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Lightweight Aggregate Industry (Clay, Shale, and Slate)

Emission Test Report Galite Corporation Rockmart, Georgia

EMISSION TEST REPORT

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

Galite Corporation
Rockmart, Georgia

ESED 80/12

by

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SECTION 1

INTRODUCTION

During the week of February 21, 1982, personnel from PEDCo Environmental conducted an emission sampling program at the lightweight aggregate facility of Galite Corporation in Rockmart, Georgia. The purpose of this test program was to provide data to assess the need for New Source Performance Standards (NSPS) for selected processes in the lightweight aggregate industry (clay, shale, and slate) and, if warranted, to develop such limits.

Comprehensive testing was conducted on 1) a coal-fired rotary kiln (No. 1), whose emissions are controlled by a medium-energy wet scrubber, and 2) a reciprocating grate clinker cooler, whose emissions are controlled by a settling chamber.

Particulate concentrations and mass emission rates were measured at the inlet and outlet of 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 particulate

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

tests. EPA Method 6* was used to measure sulfur dioxide (SO_2) concentrations and mass emission rates at the inlet and outlet of the wet scrubber serving the kiln. Nitrogen oxide (NO_x) concentration in the flue gas exiting the scrubber was determined by EPA Method 7.* In addition, the particle size distribution of particulate matter entering and exiting the kiln scrubber was determined along with the distribution of particulate exiting the clinker cooler stack. The volatile organic carbon (VOC) content of the scrubber exhaust gas 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 (slate) 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 scrubber water influent and effluent, final aggregate product, and captured particulate (clinker cooler settling chamber) were also collected during each particulate test for sulfur analyses. In addition, the scrubber water samples and captured particulate were analyzed for trace metal content. The pH of the scrubber water and the density of the final aggregate product were also determined.

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

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

SECTION 2

PROCESS OPERATION

Emission tests were conducted on the No. 1 rotary kiln and clinker cooler exhaust gas streams at Galite Corporation, Rockmart, Georgia, from February 22 through 27, 1982. Galite Corporation is a subsidiary of Big River Industries of Baton Rouge, Louisiana. This plant was selected for emissions testing for the following reasons: (1) the raw material (slate) at the plant is one of the three feedstocks used in the production of lightweight aggregate and (2) the types and arrangement of pollution control devices on the process equipment appear to be representative of future plants. The process operations during the tests were monitored by Lalit Banker and Mary Sauer while Frank Clay of EPA monitored the emission tests.

The Galite plant has two process lines (rotary kilns 1 and 2). The No. 2 kiln was not operating at the time of the test. A simplified flow diagram of the No. 1 rotary kiln process line with associated pollution control equipment is presented in Figure 1. The control equipment tested was the wet scrubber on the rotary kiln exhaust gas stream and the settling chamber on the clinker cooler exhaust gas stream.

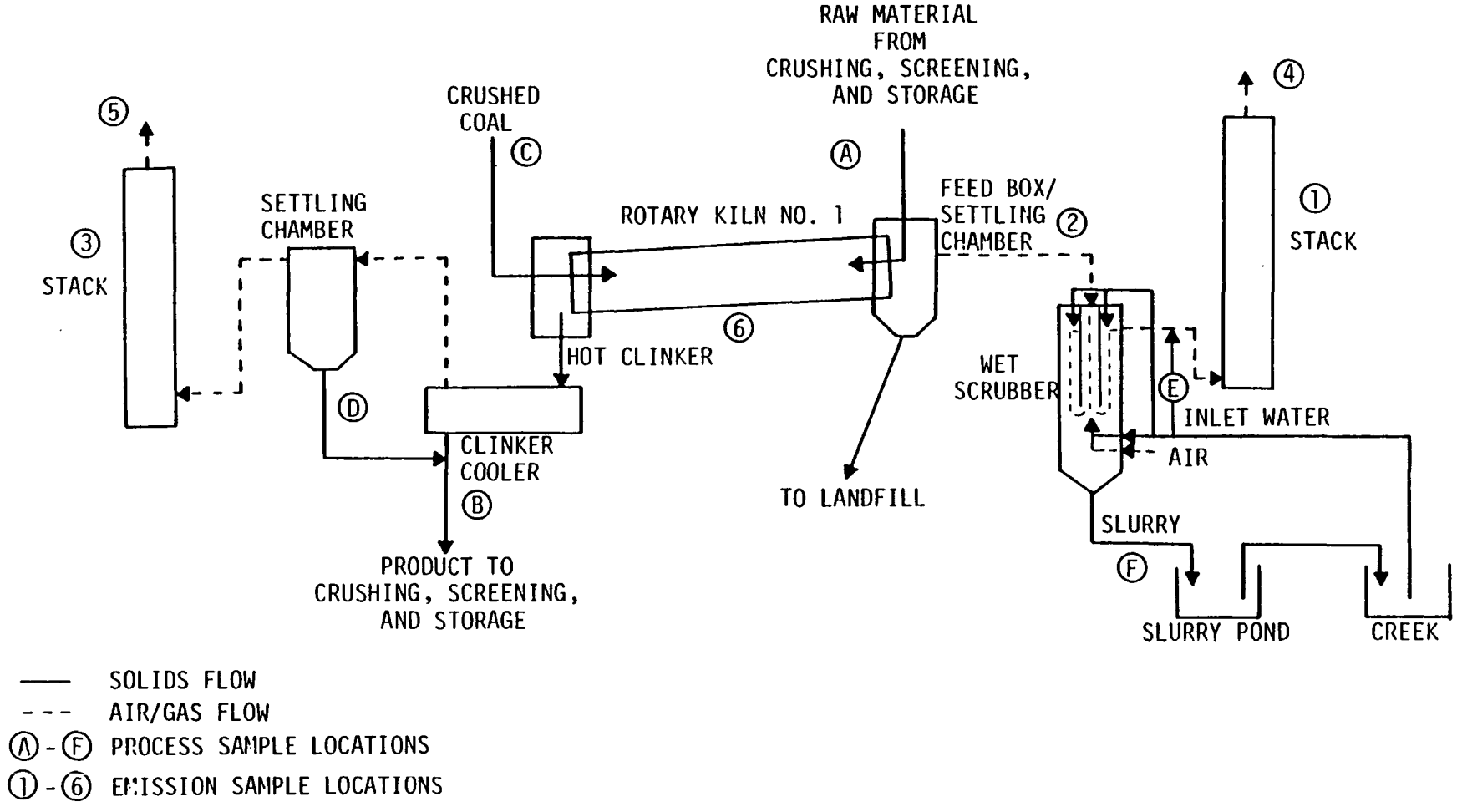

Figure 2-1. Simplified process flow diagram for the lightweight aggregate plant at Galite Corporation, Rockmart, Georgia.

Process parameters obtained by MRI during the emission tests are presented in Table 1. The raw material feed rate averaged about 30 Mg/h (33 tons/h) for the duration of the tests. The mean coal feed rate in the kiln was approximately 2,090 kg/h (4,610 lb/h), while the mean natural gas feed rate was approximately 31 m^3/h (1,090 ft^3/h). Product density ranged from 577 to 673 kg/m^3 (36 to 42 lb/ft^3) during the emission tests. The above readings were taken from the beginning to the end of the tests, and the figures in Table 1 represent averages for the total test duration.

The settling chamber and wet scrubber, including the pump supplying water to the wet scrubber, were operating normally during the emission tests. The water sprays used to suppress visible particulate emissions in the process were operating normally during the emission tests. Fugitive emissions were visible from the crushing and screening operations, clinker cooler discharge, and kiln seals.

2.1 PROCESS DESCRIPTION

The slate is mined from a quarry on plant grounds. The slate is crushed, screened, and stored in piles or enclosed silos. Belt conveyors transport the crushed slate from the storage silo to the feed box where it is charged to the rotary kiln.

The No. 1 kiln measures 57.9 meters (m) [190 feet (ft)] in length and 3.7 m (12 ft) in diameter. A dam, which measures 46 centimeters (cm) by 5 cm [18 inches (in.) by 2 in.], is located

TABLE 2-1. PROCESS DATA OBTAINED DURING EMISSION TESTS AT GALITE CORPORATION, ROCKMART, GEORGIA

Date	Test	Test duration	Raw material feed rate		Coal feed rate		Natural gas feed rate[b]		Mean product density		Mean back end temperature	
			Mg/h	tons/h	kg/h	lb/h	m^3/h	ft^3/h	kg/m^3	lb/ft^3	°C	°F
02/23/82[a]	Particulate test No. 1 on clinker cooler	12:20 p.m. to 03:43 p.m.	29.996	33.064	2,022	4,457	26	920	628	39.2	385	725
02/24/82	Particulate test No. 2 on clinker cooler	02:10 p.m. to 04:20 p.m.										
	Particulate test No. 1 on wet scrubber	02:12 p.m. to 04:33 p.m.	30.027	33.098	2,075	4,574	34	1,200	617	38.5	412	774
02/25/82	Particulate test No. 3 on clinker cooler	09:05 a.m. to 11:15 a.m.										
	Particulate test No. 2 on wet scrubber	09:05 a.m. to 11:21 a.m.	29.361	32.365	2,082	4,589	27	960	625	39.0	420	788
	Particulate test No. 3 on wet scrubber	12:47 p.m. to 02:58 p.m.	29.804	32.853	2,139	4,715	27	960	630	39.3	428	802
02/26/82	SO_2 and VOC tests	09:55 a.m. to 11:40 a.m.	30.400	33.510	2,171	4,786	40	1,400	601	37.5	451	844
02/27/82	SO_2 and VOC tests	09:15 a.m. to 10:45 a.m.	30.391	33.500	2,084	4,594	31	1,100	597	37.3	456	852
	NO_x tests	11:30 a.m. to 01:30 p.m.	30.241	33.335	2,074	4,573	31	1,100	588	36.7	448	839

[a]Simultaneous particulate test on wet scrubber was voided due to (1) excessive leakage during the post-test leak check for the inlet test and (2) loss of sample during recovery for the outlet test.
[b]Based on 24-h averages, except for tests conducted on 2/27/82.

approximately 4.3 cm (14 ft) from the back end (feed end) of the kiln. The dam increases the residence time of the raw material in the kiln and four sets of lifters improve heat exposure. The kiln rotates at approximately 3.25 revolutions per minute (rpm) during normal operation. It is designed to process approximately 36 megagrams (Mg) (40 tons) of raw material per hour at capacity. At the time of the test, approximately 30 Mg (33 tons) of raw material per hour were processed in the kiln. The raw material feed is weighed continuously on a scale before it enters the kiln. There is no continuous monitoring of actual production. Production figures [in cubic yards (yd^3)/day of product] are computed from application of a bloating factor equal to 1.05 to the raw material feed (in tons/day). The bloating factor is computed by the company and is based on experience with material loss in the process. Shipping yardage figures are obtained from information on the filled volume of the trucks transporting the finished product and the number of trucks filled each day.

The kiln is fueled primarily by crushed coal. Although the raw material feed rate is kept constant during normal operation, minor adjustments to the coal feed rate are made frequently to control the operating temperature of the kiln. Galite uses coal with an average heating volume of 2.9×10^7 Joules (J) per kg [12,500 British thermal units per pound (Btu/lb)], an ash content of approximately 12 percent, and a sulfur content of approximately 1 percent. Natural gas with an average heating value of 2.4×10^6 J/kg (1,030 Btu/ft^3) is used primarily to fuel the pilot flame.

The firing zone (front end) extends about 9 m (30 ft) into the kiln, and temperatures in this zone range from 1149° to 1177°C (2100° to 2150°F). Mid-kiln temperatures range from 982° to 1038°C (1800° to 1900°F). Temperatures in the feed end (back end) of the kiln range from 371° to 454°C (700° to 850°F) and are monitored continuously. Plant personnel stated that the shutdown period for the kiln is 48 hours. Bringing the kiln back up to operating temperature takes 36 to 48 hours. Natural gas is the primary fuel used for the reheating process.

The raw material slowly heats up as it travels through the kiln and physically expands (bloats) as volatile organic components are driven off. The residence time of the raw material in the kiln is approximately 45 minutes. Density of the product is measured hourly by plant personnel who weigh a bucket of known volume filled with the hot product.

The expanded product, or clinker, is discharged from the kiln into a clinker cooler. The clinker cooler consists of four compartments with a reciprocating grate for the circulation of air through the hot clinker. As the hot clinker is moved across the grate, four fans force air upward through the grate to cool the clinker. Approximately 100 percent of the hot exhaust air from the first compartment and 50 percent from the second compartment is recycled to the kiln to conserve combustion heat and to the coal mill to dry and preheat the coal. The gas stream recycled to the coal mill passes through a cyclone for dust removal prior to heating the coal. The remaining exhaust air from

the clinker cooler is ducted through a settling chamber and is released to the atmosphere through a stack.

Product of acceptable size falls through the reciprocating grate onto a conveyor belt for transport to the clinker silo for storage prior to crushing. Oversize material falls from the grate onto the ground where it is periodically picked up by a front end loader and transported to a storage pile for supplemental cooling and crushing. If the density or the temperature of the product is too high for the conveyor belt system, the doors to the conveyor belt are temporarily closed, and the product falls from the grate onto the ground.

The product is crushed and screened to three sizes: (1) 100 mesh to 4.8 millimeter (mm) (100 mesh to 3/16 in.), (2) 4.8 to 9.5 mm (3/16 to 3/8 in.), and (3) 9.5 to 19 mm (3/8 to 3/4 in.). The fines and the mid-size product are used mainly for concrete blocks while the larger size is used principally for structural concrete mix. Blends of product sizes are made to consumer specification. The screened product is stored in enclosed silos. Galite normally ships approximately 80 percent of its product by truck and 20 percent by rail. The company employs 50 workers and operates 365 days per year, 24 hours per day. Galite aims for actual kiln operation of approximately 80 to 90 percent of working days.

2.2 AIR POLLUTION CONTROL SYSTEM

The exhaust gases leaving the No. 1 rotary kiln pass through a settling chamber to remove the heavier particulate matter. The

waste material is landfilled on-site. The kiln exhaust emissions are controlled by a medium energy wet scrubber [Fuller/Dracco Type CAA (Compressed Air Atomizing Scrubber), Size 125-S]. A 336-kilowatt (kW) [450 horsepower (hp)] induced draft (ID) fan, located between the scrubber and the stack, pulls the exhaust gas stream from the kiln through the scrubber. The cleaned gas stream is vented to the atmosphere through a stack approximately 27 m (90 ft) high and 1.8 m (6 ft) in diameter.

Fresh water for the scrubber is pumped from a creek adjacent to the plant into a storage tank. The water is transferred from the storage tank to the scrubber by a 20-hp pump with a capacity of approximately 3,407 liters per minute (liter/min) [900 gallons per minute (gpm)]. This pump also supplies water to the rest of the plant. Plant personnel estimate that water enters the scrubber at a rate of about 400 to 450 gpm. The dirty gas flowing downward through the contact cylinder of the scrubber is contacted countercurrently by a high velocity atomized water spray introducted near the base of the scrubber. Water is also introduced through two spray bars at the top of the scrubber and one at the gas inlet to the scrubber. Dust particles are captured by the liquid droplets and accumulate at the scrubber base. A mist eliminator is present in the scrubber and was assumed by plant personnel to be operating during the tests. The scrubber effluent is pumped to a settling pond at the quarry end of the plant. The water is pumped from the pond and is discharged to the creek.

The discharge point is located close to the inlet water pipe for the scrubber water, and therefore, some mixing of fresh creek water and recycled plant water occurs. Plant personnel estimate that the influent scrubber water is typically 90 percent fresh water. No instrumentation is present at the plant to measure the scrubber pressure drop, inlet and outlet gas flow rates and temperatures, or inlet and outlet liquid flow rates.

The clinker cooler emissions from the No. 1 kiln process line are controlled by a baffled settling chamber. The collected dust is discharged to the conveyor where it is combined with the product. The clinker cooling air is pulled through the settling chamber by a 45-kW (60-hp) fan and is exhausted through a stack approximately 1.2 m (4 ft) in diameter and 12.2 m (40 ft) high. No instrumentation is available to measure the inlet and outlet gas flow rates and the temperatures across the chamber.

Water sprays are used to suppress visible particulate emissions from the crushing and screening operations and other material handling and transfer points. The flow rates for the water sprays are not available.

2.3 CONCLUSIONS AND RECOMMENDATIONS

The process and control systems operated normally for the duration of the tests. The production rate during the test was kept constant at about 83 percent of the kiln design capacity.

SECTION 3

SUMMARY OF RESULTS

This section details the results of 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.

The first set of particulate tests at the kiln exhaust scrubber were voided due to an excessive post-test leak and loss of sample during the recovery phase. These data are not included in this report.

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 the quality assurance considerations pertinent to this test project.

3.1 ROTARY KILN EXHAUST

Particulate and particle size tests were simultaneously conducted at the scrubber inlet and outlet test locations. Visible emission observations were performed during the particulate testing. Tests for sulfur dioxide were also conducted

simultaneously at the scrubber inlet and outlet test locations, and 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. At the scrubber inlet, an instack thimble was placed prior to the Method 5 filter because of the heavy particulate loading. 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," which was recently developed for EPA by Southern Research Institute (SRI).[1] At the scrubber inlet, particle size distribution was determined by a Bacho centrifugal analysis of collected samples from the particulate tests. Analytical procedures followed those described in ASME Power Test Code 28-1965. 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 and fugitive 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.

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

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 rates corrected to standard conditions [20°C and 760 mmHg (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 sampling train at a temperature of approximately 20°C (68°F) or less.

At the scrubber inlet, the volumetric flow rate averaged 41,900 dscmh (1,479,500 dscfh), the temperature averaged 475°C (887°F), and the moisture content averaged 6.4 percent. Oxygen and carbon dioxide contents averaged 13.5 and 6.6 percent,

TABLE 3-1. SUMMARY OF FLUE GAS CONDITIONS

Run No.	Date (1982)	Test time, 24-h clock	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	2/24	1412-1633	110,460	3,900,828	40,074	1,415,199	473	883	5.9	13.8	6.7	0.0
SIP-2	2/25	905-1121	119,623	4,224,440	43,197	1,525,493	473	884	6.7	13.6	6.9	0.0
SIP-3	2/25	1247-1458	118,233	4,175,348	42,416	1,497,909	478	893	6.7	13.1	6.2	0.0
Average			116,105	4,100,205	41,896	1,479,533	475	887	6.4	13.5	6.6	0.0
Scrubber outlet												
SOP-1	2/24	1412-1631	108,202	3,821,084	82,079	2,898,582	53	127	14.12[c]	16.3	4.2	0.0
SOP-2	2/25	905-1119	109,815	3,878,050	85,265	3,011,100	51	124	12.98[c]	16.4	4.0	0.0
SOP-3	2/25	1247-1456	109,986	3,884,081	84,523	2,984,887	52	126	13.61[c]	15.8	4.1	0.0
Average			109,334	3,861,072	83,956	2,964,856	52	126	13.57	16.2	4.1	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 mmHg (68°F and 29.92 in.Hg) and zero percent moisture.

[c]See Page 3-6.

TABLE 3-2. SUMMARY OF PARTICULATE EMISSIONS DATA

Test No.	Date (1982)	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	2/24	31,462	13.8	16.1	0.0070	44.9	0.0196	1,261	2,779	0.64	1.4	1.8	4.0
SIP-2	2/25	42,568	18.6	15.2	0.0066	26.8	0.0117	1,839	4,054	0.65	1.4	1.2	2.5
SIP-3	2/25	45,476	19.9	20.1	0.0088	23.9	0.0104	1,929	4,252	0.85	1.9	1.0	2.2
Average		39,835	17.4	17.1	0.0075	31.9	0.0139	1,676	3,695	0.71	1.6	1.3	2.9
Kiln exhaust scrubber outlet													
SOP-1	2/24	597.0	0.261	4.25	0.0019	17.0	0.0074	49.0	108.0	0.35	0.77	1.4	3.1
SOP-2	2/25	758.3	0.331	4.87	0.0021	15.7	0.0069	64.6	142.5	0.42	0.92	1.3	2.9
SOP-3	2/25	577.7	0.252	3.85	0.0017	17.9	0.0078	48.8	107.6	0.33	0.72	1.5	3.3
Average		644.3	0.281	4.32	0.0019	16.9	0.0074	54.1	119.4	0.37	0.80	1.4	3.1

[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).

respectively. The filterable particulate concentration averaged 39,835 mg/dscm (17.4 gr/dscf), and the corresponding mass emission rate averaged 1676 kg/h (3695 lb/h). The condensible organic and inorganic concentrations averaged 17.1 mg/dscm (0.0075 gr/dscf) and 31.9 mg/dscm (0.0139 gr/dscf), respectively. The corresponding mass emission rates averaged 0.71 kg/h (1.6 lb/h) and 1.3 kg/h (2.9 lb/h) for each fraction.

At the scrubber outlet, the volumetric flow rate averaged 84,000 dscmh (2,965,000 dscfh), the temperature averaged 52°C (126°F), and the moisture content averaged 13.6 percent. Oxygen and carbon dioxide contents averaged 16.2 and 4.1 percent, respectively. Because the gas stream was saturated and contained water droplets, two moisture determinations were made: the first involved calculations based on the water collected in the sampling trains, and the second involved psychrometric calculations. In each case, the lower value (saturation at stack temperature) was used as the correct moisture content in all calculations, as determined by EPA Method 4.*

Filterable particulate concentration averaged 644 mg/dscm (0.281 gr/dscf), and the corresponding mass emission rate averaged 54 kg/h (119 lb/h). The condensible organic and inorganic concentrations averaged 4.3 mg/dscm (0.0019 gr/dscf) and 17 mg/dscm (0.0074 gr/dscf), respectively. Organic and inorganic mass emission rates averaged 0.40 kg/h (0.80 lb/h) and 1.4 kg/h (3.1 lb/h).

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*40 CFR 60, Appendix A, Reference Method 4, July 1, 1981.

Measurements were made to determine the degree of turbulent flow at each test location as detailed in Method 2 of the Federal Register.* Select traverse points were checked by aligning the face openings of the pitot tube perpendicular to the stack cross-sectional plane, designated "0 degree reference." Null (zero) pitot readings obtained at 0 degree reference indicates an acceptable flow condition at a given point. A pitot tube angular notation of ±10 degrees to achieve a null reading is considered acceptable. Data from the clinker cooler and scrubber inlet test locations indicated acceptable flow conditions for particulate testing. At the scrubber outlet test location, the degree of angular rotation ranged from 0 to 25 degrees with an overall average of approximately 13 degrees. Typical velocity profiles from this source are presented in Figure 3-1 (east traverse) and Figure 3-2 (north traverse). Turbulent flow conditions of this type would tend to bias the velocity measurements high, thus introducing a positive bias in the calculated pollutant mass emission rates from this source. This conclusion is substantiated by a comparison of scrubber inlet and outlet flow rates on a standard basis and corrected for air inleakage (including the cold air bleedin). The measured scrubber outlet flows averaged approximately 20 percent higher than the corrected inlet flow rates.

One other source condition that should be addressed is the effect of scrubber water reentrainment. The outlet gas stream

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

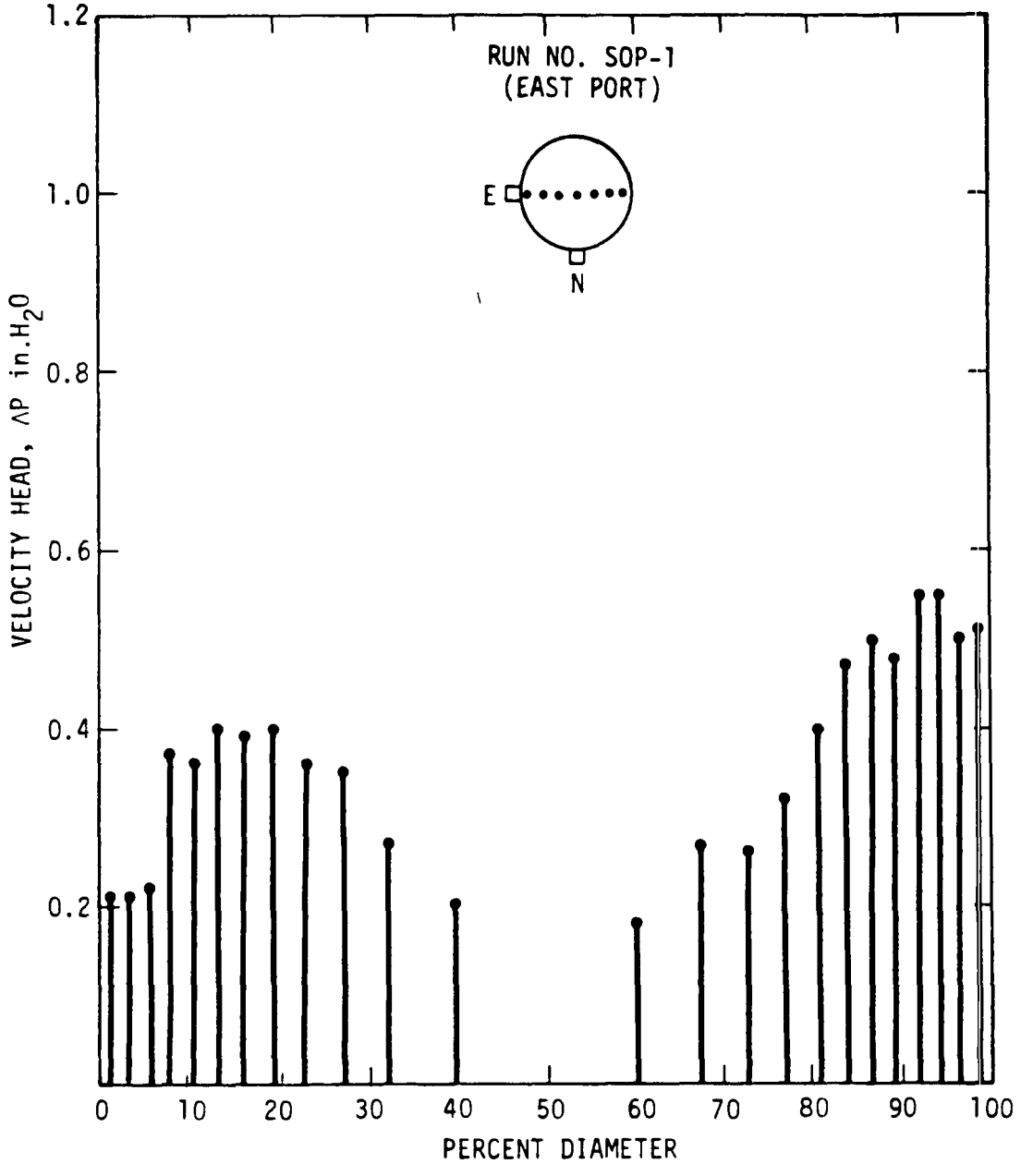

Figure 3-1. Velocity profile across east traverse of scrubber outlet.

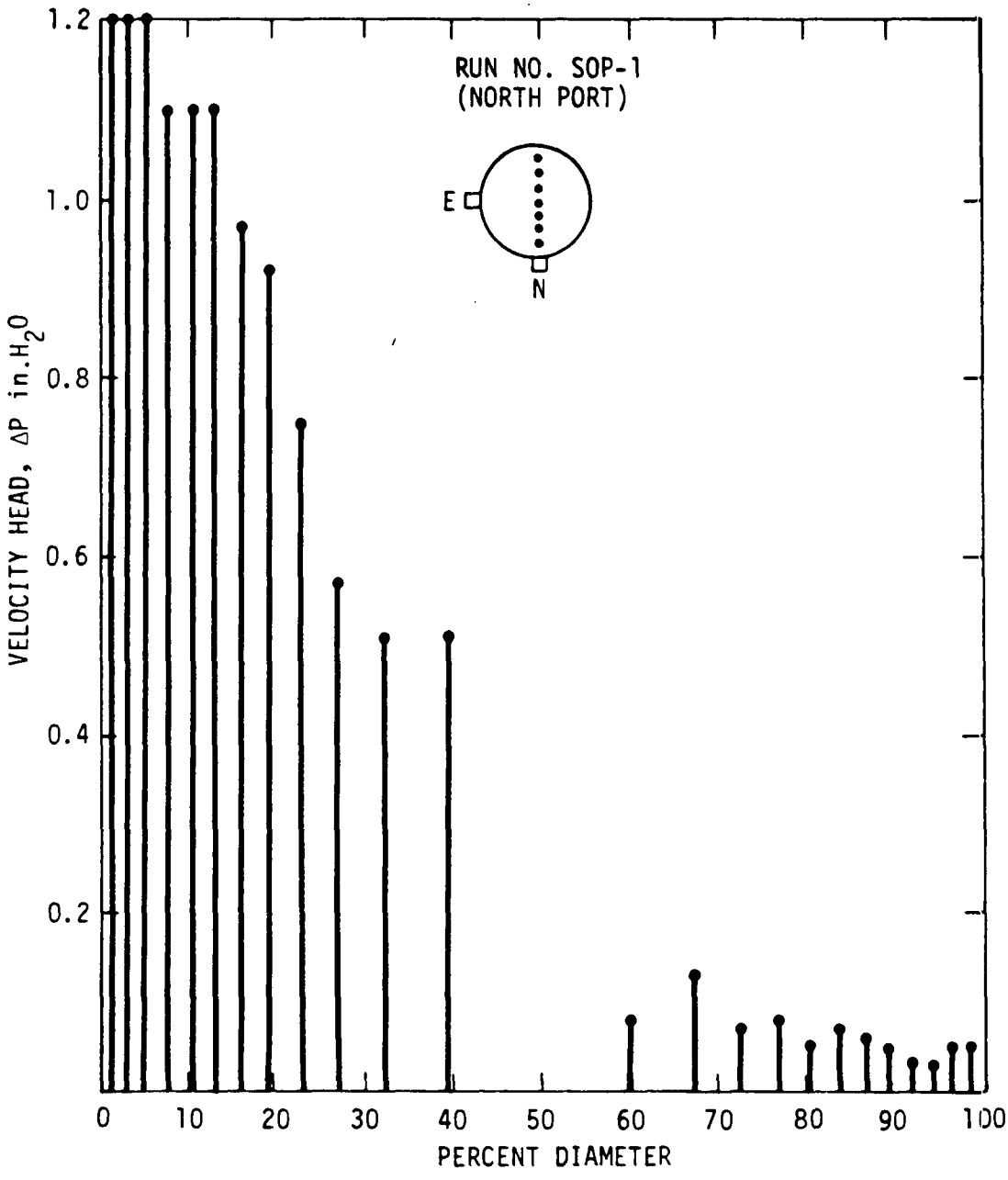

Figure 3-2. Velocity profile across north traverse of scrubber outlet.

was saturated as previously mentioned and a heavy plume water fallout was observed throughout the test period. This fallout resulted in heavy spotting of clothes and sample equipment. The average ratio of probe catch to filter catch was 1227 mg to 126 mg. The entrained water droplets laden with particulate matter were collected in the sample probe, subsequently dried by the probe heat, and recovered and measured as filterable particulate.

3.1.2 Particle Size Distribution

Three samples were collected at the scrubber inlet and eight samples at the outlet test sites. Data obtained from the particulate test runs were combined with sampling data to obtain average flow rates, moisture content, and gas composition.

At the scrubber inlet, particle size distribution was determined by a Bacho centrifugal analysis of collected samples from the particulate tests. The Bacho analyzer utilizes the centrifugal separation technique to segregate the particulate into eight different size ranges. Figure 3-3 presents the average distribution curve for the three samples collected at the scrubber inlet. Individual data points for each test were plotted manually. The results of the average distribution curve show that the size of the particulate emissions was fairly consistent during the three sampling runs. The data point distribution for these runs indicates that 50 percent of the particulate by weight was less than 13.5 μm in diameter.

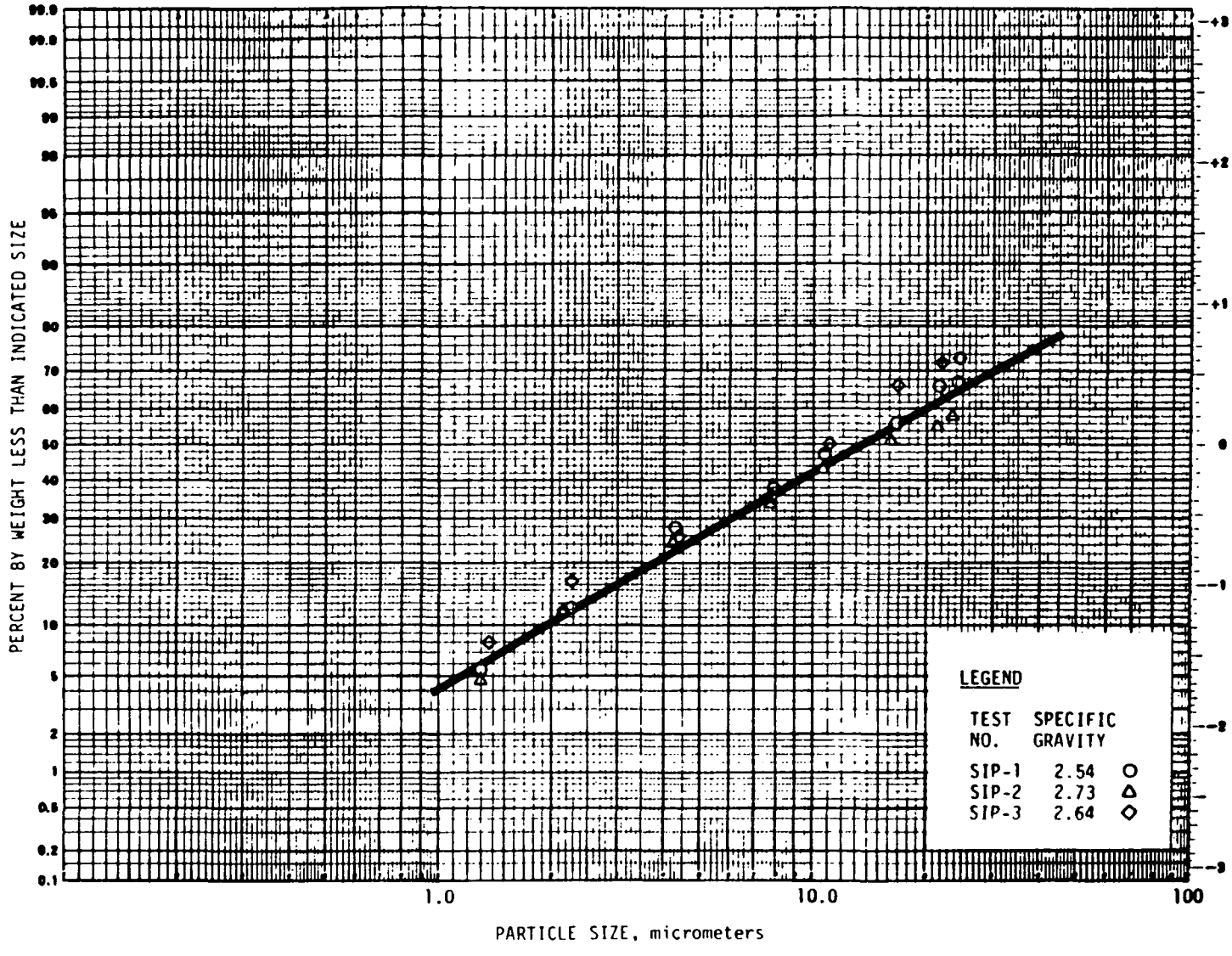

Figure 3-3. Particle size distribution - scrubber inlet.

An Andersen cascade impactor was used to collect eight particle size samples at the scrubber outlet test site. Sample Nos. SOPS-3, 7, and 9 were considered nonrepresentative due to an overloading of individual impactor stages; therefore, they are not graphically presented.

Sampling and analytical prcedures followed those described in the "Procedures Manual for Inhalable Particulate Sampler Operation," which was developed by Southern Research Institute for EPA.[1] Individual and average particle distribution curves were determined by use of a computer program detailed in the CIDRS Manual. Each specific program is briefly described here. The CIDRS Manual can provide details if described.

MPPROG - The basic program calculated stage D_{50} cut-points and cumulative distributions by two slightly different methods for each sampling run. The table of output, which was calculated by Lung Dynamics, assumed a particle density of 1 g/cm^3, calculated specific Cunningham correction factors, and yielded aerodynamic diameters. The next table, identified as Mercer, assumed both a unit particle density and a unit Cunningham factor to yield aerodynamic impaction diameters. Results in both tables were determined by reducing data according to the D_{50} method, which assumed a stage collection efficiency of 50 percent, as opposed to the Picknett method, which required stage efficiency curves. All particle size results discussed in this report were based on aerodynamic diameters unless stated otherwise. Example calculations and additional data were included in the output.

SPLIN 1 - For each sample run, a best-fit curve was calculated for size ranges, including real data, and extrapolated to the maximum particle diameter selected. Coefficients were stored for later use. This program has no tabular output.

STATIS - This program averaged the curves calculated in SPLIN 1 for a minimum of three sampling runs, removed outliers according to the upper 5 percent significance level procedure in the QA Handbook,* and calculated results for cumulative and differential distributions with 50 percent confidence intervals. All output was tabular, and curves were manually plotted with extrapolated portions indicated by dash lines. Averages for less than three runs were calculated through duplication of data sets, but confidence intervals were invalid.

Figure 3-4 presents the average particle size distribution curve for the five acceptable samples collected at the scrubber outlet. Figures 3-5 through 3-9 present the individual particle size distribution curves for each of the five sampling runs. All particle size results are based on aerodynamic diameters and unit density (1 g/cm^3).

The results of the particle size runs show that the majority of particulate was collected in the precutter of the impactor and accounted for about 60 percent of the total filterable particulate emissions. The majority of the remaining particulate collected in the impactor was between 0.4 and 2.5 μm, which accounted for about 20 percent of the total filterable particulate collected by the impactor.

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

*Quality Assurance Handbook, Volume III, EPA 600/4-77-027b, August 1977.

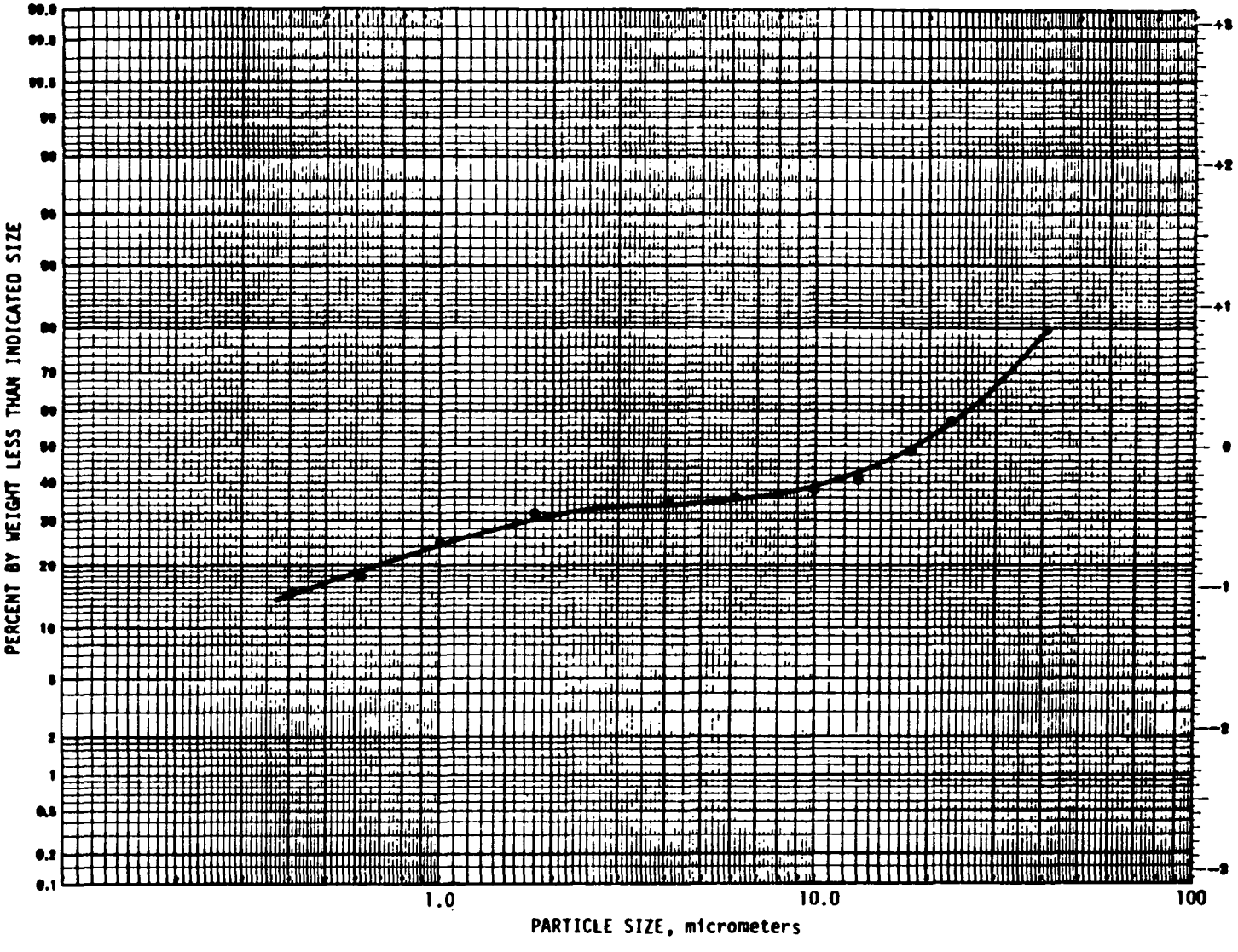

Figure 3-4. Average particle size distribution for the scrubber outlet.

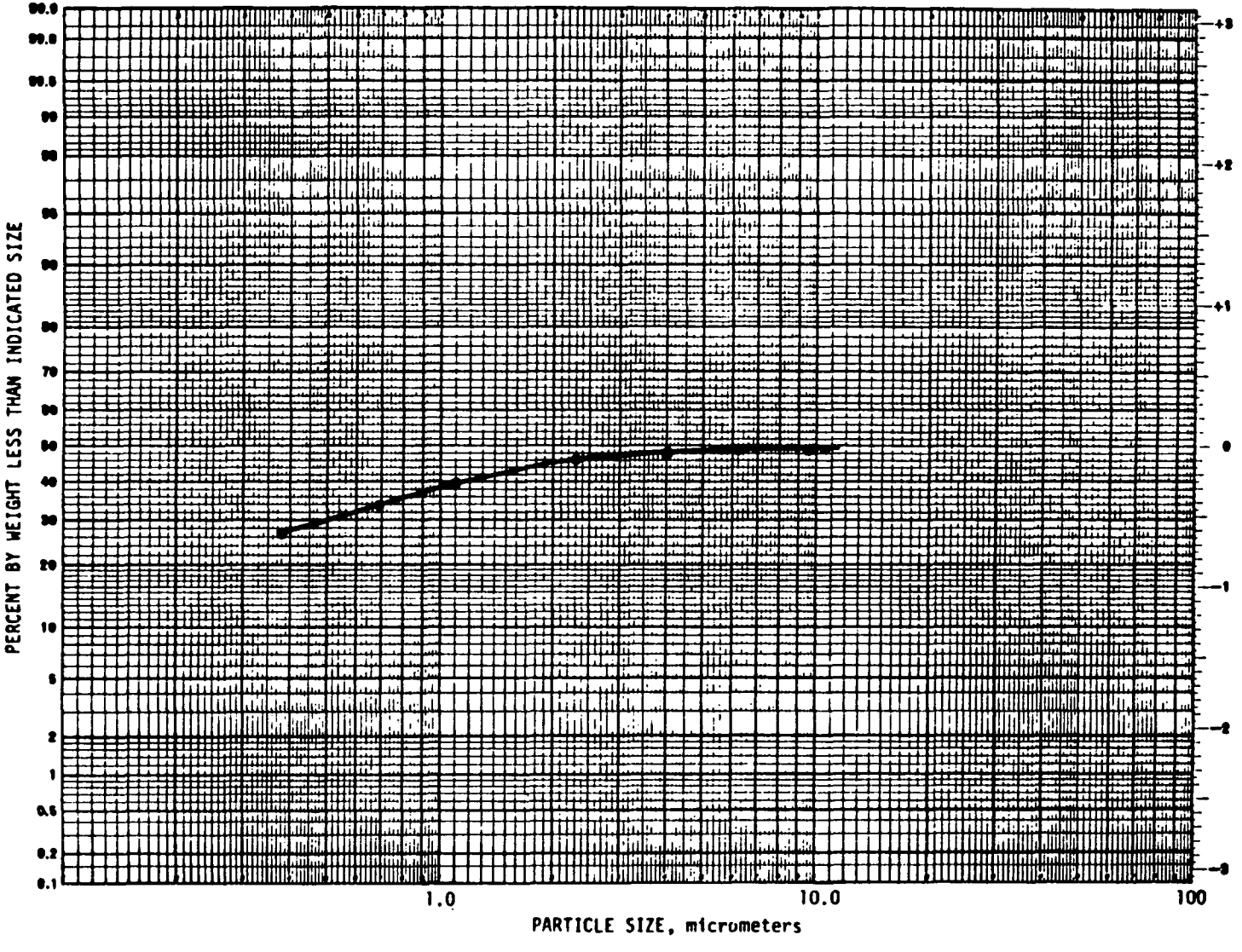

Figure 3-5. Particle size distribution for Run No. SOPS-1.

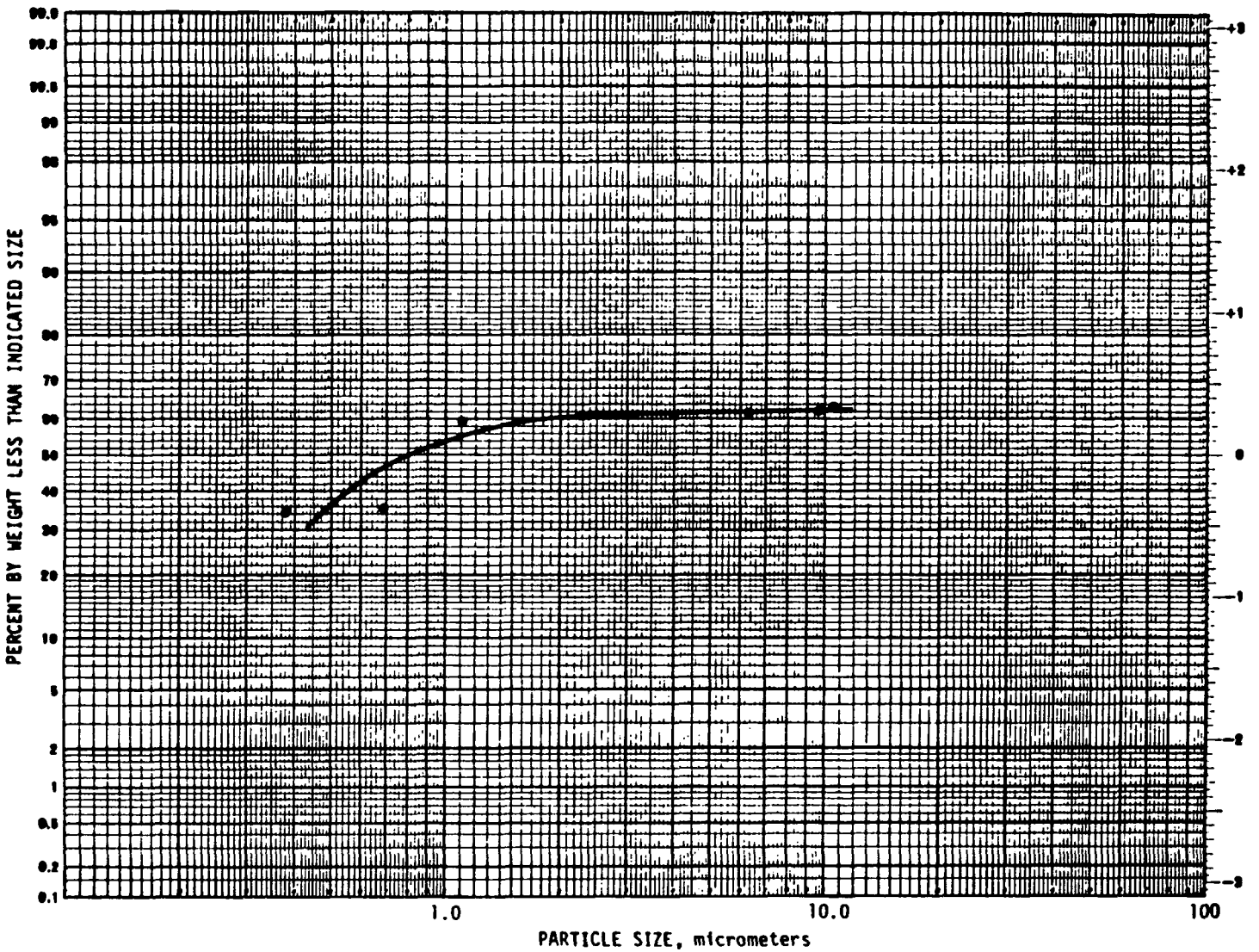

Figure 3-6. Particle size distribution for Run No. SOPS-6.

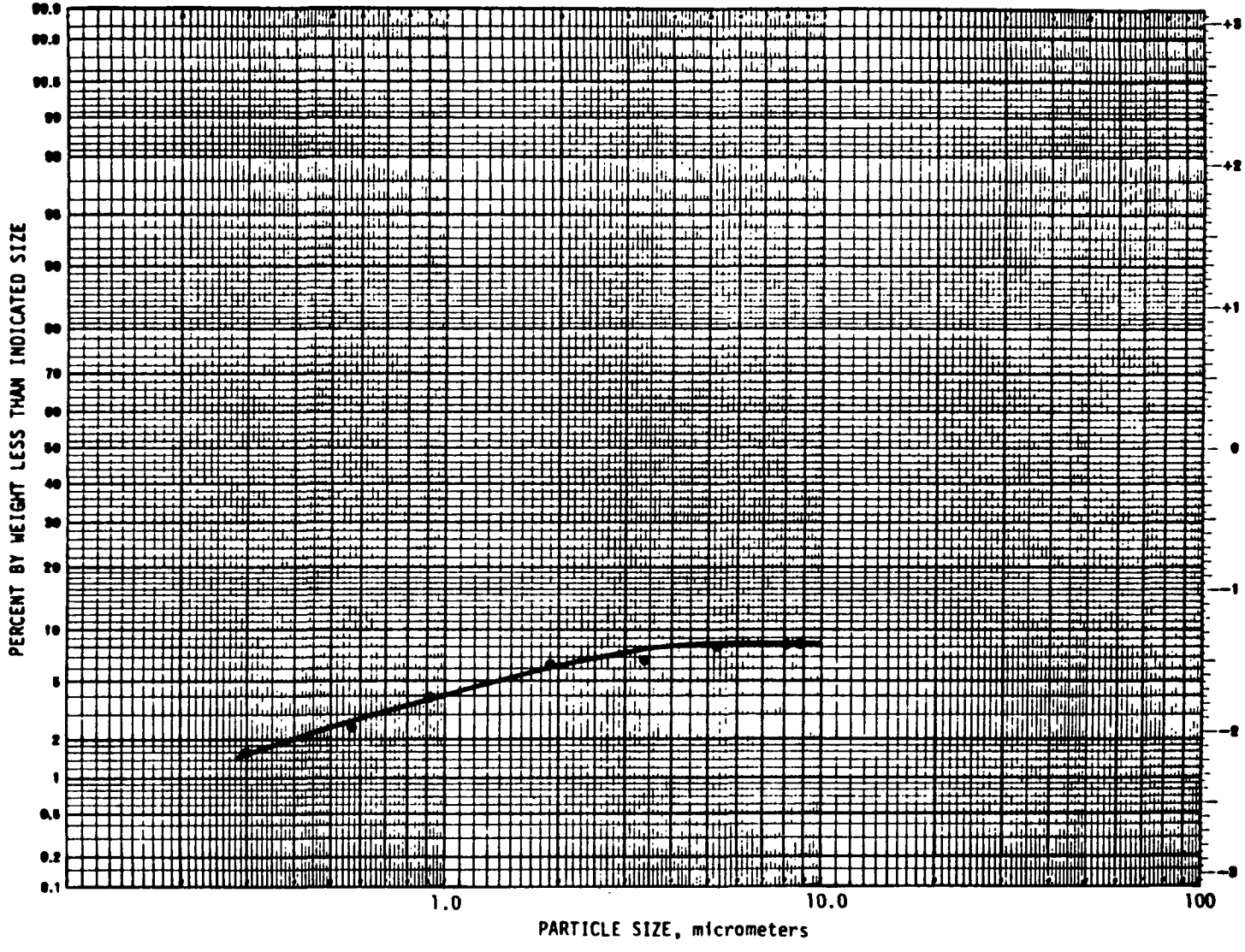

Figure 3-7. Particle size distribution for Run No. SOPS-3.

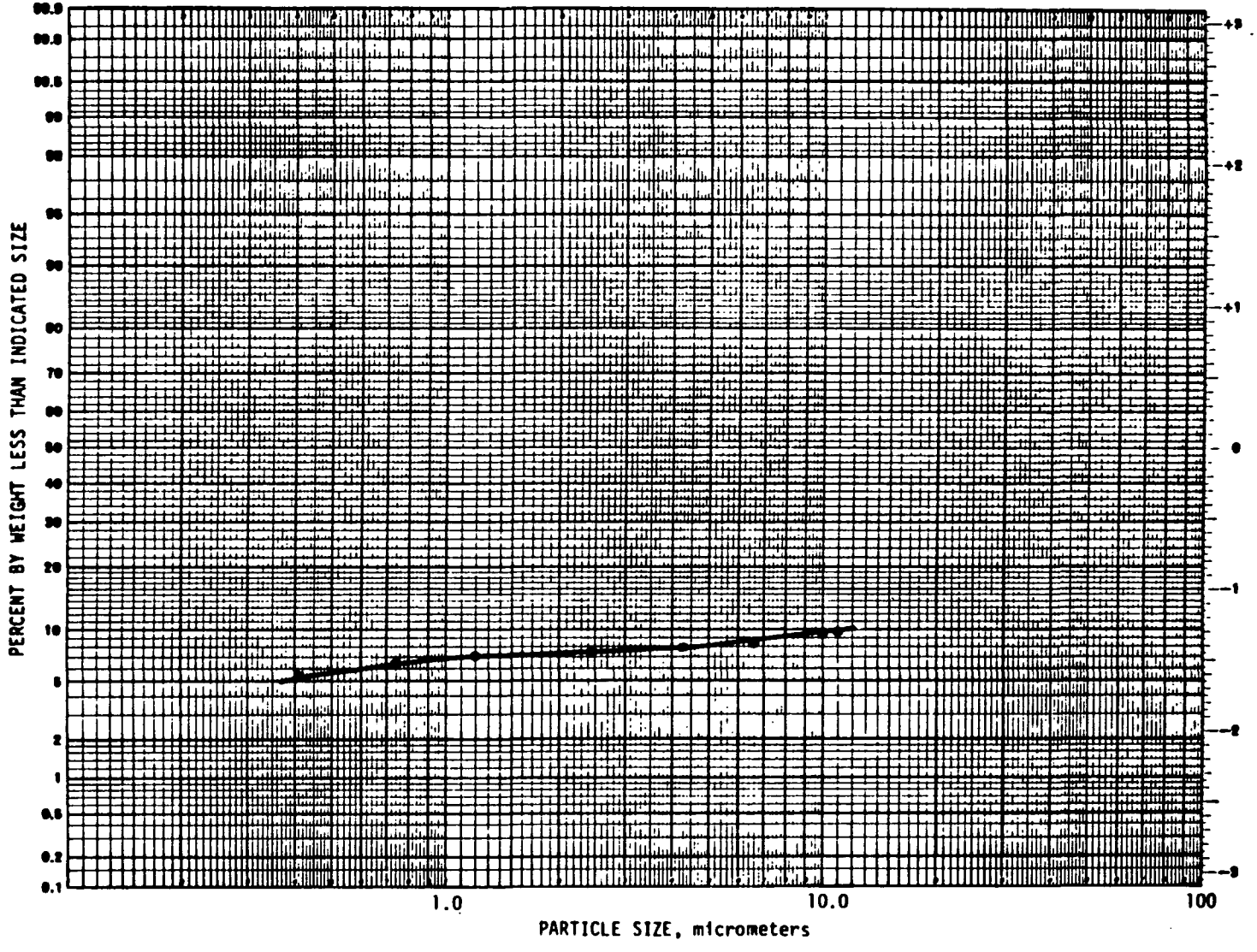

Figure 3-8. Particle size distribution for Run No. SOPS-7.

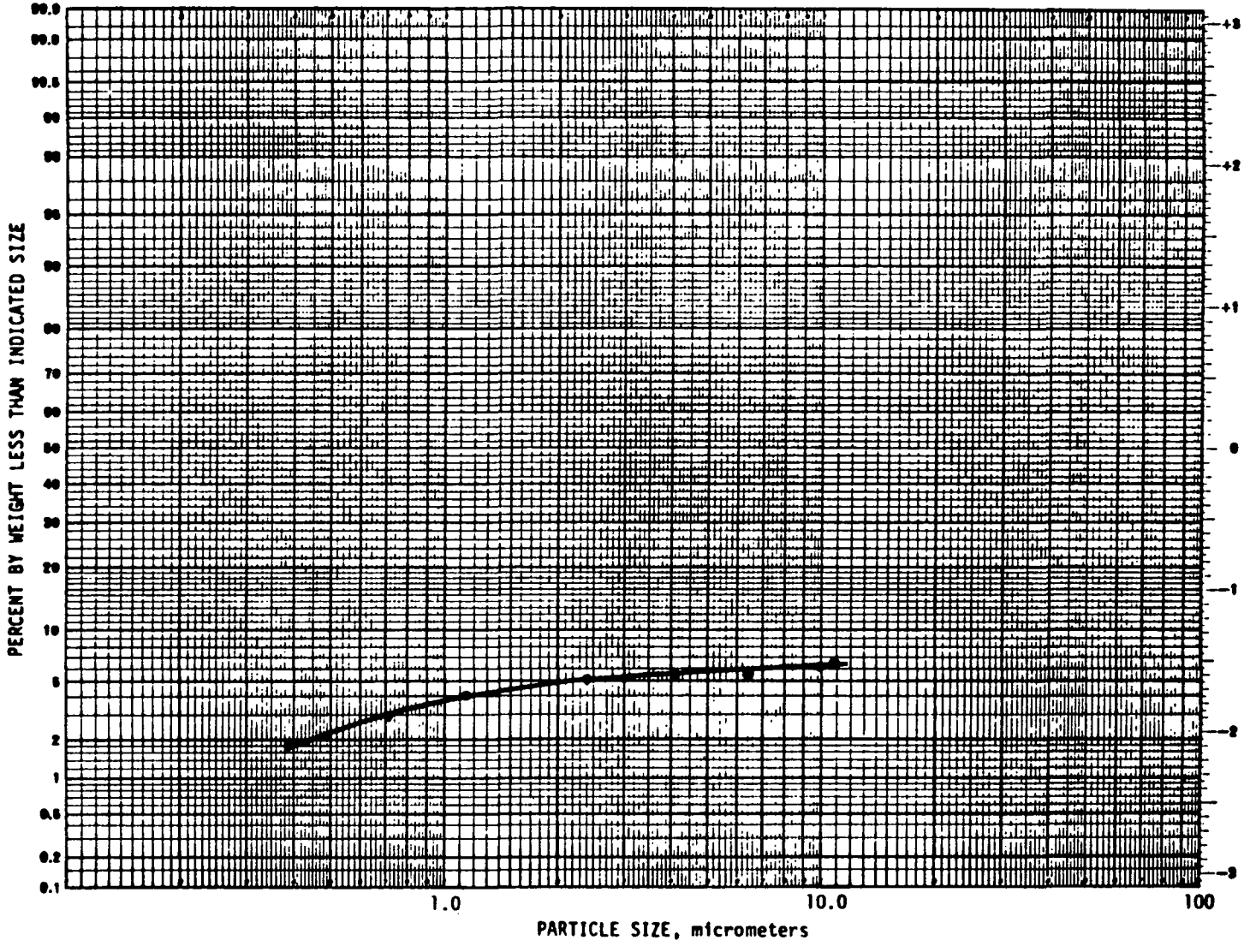

Figure 3-9. Particle size distribution for Run No. SOPS-8.

TABLE 3-3. SUMMARY OF SULFUR DIOXIDE DATA

Run No.	Date (1982)	Concentration			Mass emission rate		O_2, %	Temperature	
		ppm	mg/dscm	lb/dscf x 10^{-5}	kg/h	lb/h		°C	°F
Scrubber inlet[a]									
SIS-1	2/26	1,862	4,906	30.6	205.2	452.3	13.0	519	968
SIS-2	2/26	2,314	6,093	38.0	255.0	562.1	13.0	530	988
Average		2,088	5,500	34.3	230.1	507.2	13.0	525	978
SIS-3	2/26	2,342	6,173	38.5	258.1	568.9	11.8	524	977
SIS-4	2/27	2,135	5,628	35.1	235.2	518.5	11.6	511	954
Average		2,239	5,901	36.8	246.6	543.7	11.7	518	966
SIS-5	2/27	2,095	5,515	34.4	230.8	508.9	11.6	525	979
SIS-6	2/27	2,052	5,403	33.7	226.1	498.5	11.6	527	981
Average		2,074	5,459	34.1	228.4	503.7	11.6	526	980
Scrubber outlet[b]									
SOS-1	2/26	839	2,213	13.8	185.3	408.5	16.0	53	127
SOS-2	2/26	940	2,469	15.4	207.5	457.4	16.0	52	124
Average		890	2,341	14.6	196.4	433.0	16.0	53	126
SOS-3	2/26	957	2,517	15.7	211.2	465.6	15.2	51	123
SOS-4	2/27	879	2,309	14.4	194.1	428.0	15.8	49	121
Average		918	2,413	15.1	202.6	446.8	15.5	50	122
SOS-5	2/27	830	2,180	13.6	183.3	404.0	15.8	49	121
SOS-6	2/27	840	2,213	13.8	185.5	408.9	15.8	50	122
Average		835	2,197	13.7	184.4	406.4	15.8	50	122

[a]Mass emission rates are based on the average stack gas flow rate determined during the inlet particulate tests (41,896 dscmh and 1,479,534 dscfh).

[b]Mass emission rates are based on the average stack gas flow rate determined during the outlet particulate tests (83,956 dscmh and 2,964,856 dscfh).

mass emission rates were calculated from the measured concentrations and the average flow rate measured during the inlet particulate test run (1,479,534 dscfh). The outlet mass emission rates were calculated in a similar manner using the average measured flow rate from the outlet particulate tests (2,964,856 dscfh). Analyses were conducted on site by EPA Method 6.*

Sulfur dioxide concentrations at the inlet to the wet scrubber averaged 5620 mg/dscm (2133 ppm, 35.1 x 10^{-5} lb/dscf), and the corresponding average mass emission rate was 235 kg/h (518 lb/h). Flue gas temperature averaged 523°C (975°F), and oxygen content averaged 12.1 percent.

Sulfur dioxide concentrations at the scrubber exit stack averaged 2317 mg/dscm (881 ppm, 14.5 x 10^{-5} lb/dscf), and the corresponding average mass emission rate was 194.5 kg/h (429 lb/h). Flue gas temperature averaged 51°C (123°F), and oxygen content averaged 15.8 percent.

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 at 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 and corrected to standard conditions (2,964,856 dscfh).

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

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

Run No.	Date (1982)	Sample No.	Concentration			Mass emission rate	
			ppm	mg/dscm	lb/dscf x 10^{-4}	kg/h	lb/h
1	2/27	SON-1A	189	363	0.2262	30.4	67.1
		SON-1B	244	468	0.2920	39.3	86.6
		SON-1C	208	399	0.2488	33.5	73.8
		SON-1D	229	439	0.2739	36.8	81.2
Average			218	417	0.2602	35.0	77.2
2	2/27	SON-2A	207	396	0.2472	33.2	73.3
		SON-2B[b]	206	394	0.2455	33.0	72.8
		SON-2C[b]	300	575	0.3586	48.2	106.3
		SON-2D	201	386	0.2405	32.3	71.3
Average			205	392	0.2444	36.7	72.5
3	2/27	SON-3A[b]	154	295	0.1840	24.7	54.5
		SON-3B	215	411	0.2566	34.5	76.1
		SON-3C	198	380	0.2370	31.9	70.3
		SON-3D	192	367	0.2288	30.8	67.8
Average			202	386	0.2408	32.4	71.4

[a]Mass emission rates are based on the average stack gas flow rate determined during the scrubber outlet particulate tests (83,956 dscmh and 2,964,856 dscfh).

[b]Outlier not used in average.

Nitrogen oxide concentrations averaged 398 mg/dscm (208 ppm, 0.248×10^{-4} lb/dscf), and the corresponding mass emission rate was 34.7 kg/h (73.7 lb/h).

3.1.5 Hydrocarbon Emissions From the Kiln Scrubber Outlet

Hydrocarbon emissions from the scrubber outlet at Kiln No. 1 were sampled by use of the procedures of EPA Method 25* in order to determine total gaseous nonmethane organics (TGNMO). Four 1-hour samples were collected at the scrubber outlet. Test No. SO-VC-1 was voided due to a plug in the sampling probe. Results of the Method 25 sampling are presented in Table 3-5. In the Method 25 analytical procedures, 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 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 60 to 141 ppm with an average value of 90 ppm as methane. The average emission rate of nonmethane organic compounds was 5.4 kg/h (11.1 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.

*40 CFR 60, Appendix A, Reference Method 25, July 1, 1980.

TABLE 3-5. HYDROCARBON EMISSIONS FROM SCRUBBER OUTLET

Test No.	Date (1982)	Sampling time, 24-h		NMO[a] concentration ppm as CH_4	Hydrocarbon emission rate expressed as methane[b]	
		Start	Finish		kg/h	lb/h
SO-VC-1[c]	2/26	-	-	-	-	-
SO-VC-2	2/26	1032	1120	60	3.6	7.4
SO-VC-3	2/26	1127	1215	141	8.5	17.4
SO-VC-4	2/27	900	1010	68	4.1	8.4
Average				90	5.4	11.1

[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). Mass emission rates are calculated using the average gas flow rate measured during the particulate tests (2,964,856 dscfh).

[c]SO-VC-1 voided due to plug in sampling probe.

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

Test 1 (2/23/82)				Test 2 (2/24/82)				Test 3 (2/25/82)				Test 4 (2/25/82)			
Set No.	Time	Average % opacity	Range	Set No.	Time	Average % opacity	Range	Set No.	Time	Average % opacity	Range	Set No.	Time	Average % opacity	Range
SOVE-1-1	1215-1220	1	0-5	SOVE-2-1	1410-1415	1	0-5	SOVE-3-1	910-915	0	0-5	SOVE-4-1	1250-1255	1	0-5
SOVE-1-2	1221-1226	3	0-5	SOVE-2-2	1416-1421	1	0-5	SOVE-3-2	916-921	0	0-5	SOVE-4-2	1256-1301	1	0-5
SOVE-1-3	1227-1232	0	0-5	SOVE-2-3	1422-1427	1	0-5	SOVE-3-3	922-927	0	0-5	SOVE-4-3	1302-1307	1	0-5
SOVE-1-4	1232-1238	0	0	SOVE-2-4	1428-1433	1	0-5	SOVE-3-4	928-933	0	0-5	SOVE-4-4	1308-1313	1	0-5
SOVE-1-5	1239-1244	0	0-5	SOVE-2-5	1434-1439	1	0-5	SOVE-3-5	934-939	0	0-5	SOVE-4-5	1314-1319	1	0-5
SOVE-1-6	1245-1250	1	0-5	SOVE-2-6	1440-1445	0	0	SOVE-3-6	940-945	0	0-5	SOVE-4-6	1320-1325	0	0-5
SOVE-1-7	1251-1256	1	0-5	SOVE-2-7	1446-1451	0	0	SOVE-3-7	946-951	0	0	SOVE-4-7	1326-1331	0	0-5
SOVE-1-8	1257-1302	0	0	SOVE-2-8	1452-1457	1	0-5	SOVE-3-8	952-957	0	0-5	SOVE-4-8	1332-1337	0	0
SOVE-1-9	1303-1308	0	0	SOVE-2-9	1458-1503	0	0-5	SOVE-3-9	958-1003	0	0-5	SOVE-4-9	1338-1343	0	0
SOVE-1-10	1309-1314	0	0-5	SOVE-2-10	1504-1509	0	0	SOVE-3-10	1004-1009	0	0-5	SOVE-4-10	1344-1349	0	0
SOVE-1-11	1315-1320	3	0-5	SOVE-2-11	1510-1515	1	0-5	SOVE-3-11	1010-1015	0	0-5	SOVE-4-11	1350-1355	0	0
SOVE-1-12	1321-1326	1	0-5	SOVE-2-12	1516-1521	0	0-5	SOVE-3-12	1016-1021	0	0	SOVE-4-12	1356-1401	0	0-5
SOVE-1-13	1327-1332	0	0-5	SOVE-2-13	1522-1527	2	0-5	SOVE-3-13	1022-1027	0	0	SOVE-4-13	1402-1407	0	0
SOVE-1-14	1333-1338	0	0-5	SOVE-2-14	1528-1533	0	0-5	SOVE-3-14	1028-1033	0	0	SOVE-4-14	1408-1418	0	0
SOVE-1-15	1339-1344	0	0	SOVE-2-15	1534-1539	0	0	SOVE-3-15	1034-1039	0	0	SOVE-4-15	1414-1419	0	0
SOVE-1-16	1345-1350	0	0	SOVE-2-16	1540-1545	0	0	SOVE-3-16	1040-1045	0	0	SOVE-4-16	1420-1425	0	0
SOVE-1-17	1351-1356	0	0	SOVE-2-17	1546-1551	0	0-5	SOVE-3-17	1046-1051	0	0	SOVE-4-17	1426-1431	0	0
SOVE-1-18	1357-1402	0	0	SOVE-2-18	1552-1557	0	0	SOVE-3-18	1052-1057	0	0	SOVE-4-18	1432-1437	0	0
SOVE-1-19	1445-1450	3	0-5	SOVE-2-19	1558-1603	1	0-5	SOVE-3-19	1058-1103	0	0	SOVE-4-19	1438-1443	0	0
SOVE-1-20	1451-1456	1	0-5	SOVE-2-20	1604-1609	1	0-5	SOVE-3-20	1104-1109	0	0	SOVE-4-20	1444-1449	0	0
SOVE-1-21	1457-1502	2	0-5	SOVE-2-21	1610-1615	0	0-5								
SOVE-1-22	1503-1508	2	0-10	SOVE-2-22	1616-1621	0	0-5								
SOVE-1-23	1509-1514	2	0-5	SOVE-2-23	1622-1627	0	0-5								
SOVE-1-24	1515-1520	2	0-5	SOVE-2-24	1628-1633	0	0-5								
SOVE-1-25	1521-1526	1	0-5												
SOVE-1-26	1527-1532	2	0-5												
SOVE-1-27	1533-1538	3	0-5												
SOVE-1-28	1539-1544	1	0-5												
SOVE-1-29	1545-1550	2	0-5												

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.

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 the "Procedures Manual for Inhalable Particulate Sampler Operation," which was recently developed for EPA by Southern Research Institute.[1] Visible emission observations were made according to procedures described in EPA Method 9.* 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 sampling probe and on the filter, both of which were heated to approximately 121°C (250°F). The condensible organic and inorganic fractions represent

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

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

Run No.	Date (1982)	Test time, 24-h clock	Volumetric flow rate				Temperature		Moisture, %	O_2, %	CO_2, %	CO, %
			Actual[a]		Standard[b]							
			acmh	acfh	dscmh	dscfh	°C	°F				
CCP-1	2/23	1220-1543	58,192	2,055,032	46,362	1,637,241	89	191	<1.0	20.5	0.0	0.0
CCP-2	2/24	1410-1620	64,209	2,267,501	52,892	1,867,862	75	167	<1.0	20.4	0.0	0.0
CCP-3	2/25	905-1115	57,347	2,025,191	52,206	1,843,612	43	109	<1.0	20.5	0.0	0.0
Average			59,916	2,115,908	50,487	1,782,905	69	156	<1.0	20.5	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 mmHg (68°F and 29.92 in.Hg) and zero percent moisture.

TABLE 3-8. SUMMARY OF PARTICULATE EMISSIONS DATA

Test No.	Date (1982)	Clinker cooler outlet											
		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
CCP-1	2/23	157.9	0.069	3.17	0.0014	7.20	0.0030	7.3	16.1	0.15	0.32	0.33	0.74
CCP-2	2/24	122.1	0.053	2.19	0.0010	2.19	0.0010	6.5	14.2	0.12	0.26	0.12	0.26
CCP-3	2/25	105.4	0.046	1.67	0.0007	2.36	0.0010	5.5	12.1	0.09	0.19	0.12	0.27
Average		128.5	0.056	2.34	0.0010	3.92	0.0017	6.4	14.1	0.12	0.26	0.19	0.42

[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).

material that condensed out or was trapped in the impinger section of the sampling train at a temperature of approximately 20°C (68°F).

The volumetric flow rate averaged 50,500 dscmh (1,783,000 dscfh), the temperature averaged 69°C (156°F), and the moisture content averaged less than 1 percent. The oxygen and carbon dioxide contents averaged 20.5 and 0 percent, respectively.

Filterable particulate concentration averaged 128.5 mg/dscm (0.056 gr/dscf) with a corresponding average mass emission rate of 6.4 kg/h (14.1 lb/h). The organic and inorganic concentrations averaged 2.34 mg/dscm (0.0010 gr/dscf) and 3.92 mg/dscm (0.0017 gr/dscf), and the corresponding mass emission rates averaged 0.12 kg/h (0.26 lb/h) and 0.19 kg/h (0.42 lb/h).

3.2.2 Particle Size Distribution

A total of eight 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 describes the sampling and analytical procedures and the data reduction techniques used, respectively. Run Nos. CCPS-2, 3, and 6 were considered nonrepresentative and are not graphically presented.

Figure 3-10 presents the average particle size distribution curve for the five acceptable runs conducted at the clinker cooler outlet test site. Figures 3-11 through 3-15 present the individual particle size distribution curves for each of the five

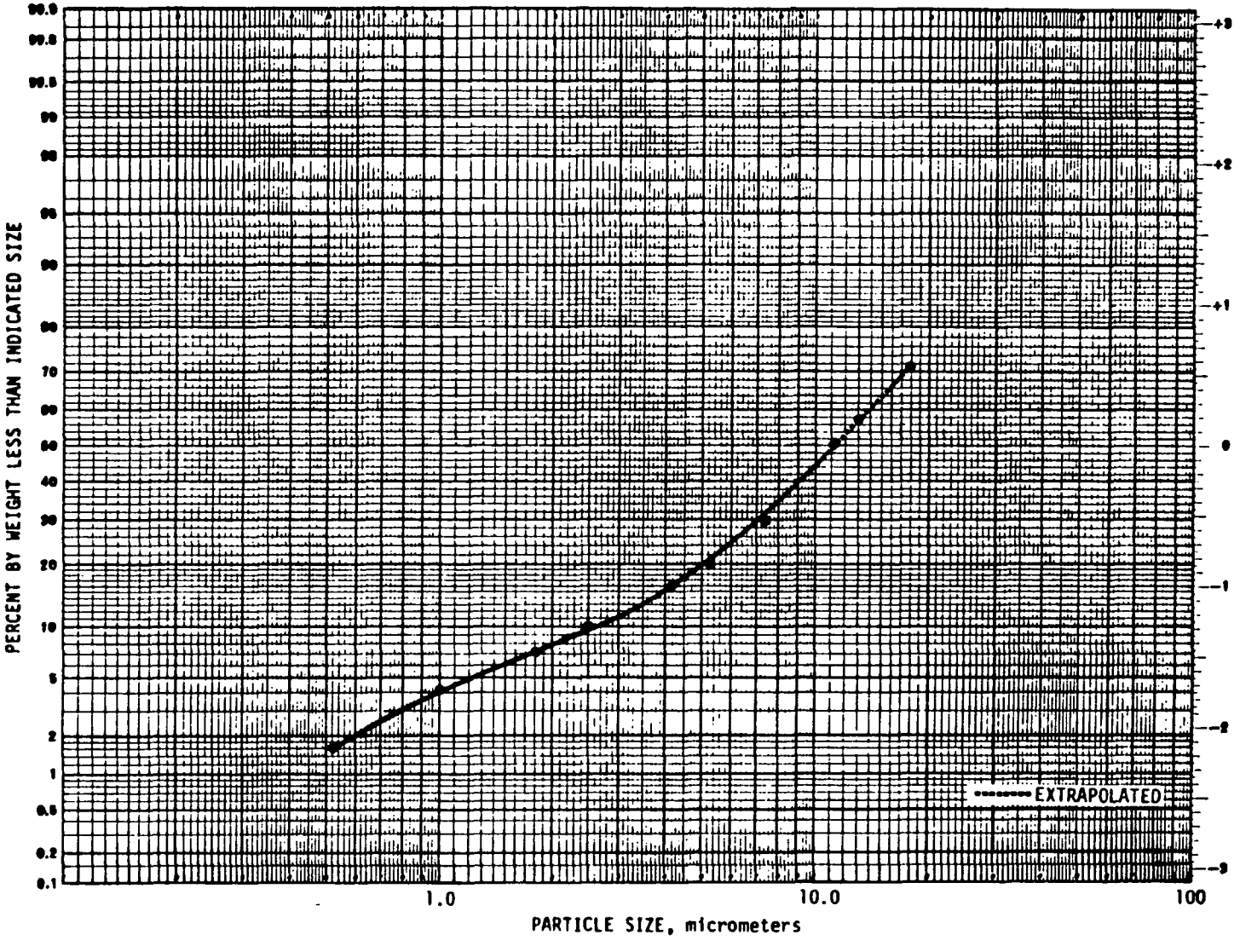


Figure 3-10. Average particle size distribution for the clinker cooler.

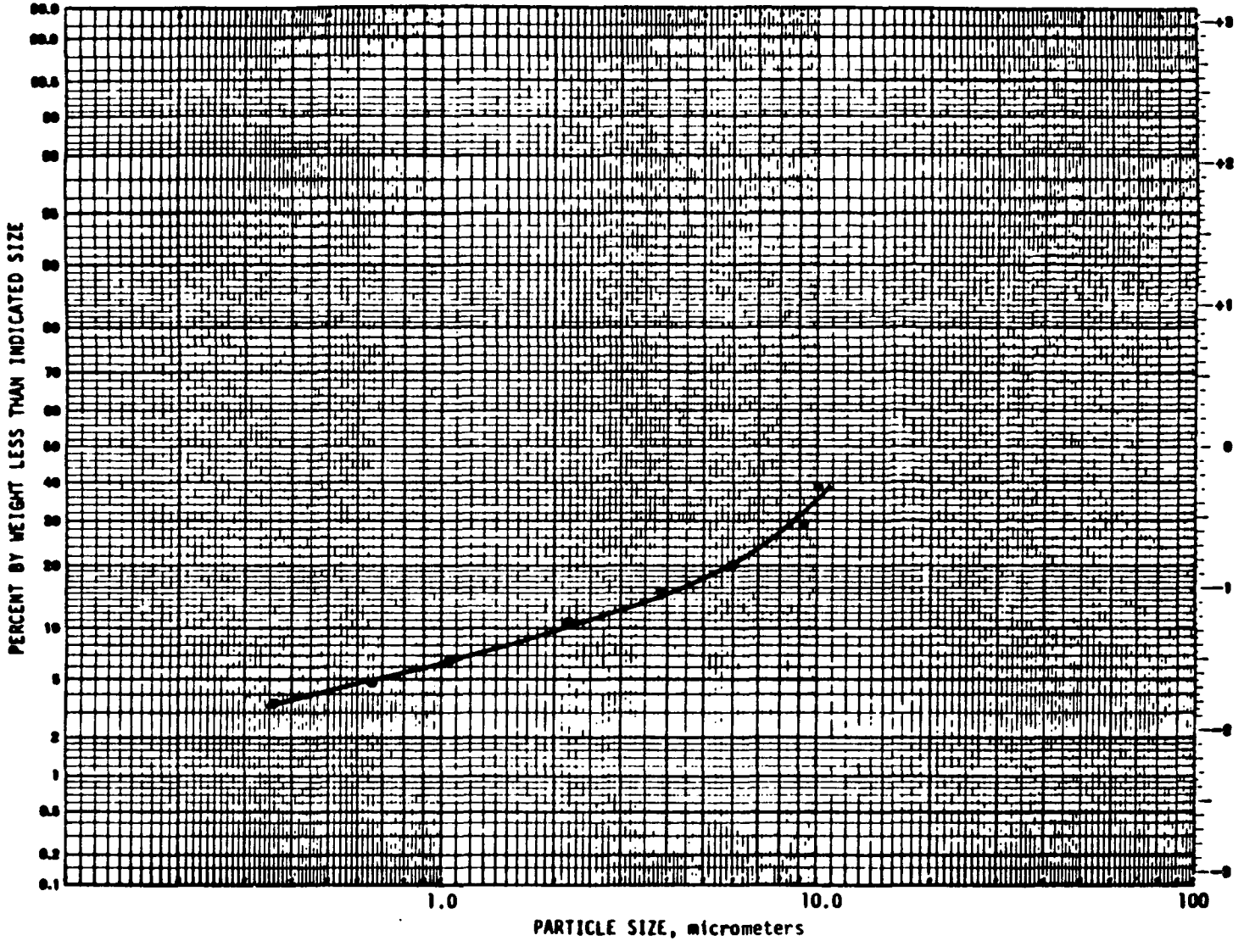


Figure 3-11. Particle size distribution for Run No. CCPS-1.

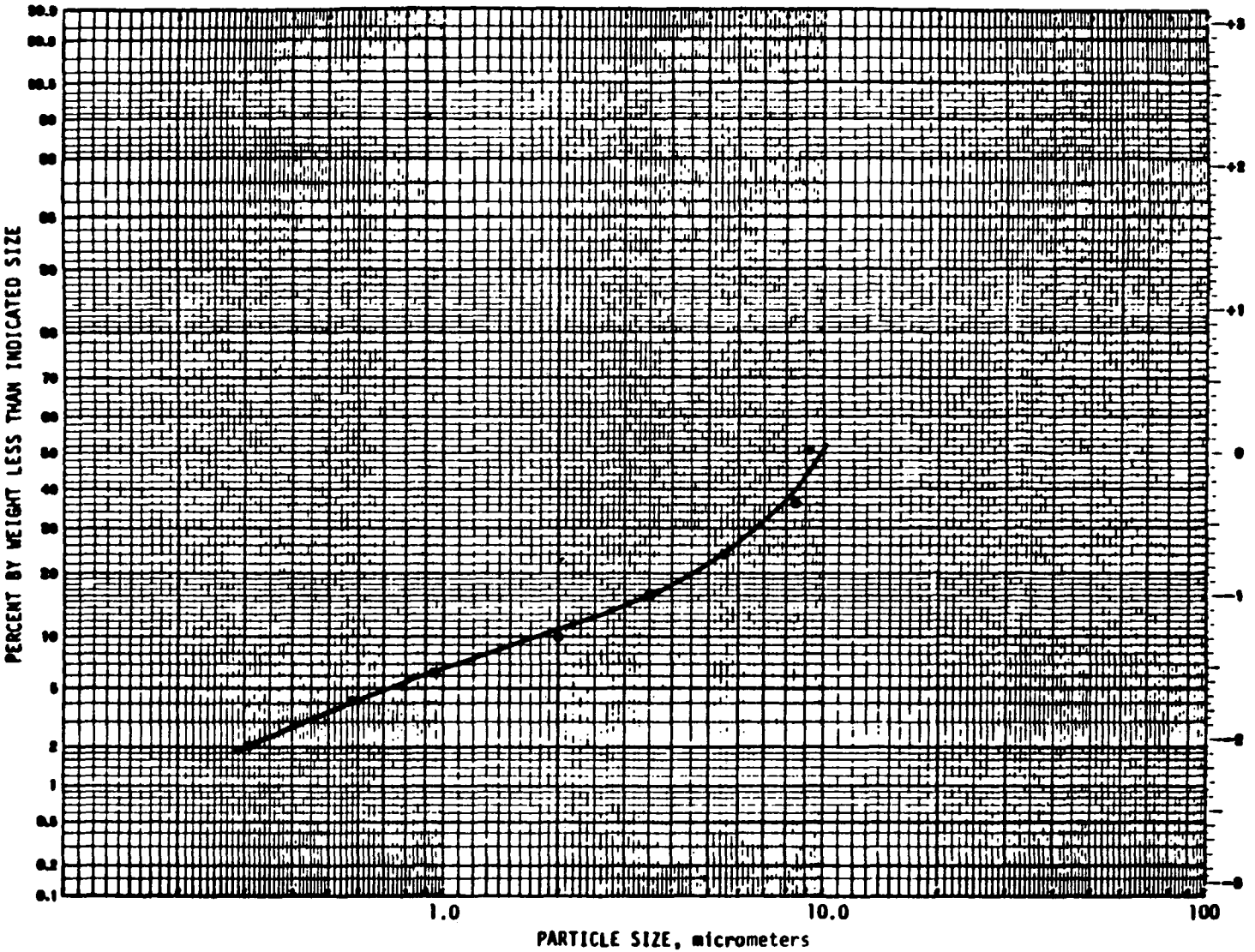


Figure 3-12. Particle size distribution for Run No. CCPS-4.

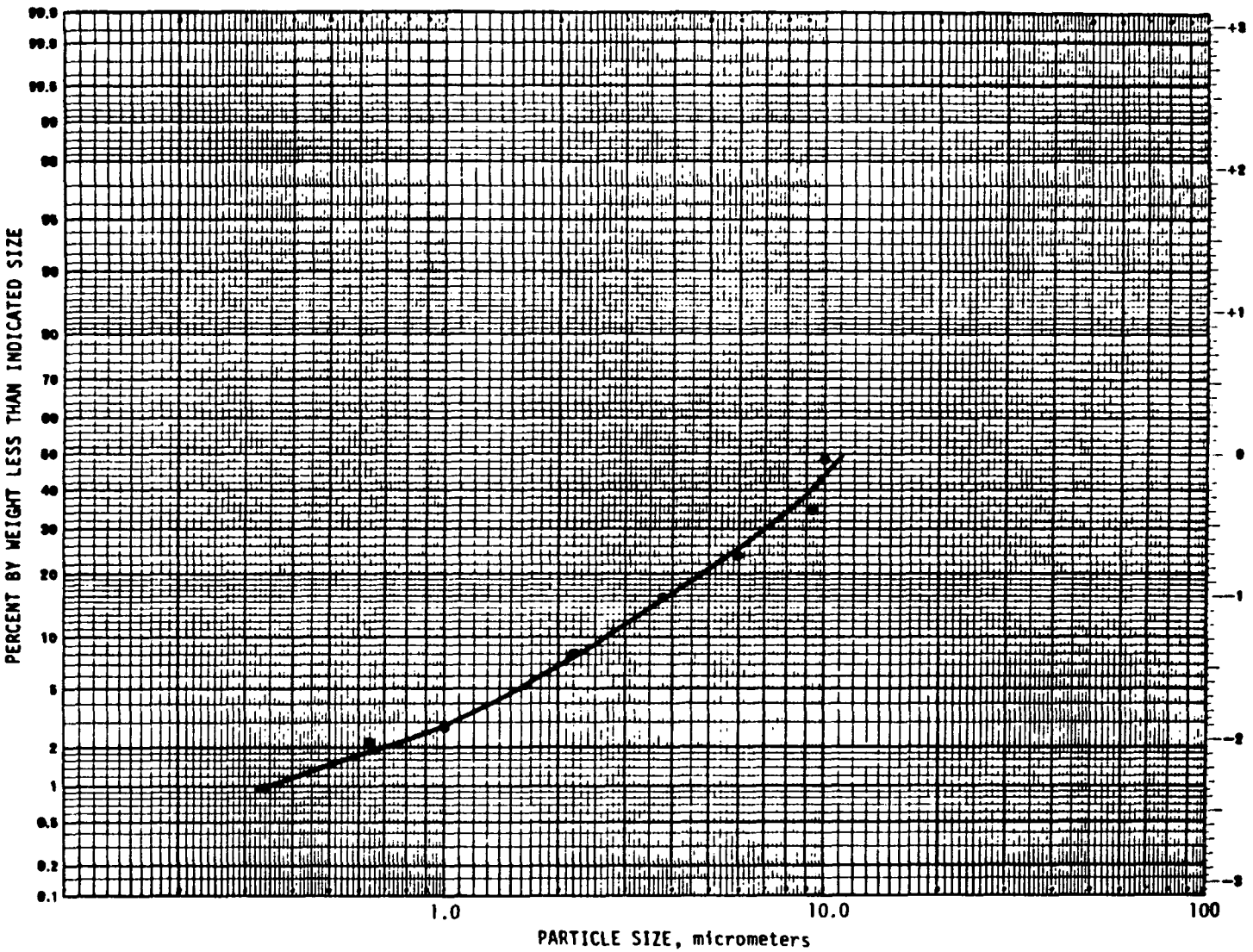


Figure 3-13. Particle size distribution for Run No. CCPS-5.

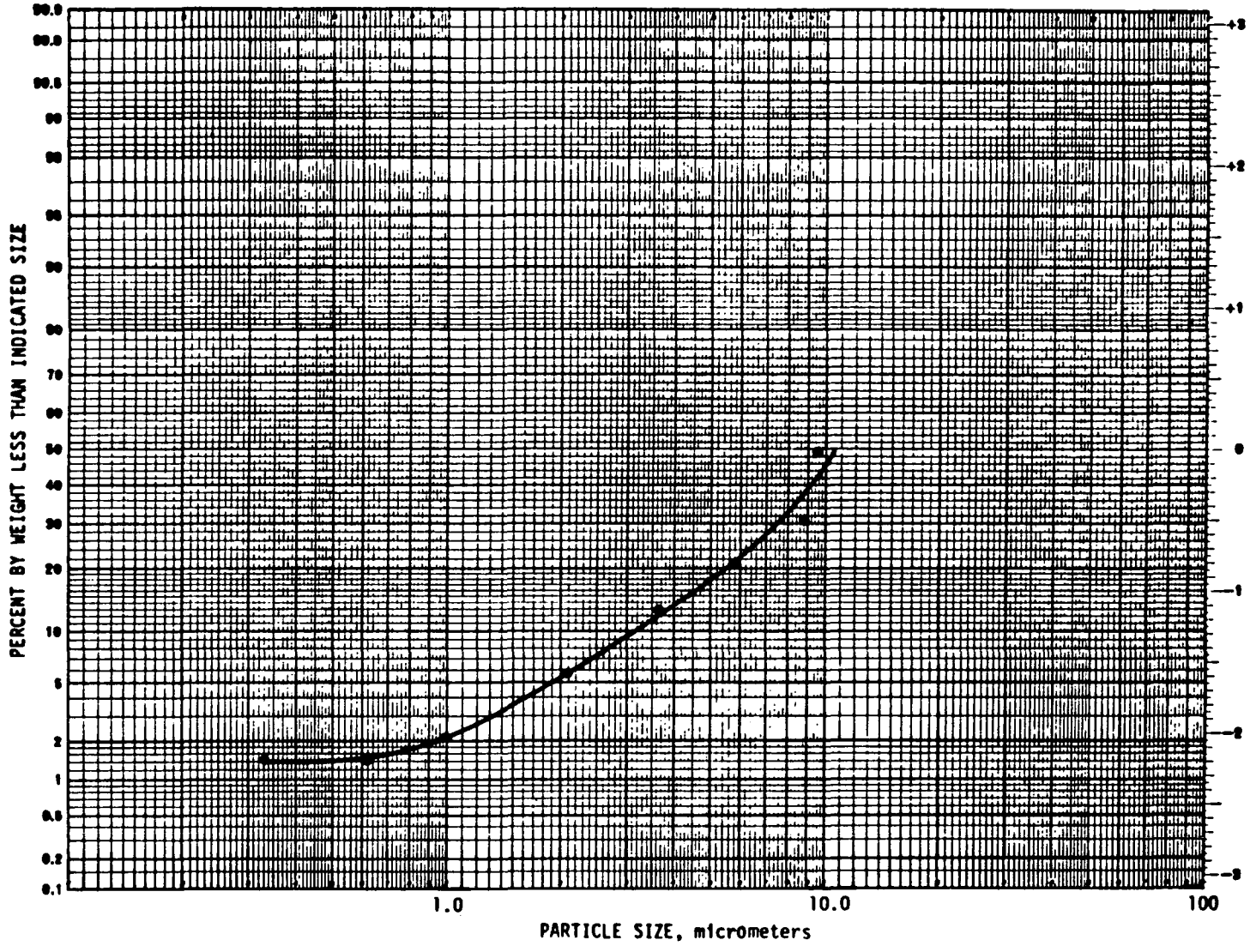


Figure 3-14. Particle size distribution for Run No. CCPS-7.

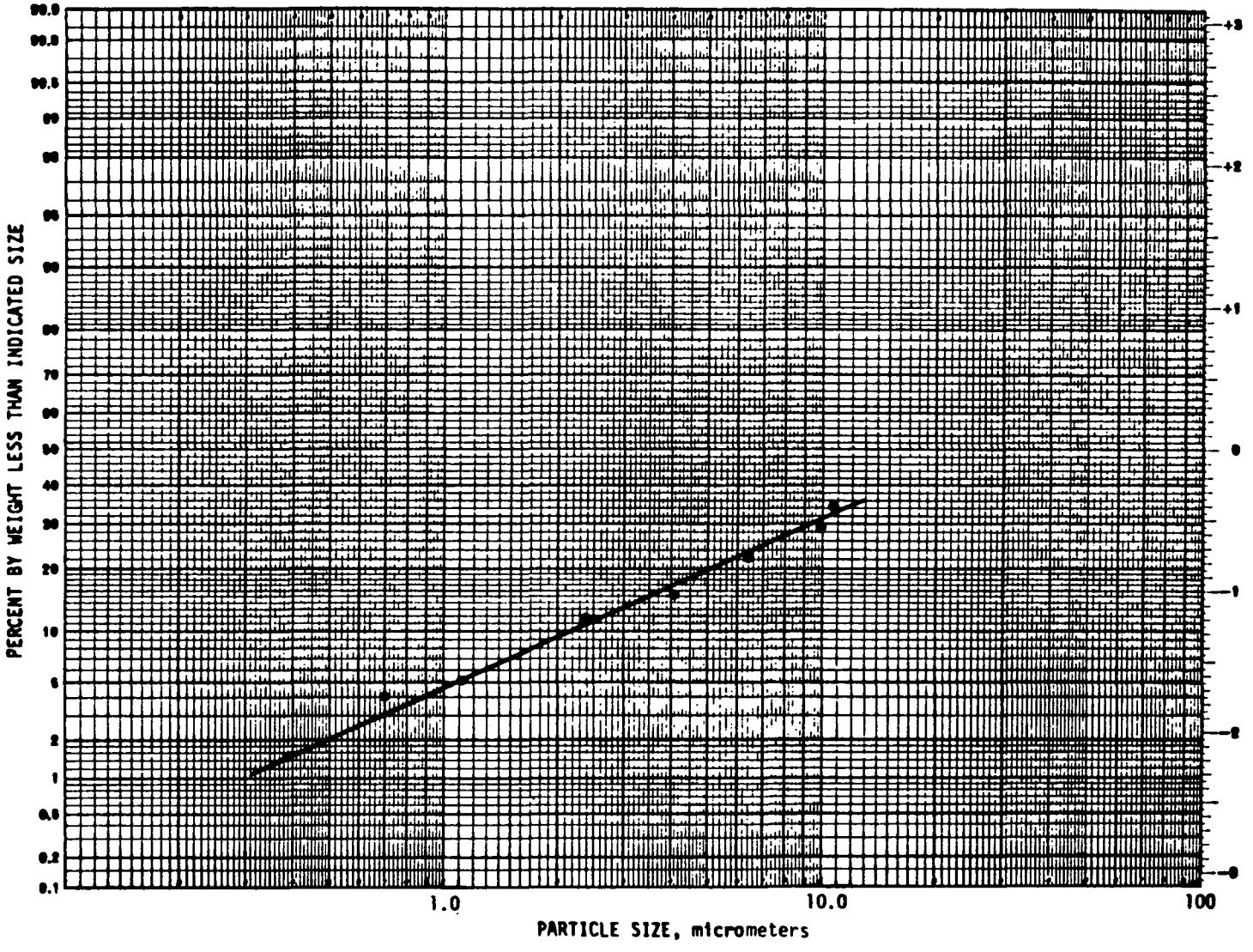


Figure 3-15. Particle size distribution for Run No. CCPS-8.

sampling runs. All particle size results are based on aerodynamics diameters and unit density (1 g/cc).

The average particle size distribution for this source shows that the particulate emissions are fairly evenly distributed by size and that about 44 percent of the particles are less than 10 μm in diameter. The individual particle size distribution curves compared closely, and the maximum deviation between the five runs at two separate cutpoints were 4 percent at 6 μm and 4.5 percent at 1 μm. This indicates that the size of the particulate emissions were fairly consistent during the testing period.

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.

3.3 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, final product crushing and screening, and kiln seals (charge and product). Table 3-10 summarizes the results of the fugitive emission survey.

3.4 PROCESS SAMPLES

Representative samples of the kiln feed material (slate) and coal used to fire the kiln were collected during each particulate

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

TABLE 3-9. SUMMARY OF VISIBLE EMISSIONS DATA FOR TESTS 1 AND 2
CLINKER COOLER OUTLET

Test 1 (2/23/82)				Test 2 (2/24/82)			
Set No.	Time	Average % opacity	Range	Set No.	Time	Average % opacity	Range
CC-1-1	1213-1218	8.1	0-15	CC-2-1	1405-1410	7.5	5-10
CC-1-2	1219-1224	11.7	10-20	CC-2-2	1411-1416	7.5	5-15
CC-1-3	1225-1230	8.5	5-10	CC-2-3	1417-1422	9.8	5-15
CC-1-4	1231-1236	8.5	5-15	CC-2-4	1423-1428	10.4	5-15
CC-1-5	1237-1242	7.5	5-10	CC-2-5	1429-1434	8.1	5-15
CC-1-6	1243-1248	8.1	5-15	CC-2-6	1435-1440	7.3	5-10
CC-1-7	1249-1254	8.1	5-15	CC-2-7	1441-1446	6.0	5-10
CC-1-8	1255-1300	7.7	5-10	CC-2-8	1447-1452	6.5	5-10
CC-1-9	1301-1306	7.1	5-10	CC-2-9	1453-1458	6.5	5-10
CC-1-10	1307-1312	9.8	5-15	CC-2-10	1459-1504	7.3	5-10
CC-1-11	1315-1320	8.1	5-15	CC-2-11	1522-1527	6.9	5-10
CC-1-12	1321-1326	10.0	5-15	CC-2-12	1528-1533	5.8	5-10
CC-1-13	1327-1332	10.6	5-15	CC-2-13	1534-1539	7.3	5-10
CC-1-14	1333-1338	16.7	10-25	CC-2-14	1540-1545	6.3	5-10
CC-1-15	1339-1344	11.7	5-20	CC-2-15	1546-1551	6.0	5-10
CC-1-16	1345-1350	10.0	5-15	CC-2-16	1552-1557	7.5	5-10
CC-1-17	1351-1356	6.7	5-15	CC-2-17	1558-1603	5.8	5-10
CC-1-18	1357-1402	6.9	5-10	CC-2-18	1604-1609	6.5	5-10
CC-1-19	1403-1408	8.5	5-15	CC-2-19	1610-1615	6.3	5-10
CC-1-20	1409-1414	7.3	5-10	CC-2-20	1616-1621	6.0	5-10
CC-1-21	1453-1458	10.2	5-15	CC-2-21	1622-1627	5.6	5-10
CC-1-22	1459-1504	8.3	5-15	CC-2-22[a]	1628-1632	5.0	5
CC-1-23	1505-1510	8.3	5-15				
CC-1-24	1511-1516	8.1	5-15				
CC-1-25	1517-1522	8.8	5-15				
CC-1-26	1523-1528	7.3	5-10				
CC-1-27	1529-1534	8.5	5-10				
CC-1-28	1535-1540	8.1	5-10				
CC-1-29	1541-1546	7.5	5-10				
CC-1-30	1547-1552	7.5	5-10				

[a]Only 5 minutes of readings.

TABLE 3-9 (continued)

Test 3 (2/25/82)				Test 4 (2/25/82)			
Set No.	Time	Average % opacity	Range	Set No.	Time	Average % opacity	Range
CC-3-1	0900-0905	3.8	0-5	CC-4-1	1250-1255	3.3	0-5
CC-3-2	0906-0911	3.8	0-5	CC-4-2	1256-1301	3.3	0-10
CC-3-3	0912-0917	1.9	0-5	CC-4-3	1302-1307	4.0	0-10
CC-3-4	0918-0923	5.4	0-10	CC-4-4	1308-1313	4.8	0-10
CC-3-5	0924-0929	5.6	0-10	CC-4-5	1314-1319	3.1	0-10
CC-3-6	0930-0935	4.6	0-10	CC-4-6	1320-1325	5.0	0-10
CC-3-7	0936-0941	3.5	0-5	CC-4-7	1326-1331	4.8	0-10
CC-3-8	0942-0947	4.4	0-5	CC-4-8	1332-1337	4.2	0-10
CC-3-9	0948-0953	5.0	0-10	CC-4-9	1338-1343	4.6	0-10
CC-3-10	0954-0959	4.6	0-10	CC-4-10	1344-1349	3.3	0-10
CC-3-11	1008-1013	2.1	0-5	CC-4-11	1358-1403	6.0	0-10
CC-3-12	1014-1019	5.6	0-10	CC-4-12	1404-1409	3.8	0-10
CC-3-13	1020-1025	7.7	5-10	CC-4-13	1410-1415	8.8	0-15
CC-3-14	1026-1031	4.6	0-10	CC-4-14	1416-1421	11.9	5-20
CC-3-15	1032-1037	5.2	0-10	CC-4-15	1422-1427	10.4	5-15
CC-3-16	1038-1043	4.2	0-10	CC-4-16	1428-1433	7.5	0-10
CC-3-17	1044-1049	3.8	0-10	CC-4-17	1434-1439	9.8	5-15
CC-3-18	1050-1055	4.8	0-10	CC-4-18	1440-1445	7.1	5-15
CC-3-19	1056-1101	6.7	5-10	CC-4-19	1446-1451	6.7	5-10
CC-3-20	1102-1107	6.3	5-10	CC-4-20	1452-1457	6.5	0-10

TABLE 3-10. SUMMARY OF VISIBLE EMISSIONS DATA FOR TEST 1 (2/23/82)
FUGITIVE SOURCES

Source	Set No.	Time	Average % opacity	Range
Raw material crusher	RC-1-1	1350-1355	15.0	10-20
	RC-1-2	1356-1401	17.1	15-20
	RC-1-3	1401-1407	21.5	15-30
Final product screen	FP-1-1	1219-1224	0.8	0-5
	FP-1-2	1453-1458	0	0
	FP-1-3	1459-1504	0	0
Finish material crusher	FC-1-1	1216-1221	0	0
	FC-1-2	1454-1459	0	0
	FC-1-3	1500-1505	0	0
	FC-1-4	1506-1511	0	0
Kiln inlet	KI-1-1	1234-1239	7.9	5-20
	KI-1-2	1240-1245	6.3	5-10
	KI-1-3	1246-1251	6.7	5-10
	KI-1-4	1535-1540	6.3	5-10
South kiln seal	KSS-1-1	1256-1301	0	0
	KSS-1-2	1302-1307	0	0
	KSS-1-3	1308-1313	0	0
North kiln seal	KSN-1-1	1320-1325	0	0
	KSN-1-2	1326-1331	0	0
	KSN-1-3	1332-1337	0	0

(continued)

TABLE 3-10 (continued)

SUMMARY OF VISIBLE EMISSIONS DATA FOR TEST 2 (2/24/82)
FUGITIVE SOURCES

Source	Set No.	Time	Average % opacity	Range
Raw material crusher	RC-2-1 RC-2-2	1511-1516 1517-1522	29.4 30.4	25-35 25-35
Final product screen	Process down			
Finish material crusher	Process down			
Kiln inlet	KI-2-1 KI-2-2 KI-2-3	1410-1415 1416-1421 1540-1545	9.0 9.5 8.1	5-10 5-10 5-10
South kiln seal	KSS-2-1 KSS-2-2 KSS-2-3	1429-1434 1435-1440 1552-1557	0 0 0	0 0 0
North kiln seal	KSN-2-1 KSN-2-2 KSN-2-3	1449-1454 1455-1500 1605-1610	0 0 0	0 0 0

(continued)

TABLE 3-10 (continued)

SUMMARY OF VISIBLE EMISSIONS DATA FOR TEST 3 (2/25/82)
FUGITIVE SOURCES

Source	Set No.	Time	Average % opacity	Range
Raw material crusher	RC-3-1	0942-0947	20.4	20-25
	RC-3-2	0948-0953	20.4	20-25
Final product screen	FP-3-1	0925-0930	5	5
	FP-3-2	0931-0936	5	5
Finish material crusher	FC-3-1	0908-0913	0	0
	FC-3-2	0914-0919	0	0
	FC-3-3	1112-1117	0	0
Kiln inlet	KI-3-1	1053-1058	10	10
	KI-3-2	1059-1104	10	10
South kiln seal	KSS-3-1	1026-1031	0	0
	KSS-3-2	1032-1037	0	0
North kiln seal	KSN-3-1	1003-1008	0	0
	KSN-3-2	1009-1014	0	0

(continued)

TABLE 3-10 (continued)

SUMMARY OF VISIBLE EMISSIONS DATA FOR TEST 4 (2/25/82)
FUGITIVE SOURCES

Source	Set No.	Time	Average % opacity	Range
Raw material crusher	RC-4-1	1432-1437	18.1	10-35
Final product screen	FP-4-1	1322-1327	5.2	5-10
	FP-4-2	1328-1333	10.6	5-15
Finish material crusher	FC-4-1	1306-1311	0	0
	FC-4-2	1312-1317	0	0
Kiln inlet	KI-4-1	1249-1254	8.1	5-10
	KI-4-2	1255-1300	8.8	5-10
South kiln seal	KSS-4-1	1344-1349	0	0
	KSS-4-2	1350-1355	0	0
North kiln seal	KSN-4-1	1408-1413	0	0
	KSN-4-2	1414-1419	0	0

test for determination of sulfur content, moisture, density, and ash content (coal only). Samples of scrubber water influent and effluent and final aggregate product were also collected during each particulate test for sulfur analysis. In addition, the scrubber water samples and captured particulate (clinker cooler) were analyzed for trace metal content. The pH of the scrubber water and the density of the final aggregate product were also determined. Table 3-11 summarizes the analytical data.

The analytical data on the raw slate showed an average sulfur content of 0.69 percent, an average moisture content of 1.04 percent, and an average density of 2.73 g/cm^3. The sulfur content of the final product averaged 0.37 percent with an average density of 2.61 g/cm^3. The coal data showed on average sulfur content of 1.47 percent and an average ash content of 14.26 percent. Moisture content averaged 5.2 percent. The average sulfate concentration of the scrubber influent and effluent was 27 and 990 mg/liter, respectively. Composite samples of scrubber influent showed a pH of 7.0, and the effluent showed a pH of 5.69. Table 3-12 summarizes trace metal data from the scrubber effluent and captured particulate samples from the clinker cooler settling chamber.

TABLE 3-11. SUMMARY OF PROCESS SAMPLE ANALYSIS

Test No.	Date (1982)	Sample type	Density, g/cm^3	Moisture, % as received	Ash, % dry basis	Sulfur, % dry basis, except where noted	pH
1	2/23	Coal	-	4.82	13.28	1.33[a]	-
		Slate (raw)	2.76	0.75	-	0.72[b]	-
		Final product	2.62	-	-	0.41[b]	-
		Scrubber influent	-	-	-	18[c]	7.11
		Scrubber effluent	-	-	-	963[c]	5.82
2	2/24	Coal	-	5.28	13.46	1.68[a]	-
		Slate (raw)	2.77	1.57	-	0.69[b]	-
		Final product	2.37	-	-	0.33[b]	-
		Scrubber influent	-	-	-	18[c]	6.93
		Scrubber effluent	-	-	-	956[c]	5.58
3	2/25	Coal	-	5.50	16.03	1.40[a]	-
		Slate (raw)	2.67	0.79	-	0.66[b]	-
		Final product	2.83	-	-	0.36[b]	-
		Scrubber influent	-	-	-	45[c]	6.95
		Scrubber effluent	-	-	-	1050[c]	5.66

[a]ASTM D3177.

[b]ASTM D2234, as received.

[c]Total sulfates in mg/liter.

TABLE 3-12. SUMMARY OF TRACE ELEMENT DATA

Elements[a]	Captured particulate[b]			Scrubber effluent		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Al	8.1	8.3	7.9	9.2	13	9.6
Sb	<7.1	<7.5	<7.5	<0.032	<0.032	<0.032
As	26	25	24	<0.057	<0.057	<0.057
Ba	680	660	630	0.11	0.13	0.17
Be	<0.13	<0.13	<0.13	<0.0005	<0.0005	<0.0005
Bi	<13	<13	<13	<0.05	<0.05	<0.05
B	<2.2	<2.2	<2.2	<0.009	<0.009	<0.009
Cd	3.7	3.7	3.5	<0.002	<0.002	<0.002
Ca	5.7	5.3	7.4	390	370	420
Cr	78	79	75	<0.001	<0.001	<0.002
Co	20	19	19	0.02	0.02	0.02
Cu	36	34	34	<0.001	<0.001	<0.001
Au	<7.5	<7.5	<7.5	<0.03	<0.03	<0.03
In	<13	<13	<13	<0.05	<0.05	<0.05
Fe	4.6	4.5	4.4	<0.008	<0.54	<0.019
Pb	100	120	100	<0.084	<0.084	<0.084
Li	64	62	59	0.18	0.20	0.22
Mg	1.8	1.8	1.7	32	32	31
Mn	520	500	620	3.0	3.0	3.0
Hg	<8	<8	<8	<0.032	<0.032	<0.032
Mo	<0.49	<0.50	<0.50	<0.002	<0.002	<0.002
Ni	40	42	41	0.027	0.023	0.017
P	270	270	270	<0.18	<0.18	<0.18
Pt	<7.5	<7.5	<7.5	<0.03	<0.03	<0.03
K	3.0	3.0	2.9	14	15	16
Se	<20	<20	<20	<0.084	<0.084	<0.084
Si	26	28	28	13	14	12
Ag	<0.49	<0.50	<0.49	<0.002	<0.002	<0.002
Na	1.0	9700	9100	3.9	4.1	4.4
Sr	300	280	380	1.3	1.3	1.5
S	4100	3400	6300	270	250	280
Te	<25	<25	<25	<0.10	<0.10	<0.10
Tl	<23	<23	<23	<0.09	<0.09	<0.09
Sm	290	300	280	<0.12	<0.12	<0.12
Ti	4600	4500	4300	<0.005	<0.005	<0.005
U	<15	<15	<15	<0.06	<0.06	<0.06
V	160	160	160	<0.003	<0.003	<0.003
W	<7.5	<7.5	<7.5	<0.03	<0.03	<0.03
Y	21	21	22	<0.002	<0.002	<0.003
Zn	150	140	130	0.076	0.22	0.075

[a]Elements: Expressed as ppm (μg/g or μg/ml) except where noted.

[b]From clinker cooler settling chamber.

SECTION 4

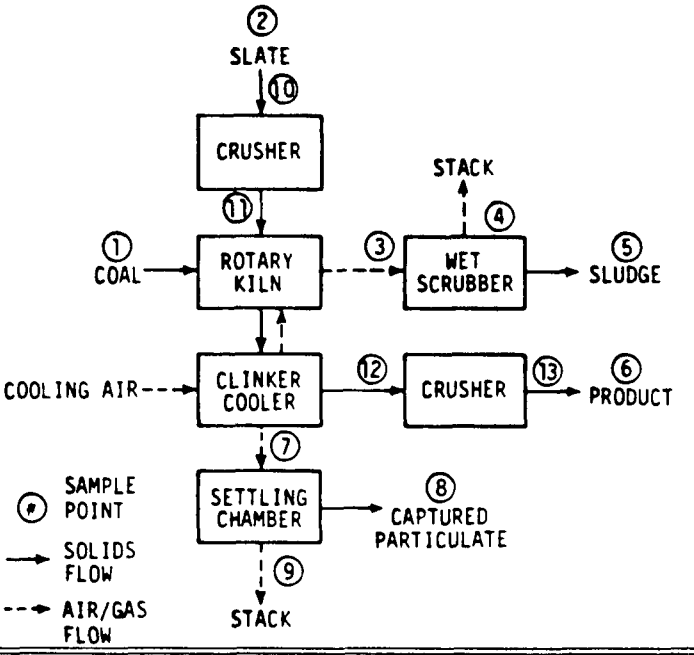
SAMPLING LOCATIONS AND TEST METHODS

Figure 4-1 presents a simplified process flow sheet depicting the sampling 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 sampling ports, 90 degrees off-center, were located 2.6 duct diameters (dd) downstream and 0.6 dd upstream from the nearest flow disturbances in the 1.4-m (4.6-ft) I.D. round duct. Due to extreme heat and inaccessibility, only one of these ports was used. Twenty-four traverse points (each point was sampled twice) 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. Constant-rate sampling techniques were used to sample sulfur dioxide emissions by placing the probe tip near the center of the duct.

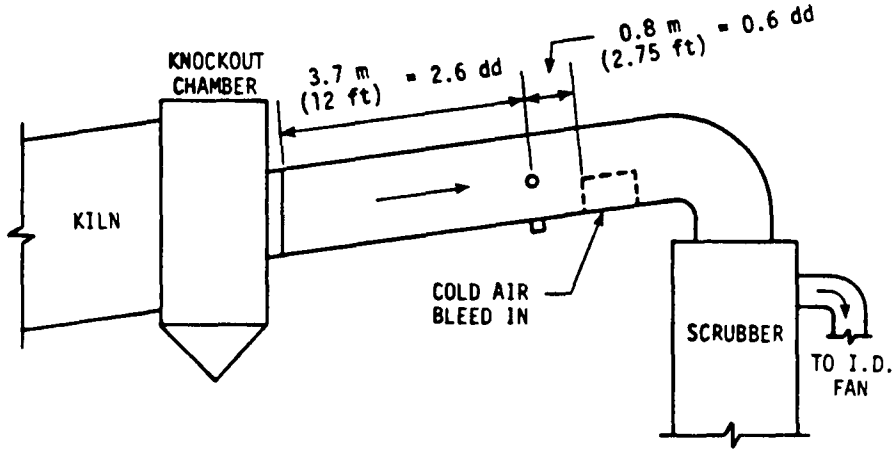


Sample type	Sample point	No. of samples	Method
Particulate	4,9	3	EPA 5[a]
Particulate	3	3	EPA 17[a]
SO_2	3,4	3	EPA 6
Particle size	3,4,9	3	Impactor, Bacho (ASTM[b] 28-1965)
NO_x	4	12 grab	EPA 7
VOC	4	3	EPA 25
Fugitive dust	Kiln seals, 10, 11,12,13	3	EPA 9
Stack opacity	4,9	3	EPA 9
Sulfur, ash, moisture 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
Trace metals	5,8	Composite	Mass Spectrometry, I-Cap, Atomic Adsorption

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

[b]American Society for Testing Materials.

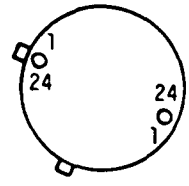
Figure 4-1. Sampling plan and process flow sheet for Galite Corporation.



TRAVERSE POINT NO.	DISTANCE* cm	in.
1	11.4	4.5
2	13.3	5.3
3	16.5	6.5
4	19.8	7.8
5	23.9	9.4
6	27.4	10.8
7	31.5	12.4
8	36.3	14.3
9	41.4	16.3
10	47.2	18.6
11	54.4	21.4
12	65.0	25.6
13	93.5	36.8
14	104.4	41.1
15	111.3	43.8
16	117.6	46.3
17	122.7	48.3
18	127.3	50.1
19	131.1	51.6
20	134.9	53.1
21	138.7	54.6
22	142.2	56.0
23	145.6	57.3
24	147.3	58.0

*INCLUDES NIPPLE LENGTH.

CROSS-SECTION



1.4 m (4.6 ft) I.D.
8.9 cm (3.5 in.) LENGTH NIPPLE

NOTE: BOTTOM PORT NOT USED DUE TO EXTREME HEAT AND INACCESSIBILITY.

Figure 4-2. Scrubber inlet sampling location.

Particle size analyses were run on the samples obtained in the thimble during the particulate tests.

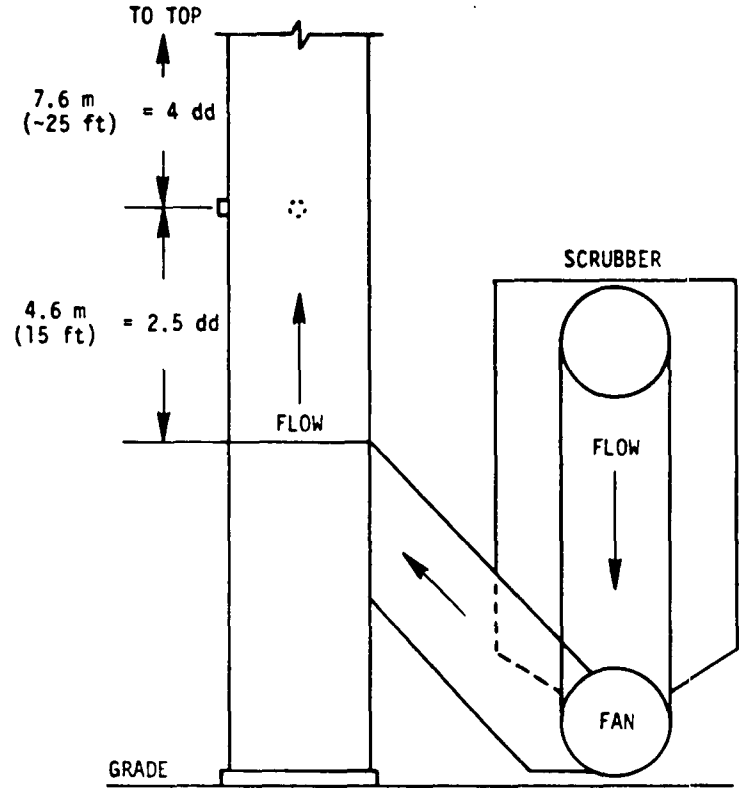
4.2 SCRUBBER OUTLET

Particulates, sulfur dioxide, nitrogen oxide, particle size distribution, and VOC content were measured at the wet scrubber outlet, as shown in Figure 4-3. Two sampling ports, 90 degrees off-center, were located 2.5 dd downstream and 4.0 dd upstream from the nearest flow disturbances in the 1.86-m (6.1-ft) I.D. round stack. Forty-eight traverse points, 24 per port, were used to traverse the cross-sectional area of the stack for the particulate test runs. Each point was sampled for 2.5 minutes, which yielded a total test time of 120 minutes. Sulfur dioxide, nitrogen oxide, and VOC sampling were conducted by use of constant-rate sampling techniques that placed the respective probe tips near the center of the stack. An Andersen in-stack impactor was used to collect particle size samples at single sampling points were representative of the average velocity of the stack.

4.3 CLINKER COOLER EXHAUST

Particulate concentrations and particle size distribution were measured at the clinker cooler exit stack, as shown in Figure 4-4. Two sampling ports, 90 degrees off-center, were located 3.0 dd downstream and 2.4 dd upstream from the nearest flow disturbances in the 1.5-m (5.0-ft) I.D. round stack. Forty-eight traverse points, 24 per port, were used to traverse the cross-sectional area of the stack for the particu-

TRAVERSE POINT NO.	DISTANCE cm	DISTANCE in.
1	12.7	5.0
2	16.0	6.3
3	20.3	8.0
4	24.9	9.8
5	29.7	11.7
6	34.8	13.7
7	40.1	15.8
8	48.8	18.2
9	52.8	20.8
10	60.7	23.9
11	70.1	27.6
12	84.1	33.1
13	121.9	48.0
14	135.9	53.5
15	145.3	57.2
16	153.1	60.3
17	159.8	62.9
18	166.1	65.4
19	171.5	67.5
20	176.5	69.5
21	181.4	71.4
22	185.7	73.1
23	190.0	74.8
24	193.8	76.3



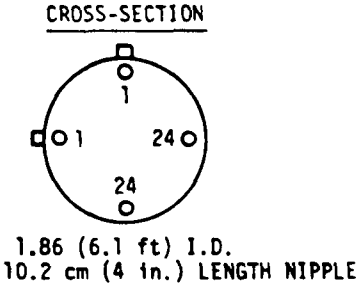
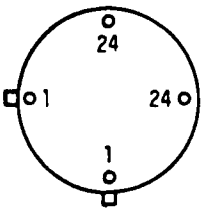


Figure 4-3. Scrubber outlet sampling location.

CROSS-SECTION



1.5 m (5 ft) I.D.
5.1 cm (2 in.)
LENGTH NIPPLE

TRAVERSE POINT NO.	DISTANCE* cm	in.
1	6.35	2.5
2	9.9	3.9
3	13.5	5.3
4	17.1	6.8
5	21.1	8.3
6	25.1	9.9
7	29.7	11.7
8	34.5	13.6
9	40.1	15.8
10	46.5	18.3
11	54.1	21.3
12	65.8	25.9
13	96.8	38.1
14	108.2	42.6
15	116.1	45.7
16	122.4	48.2
17	128.0	50.4
18	132.8	52.3
19	137.4	54.1
20	141.5	55.7
21	145.4	57.3
22	149.1	58.7
23	152.7	60.1
24	155.0	61.0

*INCLUDES NIPPLE LENGTH.

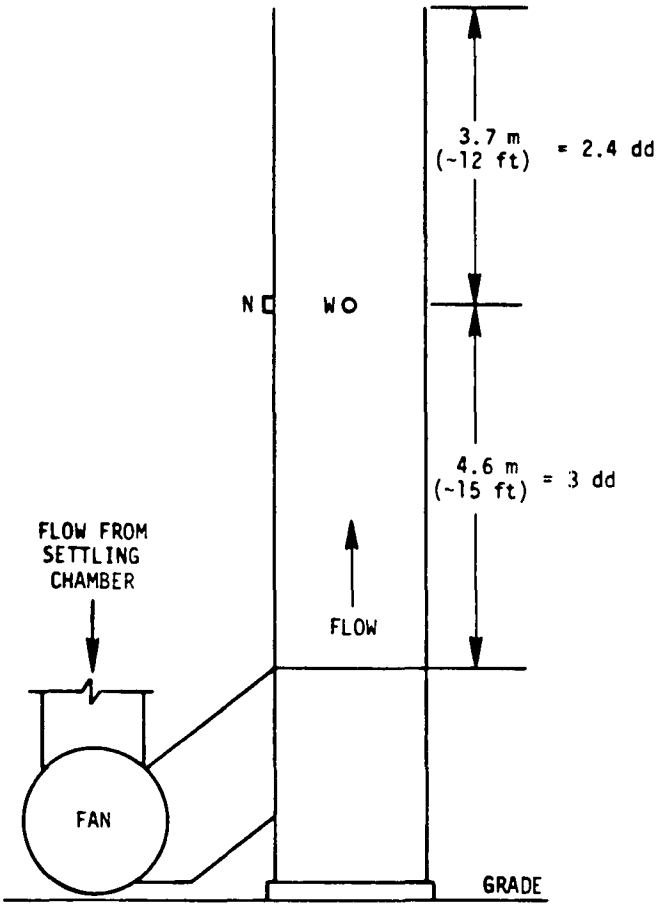


Figure 4-4. Clinker cooler sampling location.

late test runs. Each point was sampled for 2.5 minutes, which yielded a total test time of 120 minutes. An Andersen in-stack impactor was used to collect particle size samples at single sampling points that were representative of the average stack velocity. The testing 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 digital readout.

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 test and during each set of sulfur dioxide and nitrogen oxide tests. 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-

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

sectional area of the stack and regulating the sampling flow rate relative to the flue gas flow rate as measured by the pitot tube attached to the sampling probe. In each test, a sampling train was used consisting of a heated, glass-lined probe, a heated 87-mm (3-in.) diameter glass fiber filter (Reeve Angel 934 AH), and a series of Greenburg-Smith impingers. A heated quartz probe was used on the scrubber inlet sampling train due to the high flue gas temperatures at this location. In addition, an alundum thimble and cyclone were placed prior to the heated filter because of heavy particulate loading. The nozzle, probe, and filter holder were rinsed with acetone at the end of each test. The acetone rinse and the particulate caught on the filter media were dried at room temperature (105°C for scrubber outlet samples), 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

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

between the first and second impingers. A heated quartz glass probe was used on the scrubber inlet sampling train, and an alundum thimble and cyclone-filter assembly were placed prior to the impingers due to the heavy particulate loading at this location. Each test consisted of two 20-minute runs. Each sampling train was purged with ambient air for 15 minutes after the completion of each test. The contents of the second and third impingers (3% hydrogen peroxide) were measured and analyzed on site for sulfates by use of the barium-thorin titration method.

4.8 NITROGEN OXIDE

Sampling and analytical procedures were those described in EPA Method 7 of the Federal Register.* Three tests, each consisting of four grab samples taken at approximately 15-minute intervals, were conducted at 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 by use of 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 impactor were 64-mm glass fiber filters.** A constant sampling rate was maintained through-

*40 CFR 60, Appendix A, Reference Method 7, July 1, 1981.
**Whatman Reeve Angel 934 AH.

out 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).

Eight impactor runs were made at each sampling site. Sampling point locations for each stack were as shown in 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," which was recently developed for EPA by the Southern Research Institute.[1] Particle size analyses were conducted on the scrubber inlet particulate samples by use of a Bahco centrifugal classifier that separated the particulate into eight different size ranges.

4.10 HYDROCARBON EMISSIONS

EPA Method 25* was used in the sampling and analysis of hydrocarbon emissions in order to determine total gaseous non-methane organics. Gas from the stack was drawn through a dry-ice condensate trap in order to collect the sample in an evacuated sampling tank. Sampling was conducted at a single point in the stack and a constant sampling rate was maintained between 80 and 90 (ml/min). Both the sampling tank and condensate trap were analyzed to determine the nonmethane organic content of the exhaust gas.

The tank fraction was analyzed by injecting the sample into an analyzer. The analyzer separated the nonmethane organics from

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

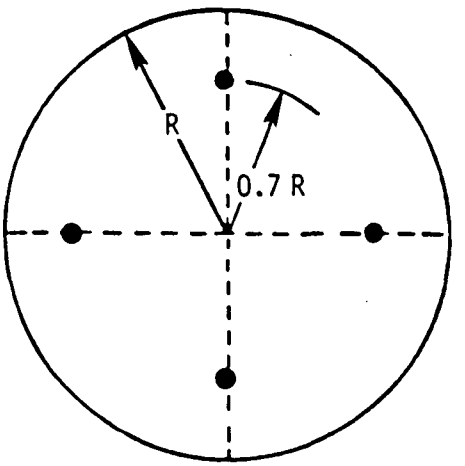


Figure 4-5. Particle size sampling points for circular stack.

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).

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 slate fed to the kiln were collected at approximately 30-minute intervals during particulate sampling. Coal samples were collected from the coal bunker before they entered the pulverizer. Slate samples were collected from the kiln feed conveyor belt. Coal samples were analyzed for sulfur content, moisture content, and percent ash. Slate samples were analyzed for sulfur content, density, and moisture content.

Samples of the influent and effluent from the kiln wet scrubber and clinker cooler settling chamber were collected and analyzed for sulfate content and pH (scrubber water only).

An analytical screening for trace elements was performed on the scrubber effluent and captured particulate samples.

4.12 VISIBLE AND FUGITIVE EMISSIONS

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

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 ensure 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 Emission Measurement Branch: the EPA Quality Assurance Handbook Volume III, EPA-600/4-77-027; 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 ensure that the testing and analytical procedures 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 sampling 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 the sampling equipment used for particulate, SO_2 and NO_x testing as well as 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 for use in 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.

Audit solutions prepared by the EPA were used to check the analytical procedures and reagents for SO_2 and NO_x sampling analysis. Tables 5-3 and 5-4 present the results of these analytical audits. The audit tests show that the analytical techniques were good.

TABLE 5-1. FIELD EQUIPMENT CALIBRATION - SCRUBBER INLET

Equipment	I.D. No.	Calibrated against	Allowable error	Actual error	Within allowable limits	Comments
Meter box	FB-4	Wet test meter	Y ±0.02 Y ΔH @ ±0.15 (Y ±0.05 Y post-test)	-0.036	✓	Used for particulate and SO_2 tests
Pitot tube	180	Standard pitot tube	Cp ±0.01	0.0	✓	
Digital indicator	207	Millivolt signals	0.5%	0.35%	✓	
Thermocouple and stack thermometer	121	ASTM-2F or 3F	1.5% (±2% saturated)	1.21%	✓	
Orsat analyzer	232	Standard gas	±0.5%	0.1%	✓	
Impinger thermometer	285	ASTM-2F or 3F	±2°F	1.0°F	✓	
Trip balance	270	Type S weights	±0.5 g	0.0 g	✓	
Barometer	225	NBS traceable barometer	±0.10 in.Hg (0.20 post-test)	0.0 in.Hg	✓	
Dry gas thermometer	Inlet Outlet	ASTM-2F or 3F	±5°F	3.0°F 1.3°F	✓ ✓	
Probe nozzle	4-106 3-118	Caliper	Dn ±0.004 in.	0.001 in. 0.001 in.	✓ ✓	Particulate only

(continued)

TABLE 5-1 (continued)
SCRUBBER OUTLET

Equipment	I.D. No.	Calibrated against	Allowable error	Actual error	Within allowable limits	Comments
Meter box	FB-1 FB-2	Wet test meter	Y ±0.02 Y ΔH @ ±0.15 (Y ±0.05 $\bar{Y}$ post-test)	+0.006 -0.019	✓ ✓	Used for particulate and SO_2 tests
Pitot tube	014	Standard pitot tube	Cp ±0.01	0.0	✓	Used for particle size tests
Digital indicator	219	Millivolt signals	0.5%	0.14%	✓	
Thermocouple and stack thermometer	255	ASTM-2F or 3F	1.5% (±2% saturated)	0.18%	✓	
Orsat analyzer	232	Standard gas	±0.5%	0.1%	✓	
Impinger thermometer	104	ASTM-2F or 3F	±2°F	1.5°F	✓	
Trip balance	270	Type S weights	±0.5 g	0.0 g	✓	
Barometer	225	NBS traceable barometer	±0.10 in.Hg (0.20 post-test)	0.0 in.Hg	✓	
Dry gas thermometer	Inlet Outlet	ASTM-2F or 3F	±5°F	4.0°F 5.0°F	✓ ✓	
	Inlet Outlet	ASTM-2F or 3F	±5°F	3.1°F 4.0°F	✓ ✓	
Probe nozzle	4-110	Caliper	Dn ±0.004 in.	0.001 in.	✓	Particulate only

(continued)

TABLE 5-1 (continued)
CLINKER COOLER OUTLET

Equipment	I.D. No.	Calibrated against	Allowable error	Actual error	Within allowable limits	Comments
Meter box	FB-6 FB-3	Wet test meter	Y ±0.02 Y ΔH @ ±0.15 (Y ±0.05 $\overline{Y}$ post-test)	+0.008 -0.008	✓ ✓	Used for particulate tests
Pitot tube	032	Standard pitot tube	Cp ±0.01	0.0	✓	Used for particle size tests
Digital indicator	262	Millivolt signals	0.5%	0.35%	✓	
Thermocouple and stack thermometer	203	ASTM-2F or 3F	1.5% (±2% saturated)	0.61%	✓	
Orsat analyzer	232	Standard gas	±0.5%	0.1%	✓	
Impinger thermometer	112	ASTM-2F or 3F	±2°F	1.0°F	✓	
Trip balance	270	Type S weights	±0.5 g	0.0 g	✓	
Barometer	225	NBS traceable barometer	±0.10 in.Hg (0.20 post-test)	0.0 in.Hg	✓	
Dry gas thermometer	Inlet Outlet	ASTM-2F or 3F	±5°F	1.0°F 3.0°F	✓ ✓	
	Inlet Outlet	ASTM-2F or 3F	±5°F	3.0°F 2.7°F	✓ ✓	
Probe nozzle	4-110	Caliper	Dn ±0.004 in.	0.002 in.	✓	

AUDIT REPORT DRY GAS METER

DATE: 2/22/82 CLIENT: USEPA (Galite)

BAROMETRIC PRESSURE (P_{bar}): 29.40 in. Hg METER BOX NO. FB-4

ORIFICE NO. 13 PRETEST γ: 1.033

ORIFICE K FACTOR: 4.591×10^{-4} AUDITOR: DRO

Orifice manometer reading ΔH in H_2O	Dry gas meter reading V_i/V_f ft^3	Temperatures: Ambient T_{ai}/T_{af} °F	Temperatures: Dry gas meter, Inlet T_{ii}/T_{if} °F	Temperatures: Dry gas meter, Outlet T_{oi}/T_{of} °F	Duration of run θ min	
1.67	39,200	50	57	52	15 of 5	Vac
	49,600	52	59	53	15.142	17.2

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 %
10.400	51	55	10.521	10.877	1.034	0.10%

$V_{m_{std}}$	$V_{m_{act}}$
$\frac{(17.647)(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)}$	$\frac{(1203)(\theta)(K)(P_{bar})}{(T_a + 460)^{1/2}}$
10.521	10.877

Audit γ	γ deviation, %
$\frac{V_{m_{act}}}{V_{m_{std}}}$	$\frac{(\gamma \text{ audit} - \gamma \text{ pre-test})(100\%)}{(\gamma \text{ audit})}$
1.034	0.10%

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

Figure 5-1. Example audit report for scrubber inlet.

AUDIT REPORT DRY GAS METER

DATE: 2-22-90 CLIENT: EPA

BAROMETRIC PRESSURE (P_{bar}): 29.40 in. Hg METER BOX NO. [illegible]

ORIFICE NO. 7 PRETEST γ: .974

ORIFICE K FACTOR: 5.036×10^{-4} AUDITOR: Hershey

Orifice manometer reading ΔH in H_2O	Dry gas meter reading V_i/V_f ft^3	Temperatures: Ambient T_{ai}/T_{af} °F	Temperatures: Dry gas meter Inlet T_{ii}/T_{if} °F	Temperatures: Dry gas meter Outlet T_{oi}/T_{of} °F	Duration of run Ø min
2.1	398.000	~~50~~ 57 /	59 /	~~49~~ /	15.08
	410.100	56	60	50	

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 %
12.100	57	55	12.252	11.824	0.965	0.93

$V_{m_{std}}$	$V_{m_{act}}$
$\frac{(17.647)(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)}$	$\frac{(1203)(\frac{15.08}{Ø})(\frac{5.036 \times 10^{-4}}{K})(P_{bar})}{(T_a + 460)^{1/2}}$
$\frac{17.647 (12.100)(29.55)}{515} =$	$(5.6)^{1/2}$

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 γ +0.05 γ

Figure 5-2. Example audit report for scrubber outlet.

AUDIT REPORT DRY GAS METER

DATE: 2/22/82 CLIENT: EPA LIGHTWEIGHT AGGR.

BAROMETRIC PRESSURE (P_{bar}): 29.36 in. Hg METER BOX NO. 1-B6

ORIFICE NO. 10 PRETEST γ: .967

ORIFICE K FACTOR: 4.778×10^{-4} AUDITOR: CLARKE

Orifice manometer reading ΔH in H_2O	Dry gas meter reading V_i/V_f ft^3	Temperatures: Ambient T_{ai}/T_{af} °F	Temperatures: Dry gas meter, Inlet T_{ii}/T_{if} °F	Temperatures: Dry gas meter, Outlet T_{oi}/T_{of} °F	Duration of run Ø min
1.5	705.000	73	76	62	15.5
	717.000	74	70	63	

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 %
12.000	73.5	67.75	11.7	11.37	.972	0.57

$V_{m_{std}}$	$V_{m_{act}}$
$\frac{(17.647)(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)}$	$\frac{(1203)(\quad Ø \quad)(\quad K \quad)(P_{bar})}{(T_a + 460)^{1/2}}$
12 (27.46 - 0.11)/533.5	15.6 4.778×10^{-4} 29.36 / 533.5

Audit γ	γ deviation, %
$\frac{V_{m\ act}}{V_{m\ std}}$	$\frac{(\gamma \text{ audit} - \gamma \text{ pre-test})(100\%)}{(\gamma \text{ audit})}$
11.37/11.7	.972 - .96 / .972

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

Figure 5-3. Example audit report for clinker cooler outlet.

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. 3530415	358.6	358.6	+ 0.2
Alundum thimble No. 248	46,195.1	46,197.6	+ 2.5
Particle size			
64 mm Reeve Angel 934 AH			
BE-41	136.9	137.1	+ 0.2
BE-18	128.7	129.0	+ 0.3
BF-17	143.0	143.2	+ 0.2
BD-64	127.0	127.2	+ 0.2
BD-29	142.2	142.4	+ 0.2
BC-68	134.3	134.6	+ 0.3
BD-75	136.8	136.9	+ 0.1
AA-84	133.7	133.9	+ 0.2
B-378	205.0	205.2	+ 0.2
Acetone blank	99,264.7	99,267.8	0.009 mg/g[a]
H_2O blank	97,605.8	97,613.8	0.013 mg/g[a]
Ether-chloroform	65,974.8	65,980.9	0.037 mg/g[a]

[a]0.01 mg/g used in calculations.

TABLE 5-3. AUDIT REPORT - SO_2 ANALYSIS

Plant Galite - Rockmart, Ga PN Number 3530-1

Date samples received 2.26.82 Date analyzed 3-2-82

Samples analyzed by Dan Schuffel

Reviewed by [signature] Date of Review 3/3/82

Sample Number	mg SO_2/dscm Determined	Source of Sample	Accepted Value	% Difference
Lot 50-980 1735	1166.8	T. Magnus (EPA)	1143.9	+2.0
Lot 50-980 5854	2333.6	" (EPA)	2287.8	+2.0

TABLE 5-4. AUDIT REPORT - NO_x ANALYSIS

Plant Galite PN Number 3530-1

Date samples received 3-1-82 Date analyzed 3-1-82, 3-2-82

Samples analyzed by Cheryl Jones

Reviewed by Ida Bennett (IIC Date of Review 3-2-82 3/3

Sample Number	mg NO_2/dscm Determined	Source of Sample	Accepted Value	% Difference
# 1665 CE 589	668.32 ✓	T. Wagner	697.3 ✓	-4.16
# 3303 CE 590	293.87	T. Wagner	298.7 ✓	-1.62

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 by use of the trap conditioning apparatus. Traps are heated to 650°C (1200°F) with carrier gas passing through the trap, oxidizer, and GC sampling loop. The sampling 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 them 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. Appendix C contains pretest equipment blank data and laboratory results. This appendix also contains chromatograms showing the blank checks for the traps and tanks used in this test.

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.*

SECTION 6

DISCUSSION OF RESULTS

Overall, the sampling program was executed as planned and, with the exception of the scrubber inlet test location, no major problems occurred with either test equipment or sampling activities. As mentioned previously, only one sampling port was used for particulate sampling at the scrubber inlet because of extreme heat and inaccessibility. With increasing distance from downstream and upstream disturbances, the effect on the results of sampling in only one plane would be less significant. Since this location met only the minimum requirements set forth in EPA Method 1, however, the particulate data could be biased high; the magnitude of which is unknown.

As discussed in Section 3 of this report, particulate mass emission rates at the scrubber outlet are probably biased high due to the cyclonic flow condition encountered. Since mass emission rate data are calculated on the basis of volumetric flow, the mass emission rate data for each measured pollutant should be considered on a qualitative basis only.

Both the filter and rinse fractions from this source were heated to 105°C (221°F) as analytically allowed in the Federal

Register.* In addition, both fractions were heated to 160°C (320°F) to preclude sample bias resulting from sulfuric acid mist retention. No significnt sample weight loss resulted from the sequential heating.

Table 6-1 summarizes particulate removal efficiency and scrubber pressure drop data. Despite the fact that the scrubber lacked an effective mist elimination device system, the particulate removal efficiency averaged greater than 98 percent with an average scrubber pressure drop of 14 inches of water. The pressure drop data is probably biased high due to frequent plugging of the inlet sample line. With an effective mist eliminator, particulate concentration would probably be significantly reduced.

The measured particulate emissions from the clinker cooler appear to be representative based on between-test data reproducibility and comparisons with plume observation and particle size data from this source.

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

TABLE 6-1. SCRUBBER EFFICIENCY SUMMARY

Particulate Test No.	Sampling location	Concentration, mg/dscm	Particulate removal efficiency, %[a]	Scrubber pressure drop, in.H_2O[b]
SIP-1	Scrubber inlet	31,462	98.1	-14.1
SOP-1	Scrubber outlet	597.8		
SIP-2	Scrubber inlet	42,568	98.2	-11.1
SOP-2	Scrubber outlet	758.3		
SIP-3	Scrubber inlet	45,476	98.7	-17.0
SOP-3	Scrubber outlet	577.7		

[a] Removal efficiency = $100 \times \frac{\text{Inlet - Outlet}}{\text{Inlet}}$

[b] Scrubber pressure drop in inches of water. A 0 to 36 inch Hg manometer and pressure taps located immediately before and after the scrubber were used for this measurement.

REFERENCES

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