Note: This is a reference cited in *AP 42, Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources.* AP42 is located on the EPA web site at www.epa.gov/ttn/chief/ap42/

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Air

EPA

Lightweight Aggregate Industry (Clay, Shale, and Slate)

Emission Test Report Vulcan Materials Company Bessemer, Alabama

° EMISSION TEST REPORT °

METHOD DEVELOPMENT AND TESTING FOR CLAY, SHALE, AND SLATE AGGREGATE INDUSTRY

Vulcan Materials Company
Bessemer, Alabama
ESED 80/12

by

PEDCo Environmental, Inc.
11499 Chester Road
Cincinnati, Ohio 45246

Contract No. 68-02-3546
Work Assignment No. 1
PN: 3530-1

EPA Task Manager
Frank Clay

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
EMISSION MEASUREMENT BRANCH
EMISSION STANDARDS AND ENGINEERING DIVISION
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711

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SECTION 1

INTRODUCTION

During the week of July 13, 1981, personnel from PEDCo Environmental conducted an emission sampling program at the lightweight aggregate facility of Vulcan Materials Company in Bessemer, Alabama. The purpose of this test program was to provide data to assess the need for New Source Performance Standards (NSPS) emission limits for selected processes in the lightweight aggregate industry (clay, shale, and slate) and, if warranted, to develop such limits.

Comprehensive testing was conducted on two specific sources detailed below:

- Coal-fired rotary kiln (No. 1), whose emissions are controlled by a medium-energy wet scrubber.
- Reciprocating grate clinker cooler, whose emissions are controlled by a settling chamber.

Particulate concentrations and mass emission rates were measured at the inlet to and the outlet from the wet scrubber serving the kiln exhaust and at the clinker cooler exit stack. U.S. Environmental Protection Agency (EPA) Method 5 was used in these measurements.* Flue gas flow rates, temperature, moisture content, and composition [oxygen (O_2), carbon dioxide (CO_2), and carbon monoxide (CO)] were measured in conjunction with the

*40 CFR 60, Appendix A, Reference Method 5, July 1, 1981.

particulate tests. Sulfur dioxide (SO_2) concentrations and mass emission rates were measured at the inlet to and outlet from the wet scrubber serving the kiln and at the clinker cooler exit stack by EPA Method 6.* Nitrogen oxide (NO_x) concentration in the flue gas exiting the scrubber was also determined by EPA Method 7.* In addition, the particle size distribution of particulate matter entering and exiting the kiln scrubber and exiting the clinker cooler stack was determined using in-stack cascade impactors. Volatile organic carbon (VOC) content of the exit gas from the kiln was determined by EPA Method 25.* Visible emission observations were made on each exit stack during the particulate tests by EPA Method 9.* Additionally, a visible determination of fugitive dust emissions from specified process locations was made during each particulate test by EPA Method 9.*

Representative samples of the kiln feed material (shale) and coal used to fire the kiln were collected during each particulate test for determination of sulfur content, moisture, density, and ash content (coal only). Samples of the scrubber water influent and effluent and final aggregate product were also collected for analyses of total sulfate. The pH of the scrubber water was also determined.

Messrs. Richard Cooper and Lalit Banker [Midwest Research Institute (MRI)] monitored process operation and collected process samples throughout the test period. Mr. Frank Clay (EPA Task Manager) observed the test program.

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*40 CFR 60, Appendix A, Reference Methods 6, 7, 9, and 25, July 1, 1981.

SECTION 2

PROCESS OPERATION

The process operation and summary of data monitored during the test period are shown in Table 2-1. Process data were collected and tabularized by personnel from MRI.

The Vulcan plant in Bessemer, Alabama, operates two kiln lines for shale lightweight aggregate production. Testing was conducted on Kiln No. 1 and its associated pollution control equipment.

The raw material (shale) is quarried from a pit located approximately 0.8 kilometers (km) (0.5 miles) from the plant. Trucks transport the shale to crushers where it is reduced to a feed size of less than 1.91 centimeters (cm) [3/4 inches (in.)] and transferred by belt conveyor to a semi-enclosed shed for storage. The semi-enclosed shed had a storage capacity of approximately 13,610 megagrams (Mg) (15,000 tons). Belt conveyors transport the raw material from the storage shed to a feed hopper for charging to the kiln.

The No. 1 kiln measures 56.4 meters (m) [185 feet (ft)] in length and 2.7 m (12 ft) in diameter and is designed to process approximately 32 Mg (35 tons) of raw material per hour. Typically, the No. 1 kiln processes approximately 26.3 Mg (29

TABLE 2-1. PROCESS DATA RECORDED DURING THE EMISSION TEST AT VULCAN MATERIALS COMPANY, BESSEMER, ALABAMA

Time	Kiln, rpm	Aggregate weight		Feed end temperature	
		kg/m^3	lb/ft^3	°C	°F
Tuesday, July 14, 1981[a]					
7:30	2.8	657	41	593	1100
8:00	2.8	705	44	599	1110
8:30	2.8	689	43	593	1100
9:00	2.8	769	48	593	1100
9:30	2.8	721	45	593	1100
10:00	2.8	737	46	593	1100
10:30	2.8	689	43	593	1100
11:00	2.8	785	49	593	1100
11:30	2.8	769	48	593	1100
12:00	2.8	705	44	593	1100
12:30	2.8	753	47	593	1100
1:00	2.8	721	45	593	1100
1:30	2.8	689	43	593	1100
2:00	2.8	737	46	593	1100
2:30	2.8	721	45	593	1100
3:00	2.8	753	47	593	1100
3:30	2.8	657	41	593	1100
4:00	2.8	641	40	593	1100
4:30	2.8	673	42	593	1100
Wednesday, July 15, 1981[b]					
7:30	2.8	641	40	593	1100
8:00	2.8	721	45	593	1100
8:30	2.8	752	47	593	1100
9:00	2.8	785	49	593	1100

(continued)

TABLE 2-1 (continued)

Time	Kiln, rpm	Aggregate weight		Feed end temperature	
		kg/m^3	lb/ft^3	°C	°F
Wednesday, July 15, 1981[b] (continued)					
9:30	2.8	737	46	593	1100
10:00	2.8	769	48	593	1100
10:30	2.8	737	46	593	1100
11:00	2.8	705	44	593	1100
11:30	2.8	721	45	599	1110
12:00	2.8	689	43	599	1110
12:30	2.8	721	45	593	1100
1:00	2.8	737	46	593	1100
1:30	2.8	705	44	593	1100
2:00	2.8	673	42	593	1100
2:30	2.8	705	44	593	1100
3:00	2.8	657	41	593	1100
3:30	2.8	641	40	593	1100
4:00	2.8	673	42	593	1100
Thursday, July 16, 1981[c]					
7:00 to 2:30		No emission tests conducted			
3:00	2.8	801	50	593	1100
3:30	2.8	577	36	582	1080
4:00	2.8	705	44	582	1080
Friday, July 17, 1981[d]					
7:30	2.8	769	48	571	1060
8:00	2.8	721	45	593	1100
8:30	2.8	657	41	593	1100
9:00	2.8	737	46	593	1100
9:30	2.8	705	44	593	1100
10:00	2.8	705	44	593	1100
10:30	2.8	752	47	593	1100
11:00	2.8	705	44	593	1100

(continued)

TABLE 2-1 (continued)

Time	Kiln, rpm	Aggregate weight		Feed end temperature	
		kg/m^3	lb/ft^3	°C	°F
Friday, July 17, 1981[d] (continued)					
11:30	2.8	769	48	593	1100
12:00	2.8	737	46	593	1100
12:30	2.8	785	49	593	1100
1:00	2.8	769	48	593	1100
1:30	2.8	833	52	593	1100
2:00	2.8	801	50	593	1100

[a]Raw material feed rate: 26.3 Mg/h (29 tons/h). Natural gas: 18,786 m^3 (633,364 ft^3). Coal: 762.6 Mg (840.75 tons).

[b]Raw material feed rate: 26 Mg/h (29 tons/h). Natural gas: 18,795 m^3 (663,668 ft^3). Coal: 819.0 Mg (902.9 tons).

[c]Raw material feed rate: 26 Mg/h (29 tons/h). Natural gas: 18,806 m^3 (664,064 ft^3). Coal: 844.1 Mg (930.5 tons).

[d]Raw material feed rate: 26 Mg/h (29 tons/h). Natural gas: 18,834 m^3 (665,045 ft^3). Coal: 880.4 Mg (970.6 tons).

Note: The natural gas and coal usage meters are read and recorded at the beginning of each shift. (The difference in the readings from one day to the next indicates the amount of fuel consumed in each 24-h period.)

tons) of raw material per hour which yields a final production rate of 21 Mg (23 tons) per hour. The kiln is fueled primarily by pulverized coal, and natural gas is used to fuel the pilot flame. The operating temperature of the kiln is approximately 1150°C (2100°F). Natural gas is the primary fuel used for the reheating process. Once the temperature of the coal mill reaches 93°C (200°F), pulverized coal is used as the primary fuel to fire the kiln. The kiln temperature climbs to 1480°C (2700°F) during the reheating and settles to 1150°C (2100°F) as the coal feed rate increases to normal and the natural gas is cut off.

The No. 1 kiln rotates at approximately 2.8 revolutions per minute (rpm). The raw material slowly heats up as it travels through the kiln and physically expands (bloats) as volatile organic components are released. The raw material residence time in the kiln is approximately 45 to 50 minutes. The expansion reduces the density of the shale to within a range of 640 to 800 kilograms per cubic meter (kg/m^3) [40 to 50 pounds per cubic foot (lb/ft^3)]. The expanded product, or clinker, is discharged from the kiln through a 1.2 by 1.8 m (4 by 6 ft) opening at the back end of the kiln onto a reciprocating grate called a clinker cooler. As the hot clinker moves across the grate, one large fan forces air upward through the grate to cool the clinker. Product of acceptable size falls through the grate onto a conveyor belt for transfer to storage piles. Oversize material falls from the grate onto the ground where it is periodically picked up by a front end loader and transferred to a crusher for supplemental

crushing prior to storage. The product is also transferred by conveyor belt from the storage piles to crushers to reduce the size of the product and then to a screen house for sizing. The product is transferred from the crushing/screening area to open stockpiles where it is stored until sold.

The No. 1 rotary kiln exhaust emissions (particulate and some SO_2) are controlled by a medium energy wet scrubber (Ducon Dynamic, UW4, Model IV, Size 144). The scrubber stack is approximately 1.5 m (5 ft) in diameter and 15 m (50 ft) high. The stack outlet is approximately 30 m (100 ft) above grade. The scrubber water is discharged to an open ditch which empties into a holding pond. Periodic checks of the scrubber water by plant personnel indicate the pH is very low, resulting in scrubber corrosion. A system for feeding caustic soda to the scrubber water is, therefore, being installed to adjust the pH. The scrubber water is recirculated from the holding pond to the wet scrubber by eight 7.5-kilowatt (kW) [10-horsepower (hp)] pumps. The clinker cooler emissions from the No. 1 kiln process line are controlled by a settling chamber. Vulcan ceased operation of the induced draft fan located downstream from the settling chamber several years ago for energy conservation purposes. Essentially, the system now operates under a natural draft flow. Since the I.D. fan no longer operates, some of the exhaust gas, which normally would be vented through the exit stack, is emitted from the oversize clinker exit area. Consequently, fugitive emission observations were made at the exit area during the particulate tests at this location.

No instrumentation was present to indicate the water flow rate to the wet scrubber or the inlet and outlet gas flow rates and temperatures and pressure drops for the settling chamber and wet scrubber. The settling chamber and wet scrubber, including the pumps supplying water to the wet scrubber, were operating normally during the emission tests. The water sprays used to suppress visible particulate emissions at the transfer points in the product stockpiling area and the raw material unloading station were operating normally.

SECTION 3

SUMMARY OF RESULTS

This section details results obtained from the emission sampling program. All emission samples and plume observation data were collected simultaneously from the kiln and clinker cooler sources. Results are reported separately for each source.

Appendix A contains complete printouts of field data, results tabulation, and example calculations. Appendices B and C present field and laboratory data sheets. Appendix D details the sampling and analytical procedures used during this test program. Appendix E shows equipment calibration procedures and results. Appendix F addresses quality assurance considerations pertinent to this test project.

3.1 ROTARY KILN EXHAUST

Particulate and particle size tests were simultaneously conducted at the inlet to and outlet of the wet scrubber serving the kiln exhaust gas stream. Visible emission observations were also performed during the particulate testing. In addition, SO_2 tests were simultaneously conducted before and after the scrubber. Tests for NO_x and VOC content in the scrubber exhaust gas were performed concurrent with the SO_2 tests.

Particulate sampling and analytical procedures followed those described in EPA Method 5 of the Federal Register* except that an ether-chloroform extraction was performed on the impinger contents to determine condensible organic and inorganic fractions. The particle size sampling and analytical procedures used at the scrubber and clinker cooler exhaust test locations followed those described in the "Procedures Manual for Inhalable Particulate Sampler Operation" recently developed for EPA by Southern Research Institute (SRI).[1] At the scrubber inlet an Andersen Heavy Grain Loading Impactor was used. Analytical procedures followed those described in the manufacturer's instruction manual. Sampling and analytical procedures for SO_2 followed those described in EPA Method 6* except that large impingers were used instead of the midget impingers specified in Method 6. Sampling and analytical procedures for NO_x followed those described in EPA Method 7.* Visible emission observations were conducted using procedures described in EPA Method 9* of the Federal Register. EPA Method 25* was used in determining the VOC content of the exhaust stream.

3.1.1 Flue Gas Conditions and Particulate Emissions

Tables 3-1 and 3-2 summarize the flue gas conditions and particulate emissions data collected at the scrubber inlet and outlet test locations. Since particulate emissions are expressed in pounds per hour and kilograms per hour, volumetric flow rates are also expressed in actual cubic meters per hour (acmh) and actual cubic feet per hour (acfh) at stack conditions. Flow

*40 CFR 60, Appendix A, Reference Methods 5, 6, 7, 9, and 25, July 1, 1981.

TABLE 3-1. SUMMARY OF FLUE GAS CONDITIONS

Run No.	Date, 1981	Volumetric flow rate: Actual[a] acmh	Volumetric flow rate: Actual[a] acfh	Volumetric flow rate: Standard[b] dscmh	Volumetric flow rate: Standard[b] dscfh	Temperature °C	Temperature °F	Moisture %	O_2, %	CO_2, %	CO, %
Scrubber inlet											
SIP-1	7/14	171,720	6,064,204	66,980	2,365,364	415	779	7.2	14.5	5.5	0.0
SIP-2	7/15	182,195	6,434,122	70,186	2,478,580	413	775	8.4	14.2	5.5	0.0
SIP-3	7/15	185,868	6,563,847	70,564	2,491,944	422	792	8.5	13.8	5.8	0.0
Average		179,928	6,354,058	69,243	2,445,296	417	782	8.0	14.2	5.6	0.0
					2,485,262				14.0		
Scrubber outlet											
SOP-1	7/14	103,886	3,668,666	70,052	2,473,854	65	149	21.2	14.6	5.5	0.0
SOP-2	7/15	106,055	3,745,268	71,543	2,526,506	63	145	21.4	14.4	5.3	0.0
SOP-3	7/15	107,452	3,794,620	71,403	2,521,561	65	148	22.1	14.8	5.6	0.0
Average		105,798	3,736,185	70,999	2,507,307	64	147	21.6	14.6	5.5	0.0
					2,524,033.5				14.6		

[a]Volumetric flow rate in actual cubic meters per hour (acmh) and actual cubic feet per hour (acfh) at stack conditions.

[b]Volumetric flow rate in dry standard cubic meters per hour (dscmh) and dry standard cubic feet per hour (dscfh): Standard conditions = 20°C and 760 mm Hg (68°F and 29.92 in.Hg) and zero percent moisture.

TABLE 3-2. SUMMARY OF PARTICULATE EMISSIONS DATA

Run No.	Date, 1981	Concentration[a]						Mass emission rate[b]					
		Filterable		Condensible				Filterable		Condensible			
				Organic		Inorganic				Organic		Inorganic	
		mg/dscm	gr/dscf	mg/dscm	gr/dscf	mg/dscm	gr/dscf	kg/h	lb/h	kg/h	lb/h	kg/h	lb/h
Kiln exhaust scrubber inlet													
SIP-1[c]	7/14	54,353	23.7	135.0	0.059	868.3	0.379	3,640	8,025	9.0	19.9	58.2	128.2
SIP-2	7/15	62,883	27.5	2.4	0.001	96.1	0.042	4,413	9,729	0.2	0.4	6.8	14.9
SIP-3	7/15	61,936	27.1	3.7	0.002	129.7	0.057	4,730	9,634	0.3	0.5	9.2	20.2
Average		59,724	26.1 27.3	47.0	0.021	364.7	0.159	4,261	9,129 9,681	3.2	6.9	24.7	54.4
Kiln exhaust scrubber outlet													
SOP-1	7/14	94.5	0.041	1.68	0.0007	35.8	0.016	6.6	14.6	0.12	0.26	2.5	5.5
SOP-2	7/15	100.9	0.044	1.18	0.0005	34.5	0.015	7.2	15.9	0.08	0.19	2.5	5.4
SOP-3	7/15	100.4	0.044	1.51	0.0007	34.7	0.015	7.2	15.8	0.11	0.24	2.5	5.5
Average		98.6	0.043 .044	1.46	0.0006	35.0	0.015	7.0	15.4 15.85	0.10	0.23	2.5	5.5

[a]Concentration in milligrams per dry standard cubic meter (mg/dscm) and grains per dry standard cubic foot (gr/dscf).

[b]Mass emission rate in kilograms per hour (kg/h) and pounds per hour (lb/h).

[c]Broken filter frit (see page 3-5).

rates corrected to standard conditions [20°C and 760 mm Hg (68°F and 29.92 in.Hg) and zero percent moisture] are expressed as dry standard cubic meters per hour (dscmh) and dry standard cubic feet per hour (dscfh). Particulate concentrations are reported in milligrams per dry standard cubic meter (mg/dscm) and grains per dry standard cubic foot (gr/dscf). Emission rates are expressed in kilograms per hour (kg/h) and pounds per hour (lb/h). The product of the concentration and the volumetric flow rate is the mass emission rate. The filterable particulate fraction represents material collected in the sample probe and on the filter, both of which were heated to approximately 121°C (250°F). The condensible organic and inorganic fractions represent material that condensed out or was trapped in the impinger section of the sample train at a temperature of approximately 20°C (68°F).

At the scrubber inlet, the volumetric flow rate averaged 69,200 dscmh (2,445,000 dscfh), temperature averaged 417°C (782°F), and moisture content averaged 8.0 percent. Oxygen and carbon dioxide contents averaged 14.2 and 5.6 percent, respectively. Filterable particulate concentration averaged 59,724 mg/dscm (26.1 gr/dscf), and the corresponding mass emission rate averaged 4261 kg/h (9129 lb/h). The condensible organic and inorganic concentrations averaged 47 mg/dscm (0.021 gr/dscf) and 365 mg/dscm (0.16 gr/dscf), respectively. The corresponding mass emission rates averaged 3.2 kg/h (6.9 lb/h) and 24.7 kg/h (54.4 lb/h) for each fraction.

During Test No. SIP-1, the filter frit support ruptured due to a high pressure drop across the frit and heat fatigue. Subsequently, some filterable sample loss did occur. However, the particulate was captured in the impinger section of the sample train resulting in the higher organic and inorganic fractions measured by ether-chloroform extraction for this run.

At the scrubber outlet, the volumetric flow rate averaged 71,000 dscmh (2,507,000 dscfh), temperature averaged 64°C (147°F), and moisture content averaged 21.6 percent. Oxygen and carbon dioxide contents averaged 14.6 and 5.5 percent, respectively. Filterable particulate concentration averaged 98.6 mg/dscm (0.043 gr/dscf), and the corresponding mass emission rate averaged 7.0 kg/h (15.4 lb/h). The condensible organic and inorganic concentrations averaged 1.5 mg/dscm (0.0006 gr/dscf) and 35 mg/dscm (0.015 gr/dscf), respectively. Organic and inorganic mass emission rates averaged 0.10 kg/h (0.23 lb/h) and 2.5 kg/h (5.5 lb/h).

The particulate removal efficiency of the scrubber averaged 99.8 percent, based on the average inlet and outlet particulate concentrations on a mg/dscm basis.

Since the inlet test location did not meet the minimum criteria set forth in EPA Method 1*, measurements were made to determine the degree of turbulent flow in the duct as detailed in Method 2 of the Federal Register.* Each traverse point was checked by aligning the face openings of the pitot tube

*40 CFR 60, Appendix A, Reference Methods 1 and 2, July 1, 1981.

perpendicular to the stack cross-sectional plane, designated "0° reference." Null (zero) pitot readings obtained at 0° reference indicated an acceptable flow condition at a given point. The overall average for all points was considerably less than 10 degrees indicating an acceptable flow condition existed in the duct. Turbulent flow conditions of this type tend to bias the velocity measurements high. The average inlet and outlet flow measurements agree to within 5 percent, indicating results obtained from this location are representative based on between-test reproducibility and subsequent velocity profile data.

3.1.2 Particle Size Distribution

A total of two samples were collected at the scrubber inlet and four samples at the outlet test sites. An Andersen Heavy Grain Load Impactor was used at the scrubber inlet. Sampling and analytical procedures followed those described in the manufacturer's specification manual. An Andersen cascade impactor was used at the scrubber outlet. Sampling and analytical procedures followed those described in the "Procedures Manual for Inhalable Particulate Sampler Operation" developed by Southern Research Institute for EPA.[1] Data obtained from the particulate test runs were combined with sampling data to obtain average flow rates, moisture content, and gas composition.

Data were reduced by computer programs as described in "A Computer-Based Cascade Impactor Data Reduction System" developed by SRI for EPA.[2] Individual computer printouts for each test and

brief descriptions of each program used are contained in Appendix A of this report.

Figure 3-1 presents the distribution curves for the samples collected at the scrubber inlet. Individual data points for each test were plotted manually. Run SIPS-1 was conducted on July 15 during the second and third particulate tests. The calculated mass loading was 65,000 mg/dscm. Run SIPS-2 was conducted on July 16 approximately one hour after the kiln had been stabilized from being down most of the day. The calculated mass loading for this run was 40,000 mg/dscm. Run SIPS-1 is considered more representative of actual particle size distribution for this source. All particle size results are based on aerodynamic diameters and unit density (1 g/cm^3). The data point distribution for these runs indicates that 50 percent of the particles by weight were less than 20 μm in diameter.

Figure 3-2 presents the average distribution curves for samples collected at the scrubber outlet. Sample Nos. SOPS-1,2,3 were considered non-representative due to overloading of individual impactor stages, therefore they are not graphically presented. The data indicate most of the particles are either large (>10 μm) or small (<3 μm) with little if any variation from these two points. The largest percentage of particles were collected in the impactor precutter (acetone rinse of nozzle) and the remaining particles collected on impactor Stages 5, 6, and 7. These stages exhibited cut-points of 2.3, 1.1, and 0.7 microns, respectively, for the specific test runs presented here. The

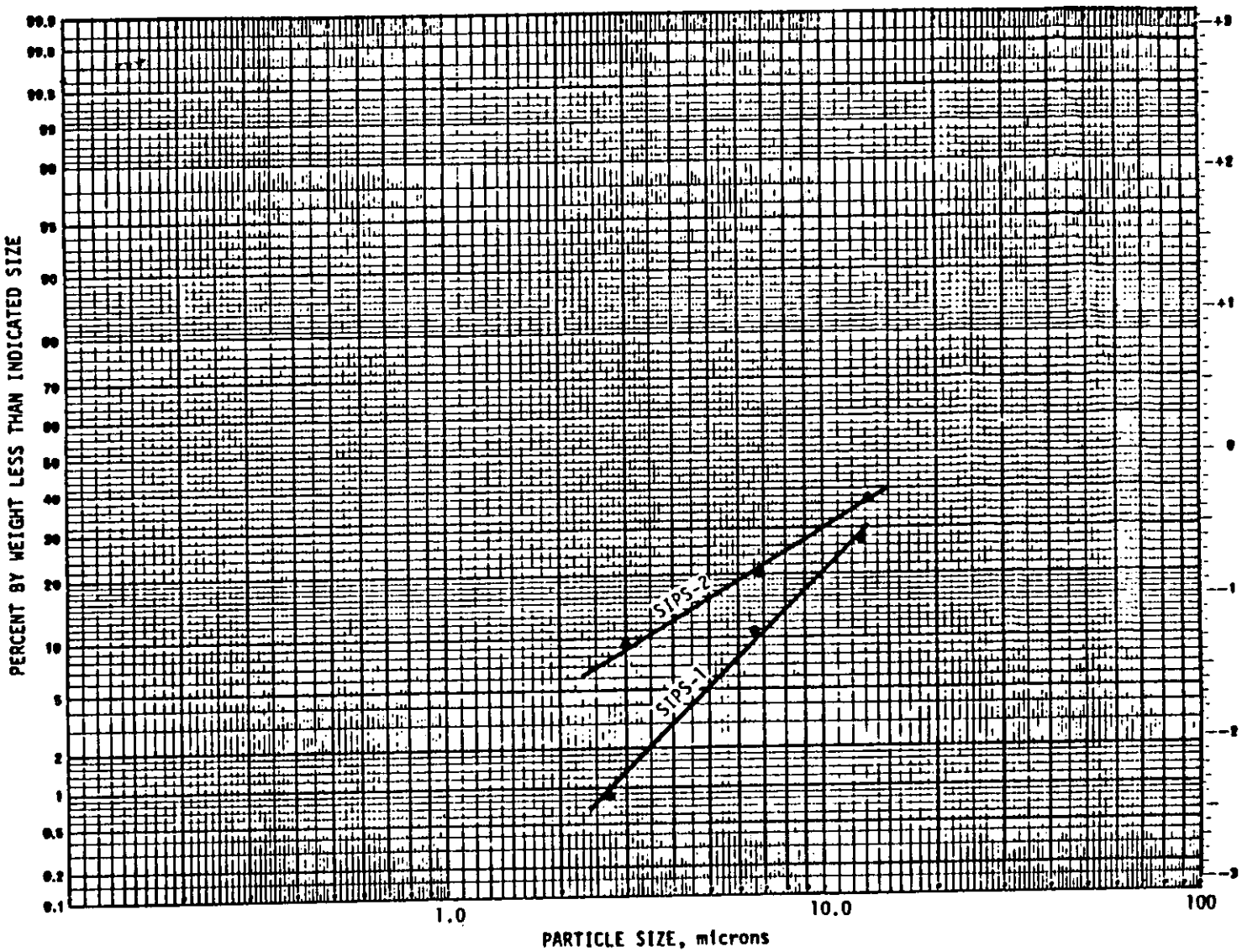

Figure 3-1. Particle size distribution - kiln exhaust scrubber inlet.

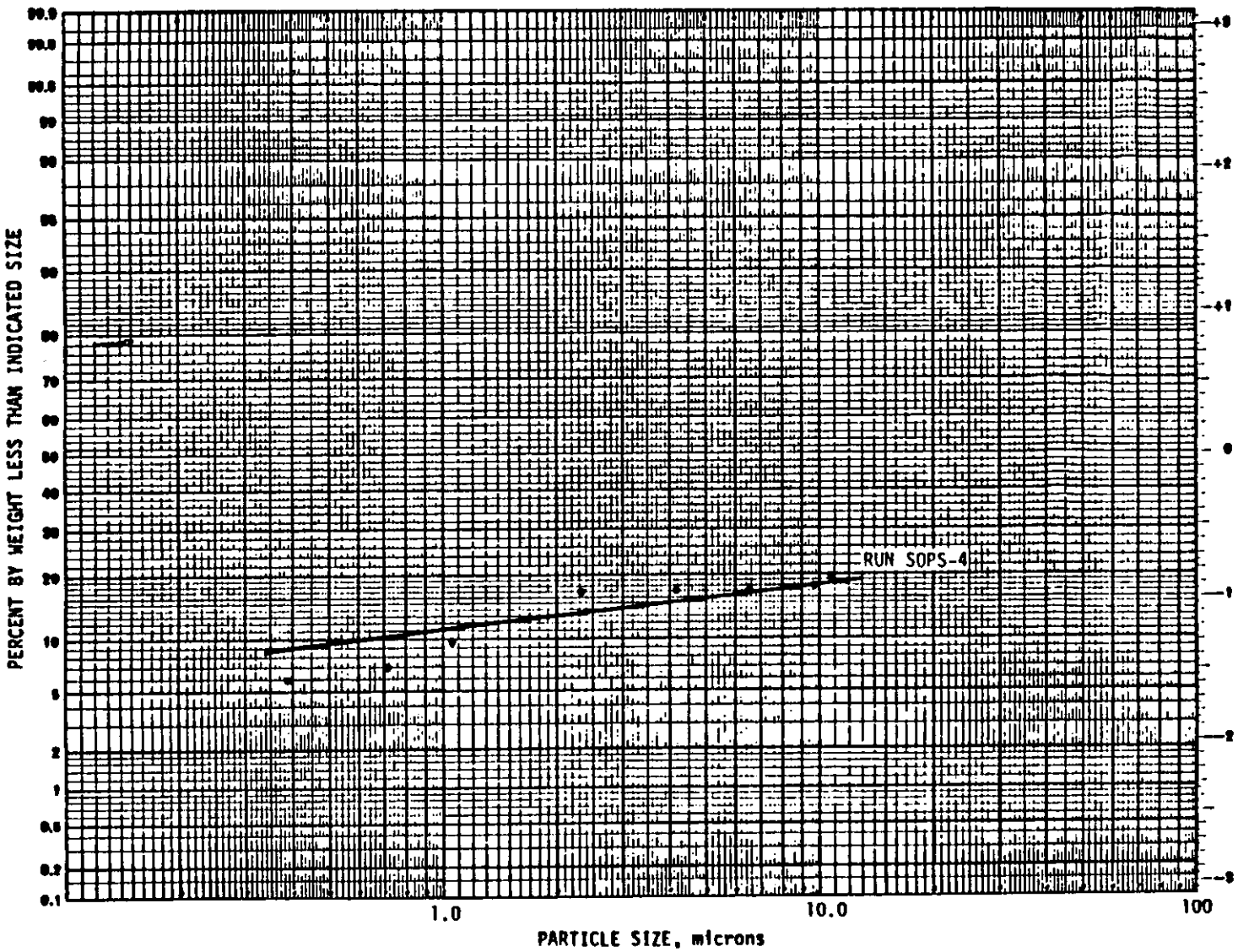

Figure 3-2. Particle size distribution - scrubber outlet.

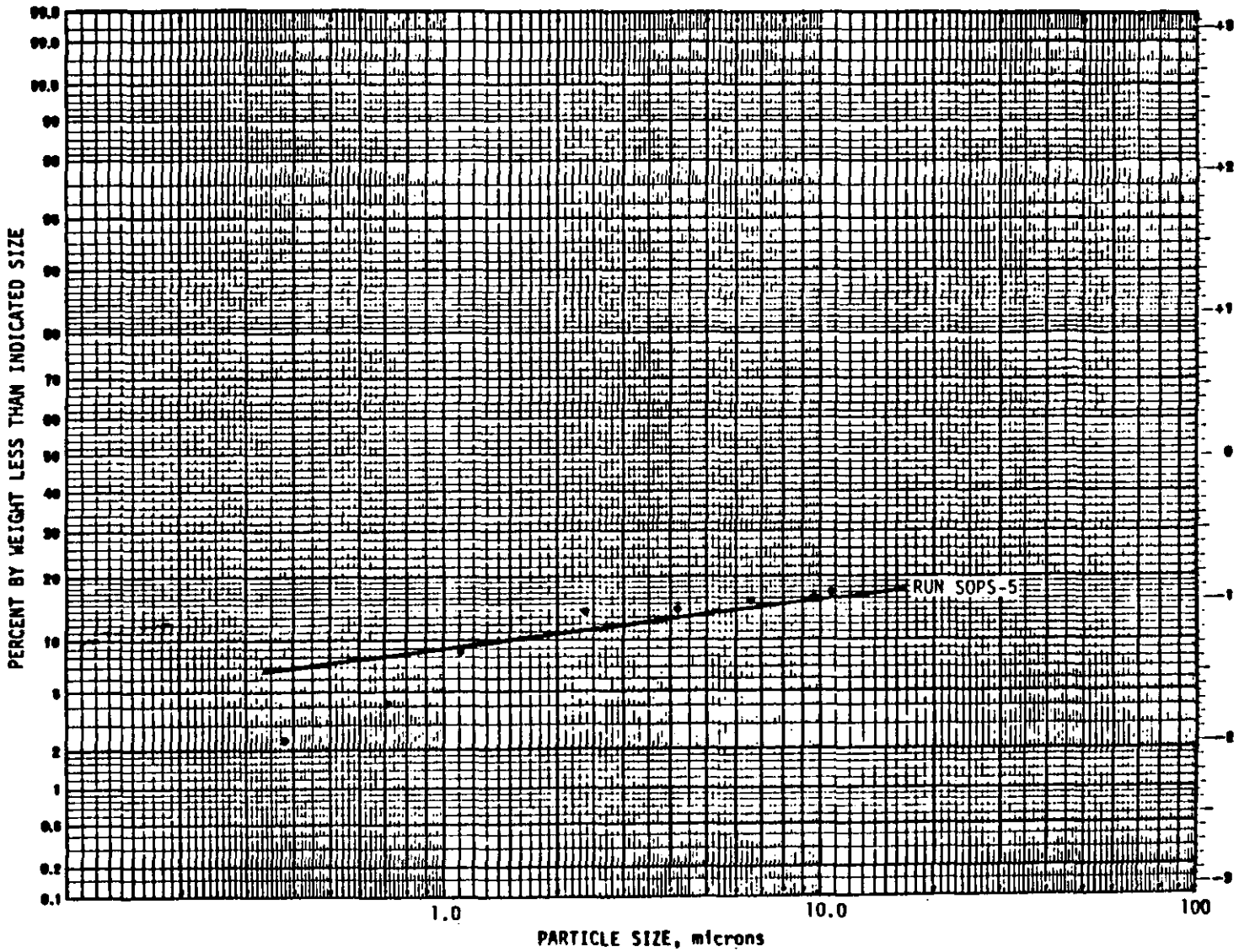

Figure 3-2 (continued)

smaller particles are probably formed by condensation of volatile matter within the kiln.

3.1.3 Sulfur Dioxide

Table 3-3 presents a summary of results for SO_2 tests conducted simultaneously before and after the wet scrubber. Concentrations are reported in parts per million by volume (ppm), milligrams per dry standard cubic meter (mg/dscm), and pounds per dry standard cubic foot (lb/dscf). Mass emission rates are reported in kilograms per hour and pounds per hour. The inlet mass emission rates were calculated from the measured concentrations and the average flow rate measured during the inlet particulate test runs (2,445,296 dscfh). The outlet mass emission rates were calculated in a similar manner using the average measured flow rate from the outlet particulate tests (2,507,307 dscfh). Analyses were conducted on site by EPA Method 6.*

Sulfur dioxide concentrations at the inlet to the wet scrubber averaged 1576 mg/dscm (592 ppm; 9.72×10^{-5} lb/dscf), and the corresponding average mass emission rate was 107.8 kg/h (237.6 lb/h). Flue gas temperature averaged 417°C (782°F), and oxygen content averaged 14.4 percent.

Sulfur dioxide concentrations at the scrubber exit stack averaged 381 mg/dscm (143 ppm; 2.35×10^{-5} lb/dscf), and the corresponding average mass emission rate was 26.7 kg/h (58.8 lb/h). Flue gas temperature averaged 64°C (147°F), and oxygen content averaged 14.7 percent.

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*40 CFR 60, Appendix A, Reference Method 6, July 1, 1981.

TABLE 3-3. SUMMARY OF SULFUR DIOXIDE DATA

Run No.	Date, 1981	Concentration ppm	Concentration mg/dscm	Concentration lb/dscf x 10^{-5}	Mass emission rate kg/h	Mass emission rate lb/h	O_2, %	Temperature °C	Temperature °F
Scrubber inlet[a]									
SIS-1	7/17	390	1038	6.40	70.9	156.4	13.4	417	782
SIS-2	7/17	660	1757	10.85	120.3	265.2	13.4	417	782
Average		525	1398	8.63	95.6	210.8	13.4	417	782
SIS-3	7/17	628	1672	10.31	114.3	252.0	14.5	417	782
SIS-4	7/17	635	1691	10.42	115.6	254.9	14.5	417	782
Average		632	1682	10.37	115.0	253.5	14.5	417	782
SIS-5	7/17	603	1605	9.89	109.7	241.9	14.4	417	782
SIS-6	7/17	635	1691	10.43	115.6	254.9	14.4	417	782
Average		619	1648	10.16	112.7	248.4	14.4	417	782
Scrubber outlet[b]									
SOS-1	7/17	131	349	2.15	24.5	54.0	14.5	64	147
SOS-2	7/17	191	508	3.14	35.7	78.6	14.5	64	147
Average		161	429	2.65	30.1	66.3	14.5	64	147
SOS-3	7/17	158	421	2.60	29.6	65.2	14.9	64	147
SOS-4	7/17	176	469	2.90	32.9	72.6	14.9	64	147
Average		167	445	2.75	31.3	68.9	14.9	64	147
SOS-5	7/17	119	317	1.95	22.2	48.9	14.7	64	147
SOS-6	7/17	82	218	1.34	15.2	33.6	14.7	64	147
Average		101	268	1.65	18.7	41.3	14.7	64	147

[a]Mass emission rates are based on the average stack gas flow rate determined during the inlet particulate tests (69,243 dscmh and 2,445,296 dscfh).

[b]Mass emission rates are based on the average stack gas flow rate determined during the outlet particulate tests (70,999 dscmh and 2,507,307 dscfh).

3.1.4 Nitrogen Oxides

Table 3-4 summarizes data on emissions of nitrogen oxides. Three tests, each consisting of four grab samples collected at 15-minute intervals, were conducted on the kiln exhaust scrubber outlet. Concentrations are reported in milligrams per dry standard cubic meter, parts per million by volume, and pounds per dry standard cubic foot. Emission rates, reported in kilograms per hour and pounds per hour, were calculated from the average flue gas flow rate measured during the particulate test runs corrected to standard conditions (2,507,307 dscfh).

Nitrogen oxide concentrations averaged 356 mg/dscm (186 ppm; 0.22×10^{-4} lb/dscf), and the corresponding mass emission rate was 25.3 kg/h (55.7 lb/h).

3.1.5 Hydrocarbon Emissions From the Kiln Scrubber Outlet

Sampling for hydrocarbon emissions from the scrubber outlet at Kiln No. 1 was accomplished using the procedures of EPA Method 25* for the determination of total gaseous nonmethane organics (TGNMO). A total of four one-hour samples were collected at the scrubber outlet. Test Nos. 1 and 2 were conducted simultaneously on one day. Test Nos. 3 and 4 were conducted in sequence on the following day. The results of the Method 25 sampling are presented in Table 3-5. In the Method 25 analytical procedure, all nonmethane organics are oxidized to carbon dioxide and reduced to methane before measurement with a flame ionization detector (FID). Therefore, organic concentrations are expressed

*40 CFR 60, Appendix A, Reference Method 25, July 1, 1981.

TABLE 3-4. SUMMARY OF NITROGEN OXIDE EMISSIONS DATA
SCRUBBER OUTLET[a]

Run No.	Date, 1981	Sample No.	Concentration			Mass emission rate	
			ppm	mg/dscm	lb/dscf x 10^{-4}	kg/h	lb/h
1	7/17	SON-1A	187	358	0.2236	25.4	56.1
		SON-1B	173	331	0.2065	23.5	51.8
		SON-1C	191	365	0.2284	26.0	57.3
		SON-1D	196	375	0.2341	26.6	58.7
Average			187	357	0.2232	25.4	56.0
2	7/17	SON-2A	181	346	0.2163	24.6	54.2
		SON-2B	191	365	0.2283	25.9	57.2
		SON-2C	175	335	0.2096	23.9	52.6
		SON-2D	197	377	0.2355	26.8	59.0
Average			186	356	0.2224	25.3	55.8
3	7/17	SON-3A	176	337	0.2105	23.9	52.8
		SON-3B	189	362	0.2257	25.7	56.6
		SON-3C	191	365	0.2280	25.9	57.2
		SON-3D	183	350	0.2180	24.8	54.7
Average			185	354	0.2206	25.1	55.3

[a]Mass emission rates are based on the average stack gas flow rate determined during the scrubber outlet particulate tests (70,999 dscmh and 2,507,307 dscfh).

TABLE 3-5. HYDROCARBON EMISSIONS FROM SCRUBBER OUTLET

Test No.	Date, 1981	Sampling time, 24-h		NMO[a] concentration ppm as CH_4	Gas stream flow rate		Hydrocarbon emission rate expressed as methane[b]	
		Start	Finish		dscmh	dscfh	kg/h	lb/h
SO-25-1	7/16	1500	1600	134	70,999	2,507,307	6.3	13.9
SO-25-2	7/16	1500	1600	231	70,999	2,507,307	10.9	24.0
SO-25-3	7/17	905	1035	378	70,999	2,507,307	17.9	39.5
SO-25-4	7/17	1045	1200	128	70,999	2,507,307	6.0	13.2
Average				218	70,999	2,507,307	10.3	22.7

[a]NMO = Nonmethane organics measured and expressed as methane (CH_4).

[b]Based on the molecular weight of methane, 16 g/g-mole (16 lb/lb-mole).

in ppm as methane and emission rates were calculated based on the molecular weight of methane (16 g/g-mole).

The nonmethane organic concentration in the outlet stack varied from 128 ppm to 378 ppm with an average value of 218 ppm as methane. The average emission rate of nonmethane organic compounds was 10.3 kg/h (22.7 lb/h) as methane.

3.1.6 Visible Emissions

Each particulate test included a survey of visible emissions at the kiln scrubber outlet. Visible emissions were read in 6-minute sets throughout each particulate test. Table 3-6 summarizes the findings. For each test, opacities ranged from 0 to 5 percent and averaged less than 1 percent for all sets.

3.2 CLINKER COOLER EXHAUST

Particulate emissions and particle size distribution tests were performed at the clinker cooler exhaust stack. Visible emissions were observed at the outlet stack during each particulate test. In addition, SO_2 tests were performed simultaneously with the scrubber test locations.

Particulate sampling and analytical procedures followed EPA Method 5* except that an ether-chloroform extraction was performed on the impinger contents to determine condensible organic and inorganic content. Particle size sampling and analytical procedures followed those described in "Procedures Manual for Inhalable Particulate Sampler Operation", recently developed for EPA by Southern Research Institute.[1] Visible emission

*40 CFR 60, Appendix A, Reference Method 5, July 1, 1981.

TABLE 3-6. SUMMARY OF VISIBLE EMISSIONS DATA
SCRUBBER OUTLET

Test 1 (7/14/81)				Test 2 (7/15/81)				Test 3 (7/15/81)			
Set No.	Time	Average % opacity	Range	Set No.	Time	Average % opacity	Range	Set No.	Time	Average % opacity	Range
SOVE-1-1	1035 - 1040	1	0 - 5	SOVE-2-1	0900 - 0905	4	0 - 5	SOVE-3-1	1355 - 1400	0	0 - 5
SOVE-1-2	1047 - 1052	1	0 - 5	SOVE-2-2	0912 - 0917	2	0 - 5	SOVE-3-2	1407 - 1412	0	0 - 5
SOVE-1-3	1059 - 1104	1	0 - 5	SOVE-2-3	0924 - 0929	1	0 - 5	SOVE-3-3	1419 - 1424	0	0
SOVE-1-4	1111 - 1116	0	0 - 5	SOVE-2-4	0936 - 0941	2	0 - 5	SOVE-3-4	1431 - 1436	1	0 - 5
SOVE-1-5	1123 - 1128	0	0 - 5	SOVE-2-5	0948 - 0953	0	0 - 5	SOVE-3-5	1443 - 1448	0	0
SOVE-1-6	1135 - 1140	1	0 - 5	SOVE-2-6	1000 - 1005	1	0 - 5	SOVE-3-6	1455 - 1500	0	0 - 5
SOVE-1-7	1147 - 1152	1	0 - 5	SOVE-2-7	1012 - 1017	0	0	SOVE-3-7	1507 - 1512	2	0 - 5
SOVE-1-8	1159 - 1204	1	0 - 5	SOVE-2-8	1024 - 1029	1	0 - 5	SOVE-3-8	1519 - 1524	1	0 - 5
SOVE-1-9	1211 - 1216	0	0	SOVE-2-9	1036 - 1041	1	0 - 5	SOVE-3-9	1531 - 1536	0	0
SOVE-1-10	1223 - 1228	0	0	SOVE-2-10	1048 - 1053	0	0 - 5	SOVE-3-10	1543 - 1548	1	0 - 5
SOVE-1-11	1240 - 1245	0	0	SOVE-2-11	1100 - 1105	0	0	SOVE-3-11	1555 - 1600	0	0
SOVE-1-12	1252 - 1257	2	0 - 5	SOVE-2-12	1112 - 1117	0	0	SOVE-3-12	1607 - 1612	1	0 - 5
SOVE-1-13	1304 - 1309	0	0 - 5	SOVE-2-13	1124 - 1129	0	0				
SOVE-1-14	1316 - 1321	1	0 - 5	SOVE-2-14	1136 - 1141	0	0				
SOVE-1-15	1328 - 1333	0	0								

observations were made by EPA Method 9.* Sulfur dioxide tests were conducted using EPA Method 6.* Concentration and mass emission rate data are expressed in units identical to those used in Section 3.1 of this report.

3.2.1 Flue Gas Conditions and Particulate Emissions

Summaries of the measured flue gas and particulate emission data from the clinker cooler exhaust are presented in Tables 3-7 and 3-8.

The filterable particulate data reported in Table 3-8 represent matter collected in the sample probe and on the filter, both of which were heated to approximately 121°C (250°F). The condensible organic and inorganic fractions represent material that condensed out or was trapped in the impinger section of the sample train at a temperature of approximately 20°C (68°F). All velocity measurements were obtained using an S type pitot tube and a 0-0.635 cm (0-0.25 in.) inclined manometer due to the low flow (natural draft) situation encountered at this site.

The volumetric flow rate averaged 11,800 dscmh (415,300 dscfh), temperature averaged 197°C (386°F), and the moisture content averaged 2.1 percent. The oxygen and carbon dioxide contents averaged 20.1 and 0.0 percent, respectively.

Filterable particulate concentration averaged 147 mg/dscm (0.064 gr/dscf) with a corresponding average mass emission rate of 1.7 kg/h (3.8 lb/h). The organic and inorganic concentrations averaged 0.63 mg/dscm (0.0003 gr/dscf) and 24 mg/dscm (0.01

*40 CFR 60, Appendix A, Reference Methods 6 and 9, July 1, 1981.

TABLE 3-7. SUMMARY OF FLUE GAS CONDITIONS
CLINKER COOLER OUTLET

No.	Date, 1981	Volumetric flow rate				Temperature		Moisture, %	O_2, %	CO_2, %	CO, %
		Actual[a]		Standard[b]							
		acmh	acfh	dscmh	dscfh	°C	°F				
CCP-1	7/14	19,748	697,376	11,438	403,918	218	424	2.0	20.3	0.0	0.0
CCP-2	7/15	19,521	689,365	11,874	419,309	194	381	1.8	19.8	0.0	0.0
CCP-3	7/15	19,125	675,396	11,968	422,646	178	353	2.4	20.2	0.0	0.0
Average		19,465	687,379	11,760	415,291	197	386	2.1	20.1	0.0	0.0

[a]Volumetric flow rate in actual cubic meters per hour (acmh) and actual cubic feet per hour (acfh) at stack conditions.

[b]Volumetric flow rate in dry standard cubic meters per hour (dscmh) and dry standard cubic feet per hour (dscfh): Standard conditions = 20°C and 760 mm Hg (68°F and 29.92 in.Hg) and zero percent moisture.

TABLE 3-8. SUMMARY OF PARTICULATE EMISSIONS DATA

Clinker cooler outlet													
		Concentration[a]						Mass emission rate[b]					
		Filterable		Condensible				Filterable		Condensible			
				Organic		Inorganic				Organic		Inorganic	
Run No.	Date, 1981	mg/dscm	gr/dscf	mg/dscm	gr/dscf	mg/dscm	gr/dscf	kg/h	lb/h	kg/h	lb/h	kg/h	lb/h
CCP-1	7/14	120.3	0.053	0.57	0.0003	19.3	0.008	1.4	3.0	0.006	0.014	0.22	0.49
CCP-2	7/15	144.2	0.063	0.23	0.0001	27.9	0.012	1.7	3.8	0.002	0.006	0.33	0.73
CCP-3	7/15	176.8	0.077	1.08	0.0005	24.4	0.011	2.1	4.7	0.013	0.028	0.29	0.64
Average		147.1	0.064	0.63	0.0003	23.9	0.010	1.7	3.8	0.007	0.016	0.28	0.62

[a]Concentration in milligrams per dry standard cubic meter (mg/dscm) and grains per dry standard cubic foot (gr/dscf)

[b]Mass emission rate in kilograms per hour (kg/h) and pounds per hour (lb/h).

gr/dscf), and the corresponding mass emission rates averaged 0.007 kg/h (0.016 lb/h) and 0.28 kg/h (0.62 lb/h).

3.2.2 Particle Size Distribution

A total of four particle size samples were collected from the clinker cooler outlet during the particulate test runs. An Andersen cascade impactor was used for these tests. Section 3.1.2 and Appendix A describe the sampling and analytical procedures and the data reduction techniques used, respectively.

Figure 3-3 presents the distribution curve for each set of four samples collected. Individual data points for each test were plotted manually. The distribution curve was plotted manually for each individual test. All particle size results are based on aerodynamic diameters and unit density (1 g/cm^3). The data show that 50 percent of the particles by weight were less than 20 μm.

3.2.3 Clinker Cooler Visible Emissions

Visible emissions were surveyed at the clinker cooler outlet during each particulate test. Visible emissions were read in 6-minute sets throughout each test. Table 3-9 summarizes the visible emissions data. No visible emissions from the stack were detected by the certified observer during the test period.

3.2.4 Sulfur Dioxide

Table 3-10 summarizes the results of SO_2 tests conducted at the clinker cooler outlet. For each test, the SO_2 concentration averaged less than 1 ppm by volume, which is below the minimum detectable limit of the analytical method.* It should be noted

*40 CFR 60, Appendix A, Reference Method 6, July 1, 1981.

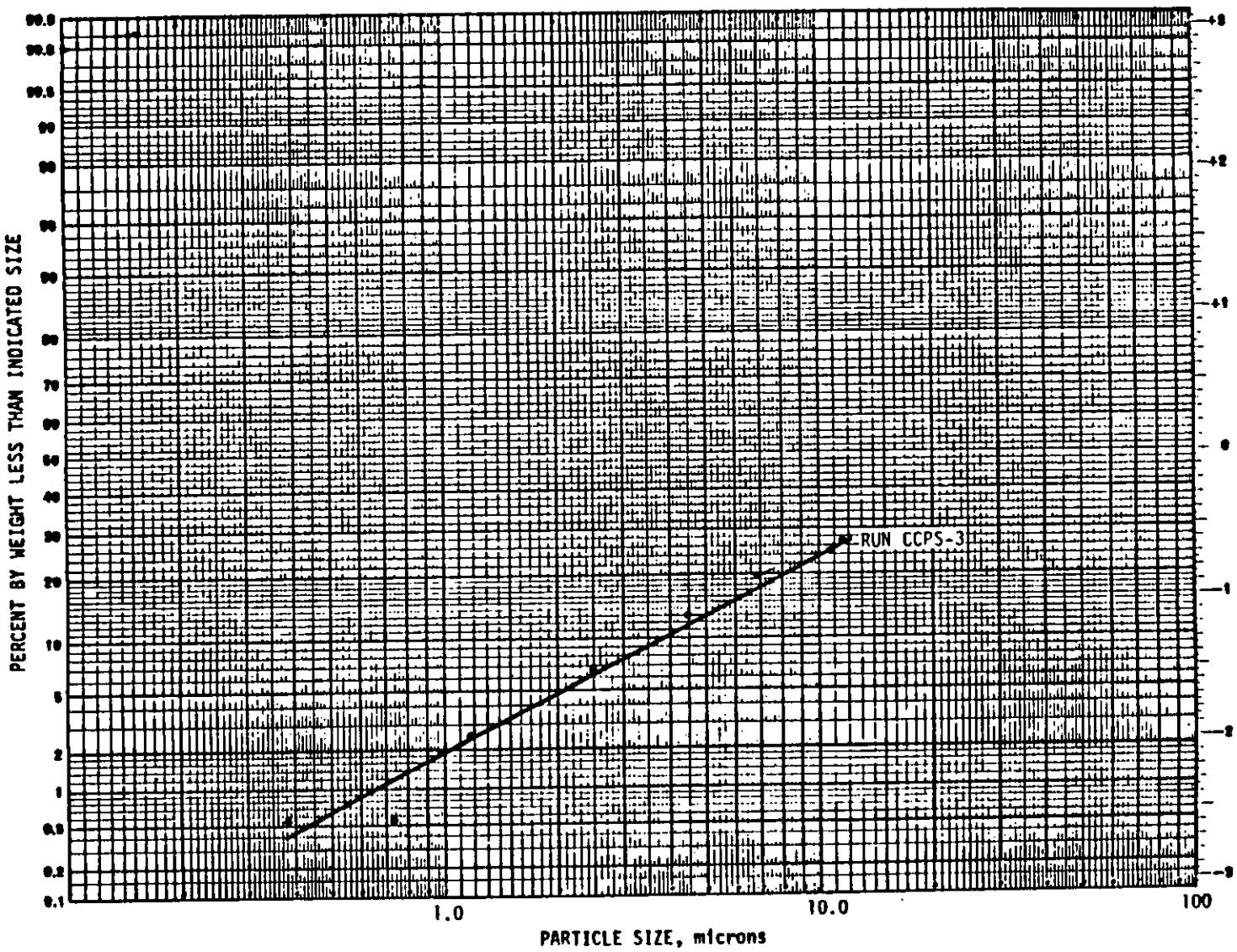

Figure 3-3. Particle size distribution - clinker cooler exhaust.

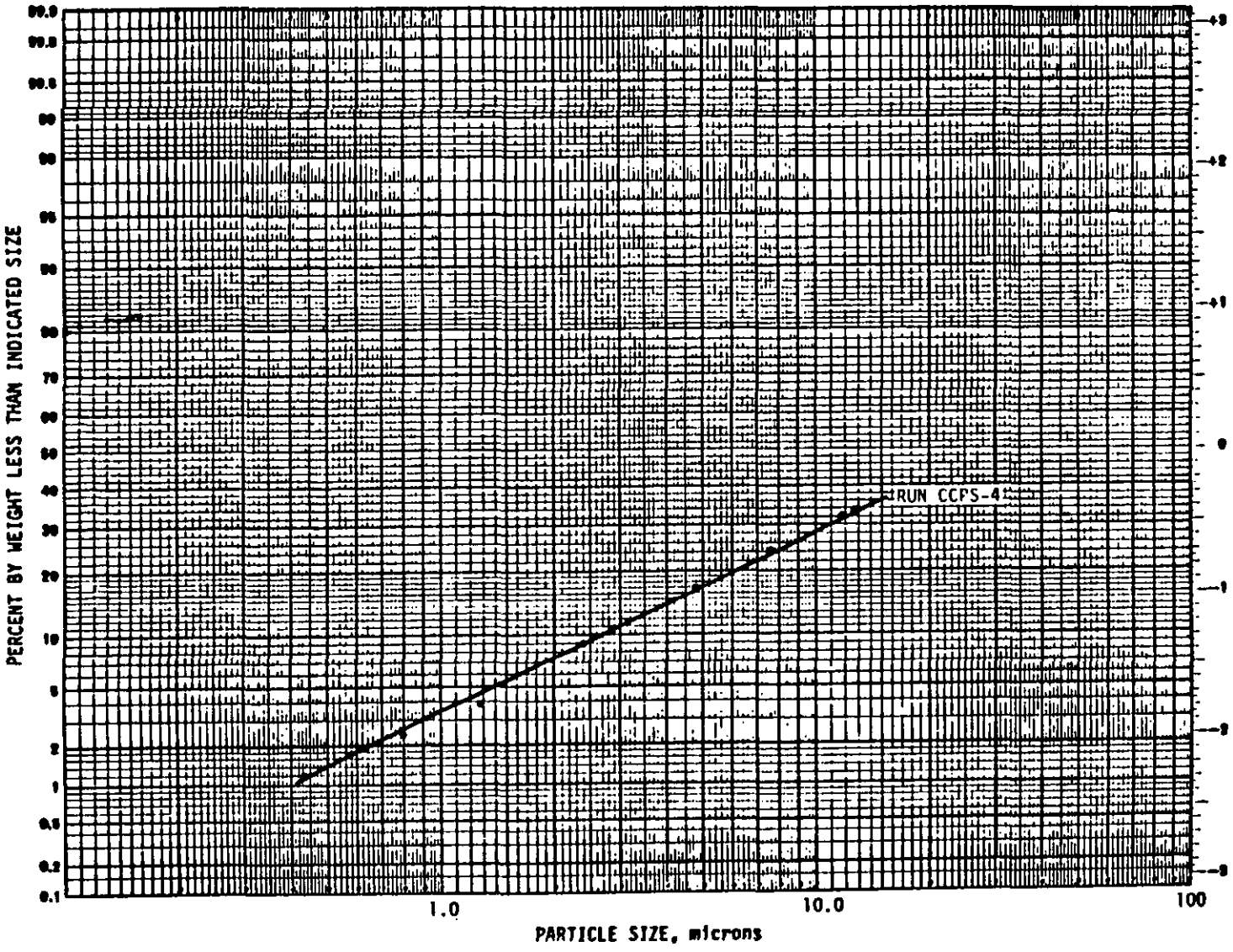

Figure 3-3 (continued)

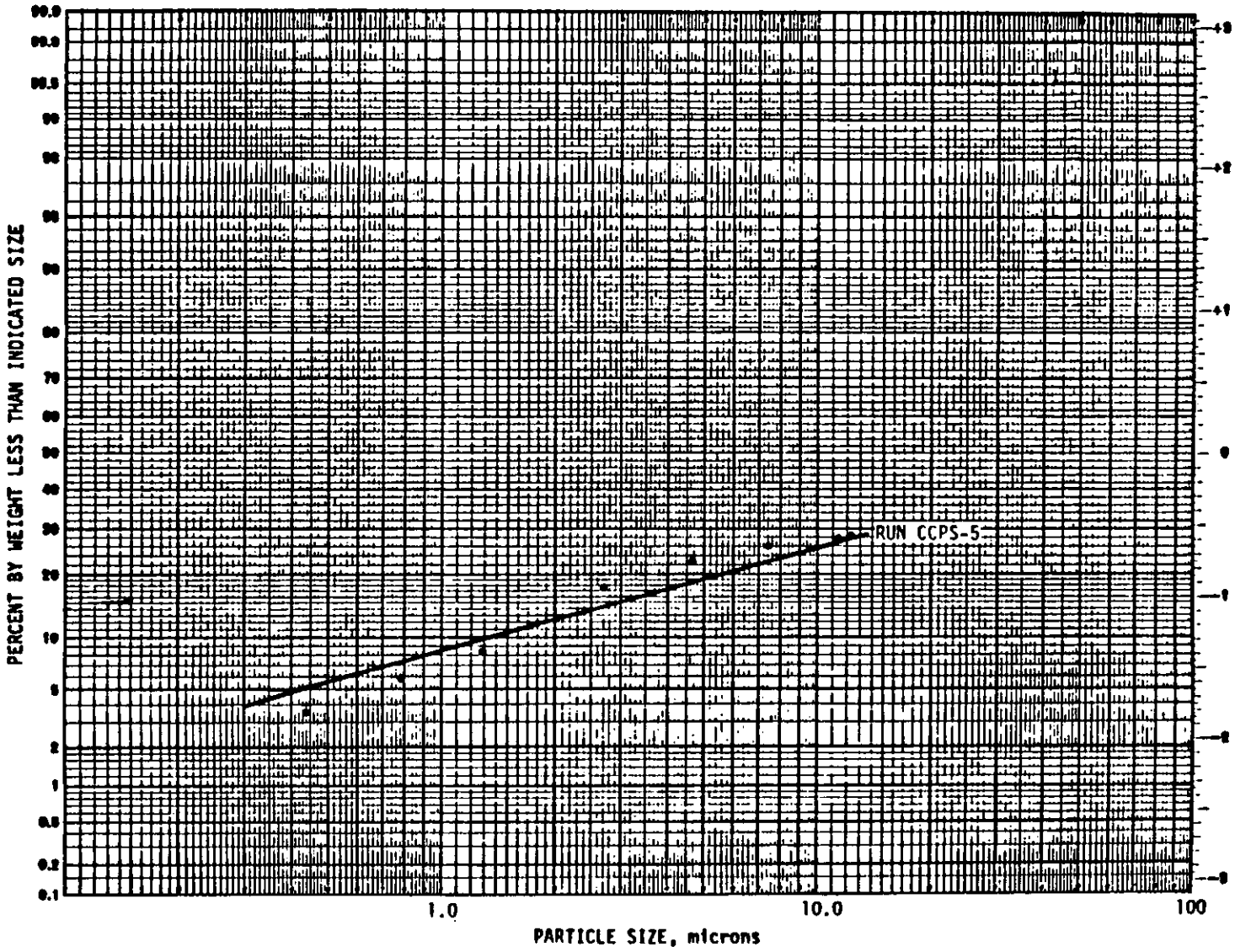

Figure 3-3 (continued)

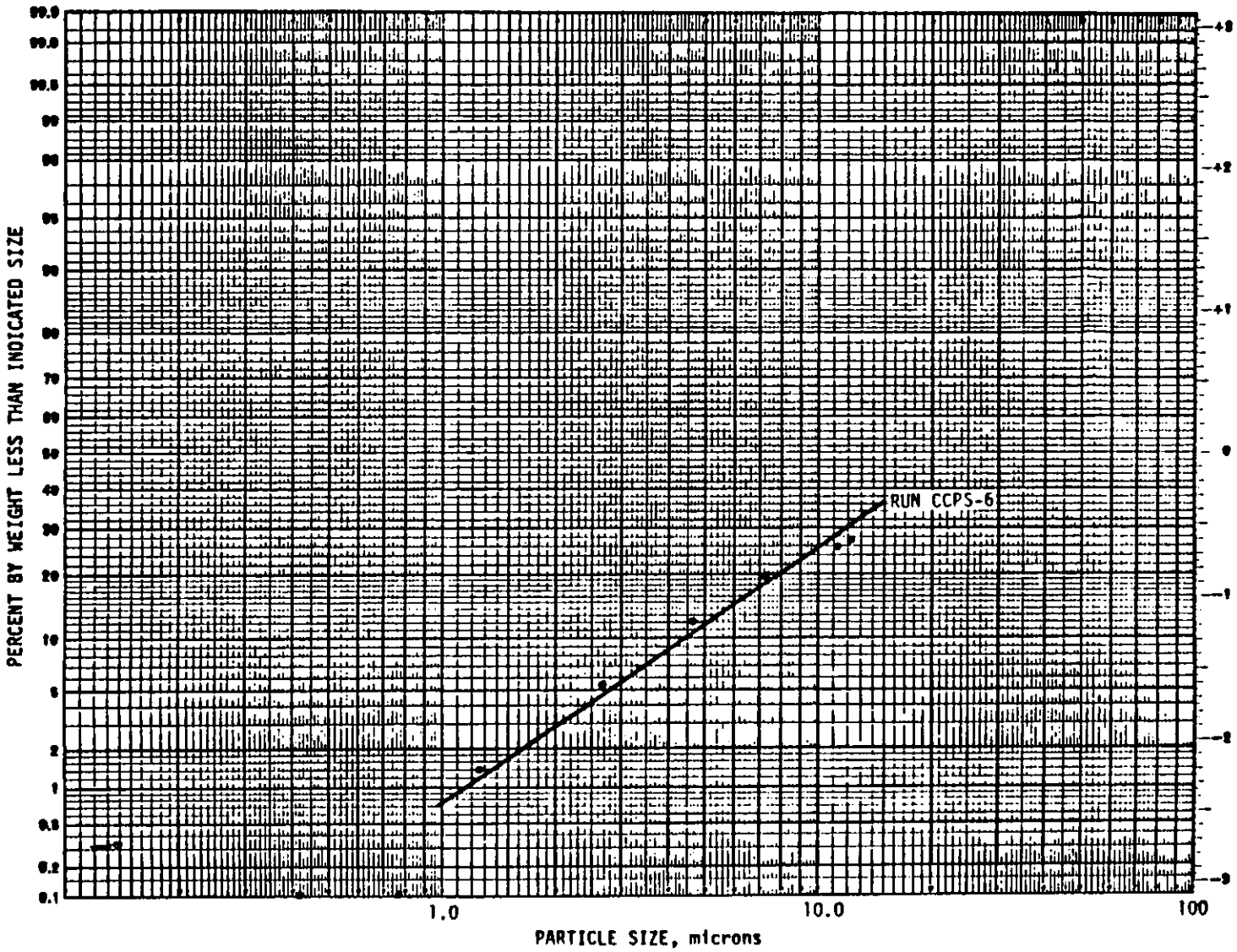

Figure 3-3 (continued)

TABLE 3-9. SUMMARY OF VISIBLE EMISSIONS DATA
CLINKER COOLER OUTLET

Test 1 (7/14/81)				Test 2 (7/15/81)				Test 3 (7/15/81)			
Set No.	Time	Average % opacity	Range	Set No.	Time	Average % opacity	Range	Set No.	Time	Average % opacity	Range
CCVE-1-1	1041 - 1046	0	0	CCVE-2-1	0906 - 0911	0	0	CCVE-3-1	1401 - 1406	0	0
CCVE-1-2	1053 - 1058	0	0	CCVE-2-2	0918 - 0923	0	0	CCVE-3-2	1413 - 1418	0	0
CCVE-1-3	1105 - 1110	0	0	CCVE-2-3	0930 - 0935	0	0	CCVE-3-3	1425 - 1430	0	0
CCVE-1-4	1117 - 1122	0	0	CCVE-2-4	0942 - 0947	0	0	CCVE-3-4	1437 - 1442	0	0
CCVE-1-5	1129 - 1134	0	0	CCVE-2-5	0954 - 0959	0	0	CCVE-3-5	1449 - 1454	0	0
CCVE-1-6	1141 - 1146	0	0	CCVE-2-6	1006 - 1011	0	0	CCVE-3-6	1501 - 1506	0	0
CCVE-1-7	1153 - 1158	0	0	CCVE-2-7	1018 - 1023	0	0	CCVE-3-7	1513 - 1518	0	0
CCVE-1-8	1205 - 1210	0	0	CCVE-2-8	1030 - 1035	0	0	CCVE-3-8	1525 - 1530	0	0
CCVE-1-9	1217 - 1222	0	0	CCVE-2-9	1042 - 1047	0	0	CCVE-3-9	1537 - 1542	0	0
CCVE-1-10	1234 - 1239	0	0	CCVE-2-10	1054 - 1059	0	0	CCVE-3-10	1549 - 1554	0	0
CCVE-1-11	1246 - 1251	0	0	CCVE-2-11	1106 - 1111	0	0	CCVE-3-11	1601 - 1606	0	0
CCVE-1-12	1258 - 1303	0	0	CCVE-2-12	1118 - 1123	0	0				
CCVE-1-13	1310 - 1315	0	0								
CCVE-1-14	1322 - 1327	0	0								

TABLE 3-10. SUMMARY OF SULFUR DIOXIDE RESULTS
CLINKER COOLER OUTLET

Run No.	Date, 1981	Concentration [a]			Mass emission rate		O_2, %	Temperature	
		ppm	mg/dscm	lb/dscf x 10^{-5}	kg/h	lb/h		°C	°F
CCS-1	7/17	<1	0.0	0.0	0.0	0.0	20.2	197	386
CCS-2	7/17	<1	0.0	0.0	0.0	0.0	20.2	197	386
Average		<1	0.0	0.0	0.0	0.0	20.2	197	386
CCS-3	7/17	<1	0.0	0.0	0.0	0.0	20.3	197	386
CCS-4	7/17	<1	0.0	0.0	0.0	0.0	20.3	197	386
Average		<1	0.0	0.0	0.0	0.0	20.3	197	386
CCS-5	7/17	<1	0.0	0.0	0.0	0.0	20.1	197	386
CCS-6	7/17	<1	0.0	0.0	0.0	0.0	20.1	197	386
Average		<1	0.0	0.0	0.0	0.0	20.1	197	386

[a]Below minimum detectable limit, when 0.001 N barium perchlorate was used to increase the minimum detectable limit.

that the normality of the barium perchlorate solution used in analyses of these samples was changed to 0.001 N to increase the detectable limit.

3.3 PROCESS SAMPLES

Table 3-11 summarizes results from analysis of process samples collected during each particulate test. Shale and coal samples were collected at approximately 30-minute intervals. Shale samples were collected from the kiln feed conveyor and coal samples after the pulverizer, before the coal entered the kiln. Samples of the final aggregate product and scrubber water effluent were also collected for determination of total sulfates. One scrubber influent sample was collected by PEDCo personnel at the end of the test program for sulfate analyses and pH determination.

The analytical data on shale showed an average sulfur content of 0.11 percent and an average moisture content of 0.61 percent. The analytical data on coal showed an average sulfur content of 2.03 percent and an average ash content of 17.8 percent. The sulfur content of the final product averaged less than 0.02 percent. The sulfate concentration of the scrubber influent sample was 1770 milligrams per liter (ml). The sulfate concentration of the effluent samples averaged 1890 ml/liter. The scrubber influent showed a pH of 4.0 and composite samples of the effluent a pH of 3.95.

TABLE 3-11. SUMMARY OF PROCESS SAMPLE ANALYSIS RESULTS

Particulate Run No.	Date, 1981	Sample type	Density, g/cm^3	Moisture, % as received	Ash, % dry basis	Sulfur, % dry basis except where noted
1	7/14	Coal	-	6.95	16.87	2.11[a]
		Shale	2.52	0.63	-	0.12[b]
2-3	7/15	Coal	-	6.61	18.67	1.95[a]
		Shale	2.60	0.58	-	0.09[b]
1-3	7/14-15	Final product	2.23	-	-	<0.02[b]
		Scrubber influent	-	-	-	1770 mg/l[c]
		Scrubber effluent	-	-	-	1890 mg/l[c] (average)

[a]ASTM D3177.

[b]ASTM D2234, as received basis.

[c]Concentration in milligrams per liter.

3.4 FUGITIVE EMISSIONS

Fugitive emissions were surveyed during each particulate test using procedures described in EPA Method 9.* Separate surveys were performed at the following locations: raw material crushing, clinker discharge chute, final product crushing and screening, and the kiln seals (charge and product). A 30-minute survey was conducted at each location during the particulate tests. Table 3-12 summarizes the results of the fugitive emission survey.

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*40 CFR 60, Appendix A, Reference Method 9, July 1, 1981.

TABLE 3-12. SUMMARY OF FUGITIVE EMISSIONS DATA

Test 1 (7/14/81)				Test 2 (7/15/81)				Test 3 (7/15/81)			
Set No.	Time	Average % opacity	Range	Set No.	Time	Average % opacity	Range	Set No.	Time	Average % opacity	Range
Raw material crusher											
VFC-1-1	1035 - 1040	0	0	VFC-2-1	1100 - 1105	0	0	VFC-3-1	1350 - 1355	0	0
VFC-1-2	1041 - 1046	1	0 - 5	VFC-2-2	1106 - 1111	0	0	VFC-3-2	1356 - 1401	0	0
VFC-1-3	1047 - 1052	0	0	VFC-2-3	1112 - 1117	0	0 - 5	VFC-3-3	1402 - 1407	0	0
VFC-1-4	1053 - 1058	0	0 - 5	VFC-2-4	1118 - 1123	0	0	VFC-3-4	1408 - 1413	0	0
VFC-1-5	1059 - 1104	0	0	VFC-2-5	1124 - 1129	0	0 - 5	VFC-3-5	1414 - 1419	0	0
Rotary kiln seals											
VFK-1-1	1110 - 1115	0	0	VFK-2-1	1020 - 1025	0	0	VFK-3-1	1425 - 1430	0	0
VFK-1-2	1116 - 1121	0	0	VFK-2-2	1026 - 1031	0	0	VFK-3-2	1431 - 1436	0	0
VFK-1-3	1122 - 1127	0	0	VFK-2-3	1032 - 1037	0	0	VFK-3-3	1437 - 1442	0	0
VFK-1-4	1128 - 1133	0	0	VFK-2-4	1038 - 1043	0	0	VFK-3-4	1443 - 1448	0	0
VFK-1-5	1134 - 1139	0	0	VFK-2-5	1044 - 1049	0	0	VFK-3-5	1449 - 1454	0	0
								VFK-3-6	1610 - 1615	0	0
								VFK-3-7	1616 - 1621	0	0
Clinker cooler											
VCCF-1-1	1150 - 1155	5	5	VCCF-2-1	0900 - 0905	8	5 - 10	VCCF-3-1	1500 - 1505	1	0 - 5
VCCF-1-2	1156 - 1201	5	5	VCCF-2-2	0906 - 0911	5	5 - 10	VCCF-3-2	1506 - 1511	6	0 - 10
VCCF-1-3	1202 - 1207	5	5 - 10	VCCF-2-3	0912 - 0917	5	5	VCCF-3-3	1512 - 1517	6	5 - 10
VCCF-1-4	1208 - 1213	5	5	VCCF-2-4	0918 - 0923	5	5	VCCF-3-4	1518 - 1523	7	5 - 10
VCCF-1-5	1214 - 1219	6	5 - 10	VCCF-2-5	0924 - 0929	7	5 - 10	VCCF-3-5	1524 - 1529	5	5
				VCCF-2-6	1138 - 1143	6	5 - 10	VCCF-3-6	1550 - 1555	6	0 - 10
								VCCF-3-7	1556 - 1601	6	5 - 10
Final product crusher											
VFCF-1-1	1230 - 1235	5	0 - 10	VFCF-2-1	0935 - 0940	2	0 - 5	VFCF-3-1	1540 - 1545	0	0
VFCF-1-2	1236 - 1241	3	0 - 5	VFCF-2-2	0941 - 0946	3	0 - 5				
VFCF-1-3	1242 - 1247	0	0 - 5	VFCF-2-3	0947 - 0952	0	0				
VFCF-1-4	1248 - 1253	0	0 - 5	VFCF-2-4	0953 - 0958	1	0 - 5				
VFCF-1-5	1254 - 1259	0	0 - 5	VFCF-2-5	0959 - 1004	1	0 - 5				
				VFCF-2-6	1150 - 1155	1	0 - 5				

SECTION 4

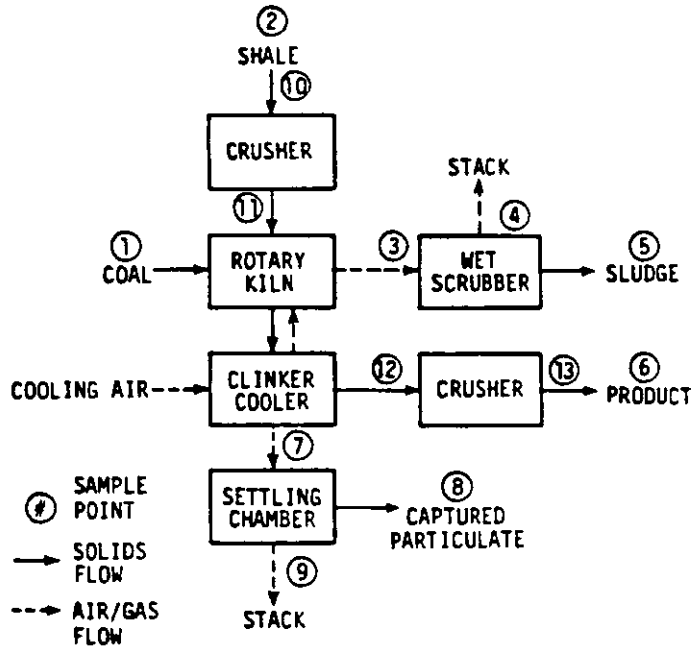
SAMPLE LOCATIONS AND TEST METHODS USED

Figure 4-1 presents a simplified process flow sheet depicting the sample locations and type of testing conducted at each site.

The following subsections describe the sampling sites for particulates, sulfur dioxide, nitrogen oxide, VOC, and particle size distribution testing.

4.1 SCRUBBER INLET

Particulates, sulfur dioxide, and particle size distribution were measured at the inlet to the wet scrubber as shown in Figure 4-2. Two sample ports, 90 degrees off-center, were located 1.8 duct diameters (dd) downstream and 0.3 dd upstream from the nearest flow disturbances in the 1.99 m (6.54 ft) I.D. round duct. Forty-eight traverse points, twenty-four per port, were used to traverse the cross-sectional area of the duct for the particulate tests. Each point was sampled for 2.5 minutes which yielded a total test time of 120 minutes. Sulfur dioxide sampling was conducted using constant rate sample techniques by placing the probe tip near the center of the duct. Particle size samples were collected at a point of average velocity in the duct using an Andersen Heavy Grain Loading Impactor.

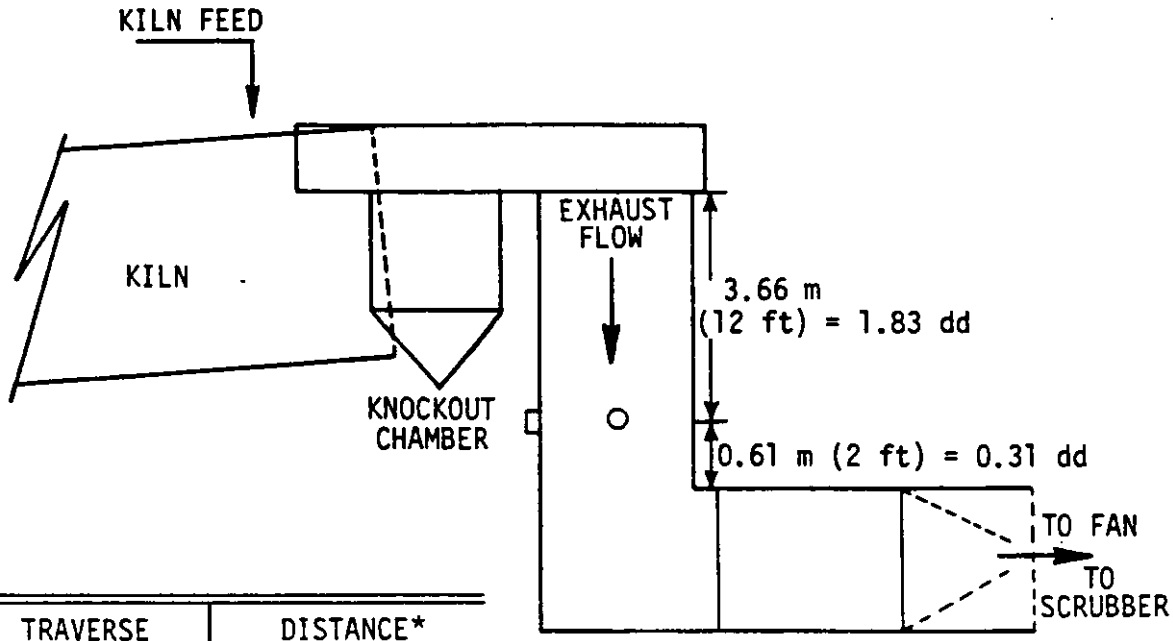


Sample type	Sample point	No. of samples	Method
Paticulate	3,4,9	3	EPA 5[a]
SO_2	3,4,9	3	EPA 6
Particle size	3,4,9	3	Impactor
NO_x	4	12 grab	EPA 7
OVC	4	3	EPA 25
Fugitive dust	Kiln seals, 10, 11,12,13	3	EPA 9
Stack opacity	4,9	3	EPA 9
Sulfur, ash, moisture content	1	24 (composite)	ASTM D3177, D3174, D3173, D2234
Density, moisture content, sulfur	2	24 (composite)	ASTM C29, Gravimetric, D1757
Sulfur	5,6	Composite	D1757
Total sulfates, pH	5 (influent and effluent)	Composite	427-C[b]

[a]Condensible organic and inorganic fractions will be determined by means of ether/chloroform extraction.

[b]Standard Methods for the Examination of Water and Wastewater, 14th Edition.

Figure 4-1. Sampling plan and process flow sheet, Vulcan Materials Company.



TRAVERSE POINT NO.	DISTANCE*	
	cm	in.
1	12.34	5.00
2	16.51	6.50
3	21.08	8.30
4	25.91	10.20
5	31.10	12.25
6	36.56	14.40
7	42.16	16.60
8	48.77	19.20
9	56.13	22.10
10	64.52	25.40
11	74.68	29.40
12	89.54	35.25
13	130.18	51.25
14	145.03	57.10
15	155.19	61.10
16	163.58	64.40
17	170.94	67.30
18	177.55	69.90
19	183.13	72.10
20	188.60	74.25
21	193.80	76.30
22	198.63	78.20
23	203.20	80.00
24	207.26	81.60

*Includes nipple length.

CROSS SECTION

1.99 m (6.54 ft) I.D.
10.2 cm (4 in.) LENGTH NIPPLE

Figure 4-2. Scrubber inlet sample location.

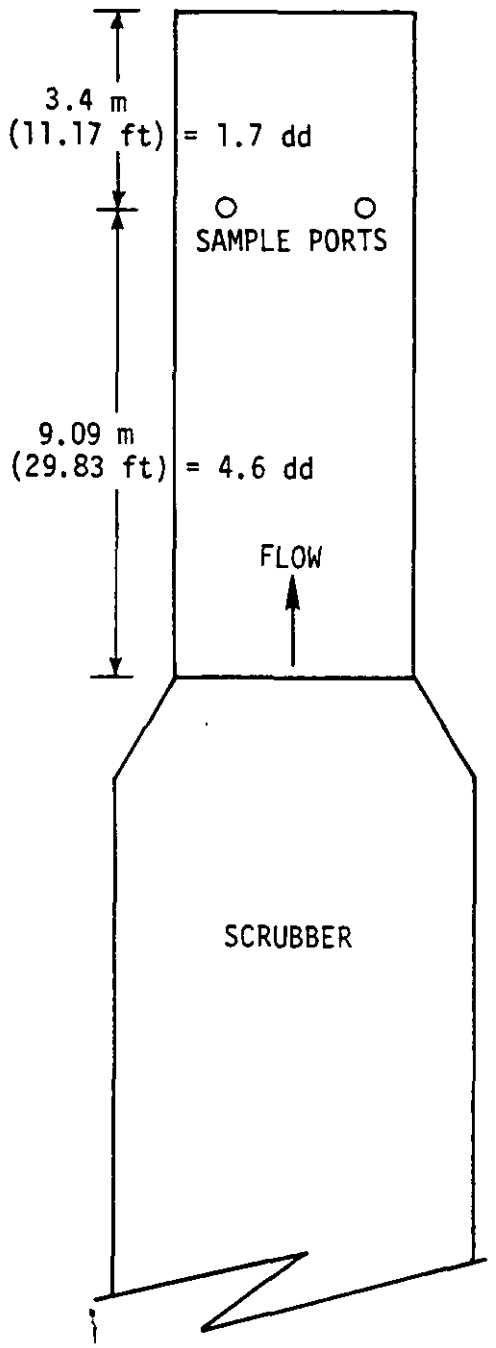
4.2 SCRUBBER OUTLET

Particulates, sulfur dioxide, nitrogen oxide, particle size distribution, and VOC contents were measured at the wet scrubber outlet, as shown in Figure 4-3. Two sample ports, 90 degrees off-center, were located 4.6 dd downstream and 1.7 dd upstream from the nearest flow disturbances in the 1.97 m (6.46 ft) I.D. round stack. Thirty-two traverse points, sixteen per port, were used to traverse the cross-sectional area of the stack for the particulate test runs. Each point was sampled for 4 minutes, which yielded a total test time of 128 minutes. Sulfur dioxide, nitrogen oxide, and VOC sampling was conducted by use of constant-rate sample techniques that placed the respective probe tips near the center of the stack. Particle size samples were collected using an Andersen in-stack impactor.

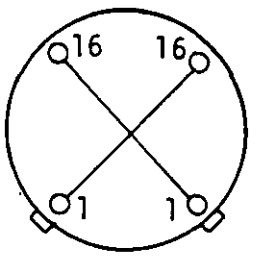
4.3 CLINKER COOLER EXHAUST

Particulate and sulfur dioxide concentrations as well as particle size distribution were measured at the clinker cooler exit stack, as shown in Figure 4-4. Two sample ports, 90 degrees off-center, were located 6 dd downstream and 2.4 dd upstream from the nearest flow disturbances in the 1.35 m (4.42 ft) I.D. round stack. Twenty-four traverse points, twelve per port, were used to traverse the cross-sectional area of the stack for the particulate test runs. Each point was sampled for 5 minutes, which yielded a total test time of 120 minutes.

Sulfur dioxide sampling was conducted at a constant sampling rate by placing the probe tip near the center of the duct.



CROSS SECTION

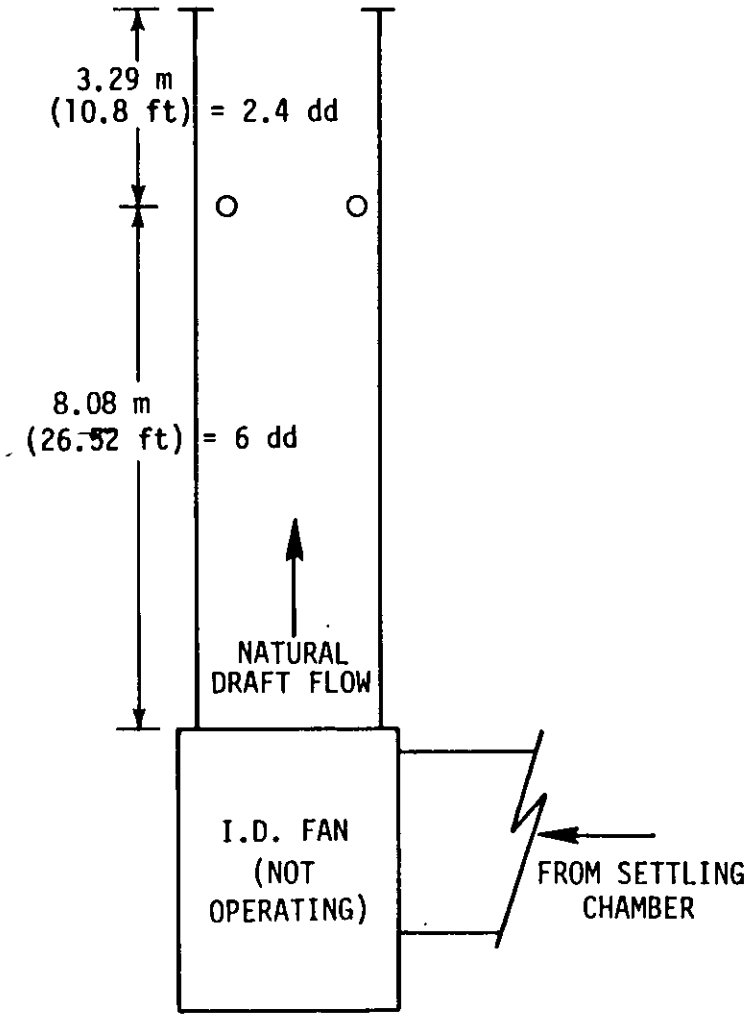


1.97 m (6.46 ft) I.D.
9.53 cm (3.75 in.)
NIPPLE LENGTH

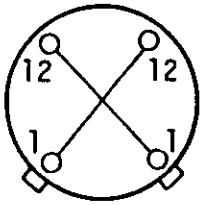
TRAVERSE POINT NO.	DISTANCE *	
	cm	in.
1	12.70	5.00
2	19.05	7.50
3	26.37	10.38
4	34.29	13.50
5	42.85	16.87
6	52.71	20.75
7	65.10	25.63
8	83.19	32.75
9	132.41	52.13
10	150.83	59.38
11	163.20	64.25
12	173.05	68.13
13	181.61	71.50
14	189.56	74.63
15	196.85	77.50
16	203.20	80.00

*Includes nipple length.

Figure 4-3. Scrubber outlet test location.



CROSS SECTION



1.35 m (4.42 ft) I.D.
9.53 cm (3.75 in.)
NIPPLE LENGTH

TRAVERSE POINT NO.	DISTANCE*	
	cm	in.
1	12.34	4.86
2	18.54	7.30
3	25.40	10.00
4	33.35	13.13
5	43.18	17.00
6	57.45	22.62
7	96.22	37.88
8	110.49	43.50
9	120.32	47.37
10	128.28	50.50
11	135.13	53.20
12	143.87	55.64

*Includes nipple length.

Figure 4-4. Clinker cooler sample location.

Particle size samples were collected using an Andersen in-stack impactor. The test and analytical procedures used are described briefly below.

4.4 VELOCITY AND GAS TEMPERATURE

A Type S pitot tube and an inclined draft gauge manometer* were used to measure the gas velocity. Velocities were measured at each sampling point across the duct to determine an average value. Measurements were made according to the procedures outlined in Method 2 of the Federal Register.** The temperature was also measured at each sampling point by use of thermocouple and potentiometer.

4.5 MOLECULAR WEIGHT

Flue gas composition was determined by using procedures described in Method 3 of the Federal Register.** A bag sample was collected during each particulate, sulfur dioxide, and nitrogen oxide test run. The bag contents were analyzed by use of an Orsat Gas Analyzer.

4.6 PARTICULATES

Particulate grain loading was measured at each test location according to Method 5, as described in the Federal Register.** All tests were conducted isokinetically by traversing the cross-sectional area of the stack and regulating the sample flow rate

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*A 0-0.635 cm (0-0.25 in.) manometer was used at the clinker cooler exit stack.

**40 CFR 60, Appendix A, Reference Methods 2, 3, and 5, July 1, 1981.

relative to the flue gas flow rate as measured by the pitot tube attached to the sample probe. A sampling train consisting of a heated, glass-lined probe, and heated 87-mm (3-in.) diameter glass fiber filter (Reeve Angel 934 AH), and a series of Greenburg-Smith impingers were used in each test. A heated 316 stainless steel probe was used on the scrubber inlet sample train due to the high flue gas temperatures at this location. In addition, a cyclone was placed prior to the heated filter due to the heavy particulate loading. The nozzle, probe, and filter holder portions of the sample train were acetone-rinsed at the end of each test. The acetone rinse and the particulate caught on the filter media were dried at room temperature, desiccated to a constant weight, and weighed on an analytical balance. Total filterable particulate matter was determined by adding these two values. The contents of the impinger section of the sampling train were recovered and analyzed for organic and inorganic content by ether-chloroform extraction.

4.7 SULFUR DIOXIDE

The test procedure used was as described in Method 6 of the Federal Register* except the midget impingers were replaced with a series of Greenburg-Smith impingers. A heated glass-lined probe preceded the series of impingers. A plug of glass wool was placed in the tip of the probe and in the connecting glassware between the first and second impingers. A heated quartz glass probe was used on the scrubber inlet sample train and a cyclone-

*40 CFR 60, Appendix A, Reference Method 6, July 1, 1981.

filter assembly was placed prior to the impingers due to the heavy particulate loading at this location. Each test consisted of two 30-minute runs. Each sampling train was purged with ambient air for 15 minutes after the completion of each test. Contents of the second and third impingers (3% hydrogen peroxide) were measured and analyzed onsite for sulfates by using the barium-thorin titration method.

4.8 NITROGEN OXIDE

Sampling and analytical procedures were those described in EPA Method 7 of the Federal Register.* A total of three tests, each consisting of four grab samples taken at approximately 15-minute intervals, were conducted on the scrubber exit stack. The samples were shipped to the laboratory for analysis.

4.9 PARTICLE SIZE DISTRIBUTION

Particle size samples from the scrubber and clinker cooler exit stacks were obtained using an Andersen 2000 Mark III Source Cascade Impactor. This in-stack, multistage cascade impactor has a total of eight stages. Particle size cutoffs range from 0.5 to 15 μm and are followed by a backup filter stage. Substrates for the Andersen were 64-mm glass fiber filters. A constant sampling rate was maintained through the test period. The rates were set for isokinetic sampling as long as the rate did not exceed the recommended flow rate for the impactor (0.70 acfm).

A total of four impactor runs were made at each sampling site. Sampling point locations for each stack were as shown in

*40 CFR 60, Appendix A, Reference Method 7, July 1, 1981.

Figure 4-5. At least one impactor run was made at each sampling point. Sampling procedures were those recommended in the "Procedures Manual for Inhalable Particulate Sampler Operation," recently developed for EPA by the Southern Research Institute.[1] Particle size samples from the scrubber inlet were obtained using an Andersen Heavy Grain Loading Impactor. This in-stack impactor has a total of three stages. Particle size cutoffs range from 2 to 17 microns (μm). A total of two samples were collected at a point of average velocity in the duct.

4.10 HYDROCARBON EMISSIONS

Sampling and analysis for hydrocarbon emissions was conducted using EPA Method 25* for the determination of total gaseous nonmethane organics. Samples were collected by drawing gas from the stack through a dry-ice condensate trap by means of an evacuated sample tank. Sampling was conducted at a single point in the stack and a constant sampling rate between 80 and 90 ml/min was maintained. Both the sample tank and the condensate trap were analyzed to determine the nonmethane organic content of the exhaust gas.

Analysis of the tank fraction was accomplished by injecting the sample into an analyzer which separated the nonmethane organics from CO, CO_2, and CH_4, oxidized the components to CO_2 and reduced the CO_2 to methane for measurement with a flame ionization detector (FID).

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*40 CFR 60, Appendix A, Reference Method 25, July 1, 1981.

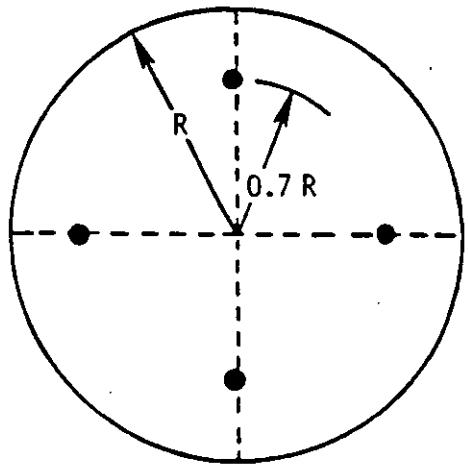

Figure 4-5. Particle size sampling points for circular stack.

Condensate was recovered by heating the trap and probe line to 650°C (1200°F), converting the contents to carbon dioxide with a catalytic oxidizer, and collecting the CO_2 in an intermediate collection tank. The intermediate tank was analyzed by injecting the contents into the analyzer where the CO_2 was reduced to methane and measured with the FID. The total gaseous nonmethane organic content was determined by summing the results of the trap and tank analyses.

4.11 PROCESS SAMPLES

Samples of the coal and shale fed to the kiln were collected at approximately 30-minute intervals during the particulate sampling. Coal samples were collected after the pulverizer, at a point just before the coal entered the kiln. Shale samples were collected from the kiln feed conveyor belt. Coal samples were analyzed for sulfur content, moisture content, and percent ash. Shale samples were analyzed for sulfur content, density, and moisture content.

Samples of the influent and effluent from the kiln wet scrubber and final aggregate product were collected and analyzed for sulfate content and pH.

4.12 VISIBLE AND FUGITIVE EMISSIONS

Visible and fugitive emission observations were performed using procedures described in EPA Method 9.* Certified visible emission readers were utilized for each task.

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*40 CFR 60, Appendix A, Reference Method 9, July 1, 1981.

SECTION 5

QUALITY ASSURANCE

Because the end product of testing is to produce representative emission results, quality assurance is one of the main facets of stack sampling. Quality assurance guidelines provide the detailed procedures and actions necessary for defining and producing acceptable data. Four such documents were used in this test program to insure the collection of acceptable data and to provide a definition of unacceptable data. The following documents comprise the source-specific test plan prepared by PEDCo and reviewed by the Emissions Measurement Branch: the EPA Quality Assurance Handbook Volume III, EPA-600/4-77-027b; the draft PEDCo Environmental Emission Test Quality Assurance Plan; and the PEDCo Environmental Laboratory Quality Assurance Plan. The last two, which are PEDCo's general guideline manuals, define the company's standard operating procedures and are followed by the emission testing groups and the laboratory groups.

Appendix F provides more detail on the quality assurance procedures, such as QA objective; data reduction; quality control checks; performance and system audits; preventive maintenance; precision, accuracy, and completeness; corrective action; and quality assurance reports to management.

Relative to this specific test program, the following steps are taken to insure that the testing and analytical procedures used will produce quality data.

- Calibration of field sampling equipment. (Appendix E describes calibration guidelines in more detail.)
- Checks of train configuration and calculations.
- Onsite quality assurance checks, such as sample train, pitot tube, and Orsat line leak checks, and quality assurance checks of all test equipment prior to use.
- Use of designated analytical equipment and sampling reagents.

Table 5-1 lists sampling equipment used for particulate, SO_2 and NO_x testing, and the calibration guidelines and limits. In addition to the pre- and post-test calibrations, a field audit was performed on the meter boxes used for particulate and SO_2 sampling. PEDCo constructed critical orifices were used for this audit. Figures 5-1 through 5-3 show an example audit run for each dry gas meter used for particulate and SO_2 testing.

As a check on the reliability of the method used to analyze the filters for the particulate and particle size tests, sets of filters that had been preweighed in the lab were resubmitted for replicate analysis. Table 5-2 summarizes the results of a blank filter and reagent analysis. In addition, particle size blanks were run at each exit location to determine if any bias may have been caused by reaction of flue gas with the impactor substrates. As expected, no bias was observed.

Audit solutions prepared by the EPA were used to check the analytical procedures and reagents for SO_2 and NO_x sample

TABLE 5-1. FIELD EQUIPMENT CALIBRATION - SCRUBBER INLET

Equipment	I.D. No.	Calibrated against	Allowable deviation	Actual deviation	Within allowable limits	Comments
Meter box	FB-2	Wet test meter	Y ±0.02 Y ΔH@ ±0.15 (Y ±0.05 Y post-test)	-1.9%	✓	Used for particulate, particle size, and SO_2 tests.
Pitot tube	024	Standard pitot tube	Cp ±0.01	0.0	✓	
Digital indicator	221	Millivolt signals	0.5%	<0.2%	✓	
Thermocouples and stack thermometers	258 NA	ASTM-2F or 3F	1.5% (±2° saturated)	0.0	✓	
Orsat analyzer	232	Standard gas	±0.5%	0.1%	✓	
Impinger thermometer	110	ASTM-2F or 3F	±2°F	<1°F	✓	
Trip balance	198	Type S weights	±0.5 g	0.0	✓	
Barometer	227	NBS traceable barometer	±0.10 in. Hg. (0.20 post test)	0.01	✓	
Dry gas thermometer	FB-2 In- Out-	ASTM-2F of 3F	±5°F	1.5°F 1.8°F	✓ ✓	
Probe nozzle	4-114	Caliper	Dn ±0.004 in.	0.001	✓	Particulate only.

TABLE 5-1 (continued)
Scrubber Outlet

Equipment	I.D. No.	Calibrated against	Allowable deviation	Actual deviation	Within allowable limits	Comments
Meter box	FB-9	Wet test meter	Y ±0.02 Y ΔH@ ±0.15 (Y ±0.05 Y post-test)	+0.2%	✓	Used for particulate and SO_2 tests.
	FB-10			-0.4%	✓	Used for particle size tests.
Pitot tube	188	Standard pitot tube	Cp ±0.01	0.0	✓	
Digital indicator	125	Millivolt signals	0.5%	<0.2%	✓	
Thermocouples and stack thermometers	259 NA	ASTM-2F or 3F	1.5% (±2% saturated)	<1.0%	✓	
Orsat analyzer	232	Standard gas	±0.5%	+0.1%	✓	
Impinger thermometer	109	ASTM-2F or 3F	±2°F	<1°F	✓	
Trip balance	198	Type S weights	±0.5 g	0.0	✓	
Barometer	227	NBS traceable barometer	±0.10 in. Hg. (0.20 post test)	0.01	✓	
Dry gas thermometer	FB-9 I	ASTM-2F of 3F	±5°F	<1°F	✓	
	FB-9 O			1°F	✓	
	FB-10 I			<1°F	✓	
	FB-10 O			<1°F	✓	
Probe nozzle	5-116	Caliper	Dn ±0.004 in.	0.000	✓	Particulate only.

TABLE 5-1 (continued)
Clinker Cooler

Equipment	I.D. No.	Calibrated against	Allowable deviation	Actual deviation	Within allowable limits	Comments
Meter box	FB-3	Wet test meter	Y ±0.02 Y ΔH @ ±0.15 (Y ±0.05 Y post-test)	0.8%	✓	Used for particulate and SO_2 tests.
	FB-7			0.5%	✓	FB-7 used for particle size runs.
Pitot tube	042	Standard pitot tube	Cp ±0.01	0.0	✓	
Digital indicator	207	Millivolt signals	0.5%	Avg. <0.42%	✓	
Thermocouples and stack thermometers	257 NA	ASTM-2F or 3F	1.5% (±2% saturated)	0.05%	✓	
Orsat analyzer	232	Standard gas	±0.5%	0.1%	✓	
Impinger thermometer	107	ASTM-2F or 3F	±2°F	<1°F	✓	
Trip balance	198	Type S weights	±0.5 g	0.0	✓	
Barometer	227	NBS traceable barometer	±0.10 in. Hg. (0.20 post test)	0.01	✓	
Dry gas thermometer	FB-3 I FB-3 O FB-7 I FB-7 O	ASTM-2F of 3F	±5°F	1.2°F 0.7°F 3.5°F 1.4°F	✓ ✓ ✓ ✓	
Probe nozzle	8-108	Caliper	Dn ±0.004 in.	+0.001	✓	Particulate only.

AUDIT REPORT SAMPLE METER BOX

DATE: 7/13/81

CLIENT: USEPA Volcan PLT

BAROMETRIC PRESSURE (P_{bar}): 29.65 in. Hg

METER BOX NO. FB-2 (Scrubber Inlet)

ORIFICE NO. #1

PRE-TEST γ: 1.003

ORIFICE K FACTOR: 5.206×10^{-4}

AUDITOR: P. Schworer

Orifice manometer reading ΔH in H_2O	Dry gas meter reading V_i/V_f ft^3	Temperatures: Ambient T_{ai}/T_{af} °F	Dry gas meter: Inlet T_{ii}/T_{if} °F	Dry gas meter: Outlet T_{oi}/T_{of} °F	Duration of run Ø min 16 min 0.7 sec
2.25	417.200	102	96	90	16.01
	430.800	100	98	91	

Dry gas meter volume V_m ft^3	Average temperatures: Ambient T_a °F	Average temperatures: Dry gas meter T_m °F	$V_{m_{std}}$ ft^3	$V_{m_{act}}$ ft^3	Audit γ	γ deviation %
13.6	101	93.75	[redacted]			

$V_{m_{std}}$	$V_{m_{act}}$
$\frac{(17.647)(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)}$	$\frac{(1203)(Ø)(K)(P_{bar})}{(T_a + 460)^{1/2}}$
12.922	12.552

Audit γ	γ deviation, %
$\frac{V_{m_{act}}}{V_{m_{std}}}$	$\frac{(\gamma \text{ audit} - \gamma \text{ pre-test})(100\%)}{(\gamma \text{ audit})}$
1.029	2.5 %

Audit γ must be in the range, pre-test γ ±0.05 γ
Audit ΔH@ must be in the range, ΔH@ ±0.15

Figure 5-1. Meter box audit, scrubber inlet.

AUDIT REPORT SAMPLE METER BOX

DATE: 7/13/81 CLIENT: USEPA

BAROMETRIC PRESSURE (P_{bar}): 29.57 in. Hg METER BOX NO. 189 - Scrubber Outlet

ORIFICE NO. 6 PRE-TEST γ: 0.977

ORIFICE K FACTOR: 4.995×10^{-5} AUDITOR: PR

Orifice manometer reading ΔH in H_2O	Dry gas meter reading V_i/V_f ft^3	Temperatures: Ambient T_{ai}/T_{af} °F	Dry gas meter: Inlet T_{ii}/T_{if} °F	Dry gas meter: Outlet T_{oi}/T_{of} °F	Duration of run $\emptyset$ min
1.03	905.000	97	104	103	15.825
	918.100	98	104	104	

Dry gas meter volume V_m ft^3	Average temperatures: Ambient T_a °F	Average temperatures: Dry gas meter T_m °F	$V_{m_{std}}$ ft^3	$V_{m_{act}}$ ft^3	Audit γ	γ deviation %
13.100	97.5	103.75	12.157	11.909	1.021	4.27

$V_{m_{std}}$	$V_{m_{act}}$
$\frac{(17.647)(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)}$	$\frac{(1203)(\emptyset)(K)(P_{bar})}{(T_a + 460)^{1/2}}$
12.157	11.909

Audit γ	γ deviation, %
$\frac{V_{m_{act}}}{V_{m_{std}}}$	$\frac{(\gamma \text{ audit} - \gamma \text{ pre-test})(100\%)}{(\gamma \text{ audit})}$
1.021	4.27

Audit γ must be in the range, pre-test $\gamma \pm 0.05\ \gamma$
Audit $\Delta H@$ must be in the range, $\Delta H@ \pm 0.15$

Figure 5-2. Meter box audit, scrubber outlet.

AUDIT REPORT SAMPLE METER BOX

DATE: 7-13-81 CLIENT: USEPA

BAROMETRIC PRESSURE (P_{bar}): 29.68 in. Hg METER BOX NO. FB-3 Clinker Cooler

ORIFICE NO. 4 PRE-TEST γ: 1.018

ORIFICE K FACTOR: 5.220×10^{-4} AUDITOR: Hawley

Orifice manometer reading ΔH in H_2O	Dry gas meter reading V_i/V_f ft^3	Temperatures: Ambient T_{ai}/T_{af} °F	Dry gas meter: Inlet T_{ii}/T_{if} °F	Dry gas meter: Outlet T_{oi}/T_{of} °F	Duration of run Ø min
2.4	595.1	97	102	96	15.1
	607.7	101	102	95	

Dry gas meter volume V_m ft^3	Average temperatures: Ambient T_a °F	Average temperatures: Dry gas meter T_m °F	$V_{m_{std}}$ ft^3	$V_{m_{act}}$ ft^3	Audit γ	γ deviation %
12.60	99	99	11.876	11.903	.998	2.0

$V_{m_{std}}$	$V_{m_{act}}$
$\frac{(17.647)(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)}$	$\frac{(1203)(\text{Ø})(K)}{(T_a + 460)^{1/2}}(P_{bar})$

Audit γ	γ deviation, %
$\frac{V_{m_{act}}}{V_{m_{std}}}$	$\frac{(\gamma \text{ audit} - \gamma \text{ pre-test})(100\%)}{(\gamma \text{ audit})}$

Audit γ must be in the range, pre-test $\gamma \pm 0.05\ \gamma$
Audit $\Delta H@$ must be in the range, $\Delta H@ \pm 0.15$

Figure 5-3. Meter box audit, clinker cooler.

TABLE 5-2. EXAMPLE BLANK FILTER AND REAGENT ANALYSIS

Sample type	Original tare weight, mg	Blank weight, mg	Net weight, mg
Particulate			
87 mm Reeve Angel 934 AH No. 0002267	359.2	359.4	+0.2
Particle size 64 mm Reeve Angel 934 AH			
S-15	142.1	142.6	+0.5
J-144	138.4	138.6	+0.2
S-39	143.4	143.4	0.0
J-126	141.0	141.0	0.0
S-33	143.4	143.4	0.0
J-134	136.3	136.3	0.0
S-77	144.6	144.5	-0.1
J-116	135.8	136.1	+0.3
B-462	206.0	206.2	+0.2
Acetone blank	99690.6	99698.6	0.02 mg/g[a]
H_2O blank	93932.9	93972.2	0.10 mg/g[a]
Ether-chloroform	65872.8	65877.8	0.03 mg/g[a]

[a]0.01 mg/g used in calculations.

analysis. Tables 5-3 and 5-4 present the results of these analytical audits. The audit tests show that the analytical techniques were good.

The quality assurance procedures specified in Method 25 include oxidation and reduction catalyst checks, complete calibration of the NMO analyzer, use of proper materials of construction for sampling tanks and traps (316 stainless steel), and checks to determine the blank values for the analyzer and trap conditioning apparatus carrier gases. In addition, PEDCo has found it necessary to use the following procedures to check and prepare sampling equipment before testing. Prior to each test, all condensate traps are checked for cleanliness using the trap conditioning apparatus. Traps are heated to 650°C (1200°F) with carrier gas passing through the trap, and oxidizer, and through the GC gas sample loop. The sample loop contents are then injected to the NMO analyzer to determine the level of contaminant remaining in the trap. This process is repeated until an acceptable blank value is obtained. Typical blank values for traps range from 5 to 10 ppm.

Gas sampling tanks are cleaned by evacuating the tanks and filling with nitrogen. This procedure is repeated until an analysis of the tank on the Method 25 analyzer demonstrates that the tank contains no contaminants from previous sampling jobs. All tanks to be used in a testing program are checked in this manner before shipment to the sampling site.

TABLE 5-3. AUDIT REPORT SO_2 ANALYSIS
- ONSITE AUDIT -

Plant VULCAN MATERIALS PN Number 3530-1

Date samples received 7.16.81 Date analyzed 7.16.81

Samples analyzed by DAN SCHEFFEL

Reviewed by [signature] Date of Review 7-16-81

Sample Number	mg SO_2/dscm Determined	Source of Sample	Accepted Value	% Difference
8025	785	USEPA per T. Wagner	763	+2.8
5373	1752	USEPA per T. Wagner	1716	+2.0
9116	364	USEPA per T. Wagner	353	+3.0

LOT SSB

TABLE 5-4. AUDIT REPORT NO_x ANALYSIS

Plant EPA Vulcan PN Number 3530-1

Date samples received 7-21-81 Date analyzed 7-24-81

Samples analyzed by W. Steward

Reviewed by I. Bennett T.J.R. Date of Review 7-27-81 7-28-81

Sample Number	mg NO_2/dscm Determined	Source of Sample	Accepted Value	% Difference
7220	866.5	T. Wagner	896.5	-3.3
8460	148.6	T. Wagner	149.4	-0.5

Chromatograms showing the blank checks for the traps and tanks used in this test are in Appendix C with the laboratory results.

The sampling equipment, reagents, and analytical procedures for this test series were in compliance with all necessary guidelines set forth for accurate test results as described in Volume III of the Quality Assurance Handbook.*

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*Quality Assurance Handbook for Air Pollution Measurement Systems, Volume III, EPA-600/4-77-027b, August 1977.

SECTION 6

DISCUSSION OF RESULTS

Overall, the sampling program was executed as planned and no major problems occurred with either test equipment or sampling activities. In addition, the process operation was characterized as normal throughout the test period by plant personnel and the NSPS contractor.

The measured particulate emissions appear to be representative based on between-test data reproducibility and comparisons with the plume observation and particle size distribution data collected concurrent with the particulate tests.

The particulate concentration as determined by Method 5 at the inlet to the wet scrubber compares favorably with the calculated mass loading obtained from the Andersen Heavy Grain Impactor used at this site (50,000 mg/dscm vs. 53,000 mg/dscm). In addition, the measured volumetric flow rate compared to within 5 percent of the measured flow at the scrubber outlet test location. This difference is attributed to air in-leakage between the inlet and outlet test locations. Particulate, particle size, and plume observation data obtained from the source indicate that the control device operated efficiently throughout the test period.

At the clinker cooler, particulate results appear to be representative of what would be expected from a natural draft system. It should be noted that the opacity of fugitive emissions from the oversized clinker discharge chute ranged from 5 to 10 percent throughout the test period. No visible emissions were detected from the clinker cooler exit stack.

The process sample analysis shows the shale material used at this plant possesses a low sulfur (0.10 percent) content. Therefore, it is reasonable to conclude SO_2 emissions are generated primarily from combustion of coal in the kiln.

REFERENCES

1. Southern Research Institute. Procedures Manual for Inhalable Particulate Sampler Operation. Prepared for EPA under Contract No. 68-02-3118. November 1979.

2. Southern Research Institute. A Computer-Based Cascade Impactor Data Reduction System. Prepared for EPA under Contract No. 68-02-2131. March 1978.

Ref. 3 (AP-42
4-1

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d3006-4/971130
03/30/92 1

Emission Test Report
Review Checklist

Reviewer: Brian Shrager
Review Date: April 27, 1992

A. Background Information

1. Facility name: Vulcan Materials Company

   Location: Bessemer, Alabama

2. Source category: Lightweight Aggregate Production

3. Test date: Week of July 13, 1981

4. Test sponsor: EPA/EMB

5. Testing contractor: PEDCo Environmental

6. Purpose of test: To provide data to assess the need for New Source Performance Standards emission limits.

7. Pollutants measured

   PM PM-10 CO SO_2 NO_x VOC Pb CO_2

   Others (list): Hydrocarbons, VOC, PS

8. Process overview: On an attached page provide a block diagram of the unit operations and associated air pollution control systems at the facility. Identify process tested with letters from the beginning of the alphabet (A, B, C, etc.) and APC systems with letters from end of alphabet (V, W, X, etc.). Also identify test locations with Arabic numerals (1,2,3, ...). Using the ID symbols from that sketch complete the table below that identifies processes or unit operations tested.

Test ID	Process	Process ID	Emissions tested		APCD (controlled emissions only)
			Uncontrolled	Controlled	
1	Kiln	A	✓		
2	Kiln	A		✓	Medium-energy wet scrubber
3	Clinker Cooler	B		✓	Settling Chamber
	(Kiln fired w/ coal)				

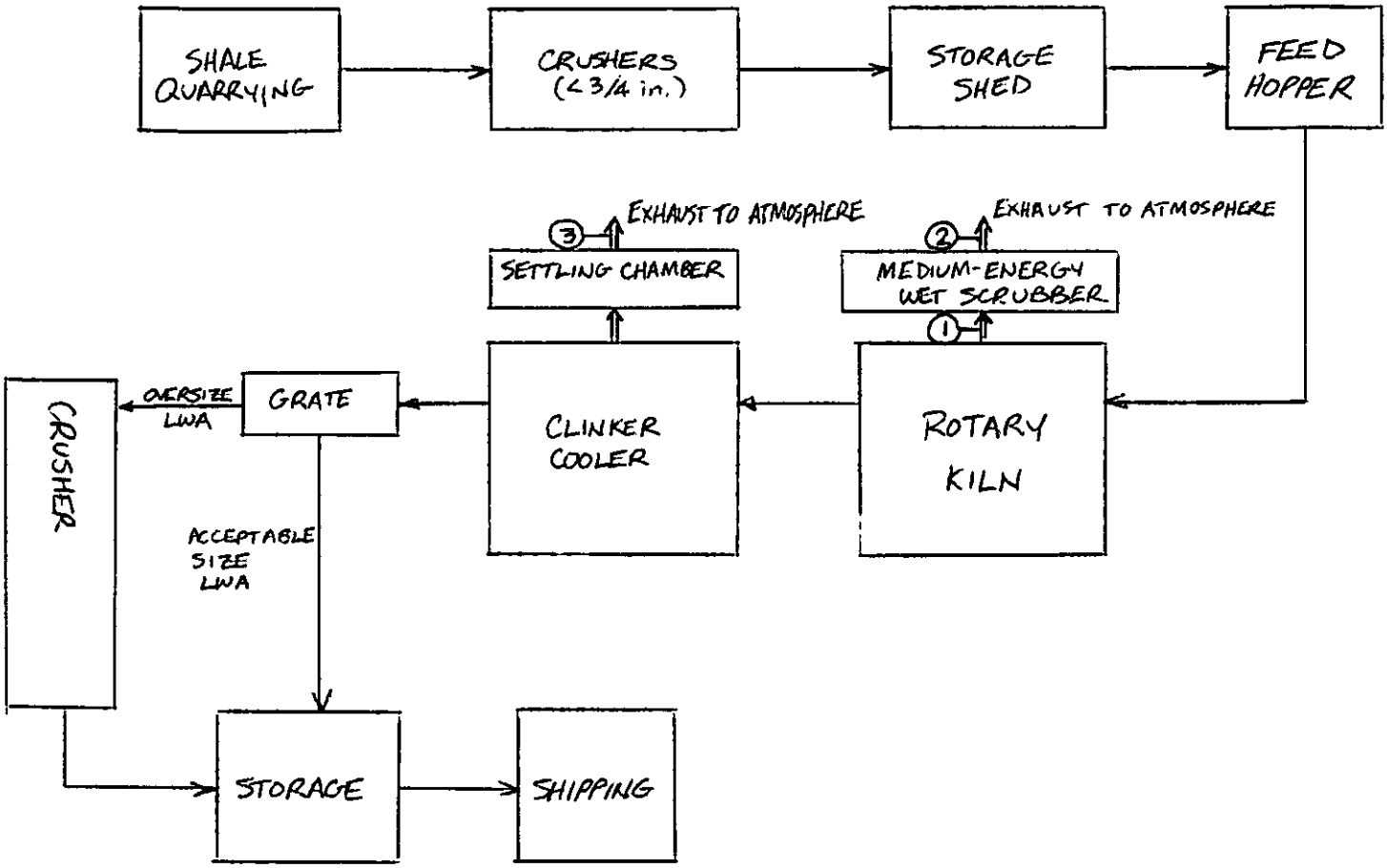
B. Process Information

1. Provide a brief narrative description of the process. With as much detail as possible, (e.g., if a furnace or conveyor system is used, identify the type of unit) describe the equipment used for those operations tested. (Note: If process description provided in test report is adequate, attach copy or reproduce here.)

The raw material (shale) is quarried from a pit located approximately 0.8 kilometers (km) (0.5 miles) from the plant. Trucks transport the shale to crushers where it is reduced to a feed size of less than 1.91 centimeters (cm) [3/4 inches (in.)] and transferred by belt conveyor to a semi-enclosed shed for storage. The semi-enclosed shed had a storage capacity of approximately 13,610 megagrams (Mg) (15,000 tons). Belt conveyors transport the raw material from the storage shed to a feed hopper for charging to the kiln.

The No. 1 kiln measures 56.4 meters (m) [185 feet (ft)] in length and 2.7 m (12 ft) in diameter and is designed to process approximately 32 Mg (35 tons) of raw material per hour. Typically, the No. 1 kiln processes approximately 26.3 Mg (29 tons) of raw material per hour which yields a final production rate of 21 Mg (23 tons) per hour. The kiln is fueled primarily by pulverized coal, and natural gas is used to fuel the pilot flame. The operating temperature of the kiln is approximately 1150°C (2100°F). Natural gas is the primary fuel used for the reheating process. Once the temperature of the coal mill reaches 93°C (200°F), pulverized coal is used as the primary fuel to fire the kiln. The kiln temperature climbs to 1480°C (2700°F) during the reheating and settles to 1150°C (2100°F) as the coal feed rate increases to normal and the natural gas is cut off.

The No. 1 kiln rotates at approximately 2.8 revolutions per minute (rpm). The raw material slowly heats up as it travels through the kiln and physically expands (bloats) as volatile organic components are released. The raw material residence time in the kiln is approximately 45 to 50 minutes. The expansion reduces the density of the shale to within a range of 640 to 800 kilograms per cubic meter (kg/m^3) [40 to 50 pounds per cubic foot (lb/ft^3)]. The expanded product, or clinker, is discharged from the kiln through a 1.2 by 1.8 m (4 by 6 ft) opening at the back end of the kiln onto a reciprocating grate called a clinker cooler. As the hot clinker moves across the grate, one large fan forces air upward through the grate to cool the clinker. Product of acceptable size falls through the grate onto a conveyor belt for transfer to storage piles. Oversize material falls from the grate onto the ground where it is periodically picked up by a front end loader and transferred to a crusher for supplemental crushing prior to storage. The product is also transferred by conveyor belt from the storage piles to crushers to reduce the size of the product and then to a screen house for sizing. The product is transferred from the crushing/screening area to open stockpiles where it is stored until sold.


SHALE QUARRYING
CRUSHERS (< 3/4 in.)
STORAGE SHED
FEED HOPPER
EXHAUST TO ATMOSPHERE
EXHAUST TO ATMOSPHERE
3
2
1
SETTLING CHAMBER
MEDIUM-ENERGY WET SCRUBBER
CRUSHER
OVERSIZE LWA
GRATE
CLINKER COOLER
ROTARY KILN
ACCEPTABLE SIZE LWA
STORAGE
SHIPPING

2. For each process tested list feedstock materials and products. Indicate if activity factors are for feed (F) rate or product (P) rate.

Process ID	Feedstock materials	Products	Basis for activity factor	F/P
A	Shale	LWA	LWA	P
B	Clinker	LWA	LWA	P
				F
				F

Basis for data: Pg. 2-1
(Indicate page/table Nos. in test report)

3. For each process or operation tested and each test run note process capacity and operating rate during test.

29 feed tons/hr
= 23 tons/hr product

Process ID	Capacity	Units	Test run	Process rate	Units
A	35	tons feed/hr	1	23 29F	tons prod./hr
			2		
			3		
			4		
B	35	tons feed/hr	1	23 29F	tons prod/hr
			2		
			3		
			4		
			1		
			2		
			3		
			4		
			1		
			2		
			3		
			4		

Basis for data: Pg 2-1, 2-5

C. Air Pollution Control Systems Tested

1. For each air pollution control system pollution control system identified in A.8, note the following

ID	Type of APCD	Manufacturer	Model No.
Y	Medium-energy wet scrubber	Ducon Dynamic, UW4 Model IV,	SIZE 144
Z	Settling Chamber		

Note: Be as specific as possible in identifying APCD. For example, indicate "pulse jet fabric filter" rather than simply "fabric filter."

2. For each system identified above, provide a narrative description. For fugitive systems describe capture techniques as well as the removal techniques (use a separate page if necessary)

3. Using the attached parameter list for guidance complete the table below. (Use additional pages as needed.)

APCD ID	Parameter	Units	Readings			
			Run 1	Run 2	Run 3	Run 4
Y						
Type of APCD: Medium-Energy Wet Scrubber						
Z						
Type of APCD: Settling Chamber						
Type of APCD:						

D. Sampling and Analysis Methods

1. Complete the following table

Test location	Pollutant	S & A method	Reference/ conditional method	Deviations noted
1	Particulate	Method 5	Y/N	Y/N
	SO_2	Method 6	Y/N	Y/N
	NO_x	Method 7	Y/N	Y/N
	VOC	Method 25	Y/N	Y/N
			Y/N	Y/N
2	Particulate	Method 5	Y/N	Y/N
	SO_2	Method 6	Y/N	Y/N
			Y/N	Y/N
			Y/N	Y/N
			Y/N	Y/N
3	Particulate	Method 5	Y/N	Y/N
	SO_2	Method 6	Y/N	Y/N
			Y/N	Y/N
			Y/N	Y/N
			Y/N	Y/N
			Y/N	Y/N
			Y/N	Y/N
			Y/N	Y/N
			Y/N	Y/N
			Y/N	Y/N
			Y/N	Y/N
			Y/N	Y/N
			Y/N	Y/N
			Y/N	Y/N
			Y/N	Y/N

2. If a method used was not a reference or conditional method, provide a narrative discussion including any data manipulation needed to make results correspond to reference or conditional method results.

3. **Describe any deviations identified above.**

Method 5 - An ether chloroform extraction was performed on the impinger contents to determine condensible organic and inorganic fractions.

Method 6 - Large impingers were used instead of the midget impingers specified in method 6.

E. Emission Data Documentation

1. Tabulate the following stack gas data from the test report. (Use additional pages as needed.)

Test ID	Parameter	Units	Values reported			
			Run 1	Run 2	Run 3	Run 4
1	Stack temperature	°F	779	775	792	
	Moisture	% VOL.	7.2	8.4	8.5	
	Oxygen	% VOL.	14.5	14.2	13.8	
	Volumetric flow, actual	acfh	6,064,204	6,434,122	6,563,847	6,3
	Volumetric flow, standard	dscfh	2,365,364	2,478,580	2,491,944	2,445,296
	Percent isokinetic					
	Pollutant concentration:					
	CO_2	% VOL.	5.5	5.5	5.8	
	Filterable PM	gr/dscf	23.7	27.5	27.1	
	Condensible Organic PM	gr/dscf	0.059	0.001	0.002	
	Condensible Inorganic PM	gr/dscf	0.379	0.042	0.057	
	* SO_2	lb/dscf	8.63E-05	10.37E-05	10.16E-05	
2	Stack temperature	°F	149	145	148	
	Moisture	% VOL.	21.2	21.4	22.1	
	Oxygen	% VOL.	14.6	14.4	14.8	
	Volumetric flow, actual	acfh	3,668,666	3,745,268	3,794,620	
	Volumetric flow, standard	dscfh	2,473,854	2,526,506	2,521,561	
	Percent isokinetic					
	Pollutant concentration:					
	CO_2	% VOL.	5.5	5.3	5.6	
	Filterable PM	gr/dscf	0.041	0.0007	0.016	
	Condensible Organic PM	gr/dscf	0.044	0.0005	0.015	
	Condensible Inorganic PM	gr/dscf	0.044	0.0007	0.015	
	** SO_2	lb/dscf	2.65 E-05	2.75 E-05	1.65 E-05	
	** NO_x	lb/dscf	2.23E-05	2.22 E-05	2.21 E-05	
**	Hydrocarbon (as expressed Methane)	PPM	134	231	378	128
3	Stack temperature	°F	424	381	353	
	Moisture	% VOL.	2.0	1.8	2.4	
	Oxygen	% VOL.	20.3	19.8	20.2	
	Volumetric flow, actual	acfh	697,376	689,365	675,396	
	Volumetric flow, standard	dscfh	403,918	419,309	422,646	
	Percent isokinetic					
	Pollutant concentration:					
	Filterable PM	gr/dscf	0.053	0.063	0.077	
	Condens. Organic PM	gr/dscf	0.0003	0.0001	0.0005	
	Condens. Inorganic PM	gr/dscf	0.008	0.012	0.011	

* Based on average flow rate = 2,445,296 dscfh

** Based on average flow rate = 2,507,307 dscfh

2. Tabulate pollutant mass flux rates

Test ID	Pollutant	Units	Mass flux rates			
			Run 1 14,948	Run 2 15664	Run 3 16606	Run 4
1	CO_2	*lb/hr	~~15,221~~	~~15,950~~	~~16,910~~	
	Filt. PM	lb/hr	**8,025	9,729	9,634	
	C.O. PM	lb/hr	**19.9	0.4	0.5	
	C. I. PM	lb/hr	**128.2	14.9	20.2	
	SO_2	lb/hr	210.8	253.5	248.4	
			15633	15386	16224	
2	CO_2	*lb/hr	~~15,919~~	~~15,667~~	~~16,529~~	
	Filt. PM	lb/hr	14.6	15.9	15.8	
	C.O. PM	lb/hr	0.26	0.19	0.24	
	C.I. PM	lb/hr	5.5	5.4	5.5	
	SO_2	lb/hr	66.3	68.9	41.3	
	NO_x	lb/hr	56.0	55.8	55.3	
	Hydrocarbons	lb/hr	13.9	24.0	39.5	13.2
3	Filt. PM	lb/hr	3.0	3.8	4.7	
	C.O. PM	lb/hr	0.014	0.006	0.028	
	C.I. PM	lb/hr	0.49	0.73	0.64	

* Density @ STP = 0.1170 lb/ft³
** Filter Frit support ruptured leading to a loss of filterable particulate which was captured by the impinger. Do Not use this information!

Result: low filterable reading + high condensible reading

3. Present example emission factor calculations below.

TEST 1

CO_2 $\left(\frac{15221}{23} + \frac{15950}{23} + \frac{16910}{23}\right) \frac{lb/hr}{ton/hr} \div 3 = 696.8$ lb/ton

Process	Pollutant	RUN 1	RUN 2	RUN 3	RUN 4
A	CO_2	$\frac{15221}{23} = 661.8$	$\frac{15950}{23} = 693.5$	$\frac{16910}{23} = 735.2$	
UNCONTROLLED	Filt. PM	$\frac{8025}{23} = 348.9$ *	$\frac{9729}{23} = 423.0$	$\frac{9634}{23} = 418.9$	
	Cond. Org. PM	$\frac{19.9}{23} = 0.865$ *	$\frac{0.4}{23} = 0.0174$	$\frac{0.5}{23} = 0.0217$	
	Cond. Inorg. PM	$\frac{128.2}{23} = 5.57$ *	$\frac{14.9}{23} = 0.648$	$\frac{20.2}{23} = 0.878$	
	SO_2	$\frac{210.8}{23} = 9.17$ 7.27	$\frac{253.5}{23} = 11.02$ 8.74	$\frac{248.4}{23} = 10.8$ 8.56	AVG 8.20
A	CO_2	$\frac{15919}{23} = 692.1$	$\frac{15667}{23} = 681.2$	$\frac{16,521}{23} = 718.3$	
CONTROLLED	Filt. PM	$\frac{14.6}{23} = 0.635$ 0.50	$\frac{15.9}{23} = 0.691$ 0.55	$\frac{15.8}{23} = 0.687$ 0.54	0.53
	Cond. Org. PM	$\frac{0.26}{23} = 0.0113$ 0.010	$\frac{0.19}{23} = 0.00826$ 0.0066	$\frac{0.24}{23} = 0.0104$ 0.0082	0.0083
	Cond. Inorg. PM	$\frac{5.5}{23} = 0.239$ 0.190	$\frac{5.4}{23} = 0.235$ 0.186	$\frac{5.5}{23} = 0.239$ 0.186	0.19
	SO_2	$\frac{66.3}{23} = 2.88$ 2.28	$\frac{68.9}{23} = 3.00$ 2.38	$\frac{41.3}{23} = 1.80$ 1.43	2.03
	NO_x	$\frac{56.0}{23} = 2.43$ 1.93	$\frac{55.8}{23} = 2.43$ 1.93	$\frac{55.3}{23} = 2.40$ 1.90	1.92
	Hydrocarbons	$\frac{13.9}{23} = 0.604$ 0.48	$\frac{24.0}{23} = 1.04$ 0.82	$\frac{39.5}{23} = 1.72$ 1.36	$\frac{13.2}{23} = 0.574$ 0.46 0.78
B	Filt. PM	$\frac{3.0}{23} = 0.130$ 0.10	$\frac{3.8}{23} = 0.165$ 0.131	$\frac{4.7}{23} = 0.204$ 0.163	0.131
	Cond. Org. PM	$\frac{0.014}{23} = 6.09E-4$ 4.83	$\frac{0.006}{23} = 2.61E-04$ 2.07	$\frac{0.028}{23} = 1.22E-03$ 0.97	5.53
	Cond. Inorg. PM	$\frac{0.49}{23} = 0.0213$ 0.017	$\frac{0.73}{23} = 0.0317$ 0.025	$\frac{0.64}{23} = 0.0278$ 0.022	0.021

* DO NOT USE FOR AVG. EF

MUST CONVERT ALL TO FEED RATE BASIS

$\frac{23}{29} = 0.793$

4. Tabulate emission factors

Process	Pollutant	Units	Average emission factor	
			Uncontrolled	Controlled
A	CO_2	lb/ton produced	696.8	
	Filt. PM	"	420.9	
	Cond. Org. PM	"	0.0196	
	Cond. Inorg. PM	"	0.763	
	SO_2	"	10.33	
A	CO_2	lb/ton produced	697.2	
	Filt. PM	"		0.671
	Cond. Org. PM	"		0.01
	Cond. Inorg. PM	"		0.238
	SO_2	"		2.56
	NOx	"		2.42
	Hydrocarbons	"		0.985
B	Filt. PM	lb/ton produced		0.167
	Cond. Org. PM	"		6.96 E-04
	Cond. Inorg. PM	"		0.0270
	PM10	"		0.0434**
A (scrubber outlet)	PM10	lb/ton produced		0.114*

* Filt. PM x % PM10 (17%)
** Filt. PM x % PM10 (26%)

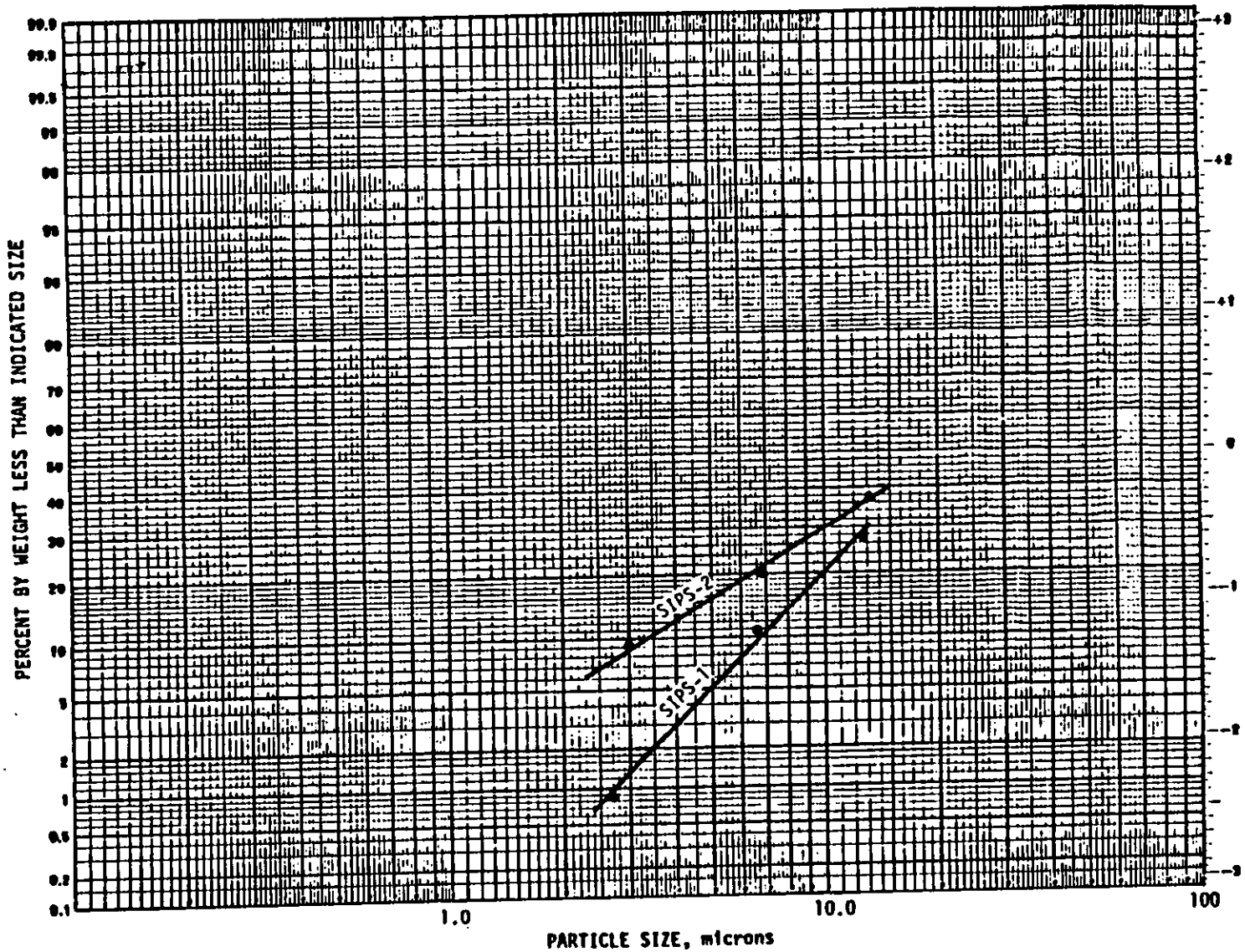


Figure 3-1. Particle size distribution - kiln exhaust scrubber inlet.

Size	%
2.5	
6.0	
10.0	
15.0	
20.0	

SIPS-1 PM10 = 20%
SIPS-2 PM10 = 30% ← SIPS-2 VOID (NOT TAKEN DURING PM TEST)
AVG FOR SCRUBBER INLET = ~~25%~~
DON'T USE THIS INFORMATION - ONLY 1 VALID PS TEST RUN @ Scrubber Inlet!

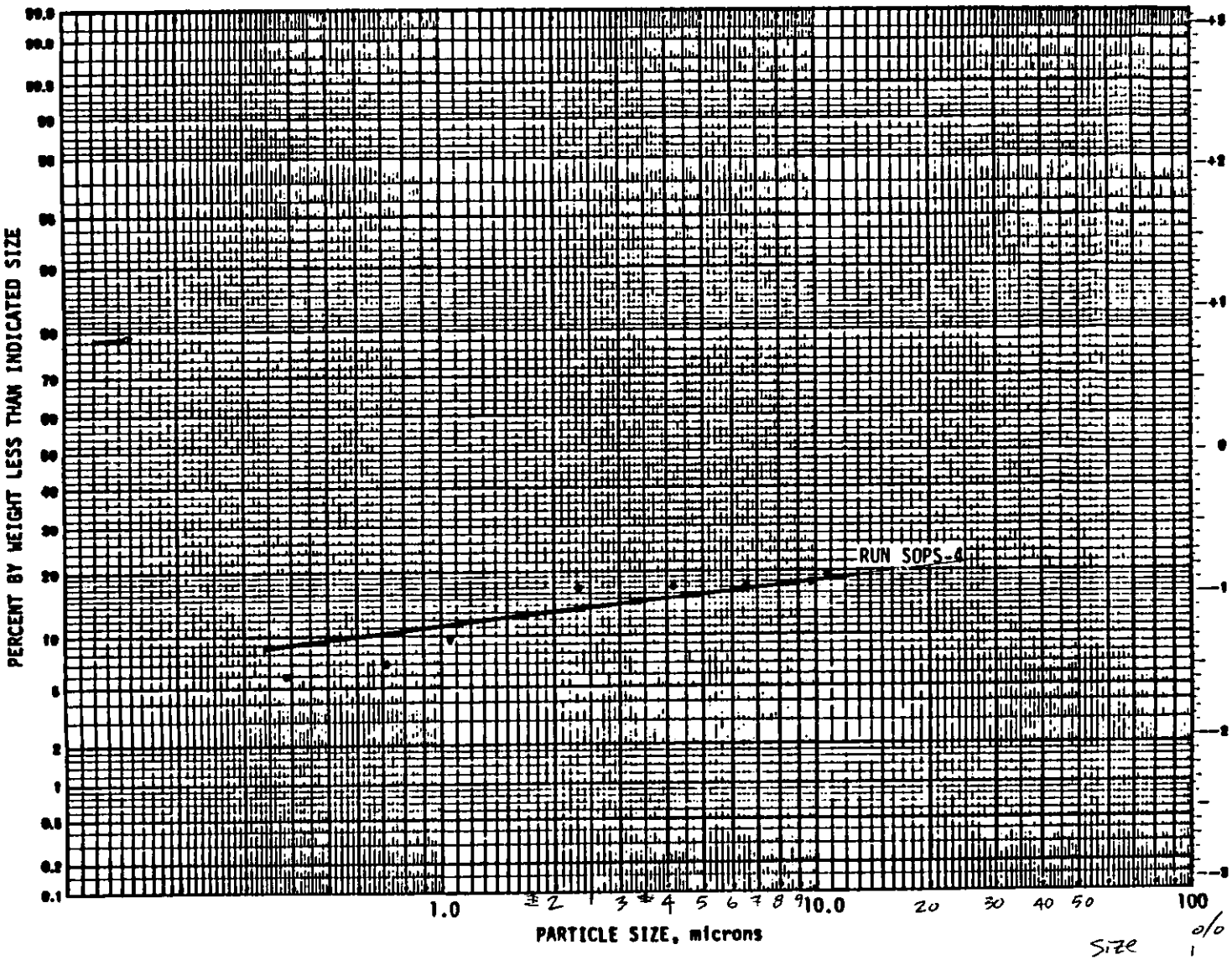


Figure 3-2. Particle size distribution - scrubber outlet.

PM10 = 18%

Size	% 1	2	AVG
2.5	14	11	13%
6.0	16	14	15%
10.0	18	16	17%
15.0	20	17	19%
20.0	21	18	20%

AVERAGE PM10 % FOR SCRUBBER OUTLET = $\frac{18\% + 16\%}{2}$ = 17%

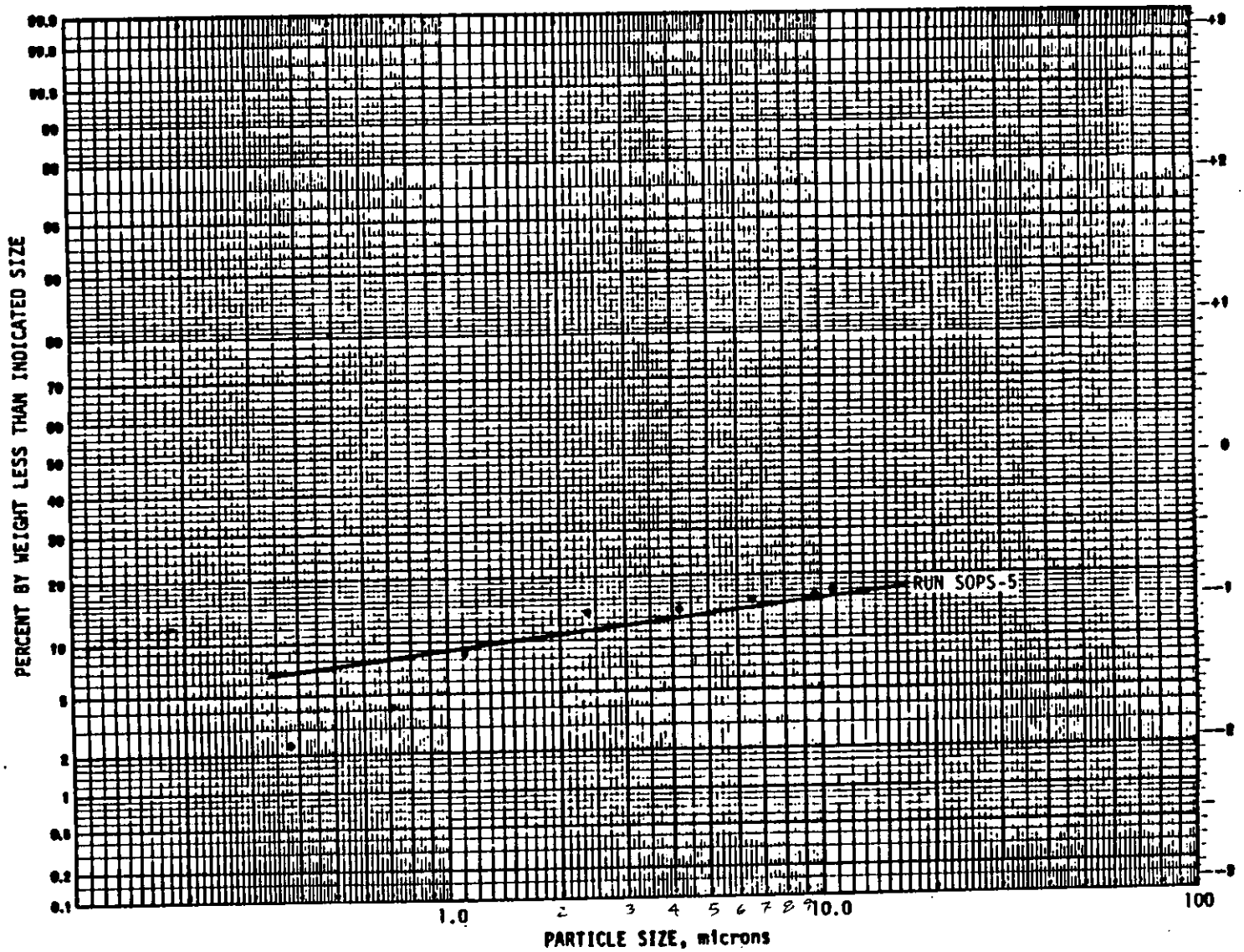


Figure 3-2 (continued)

PM10 = 16 %

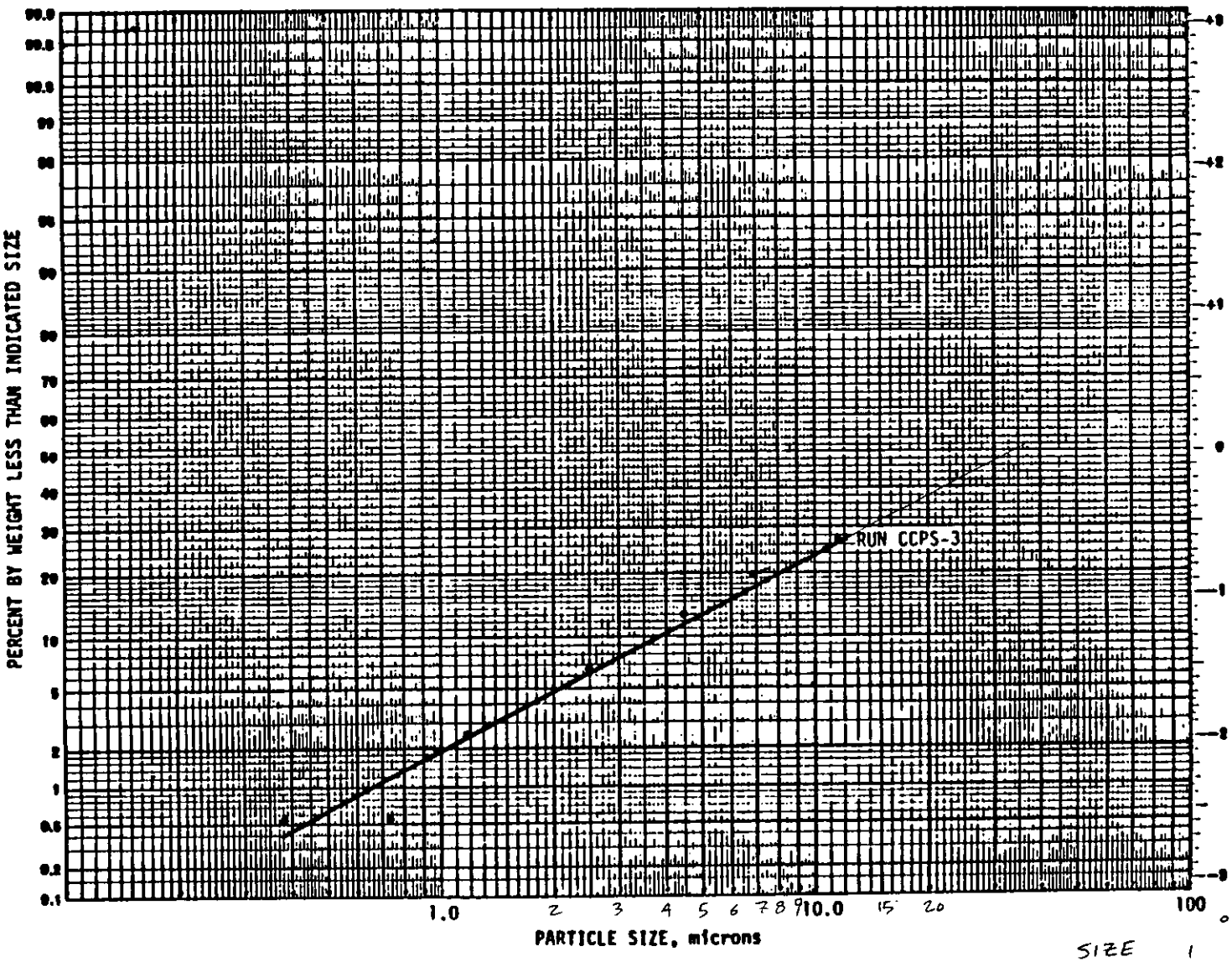


Figure 3-3. Particle size distribution - clinker cooler exhaust.

PM10 = 24%

SIZE	1	2	3	4	AVG
	%				
2.5	6%	9%	14%	4%	8%
6.0	15%	20%	20%	15%	18%
10.0	24%	28%	26%	26%	26%
15.0	32%	36%	30%	36%	34%
20.0	38%	42%	34%	46%	40%

AVG. PM10% FOR CLINKER COOLER EXHAUST

$= \frac{24\% + 28\% + 26\% + 26\%}{4} = 26\%$

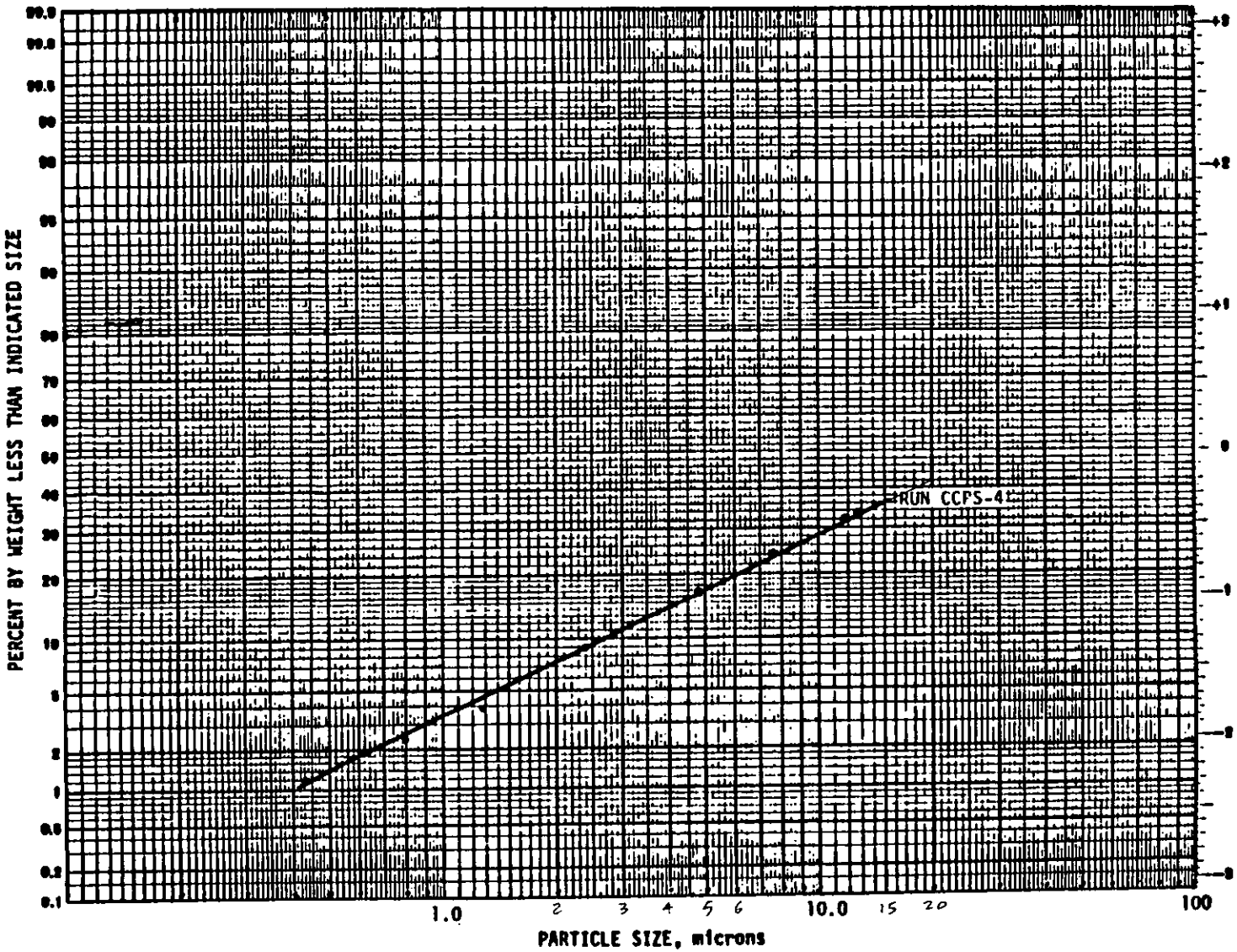


Figure 3-3 (continued)

PM10 = 28%

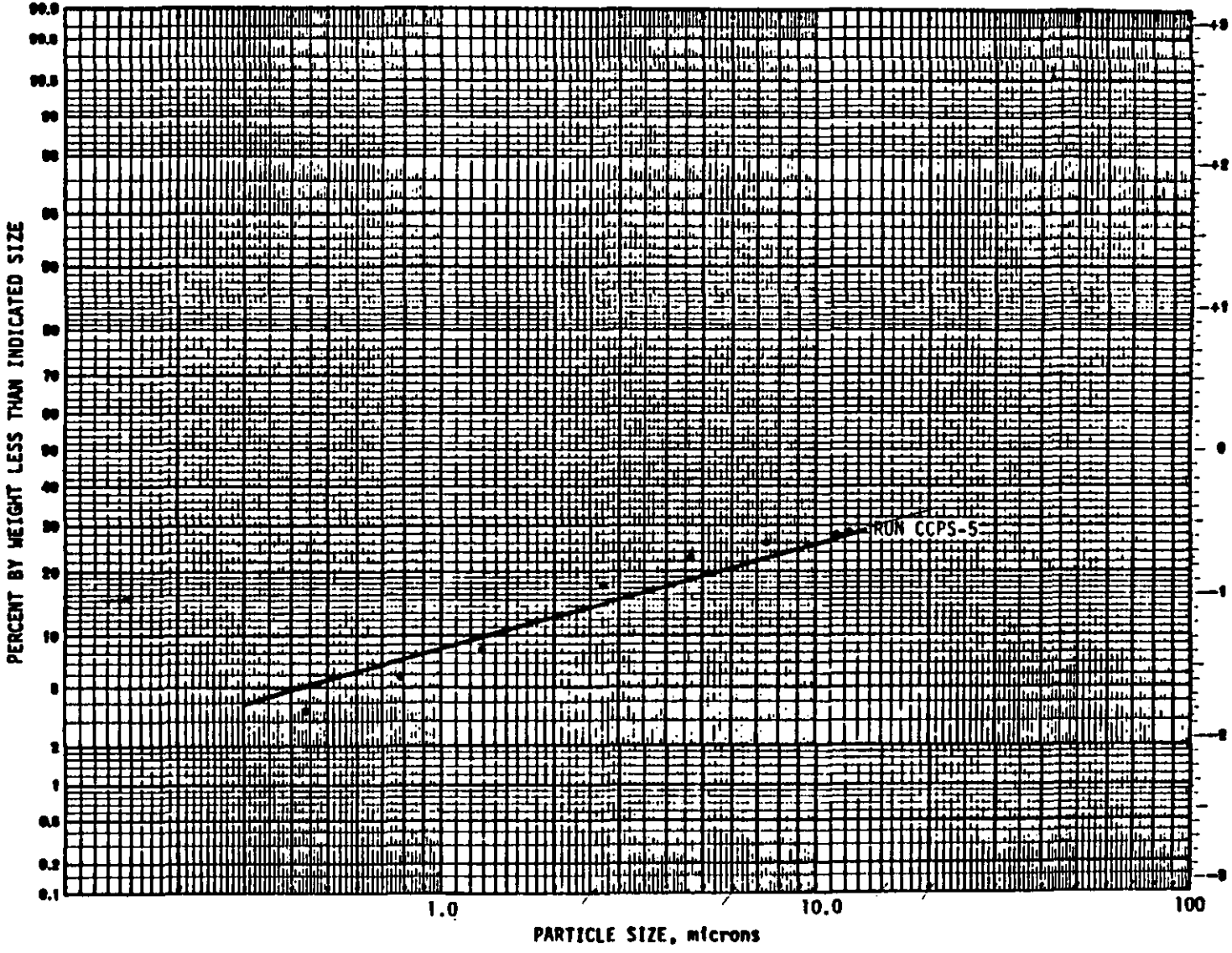


Figure 3-3 (continued)

PM10 = 26 %

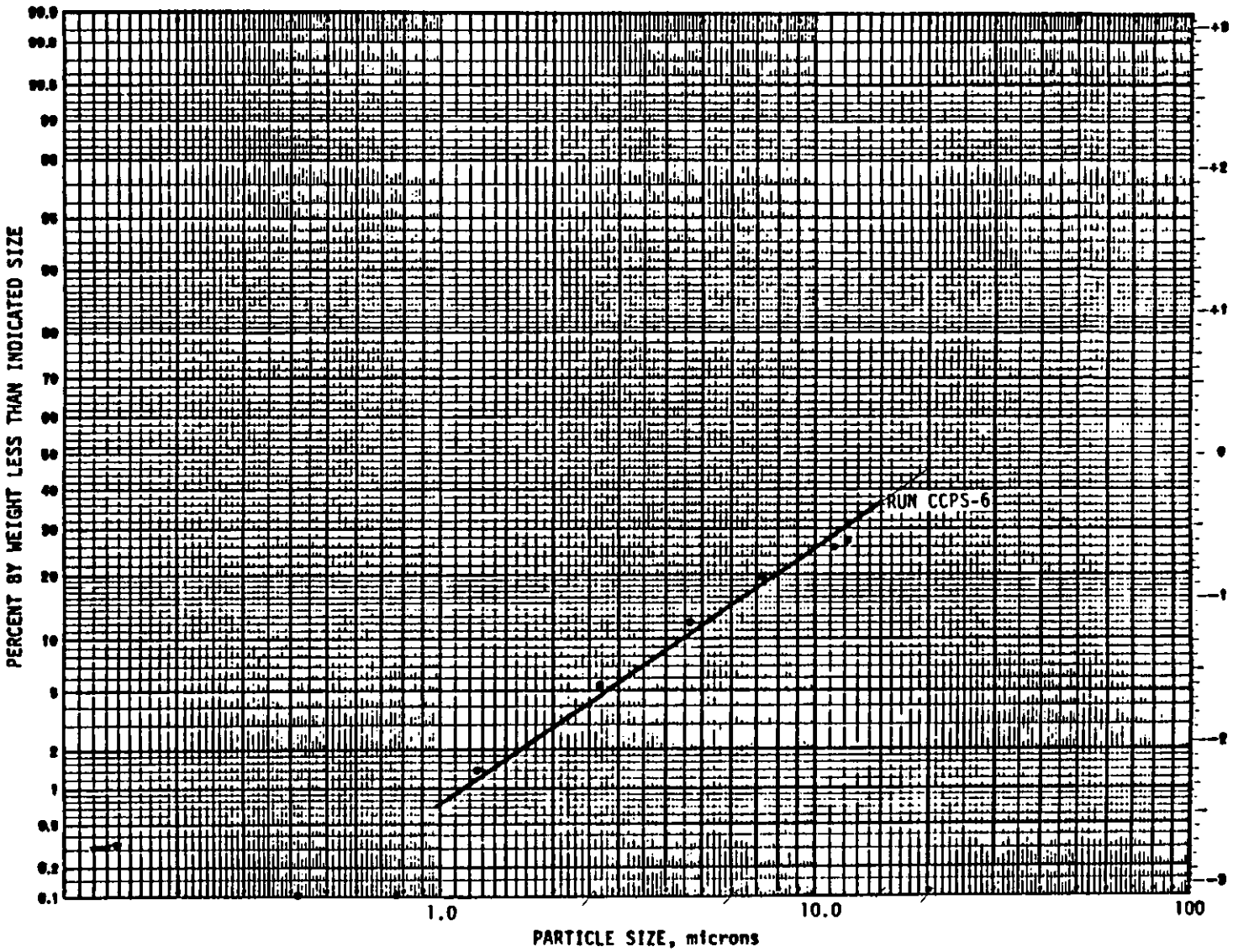


Figure 3-3 (continued)

PM10 = 26 %