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Effects of Conditioning Agents on Emissions from Coal-fired Boilers: Test Report No. 2

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Effects of Conditioning Agents on Emissions from Coal-fired Boilers: Test Report No. 2

by

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ABSTRACT

A field performance test was done on an electrostatic precipitator (ESP) which uses Apollo Chemical Company's LPA 445 and LAC 51B flue gas conditioning agents. The ESP is located at an electric utilities power plant, burning approximately 1 to 2% sulfur coal.

Tests were conducted with and without injection of the conditioning agents. The ESP performance was characterized in terms of particle collection efficiency and the chemical composition of particulate and gaseous emissions. Fly ash resistivity and flue gas opacity were also measured.

Measurements indicate that there was no significant change in overall penetration (0.4%) between the conditioned and unconditioned tests. There was some evidence that the conditioning agents reduced reentrainment during electrode rapping and possibly improved the fractional collection efficiency slightly for particles smaller than about 5 μm diameter.

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ACKNOWLEDGMENT

A.P.T. wishes to express its appreciation to Dr. H.J. White who provided valuable consultation, and to Dr. Leslie Sparks, the EPA Project Officer, for excellent coordination and technical assistance in support of this test program. The assistance and coordination provided by plant personnel at the test site also is sincerely appreciated.

SECTION 1

INTRODUCTION

The Particulate Technology Branch of the U.S.E.P.A. Industrial Environmental Research Laboratory, Research Triangle Park, NC has contracted with A.P.T., Inc. to conduct a series of performance tests on electrostatic precipitators (ESPs) which use flue gas conditioning agents. This report is the result of a performance evaluation test conducted at an electric utilities plant in the Spring of 1978.

Conditioning agents are used either to improve the overall particle collection efficiency of ESPs or to reduce the opacity of the emissions. The improved performance is often a result of a decrease in the fly ash electrical resistivity. However, other effects such as an increase in space charge and a reduction in rapping reentrainment losses may be more important than resistivity in some situations.

The purpose of this test program is to obtain an extensive data base which may be used to evaluate the effect of gas conditioning agents on overall ESP performance. Furthermore, the tests will identify and quantify any additional pollutants which may be emitted when using the conditioning system.

SECTION 2

SUMMARY AND CONCLUSIONS

A performance test was done on an electrostatic precipitator (ESP) which used an Apollo Chemical Company conditioning system. The conditioning agents were LPA 445 and LAC 51B. The chemical composition of the conditioning agents is proprietary. ESP performance was evaluated with and without the use of the conditioning system. The primary performance criteria were the changes in the overall and fractional particle penetrations. The chemical composition of particulate and gaseous emissions, opacity in the ESP exit duct, and fly ash resistivity were also measured.

The data indicate that the average overall penetration (0.4%) was not affected by the conditioning agent. These data cover a wide range of boiler load, volumetric flow, sulfur concentration and other parameters.

Due to fluctuations in boiler load all of the tests are not comparable. However, tests run on May 11 with the conditioning system operating and the tests run on May 16 with the conditioning system turned off were run while the boiler was operating at a load of 440 MW. The three (conditioned) runs on May 11 resulted in particle penetrations of 0.1, 0.2, and 0.1%; on May 16 (unconditioned) the resultant penetrations were 0.2, 0.3, and 0.3%. The apparent change of approximately a tenth of percent in penetration represents a change of more than 100% in outlet particulate loading. The fractional penetration curves also indicate an improvement in collection of particles from 0.2 μm to 2.0 μm diameter associated with conditioning. However, the improvement is not reflected in the precipitation rate parameter (Table 1).

The recorder plots of the duct opacity clearly show reentrainment "puffing spikes." The puffing spikes are much larger during the unconditioned tests than during the conditioned tests. The average opacity between "puffing spikes" was approximately the same for both tests.

The primary composition of the stack gas was not noticeably altered by the injection of the Apollo additives. The flue gas sulfur dioxide content fluctuated erratically during both test periods, corresponding roughly to sulfur content changes in the coal. The electrical resistivity of the fly ash increased slightly during the conditioned tests, but the difference is statistically insignificant.

TABLE 1. ELECTROSTATIC PRECIPITATOR DESIGN AND TEST DATA

DESIGN DATA

Start in 1968.

Rated for 697 m^3/s (1,470,000 ACFM) @ 98% efficiency.

Gas velocity 2.14 m/s (7.0 ft/s)

78 ducts per chamber - 9.15 m (30 ft) high, 8.24 m (27 ft) long, 0.229 m (9 in) wide.

Collection surface area per chamber - 11,739 m^2 (126,360 ft^2).

Specific collection area (SCA) - 34 $m^2/m^3/s$ (171 ft/1,000 ACFM).

36 wires/duct - 2.77 mm (0.109 in) diameter, equally spaced with respect to plates and each other.

5 electrically isolated transformer-rectifier sets per chamber - maximum power consumption approximately 77 kW/set; each set rated at 400 line volts, 240 line amps, 45 kV and 1.5 amps in the precipitator.

Precipitation rate parameter - $W_e = 0.115$ m/s (0.377 ft/s).

TEST DATA - ESP 3B

Conditioned - May 11 (3 Tests)

Average Flow - 431.3 m^3/s @ the inlet, 334.9 m^3/s @ the outlet

SCA* - 35.0 $m^2/m^3/s$

$W_e = 0.19$ m/s (0.62 ft/s) based on an overall average efficiency of 99.9%.

Unconditioned - May 16 (3 Tests)

Average Flow - 461.7 m^3/s @ the inlet, 371.7 m^3/s at the outlet

SCA* - 31.6 $m^2/m^3/s$

$W_e = 0.18$ m/s (0.60 ft/s) based on an overall average efficiency of 99.7%.

*The SCA is based on the outlet flow rates since they are generally more reliable (White, 1963).

SECTION 3

PHYSICAL AND MECHANICAL PARAMETERS

The utilities power plant which was the emissions source for this study operates at a total output of 1,600 MW. The testing was performed on unit No. 3, a Babcock & Wilcox boiler which is rated at 480 MW. Normal operation results in a daily average of 300 MW producing 24,820 kPa (3,500 psi) steam at 593°C (1,000°F).

Two parallel ESPs are used to collect the fly ash produced by unit No. 3. The plant layout is shown schematically in Figure 1. The gas flow through each unit depends on pressure drop through the air preheaters. The inlet ducting drops in elevation by about half a diameter through an offset bend and into a diverging section immediately before the ESP. Twelve inlet sampling ports are located at the upstream edge of this diverging section. At the downstream end of the ESP is a diverging section where four outlet sampling ports are located. The ESPs are divided into five sections, each one electrically isolatable and each one equipped with a transformer-rectifier set. This configuration is presented schematically in Figure 2. Magnetic impact type rappers operating every two minutes remove the collected fly ash from the plates. The ash falls into hoppers and is subsequently transferred by a pneumatic handling system to a water sluicing tank and settling pond.

The flue gas conditioning system was provided by Apollo Chemical Corporation. Two conditioning agents were injected; LPA 445 and LAC 51B. LPA 445 was injected through six nozzles into the economizer section where the flue gas temperature was approximately 600°C. LAC 51B was injected downstream from the

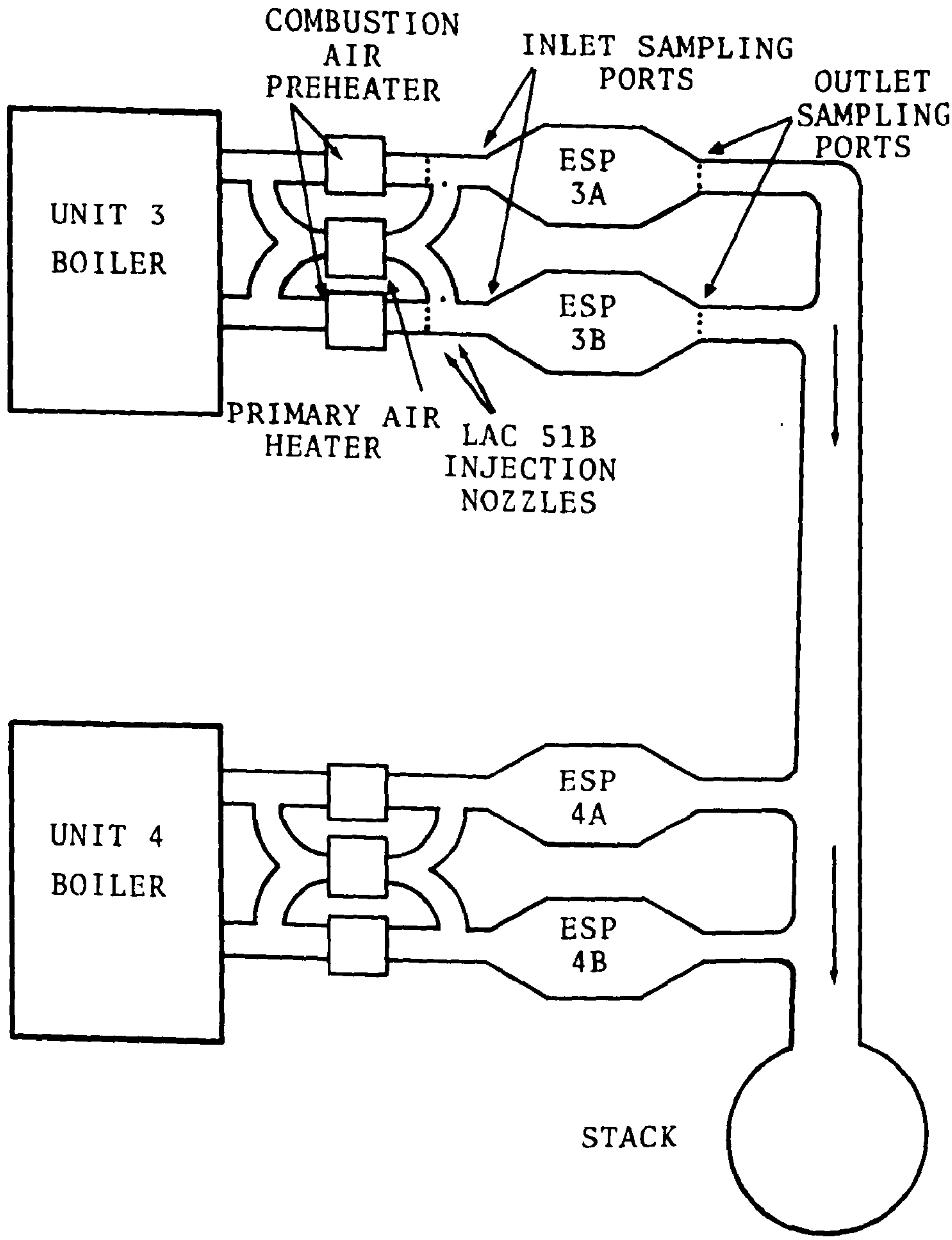

Figure 1. Plant layout.

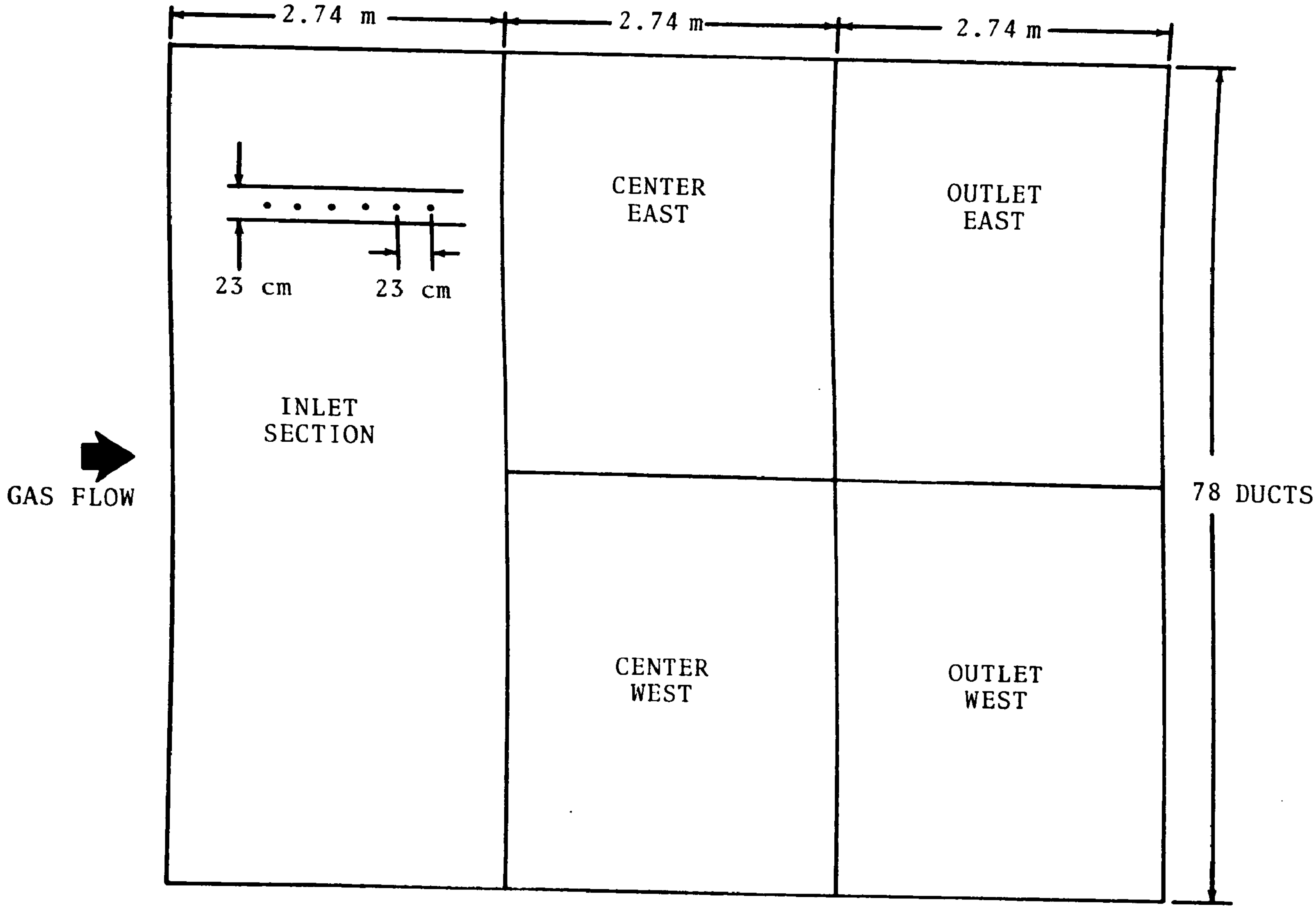

Figure 2. Schematic of ESP 3A (not drawn to scale).

air preheater through four nozzles. The flue gas at this injection point was approximately 120°C. The injection rate for both additives was automatically controlled with the coal feed rate: 0.31 cm^3 LPA 445/kg of coal (0.075 gal/ton) and 0.42 cm^3 LAC 51B/kg of coal (0.10 gal/ton).

During the test period the boiler was operated at levels above the average load (300 MW) but generally below full load. The generator output is summarized in Table 2. Previous to the installation of the conditioning system the stack gas particulate loading exceeded compliance limits (0.1 kg/J; 0.24 lbs/10^6 BTU) for generator output in excess of 300 MW, hence boiler load levels were high enough to provide representative emissions.

Current-voltage characteristics were generated for ESP 3B for both the conditioned and unconditioned test periods (Figures 3-7). The conditioned gas curves demonstrate increases in voltage and decreases in current relative to the baseline curves. However the inlet section of the ESP was inoperable on April 21 when the V-I data were being obtained during the conditioned test period. This very likely accounts for the significant difference between the conditioned and baseline cases. With the inlet section shorted there will be no particle collection, hence particle concentration will be much greater in the following sections. The higher concentration of charged particles will result in a substantial space charge which will act to suppress the corona currents. This explanation is consistent with the observation that the difference is smaller in the outlet section where the particle concentration is not as high and the space charge consequently not so great.

The normal operating conditions of ESP 3B are presented in Table 3. The 5 kV drop in the average secondary voltage may have been due to meter or voltage divider malfunction and should not be considered as indicative of a system alteration. This is borne out by the fact that neither the currents nor efficiencies change as would be expected for a significant voltage drop.

TABLE 2. BOILER LOAD

Date	Boiler Load MW
4/12/78	460
4/18/78	460
4/19/79	460
4/20/78	460 (380 mid-day)
4/21/78	440 (450 afternoon)
4/22/78	440 (350 before 11 AM)
5/10/78	420 (320 mid-day)
5/11/78	440
5/16/78	440
4/17/78	400

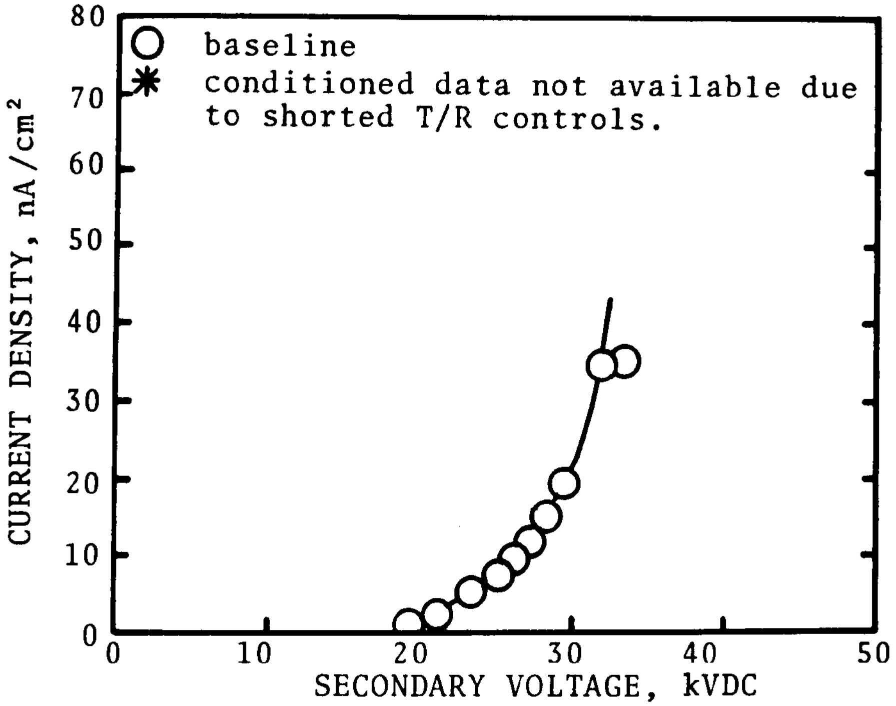

Figure 3. ESP voltage-current relationship, inlet section.

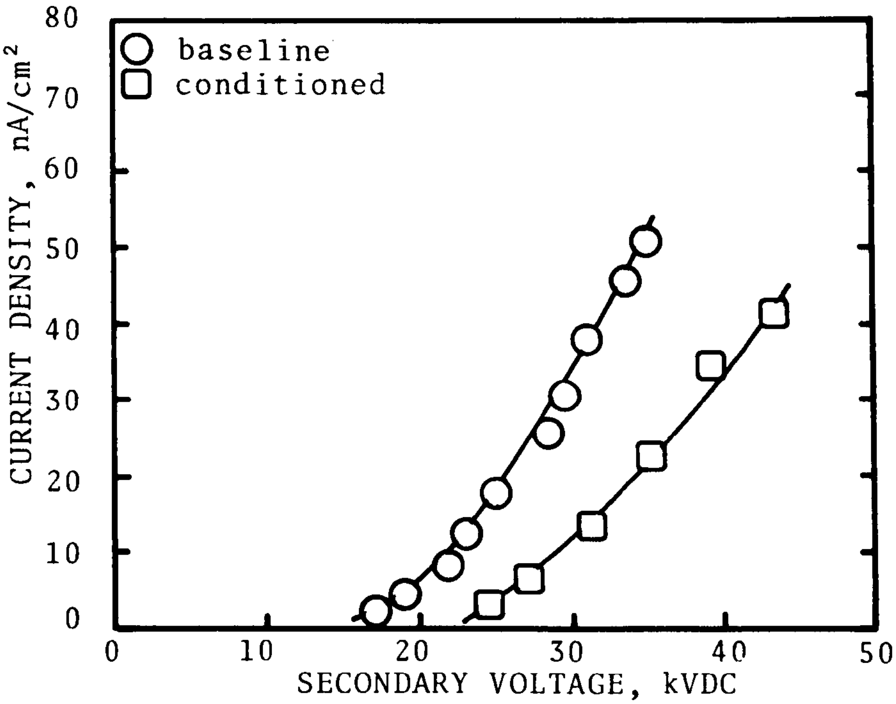

Figure 4. ESP voltage-current relationship, center east section.

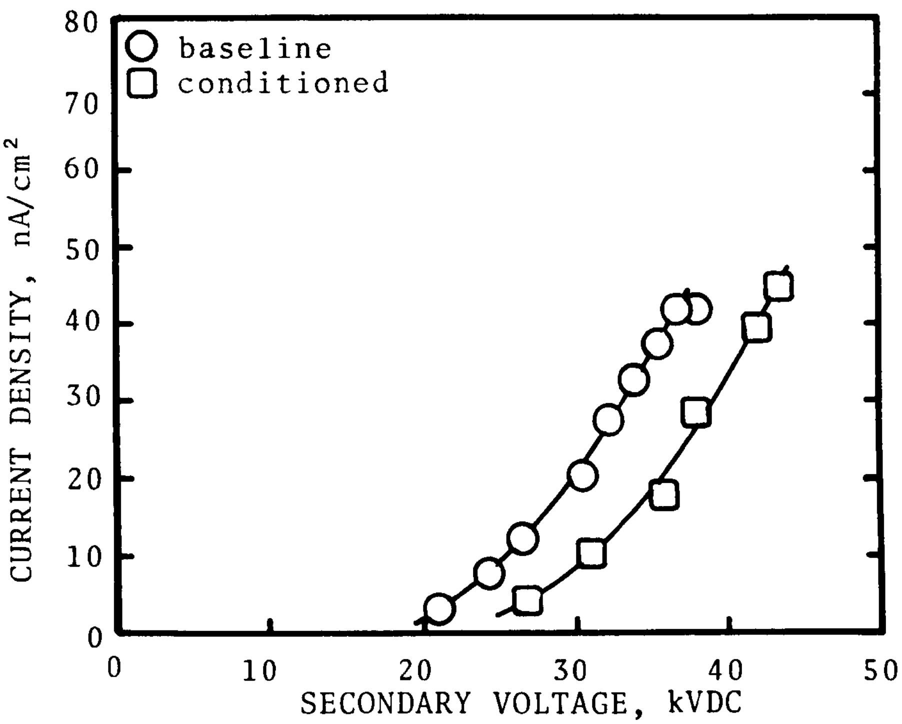

Figure 5. ESP voltage-current relationship, center west section.

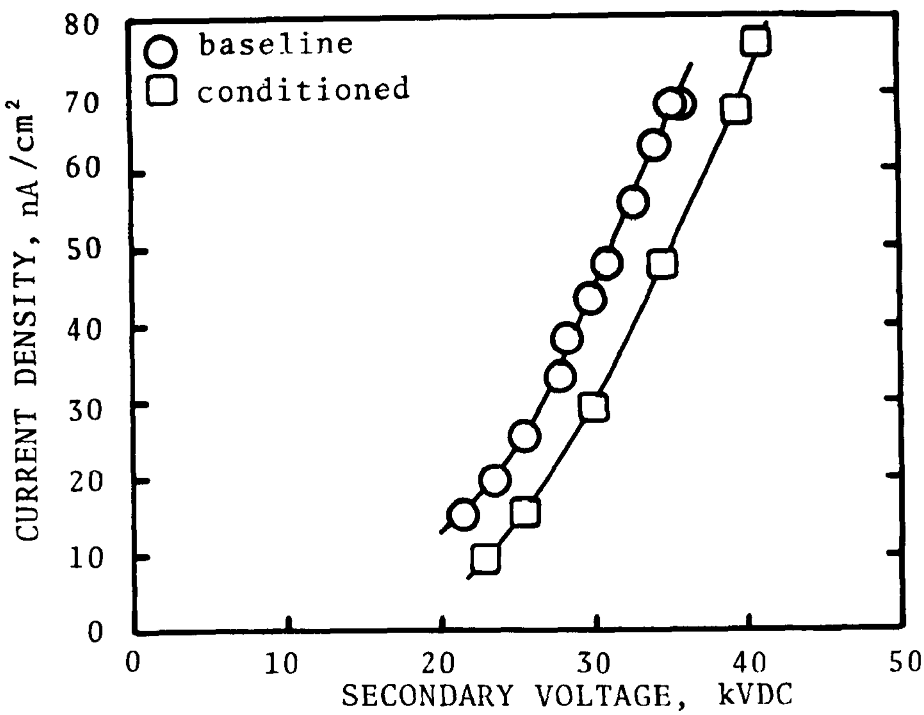

Figure 6. ESP voltage-current relationship outlet, east section.

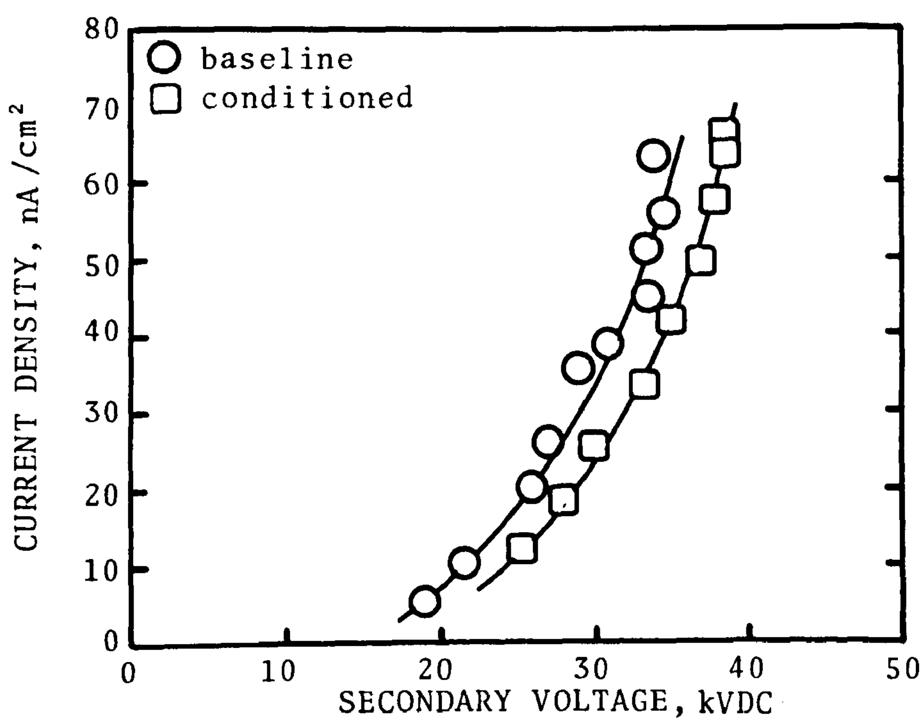

Figure 7. ESP voltage-current relationship outlet, west section.

TABLE 3. AVERAGE ELECTRICAL CONDITIONS FOR ESP 3B

DATE	INLET		OUTLET WEST		OUTLET EAST	
	Secondary Voltage kVDC	Secondary Current DC amps	Secondary Voltage kVDC	Secondary Current DC amps	Secondary Voltage kVDC	Secondary Current DC amps
4/17	45.5	1.30	39.5	1.20	41.0	1.50
4/18	44.0	1.26	40.0	1.30	42.0	1.40
4/19	42.0	1.47	37.0	1.12	39.2	1.45
4/20	42.7	1.36	38.8	1.29	40.0	1.48
4/21	----	1.32	43.8	1.31	41.5	1.48
4/22	----	1.30	38.9	1.30	39.8	1.50
5/10	32.8	1.31	36.7	1.33	36.0	1.38
5/11	34.3	1.32	38.2	1.26	37.0	1.36
5/16	32.7	1.31	36.8	1.28	36.5	1.38
5/17	35.5	1.30	36.3	1.28	37.0	1.37
5/18	32.4	1.28	36.5	1.22	36.0	1.34

Average totals across ESP:		Secondary Voltage	Secondary Current	Current Density
Conditioned:	4/17-4/20	41.0 kVDC	1.35 A	1.18×10^{-4} A/m^2
	5/10-5/11	35.8 kVDC	1.33 A	1.13×10^{-4} A/m^2
Baseline:	5/16-5/18	35.5 kVDC	1.31 A	1.11×10^{-4} A/m^2

SECTION 4

TESTS

The field test spanned the period from April 17, 1978 through May 18, 1978. On April 21 the inlet section of ESP 3B was shorted and tests were suspended on April 22 due to problems arising from this malfunction. The conditioned tests were resumed on May 10 and completed May 11. After a deconditioning period, the unconditioned tests commenced on May 16 and were concluded on May 18. Table 4 summarizes the tests performed and methods employed.

TABLE 4. TEST METHODS

ANALYTE	TEST	METHOD
Particulate	Mass & size distribution	Cascade impactor
	Overall collection efficiency	Modified method 5 and cascade impactor
	Resistivity	In-situ point to probe plane
	$SO_4^{=}$	Acid-base titration bromophenol blue as indicator
	Elemental composition	Ion excited x-ray emission
Flue Gas (Composition)	% O_2 % CO_2 % CO	Orsat
	% H_2O	Wet-bulb dry bulb impinger catch
	SO_2 concentration	Dupont SO_2 stack analyzer
	SO_3 concentration	Controlled condensation
	NH_3 concentration	Kjeldahl method
Flue Gas (Physical Properties)	Velocity Static pressure	S-type pitot
	Molecular weight Density	Calculated from composition and temperature

SECTION 5

TEST RESULTS

PARTICULATE

Overall and fractional penetrations for ESP 3B were determined from particle mass data using in-stack cascade impactors. There is no change in average penetrations for the two tests. Both tests, conditioned and baseline, result in an average overall penetration of 0.4% with a standard deviation of 0.3. The results of the tests run at identical boiler loads do, however, indicate a slight improvement in overall penetration for the conditioned case. Table 5 summarizes the results for each impactor run. Also included are the results from the modified Method 5 which demonstrates the difference in penetration between the parallel ESPs on unit No. 3.

The size distributions from the inlet and outlet sampling ports for both cases are illustrated in Figure 8. Detailed particulate data are presented in Appendix "A". The volume median diameters (VMD) decrease from roughly 20 μm at the inlet to slightly below 10 μm at the outlet which is consistent with the total penetration results, as is the generally good agreement between the distributions for the different cases. Extrapolation was necessary to estimate the VMD for the inlet cases because a pre-cutter was needed on the inlet impactor runs to reduce the total sample load. The average cut point for the pre-cutter ranged from approximately 6 to 7 μmA* for these tests.

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*The convention of using "μmA" for aerodynamic diameters and "μm" for physical diameters is adhered to in this report. The aerodynamic diameter "d_{pa}" is related to the physical particle diameter "d_p" by:

$$d_{pa} = d_p(C'\rho_p)^{1/2}$$

TABLE 5. SUMMARY OF OVERALL PENETRATIONS

Run No.	Boiler Load MW	Inlet Conc. mg/DNm^3	Outlet Conc. mg/DNm^3	Overall Penet. %
With Conditioning Agent				
2	460	4,200	30.0	0.7
5	460	21,900	43.3	0.2
7 Blank	NA	12,200	28.0	0.2
8 Blank	NA	5,140	27.0	0.5
9	320	6,620	17.0	0.3
10	450	5,850	60.3	1.0
11	440	6,460	7.5	0.1
12	440	7,570	11.3	0.2
13	440	10,500	6.4	0.1
			Average	0.4
			Std. Dev.	0.3
1-M5 (3A)		6,330	183.0	2.9
1-M5 (3B)		6,750	69.9	1.0
Without Conditioning Agent				
14 Blank	NA	7,460	16.8	0.2
15	440	9,850	7.9	0.2
16	440	8,420	21.8	0.3
17	440	10,600	29.7	0.3
20	NA	7,890	10.9	0.2
19 Blank	NA	7,400	9.8	0.2
21	NA	6,060	44.3	0.8
22	410	9,060	95.9	1.1
			Average	0.4
			Std. Dev.	0.3

*Runs 2 through 7 were run from 4-17-78 through 4-22-78.

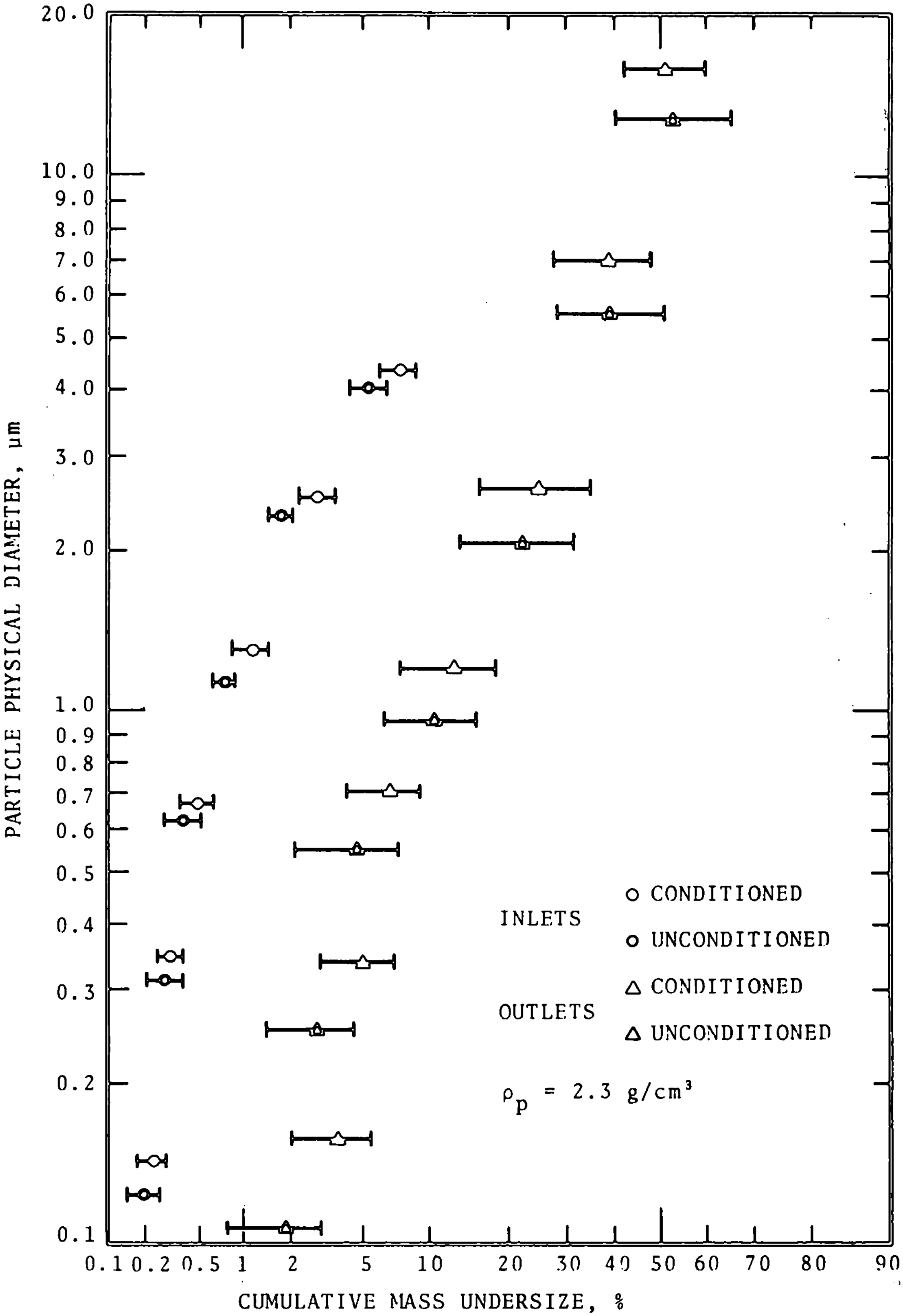


Figure 8. Particle size distribution showing 90% confidence intervals.

Consequently, extrapolation into the 20 μm range for the physical VMD for the inlet mass loading is subject to some question. However, the estimated VMD of 20 μm and geometric standard deviation of about 3.0 are consistent with published data for pulverized coal-fired boilers (Oglesby, 1970).

The grade penetration curves present evidence from the particulate data that there is a difference between the conditioned and unconditioned tests. A logarithmic spline fit to the cumulative mass curves for simultaneous inlet and outlet samples was used to generate the grade penetration curves shown in Figures 9 and 10. The conditioned test curves appear to average a lower penetration for fine particles than the unconditioned test. This is borne out when the average curves for the tests run during similar plant operation are plotted (Figure 11); however, the standard deviations of the data render the difference between the curves questionable.

An ESP performance model (Sparks, 1978) was used to generate the predictions of ESP penetration shown in Figure 11. Clearly the precipitator performed with much greater efficiency than the model predicted. For the conditioned case this may be due to the additives; however, baseline performance is also nearly an order of magnitude better than predicted.

Fly ash samples were analyzed for sulfate particles and elemental composition. Fly ash resistivity was measured in-situ. The particulate sulfate for all runs that were analyzed was below the 1 ppm detection limit for the method employed. The resistivity and elemental composition data are presented in Table 6 and Figures 12 and 13, respectively. The elemental composition results are estimated from results based on a 0.125 cm^2 area of the substrate which was analyzed by ion-excited X-ray emission. The viewing area is representative of the mass collected but correlation to the volume sampled is necessarily an approximation. Detailed results from the elemental analyses are also presented in Appendix "B". There is little or no significant change in these parameters for the two cases.

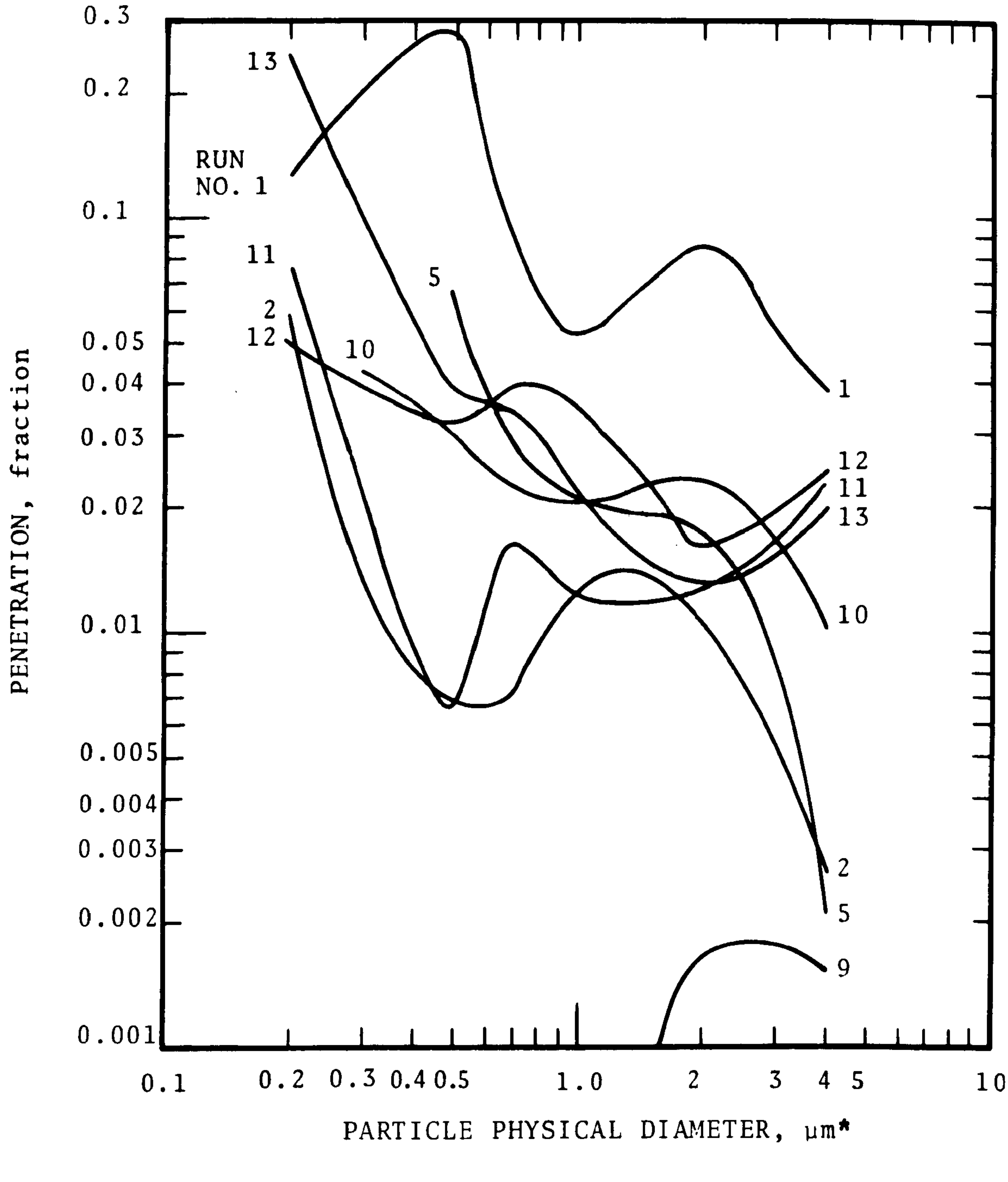


Figure 9. Fractional penetration curves for conditioned tests.

* Calculated from aerodynamic diameter using a particle density of 2.3 g/cm³

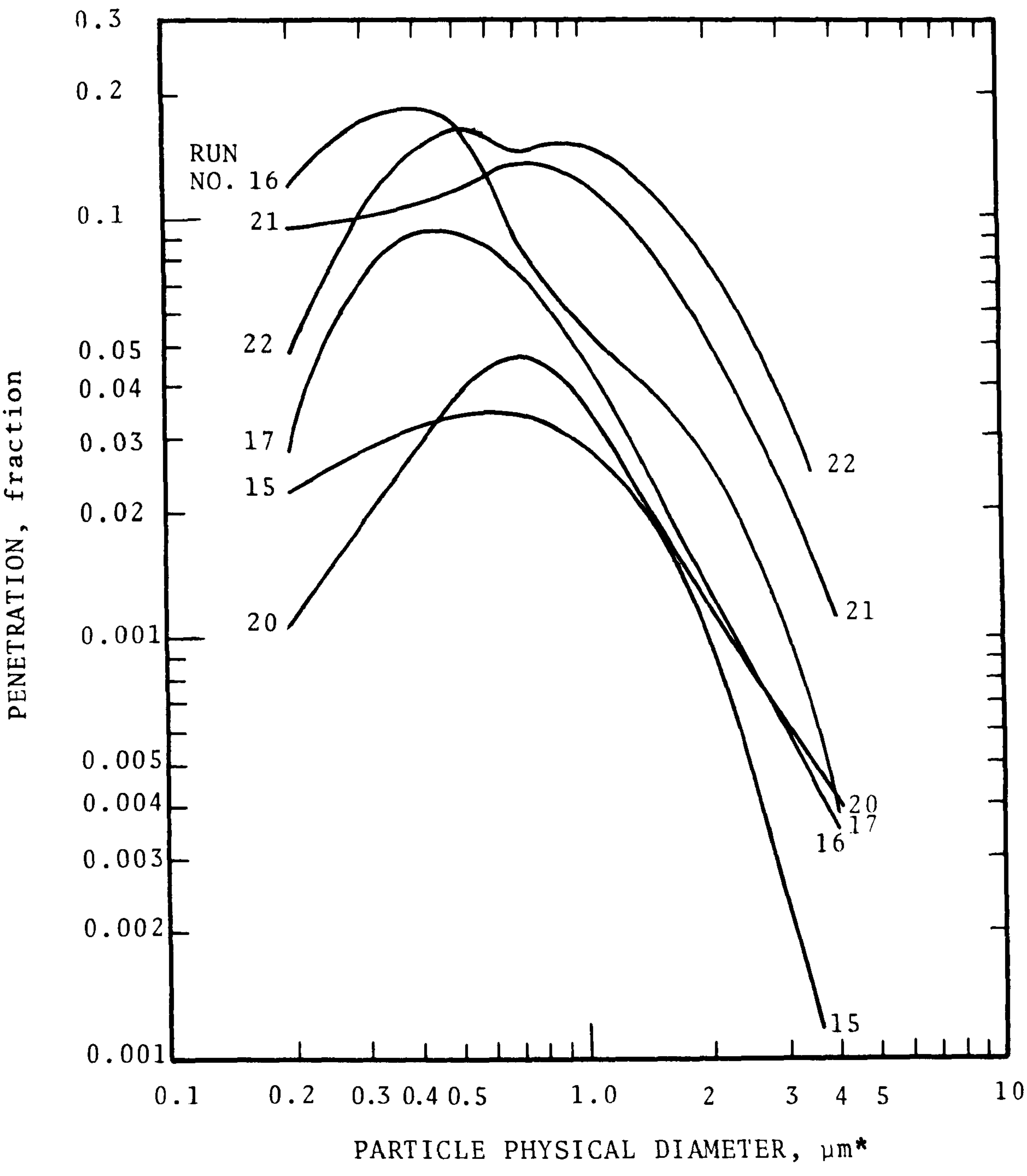


Figure 10. Fractional penetration curves for baseline tests.

* Calculated from aerodynamic diameter using a particle density of 2.3 g/cm³

TABLE 6. FLY ASH RESISTIVITY

Date	Temperature °C	(°F)	Resistivity Ω-cm
With conditioning agent			
4/20	117	(242)	6.5×10^{10}
4/21	114	(238)	9.0×10^{10}
4/22	107	(225)	6.7×10^{10}
4/22	110	(230)	5.4×10^{10}
		Avg.	6.9×10^{10}
		Std. Dev.	1.5×10^{10}
Without conditioning agent			
5/17	108	(227)	8.5×10^{10}
5/18	141	(286)	4.7×10^{10}
		Avg.	6.6×10^{10}
		Std. Dev.	2.7×10^{10}

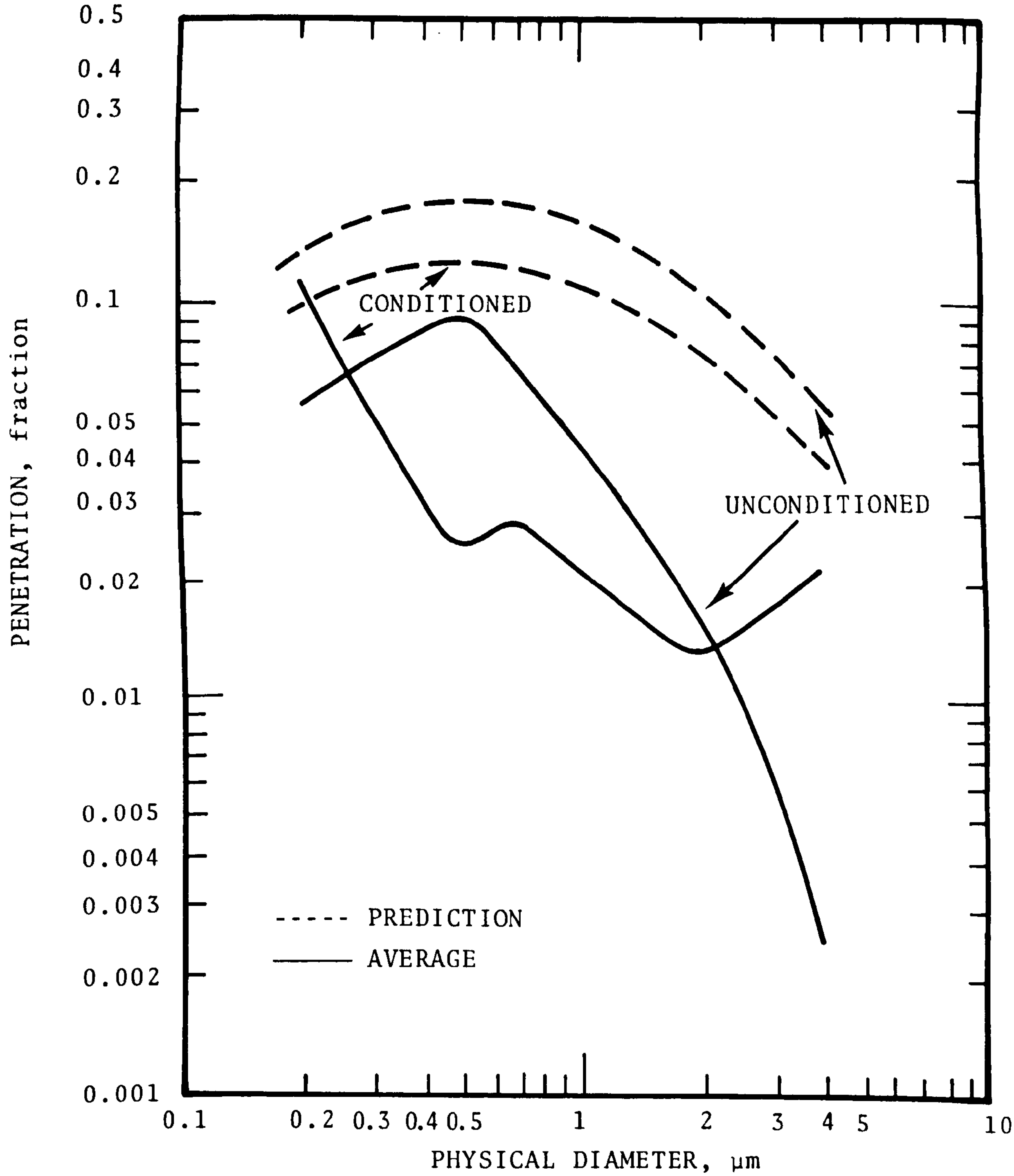


Figure 11. Average penetration curves for runs of May 11 and May 16.

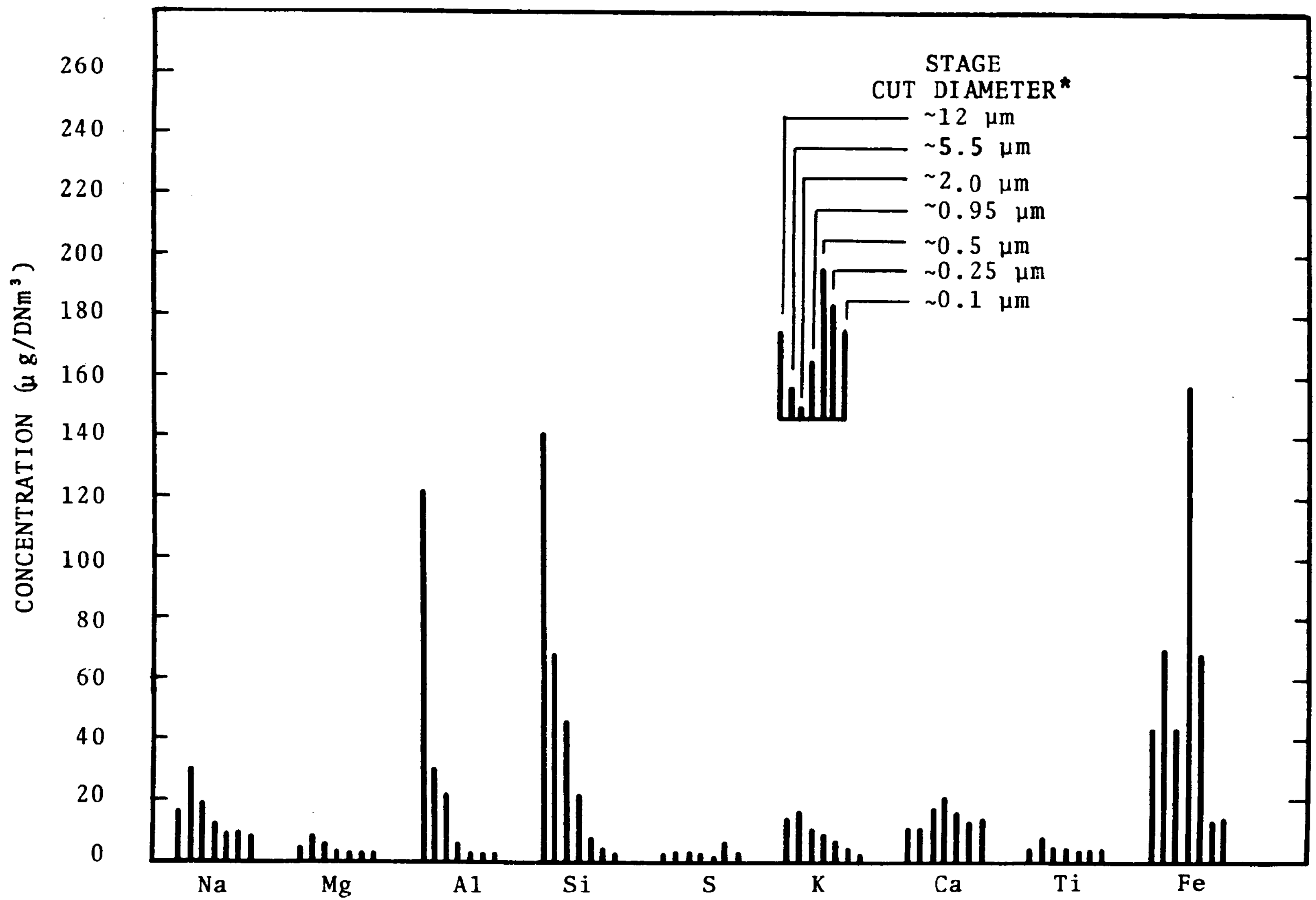


Figure 12. Mass concentrations of major elements in fly ash with conditioning.

* Physical diameter; calculated from aerodynamic

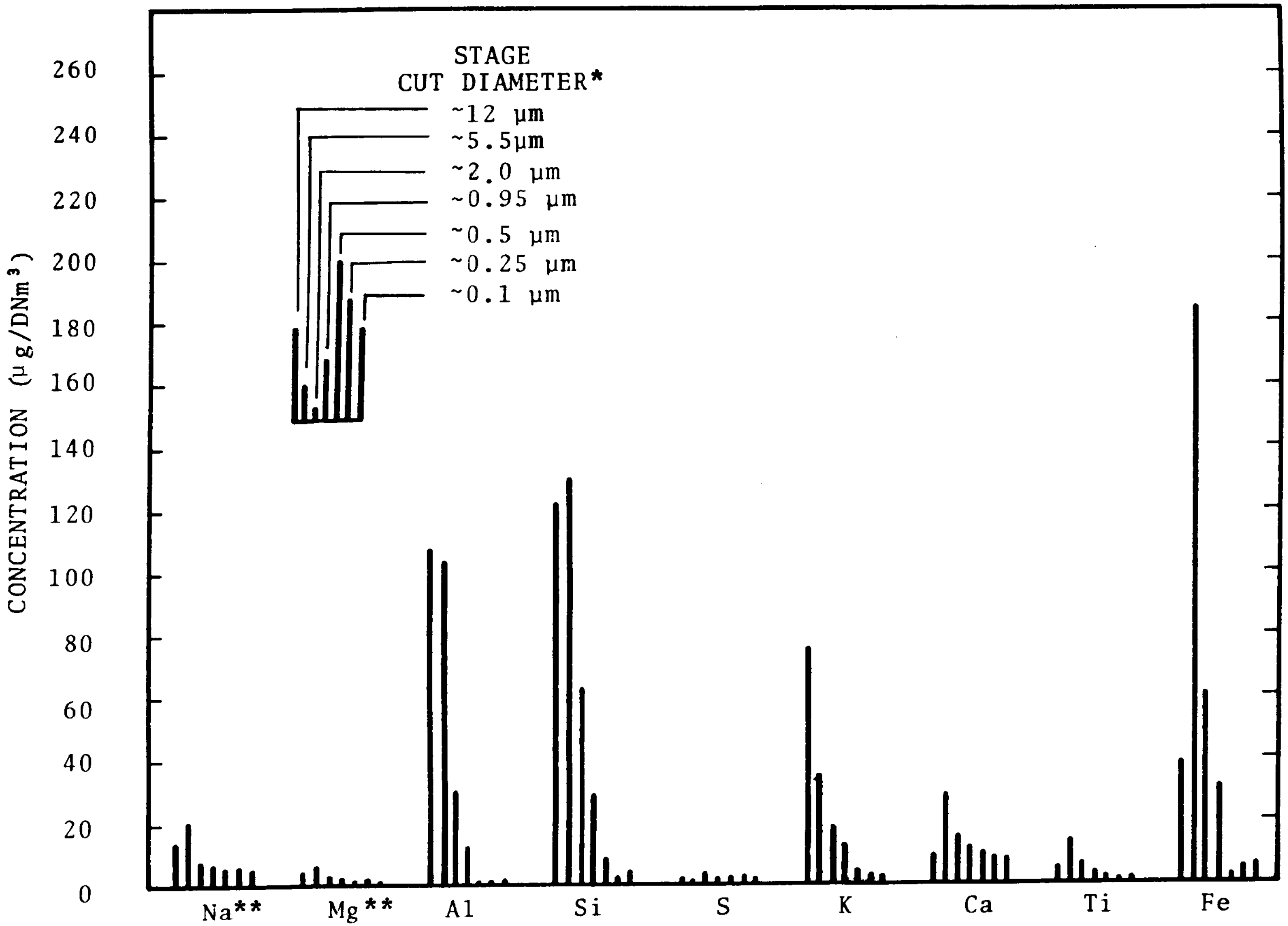


Figure 13. Mass concentrations of major elements in fly ash during baseline test.

* Physical diameter; calculated from aerodynamic diameter using a density of 2.3 g/cm³

**Denotes amount was less than this minimum detectable limit

FLUE GAS

The primary composition of the gas is consistent from inlet to outlet and from conditioned to unconditioned tests. The concentrations by volume percent of CO_2, O_2, CO, H_2O, and SO_2, are presented in Tables 7 and 8. The SO_2 concentration fluctuations closely follow the change in the sulfur content of the coal. Sulfur trioxide concentrations were near the method limit of detection, consequently long sampling times were required, magnifying analytical errors and possibly producing erroneous data. Generally the SO_3 concentration was below 1 ppm and showed no statistically significant changes for the two cases. The ammonia concentration of the flue gas was below the method limit of detection of 1 ppm. The flue gas composition is clearly unaffected by the additives and consequently would appear to have nothing to do with any performance changes due to the conditioning agents.

Opacity is one property of the stack gas which may reflect the operation and mechanism of the conditioning additives. The opacity was continuously monitored in the ESP outlet duct for the duration of both test periods. During the first week of the conditioned tests the opacity averaged approximately 30%. It rose slightly on April 21 when the inlet section of the ESP became inoperable. When testing was resumed after repair to the precipitator, the opacity had decreased to 15% and was steady during the remaining conditioned tests.

After the Apollo system was turned off, the nature of the stack gas opacity changed dramatically. Figure 14 illustrates the contrast; the spikes on the trace are due to reentrainment puffs during rapping. Clearly the conditioning agent effectively dampens reentrainment even though the minimum or baseline opacity appears unchanged. Determining the effective opacity quantitatively during the unconditioned test is obviously difficult, but the qualitative difference is clear.

COAL

Coal samples were taken from the coal pulverizers and from the coal conveyor. Table 9 contains the results of the chemical

TABLE 7. ESP INLET FLUE GAS CONDITIONS (DAILY AVERAGE)

Date	Flue Gas Temperature °C	Flue Gas Composition, Vol./Vol.				Average Velocity m/s
		$\%O_2$	$\%CO_2$	$\%H_2O$	SO_2 ppm	
4/17/78	123	--	--	4.4	--	15.4
4/18/78	129	4.4	14.0	3.3	--	--
4/19/78	129	--	--	--	836	--
4/20/78	123	--	--	3.5	1,118	18.5
4/21/78	119	3.2	14.6	--	779	--
4/22/78	107	5.0	13.9	3.4	849	--
5/10/78	114	6.6	12.6	6.2	612	14.4
5/11/78	121	3.0	15.4	8.6	1,080	17.1
5/16/78	116	--	--	5.7	729	17.7
5/17/78	116	--	--	5.7	962	15.1

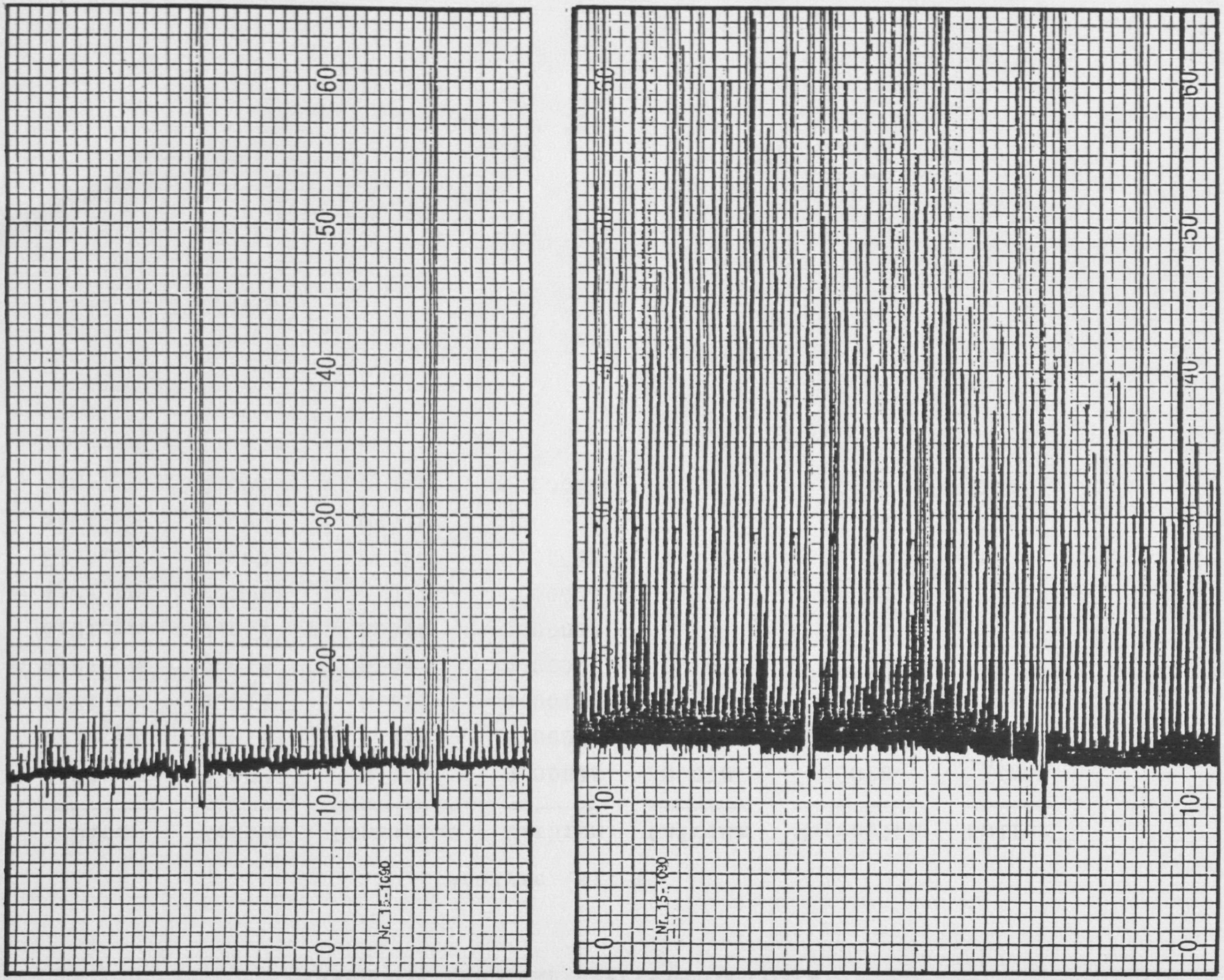
TABLE 8. ESP OUTLET FLUE GAS CONDITIONS (DAILY AVERAGE)

Date	Flue Gas Temperature °C	Flue Gas Composition, Vol./Vol. $\%O_2$	$\%CO_2$	$\%H_2O$	SO_2 ppm	Average Velocity m/s
4/17/78	123	--	--	4.4	--	13.4
4/18/78	129	3.4	14.8	3.3	--	--
4/19/78	116	--	--	--	836	--
4/20/78	123	--	--	4.1	1,120	12.1
4/21/78	114	5.4	13.8	--	779	--
4/22/78	115	5.1	13.8	6.1	849	--
5/10/78	123	7.4	11.6	6.2	612	10.8
5/11/78	130	3.9	14.8	8.6	1,080	12.1
5/16/78	120	--	--	5.7	729	10.2
5/17/78	120	--	--	5.7	962	10.5

TABLE 9. CHEMICAL ANALYSIS OF COAL*

	Analyte (Wt. %)					
Date	Sodium	Potassium	Lithium	Calcium	Magnesium	Sulfur
4/20 am	0.009	0.030	0.00018	0.070	0.020	1.6
4/20 pm	0.011	0.040	0.00025	0.090	0.040	1.6
4/21 am	0.014	0.033	0.00038	0.160	0.080	2.6
4/21 am	0.013	0.042	0.00026	0.100	0.050	1.1
4/21 pm	0.014	0.048	0.00034	0.120	0.070	1.5
4/22 am	0.014	0.032	0.00023	0.150	0.040	1.2
5/16,17	0.008	0.032	0.00018	0.090	0.050	0.9
5/18 am	0.007	0.035	0.00020	0.070	0.040	1.5
5/18 pm	0.004	0.027	0.00012	0.040	0.020	1.4

*From coal conveyer



CONDITIONED BASELINE

Figure 14. Recorder plate for duct opacity.

analysis of the samples. The coal sulfur content is also plotted in Figure 15. The SO_2 concentration closely follows the change in the sulfur content of the coal. The sulfur content of the coal is generally high enough to prevent collection difficulties associated with resistivity. The sulfur content cannot, however, be directly related to the resistivity values reported above.

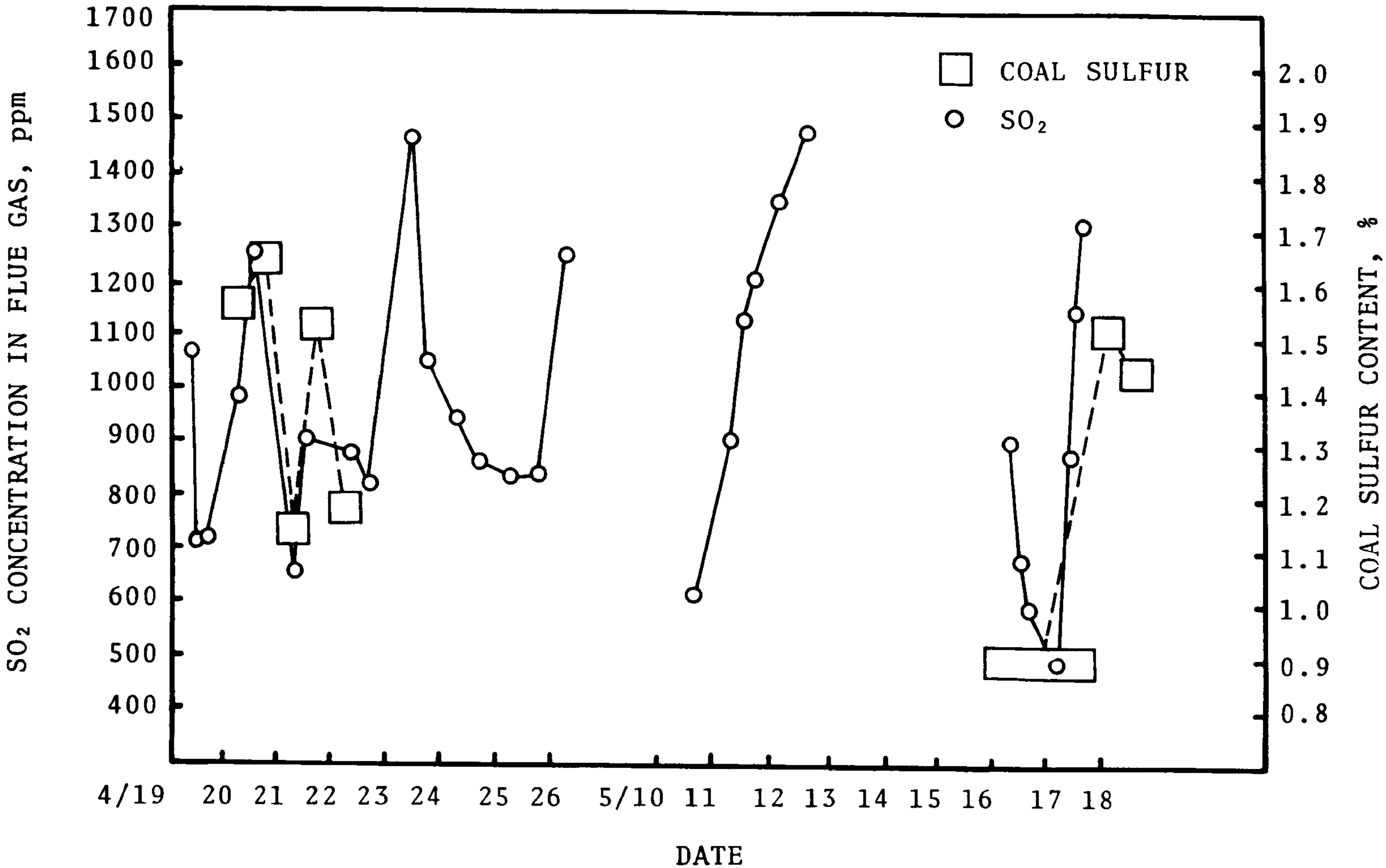


Figure 15. SO_2 concentration in flue gas and coal sulfur content.

SECTION 6

ECONOMICS

The ESP conditioning system for unit 3B went on line in 1977. Several conditioning systems were tested and evaluated, settling on the reported system in January, 1978.

The capital and operating costs are shown in Table 10.

TABLE 10. CAPITAL AND OPERATING COSTS FOR SECOND TEST SITE, 1978

	Per Unit
2 Pump Skids	$160,000
Equipment Lease	43,000 per year
Generation	2,495,232 X 1000 kWh
Approximate Unit Heat Rate	10,000 Btu/kWh
Approximate Coal Heating Value	11,800 Btu/lb
Chemical Feed Rate	0.1 gal/ton LAC - 43¢/lb
Chemical Feed Rate	0.075 gal/ton LPA - 38¢/lb

$$\text{Chemical cost/ton coal} = \left(0.1\ \frac{\text{gal}}{\text{ton}} \times \frac{43¢}{\text{lb}} \times \frac{8.2\ \text{lb}}{\text{gal}}\right) + \left(0.075\ \frac{\text{gal}}{\text{ton}} \times \frac{38¢}{\text{lb}} \times 8.2\ \frac{\text{lb}}{\text{gal}}\right) = 58.63¢/\text{ton}$$

$$\frac{\text{kWh}}{\text{Ton Coal}} = \frac{11{,}800\ \text{Btu/lb coal}}{10{,}000\ \text{Btu/kWh}} \times 2000\ \frac{\text{lb coal}}{\text{ton}} = 2360\ \frac{\text{kWh}}{\text{Ton Coal}}$$

$$\text{Chem. Cost} = \frac{58.63¢/\text{ton coal}}{2360\ \text{kWh/ton coal}} + 0.0248¢/\text{kWh}$$

$$\text{Chem. Cost} = 0.248\ \text{mills/kWh}$$

$$\text{Lease Cost} = \frac{\$43{,}000/\text{year}}{2{,}495{,}232 \times 1{,}000\ \text{kWh/year}} = \$0.000017\ \text{kWh}$$

$$\text{Lease Cost} = 0.017\ \frac{\text{mills}}{\text{kWh}}$$

$$\text{Total Cost} = \text{Chem. cost} + \text{lease cost} = 0.248\ \frac{\text{mills}}{\text{kWh}} + 0.017\ \frac{\text{mills}}{\text{kWh}}$$

$$\text{Total Cost} = 0.250\ \frac{\text{mills}}{\text{kWh}}$$

REFERENCES

Oglesby, Sabert et al., A Manual of Electrostatic Precipitator Technology, Southern Research Institute, Birmingham, Alabama, 1970.

Sparks, L. E., "SR-52 Programmable Calculator Programs for Venturi Scrubbers and Electro-Static Precipitators," EPA 600/7-78-026, March 1978.

White, Harry J., Industrial Electrostatic Precipitation, Addison-Welsey Publishing Co., Inc., 1963.

APPENDIX "A"

PARTICLE SIZE DATA

TABLE A-1. INLET AND OUTLET PARTICLE DATA FOR RUN NO. 1
Taken 4/17/78 at 9:45 am. Boiler load 460 MW.

IMPACTOR STAGE NUMBER	INLET			OUTLET		
	M_{cum} (mg/DNm^3)	d_{pc} (μmA)	d_p (μm)	M_{cum} (mg/DNm^3)	d_{pc} (μmA)	d_p (μm)
Precutter & Nozzle	5,141	6.57	4.22	198.2		
1	3,613	22.88	14.97	167.4	23.44	15.35
2	1,327	10.02	6.49	140.4	10.27	6.66
3	499	3.88	2.45	48.6	3.97	2.51
4	173	1.93	1.16	14.5	2.05	1.25
5	62	1.16	1.66	5.7	1.19	0.68
6	22	0.65	0.33	2.8	0.67	0.34
7	17	0.37	0.14	1.4	0.37	0.15
Filter	16			1.1		
Sample Volume (DNm^3)	0.086			0.282		

TABLE A-2. INLET AND OUTLET PARTICLE DATA FOR RUN NO. 2
Taken 4/17/78 at 1:15 pm. Boiler load 460 MW.

IMPACTOR STAGE NUMBER	INLET			OUTLET		
	M_{cum} (mg/DNm^3)	d_{pc} (μmA)	d_p (μm)	M_{cum} (mg/DNm^3)	d_{pc} (μmA)	d_p (μm)
Precutter & Nozzle	4,209	6.58	4.22	29.9		
1	935	22.89	14.98	22.9	23.82	15.60
2	578	10.03	6.50	13.4	10.44	6.77
3	445	3.88	2.44	9.0	4.04	2.56
4	199	2.00	1.21	5.4	1.95	1.18
5	77	1.15	0.65	1.7	1.19	0.68
6	29	0.66	0.33	0.5	0.64	0.32
7	19	0.34	0.12	0.5	0.37	0.15
Filter	15			0.2		
Sample Volume (DNm^3)	0.176			0.411		

N: 20°C, 1 atm; $\mu mA = \mu m(g/cm^3)^{1/2}$

TABLE A-3. INLET AND OUTLET PARTICLE DATA FOR RUN NO. 5
Taken 4/20/78 at 9:00 am. Boiler load 460 MQ.

IMPACTOR STAGE NUMBER	INLET			OUTLET		
	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)
Precutter & Nozzle	21,860	6.27	4.02	43.3		
1	5,479	21.83	14.28	29.8	23.54	15.41
2	4,496	9.56	6.19	21.0	10.31	6.69
3	1,549	3.70	2.32	17.4	3.99	2.52
4	422	1.84	1.10	10.6	1.92	1.16
5	138	1.11	0.62	4.6	1.18	0.67
6	64	0.62	0.30	2.9	0.63	0.31
7	43	0.35	0.13	1.5	0.37	0.15
Filter	31			1.5		
Sample Volume (DNm³)	0.159			0.547		

TABLE A-4. INLET AND OUTLET PARTICLE DATA FOR RUN NO. 9
Taken 4/20/78 at 10:30 am. Boiler load 320 MW.

IMPACTOR STAGE NUMBER	INLET			OUTLET		
	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)
Precutter & Nozzle	6,630	7.28	4.69	17.7		31.04
1	979	25.34	16.60	11.3	31.04	20.36
2	556	11.10	7.21	5.5	13.60	8.86
3	471	4.30	2.73	3.2	5.26	3.36
4	178	2.21	1.35	1.9	2.54	1.57
5	67	1.28	0.74	1.6	1.55	0.92
6	31	0.74	0.38	1.6	0.83	0.44
7	17	0.38	0.15	1.6	0.49	0.23
Filter	12			1.6		
Sample Volume (DNm³)	0.346			0.311		

N: 20°C, 1 atm; μmA = μm(g/cm³)$^{1/2}$

TABLE A-5. INLET AND OUTLET PARTICLE DATA FOR RUN NO. 10 Taken 5/10/78 at 2:30 pm. Boiler load not available.

IMPACTOR STAGE NUMBER	INLET			OUTLET		
	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)
Precutter & Nozzle	5,857	7.45	4.80	60.3		
1	881	25.96	17.00	48.3	31.93	20.94
2	459	11.37	7.39	16.1	13.99	9.11
3	395	4.40	2.79	9.6	5.41	3.46
4	177	2.27	1.39	5.0	2.69	1.66
5	74	1.32	0.76	2.2	1.62	0.96
6	34	0.74	0.39	1.2	1.92	0.50
7	19	0.42	0.18	0.7	0.53	0.25
Filter	15			0.5		
Sample Volume (DNm³)	0.219			0.735		

TABLE A-6. INLET AND OUTLET PARTICLE DATA FOR RUN NO. 11 Taken 5/10/78 at 4:30 pm. Boiler load 440 MW.

IMPACTOR STAGE NUMBER	INLET			OUTLET		
	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)
Precutter & Nozzle	6,486	7.47	4.81	7.5		
1	1,292	26.03	17.05	5.2	21.71	14.20
2	761	11.40	7.40	4.2	8.51	6.16
3	642	4.41	2.80	4.1	3.68	2.32
4	308	2.27	1.39	3.0	1.77	1.06
5	141	1.31	0.76	1.5	1.08	0.61
6	57	0.76	0.39	0.7	0.58	0.28
7	28	0.37	0.16	0.6	0.34	0.13
Filter	21			0.4		
Sample Volume (DNm³)	0.166			0.951		

N: 20°C, 1 atm; μmA = $\mu m(g/cm^3)^{1/2}$

TABLE A-7. INLET AND OUTLET PARTICLE DATA FOR RUN NO. 12
Taken 5/11/78 at 10:30 am. Boiler load 440 MW.

IMPACTOR STAGE NUMBER	INLET			OUTLET		
	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)
Precutter & Nozzle	7,620	6.41	4.12	11.2		
1	1,863	22.33	14.61	8.2	22.76	14.90
2	1,008	9.78	6.34	7.0	9.97	6.46
3	582	3.78	2.38	6.2	3.86	2.44
4	216	1.95	1.18	4.8	1.92	1.16
5	86	1.13	0.64	2.7	1.16	0.66
6	38	0.64	0.32	1.2	0.65	0.32
7	27	0.35	0.14	0.8	0.37	0.15
Filter	20			0.5		
Sample Volume (DNm³)	0.225			1.30		

TABLE A-8. INLET AND OUTLET PARTICLE DATA FOR RUN NO. 13
Taken 5/11/78 at 1:15 pm. Boiler load 440 MW.

IMPACTOR STAGE NUMBER	INLET			OUTLET		
	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)
Precutter & Nozzle	9,843	6.24	4.00	6.4		
1	862	21.73	14.22	4.7	21.38	13.99
2	650	9.52	6.17	4.1	9.37	6.07
3	455	3.68	2.32	3.7	3.63	2.28
4	184	1.90	1.14	2.8	1.75	1.05
5	65	1.10	0.62	1.5	1.07	0.60
6	28	0.63	0.31	0.7	0.57	0.27
7	23	0.32	0.12	0.5	0.33	0.12
Filter	13			0.3		
Sample Volume (DNm³)	0.159			1.48		

N: 20°C, 1 atm; μmA = μm(g/cm³)$^{1/2}$

TABLE A-9. INLET AND OUTLET PARTICLE DATA FOR RUN NO. 15
Taken 5/16/78 at 12:00 pm. Boiler load 440 MW.

IMPACTOR STAGE NUMBER	INLET			OUTLET		
	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)
Precutter & Nozzle	9,851	6.41	4.11	7.9		
1	1,408	22.33	14.61	5.1	18.55	12.12
2	657	9.78	6.33	4.5	8.13	5.25
3	447	3.79	2.39	3.7	3.13	1.96
4	167	1.95	1.18	2.8	1.56	0.92
5	62	1.13	0.64	1.3	0.94	0.52
6	31	0.64	0.32	0.7	0.53	0.25
7	21	0.35	0.14	0.5	0.28	0.10
Filter	16			0.4		
Sample Volume (DNm³)	0.180			1.30		

TABLE A-10. INLET AND OUTLET PARTICLE DATA FOR RUN NO. 16
Taken 5/16/78 at 12:30 pm. Boiler load 440 MW.

IMPACTOR STAGE NUMBER	INLET			OUTLET		
	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)
Precutter & Nozzle	8,424	6.42	4.12	21.8		
1	2,664	22.36	14.63	18.5	19.85	12.98
2	1,413	9.80	6.35	15.3	8.70	5.62
3	601	3.79	2.39	12.5	3.36	2.10
4	177	1.95	1.18	8.1	1.62	0.96
5	64	1.13	0.64	4.1	0.99	0.55
6	23	0.65	0.32	2.1	0.53	0.25
7	16	0.33	0.12	1.2	0.30	0.11
Filter	12			0.8		
Sample Volume (DNm³)	0.225			1.13		

N: 20°C, 1 atm; μmA = μm(g/cm³)$^{1/2}$

TABLE A-11. INLET AND OUTLET PARTICLE DATA FOR RUN NO. 17 Taken 5/16/78 at 3:30 pm. Boiler load 440 MW.

IMPACTOR STAGE NUMBER	INLET			OUTLET		
	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)
Precutter & Nozzle	10,570	6.34	4.07	29.8		
1	2,847	22.07	14.44	12.9	19.25	12.58
2	1,855	9.67	6.27	9.8	8.43	5.45
3	547	3.74	2.36	8.1	3.26	2.04
4	180	1.93	1.17	4.6	1.62	0.96
5	66	1.12	0.64	2.4	0.98	0.54
6	32	0.63	0.32	0.8	0.55	0.26
7	23	0.35	0.14	0.3	0.30	0.11
Filter	16			0.1		
Sample Volume (DNm³)	0.187			1.20		

TABLE A-12. INLET AND OUTLET PARTICLE DATA FOR RUN NO. 20 Taken 5/17/78 at 10:30 am. Boiler load not available.

IMPACTOR STAGE NUMBER	INLET			OUTLET		
	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)
Precutter & Nozzle	7,885	6.35	4.08	10.9		
1	1,171	22.10	14.46	7.1	19.44	12.71
2	493	9.68	6.27	5.7	8.52	5.51
3	337	3.75	2.37	4.8	3.29	2.06
4	146	1.93	1.17	2.9	1.59	0.94
5	62	1.11	0.62	1.3	0.97	0.54
6	31	0.64	0.32	0.4	0.51	0.24
7	23	0.32	0.12	0.3	0.30	0.10
Filter	16			0.2		
Sample Volume (DNm³)	0.234			1.19		

N: 20°C, 1 atm; μmA = μm(g/cm³)$^{1/2}$

TABLE A-13. INLET AND OUTLET PARTICLE DATA FOR RUN NO. 21 Taken 5/17/78 at 11:45 am. Boiler load not available.

IMPACTOR STAGE NUMBER	INLET			OUTLET		
	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)
Precutter & Nozzle	6,072	6.25	4.01	44.3		
1	1,387	21.76	14.24	36.6	19.64	12.84
2	637	9.53	6.17	24.7	8.60	5.56
3	379	3.69	2.32	17.4	3.32	2.08
4	123	1.90	1.15	9.2	1.60	0.95
5	58	1.10	0.66	4.5	0.98	0.54
6	35	0.63	0.32	2.2	0.52	0.24
7	25	0.31	0.12	1.3	0.30	0.11
Filter	18			0.8		
Sample Volume (DNm³)	0.242			1.46		

TABLE A-14. INLET AND OUTLET PARTICLE DATA FOR RUN NO. 22 Taken 5/17/78 at 11:10 pm. Boiler load 510 MW.

IMPACTOR STAGE NUMBER	INLET			OUTLET		
	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)	M_{cum} (mg/DNm³)	d_{pc} (μmA)	d_p (μm)
Precutter & Nozzle	9,085	5.96	3.82	97.8		
1	1,782	20.76	13.58	85.5	19.86	12.98
2	667	9.09	5.89	53.5	8.70	5.62
3	388	3.52	2.22	30.7	3.37	2.11
4	124	1.81	1.09	12.9	1.67	0.99
5	60	1.05	0.59	6.0	1.01	0.56
6	38	0.59	0.29	3.3	0.57	0.27
7	32	0.33	0.12	2.5	0.31	0.11
Filter	20			1.9		
Sample Volume (DNm³)	0.214			1.12		

N: 20°C, 1 atm; μmA = μm(g/cm³)$^{1/2}$

TABLE A-15. INLET AND OUTLET PARTICLE DATA FOR BLANK RUN #3
Taken 4/18/78

Impactor stage number	Inlet		Outlet	
	Loading mg	Cut Dia. µmA	Loading mg	Cut Dia. µmA
Probe	146.1		7.0	
Pre-filter	64.5		14.0	
1	2.90	22.04	0.20	23.98
2	0.30	9.66	3.60	10.51
3	0.30	3.74	0.00	4.06
4	0.00	1.92	0.00	2.02
5	0.00	1.12	0.00	1.22
6	0.00	0.63	0.00	0.69
7	0.00	0.33	16.4	0.39
Filter	0.00		32.7	
Sample volume, DNm³	0.076		0.338	

TABLE A-16. INLET AND OUTLET PARTICLE DATA FOR BLANK RUN #7
Taken 4/20/78

Impactor stage number	Inlet		Outlet	
	Loading mg	Cut Dia. µmA	Loading mg	Cut. Dia. µmA
Probe	595.0		3.1	
Pre-filter	251.1		10.8	
1	0.00	25.28	0.00	24.81
2	0.00	11.07	0.00	10.87
3	0.00	4.28	0.00	4.20
4	0.00	2.21	0.00	2.09
5	0.00	1.28	0.00	1.26
6	0.00	0.72	0.00	0.71
7	0.00	0.41	0.00	0.41
Filter	0.40		0.00	
Sample volume, DNm³	0.070		0.495	

S: 20°C, 1 atm µmA = µm $(g/cm^3)^{1/2}$

TABLE A-17. INLET AND OUTLET PARTICLE DATA FOR BLANK RUN #8
Taken 4/21/78

Impactor stage number	Inlet		Outlet	
	Loading mg	Cut Dia. μmA	Loading mg	Cut Dia. μmA
Probe	1011.0		1.5	
Pre-filter	308.7		6.2	
1	0.10	23.95	0.30	31.60
2	0.00	10.49	0.00	13.84
3	0.00	4.06	0.00	5.36
4	0.00	2.09	0.10	2.67
5	0.00	1.22	0.00	1.61
6	0.10	0.69	0.00	0.91
7	0.00	0.38	0.00	0.52
Filter	0.10		0.00	
Sample volume, DNm^3	0.257		0.300	

TABLE A-18. INLET AND OUTLET PARTICLE DATA FOR BLANK RUN #14
Taken 5/16/78

Impactor stage number	Inlet		Outlet	
	Loading mg	Cut Dia. μmA	Loading mg	Cut. Dia. μmA
Probe	1040.0		2.6	
Pre-filter	214.0		8.3	
1	1.90	21.30	0.00	20.20
2	4.30	9.33	0.50	8.85
3	2.70	3.61	0.30	3.42
4	1.20	1.86	0.10	1.65
5	0.70	1.07	0.20	1.01
6	0.50	0.62	0.00	0.54
7	0.30	0.31	0.00	0.31
Filter	0.10		0.20	
Sample volume, DNm^3	0.170		0.720	

S: 20°C, 1 atm   μmA = μm $(g/cm^3)^{1/2}$

TABLE A-19. INLET AND OUTLET PARTICLE DATA FOR BLANK RUN #19 TAKEN 5/17/78

Impactor stage number	Inlet		Outlet	
	Loading mg	Cut Dia. μmA	Loading mg	Cut Dia. μmA
Probe	746.4		4.0	
Pre-filter	191.8		6.8	
1	0.00	22.13	0.10	20.02
2	0.00	9.69	0.00	8.77
3	0.00	3.75	0.00	3.39
4	0.00	1.93	0.10	1.64
5	0.00	1.12	0.00	1.00
6	0.00	0.64	0.00	0.53
7	0.00	0.32	0.00	0.31
Filter	0.00		0.00	
Sample volume, DNm^3	0.127		1.12	

TABLE A-17. INLET AND OUTLET PARTICLE DATA FOR BLANK RUN #8
Taken 4/21/78

Impactor stage number	Inlet Loading mg	Inlet Cut Dia. μmA	Outlet Loading mg	Outlet Cut Dia. μmA
Probe	1011.0		1.5	
Pre-filter	308.7		6.2	
1	0.10	23.95	0.30	31.60
2	0.00	10.49	0.00	13.84
3	0.00	4.06	0.00	5.36
4	0.00	2.09	0.10	2.67
5	0.00	1.22	0.00	1.61
6	0.10	0.69	0.00	0.91
7	0.00	0.38	0.00	0.52
Filter	0.10		0.00	
Sample volume, DNm^3	0.257		0.300	

TABLE A-18. INLET AND OUTLET PARTICLE DATA FOR BLANK RUN #14
Taken 5/16/78

Impactor stage number	Inlet Loading mg	Inlet Cut Dia. μmA	Outlet Loading mg	Outlet Cut. Dia. μmA
Probe	1040.0		2.6	
Pre-filter	214.0		8.3	
1	1.90	21.30	0.00	20.20
2	4.30	9.33	0.50	8.85
3	2.70	3.61	0.30	3.42
4	1.20	1.86	0.10	1.65
5	0.70	1.07	0.20	1.01
6	0.50	0.62	0.00	0.54
7	0.30	0.31	0.00	0.31
Filter	0.10		0.20	
Sample volume, DNm^3	0.170		0.720	

S: 20°C, 1 atm   μmA = $\mu m\ (g/cm^3)^{1/2}$

TABLE A-19. INLET AND OUTLET PARTICLE DATA FOR BLANK RUN #19 TAKEN 5/17/78

Impactor stage number	Inlet		Outlet	
	Loading mg	Cut Dia. μmA	Loading mg	Cut Dia. μmA
Probe	746.4		4.0	
Pre-filter	191.8		6.8	
1	0.00	22.13	0.10	20.02
2	0.00	9.69	0.00	8.77
3	0.00	3.75	0.00	3.39
4	0.00	1.93	0.10	1.64
5	0.00	1.12	0.00	1.00
6	0.00	0.64	0.00	0.53
7	0.00	0.32	0.00	0.31
Filter	0.00		0.00	
Sample volume, DNm^3	0.127		1.12	

APPENDIX "B"

ELEMENTAL ANALYSIS DATA

TABLE B-1. RESULTS OF ELEMENTAL ANALYSIS OF FLY ASH ON CASCADE IMPACTOR SUBSTRATES.

Run	Stage	ng/cm² of substrate								
		Na	Mg	Al	Si	S	K	Ca	Ti	Fe
4*	1	0.12	0.032	0.74	0.93	0.012	0.088	0.074	0.035	0.36
	2	0.34	0.086	0.22	0.50	0.030	0.13	0.23	0.063	0.50
	3	0.20	0.052	0.22	0.44	0.022	0.10	0.19	0.045	0.31
	4	0.12	0.030	0.050	0.21	0.020	0.080	0.26	0.045	0.45
	5	0.095	0.025	0.025	0.051	0.017	0.056	0.16	0.034	0.24
	6	0.10	0.028	0.028	0.025	0.099	0.040	0.15	0.033	0.10
	7	0.085	0.022	0.022	0.017	0.034	0.027	0.17	0.029	0.083
9*	1	0.20	0.052	1.70	1.88	0.010	0.18	0.11	0.052	0.53
	2	0.27	0.067	0.38	0.84	0.019	0.19	0.20	0.076	0.88
	3	0.17	0.043	0.22	0.48	0.018	0.11	0.16	0.039	0.57
	4	0.11	0.030	0.070	0.22	0.010	0.090	0.17	0.040	2.7
	5	0.083	0.022	0.022	0.065	0.015	0.056	0.15	0.030	1.1
	6	0.069	0.018	0.018	0.027	0.013	0.031	0.12	0.018	0.18
	7	0.069	0.018	0.018	0.016	0.013	0.022	0.11	0.026	0.21
23	1	0.13	0.034	1.06	1.2	0.021	0.11	0.066	0.039	0.28
	2	0.14	0.035	0.031	0.10	0.013	0.14	0.13	0	0.48
	3	0.11	0.029	0.17	0.44	0.016	0.08	0.10	0.028	0.21
	4	0.06	0.016	0.11	0.26	0.003	0.075	0.085	0.026	0.19
	5	0.054	0.014	0.016	0.095	0.010	0.039	0.097	0.017	0.11
	6	0.051	0.013	0.014	0.028	0.009	0.023	0.093	0.014	0.043
	7	0.047	0.012	0.006	0.042	0.008	0.025	0.079	0.019	0.056
28	1	0.14	0.03	1.10	1.2	0.011	1.4	0.095	0.047	0.48
	2	0.29	0.073	1.77	2.5	0.009	0.55	0.42	0.26	3.2
	3	0.055	0.039	0.42	0.83	0.045	0.25	0.20	0.088	1.0
	4	0.074	0.019	0.11	0.33	0.029	0.13	0.13	0.042	0.43
	5	0.052	0.014	0.014	0.044	0.028	0.038	0.083	0.018	0.14
	6	0.045	0.012	0.012	0.012	0.029	0.022	0.073	0.016	0.058
	7	0.047	0.012	0.012	0.009	0.019	0.019	0.087	0.018	0.067

* Conditioned test

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

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16. ABSTRACT

The report gives results of a field performance test of an electrostatic precipitator (ESP) which uses Apollo Chemical Co.'s LPA 445 and LAC 51B flue gas conditioning agents. The ESP is at an electric utility power plant, burning approximately 1% to 2% sulfur coal. Tests were conducted with and without injection of the conditioning agents. ESP performance was characterized in terms of particle collection efficiency and the chemical composition of particulate and gaseous emissions. Fly ash resistivity and dust opacity were also measured. Measurements show that there was no significant change in overall efficiency (99.6%) between the conditioned and unconditioned tests. There was some evidence that the conditioning agents reduced entrainment during electrode rapping and possibly improved the fractional efficiency slightly for particles smaller than about 5 micrometers in diameter.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Fly Ash	Pollution Control	13B	
Flue Gases	Electrical Resistivity	Stationary Sources	21B	
Treatment		Conditioning Agents	14B	20C
Coal	Dust		21D	11G
Combustion	Opacity			
Electrostatic Precipitation			13H	

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