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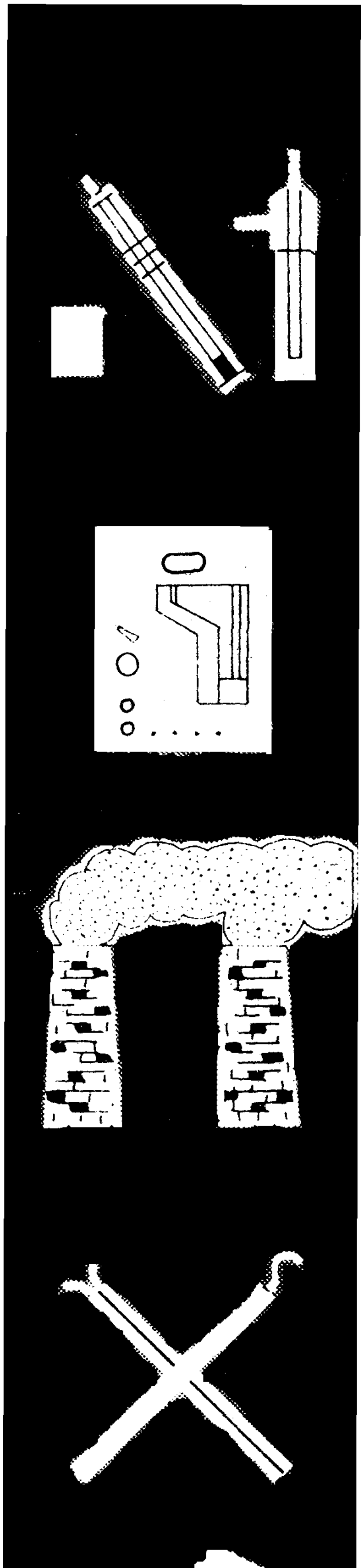

AIR POLLUTION EMISSION TEST

FINAL REPORT
WESTMORELAND COAL COMPANY
QUINWOOD
WEST VIRGINIA

MAY 25 1976

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Emission Measurement Branch
Research Triangle Park, North Carolina

FINAL REPORT

on

COAL CLEANING PREPARATION PLANT EMISSIONS AT WESTMORELAND COAL COMPANY, QUINWOOD, WEST VIRGINIA

to

ENVIRONMENTAL PROTECTION AGENCY

May 14, 1976

by

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COAL CLEANING PREPARATION PLANT EMISSIONS AT WESTMORELAND COAL COMPANY, QUINWOOD, WEST VIRGINIA

by

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INTRODUCTION

In accordance with Section 111 of the Clean Air Act of 1970, the Environmental Protection Agency is charged with the responsibility of developing standards of performance for emissions from new stationary sources (New Source Performance Standards) which may contribute significantly to air pollution. A standard of performance developed under the Act for emissions of air pollutants must be based on the best emission reduction systems that have been adequately demonstrated, taking into account economic considerations.

The development of standards of performance utilizes emissions data for pollutant sources in the particular industry being studied. In response to comments on the proposed emission standards by the coal cleaning industry, the emission control systems (venturi scrubbers) of the Westmoreland Coal Company, Quinwood, West Virginia, were selected by EPA for an emission testing program to provide test data by which the effectiveness of that emission control system could be compared with other facilities previously tested.

The Westmoreland Coal Company contested the proposed standards as a result of their preliminary tests which indicated that their specific type of coal could present an emissions control problem not previously considered by EPA. The Westmoreland data implied that the particle size of the particulate matter entering the venturi scrubber device was finer than had previously been acknowledged. The data indicated that one type of coal (Sewell) processed at the Quinwood plant presented different size characteristics than coal on which the proposed standards were based.

In order to adequately evaluate these allegations, EPA decided to conduct an extensive test program at the Quinwood facility.

Coal delivered to the plant is crushed to a variety of sizes and then washed, screened, and separated by both water and concentration tables. The coal washing occurs in a continuous process which reduces ash content from 16 to 3 percent. The 0 x 3/8-inch size of coal of interest in this study is dewatered by vacuum discs, then dried in a fluidized bed. Coal drying is accomplished by use of flue gas (produced by a coal-fired furnace) reduced in temperature by dilution air. The fluidized bed is contained in a chamber loaded with 40 or more multiclones which separate the coal from the fine dusts. Dust particles pass from the multiclones of the dryer through a high-pressure blower to a venturi scrubber, then to a large mist eliminator, and finally out an 81-inch-diameter stack.

EPA requested Battelle-Columbus to: sample particulate and gaseous emissions from the inlet and outlet stacks of the venturi scrubber control device at the Westmoreland Coal Company, Quinwood, West Virginia. The test program was conducted from June 18, through June 25, 1975 during the times the plant was processing Sewell coal. High mass loading at the inlet required the use of an in-stack Alundum* thimble (in conjunction with an EPA Method 5 train). Tests for particle size distribution of the inlet particulate were made by EPA utilizing a special multilpe-cyclone sampler. Grab samples of the process coal and venturi scrubber water were taken simultaneously with the particulate and gaseous measurements. The purpose of the aforementioned measurements is to provide EPA with additional data for support of their standards development efforts.

In order to evaluate the effect of particle size on the venturi scrubber equipment it was necessary to determine the particle size distribution of the particulate matter entering the scrubber for each type coal. Particle size comparison by sieve analysis was conducted on both types of process coal (Sewell and Pocahontas). Particle sizes of the suspended particulate at the scrubber inlet, suspended particulate in the

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* Mention of trade names does not constitute endorsement or recommendation for use by the Environmental Protection Agency.

scrubber water, and <325 mesh process coal from the sieve analysis were determined by Coulter Counter[(1)*]. A Mine Safety Appliance Particle Size Analyzer[(2)] was also used to determine the particle size of the <325 mesh particulate in an effort to substantiate the test results as determined by Coulter Counter. Particle size data, as presented in the figures throughout this report , were determined from one aliquot per sample unless otherwise noted.

Since the effectiveness of the venturi scrubber was in question relative to the process coal particle size, additional effort was placed on determining venturi inlet particulate size distribution. A special EPA series cyclone was used to futher evaluate the size cut of the inlet particles.

Trace metals in Run No. 4 outlet emission samples were determined by optical emission spectroscopy.

Present opacity of the outlet stack emissions was monitored by two certified observers during the particulate sampling. The test program was conducted to determine mass concentration levels and size distributions of particulate emissions during normal plant operation. Process conditions were carefully observed and tests were performed only when the process operations appeared to be operating normally. Process and/or scrubber malfunctions occurred during Runs 2, 3, and 5 at which time the particulate sampling was terminated. Opacity readings continued throughout the entire period including times when high values were observed because of scrubber malfunction.

A total of five outlet and six inlet runs were made for particulate loading. Run No. 1 inlet was voided due to incorrect (Pocahontas) coal being processed. Run No. 2 outlet was not considered valid due to an open circuit in the probe heater and a leak in the filter which allowed some particulate to pass through into the impinger catch. Run No. 3 inlet was voided due to nonrepresentative sampling caused by incorrect placement of the sampling nozzle and, therefore, incorrect sampling point location. Inlet Runs No. 4, 5, and 6 and outlet Runs 3, 4, and 5 were essentially

* References are given on page 65.

simultaneous and considered valid. The following sections of this report cover the summary of results, process description and operation, location of sampling points, and sampling and analytical procedures.

SUMMARY AND DISCUSSION OF SAMPLING RESULTS

Particle Size Results

Process Coal Sieve Results

The effectiveness of a venturi scrubber is, among other factors, related to the particle size of the effluent to be scrubbed. To better understand and evaluate the final outlet emission results of this study it is pertinent to obtain a size distribution of the bulk process coal. Figure 1 graphically depicts the sieve analysis results of two types of coal processed by the Westmoreland Coal Company. (Run No. 1 is probably an unknown composite of both Sewell and Pocahontas types of coal.) The size distributions of the Sewell process coal used during outlet Runs 3, 4, and 5 show very good agreement. As indicated, the Sewell coal has a mass mean diameter of 1000 μm with approximately 3 to 4 percent being less than 325 mesh (44 μm). The Pocahontas coal, as indicated in Figure 1, is relatively smaller than the Sewell coal having a mass mean diameter of 250 μm, but with approximately 4 percent being smaller than 325 mesh. Table 1 is a tabular summary of the Sewell and Pocahontas sieve analysis data.

TABLE 1. SIEVE ANALYSES OF COAL SAMPLES FROM WESTMORELAND COAL COMPANY(a)

Sieve Size		Particle Size Range Collected per Stage, μm	Accumulative Weight-Percent Retained per Stage and Smaller Stages				
U.S. Sieve Number	Screen Opening, μm		Run 1	Run 3	Run 4	Run 5	Pocahontas
4	4,760	>4760	100.0	100.0	100.0	99.9	100.0
8	2,380	2380-4760	90.3	92.9	91.0	91.5	97.8
16	1,190	1190-2380	72.5	75.8	72.4	73.1	92.5
30	590	590-1190	54.0	57.5	53.4	53.9	84.2
50	297	297-590	38.5	41.7	38.2	38.3	72.2
100	149	149-297	25.2	27.9	25.7	25.2	54.9
200	74	74-149	16.7	17.9	17.1	16.4	36.4
325	44	44-74	10.8	11.6	11.3	10.5	21.8
Pan (-325)	<44	<44	3.7	3.1	2.9	3.9	4.0

Note: Run No. 2 discarded
(a) Sample size approximately 900 grams (2 lb)

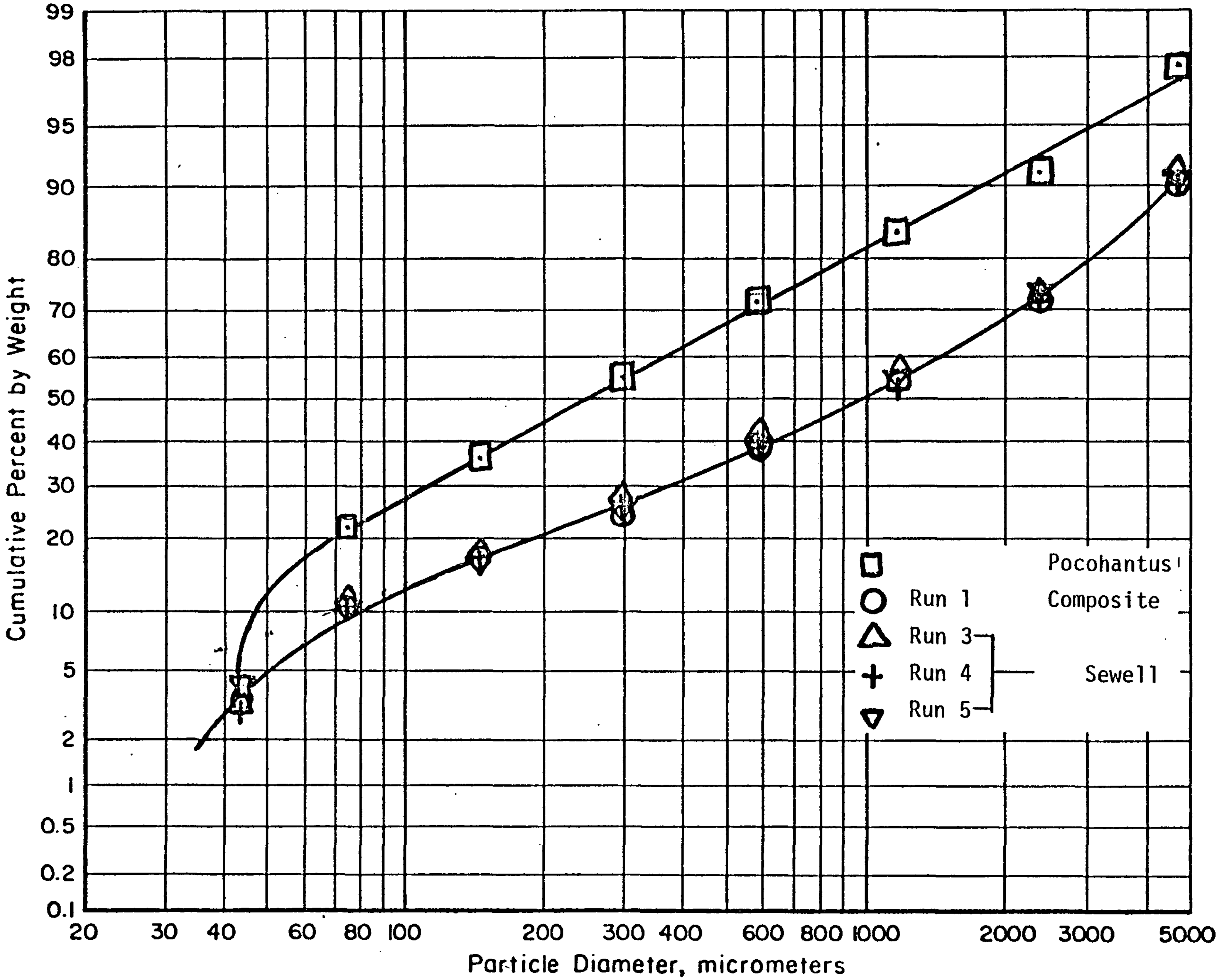


FIGURE 1. PROCESS COAL SIEVE ANALYSIS

In order to evaluate the proportion of ultrafines (<2 μm) that is of primary importance relative to venturi scrubber effectiveness, Coulter Counter analyses of the subsieve fraction (<325 mesh) were performed for the indicated runs. The results are shown in Figure 2. Again the size distribution for the Sewell coal for outlet Runs 3, 4, and 5 show good agreement, the mass mean diameter being approximately 17 μm and approximately 1 to 2 percent being less than 2 μm. The Pocahontas coal has more fines than the Sewell coal, with a mass mean diameter of approximately 12 μm and approximately 2.5 to 3 percent being less than 2 μm. Therefore, with all other factors equal, the Sewell coal emissions are no more difficult to collect with venturi scrubber equipment than the Pocahontas coal emissions.

The Mine Safety Appliance Particle Size Analyzer results as depicted in Figure 3 essentially substantiate the Coulter Counter results for the Sewell samples but shows the Pocahontas and Sewell with essentially an equal size distribution except in the relatively smaller size fractions where scatter in the data occurs. If one averages the MSA data in the smaller size fraction, 2 to 3 percent of the size distribution is less than 2 μm; this agrees with the Coulter Counter data of Figure 2. Table 2 is a tabular summary of the Sewell and Pocahontas results for size measurements with the MSA Particle Size Analyzer.

Particulate Collected by the Scrubber

It is to be expected that the venturi scrubber used to clean particulate from the effluent gas stream will remove large particles more efficiently than smaller particles. To directly measure such effects, mass concentrations and size distributions are required for particles in the gas stream entering the scrubber and in the scrubber water. Because of the time averaging effect of scrubber water recirculation, a direct measurement of particulate mass collected in the water over the inlet gas sampling time was not possible. The scrubber water samples were collected over a very short time interval and, hence, a time averaged value for the particulate collected by the water prior to the sampling time was determined.

TABLE 2. SUBSIEVE PARTICLE SIZE DISTRIBUTION OF WESTMORELAND COAL COMPANY SAMPLES BY MSA PARTICLE SIZE ANALYZER[a]

Particle	Weight Percent of <44 μm Portion[b]					Weight Percent of Total Sample[b]				
Size, μm	Run 1	Run 3	Run 4	Run 5	Pocahontas	Run 1	Run 3	Run 4	Run 5	Pocahontas
60	--	--	--	--	100.0	--	--	--	--	4.00
50	100.0	100.0	100.0	--	97.5	3.70	3.10	2.90	--	3.90
40	98.1	97.6	97.1	100.0	93.7	3.63	3.03	2.82	3.90	3.75
35	97.1	95.3	94.9	97.2	91.2	3.59	2.95	2.75	3.79	3.65
25	79.2	79.2	76.1	78.3	73.3	2.93	2.46	2.21	3.05	2.93
20	63.3	63.4	62.5	65.0	57.5	2.34	1.97	1.81	2.54	2.30
15	43.7	46.7	47.5	48.3	42.9	1.62	1.45	1.38	1.88	1.72
12	33.1	31.9	39.1	38.5	32.9	1.22	0.99	1.13	1.50	1.32
10	26.8	25.8	29.4	30.8	25.0	0.99	0.80	0.85	1.20	1.00
8	18.5	22.5	21.3	21.7	17.1	0.68	0.70	0.62	0.85	0.68
6	12.2	15.5	12.9	14.0	9.6	0.45	0.48	0.37	0.55	0.38
4	5.3	6.4	9.2	8.4	4.6	0.20	0.20	0.27	0.33	0.18
2	1.3	0.7	5.9	4.9	1.3	0.05	0.02	0.17	0.19	0.05
1	0	0	0	0.7	0	0	0	0	0.03	0
0.8	--	--	--	0	--	--	--	--	--	--

Note: Run No. 2 discarded.
(a) Sedimentation liquid--isopropyl alcohol; feed liquid--50 percent isopropyl alcohol, 50 percent heptane.
(b) Data are reported as less than indicated size.

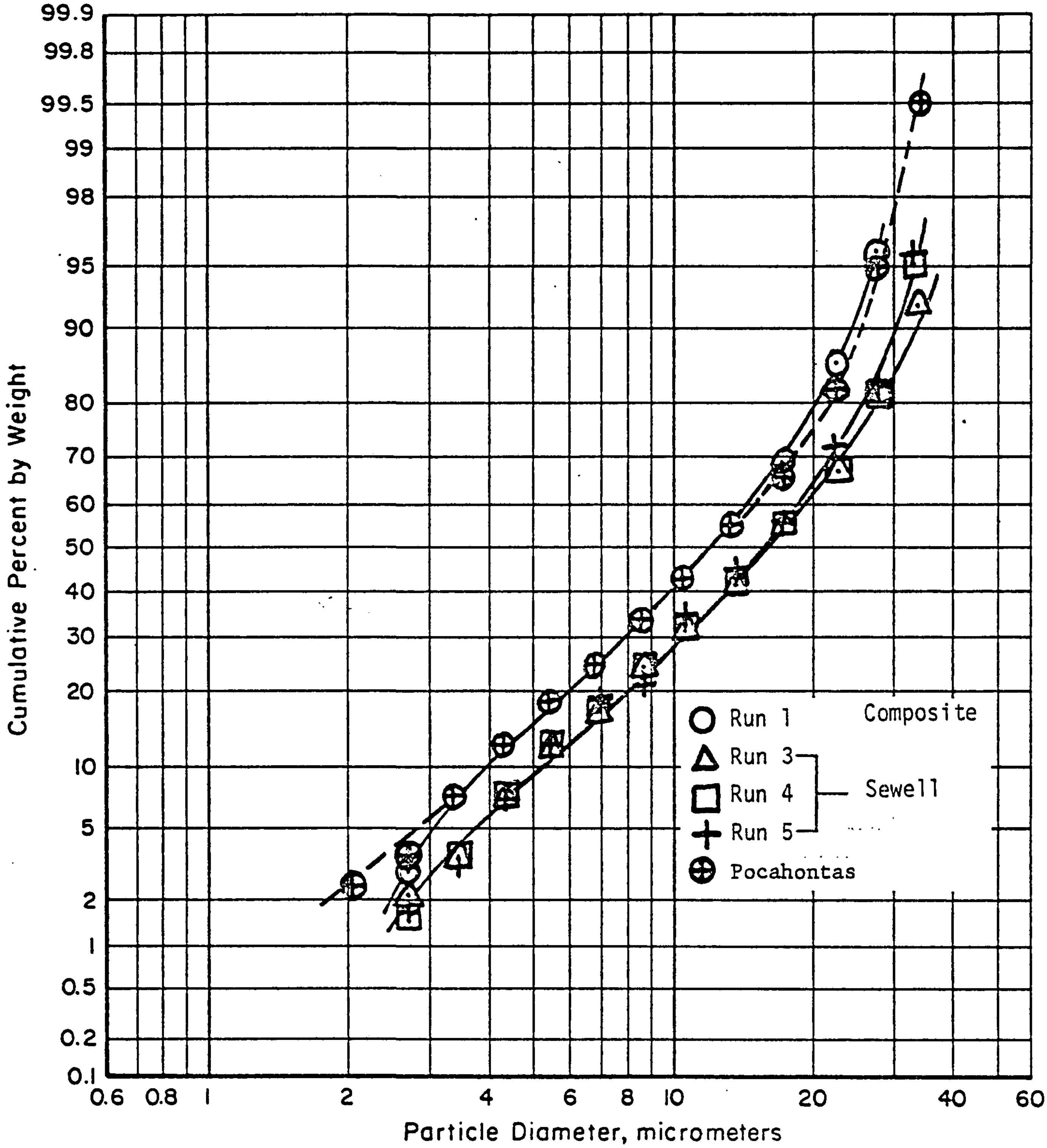


FIGURE 2. SUBSIEVE SIZE DISTRIBUTION OF PROCESS COAL BY COULTER COUNTER

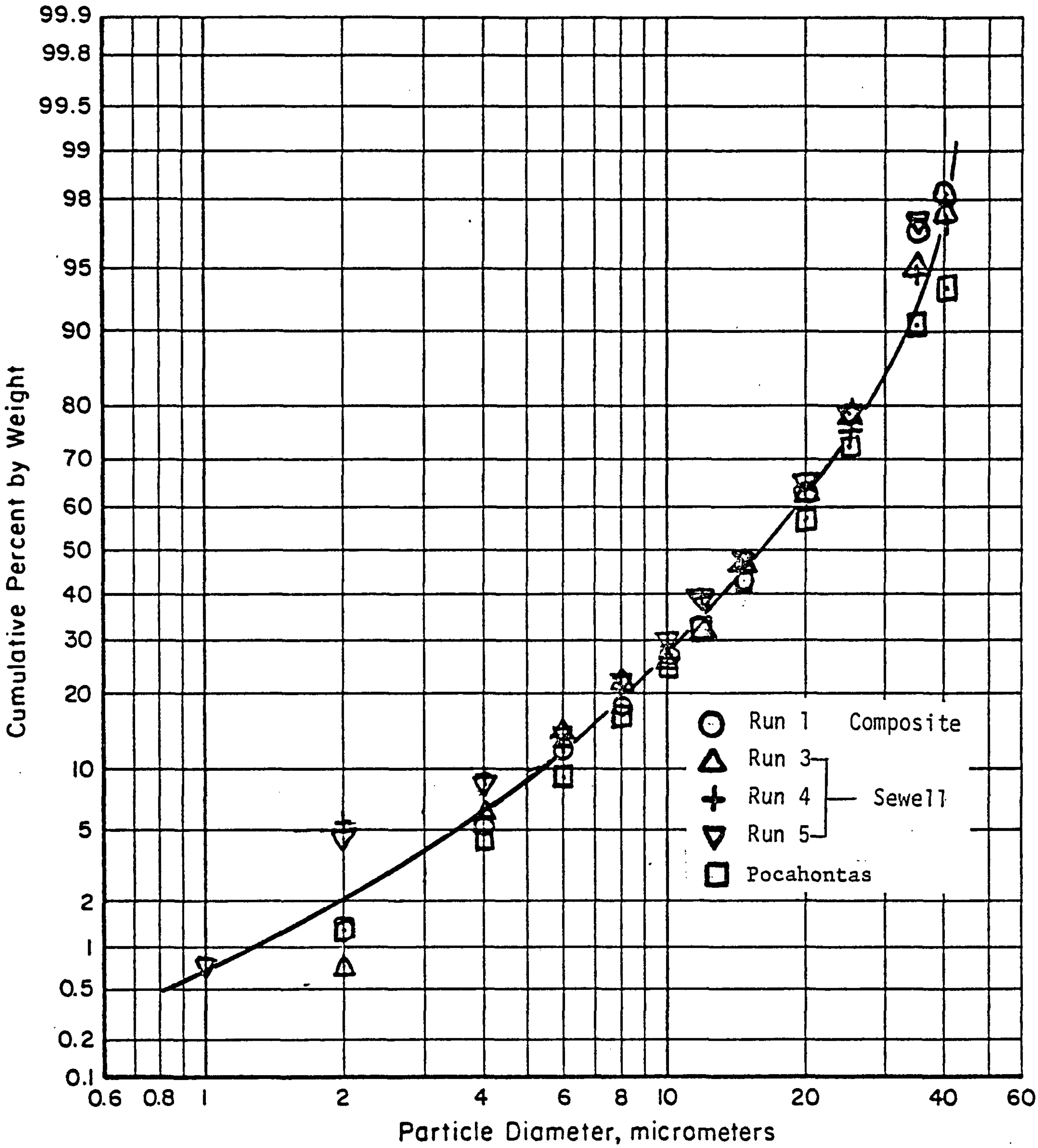


FIGURE 3. SUBSIEVE SIZE DISTRIBUTION OF PROCESS COAL BY MINE SAFETY APPLIANCE PARTICLE SIZE ANALYZER

However, the samples were collected to determine if any differences between inlet suspended particulate and scrubber water particulate existed. These differences could lead to significant inferences regarding scrubber collection efficiency as dependent on particle size.

The size distribution curves given in Figures 4, 5, 6, and 7 allow comparisons between suspended inlet particulate and scrubber collected particulate for Runs 2, 4, 5, and 6, respectively. Inlet Runs 1 and 3 were voided as explained in the Introduction. The results may appear to be inconclusive because of the data in Figures 4 and 5, which show less particulate below about 2 μm in the scrubber water than in the inlet gas, and Figures 6 and 7, which show the reverse. Table 3 is a tabulation of these data. Within the error of the particle sizing methods, the data show that the particle size distribution in the scrubber water is practically the same as the distribution at the scrubber inlet. This result could be predicted when the scrubber collects essentially all of the particulate matter. Data of this type cannot be used to obtain size dependent collection efficiencies. Any major impact on control effectiveness would occur only if a sufficiently large fraction of the particulate material had sizes too small for efficient collection. Size distributions for the suspended inlet particulate indicate that only about 5 percent of the particles have sizes below about 2 μm. This low fraction in the small size range makes comparison impractical since the small sizes constitute a nearly negligible portion of the particulate for measurement purposes. If, however, the differences between the curves are attributable to normal scatter in the experimental data, as is likely, it can be concluded that the overall efficiency is not sensitive to low collection efficiency for these small sizes. This is because such a small fraction of the total entering particles are smaller than the size where efficiency drops off. Therefore, valid conclusions that can be drawn from these data are that the venturi scrubber essentially collects all sizes of particulate in excess of 2 μm. The amount of particulate matter less than 2 micrometers that reduces the scrubber's collection efficiency is not significantly different for Sewell coal as compared with Pocahontas coal.

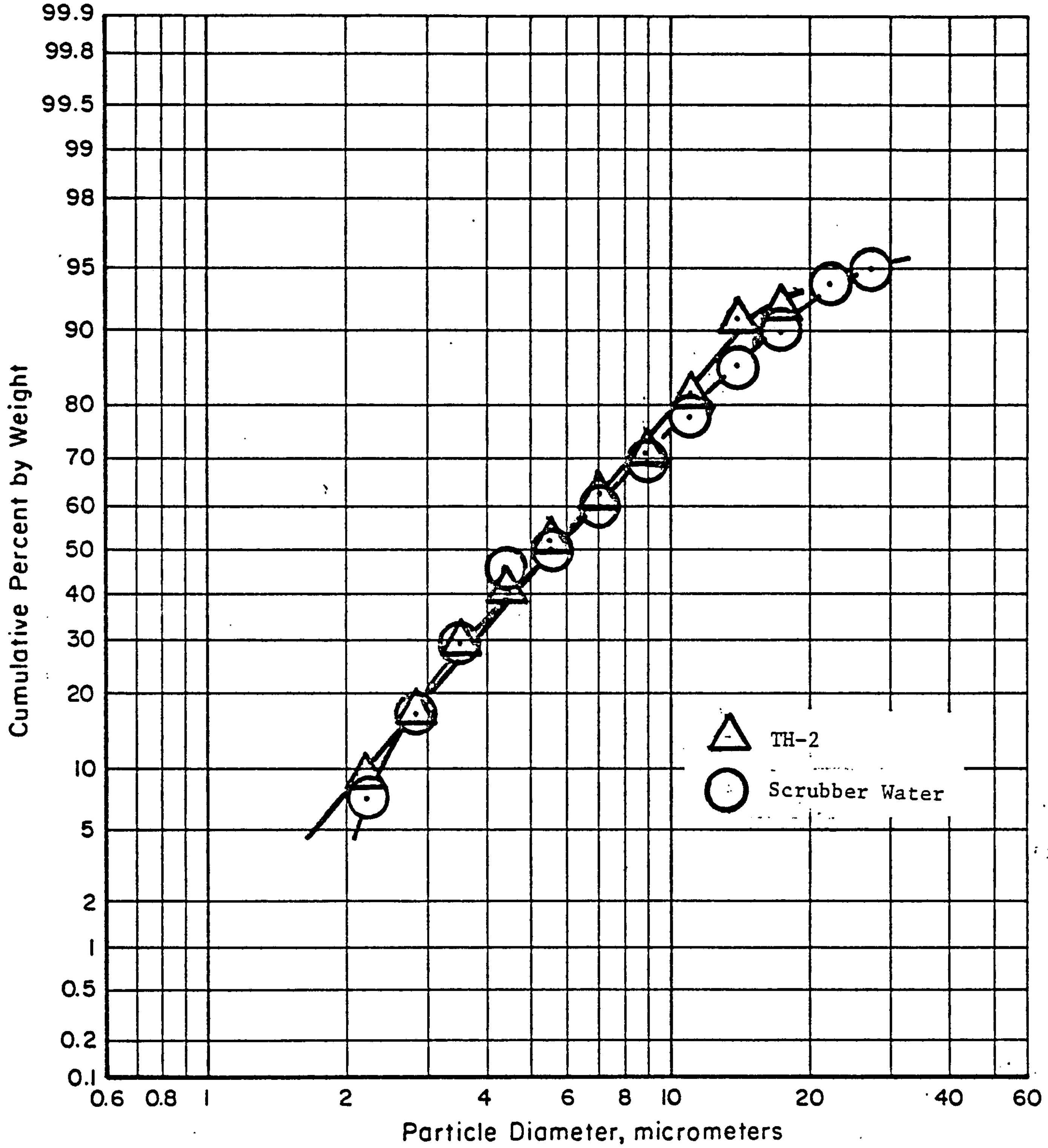


FIGURE 4. COMPARISON OF RUN 2 THIMBLE CATCH AND ASSOCIATED SCRUBBER WATER SUSPENSION, COULTER COUNTER ANALYSES

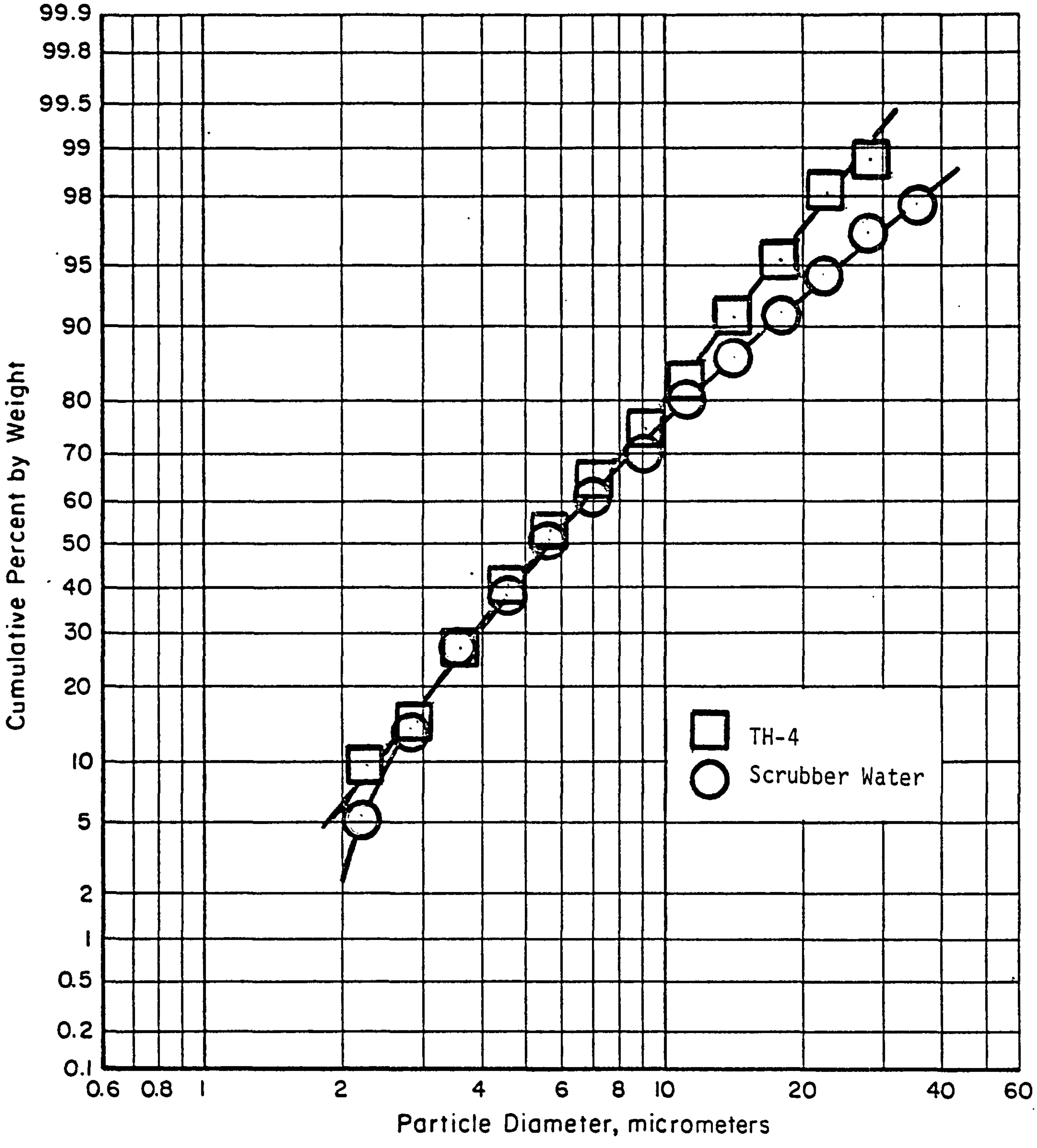


FIGURE 5. COMPARISON OF RUN 4 THIMBLE CATCH AND ASSOCIATED SCRUBBER WATER SUSPENSION, COULTER COUNTER ANALYSES

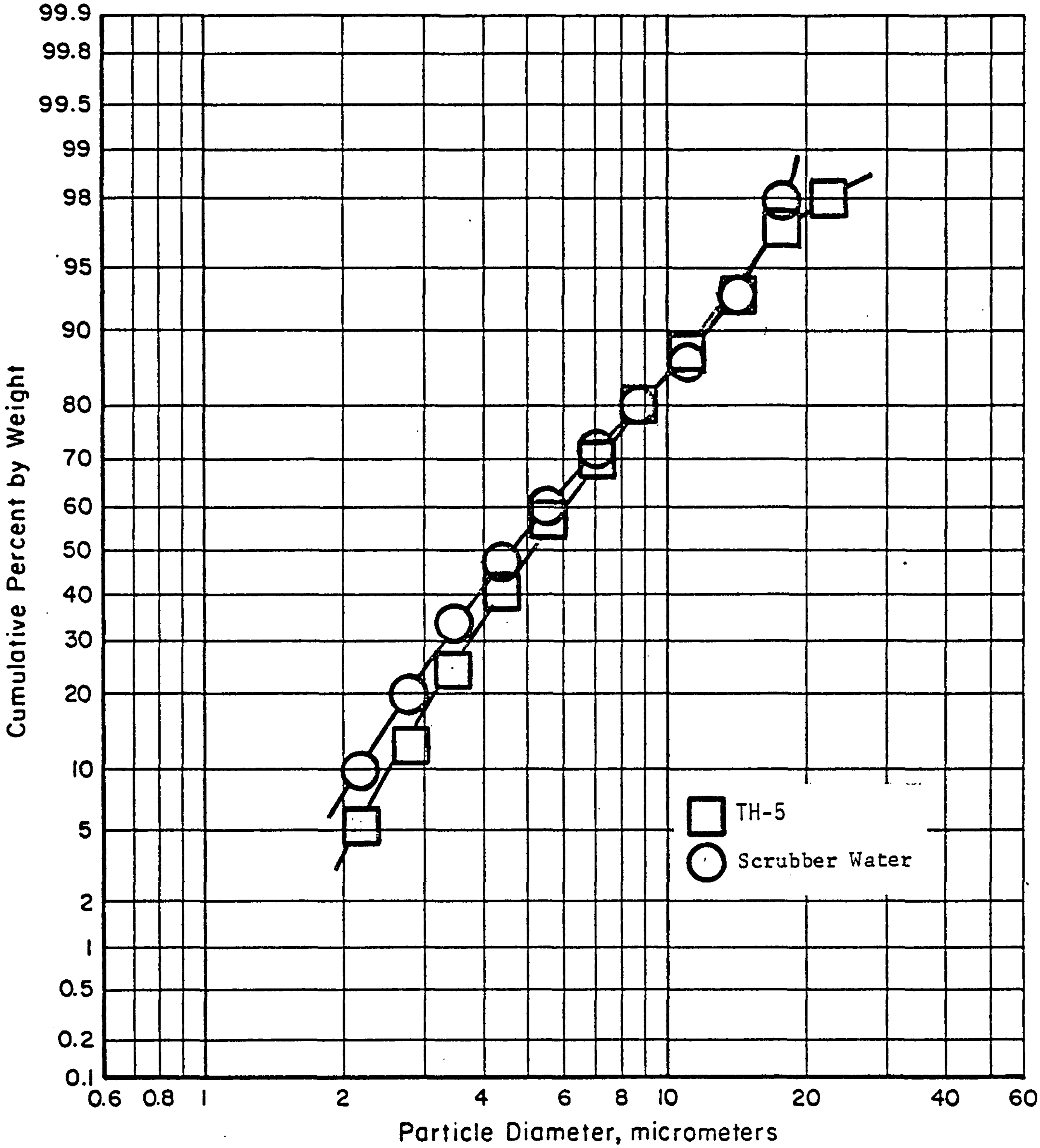


FIGURE 6. COMPARISON OF RUN 5 THIMBLE CATCH AND ASSOCIATED SCRUBBER WATER SUSPENSION, COULTER COUNTER ANALYSES

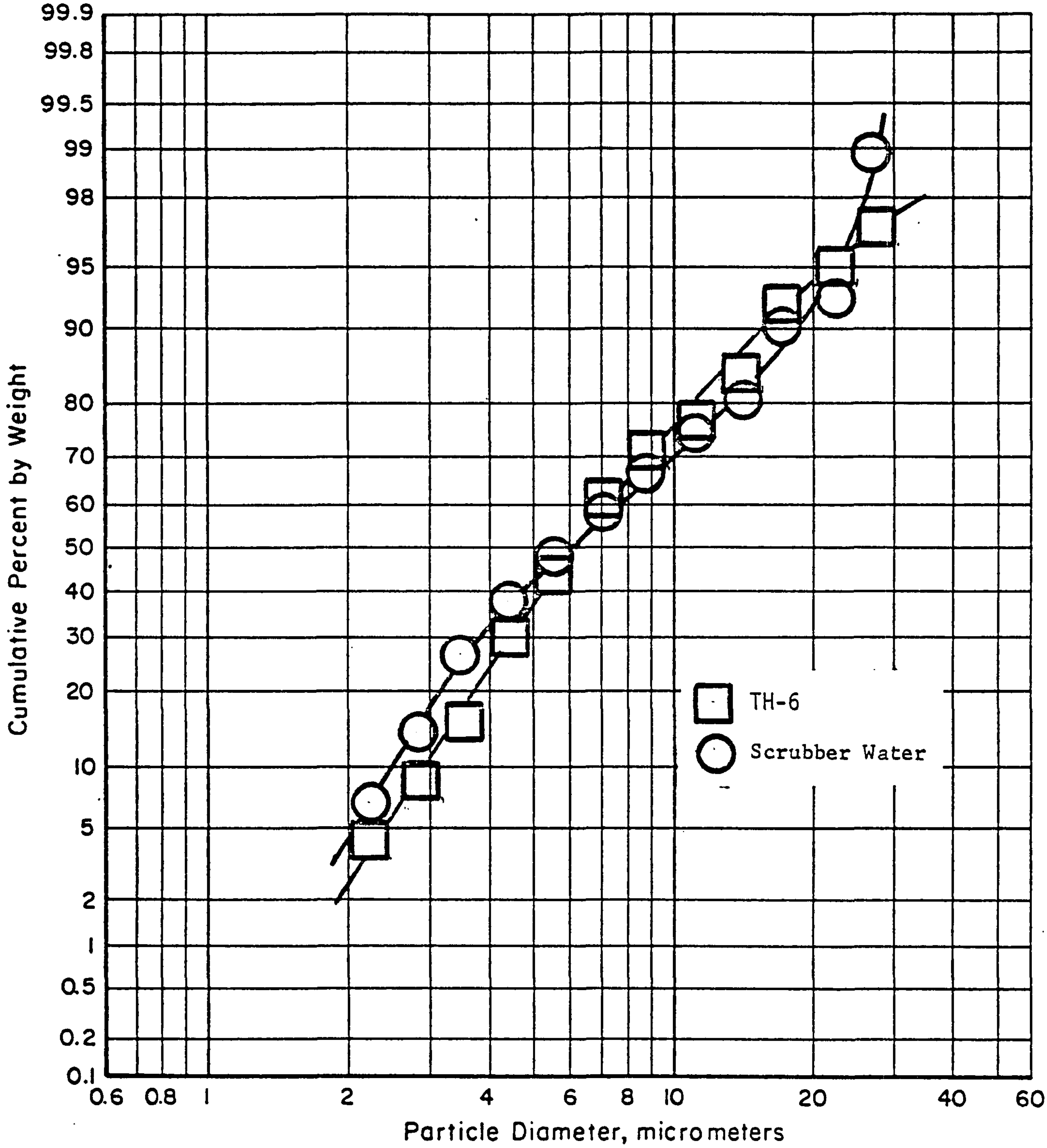


FIGURE 7. COMPARISON OF RUN 6 THIMBLE CATCH AND ASSOCIATED SCRUBBER WATER SUSPENSION, COULTER COUNTER ANALYSES

TABLE 3. SIZE DISTRIBUTION COMPARISON OF PARTICLES ENTERING THE SCRUBBER AND PARTICLES CAUGHT BY THE SCRUBBER WATER[(a)], FROM WESTMORELAND COAL COMPANY

(Percent less than indicated size)

Particle Size, μm	Run 2 Thimble Catch	Run 2 Scrubber Water	Run 4 Thimble Catch	Run 4 Scrubber Water	Run 5 Thimble Catch	Run 5 Scrubber Water	Run 6 Thimble Catch	Run 6 Scrubber Water
44.2	--	--	--	100.0	--	--	--	--
35.1	--	100.0	100.0	97.88	--	--	100.0	100.0
27.8	--	94.81	98.89	96.82	100.00	--	97.12	98.96
22.1	100.0	94.29	98.34	94.70	98.27	100.00	94.26	93.24
17.5	91.87	89.61	95.43	91.25	97.11	98.33	92.79	90.90
13.9	91.13	85.58	91.20	85.94	92.78	93.13	85.58	81.54
11.1	81.52	78.11	83.37	79.47	86.78	86.47	78.42	74.45
8.8	70.98	70.02	75.48	70.03	79.04	80.63	71.14	67.52
7.0	63.11	60.80	66.11	60.75	69.67	71.78	61.73	58.60
5.5	53.00	50.43	53.83	51.00	57.55	60.53	44.97	48.65
4.4	41.33	46.38	40.70	38.41	40.95	48.15	29.89	38.03
3.5	28.89	29.87	26.95	26.71	24.51	34.07	16.54	27.83
2.8	17.68	17.67	14.82	14.15	12.36	20.47	9.03	14.83
2.2	9.48	7.57	9.53	5.93	5.54	10.02	4.90	7.61

(a) Size distribution of thimble particle catch and scrubber water particle suspension determined by Coulter Counter using an aperture diameter of 100 μm, and a manometer volume of 500 μℓ.

Cyclone Catch Analyses

Tests were conducted using a sample train consisting of two aluminum cyclones followed by a glass fiber filter. The purpose of the tests was to determine the mass loading of particulates less than 2.5 μm in diameter. All tests were conducted at the inlet to the scrubber. The testing cyclones were developed by an independent contractor for the Environmental Protection Agency. Since the equipment had not been previously used by the tester, numerous problems were encountered until a sampling technique was established. A total of 13 runs was conducted. During the first six runs, problems were encountered with the testing; Runs 7-13 were valid tests. However, during Runs 8, 10, and 12, the process was operating under a light load. Furthermore, Run 13 was conducted when Type 7 Sewell surface-mined coal was being processed.

Tables 4 and 5 summarize the test data and analytical data. Table 6 summarizes the test results. The tests were conducted at a nominal flow rate of 1 acfm, yielding cut-off points of 2.5 and 1.0 μm for the first and second cyclones, respectively. Therefore, the particulate less than 2.5-μm diameter was calculated as the total mass minus the mass collected in the first cyclone.

Two tests with a cascade impactor were attempted, but were not successful. In one case, the stages were overloaded, and in the other case, the collection substrates were knocked ajar.

Table 6 summarizes the test results. As previously noted, Tests 7-13 were considered the best tests as far as sampling procedures are concerned. In performing the calculations, an average stack gas moisture (9.9 percent) calculated from the five Alundum thimble runs was used. The results presented in Table 6 show a reasonable correlation between the Alundum thimble and cyclone methods for determining particulate concentration of particles less than 2.5 μm diameter. For cyclone Runs 7-13 the mass percent less than 2.5 μm ranged from 11.6 to 17.6 percent with an average of 14.5 percent. For the Alundum thimble Runs 2, 4, 5, and 6, the mass percent less than 2.5 μm ranged from 7 to 15 percent with an average value of 11.5 percent.

TABLE 4. TEST DATA FOR PARTICLE SIZE RUNS WITH MULTIPLE-CYCLONE SAMPLER

Run Number	Date	Start Time	Port Identification	Sample Period (minutes)	Meter Volume (acf)	Stack Temp. (F)	Nozzle Diameter (inches)	Absolute Stack Pressure (in. Hg)	Volume Sampled (dscf)	Sample Rate (acfm)(a)	Percent Isokinetic
1	6/18	1800	S	22	22.345	190	0.4375	29.68	20.16	1.3	(b)
2	6/19	1415	S	10	8.000	190	0.4375	29.80	7.24	1.0	(b)
3	6/19	1715	S	11	10.520	170	0.4375	29.80	9.52	1.1	(b)
4	6/20	1115	E	11	7.230	170	0.4375	29.80	6.54	0.8	(b)
5	6/20	1445	E	11	9.050	170	0.4375	29.80	8.20	1.0	(b)
6	6/23	1700	E	11	8.675	200	0.1875	29.81	7.84	1.0	(b)
7	6/23	2000	E	11	8.600	200	0.1875	29.81	7.75	0.9	77.8
8	6/25	1005	E	11	8.520	155	0.1875	29.74	7.68	0.9	78.5
9	6/25	1255	E	11	8.525	150	0.1875	29.74	7.68	0.9	78.5
10	6/26	1650	S	11	--	170	0.1875	29.74	--	--	--
11	6/26	1225	S	11	7.895	180	0.1875	29.63	7.08	0.9	85.2
12	6/26	1420	E	11	8.600	180	0.1875	29.63	7.72	1.0	78.1
13	6/26	1550	S	11	8.715	180	0.1875	29.63	7.82	1.0	77.0

(a) Stack conditions.

(b) Used incorrect sample nozzle.

TABLE 5. ANALYTICAL DATA FOR PARTICLE SIZE RUNS WITH MULTIPLE-CYCLONE SAMPLER[a]

Test	First Cyclone	Second Cyclone	Filter	First Cyclone Wash	Second Cyclone Wash	Filter Assembly Wash	First Cyclone Total	Second Cyclone Total	Filter Total	Total
1	--	--	--	--	--	--	--	--	--	--
2	0.3349	N/A	0.0620	N/A	N/A	N/A	0.3349	N/A	0.0620	0.3969
3	1.7575	N/A	0.1144	N/A	N/A	N/A	1.7575	N/A	0.1144	1.8719
4	3.9237	N/A	0.1266	N/A	N/A	N/A	3.9237	N/A	0.1266	4.0503
5	3.6606	2.2320	0.0229	N/A	N/A	0.0085	3.6606	2.2320	0.0314	5.9241
6	1.3006	0.1659	--	N/A	N/A	--	1.3006	0.1659	--	--
7	1.1888	0.1346	0.0450	N/A	N/A	0.0073	1.1888	0.1346	0.0523	1.3757
8	0.5013	0.0535	0.0278	N/A	N/A	0.0048	0.5013	0.0535	0.0326	0.5874
9	1.2658	0.1166	0.0383	0.0060	0.0076	0.0048	1.2718	0.1242	0.0431	1.4391
10	0.6590	0.0752	0.0234	0.0035	0.0062	0.0040	0.6625	0.0814	0.0274	0.7713
11	1.6196	0.2217	0.109	0.0081	0.0089	0.0086	1.6277	0.2306	0.1176	1.9759
12	1.0512	0.1151	0.000	0.0059	0.0172	0.0070	1.0571	0.1323	0.0070	1.1964
13	0.5947	0.0771	0.0386	0.0048	0.0098	0.0028	0.5995	0.0869	0.0414	0.7278

(a) All masses are reported in grams.

N/A Not Applicable.

TABLE 6. SUMMARY OF RESULTS OF PARTICLE SIZE RUNS

Run Number	Mass Loading, gr/scf Total	Mass Loading, gr/scf Less than 2.5 μm[a]	*Mass Less than 2.5 μm,[a] percent
Cyclones:			
1	--	--	--
2	.84	0.14	15.6
3	3.02	0.19	6.1
4	9.54	0.30	3.1
5	11.13	4.25	38.2
6	--	--	--
7	2.73	0.37	13.6
8	1.18	0.17	14.7
9	2.90	0.34	11.6
10	--	--	--
11	4.30	0.76	17.6
12	2.39	0.28	11.6
13	1.43	0.25	17.6
Alundum Thimbles:			
1	2.73	--	--
2	1.79	0.27	15
4	2.89	0.35	12
5	3.23	0.39	12
6	2.67	0.19	7

(a) Total mass, less mass collected in first cyclone.

Figures 8 presents the particle size distribution of the cyclone catches which were analyzed by electronic counter. Field data sheets are presented in Appendix C. Cyclone sample identification and analytical results are presented in Appendix G.

Figure 9 indicates the location of the sampling points. Because of the design of the equipment only the first 22 points on each traverse could be sampled. Each test (Runs 6-13) was conducted using two cyclones in series with a back-up filter. The sampling rate was kept constant during each test at a nominal flow of 1 acfm. Each test was conducted across only one traverse and was only 11 minutes in duration. It was necessary to limit each test to only one traverse because of the capacities of the cyclone collection cups.

Prior to each test the sample train was checked for leaks and then inserted into the stack (with nozzle plugged) in order to allow the cyclones to heat to stack temperature. After a 20-minute pre heat, the cyclones were removed, the nozzle unplugged, the cyclones reinserted, and the test begun.

The sample train was constructed so that the nozzle was inserted directly into the first cyclone. The first cyclone was immediately followed by the second cyclone and a back-up filter connected to the probe. During sampling, both cyclones and filter were in-stack. A flexible hose was used to connect the probe to a silica gel impinger, vacuum pump, and dry gas meter, in that order. Figure H-1 of Appendix H is a block diagram of the cyclone and filter assembly. Figure H-2 shows the calibration curves for the cyclones. Figure H-3 shows the calibration curves for each cyclone and relates the particle cut-off size, μm, as a function of flow rate.

The particulate catch of each cyclone was emptied from the collection cup into a weighing vessel. All residual material was brushed into these vessels using a camel hair brush. In addition, for Runs 9-13, acetone rinses were conducted on the cyclones and filter holder.

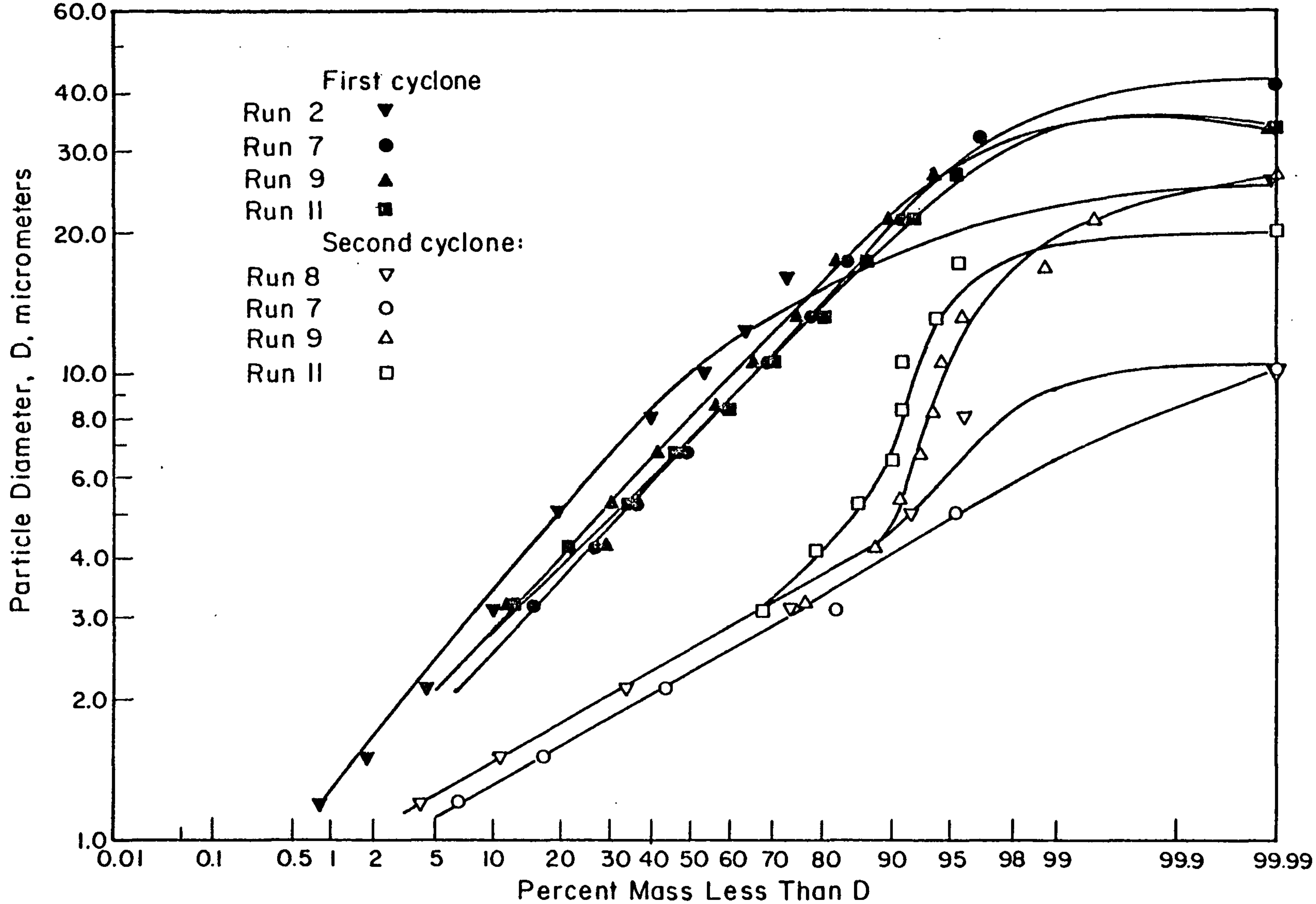
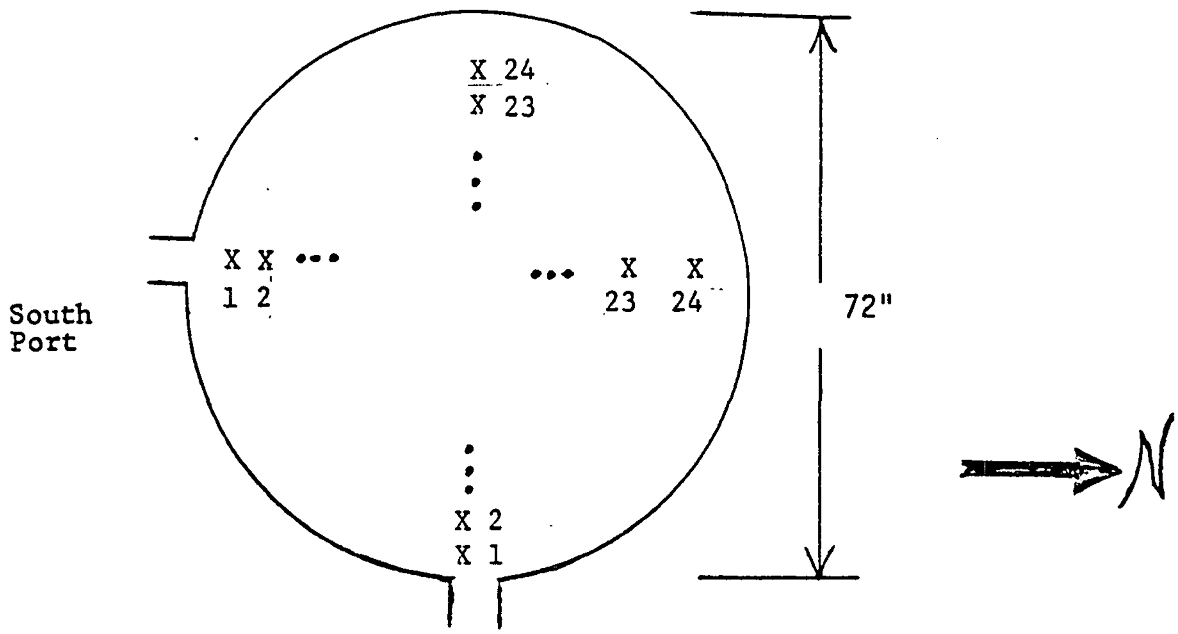


FIGURE 8. PARTICLE SIZE DISTRIBUTIONS OF CYCLONE CATCHES, COULTER COUNTER ANALYSES



Traverse points:

1	1 inch	13	43.25
2	2.25	14	48.75
3	4	15	52.5
4	5.75	16	55.5
5	7.5	17	58
6	9.5	18	60.5
7	11.5	19	62.5
8	14	20	64.5
9	16.5	21	66.25
10	19.5	22	68
11	23.25	*23	69.75
12	28.75	*24	71

*Not Sampled.

FIGURE 9. SAMPLE POINT LOCATION

For several cyclone catches, the particle size distribution of the collected material was determined using an electronic counter. The sizing procedures used were the same as those employed for the Alundum thimble particulate catches.

Scrubber Inlet Measurement Results

Tables 7 and 8 show computer output tabular summaries (in English and metric units, respectively) of results of Runs 1 through 6, Run 3 being aborted because of operator error. Runs 1 and 2 are not considered representative relative to outlet comparison but are being presented only as support data to aid in ascertaining a better understanding of inlet sampling conditions. Weight concentration for Runs 4, 5, and 6 ranged from 2.68 to 3.23 gr/dscf (6144 to 7407 mg/Nm^3) resulting in a mean of 2.93 gr/dscf (6728 mg/Nm^3). Isokinetic sampling for Runs 4 to 6 varied from 100 to 106 percent, in spite of the undesirable working conditions encountered, which is well within the desired limits of 100 $\pm$ 10 percent for producing valid data.

Scrubber Outlet Results

Tables 9 and 10 show summarized data by computer (in English and metric units, respectively) obtained at the outlet stack of the Westmoreland Coal Company. Runs 1 and 2, as previously mentioned, are not considered representative because of plant and/or BCL operator error, but have been presented as additional support data.

For Runs 3 to 5, the dry catch (probe and filter) weight concentration results are 0.037, 0.059, and 0.035 gr/dscf (86.1, 134.5, and 80.6 mg/Nm^3 , respectively. The impinger catch results for Runs 3 to 5 increased the weight concentrations an average of 25 percent, the total catch (probe, filter, and impingers) being 0.054, 0.072, and 0.049 gr/dscf (123.2, 164.6, and 112.9 mg/Nm^3), respectively.

TABLE 7. INLET MEASUREMENT RESULTS SUMMARY (ENGLISH UNITS)

WESTMORELAND COAL COMPANY INLET RESULTS						
RUN NO.[a]	1	2	4	5	6	Average[e]
TEST DATE	6/18	6/19	6/20	6/23	6/25	
VOLUME OF GAS SAMPLED, DSCF[b]	118.3	88.8	90.4	140.0	126.6	119.0
PERCENT MOISTURE BY VOLUME	11.2	7.0	9.1	10.7	12.1	10.6
AVERAGE STACK TEMPERATURE, F	166	164	171	202	181	185
STACK VOLUMETRIC FLOW RATE, DSCFM[c]	136913	148680	144041	138019	135899	137986
STACK VOLUMETRIC FLOW RATE, ACFM[d]	183212	191155	190094	193875	188004	190657
PERCENT ISOKINETIC	98.6	94.6	100.0	106.1	99.7	101.9
PERCENT EXCESS AIR	1072	1786	2411	2267	1595	2091
PERCENT OPACITY	NA	NA	NA	NA	NA	NA
FEED RATE, TONS/HR	ND	ND	ND	ND	ND	ND
PARTICULATES - PROBE,CYC,FILTER CATCH						
MG	18144.0	9271.0	15368.0	26167.0	20087.0	20540.0
GR/DSCF -	2.729	1.785	2.888	3.225	2.675	2.929
GR/ACF -	2.038	1.387	2.187	2.294	1.932	2.138
LB/HR -	3201.3	2273.3	3564.1	3812.9	3114.2	3497
LB/TON FEED	ND	ND	ND	ND	ND	ND

ND - No Data

NA - Not Applicable

(a) Run No. 3 aborted.
(b) Dry standard cubic feet at 70° F, 29.92 in. Hg.
(c) Dry standard cubic feet per minute at 70° F, 29.92 in. Hg.
(d) Actual cubic feet per minute.
(e) Average includes only Runs 4, 5, and 6.

TABLE 8. INLET MEASUREMENT RESULTS SUMMARY (METRIC UNITS)

WESTMORELAND COAL COMPANY INLET RESULTS

RUN NO. / TEST DATE	1 / 6/18	2 / 6/19	4 / 6/20	5 / 6/23	6 / 6/25	Average
VOLUME OF GAS SAMPLED, NCM (a)	3.3	2.5	2.6	3.9	3.6	3.4
PERCENT MOISTURE BY VOLUME	11.2	7.0	9.1	10.7	12.1	10.6
AVERAGE STACK TEMPERATURE, C	74	73	77	94	82	84
STACK VOLUMETRIC FLOW RATE, NCMM (b)	3862	4194	4063	3893	3833	3930
STACK VOLUMETRIC FLOW RATE, CMM (c)	5168	5392	5362	5469	5303	5378
PERCENT ISOKINETIC	98.6	94.6	100.0	106.1	99.7	101.9
PERCENT EXCESS AIR	1072	1786	2411	2267	1595	2091
PERCENT OPACITY	NA	NA	NA	NA	NA	NA
FEED RATE, MTON/HR	ND	ND	ND	ND	ND	ND
PARTICULATES - PROBE,CYC,FILTER CATCH						
MG	18144.0	9271.0	15368.0	26167.0	20087.0	20540
MG/NCM -	6269.3	4099.4	5634.4	7407.2	6144.3	6728.6
MG/CM -	4680.7	3185.7	5022.5	5268.2	4437.2	4909.3
KG/HR -	1452.1	1031.2	1616.7	1729.5	1412.6	1586.3
KG/MTON FEED	ND	ND	ND	ND	ND	ND

ND - No Data.

(a) Normal cubic meter (dry) 20.0 C, 760 mm Hg.
(b) Normal cubic meter per minute (dry) at 20.0 C, 760 mm Hg.
(c) Actual cubic meters per minute.

NA = Not Applicable

TABLE 9. OUTLET MEASUREMENT SUMMARY RESULTS (ENGLISH UNITS)

WESTMORELAND COAL COMPANY OUTLET RESULTS

RUN NO. / TEST DATE	1 / 6/18	2 / 6/19	3 / 6/20	4 / 6/23	5 / 6/25	Average[d]
VOLUME OF GAS SAMPLED, DSCF[b]	109.5	100.5	106.7	109.2	104.0	106.6
PERCENT MOISTURE BY VOLUME	11.8	11.4	11.4	13.2	11.9	12.2
AVERAGE STACK TEMPERATURE, F	113	105	110	116	112	113.3
STACK VOLUMETRIC FLOW RATE, DSCFM[c]	132543	125534	139320	135983	137815	137629
STACK VOLUMETRIC FLOW RATE, ACFM[d]	175923	163761	182820	184172	182959	183457
PERCENT ISOKINETIC	106.4	103.3	100.6	103.8	97.1	100.6
PERCENT EXCESS AIR	1072	1786	2411	2267	1595	2091
PERCENT OPACITY	15[e]	20	25	13	20	19
FEED RATE, TONS/HR	ND	ND	ND	ND	ND	ND
PARTICULATES - PROBE,CYC,FILTER CATCH						
MG	244.4	328.1	239.6	376.9	214.2	276.9
GR/DSCF -	0.038	0.055	0.037	0.059	0.035	0.044
GR/ACF -	0.029	0.042	0.029	0.043	0.026	0.033
LB/HR -	43.2	59.7	44.7	68.2	41.4	51.4
LB/TON FEED	ND	ND	ND	ND	ND	ND
PARTICULATES - TOTAL CATCH						
MG	299.7	448.2	342.9	461.4	300.2	368.2
GR/DSCF -	0.047	0.075	0.054	0.072	0.049	0.058
GR/ACF -	0.035	0.058	0.041	0.053	0.037	0.044
LB/HR -	52.9	81.5	64.0	83.5	58.0	68.5
LB/TON FEED	ND	ND	ND	ND	ND	ND
PERCENT IMPINGER CATCH	18.5	26.8	30.1	18.3	28.6	25.7

ND - No Data.

(a) Dry standard cubic feet at 70° F, 29.92 in. Hg.
(b) Dry standard cubic feet per minute at 70° F, 29.92 in. Hg.
(c) Actual cubic feet per minute.
(d) Average includes only Runs 3, 4, and 5.
(e) Opacity measured only during portion of run.

TABLE 10. OUTLET MEASUREMENT RESULTS SUMMARY (METRIC UNITS)

WESTMORELAND COAL COMPANY OUTLET RESULTS						
RUN NO. TEST DATE	1 6/18	2 6/19	3 6/20	4 6/23	5 6/25	Average
VOLUME OF GAS SAMPLED, NCM (a)	3.1	2.8	3.0	3.1	2.9	3.0
PERCENT MOISTURE BY VOLUME	11.8	11.4	11.4	13.2	11.9	12.2
AVERAGE STACK TEMPERATURE, C	45	41	43	46	44	44
STACK VOLUMETRIC FLOW RATE, NCMM (b)	3739	3541	3930	3836	3887	3884
STACK VOLUMETRIC FLOW RATE, CMM (c)	4962	4619	5157	5195	5161	5171
PERCENT ISOKINETIC	106.4	103.3	100.5	103.8	97.1	100.6
PERCENT EXCESS AIR	1072	1786	2411	2267	1595	2091
PERCENT OPACITY	15	20	25	13	20	19
FEED RATE, MTON/HR	ND	ND	ND	ND	ND	ND
PARTICULATES - PROBE,CYC,FILTER CATCH						
MG	244.4	328.1	239.5	376.9	214.2	276.9
MG/NCM -	87.3	127.4	85.1	134.5	80.6	100.4
MG/CM -	65.7	97.5	65.5	99.2	60.6	75.1
KG/HR -	19.6	27.1	20.3	30.9	18.8	23.3
KG/MTON FEED	ND	ND	ND	ND	ND	ND
PARTICULATES - TOTAL CATCH						
MG	299.7	448.2	342.9	461.4	300.2	368.2
MG/NCM -	107.1	174.1	123.2	164.6	112.9	133.6
MG/CM -	80.6	133.3	93.8	121.4	85.0	100.1
KG/HR -	24.0	37.0	29.0	37.9	26.3	31.1
KG/MTON FEED	ND	ND	ND	ND	ND	ND
PERCENT IMPINGER CATCH	19.5	26.9	30.1	18.3	28.6	

ND - No Data.

(a) Normal cubic meter (dry) at 20.0 C, 760 mm Hg.
(b) Normal cubic meters per minute (dry) at 20.0 C, 760 mm Hg.
(c) Actual cubic meters per minute.

Inlet and outlet volumetric flow rates compare reasonably well when considering the relatively poor inlet sampling location. Insufficient downstream stack diameters from the inlet sampling location did not allow sufficient time to establish a uniform flow profile; the end result being a poor velocity profile which could be a reasonable explanation for the inlet and outlet volumetric flow rate difference.

Moisture condensation in the outlet stack and reentrainment of water droplets resulted in the effluent gases being supersaturated and, thus, the stack gas moisture content of the gases was greater than the moisture corresponding to the dew point.

Complete particulate results by computer, which include additional operational data, and sample calculations for outlet Run No. 4 can be seen in Appendix A.

Total Solids in Scrubber Outlet Water

Solids in the scrubber water samples were determined by passing a 50-ml aliquot of the scrubber water through a tared 45-mm glass fiber filter. The sample was then dried to a constant weight. Table 11 shows the results for the indicated runs.

TABLE 11. SCRUBBER WATER ANALYSIS

Outlet Run No.	Total Solids, percent
2	7.64
3	8.69
4	7.74
5	6.94

Opacity Measurements

Visible emissions were observed by two BCL certified smoke readers simultaneous with particulate sampling. During the five runs, opacity values ranged from 10-30 percent. Particulate sampling was terminated during periods of time when the venturi scrubber was malfunctioning. Opacity readings for the most part were taken during all periods. A complete summary of the data is presented in Appendix B-1 and B-2. Tables 12 and 13 are computer summaries of Appendices B-1 and B-2 and list the frequency each observer exceeded the stated opacities.

In order to make it easier to interpret this large amount of data a graphic presentation of each run has been prepared and is presented in Figures 11 through 15. Each graph shows the percent opacity as a function of time of day for the total reading period for each test. Runs 3 and 5 have been divided into A and B sections because of relatively long interruptions in opacity observations and also to facilitiate computer data reduction. Also shown on the graphs, by means of horizontal arrows, are the time periods during which "Particulate Sampling" occurred. These graphs make it possible to quickly determine the ranges of visible emissions during particulate sampling times for each of the five test runs. Because opacity readings were continued when scrubber malfunctions occurred, abnormal values of visible emissions may have been observed. Emphasis should be placed only on the visible emission data obtained during particulate sampling. Figure 11 shows the relative positions of the observation sites with respect to the outlet stack and adjacent structures. Site B was used for opacity reading in the mornings and Site A in the afternoons.

TABLE 12. FREQUENCY OBSERVATION AVERAGES EXCEEDING STATED OPACITY FOR PARTICULATE SAMPLING ONLY

FREQUENCY OBSERVER AVERAGE EXCEEDS STATED OPACITY:

	Run No. 1		Run No. 2		Run No. 3A		Run No. 3B	
	PLCHR	SNYDR	PLCHR	SNYDR	PLCHR	SNYDR	PLCHR	SNYDR
30%	0	0	3	5	10	0	0	0
25%	0	0	5	10	14	3	0	0
20%	0	2	8	14	17	17	0	3
15%	3	5	17	20	18	19	5	4
10%	6	7	22	22	18	20	5	4
5%	7	7	22	22	18	20	5	4
0%	7	7	22	22	18	20	5	4

FREQUENCY OBSERVER AVERAGE EXCEEDS STATED OPACITY:

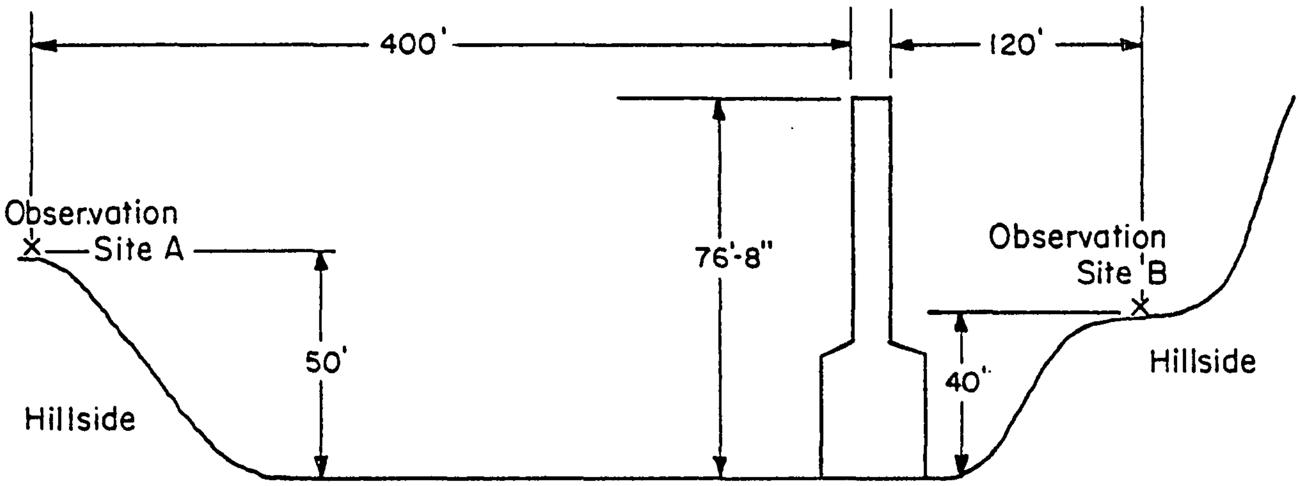
	Run No. 4		Run No. 5A		Run No. 5B	
	PLCHR	SNYDR	PLCHR	SNYDR	PLCHR	SNYDR
30%	0	0	0	0	0	0
25%	0	0	0	0	1	5
20%	0	1	0	1	6	11
15%	5	7	0	4	9	13
10%	21	20	8	10	10	13
5%	21	22	8	10	10	13
0%	21	22	8	10	10	13

TABLE 13. FREQUENCY OBSERVATION AVERAGES EXCEEDING STATED OPACITY FOR TOTAL OPACITY DATA

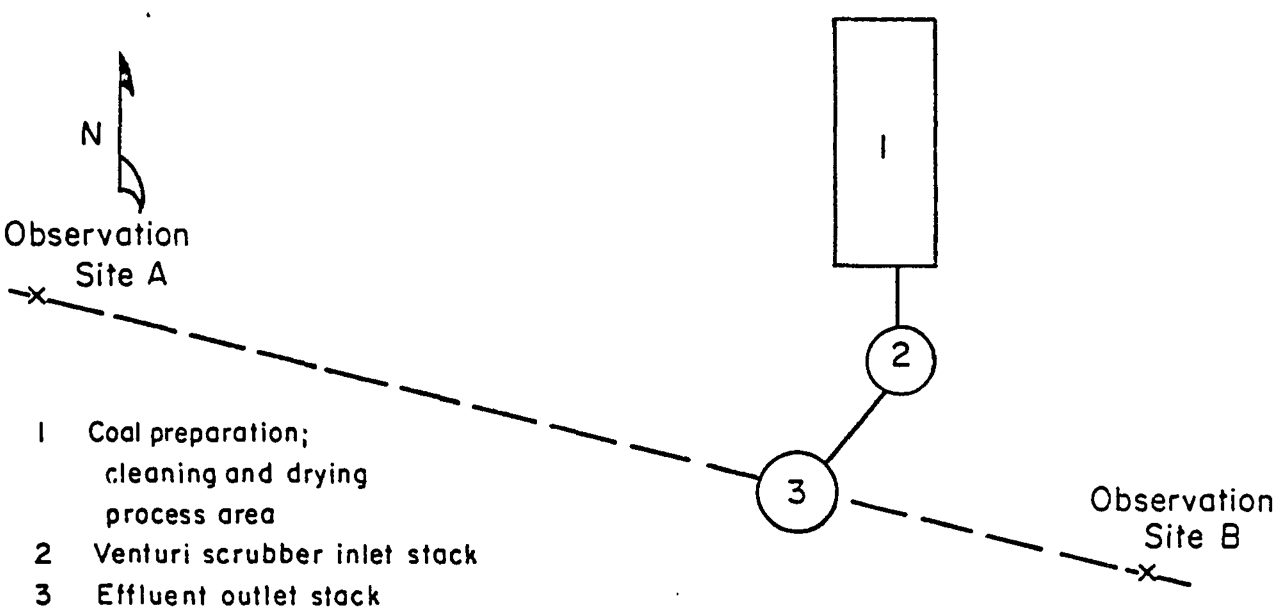
FREQUENCY OBSERVER AVERAGE EXCEEDS STATED OPACITY:

	Run No. 1		Run No. 2		Run No. 3A		Run No. 3B	
	FLCHR	SNYDR	FLCHR	SNYDR	FLCHR	SNYDR	PLCHR	SNYDR
30%	0	0	2	6	11	0	0	0
25%	0	0	6	11	15	4	0	0
20%	0	2	9	17	23	19	0	5
15%	3	5	22	24	25	27	4	11
10%	6	7	27	26	25	28	11	12
5%	7	7	27	26	27	29	11	12
0%	7	7	27	26	27	29	11	12

	Run No. 4		Run No. 5A		Run No. 5B	
	FLCHR	SNYDR	PLCHR	SNYDR	PLCHR	SNYDR
30%	3	0	0	1	2	2
25%	3	0	2	5	3	2
20%	3	2	14	25	4	4
15%	4	9	25	28	6	7
10%	19	23	29	30	15	14
5%	34	35	29	30	15	14
0%	35	35	29	30	15	14



Cross-Sectional View



Top View

FIGURE 10. OPACITY OBSERVATION SITES

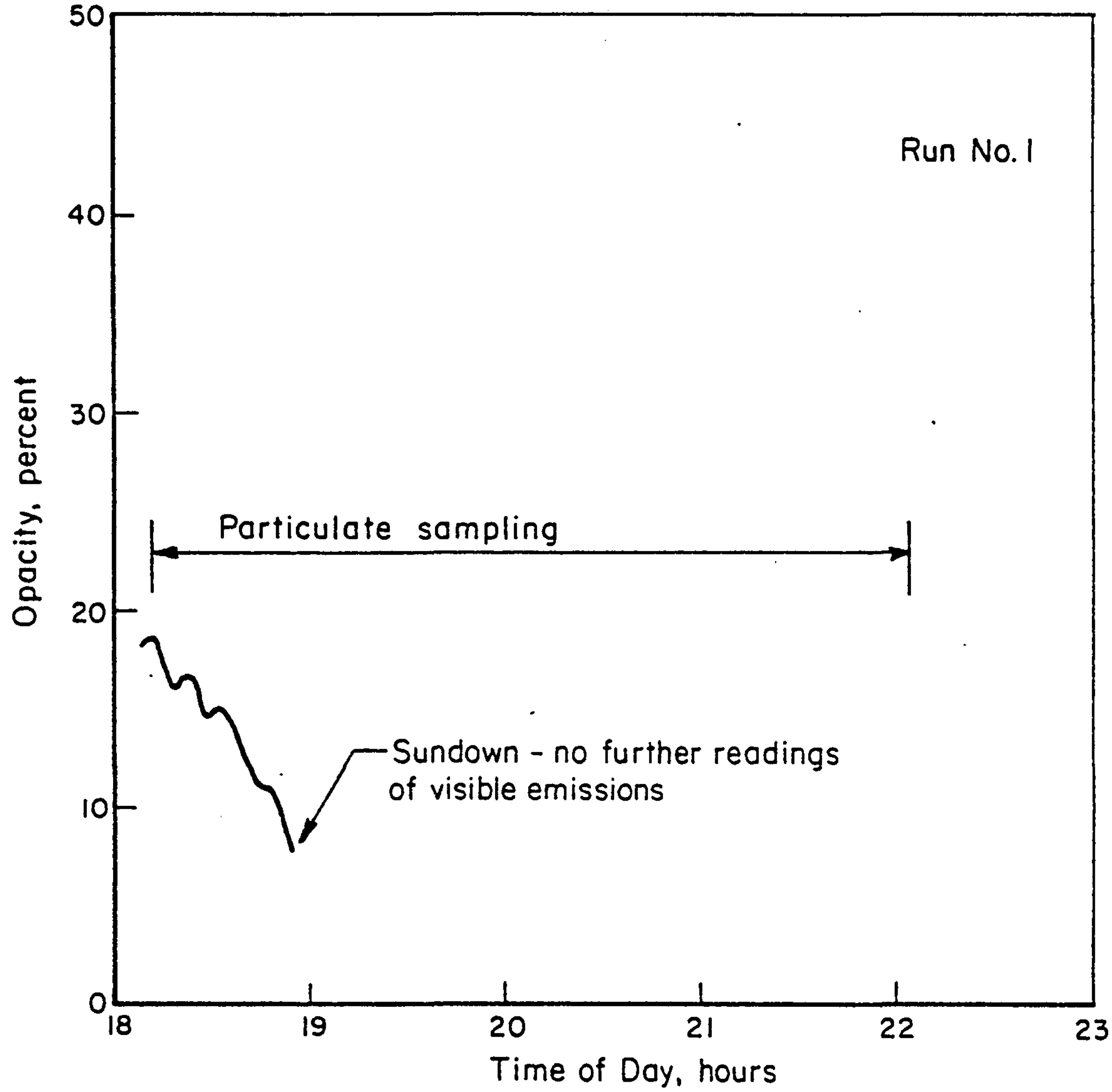


FIGURE 11. RUN NO. 1 OPACITY RESULTS AS A FUNCTION OF TIME OF DAY

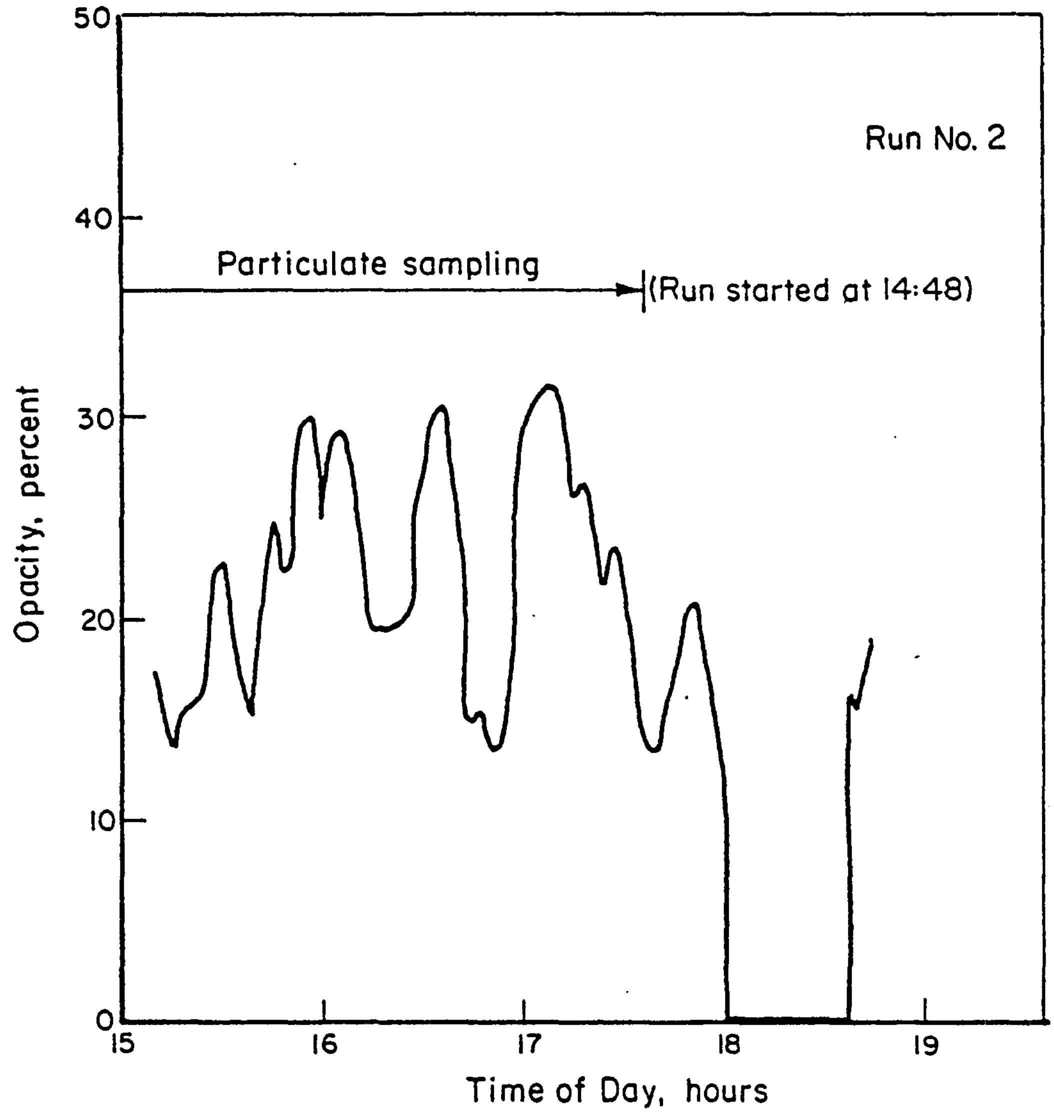


FIGURE 12. RUN NO. 2 OPACITY RESULTS AS A FUNCTION OF TIME OF DAY

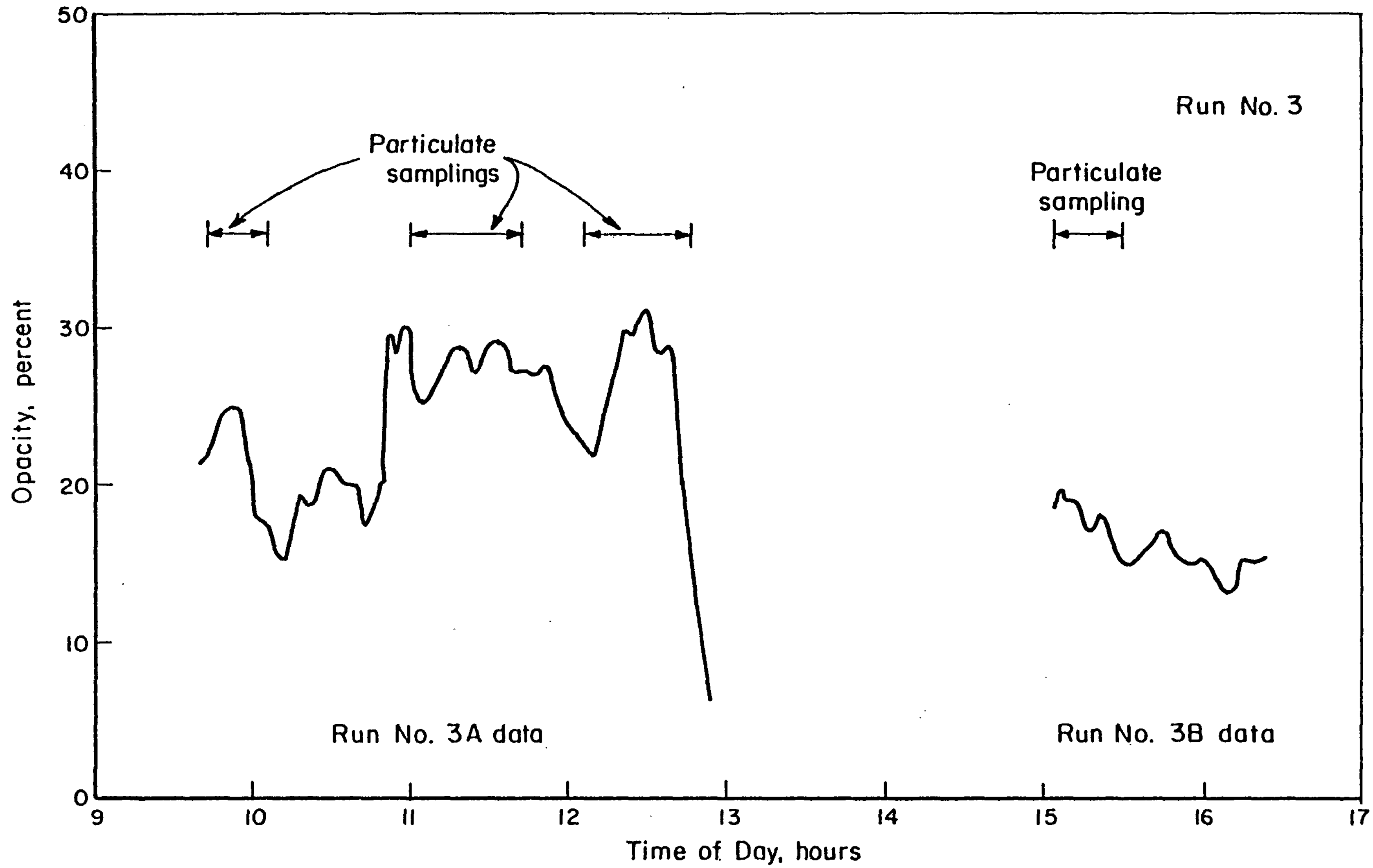


FIGURE 13. RUN NO. 3 OPACITY RESULTS AS A FUNCTION OF TIME OF DAY

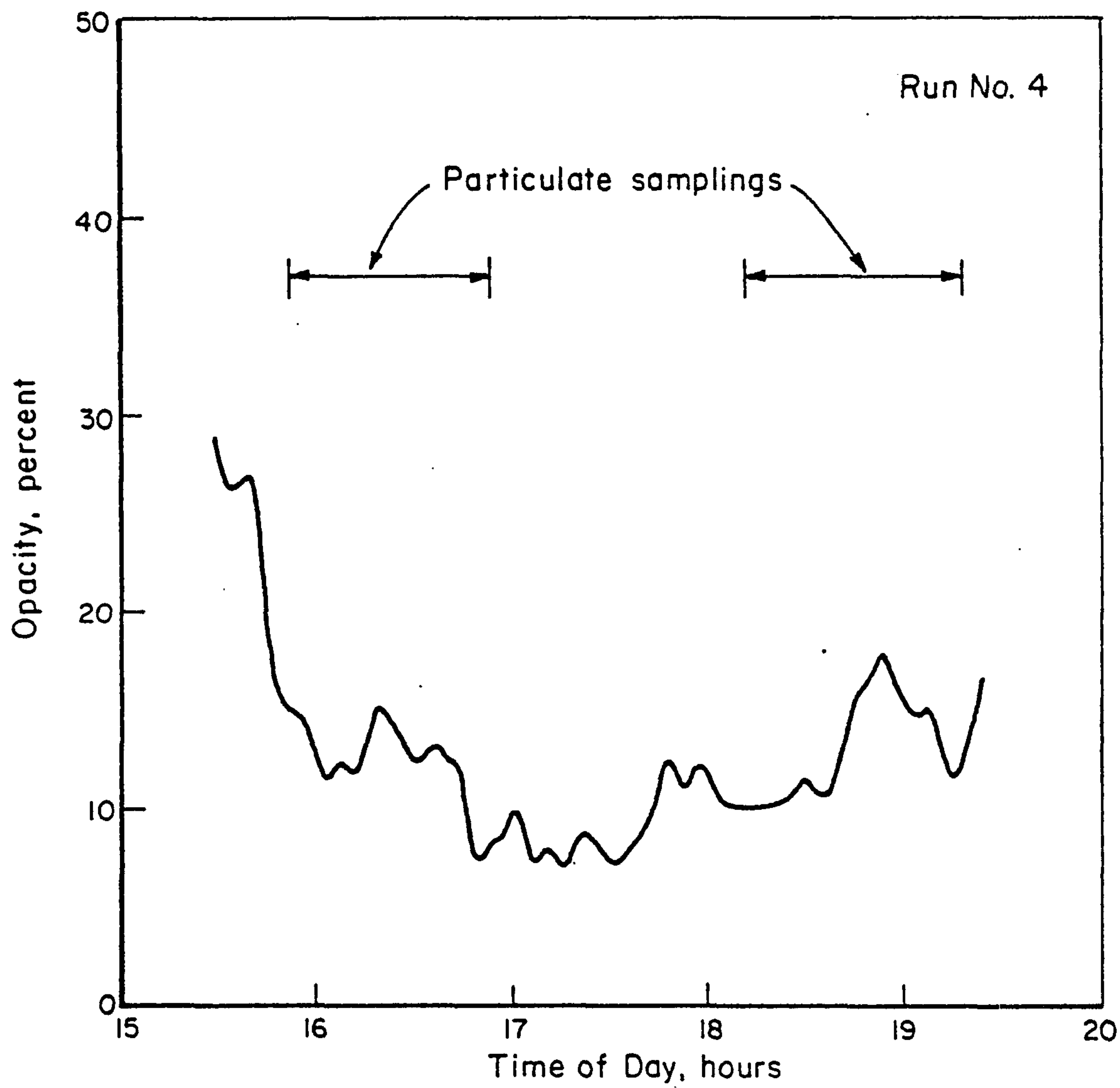


FIGURE 14. RUN NO. 4 OPACITY RESULTS AS A FUNCTION OF TIME OF DAY

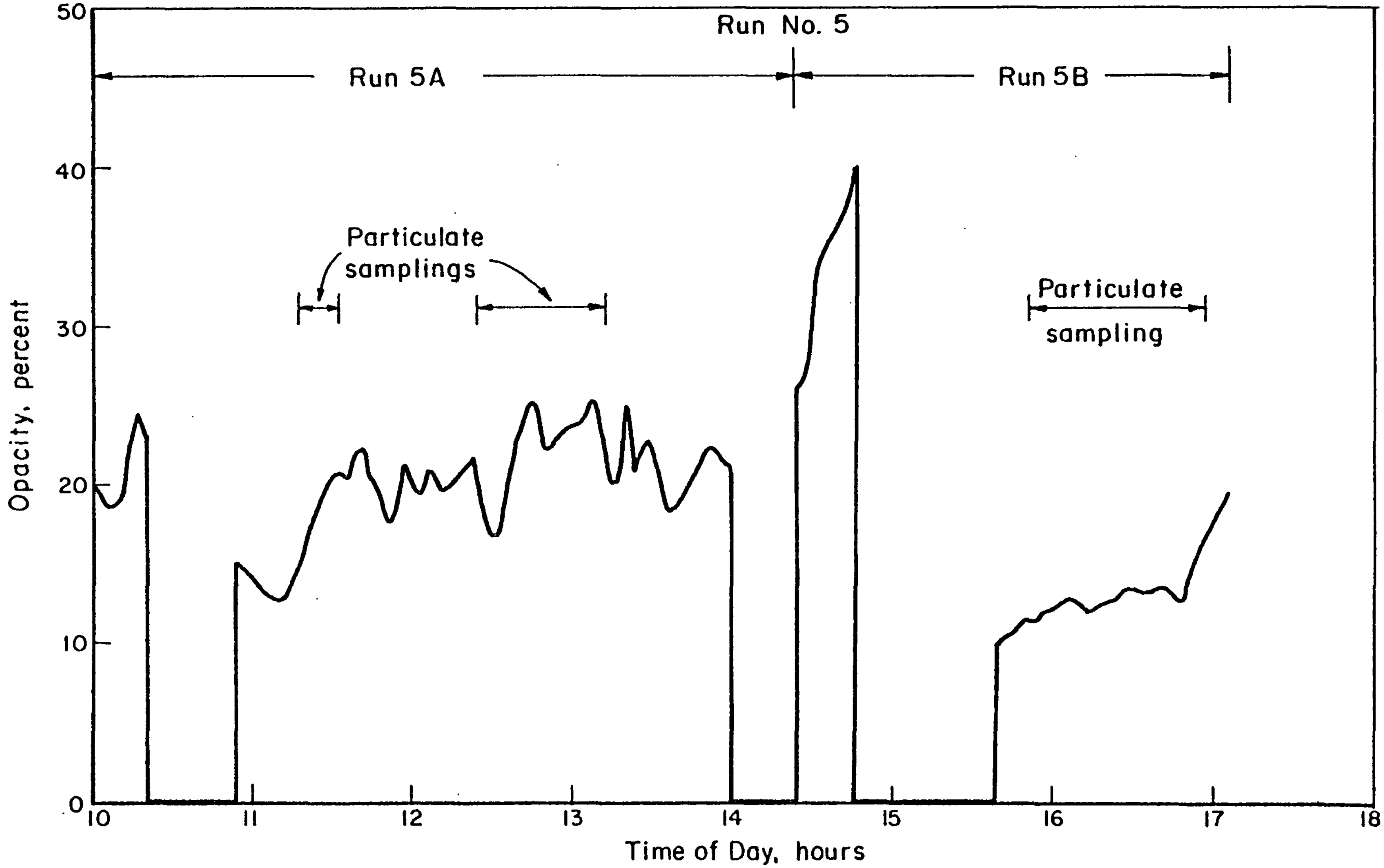


FIGURE 15. RUN NO. 5 OPACITY RESULTS AS A FUNCTION OF TIME OF DAY

Data Applicable to All Five Runs

The following data, required by the EPA "Guidelines for Preparing Summary of Visible Emissions", apply to all five of the test runs.

Type of Plant: Coal cleaning

Type of Discharge: Emissions from thermal dryer

Location of Discharge: Stack above dryer

Height of Point of Discharge: 76 feet, 8 inches above ground level

Distance from Observer to Discharge Point:

Site A: 400 ft northwest of stack
Site B: 120 ft southeast of stack

Height of Observation Point:

Site A: 50 ft above base of stack
Site B: 40 ft above base of stack

Direction of Observer from Discharge Point:

Site A: northwest of stack (in afternoon)
Site B: southeast of stack (in morning)

The remaining data called for in the EPA guidelines are different for each run and are presented in Table 14. An examination of Figures 11 through 15 show the opacity ranges as follows.

Test Run 1 - Opacity ranged from about 8 to 18 percent during the 50 minutes of observations prior to sundown.

Test Run 2 - Opacity ranged from about 14 to 31 percent during time of particulate sampling which extended from 1448 to 1736 hours.

Test Run 3A - Opacity ranged from 22 to 31 percent.

Test Run 3B - Opacity ranged from 15 to 20 percent.

Test Run 4 - Opacity ranged from about 7 to 18 percent during the times of particulate sampling which were 1552 to 1655 hours and 1811 to 1917 hours.

Test Run 5A - Opacity ranged from about 17 to 25 percent during the first two particulate sampling periods.

Test Run 5B - Opacity ranged about 12 percent at the start of the third particulate sampling period.

TABLE 14. OPACITY OBSERVATION SUMMARY

Run No.	Date (1975)	24 Hr. Clock Time	Observation Site	Description of Background	Description of Sky	Wind Direction	Wind Velocity, mph	Color of Plume	Comments	Duration of Observation
1	1/18/75	1809-1859	A	Sky	20% clouds	from NNW	0-5	Black with steam plume near stack	Black plume obscured by attached steam plume sometimes extending 200 ft above stack	50 min; discontinued at sundown (7:00 p.m.)
2	6/19/75	1510-1850	A	Sky	50% clouds	from SW	5-10	Black with steam plume near stack	Black plume obscured by attached steam plume up to 75 ft above stack	3 hrs, 40 min
3A	6/20/75	0940-1300	B	Sky	Overcast (100% clouds)	from NE	0-5	Black with steam plume attached to stack	Black plume obscured by attached steam plume extending 100 to 200 ft above stack	3 hrs, 20 min
3B	6/20/75	1504-1628	A	Sky	Overcast (100% clouds)	from NE	0-5	Black with steam plume attached to stack	Black plume obscured by attached steam plume extending 50 to 100 ft above stack	1 hr, 24 min
4	6/23/75	1530-1930	A	Sky	Overcast (100% Clouds)	from NW but variable	0-5	Black with steam plume attached to stack	Black plume obscured by attached steam plume extending 75 to 250 ft above stack	4 hrs
5A	6/25/75	1004-1400	B[(a)]	Sky	Slightly overcast (10% clouds)	from NE	0-5	Black with steam plume attached to stack	Steam plume extended 50 to 125 ft above stack	3 hrs, 56 min
5B	6/25/75	1430-1715	A	Sky	Slightly overcast (10% clouds)	from NE	0-5	Black with steam plume attached to stack	Steam plume extended 50 to 125 ft above stack	2 hrs, 45 min

(a) Moved to Site A at 1310 hours.

Trace Metal Results

The catch from Run No. 4 was analyzed for trace metals and the results are shown in Table 15. For the most part these data are considered to be representative of what one might expect from coal. The results must be interpreted with consideration of mass for each sample. The ppm values, as presented, tend to be misleading if one does not relate the indicated ppm values to the associated sample mass (as presented at the bottom of the table) to obtain the mass per sample of each element. The major constituents based on the mass collected on probe and filter catch are iron, potassium, sodium, and zinc. Relatively small amounts of other elemental constituents were picked up in the acetone rinse of the impingers but are insignificant when considering their relative mass. Silicon, being the predominant metal, is most likely present due to its occurrence in coal ash. However, some portion of the silicon may represent fragments of filter picked up during the probe-and-filter-holder acetone rinse.

LOCATION OF SAMPLING POINTS

Inlet to Venturi Scrubber

Particulate samples were collected from the scrubber inlet gases using an Alundum thimble in conjunction with a standard EPA Method 5 rig. A rather large port consisting of a 6-inch-diameter nipple was necessary to accept the special EPA series cyclone used to classify particle size. The cyclone had an overall height of 5-1/2 inches. Due to the high pressure drop across the scrubber (30 inches water pressure), it was necessary to fabricate a sealed holding chamber and sliding gate valve assembly (Figure 16) so that the sampling probe could be inserted into the stack against the high static pressure. The relatively large holding chamber would not allow complete traversing of one stack diameter

TABLE 15. OPTICAL EMISSION SPECTROSCOPY ANALYSIS FOR TRACE METALS (RUN NO. 4), PPM

Element	Samples(a,b) -441(1)	-441(2)	-442	-443	-444	-445
Hg	--	--	--	--	--	--
Be	1	1	<1	<1	<1	<1
Cd	<200	<200	<200	<10	<170	<285
As	<200	<200	<200	<10	<170	<285
V	30	30	30	<3	<60	<95
Mn	10	10	200	<3	10	70
Ni	50	50	100	<3	<60	190
Sb	<50	<50	<50	<10	<170	<285
Cr	50	50	300	<3	<60	95
Zn	1,000	1,000	300	<20	600	950
Cu	300	300	50	<3	<60	1,900
Pb	50	50	<20	40	120	190
Se	--	--	---	--	--	--
B	100	200	200	<3	170	280
F	--	--	--	--	--	--
Li	<600	<600	<600	<25	<570	<950
Ag	<1	<1	150	10	30	50
Sn	10	10	<10	115	570	1,900
Fe	3,000	3,000	6,000	<3	400	570
Sr	50	20	100	10	<15	70
Na	2,000	2,000	2,000	115	570	2,900
K	3,000	3,000	2,000	45	860	2,400
Ca	500	500	1,000	370	<60	1,900
Si	--	--	15,000	100	1,700	1,900
Mg	300	300	600	45	<60	1,600
Ba	50	50	100	3	60	285

(a) Descriptions of Sample Nos. S75-001-441 through -445 and Blank Nos. -493 through -496 are as follows:

		Wt (Solid), mg	Vol (Liquid), ml
-441	Glass fiber filters (2 each)	54.3/54.1	--
-442	Acetone, wash of front half	268.8	160
-443	Impinger catch and water rinse	87.0	815
-444	Chloroform/ether extraction	3.5	150
-445	Final acetone rinse of back half	2.1	325
-493	Glass fiber filter (3 each)	0	--
-494	Acetone blank, Burdick and Jackson Lot #7150	0.4	200
-495	Demineralized double distilled water, OSU	1.6	200
-496	Chloroform/ether, Baker A.R.	1.9	150 .

(b) Background Subtracted.

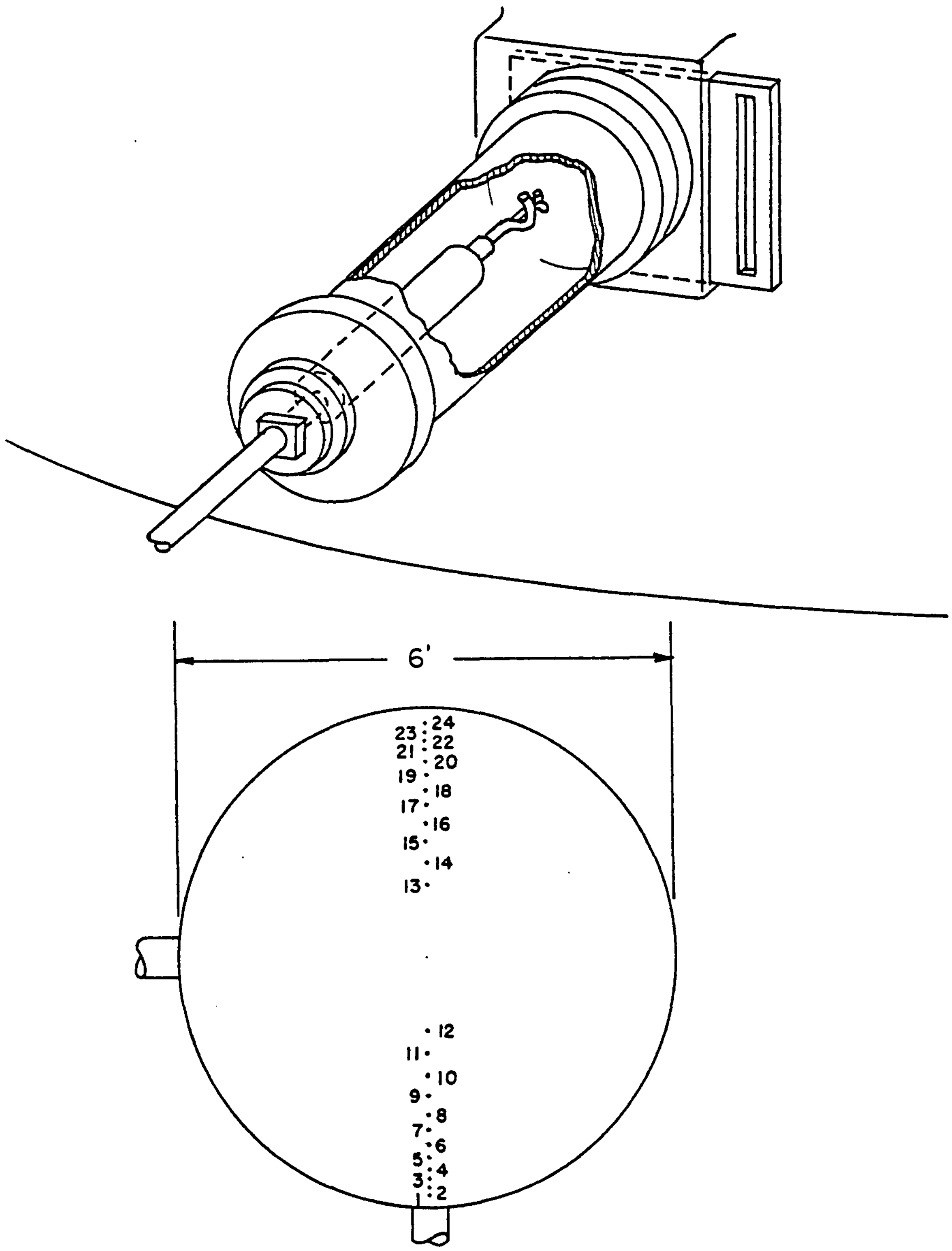


FIGURE 16. INLET STACK SPECIAL ADAPTER WITH GATE VALVE SHOWING POSITION OF ALUNDUM THIMBLE PRIOR TO SAMPLING

due to insufficient probe length; therefore, the second half of the stack was traversed without the holding chamber. Working conditions were very undesirable because of the hot exhaust gases (180-200 F) escaping through the 6-inch-diameter nipple at approximately 300 cfm. During the second half of each of the two stack traverses, the gate valve was opened, the probe was inserted into the stack against the flow of hot exhaust gases, the 6-inch pipe reducing coupling was threaded into the valve assembly, and traversing continued.

Figure 17 shows the inlet stack geometry relative to sampling locations. According to the December 23, 1971, Federal Register[3], Method 1, sampling two diameters upstream and less than one diameter downstream from a disturbance requires at least 48 sampling points, 24 on a diameter as indicated on Figures 16 and 17. Specific distances for traverse points are given in Table 16.

Outlet of Mist Eliminator

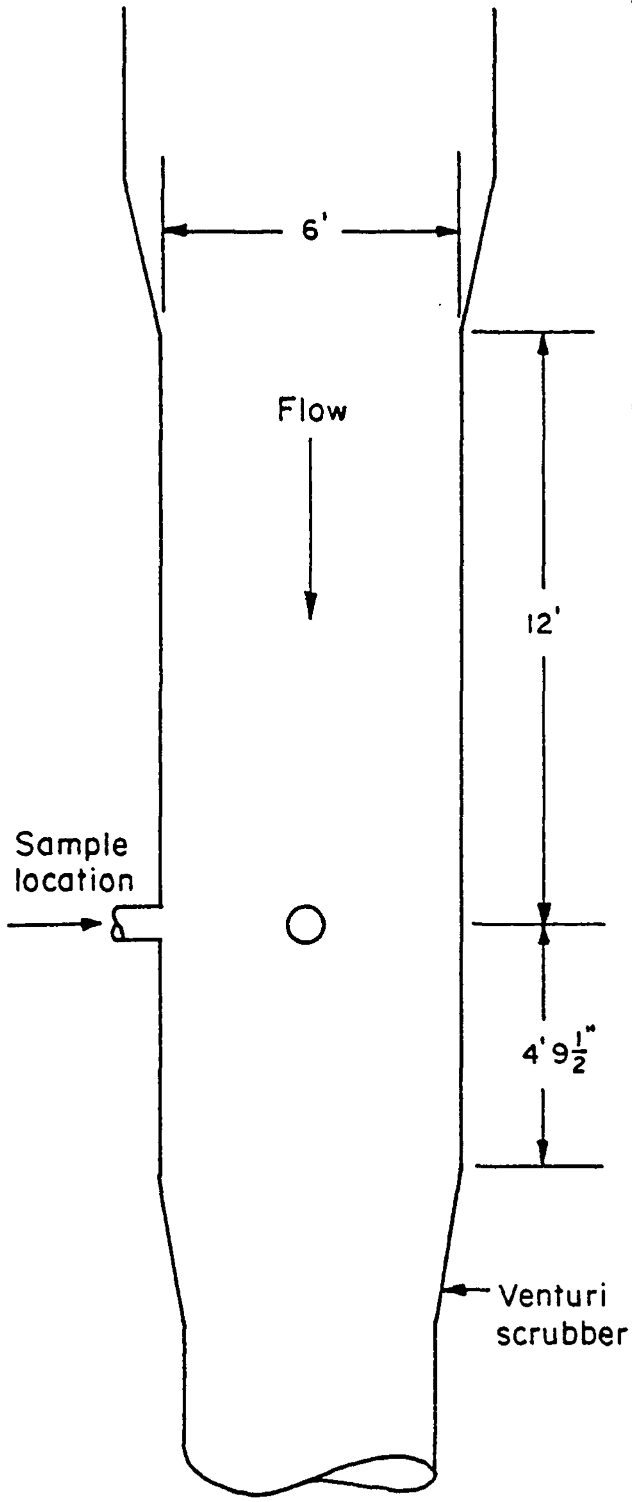
Particulate and gaseous emissions were sampled at the outlet of the mist eliminator. Figure 18 shows the geometry relative to the sampling locations. According to the December 23, 1971, Federal Register, Method 1, 22 sampling points per stack diameter were required relative to the associated upstream and downstream stack diameters. Table 17 shows specific distances for traverse point locations.

Prior to outlet particulate sampling, it was necessary to install straightening vanes to reduce the cyclonic swirl caused by the mist eliminator. This was accomplished by the insertion of two 8-foot lengths of metal at right angles to each other as depicted in Figure 18.

TABLE 16. TRAVERSE PORT LOCATIONS--INLET

Point	Percent of Diameter	Distance from Outside of Sample Port[a], in.	Point	Percent of Diameter	Distance from Outside of Sample Port[b], in.
1	1.1	41	13	60.2	57-3/8
2	3.2	42-1/8	14	67.7	61-3/4
3	5.5	44	15	72.8	65-3/8
4	7.9	45-3/4	16	77.0	68-1/2
5	10.5	47-5/8	17	80.6	69
6	13.2	49-1/2	18	83.9	73-3/8
7	16.1	51-5/8	19	86.8	75-1/2
8	19.4	54	20	89.5	77-1/2
9	23.0	56-5/8	21	92.1	79-1/4
10	27.2	59-5/8	22	94.5	81
11	32.3	63-1/4	23	96.8	82-3/4
12	39.8	68-5/8	24	98.9	84

(a) Using "holding chamber".
(b) Using "short nipple".



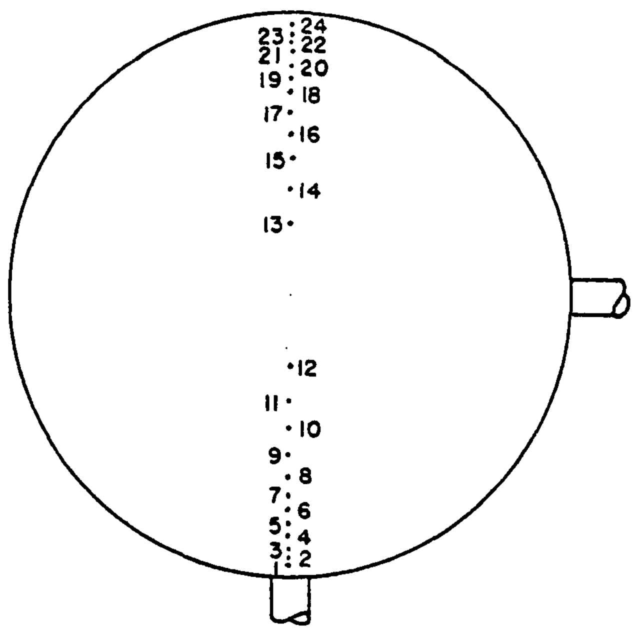


FIGURE 17. INLET STACK GEOMETRY SHOWING SAMPLING LOCATION AND SAMPLE POINT CONFIGURATION

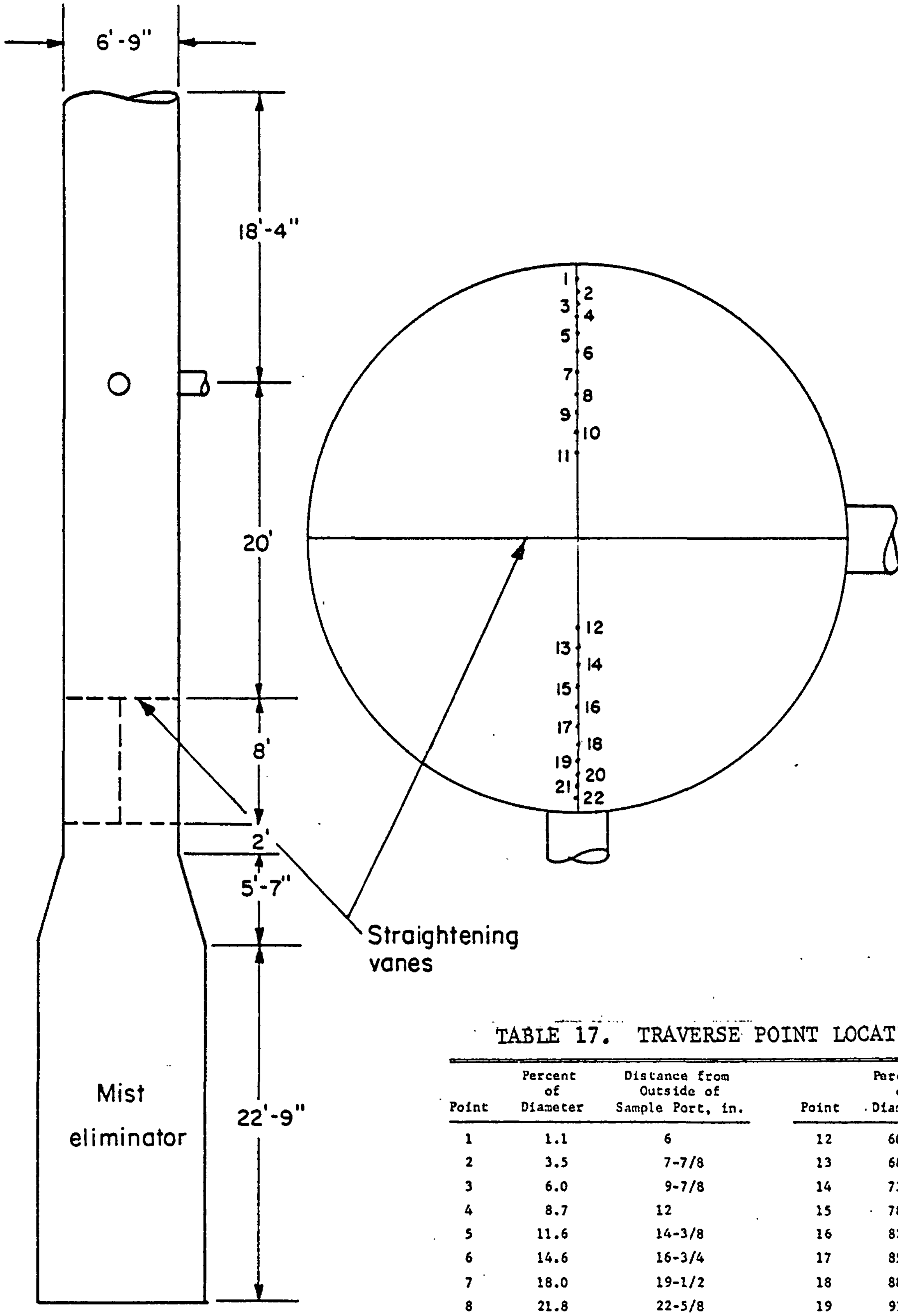


TABLE 17. TRAVERSE POINT LOCATIONS --OUTLET

Point	Percent of Diameter	Distance from Outside of Sample Port, in.	Point	Percent of Diameter	Distance from Outside of Sample Port, in.
1	1.1	6	12	60.7	54
2	3.5	7-7/8	13	68.5	60-3/8
3	6.0	9-7/8	14	73.9	64-3/4
4	8.7	12	15	78.2	68-1/4
5	11.6	14-3/8	16	82.0	71-1/4
6	14.6	16-3/4	17	85.4	74
7	18.0	19-1/2	18	88.4	76-1/2
8	21.8	22-5/8	19	91.3	78-3/4
9	26.1	26-1/8	20	94.0	81
10	31.5	30-1/2	21	96.5	83
11	39.3	36-3/4	22	98.9	84-3/4

FIGURE 18. OUTLET STACK GEOMETRY SHOWING SAMPLING LOCATION AND SAMPLE POINT CONFIGURATION

PROCESS DESCRIPTION AND OPERATION

The Westmoreland Coal Company installation near Quinwood, West Virginia in Nicholas County thermally dries Pocahontas No. 3 Sewell and Dorchester-Imboden coal. The demand for thermal drying is due to freight rate savings, the elimination of handling problems due to freezing, and the needs of the customer's process (coke ovens must control bulk density and power plants must control plugging of pulverizers). A venturi scrubber is used to control particulate emissions from the thermal dryer. Tests for particulate emissions were conducted on the thermal dryer exhaust only during periods of typical plant operations.

Process Description

Coal is delivered to the plant and is crushed to a variety of sizes. It is then washed, screened and separated by both water tables and concentration tables. The coal washing is a continuous process and reduces ash content from 16 percent to 3 percent.

The coal that is thermally dried, the 3/8 x 0-inch coal or the slack is dewatered by shaker tables and vacuum discs and then dried to 2.0 percent to 3.5 percent surface moisture in a thermal dryer. Coal drying is accomplished by use of flue gas (produced by a coal-fired furnace) reduced in temperature by dilution air. The emissions from the fluidized bed thermal dryer are exhausted to a chamber loaded with 40 or more multiclones which separate much of the fine dust from the emissions. The finer dust particles pass from the multiclones of the dryer through a high pressure blower to a venturi scrubber and a demister where over 95 percent of the particles are collected. The emissions to the atmosphere are ducted via an 81-inch diameter stack. Figure 19 is a sketch of the thermal dryer system. The design capacity of the thermal dryer is 270 ton/hr of coal at approximately 250 F. The plant is usually operated at two-thirds to three-fourths of this rate because of the moisture level. The actual operating capacity of the dryer is limited by the tons of water evaporated per hour rather than the amount of coal being processed. The plant runs on a schedule of two 8-hour shifts and is typically closed on weekends.

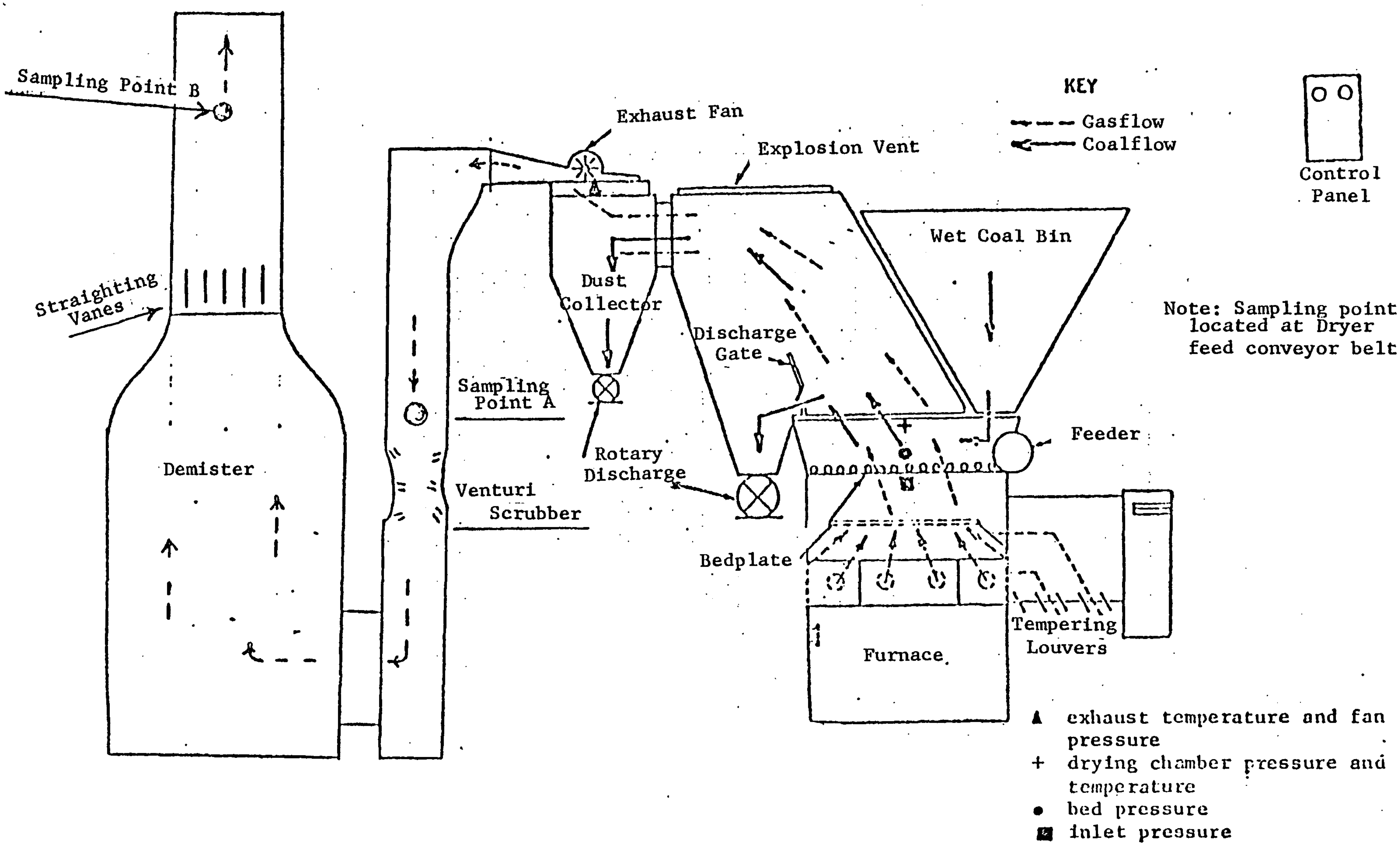


FIGURE 19. EXHAUSTING-TYPE FLUIDIZED-BED THERMAL COAL DRYER, SHOWING COMPONENT PARTS AND FLOW OF COAL AND DRYING GASES, WESTMORELAND COAL COMPANY, IMPERIAL SMOKELESS DIVISION, QUINWOOD, WEST VIRGINIA

Emission Control Equipment

The thermal dryer exhausts into a cyclone separator where the large particles are removed. Next, the exhaust is blown into the venturi scrubber where the fine particles are impacted upon water droplets which are removed from the effluent gases by the mist eliminator. From there, the exhaust gases exit the mist eliminator and go out the stack. The fan volume is rated at 134,000 cfm for the maximum design capacity of 270 ton/hr. The pressure drop across the venturi scrubber is 32 in. H_2O, 3 to 4 in. H_2O attributable to the mist eliminator.

Process Operation

Samples were collected from the inlet and outlet gases to the venturi scrubber control equipment. Opacity observations and dryer feed samples were gathered concurrently. Each test run is described as follows.*

June 18, 1975 - Refer Appendix E Run 1

Test went well with only one interruption that occurred due to low feed. Also, Sewell No. 3 strip mined coal was used for the majority of the time instead of Sewell deep-mined coal. Though the data are not suitable for evaluation of Sewell No. 7, they do provide an interesting comparison between the two coal mining methods.

June 19, 1975 - Refer Appendix E Run 2

The test had only two interruptions but process operations were unsteady. Feed to thermal dryer was discontinued, problems with the water supply to the venturi scrubber were suspected, and the supply of raw coal to the plant was inconsistent. These data are not typical of routine operation. Repairs were made to the venturi scrubber water supply system prior to commencing the next test.

June 20, 1975 - Refer Appendix E Run 3

The test was very good, even though it was necessary to temporarily suspend sampling twice due to process malfunctions. Process on the whole operated very smoothly, and during actual testing was very consistent. The test data are representative of typical operations.

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*Run numbers are relative to outlet.

June 23, 1975 - Refer Appendix E Run 4

Test was very good with no delays at all. High drying chamber temperatures occurred for one-half hour from 4:45 to 5:20 p.m. but were not extreme.

June 24, 1975

Process shut down every half hour due to broken equipment. There was no continuity to process whatsoever. Testing was cancelled for the day.

June 25, 1975 - Refer Appendix E Run 5

Test very good. Sampling was interrupted briefly during two short process delays. Drying chamber temperatures were a bit high from 12:30 p.m. to 1:05 p.m. and from 4:40 p.m. to 5:03 p.m. but were not abnormal.

June 26, 1975 - Refer Appendix E

Several special inlet tests were done by Roy Neulicht. The first and second tests were good with no problems. The third and fourth tests had high but not normal drying chamber temperatures. All tests were conducted during the processing of Sewell No. 7 deep-mined coal except the fourth test which was Park Sewell or Sewell No. 3 strip-mined coal.

The production for the second half of Test No. 5 (June 25, 1975) was determined to be 180 ton/hr. The average process rate for that day, however, was only 137.7 ton/hr because of production stoppages (see Table 18). The rate during actual sampling was higher. The reason for this inconsistency is that testing was never done during process malfunctions or slow ups because of the abnormally high drying chamber temperatures that occur. The emission tests were conducted only during periods when conditions were typical of routine operation and the data, therefore, are representative of normal production.

TABLE 18. PRODUCTION RATES
(June 25, 1975)

Recorder	Time Period	Amount Time, minutes	Process Rate, ton/hr
Westmoreland Coal Co.	Both shifts	1035	137.7
EPA	10:00 to 11:18	438	158.9
EPA	14:55 to 16:18	83	187.9
EPA	16:18 to 17:18	60	180.0

SAMPLING AND ANALYTICAL PROCEDURES

Plant operations, by necessity, were monitored by EPA personnel prior to and during all sampling to ensure the validity of the measurements being presented in this report.

Standard EPA sampling methods, as reported in the December 23, 1971, Federal Register, were followed to obtain samples of gaseous emissions for CO_2, CO, and O_2. Samples of scrubber water and process coal were taken under the direction of the EPA Project Officer. Sample times are reported in the Sample Collection Log presented in Appendix D.

A temporary on-site lab facility was set up for equipment cleanup. Due to the nature of the process, it was important to isolate, as much as possible, the cleanup and analytical area from plant operations.

Analytical balances were set up in the temporary lab and mass determination of BCL inlet and outlet samples and for the EPA cyclone catches were determined on site after each run. All calculations pertinent to isokinetic sampling were determined after each run to ensure results were within EPA guidelines.

Coal Sample Collection Method

Representative samples of the process coal were collected for sieve analysis during each run. Figure 20 depicts the process feed system used at the Westmoreland Coal Company and also gives a pictorial diagram of how coal sample aliquots were collected.

The conveyor pushes the coal into a large hopper where it is fed into the dryer. The bulk or large mass of the coal falls into the hopper just as it passes the end of a stationary, inclined ramp. As the conveyor reaches the end of its travel and starts its return, additional coal which has adhered to the conveyor surface is thrown off and appears in the hopper as relatively fine particles.

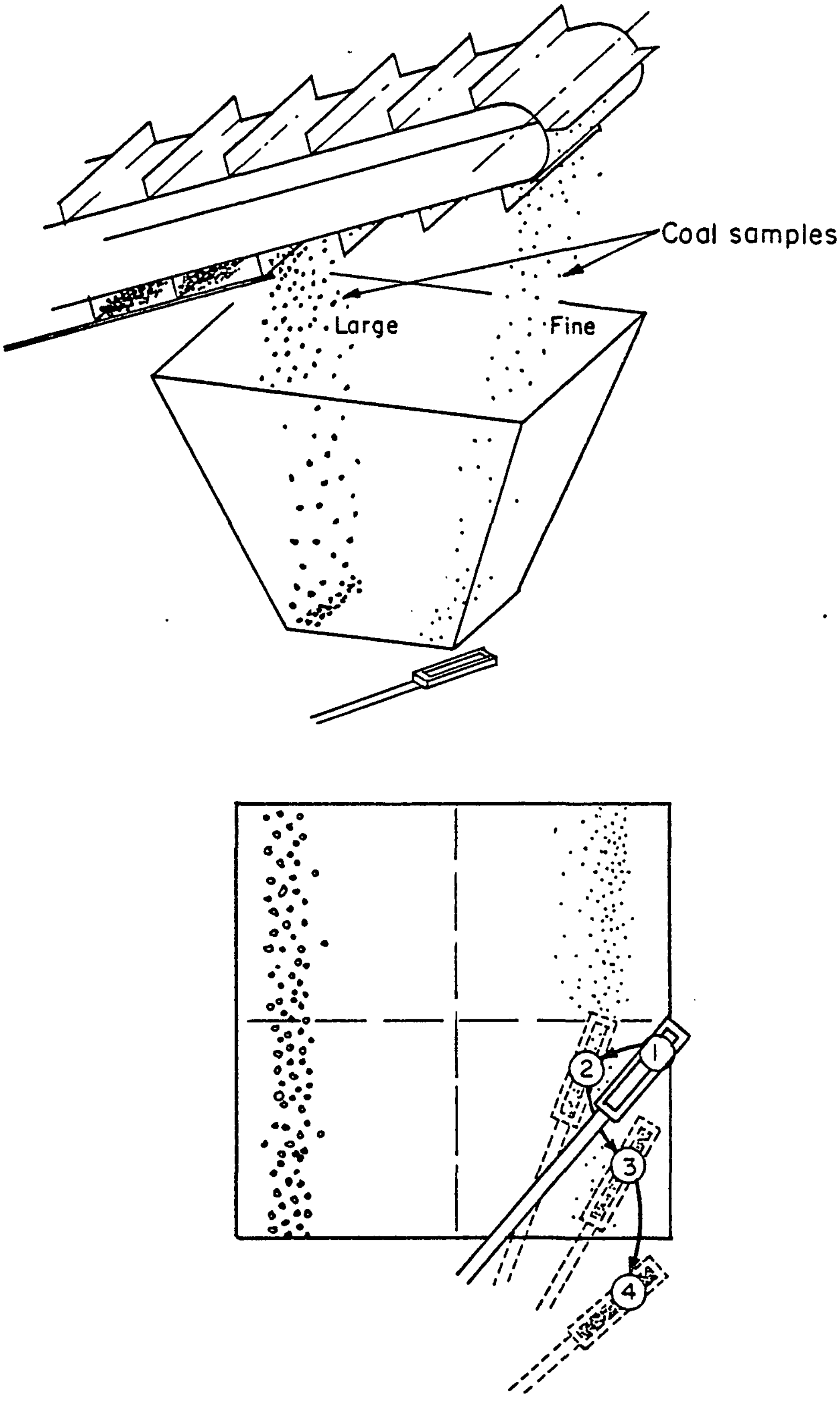

FIGURE 20. COAL SAMPLE COLLECTION METHOD

The hopper outlet coal samples were collected from each of four quadrants as depicted in Figure 20. The sample collector, fabricated according to ASTM standards[4], was inverted and placed behind the stream of coal as in Position 1. The collector was then turned upright and moved into and through the stream of coal as in Positions 2, 3, and 4. The sample collector was emptied into a sample container and the collection method was repeated for each of the other quadrants to obtain one composite sample. Three samples were collected each 15 minutes during the entire particulate sample run. The coal samples for each run were combined and a fraction was removed for sieve analysis according to ASTM Standards[4].

Scrubber Water Collection

To develop a better understanding of the operation and effectiveness of the venturi scrubber, samples of water which had passed through the venturi were collected at the outlet of the scrubber sump. Figure 21 is a simple schematic depicting the basic flow pattern of the scrubber system. As indicated, about 80 percent of the scrubber sump water is recirculated back to the venturi for reuse while the other 20 percent is sent to a static thickner where the particles collected in the scrubber water settle by gravitational forces. The scrubber water sample to be used for size distribution of the collected particles was taken from the 20 percent by-pass line as indicated. It is assumed that sufficient water flow is maintained in the recirculation system to allow a representative water sample to be collected relative to the associated outlet emission sampling. If this assumption is valid then a comparison can be made of the inlet particle size distribution and the associated particle size measured in the scrubber water. However, it should be noted that the particles collected in the scrubber water represent a time-averaged representation of the particles removed from the gas stream. The volume of the scrubber sump relative to the 20 percent discharge volume flow would indicate the extent of time averaging involved relative to the gas sampling time. Only if there exist steady-state scrubber operation and

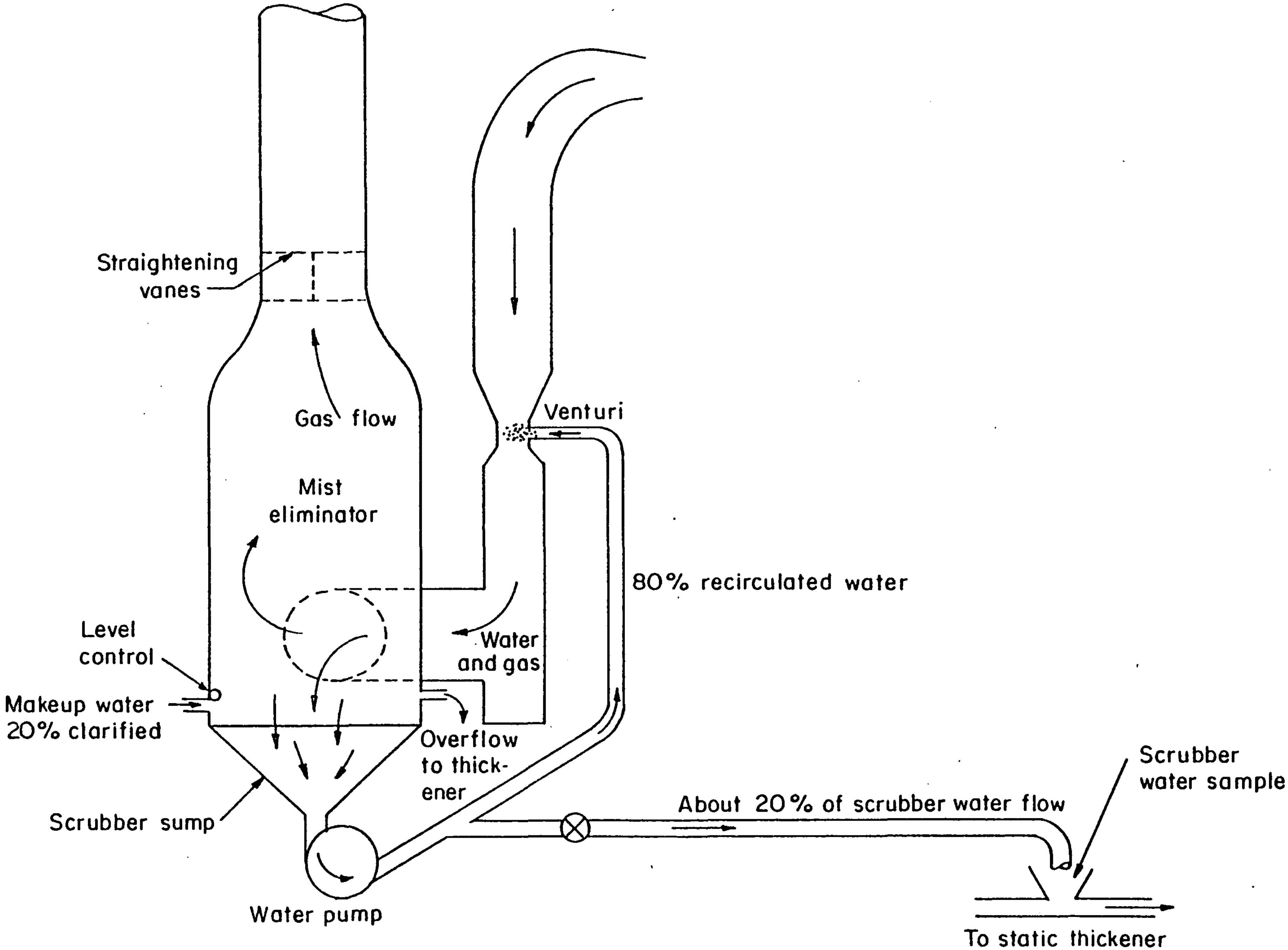

FIGURE 21. SCHEMATIC OF VENTURI SCRUBBER WATER FLOW SYSTEM

an unchanging gas borne particulate feed to the scrubber can the particles found in the scrubber be directly compared with gas samples for evaluating scrubber performance.

Particle Sizing Methodology

Particulate samples were collected by sampling the venturi scrubber inlet stack gases at an isokinetic rate into an Alundum thimble. During sampling, the thimble was located in the stack and was at stack gas temperatures, thereby minimizing condensation. Size distribution for particles collected in the thimbles, in a cyclone sampler, and from bulk coal samples were determined with a Coulter Counter[1]. A Mine Safety Appliance (MSA) Particle Size Analyzer[2] complemented Coulter Counter data relative to <325 mesh samples. The following questions were considered relative to analysis techniques which, if not applied properly, could alter the reported particle size distribution:

(1) What effect would sample drying have on the particle size distribution?

(2) Would particle dispersion by ultrasonic vibration alter the particle size distribution?

(3) What particle concentrations would be "generated" from thimble breakup during ultrasonic cleaning?

(4) If ultrasonic thimble cleaning were feasible because of insignificant thimble particle concentration, would it be possible to obtain a representative aliquot from a relatively large electrolyte volume?

(5) Since the MSA particle size analyzer utilizes various fluids to determine particle size from settling velocity, might the coal particles be soluble enough in the fluids to affect their sizes?

Experimental efforts were undertaken to answer these questions so that a valid experimental procedure for size distribution measurements could be established. The following particle size distribution results are an average of three runs per aliquot, which is a routine procedure for Coulter Counter analyses. One aliquot per sample was taken for Coulter Counter analyses and one aliquot per sample was taken for analyses by the Mine Safety Appliance Particle Size Analyzer.

Distribution Change Due to Drying[a]

It was determined by desiccator drying of samples collected in thimbles at the scrubber inlet that they contained <1.0 percent moisture; therefore, particle size change due to drying was expected to be insignificant. This was verified by Coulter Counter size analyses as shown in Figure 22. Only slight differences between the particle size distribution curves of "undried" or "dried" samples are seen. These differences are considered to be within experimental error and, hence, no effect of coal sample drying was found.

The bulk process coal samples were wet when collected and, therefore, a change in particle size distribution due to drying was considered. An extra bulk feed coal sample was divided into two equal portions according to ASTM standards[4]. One half was dried at 100 F and sieved dry. The other half was sieved wet to determine if the size distribution would show a difference. Figure 23 shows the results of these measurements which indicate essentially no difference except in the pan catch (<325 mesh or <44 μm) which shows a slightly higher catch for the wet sieving. This could be attributed to experimental error or possibly the loss of the relatively fine catch during the drying process.

Effect of Ultrasonic Dispersion
Compared with Mechanical Dispersion

Before particle dispersion by ultrasonic techniques could be utilized, it was necessary to determine to what extent the particle size distribution would be altered by ultrasonic dispersion techniques and what procedures were sufficient to assure adequate dispersion. A sample

(a) The effects of drying on size distribution were determined with coal samples which may not have been representative aliquots and, therefore, the data can only be considered relative with respect to size distribution and are valid only for evaluating drying effects.

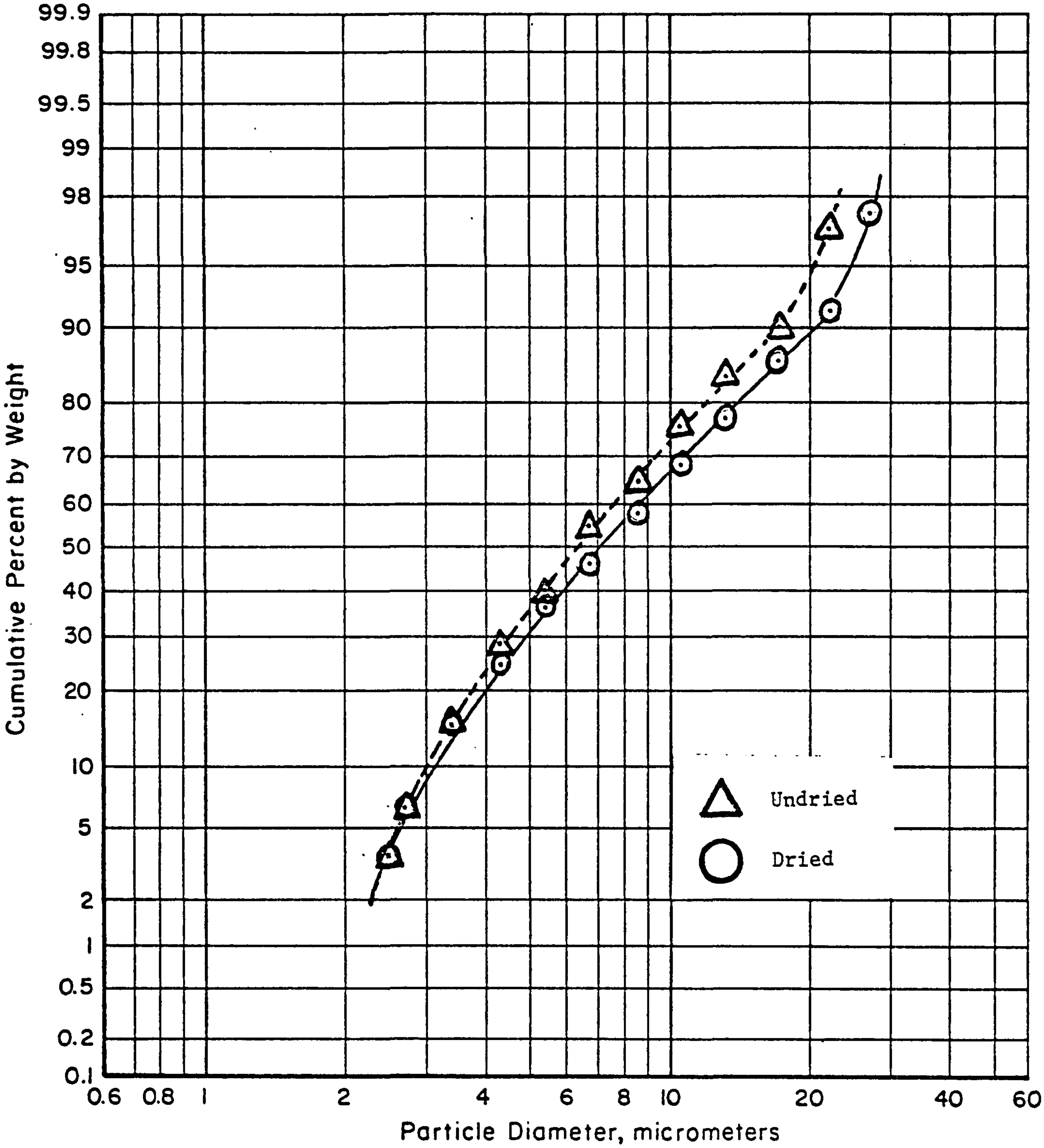

FIGURE 22. DISTRIBUTION OF DRIED AND UNDRIED COAL SAMPLES FROM A THIMBLE CATCH, COULTER COUNTER ANALYSES

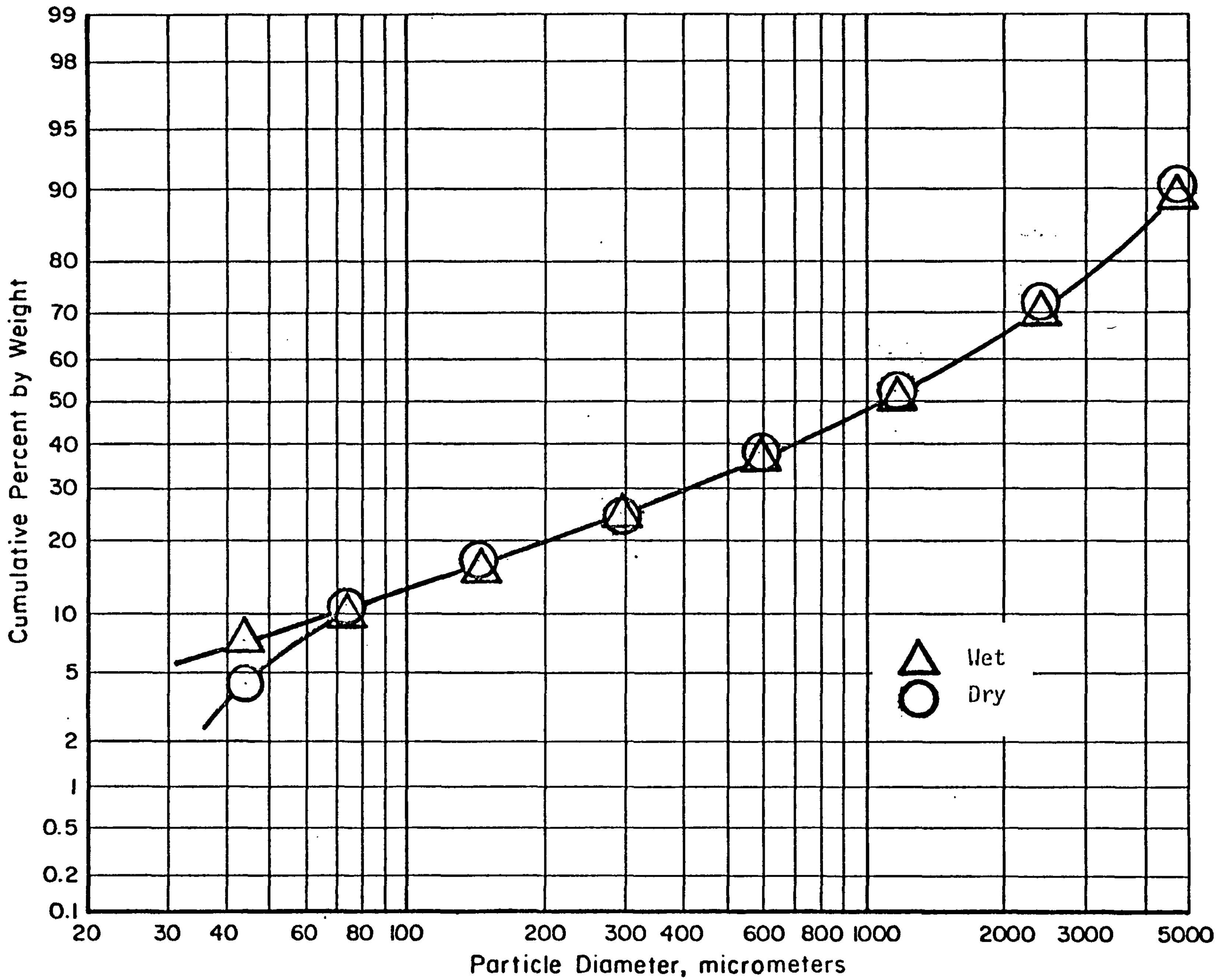

FIGURE 23. COMPARISON DISTRIBUTION OF WET AND DRY SIEVED PROCESS COAL SAMPLES

aliquot of a thimble catch was placed in a dram vial containing the wetting agent and electrolyte solution. Mixing was accomplished by repeated filling and emptying of a medicine dropper (the usual technique for dispersing particles prior to Coulter Counter sizing). A size distribution then was determined for an aliquot of this dispersion. The dispersion was then subjected to ultrasonic vibration; another aliquot was removed, and a size distribution determined. Figure 24 depicts the results of the two dispersion methods. Although slight differences can be seen, the differences are within experimental error and it can be concluded that either method of dispersion could be used without substantial error. (This conclusion applies only to the specific samples of this task. Other materials could possibly respond differently depending on their morphology and wetting properties.) Particles from the solutions used in the analysis by the Coulter Counter were collected on a silver membrane filter and observed by means of a scanning electron microscope for possible size differences in an additional effort to verify that ultrasonic dispersion did not modify the particle size. Electron photomicrographs were taken of representative areas of the filters and it was observed from these photos that the particles are essentially the same in number and size with and without ultrasonic dispersion.

Ultrasonic Cleaning of Alundum Thimble

To determine the extent and nature of particle release from an unused thimble, a new Alundum thimble was placed in 825 cc of 4.0 percent sodium chloride (Coulter Counter electrolyte) and cleaned by ultrasonic vibration for 30 minutes at a nominal frequency of 28 kHz $\pm$ 1.5 kHz. This procedure was repeated three times, each time using the same thimble in clean electrolyte to determine if any change would occur in the rate of particle generation. A size distribution by Coulter Counter was determined from each 825-cc volume. Table 19 compares the total number of particles generated each time by ultrasonic cleaning.

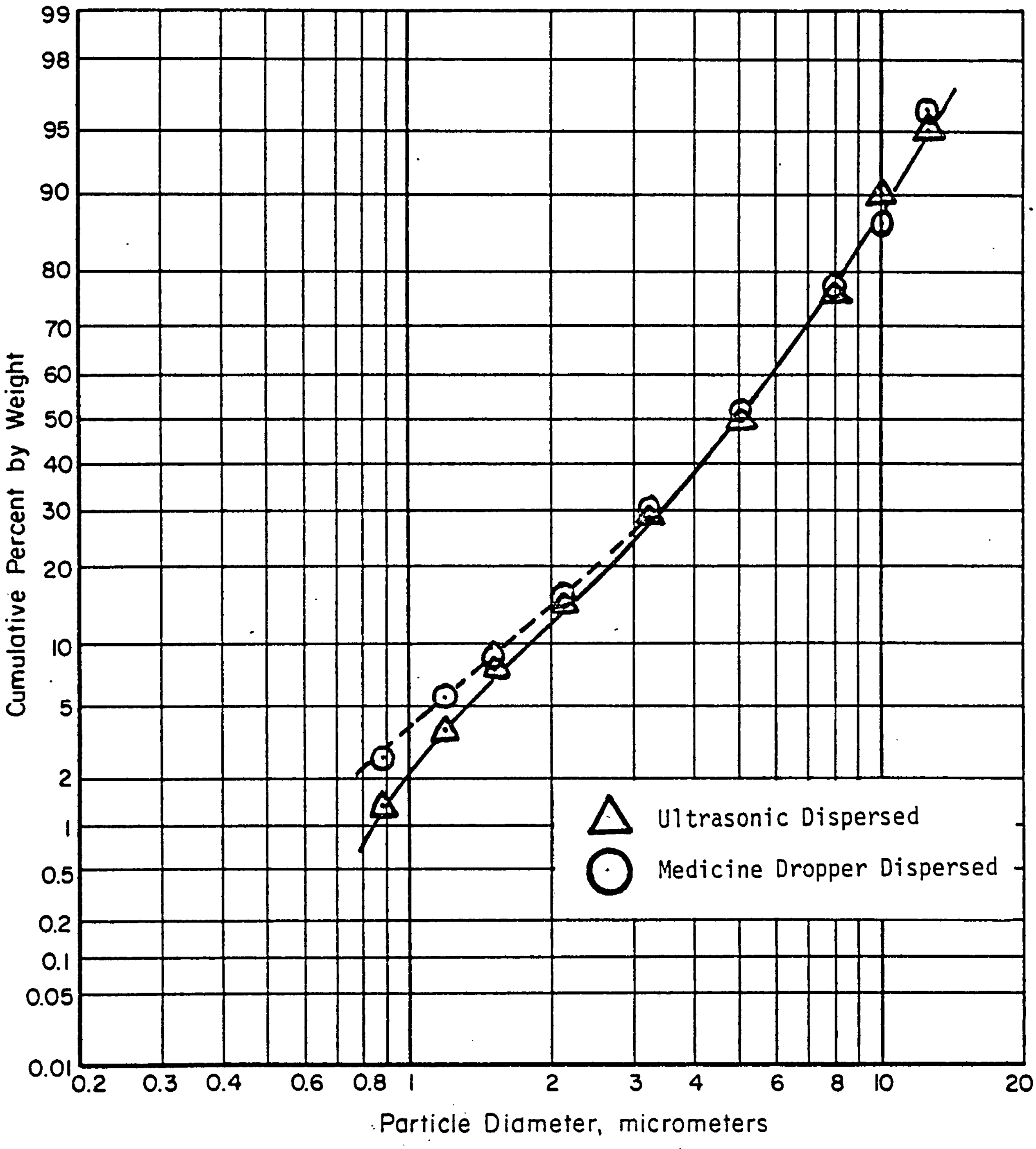

FIGURE 24. COMPARISON OF ULTRASONIC AND MEDICINE DROPPER DISPERSION TECHNIQUES, COULTER COUNTER ANALYZER

TABLE 19. PARTICLES GENERATED FROM ULTRASONIC THIMBLE CLEANING, COULTER COUNTER ANALYSES

Size, μm	Accumulative Number of Particles Larger Than Indicated Size, x 10^{-3} Run 1	Run 2	Run 3
22.0	0	2	0
17.5	0	3	3
14.0	0	16	5
11.0	13	38	3
8.8	83	51	25
7.0	173	130	61
5.5	233	231	125
4.4	488	393	229
3.5	1,023	690	338
2.8	1,922	904	546
2.2	3,235	1,548	843
1.7	10,213	3,765	2,020

It appears that the number of particles generated decreases with each successive cleaning and begins to level off to some extent. One can conclude from these data that thimble cleaning prior to use may reduce error in the size-distribution data where relatively small sample catches are expected.

Relative Comparison--
Particle Concentration

The importance of the relative concentration of thimble-generated particles compared with collected coal particles in the particle population being sized was determined. Sample contamination due to ultrasonic thimble cleaning was found to be insignificant when determining size distribution if a sufficient sample mass was collected. Table 20 shows the total number of particles generated during initial thimble cleaning is of the order of 10×10^6 and is significantly reduced with successive cleanings. For comparison, it has been determined, during this study, that the total number of particles in a measured aliquot of 2.16 mg of coal is of the order of 12×10^6. During this study, the thimble sample catch range was from 9,271 mg to 26,167 mg (see Table 7). By ratio (9,271 mg:2.16 mg), the thimble sample particle population is greater by at least a factor of the order of 4,000. Therefore, it can be concluded that the relative number of particles generated by thimble cleaning is insignificant by comparison with the mass contained in any of the thimble samples collected during this study. As previously mentioned, if one expects a relatively small thimble catch it would be advisable to preclean the thimble several times before use to eliminate the possiblity of a significant background particle contribution.

Representative Aliquots From Large Electrolyte Volumes

Thimble cleaning and particle dispersion were both accomplished via ultrasonic vibration. The thimble contents were emptied into a beaker containing 825 cc of isopropyl alcohol, the alcohol being used because of its wetting characteristics. The thimble was then placed into the alcohol bath and ultrasonically vibrated at a nominal frequency of 28 kHz $\pm$ 1.5 kHz for 30 minutes. Obtaining a aliquot from three different beaker levels while the particles are in suspension would give some identification of possible stratification due to nonuniform mixing and check the representative nature of aliquot collection for analysis. Figure 25 depicts the size distribution indicating that a representative aliquot can be selected from a relatively large volume of solution with a very dense particle concentration if the suspension is maintained by ultrasonic mixing. A further conclusion from these results is that the measurement technique is repeatable and random errors are small.

Coal Particle Solubility

Solubility of coal particles in the solutions used with the Mine Safety Appliance Particle Size Analyzer was found to be negligible. The operating principle of this device is essentially to measure the particle sedimentation rate as a function of time in an appropriate liquid media. The particles need to be thoroughly wetted and are placed in a feed liquid prior to being placed in the sedimentation liquid. The feed liquid consisted of 50 percent isopropyl alcohol and 50 percent heptane. A solubility check for coal particles in this mixture was made by measuring weight loss during the washing of a coal sample with a large excess of the solution. A weight loss of 0.08 percent was found which is considered to be insignificant.

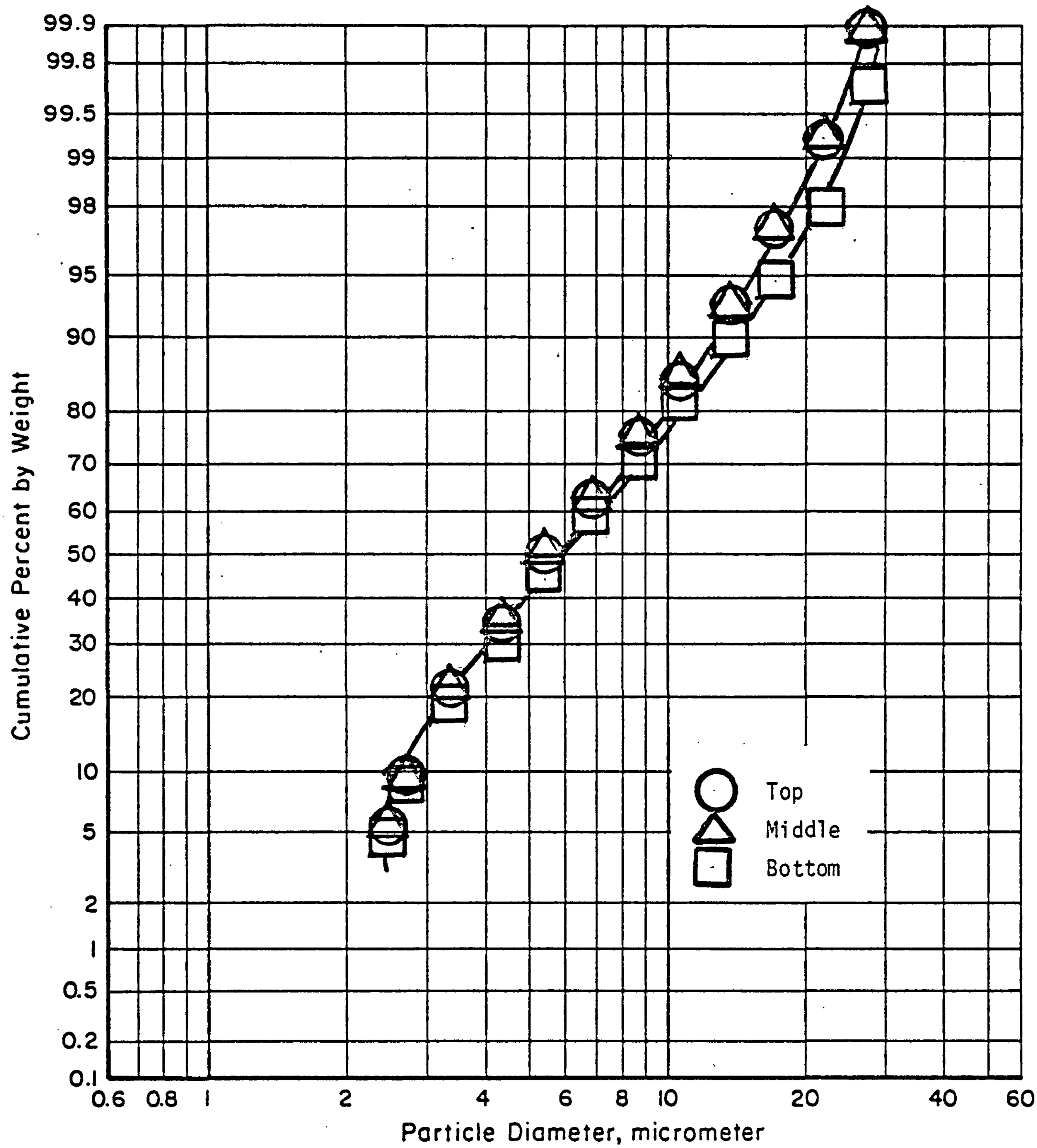

FIGURE 25. REPRESENTATIVE ALIQUOT CHECK OF LARGE SOLUTION VOLUME HAVING HIGH-PARTICLE DENSITY, COULTER COUNTER ANALYSES

REFERENCES

(1) Coulter Counter Industrial Model B Instruction Manual, Coulter Counter Industrial Division, Franklin Park, Illinois 60131.

(2) Whitby, K. T., "A Rapid General Purpose Centrifuge Sedimentation Method for Measurement of Size Distribution of Small Particles", Mechanical Engineering Department, University of Minnesota, 1955; presented at the 61st Annual Meeting of ASHRAE, Philadelphia, Pennsylvania, January, 1955.

(3) Federal Register, December 23, 1971, Vol. 32, No. 247.

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