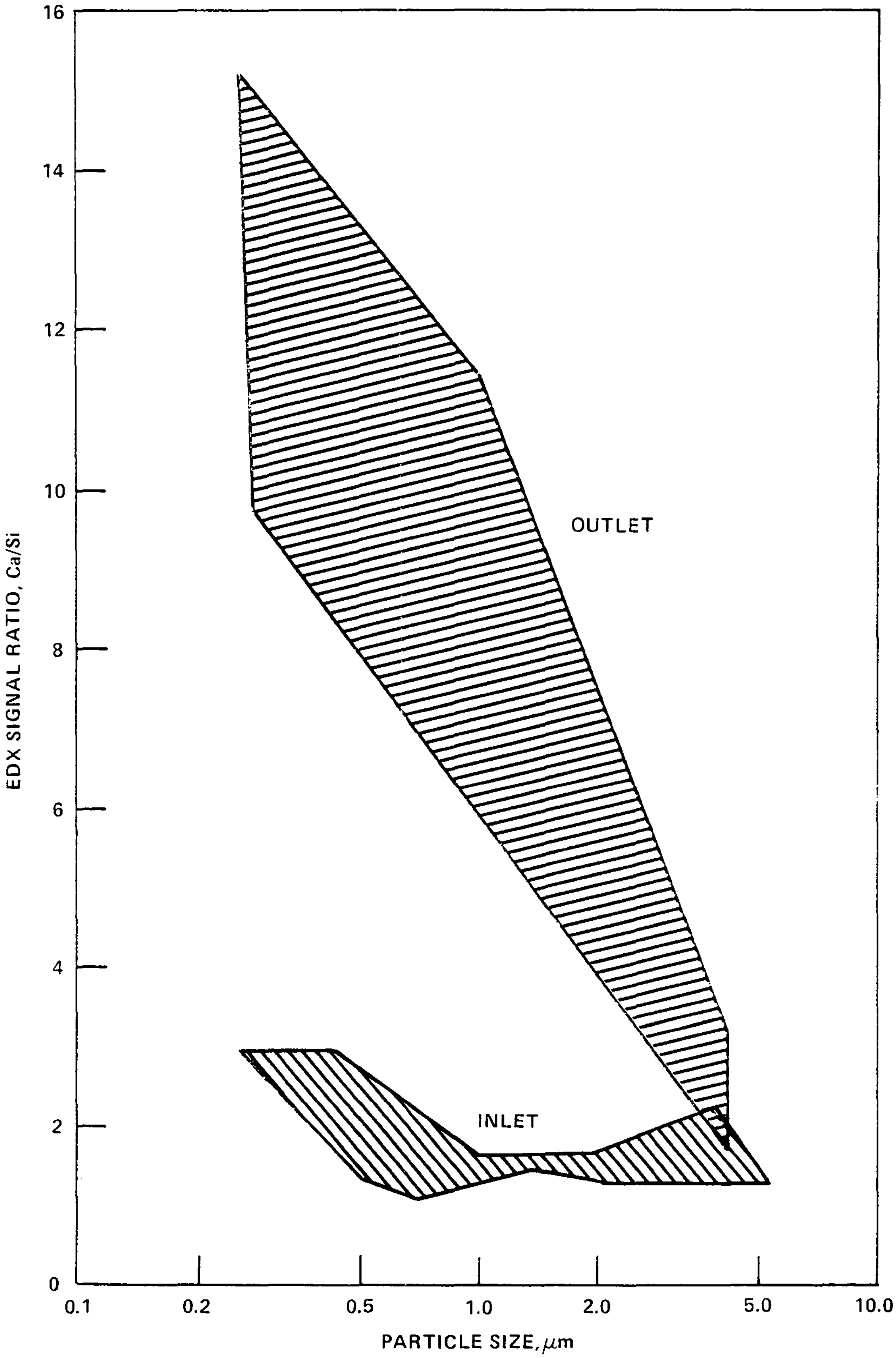

Figure 10. EDX Derived Calcium to Silicon Ratios vs. Particle Size for E-SOX Impactor Substrate Samples

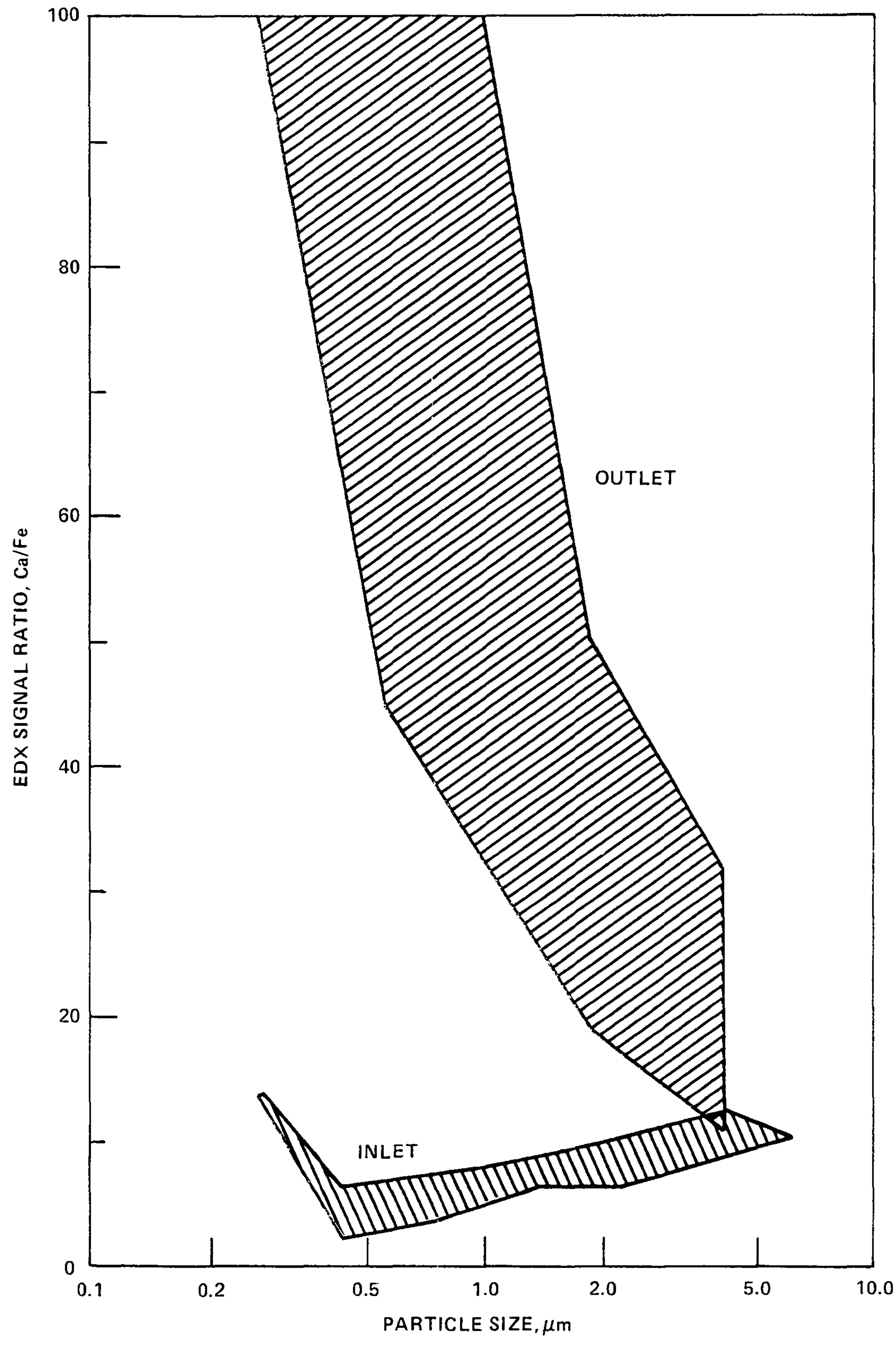

Figure 11. EDX Derived Calcium to Iron Ratios vs. Particle Size for E-SOX Impactor Substrate Samples

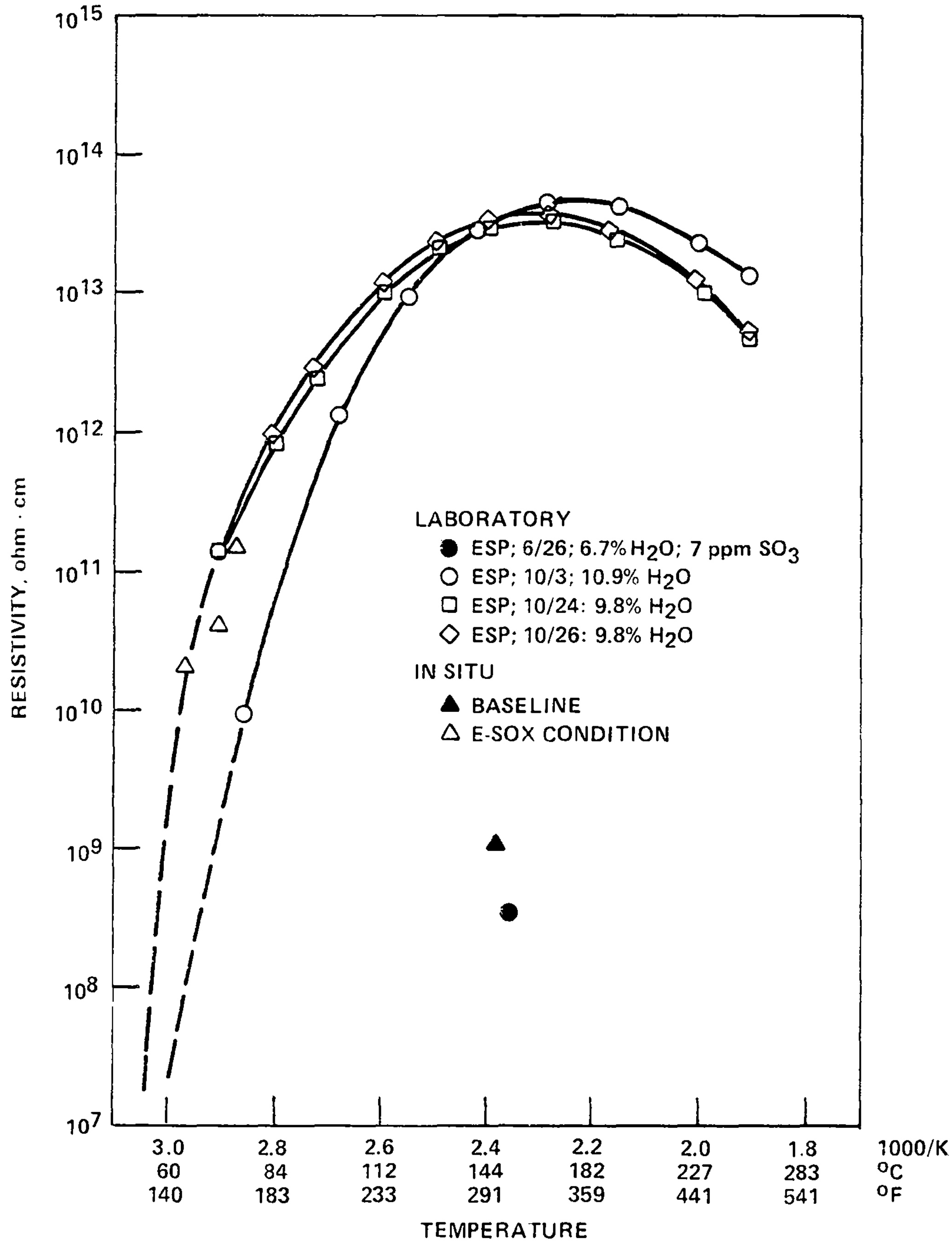

Figure 14. Laboratory and In Situ Resistivity Measurements, E-SOX Demonstration Tests

Table 8

BURGER PILOT SYSTEM E-SOX SOLIDS

%	Mass Train Inlet[a]	Hoppers[b] Trans.	Hoppers[b] ESP	Mass Train After DID[b]	Outlet[b]
Li_2O	0.03	0.02	0.02	0.01	0.01
Na_2O	0.3	0.2	0.2	0.2	0.1
K_2O	1.9	1.0	0.9	0.8	0.7
MgO	1.1	1.4	1.5	1.5	1.3
CaO	3.0	30.6	40.2	39.2	38.3
Fe_2O_3	22.8	13.9	7.7	6.6	6.4
Al_2O_3	22.4	11.9	10.1	9.0	8.5
SiO_2	47.0	26.0	20.9	17.9	17.3
TiO_2	1.3	0.6	0.6	0.5	0.4
P_2O_5	0.5	0.1	0.1	0.2	0.2
SO_3	0.6	13.6	16.2	21.0	24.7

a. Ash only
b. Ash plus sorbent

Table 9

COAL COMPOSITIONS FROM BASELINE AND E-SOX TEST SERIES
ANALYSES BY CT&E

%	Baseline	E-SOX Condition
H_2O	8.25	6.67
C	64.83	67.89
H	4.25	4.32
N	1.24	1.33
Cl	0.00	0.06
S	2.64	2.67
Ash	12.18	11.02
Volatile	33.50	34.78
Fix. C	46.08	47.54
Btu/lb	11627	12120

should not result in low resistivity reentrainment. However, the samples of 10/3 indicate resistivity values below 10^{10} ohm-cm at 170°F, and exhibit a very steep slope which would result in resistivity values of less than 10^{8} ohm-cm at 140°F. It should be noted that the laboratory atmosphere is only a static simulation of the dynamic environment which exists in the ESP. It could be argued that the presence of sulfur oxides and surface moisture in the actual environment is likely to produce a lower real-time resistivity value with a representative sample than would be obtained in the laboratory air-water vapor environment with samples obtained from system hoppers.

Baseline resistivity data are also shown on Figure 14. The probe provided data in good agreement with the laboratory data in equilibrium with 7 ppm SO_3. This value of SO_3 was estimated to result from the sulfur content of the coal. The observed fact that neither the probe nor the ESP experienced any difficulty in collecting an ash with a resistivity of 10^{9} ohm-cm suggests that low resistivity may not be the only property of a dust responsible for excessive reentrainment.

Ash cohesivity is also expected to be relevant in efforts to quantify factors responsible for excessive reentrainment. Measurements of cohesivity of fly ash and ash/sorbent mixtures were performed on fly ash alone and on the ash/sorbent mixtures from the ESP with slurry injection. These measurements produced the surprising result that the E-SO_x solids at 145°F exhibited a cohesivity in the low end of the range (40.3°, angle of internal friction[6]) measured for a large number of fly ash samples. Furthermore, the angle of internal friction of the fly ash at 285°F was 45.5°, which is significantly higher than the E-SO_x solids at 145°F. Low cohesivity would be expected to aggravate a reentrainment tendency resulting from low dust resistivity.

Discussion

Table 10 contains a summary of measured and model predictions of outlet mass loading and efficiencies for the E-SO_x pilot facility. Since all measurements were conducted with rappers off, the model estimates are all "no rap" values. The modeling factors represent the fraction of sneakage/reentrainment which is assumed to occur over four stages, and the sigma g value is the normalized standard deviation of the gas velocity distribution. The value of 0.25 is assumed for the baseline test; the value of 0.36 is based on the measurements presented in Table 6.

A comparison of measured and predicted results shows that the model failed to predict the performance trends as well as the absolute value of outlet emissions. Performance improvements were predicted because of increased electrical migration velocities at the lower temperatures with slurry injection. However, outlet emissions increased with slurry injection from predicted values by factors ranging from 28 to 390. Model output could be forced to match the measured results by assigning reentrainment values per stage ranging from 40 to 85%.

These results are qualitatively similar to those of Durham,[3] in which model predictions of the Shawnee spray dryer ESP were off by a factor of 80, and a reentrainment factor of 60% was required to match measured and modeled penetrations under spray dryer conditions. However, there are significant quantitative differences in that omega k values for the E-SO_x unit ranged from a low of

Table 10

MODELING RESULTS - BURGER PILOT ESP

	Measured Performance		Modeled Performance		
	Mass Loading lb/MMBtu	Efficiency %	Mass Loading lb/MMBtu	Efficiency %	Modeling Factors[a]
Baseline	0.008	99.92	0.009	99.91	0.10/0.25
E-SOX (anticipated)			0.004	99.94	0.10/0.25
E-SOX (180°F)	0.113	98.56	0.100	98.7	0.40/0.36
E-SOX (170°F)	0.313	96.02	0.274	96.5	0.55/0.36
E-SOX (160°F)	1.55	80.27	1.8	76.9	0.85/0.36

[a]Combined sneakage & reentrainment/σ_g

4.7 cm/sec to a high of 32.9 cm/sec. In contrast, the Shawnee data indicated omega k values ranging from a low of 32.3 cm/sec with a two field configuration to 51 to 53 cm/sec with three or four fields.

The extreme temperature sensitivity of the E-SO_x ESP performance is believed to result from the combined high-velocity/low-temperature regions near the bottom of the precipitator. These conditions would magnify the process of electrical reentrainment which also appears to be occurring to some degree at the higher temperatures. Since the particulate emission levels with slurry injection were unacceptable, additional testing was performed after B & W improved the inlet gas flow. Results from these measurements are provided in the following section.

SECTION 3

ADDITIONAL MEASUREMENTS WITH IMPROVED INLET GAS FLOW CONDITIONS

Introduction

The gas velocity and temperature distribution data in Table 6 indicated a coincidence of the high velocity and low temperature regions near the bottom of the precipitator. B & W personnel modified the gas flow distribution prior to the performance of additional precipitator testing. The objective of this additional testing (termed the E-SO_x ESP Performance Extension Test) was to determine whether the modifications to the ESP inlet gas distribution would permit achievement of the performance goals for the program. These goals are 50% SO_2 removal with less than 0.1 lb per million BTU particulate emissions.

Table 11 presents gas velocity data obtained by B & W personnel following modifications to the inlet baffling. These data indicate a significant improvement from the distribution illustrate in Table 6. For example, the V/Vavg ratio for the bottom row is only 1.18, whereas the comparable measurements from Table 6 indicate a V/Vavg ration of 1.50.

Similar improvements were obtained in temperature distributions. For example, B & W data taken with slurry injection after the modifications show that the average bottom row temperature is 160.0°F when the inlet average is 160.5°F.

Site preparation for the additional field work began on July 30, 1990, and testing ended on August 18, 1990. When the pilot facility was operational, the ESP was operated during the daylight hours and kept warm during the night with the system in a closed loop configuration. SRI obtained inlet mass measurements during the baseline tests, and outlet mass measurements during the baseline and slurry injection tests. Particle size measurements were obtained only on August 17, 1990 at the outlet sampling location and after the DID (Droplet Impingement Device) at the ESP inlet. Voltage-current data were gathered during the various tests conditions when the system was considered stable.

Mass Concentration Measurements

Mass measurements were obtained on August 8 and 9, 1990, at the system inlet and outlet sampling locations under baseline conditions and these data are presented in Table 12. Table 13 contains the data in Table 12 but averaged by day and includes efficiency, SCA, and omega K calculations and baseline data from the 1989 test program. The specific collection area (SCA) and precipitation rate parameter (omega K) calculations assume that all four fields are operational. As can be seen from the data in Table 12, the outlet emissions tended to decrease during the day when the conditions of the ESP were set to remain constant for the test day. If the average inlet mass loading is used for the ninth, the efficiency of the ESP went from 98.44% to 99.7% over an eight and one half hour period. The ESP did not have sufficient time to equilibrate under the daily operating conditions of the test program. The increase in efficiency with operating time suggest non-rapping reentrainment emissions decreased as the temperature of the electrodes increased from night time closed loop operating

Table 11

E-SO_X FIELD PILOT DEMONSTRATION
ESP FLOW DISTRIBUTION TESTS 8/2/90
(DATA OBTAINED BY B&W)

Conditions: Atomizing Air at 121-130 psig
Perforated Plate Cleaned
Horizontal Perf Plate at Bottom of DID Covered
6" Side Baffles Installed

Grid shown is view looking with the gas flow

Column Number	1	2	3	4	5	6	Row Avg
Row 10	1.47 373	1.19 301	1.20 303	1.19 300	1.25 317	1.48 374	1.30 V/Vavg 328 feet/min
Row 9	1.38 350	1.19 301	1.19 300	1.19 300	1.15 292	1.21 305	1.22 308
Row 8	1.20 304	1.16 293	1.08 272	1.13 287	0.81 204	0.75 191	1.02 259
Row 7	0.74 186	1.01 255	1.05 265	1.15 290	1.02 259	0.63 159	0.93 236
Row 6	0.58 248	0.83 210	1.01 256	1.02 257	0.90 227	0.56 141	0.82 207
Row 5	0.50 126	0.49 124	0.81 205	1.03 260	0.76 192	0.74 188	0.72 183
Row 4	0.74 186	0.76 192	0.88 223	0.95 241	0.84 212	0.84 213	0.83 211
Row 3	1.13 287	0.80 202	0.82 207	0.90 227	0.79 200	0.99 251	0.91 229
Row 2	1.28 325	1.04 262	0.88 222	0.96 243	1.05 265	1.25 317	1.08 272
Row 1	1.41 356	1.12 283	1.04 264	1.04 262	1.07 270	1.40 355	1.18 298
Col Avg	1.04 264	0.96 242	0.99 252	1.05 267	0.96 244	1.01 256	
						Grid Avg	253 feet/min 4.2 feet/sec

IGCI ESP INLET VELOCITY DISTRIBUTION STANDARDS:

99% of points with V/Vavg < 1.40	% of points with V/Vavg < 1.40 Vavg	91
85% of points with V/Vavg < 1.15	% of points with V/Vavg < 1.15 Vavg	80

Table 12

E-SO_x PILOT PRECIPITATOR DATA, BASELINE

INLET MASS TRAIN MEASUREMENTS

Date	Run ID	% O_2	Avg. Gas Temp.	Gas Flow acfm	Gas Flow dscfm	Mass Loading[a] gr/acf	Mass Loading[a] gr/dscf	Mass Loading[a] lbs/ Million Btu	Condition
8-8-90	DBIN-1	6.6	291	8,936	5,505	2.2081	3.5849	7.3502	Baseline
8-8-90	DBIN-2	6.6	290	9,353	5,642	2.6068	4.3215	8.8605	Baseline
8-9-90	DBIN-3	7.3	291	11,341	6,912	2.8242	4.6341	9.9904	Baseline
8-9-90	DBIN-4	7.3	286	11,112	6,812	2.6588	4.3377	9.3516	Baseline

OUTLET MASS TRAIN MEASUREMENTS

Date	Run ID	% O_2	Avg. Gas Temp.	Gas Flow acfm	Gas Flow dscfm	Mass Loading gr/acf	Mass Loading gr/dscf	Mass Loading lbs/ Million Btu	Condition
8-8-90	DBOT-1	9.2	259	9,572	6,498	0.0131	0.0193	0.0484	Baseline
8-8-90	DBOT-2	9.2	261	9,752	6,510	0.0058	0.0087	0.0219	Baseline
8-9-90	DBOT-3	10.2	259	11,315	7,609	0.0370	0.0551	0.1510	Baseline
8-9-90	DBOT-4	10.2	267	11,378	7,545	0.0104	0.0157	0.0429	Baseline
8-9-90	DBOT-5	10.2	259	11,426	7,682	0.0072	0.0107	0.0294	Baseline

[a]All mass loadings were obtained, without electrode rapping

Table 13

AVERAGE BASELINE RESULTS

	8/8/90	8/9/90	6/24/89	6/26/89
SYSTEM INLET				
Temp., °F	291	289	308	315
gr/scf	3.953	4.486	4.199	4.018
lb/MMBtu	8.105	9.671	9.258	8.296
DSCFM	5574	6862	8553	9017
OUTLET[a]				
Temp., °F	260	262	276	277
gr/scf	0.014	0.027	0.0045	0.0033
lb/MMBtu	0.035	0.074	0.012	0.008
EFFICIENCY[b], %	99.57	99.23	99.87	99.90
SCA, ft^2/kacfm[c]	367.5	299.3	231	215
OMEGA K, cm/sec	41.0	40.2	97.1	112.7

[a]No Rapping
[b]Based on lb/MMBtu
[c]Inlet Gas Flow Data Used

conditions (approximately 200°F) to the gas temperature maintained during the test series.

The average baseline efficiencies for August 8 and 9, 1990 were 99.57% and 99.23%, respectively. These data are considerably different from those of the 1989 baseline tests (see Table 2, last two columns) in that the SCA's are higher and the omega K's are much lower (these calculations are based on four field operation). It should be noted that the baseline data taken during the June 1989 test period were obtained with flue gas flowing through the ESP 24 hours per day.

Slurry testing began during the afternoon of August 11, 1990, but operational problems with the facility delayed further testing until the August 15. Table 14 contains the mass data from the outlet sampling location during the slurry injection tests. The first two mass measurements of August 15, 1990 were single port tests of only 20 minutes duration. These tests were used to establish the flow and temperature conditions of the slurry tests program so that the objectives of the program could be met. The last test on the 15th was also of 20 minutes duration. This test was conducted with the average ESP inlet temperature at 158.9°F in order to estimate emissions level of future tests. Table 15 presents the data obtained by B & W for the various conditions tested, along with the mass data obtained by SRI during these test segments.

On August 18, 1990, the average ESP inlet temperature was set at approximately 160°F for the additive tests. The first two outlet mass measurements were determined with a one hour run time; all other measurements on the 18th were for 30 minutes. Each of the three sampling ports were traversed during each test on the 18th. When alum ($Al_2(SO_4)_3 \bullet xH_20$ where x is approximately 14) was added to the slurry, the outlet emissions increased under the conditions tested. It was expected that the outlet emissions would decrease with the use of the additive, but this did not occur. After the second test with alum, the average inlet temperature to the ESP was raised to determine whether the outlet emissions would decrease. Past experience indicated that emissions decreased with increasing temperature, if there were no contributing difficulties other than the expected low resistivity and/or deagglomeration of lime slurry particulate within the ESP. Once again, the outlet emissions decreased when the average temperature was increased to 171.5°F. These data provide no evidence of a beneficial effect due to the use of alum. This same conclusion was reached when calcium chloride was added to the slurry for the last two tests of the extended test program. The elevated emissions of the calcium chloride tests may have been in part due to the length of the test day during which the ESP performance deteriorated throughout the 160°F test day.

Figure 15 presents the data in Table 14 plotted as omega K vs temperature. This temperature-emissions relationship was evident during the 1989 test program as it was during the 1990 extended test program. The data in Figure 15 displayed as solid symbols were obtained when the temperature (average ESP inlet) was quickly changed to check emissions and the system was not given time to reach thermal stability. Note that the ESP performance exhibits a drastic deterioration as the inlet temperature approaches 160°F.

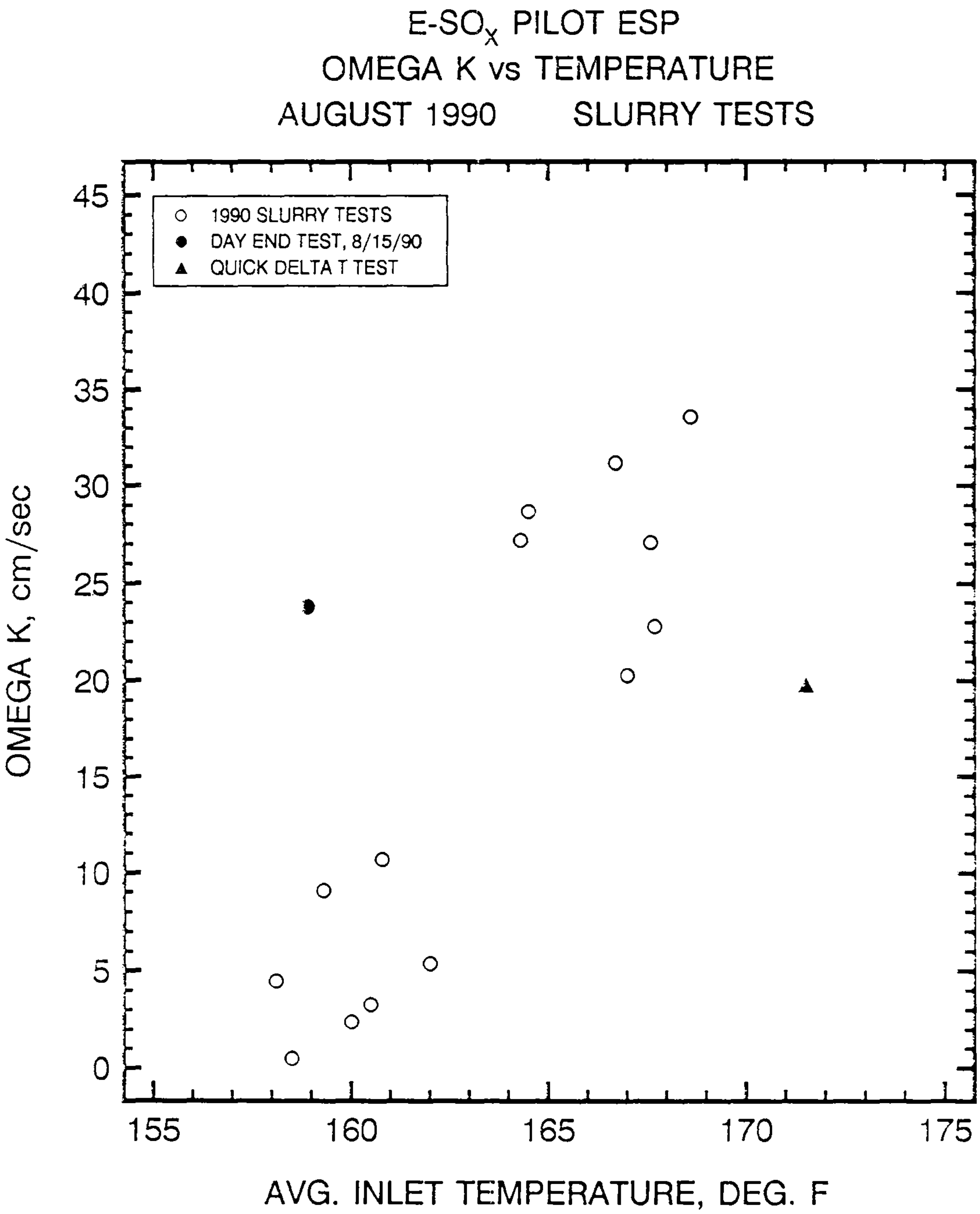

Figure 15. Omega K vs. Temperature for August 1990 E-SOX Extension Test.

Table 14

E-SO_x PILOT PRECIPITATOR EXTENSION TEST
OUTLET MEASUREMENTS - SLURRY INJECTION

Date	Run ID	Inlet Gas Temp.	Gas Flow acfm	Mass Loading lbs/MMBtu	Reference SCA[a]	Collection Efficiency[b]	Omega K, cm/sec	Test Conditions
8/11/90	DBOT-6	160.8°F	11202	0.3888	299.9	91.92	10.7	Lime Slurry, Low Temp
8/15/90	DBOT-7	~167	12293	0.1760	273.3	96.34	20.3	Lime Slurry
	DBOT-8	167.7	11896	0.1372	282.4	97.15	22.8	Lime Slurry
	DBOT-9	164.5	10248	0.0651	327.9	98.65	28.7	Lime Slurry
	DBOT-10	158.9	11481	0.1187	292.7	97.53	23.8	Lime Slurry, Lowered Temp
8/16/90	DBOT-11	167.6	9906	0.0682	339.2	98.58	27.1	Unit 8, Lime Slurry
	DBOT-12	168.6	9830	0.0413	341.8	99.14	33.6	Unit 7, Lime Slurry
	DBOT-13	166.7	11234	0.0663	299.1	98.62	31.2	Lime Slurry
	DBOT-14	164.3	10192	0.0722	329.7	98.50	27.2	Lime Slurry

(continued)

Table 14 (continued)

E-SO_X PILOT PRECIPITATOR EXTENSION TEST
OUTLET MEASUREMENTS - SLURRY INJECTION

Date	Run ID	Inlet Gas Temp.	Gas Flow acfm	Mass Loading lbs/MMBtu	Reference SCA[a]	Collection Efficiency[b]	Omega K, cm/sec	Test Conditions
8/18/90	DBOT-15	159.3	9995	0.4129	336.2	91.42	9.1	Lime Slurry, Low Temp
	DBOT-16	162.0	10071	0.7306	333.6	84.81	5.4	Lime Slurry + 1 wt. % Alum
	DBOT-17	160.5	10256	1.1190	327.6	76.74	3.3	Lime Slurry + 1 wt. % Alum
	DBOT-18	171.5	10314	0.1360	325.8	97.17	19.8	Lime Slurry + 1 wt. % Alum 170°F Set Pt.
	DBOT-19	158.1	10289	0.8772	326.6	81.77	4.5	Lime Slurry
	DBOT-20	160.0	10104	1.3893	332.5	71.12	2.4	Lime Slurry + 1 wt. % $CaCl_2$
	DBOT-21	158.5	10222	2.7798	328.7	42.22	0.5	Lime Slurry + 1 wt. % $CaCl_2$

[a]Used outlet acfm for estimate of flow
[b]Estimated inlet loading to ESP is 4.811 lbs/MMBtu

Impactor Measurements

Particle size distributions were obtained at the ESP inlet, after the DID, and at the ESP outlet on August 17, 1990. The condition established for this test day was for the ESP to operate at approximately 165°F and the Ca/S ratio to be approximately 1.2. These conditions were expected to produce 50% removal of SO_2 and less than 0.1 pounds per million Btu of particulate exiting the ESP.

Figures 16 through 19 present the inlet particle size data as cumulative mass loading, cumulative percent, DM/DLOG D and DN/DLOG D vs. particle size, respectively. Figures 20 through 23 present these data for the outlet particle mass concentrations. The average inlet mass loading, using the impactor loadings, was 1.576 gr/acf or 2.28 gr/scf. The average of the outlet data resulted in a loading of 0.0249 gr/acf or 0.0343 gr/scf (data from 1989 were 0.0497 gr/scf). This equaled an emission level of 0.083 lbs/MMBtu at an SCA of approximately 310 ft^2/kacfm (four field operation). Past comparisons of calculated outlet emissions for mass trains and impactors have indicated that impactor measurements usually provide a mass concentration average which differs by 25% or less from that obtained with mass trains. This difference is due to the inability of the impactor to sample isokinetically at each sample point.

Figure 24 presents the fractional collection efficiency for the pilot ESP on August 17, 1990. As past data have indicated, the apparent minimum in collection efficiency occurs at approximately one micron particle diameter. The average overall efficiency for the 17th, using the impactor data on a lbs/MMBtu basis, was 98.18% (these data were obtained without the rappers operating during the impactor measurements).

Voltage-Current Data

Table 16 contains the averages of secondary voltage and current readings taken during the various conditions stated in the table. Figures 25, 26, and 27 present voltage vs current density curves for the baseline and slurry injection conditions. These curves were obtained at the end of the test day indicated, where conditions were considered to be fairly stable. The fourth field voltage-current readings were abnormal. The fourth field transformer was connected to the third field to check for possible misalignment, but the readings did not change, indicating a problem with the TR set or the associated instrumentation. It was thought that the current metering loop was in error by approximately a factor of ten. There was no equipment on site to check this, nor time after the test program was terminated to investigate the problem. Figure 27 also has a curve included that is a fourth field curve assuming the current for the voltage read on the 17th of August 1990 would have corresponded to that of October 25, 1989. The data in Table 16, for the eighteenth of August, do not indicate that there were any significant differences in the voltage and current data under the various tests conditions of that day.

Electron Microscopy

Impactor substrates from an inlet impactor (Brink) and an outlet impactor (University of Washington) were subjected to Energy Dispersive X-Ray (EDX) analysis. These data, presented as calcium to silica ratio vs. particle size,

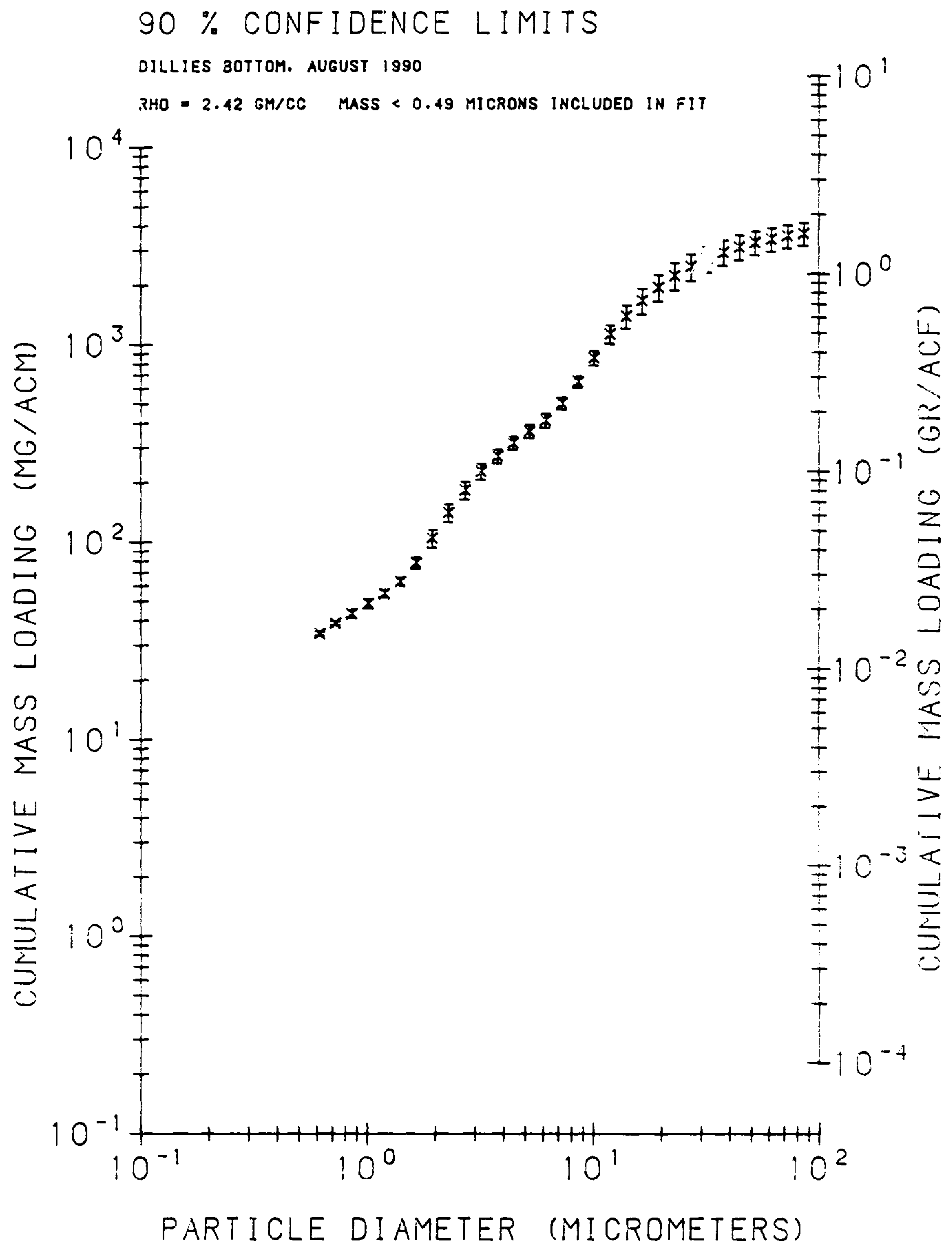

Figure 16. Inlet Cumulative Mass vs. Particle Diameter for the E-SOX Extension Test, August 17, 1990.

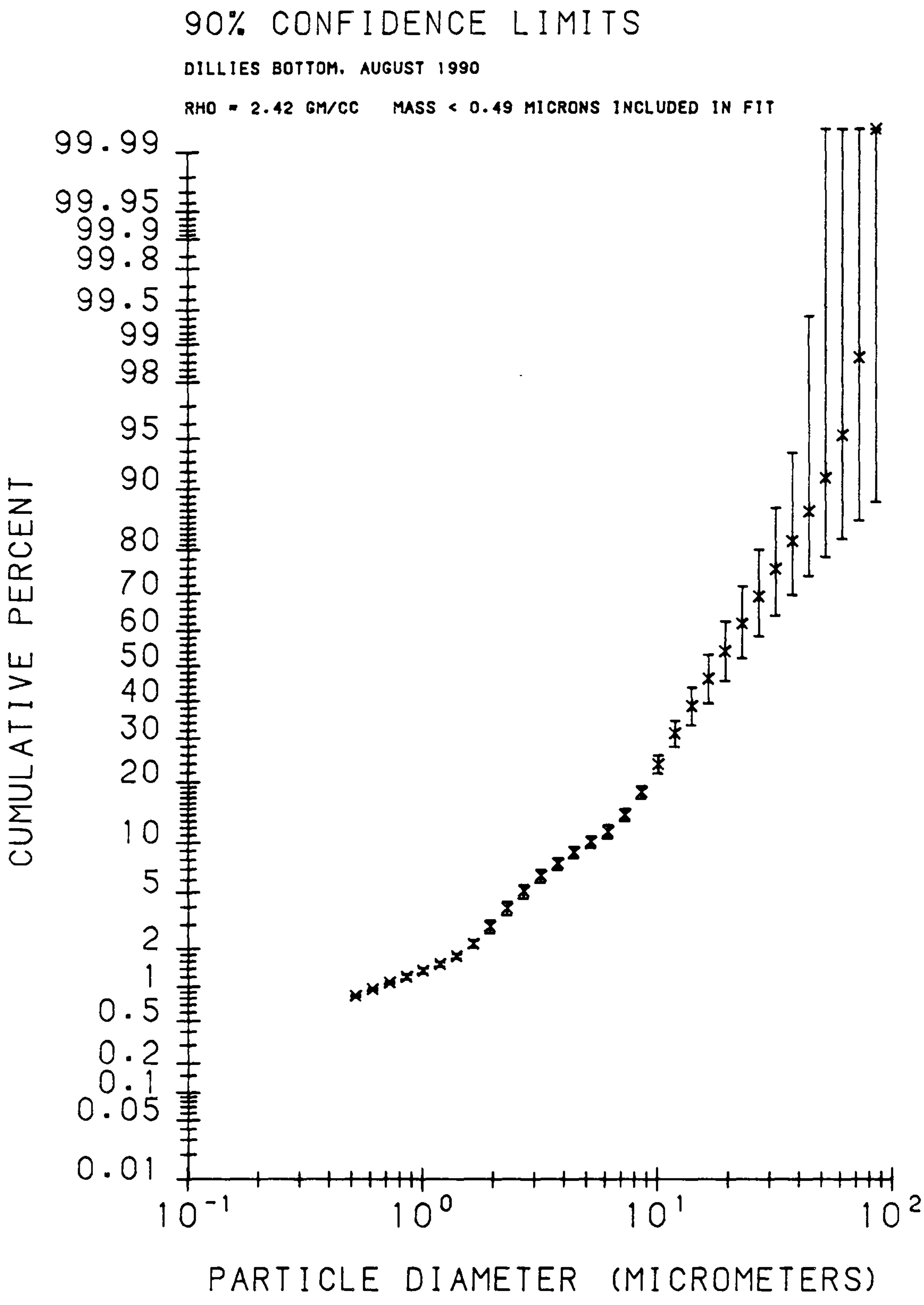

Figure 17. Inlet Cumulative Percent vs. Particle Diameter for the E-SOX Extension Test, August 17, 1990.

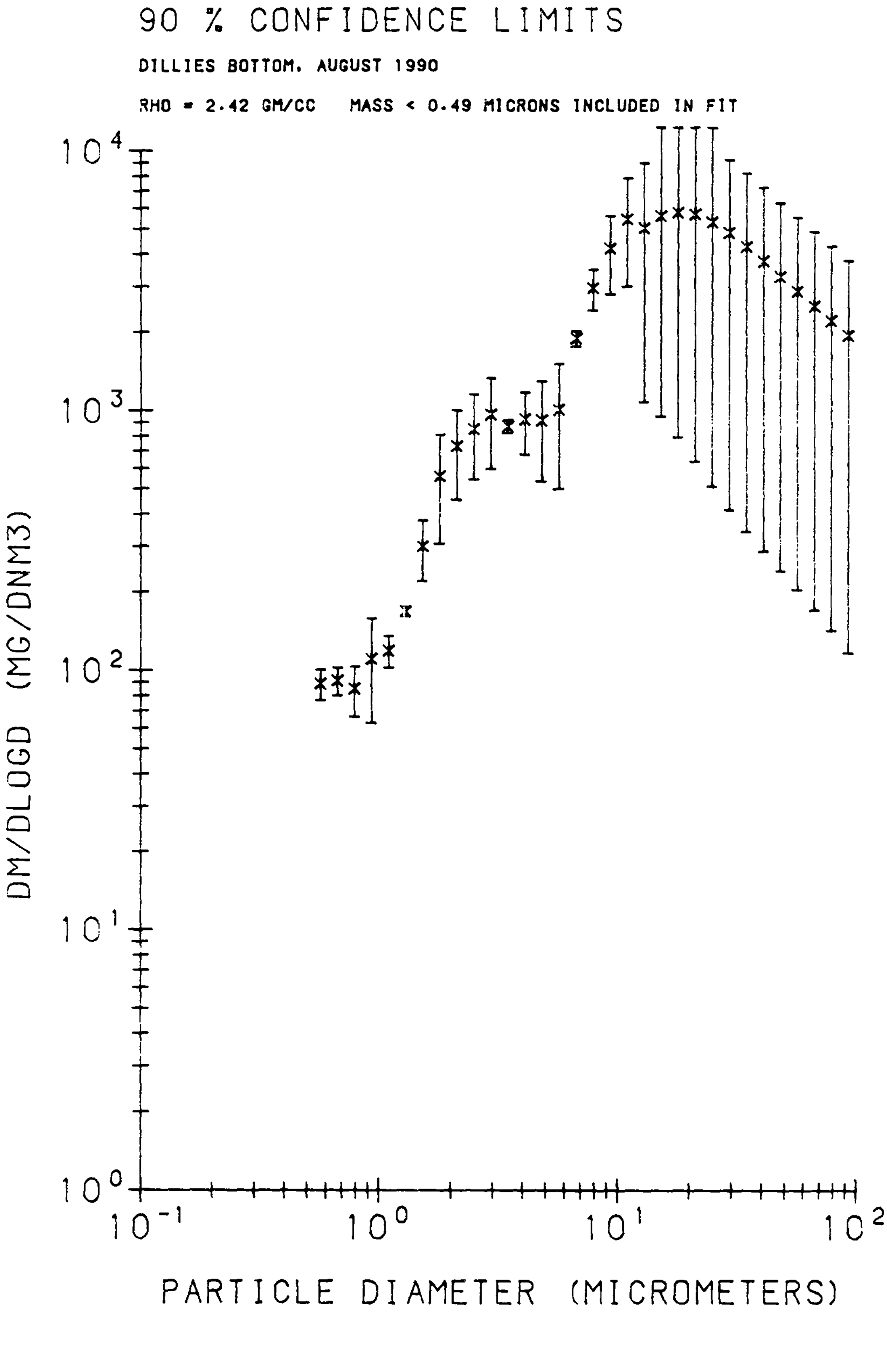

Figure 18. Inlet DM/DLOGD vs. Particle Diameter for the E-SOX Extension Test, August 17, 1990.

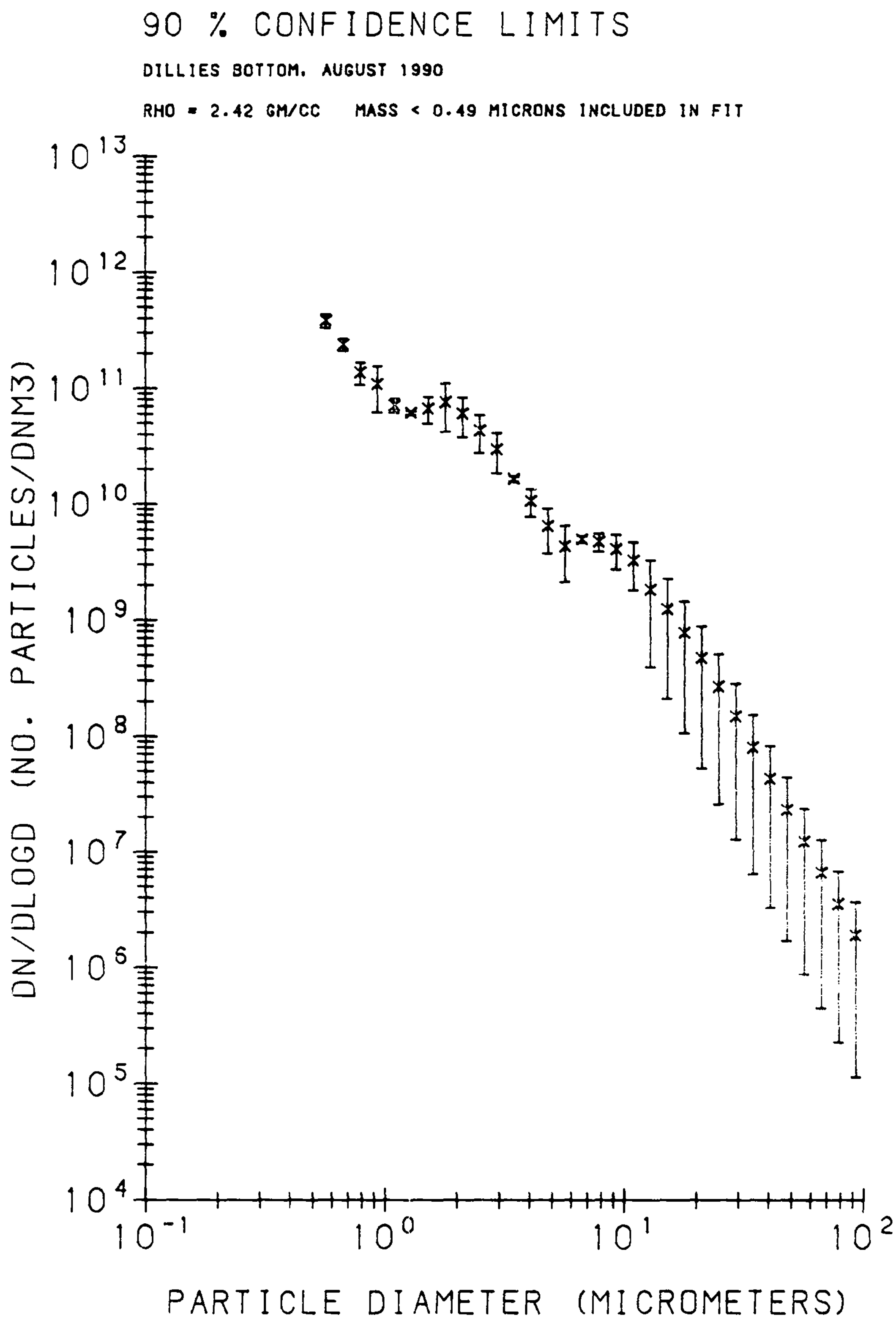

Figure 19. Inlet DN/DLOGD vs. Particle Diameter for the E-SOX Extension Test, August 17, 1990.

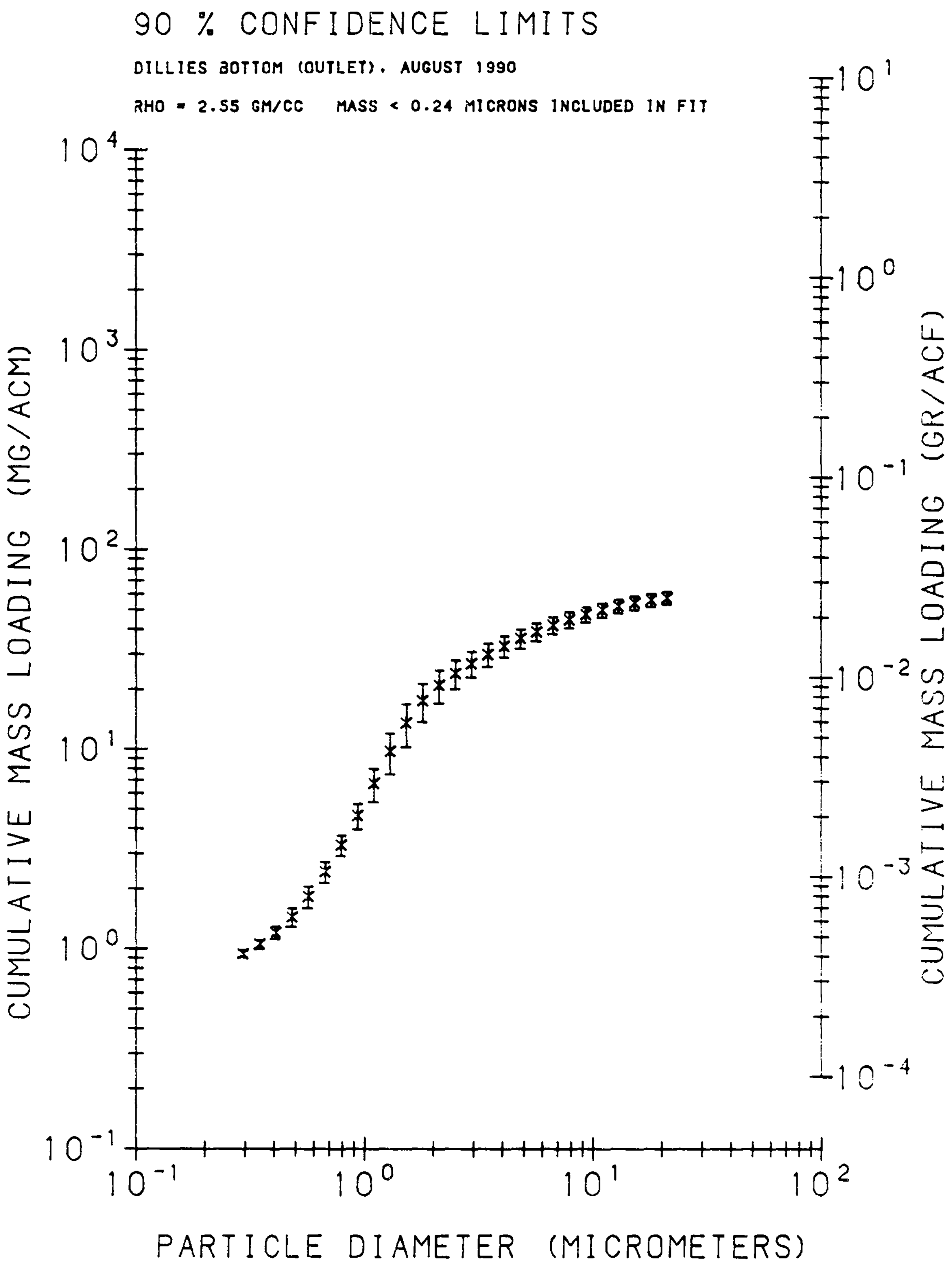

Figure 20. Outlet Cumulative Mass vs. Particle Diameter for the E-SOX Extension Test, August 17, 1990.

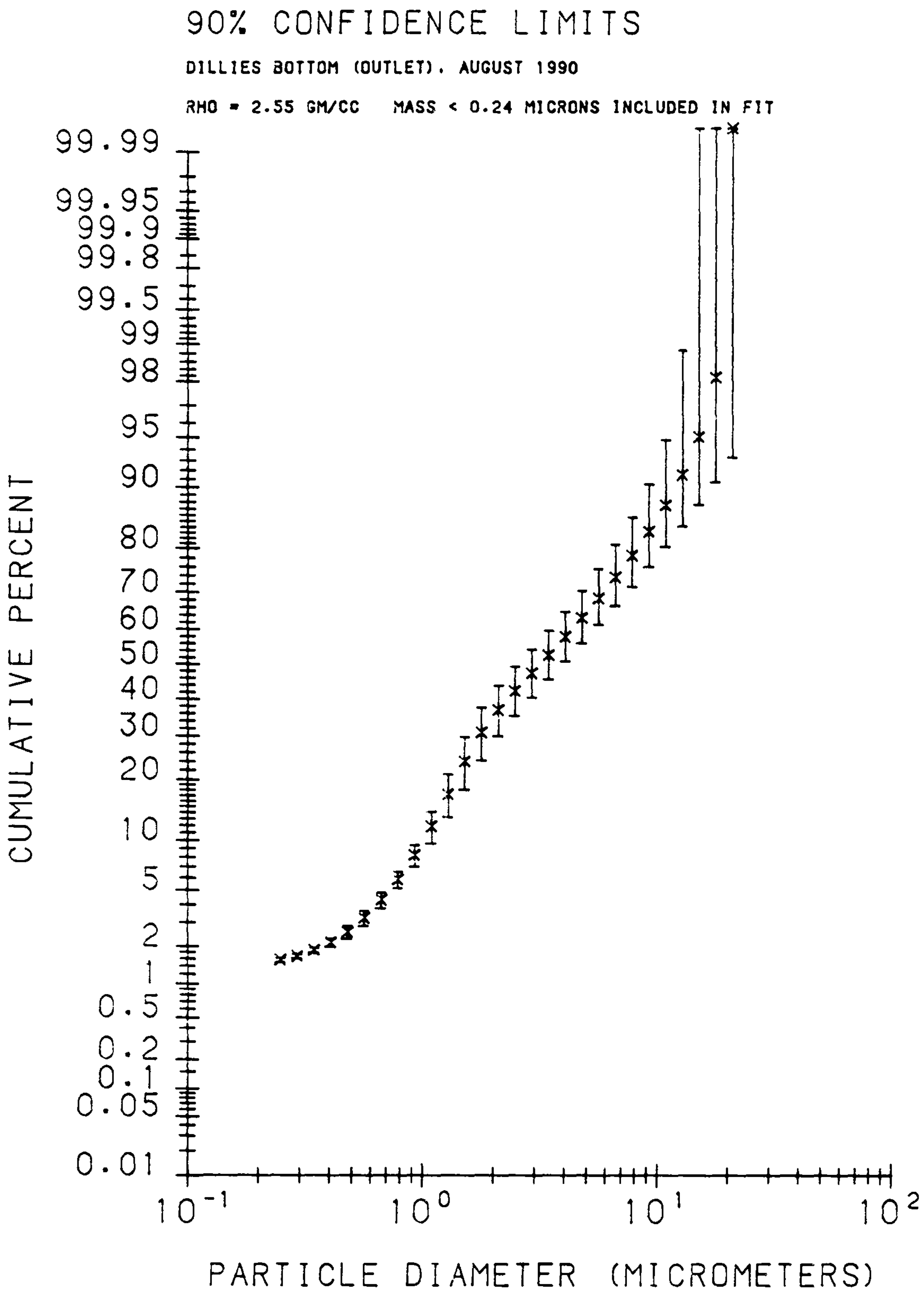

Figure 21. Outlet Cumulative Percent vs. Particle Diameter for the E-SOX Extension Test, August 17, 1990.

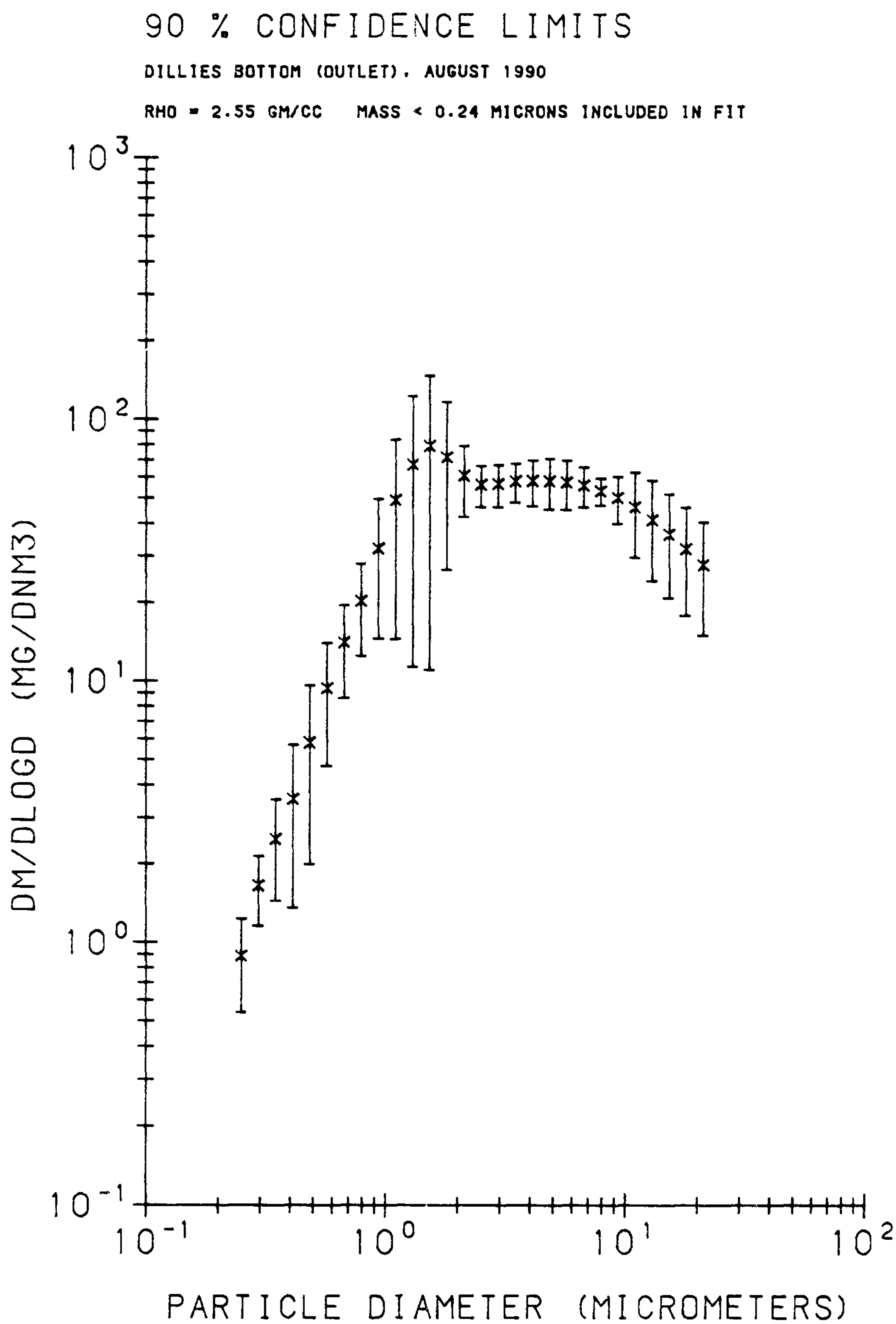

Figure 22. Outlet DM/DLOGD vs. Particle Diameter for the E-SOX Extension Test, August 17, 1990.

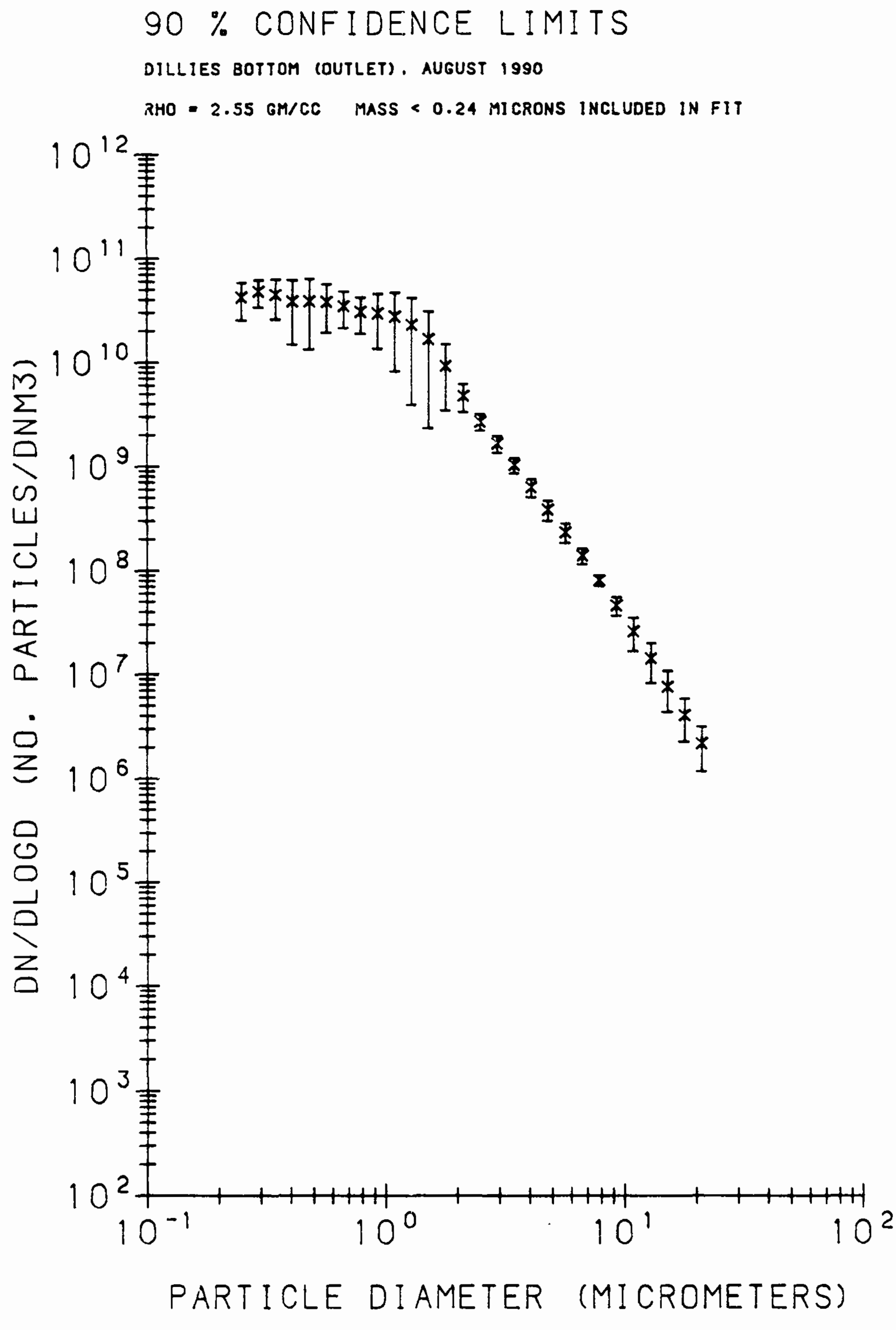

Figure 23. Outlet DN/DLOGD vs. Particle Diameter for the E-SOX Extension Test, August 17, 1990.

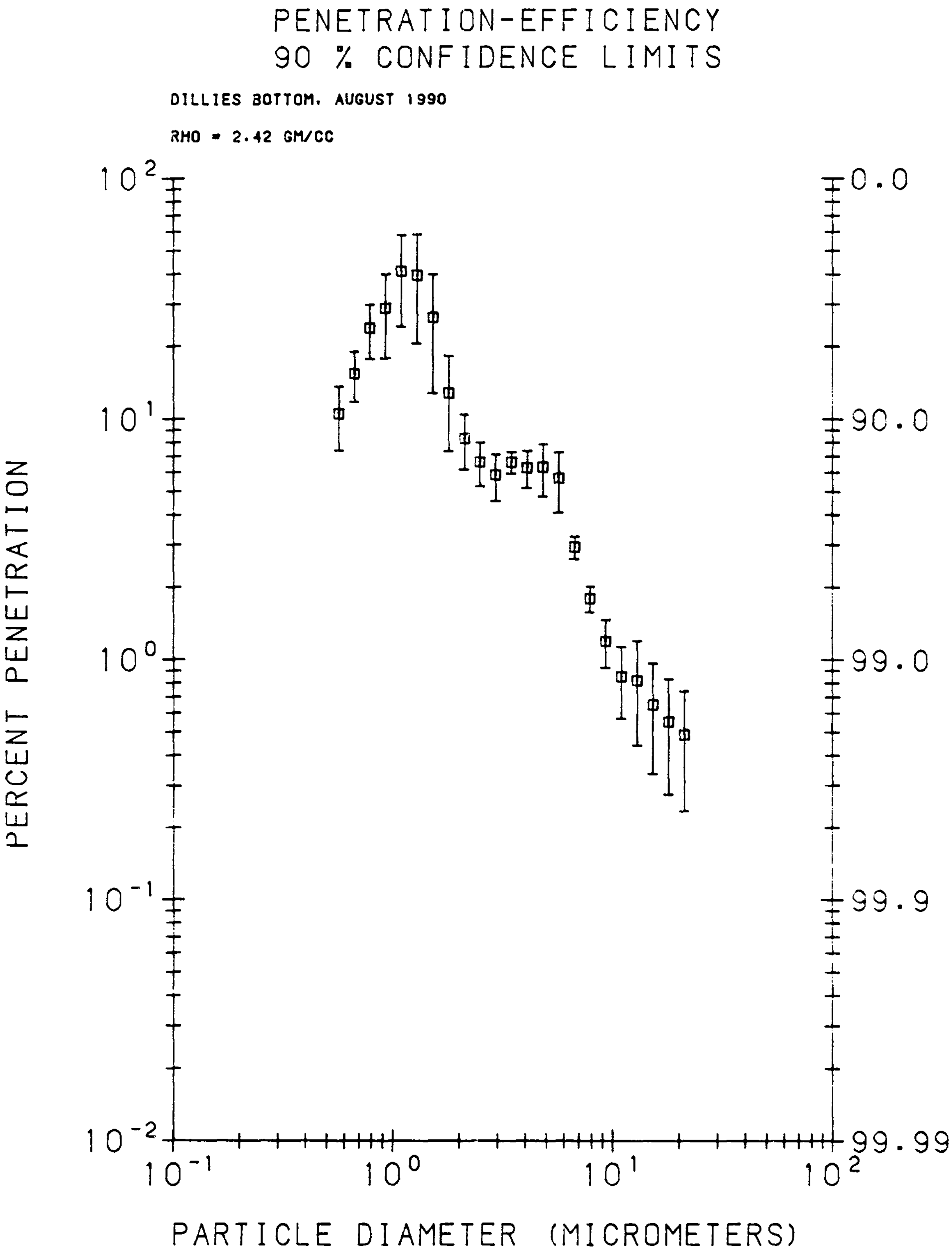

Figure 24. Fractional Collection Efficiency, E-SOX Extension Test, August 17, 1990.

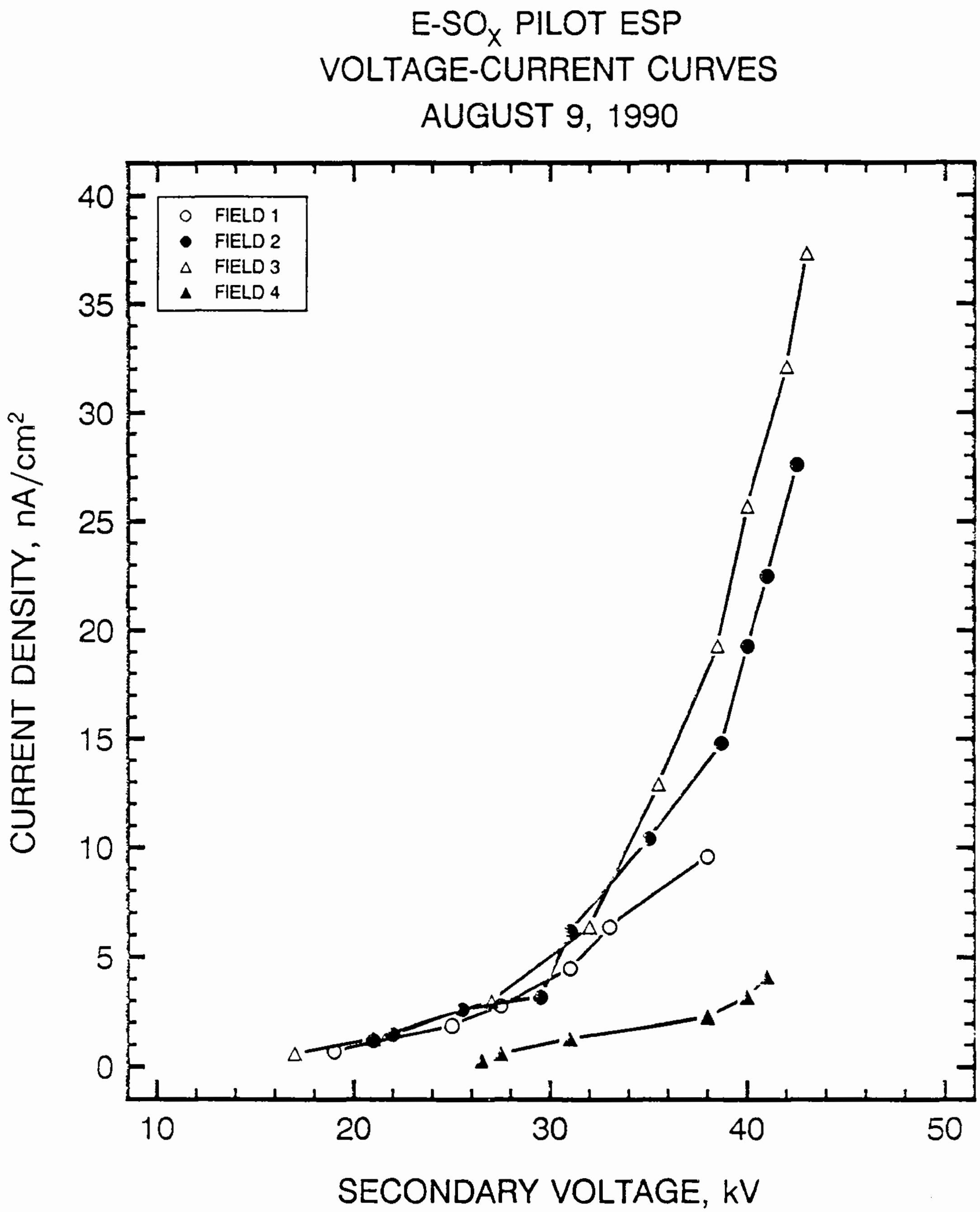

Figure 25. Voltage-Current Curves for August 9, 1990; Baseline.

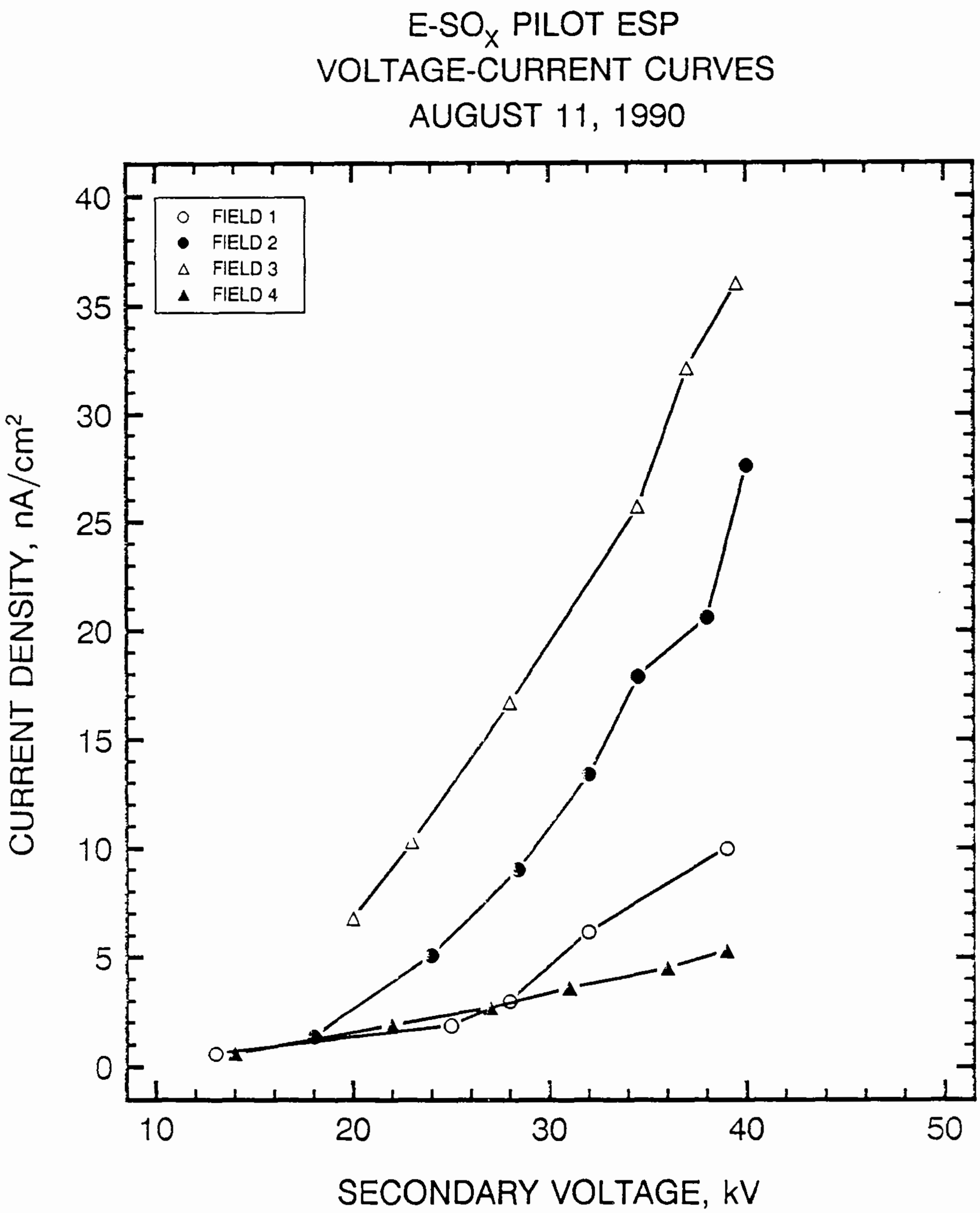

Figure 26. Voltage-Current Curves for August 11, 1990; Lime Slurry.

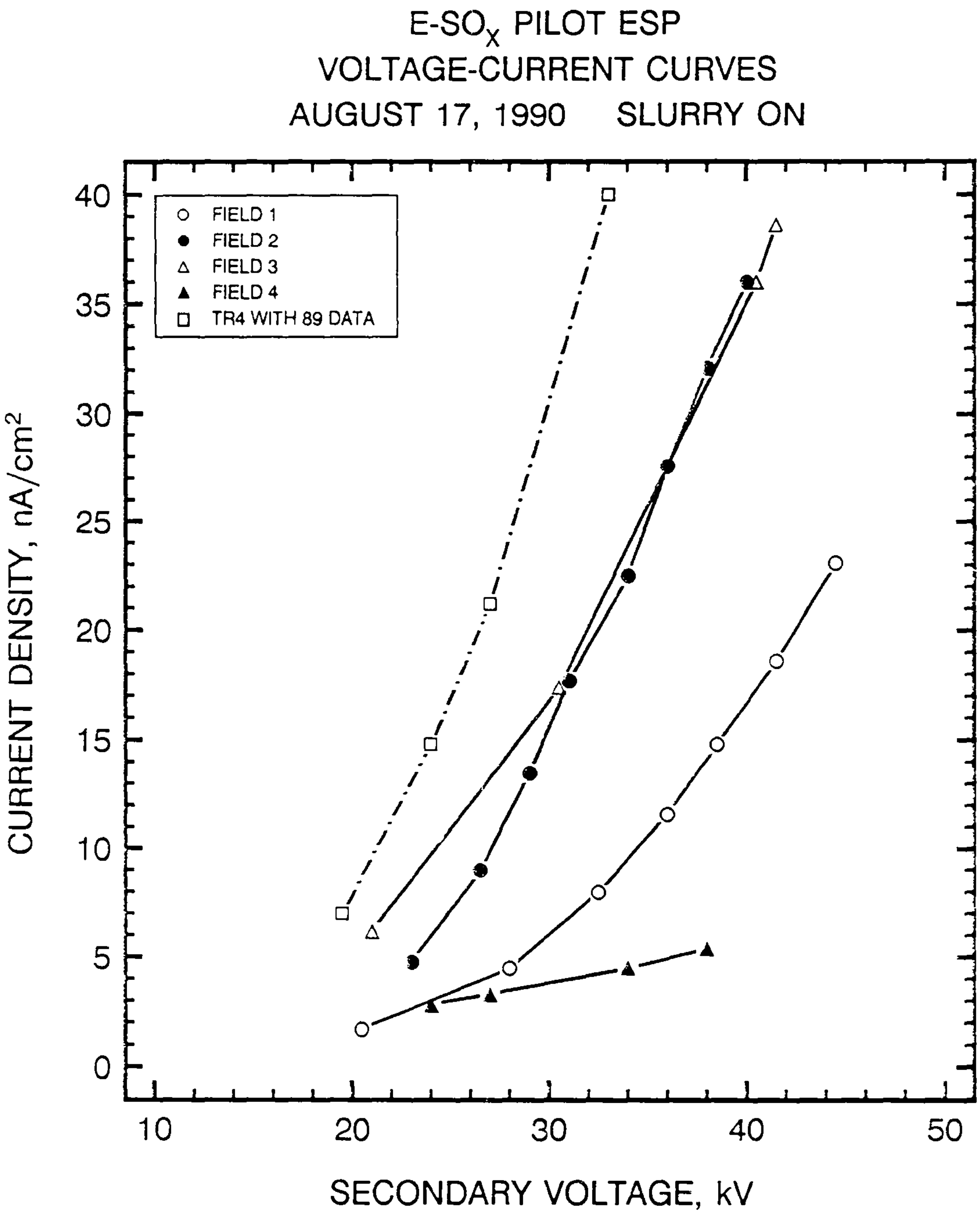

Figure 27. Voltage-Current Curves for August 17, 1990; Lime Slurry.

Table 16

E-SO_x PILOT PRECIPITATOR
AVERAGE OF VOLTAGE AND CURRENT READINGS
AUGUST, 1990

	TR #1		TR #2		TR #3		TR #4		
Date	kV	mA	kV	mA	kV	mA	kV	mA	Conditions
8/9/90	35.4	7.5	42.5	21.5	48.1	28.6	41.4	3.2	Baseline Flyash
8/11/90	38.5	7.5	39	21.9	38	29	38.3	3.3	Baseline
8/11/90	38.3	7.6	39.3	21.8	37.7	30	37.7	4.2	Zeroed Meters Ca/S = 1.05 160°F
8/16/90	42.75	17.8	38.8	30.5	37.8	30	34.3	4.2	Unit 8 Ca/S = 1.33
	40.4	18	38.8	30	38.3	30	35.5	4.1	Unit 7 Ca/S = 1.15
8/17/90	41.2	18	39.7	31.2	40.3	30	36.7	4	Impactors Today Ca/S = 1.2 165°F
8/18/90	41	18	40	28	41	29	39	4.2	Slurry @ Ca/S = 1.45 160°F
	44	17.9	41	29.7	42.8	29.7	39.7	4	Slurry + alum Ca/S = 1.35 160°F
	45.25	18	42	30	42	29.5	39.5	4	Slurry + alum Ca/S = 1.35 170°F
	44.75	18	41	29	42.5	30	40	4	Slurry Ca/S = 1.36 160°F
	45.5	18	41.3	29.2	42.9	29.8	40.5	4.1	Slurry + $CaCl_2$ Ca/S = 1.35 160°F

are contained in Figure 28, while Figure 29 presents the data as calcium to iron ratio vs. particle size. These data are similar to those from the 1989 test series in that they demonstrate an enrichment of calcium in the outlet fine particle size bands. This observation again suggests deagglomeration of slurry residue within the ESP.

Discussion

With the modifications to the ESP inlet gas flow and temperature distribution, data in Table 15 indicate that 50% removal of SO_2 and emissions of less than 0.1 lb/MMBtu were attained during one of the tests and possibly during the impactor test day. Steady state conditions were never achieved during the pilot ESP extension tests due to the fact that the ESP was placed in a closed loop arrangement each night. Because of this, long term conclusions cannot be drawn from these results. Although the temperature maldistribution at the inlet of the ESP was solved, the dependence of the outlet emissions on temperature is still quite evident. The data in Table 14 and Figure 15 indicate clearly the effect of temperature and outlet emissions as related to the E-SO_X process at the Burger Station facility.

The additives, alum and calcium chloride, were expected to reduce the outlet emissions by increasing the tensile strength properties of the particulate layer, thus reducing reentrainment within the ESP. Others have reported the positive effect of calcium chloride[7] used in spray dryer FGD systems followed by an ESP. The EPRI article states that SO_2 removal and the removal efficiency of the ESP were enhanced with chloride addition. Neither of these increases were observed during the limited time the chloride additive was injected at the E-SO_X facility.

The dependence of ESP collection efficiency on inlet temperature, while slurry was injected, was again demonstrated, as the data in Figure 15 illustrate. The outlet emissions were reduced while alum was being added by raising the average inlet temperature 10°F.

The voltage-current data indicated a possible problem with the fourth field transformer, but there were no spare transformer-rectifiers available for substitution during the test program.

E-SO_X PILOT ESP
EDX SIGNAL RATIOS vs PARTICLE SIZE
Ca/Si RATIOS FROM IMPACTOR SUBSTRATES

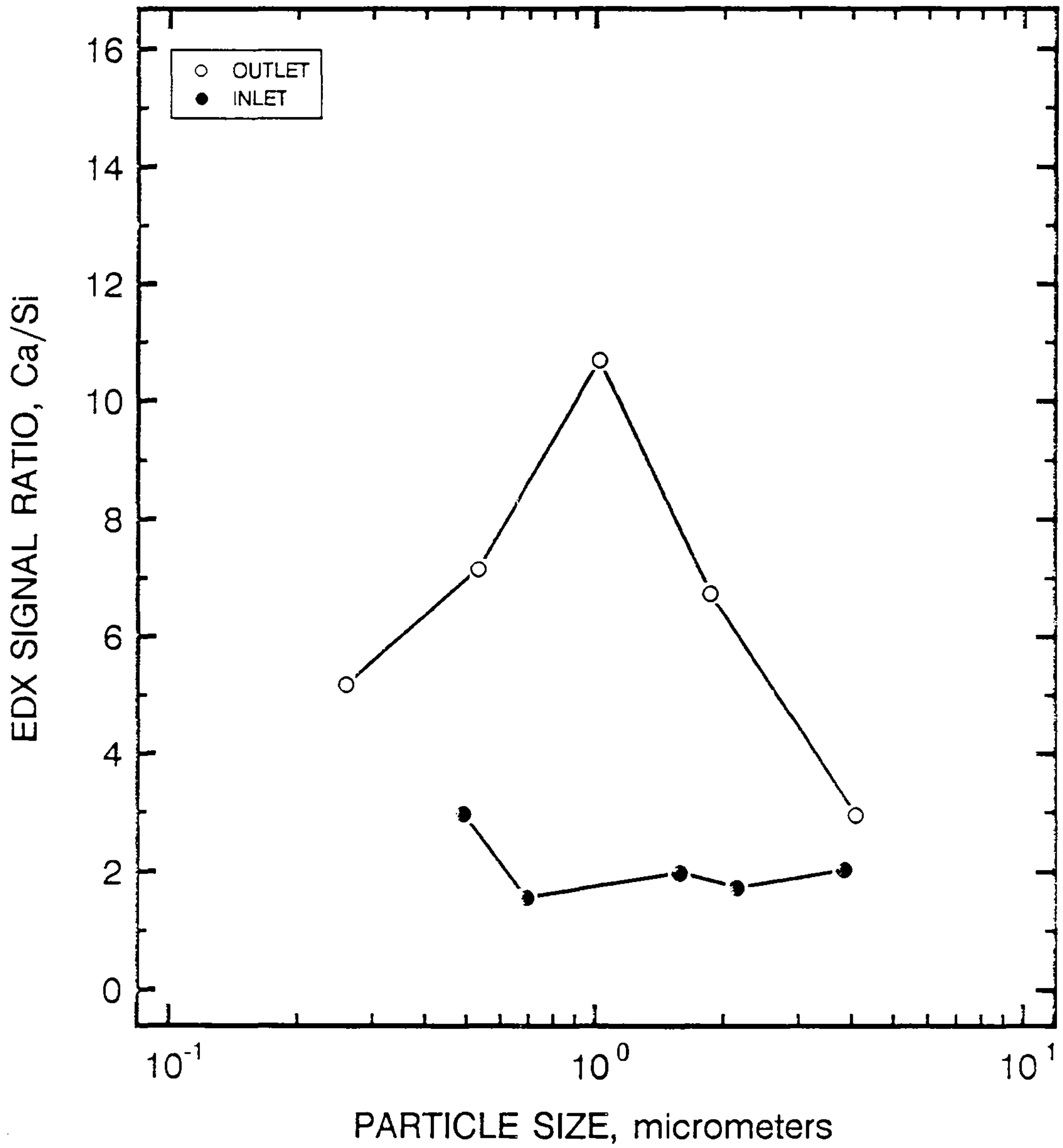

Figure 28. Ca/Si EDX Ratios vs. Particle Size; August 1990.

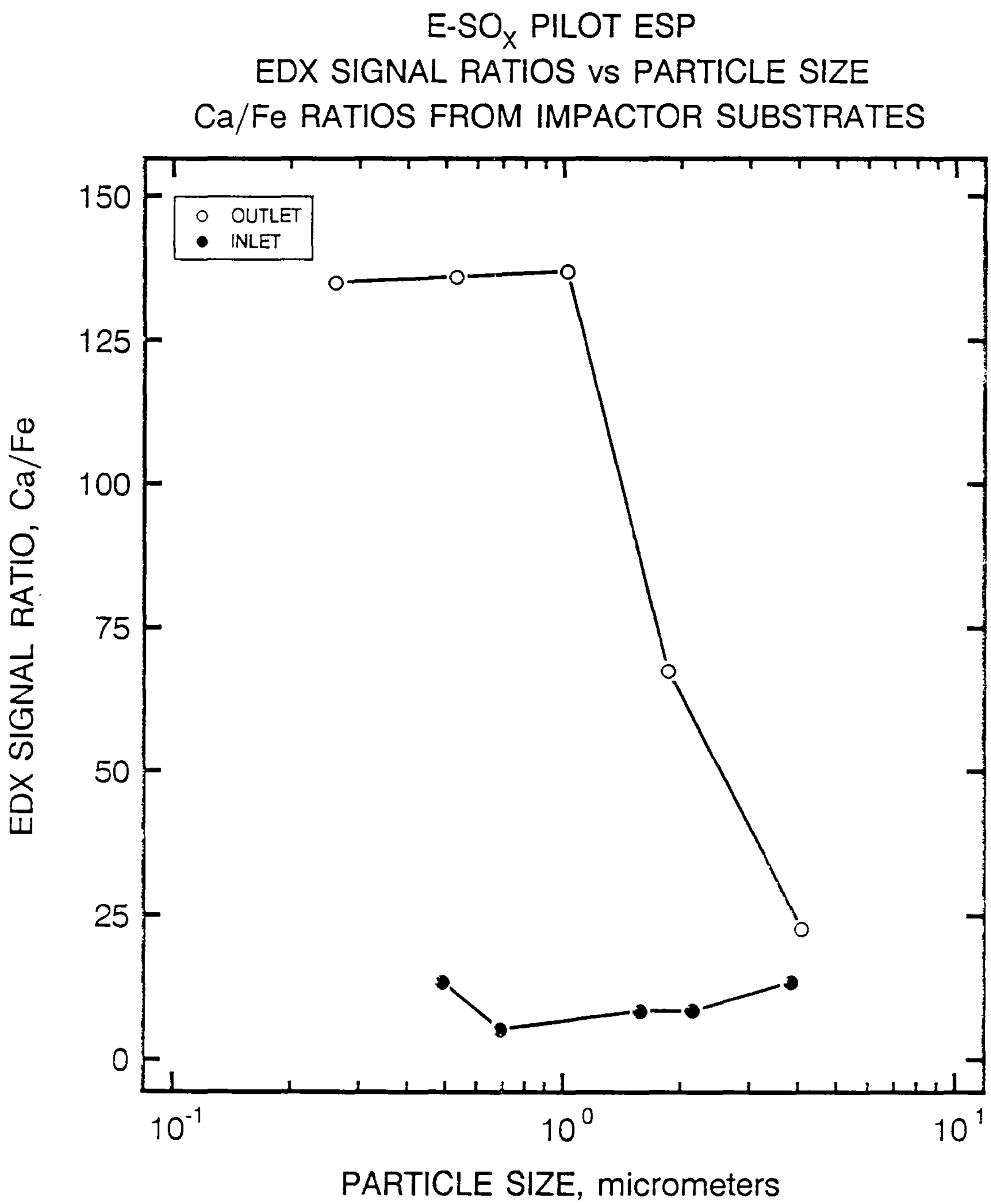

Figure 29. Ca/Fe EDX Ratios vs. Particle Size; August 1990

SECTION 4

CONCLUSIONS

1. Analysis of particle size fractions collected on impactor stages at the inlet and outlet of the E-SO_x ESP showed a large increase in the relative calcium content of the finer size fractions across the ESP.

2. Massive reentrainment of ash/sorbent mixtures could be induced without electrode rappers in service by lowering the operating temperature of the ESP inlet. The reentrainment could be reduced by elevating the average inlet operating temperature 10 to 20°F with no accompanying change in secondary voltages and currents.

3. ESP performance for the E-SO_x process, as evaluated at the Burger station with the coal, lime and conditions present during testing, is dominated by two factors not represented in the existing EPA-SRI versions of the mathematical model of ESP performance. These factors are instantaneous reentrainment of low resistivity ash/sorbent particles and deagglomeration of slurry residue within the ESP.

4. Significant improvement of the velocity and temperature profiles downstream from the DID array allowed outlet particulate emissions to be reduced to less than 0.1 lb/10^6 Btu with 50% SO_2 removal. However, the severe reentrainment problem within the ESP was still present, especially at temperatures below 160°F.

5. Additional work would help develop a quantitative understanding of the chemical and physical properties of slurry residues which result in poor ESP performance. Slurry additives designed to increase dust layer tensile strength and reduce reentrainment showed no beneficial effects during the brief test periods that were possible in the current program. Additional testing with these additives could include longer term and more stable process operating conditions.

SECTION 5

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16. ABSTRACT The report gives results of an evaluation of the E-SOx process at Ohio Edison's Burger Station. Adequate sulfur dioxide (SO2) removal and acceptable particulate emission levels from the electrostatic precipitator (ESP) were the prime objectives of this investigation. The report describes limited ESP performance testing under both baseline and E-SOx conditions. The ESP data collected under E-SOx conditions, which give the required 50% SO2 removal, show evidence of ESP performance dominated by factors not represented in existing versions of ESP performance models. Analyses of particle size fractions from impactor stages revealed that the relative calcium content of the finer size fractions increased from inlet to outlet. These analyses and other considerations indicate that the factors which dominate under the conditions tested are a combination of instantaneous reentrainment of low resistivity ash/sorbent particles and deagglomeration of slurry residues within the ESP. These observations may be important to other sorbent injection processes as well as to E-SOx. Improvement of the gas velocity and temperature distributions at the ESP inlet improved the ESP performance, but performance was still dominated by the reentrainment process and was therefore lower than mathematical model predictions.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Electrostatic Precipitators	Stationary Sources	13I
Sulfur Dioxide	E-SOx Process	07B
Particles	Particulate	14G

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