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PARTICULATE COLLECTION EFFICIENCY MEASUREMENTS ON AN ELECTROSTATIC PRECIPITATOR INSTALLED ON A PAPER MILL RECOVERY BOILER

Industrial Environmental Research Laboratory
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PARTICULATE COLLECTION EFFICIENCY MEASUREMENTS ON AN ELECTROSTATIC PRECIPITATOR INSTALLED ON A PAPER MILL RECOVERY BOILER

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SECTION I
SUMMARY AND CONCLUSIONS

Fractional and overall collection efficiency measurements were made on an electrostatic precipitator collecting "salt cake" from a Kraft recovery boiler. The mass median diameter of the particulate entering the collector was approximately 1.0 μm, and the minimum average collection efficiency in the 0.1 to 2.0 μm diameter range was 99.92%. Size distributions at the precipitator inlet and outlet were measured with cascade impactors and an electrical aerosol analyzer. Overall mass efficiency measurements, based on a mass train with an in-stack filter, ranged from 99.92 to 99.96%. Fair agreement was obtained between the total mass loadings obtained with the mass trains and the impactors.

The average precipitator operating conditions during the test period were: secondary voltage and current density values of, 47.1 kV and 32.6 x 10^{-9} amps/cm^2, a specific collecting area of 114 $m^2/(m^3/sec)$, a temperature of 198°C, and a gas velocity of 0.76 m/sec.

SECTION II
INTRODUCTION

This report presents the results obtained from a performance test conducted by Southern Research Institute on an electrostatic precipitator collecting "salt cake" from a Kraft recovery boiler. The objectives of the test were (1) to determine the overall particulate collection efficiency of the electrostatic precipitator, (2) to compare the measured performance of the precipitator with that projected from a mathematical model. The appendix to this report presents data reduction procedures for the impactors and the ultrafine particle sizing instruments used during the test program. Raw data sets obtained from the instruments are also presented.

The electrostatic precipitator on which this test was conducted is a wire and plate design with six electrical sections in series in the direction of gas flow. Plate-to-plate spacing is 25.4 cm (10 inches), and the parallel plate collecting electrode length is 11.087 m long (36'4½") and 9.144 m high (30 ft). Each electrical set powers 70 gas passages. The total collecting area is 14194.7 m^2 (152,796 ft^2). The precipitator was designed with a specific collection area of approximately 100.25 $m^2/(m^3/sec)$ (509 ft^2/1000 ACFM). The test series was conducted at a boiler firing rate of 794.9 l/min (210 gal/min) which resulted in an average specific collection area of 114 $m^2/(m^3/sec)$ (579 ft^2/ 1000 ACFM).

Pneumatic rappers are utilized for the removal of the particulate on both the emitting and collecting electrodes. The emitting electrodes consist of two #9 wires which are twisted together [estimated diameter of 7.52 mm (.296")] and which are 9.67 m long (31'8 3/4"). This precipitator is considered to be a "dry bottom" unit which employs a drag scrapper for removal of the particulate.

SECTION III
MEASUREMENT TECHNIQUES

MASS CONCENTRATION MEASUREMENTS

Mass loading determinations were conducted at the inlet and outlet sampling locations with in-stack filters. Glass fiber thimbles were used at the inlet to collect the particulate mass and conditioned Gelman 47 mm filters were used at the outlet and as back up filters at the inlet. The sampling probe used at the outlet was heated and contained a pitot tube to monitor the velocity at each sampling location. Due to spatial limitations at the inlet, the inlet sampling probe was not heated nor did it contain a pitot tube. A pitot traverse was obtained in each sampling port before and after each inlet mass loading determination. The pitot readings which were obtained before each inlet measurements were used to obtain as near an isokinetic traverse as possible. A 40 point isokinetic traverse across the stack was conducted at the precipitator outlet. The Gelman 47 mm filters were weighed before and after each test in the field on a Cahn electrobalance, whereas the inlet thimbles were weighed in the laboratory before and after the test due to the absence of a suitable balance at the test site.

GAS ANALYSIS MEASUREMENTS

The concentrations of sulfur trioxide, sulfur dioxide, oxygen, carbon dioxide, and the moisture content of the flue gas were determined at the inlet of the precipitator. The sulfur trioxide samples were collected by a condensation method while the sulfur dioxide was collected in a hydrogen peroxide solution, which oxidized the sulfur dioxide to sulfur trioxide. Each of the sampling techniques for the oxides of sulfur produced a sample for analysis that was a dilute sulfuric acid. The concentration of acid (specifically SO_2 and SO_3) was determined by barium perchlorate titration using thorin indicator.

The percentage of oxygen and carbon dioxide were determined by the use of Fyrite gas analyzers. The moisture content of the flue gas was determined by pulling a known volume of gas through a preweighed packed drierite column.

V-I MEASUREMENTS

Secondary voltages were obtained on five of the six transformers by the precipitator vendor on November 13, 1975. Voltage divider resisters were attached to the high voltage side of the transformers and the secondary voltage calculated from the voltage drop across the measurement resistor. As the transformer settings were manually increased, the secondary currents were recorded from the panel meters in the precipitator control room.

Primary voltages and currents and secondary currents were recorded during each test day. The secondary voltage for each test day was then determined from the V-I curves obtained previously.

OPACITY MEASUREMENTS

A Lear Siegler RM41p portable optical transmissometer was used at the outlet sampling location to measure the opacity of the stack. The portable transmissometer has an optical path length of two meters and compensation circuitry for determining opacity in terms of the stack exit diameter. All opacity measurements in this report are given in terms of a two-meter optical path length.

PARTICLE SIZE MEASUREMENTS

Particle size and concentration measurements were conducted using the following methods: (1) inertial techniques using cascade impactors for determining concentrations and size distributions on a mass basis for particles having diameters between approximately .2 μm and 10.0 μm, (2) optical techniques for determining concentrations and size distributions for particles having diameters between approximately 0.3 μm and 2.0 μm, (3) an electrical mobility analyzer for size and concentration measurements in the diameter range 0.015 to 0.3 μm.

Andersen and University of Washington (U. of W.) Impactors were used at the outlet while Brink Impactors were used to sample at the inlet. A substrate-gas interference problem was noted during the preliminary tests with both conditioned and unconditioned glass fiber substrates. Therefore, aluminum foil substrates were used with the Brink and U. of W. Impactors. Due to the complicated jet configuration of the Andersen stages, only glass fiber substrates may be used. These were preconditioned by overnight exposure to the flue gas. Blank runs with aluminum and glass fiber substrates were run daily. The particulate sampled at St. Regis was very adhesive and it was possible to operate at higher than normal flow rates. A flow rate of 3.8×10^{-5} m^3/sec (.08 cfm) was used for the Brink Impactor, and 3.8×10^{-4} m^3/sec (.8 cfm) was used for both the Andersen and U. of W. Impactors.

The inlet duct was rectangular and had 16 horizontal ports, of which six ports at evenly spaced intervals were used for impactor sampling. Each of these six ports was sampled once a day using a Brink Impactor with a 2 mm nozzle by conducting a 2-point traverse. The Brink Impactors were run with stages 0-5 and the back up filter. The outlet stack was round with a 2.74 m (9') ID with two ports 90° apart. A 12-point traverse was conducted at each port. Run times were 30 minutes to 60 minutes. One Andersen and two U. of W. impactor tests were conducted each day, all with 4.75 mm 90° nozzles. The impactors were not externally heated.

A system based on the use of two techniques, particle mobility analysis and single particle light scattering, was used for obtaining essentially real time data on concentration and size distribution over the range of particle diameters from 0.01 μm to about 2 μm. The data obtained with this sytem is on a volume concentration by number rather than weight basis. Two types of mobility analyses were considered for use in this test: (1) diffusional methods based on particle losses resulting from Brownian motion causing particles to contact and adhere to the walls of a set of "diffusion batteries" (a set of high surface area to volume flow channels through which the sample gas stream is passed under controlled flow conditions) and (2) electrical mobility analysis. The latter method operates by placing a known charge on the particles and precipitating the particles under closely controlled conditions. Size selectivity is obtained by varying the electric field in the precipitator section of the mobility analyzer. Charged particle mobility is monotonically related to particle diameter in the operating regime of the instrument (0.01 to 0.3 μm). Because of the instrument's compactness (29.5 kg) and the short measurement time (2 minutes) required for obtaining size distributions with the electrical mobility method as compared to the diffusional method, (136 kg and 2 hours) the former was selected for use on this test (a Thermosystems Model 3030 Electrical Aerosol Analyzer). An optical single particle counter (Royco 225) was used in parallel with the mobility analyzer to provide size distribution data over the approximate diameter range from 0.3 to 2 μm.

None of the instruments for the above techniques can operate with raw flue gases as sample streams nor can they cope with the particle concentrations encountered in the flue gas. Thus this system is based on extractive sampling with a metered sample being diluted with clean dry air, to both condition the sample and reduce the particle concentrations to levels within the operating limits of the instruments. The required dilution typically ranges from 10:1 to 1000:1 depending on the particulate source and the location of the sampling point (i.e., upstream or downstream of the control device). A diagrammatic representation of the system is shown in Figure 1.

SECTION IV
RESULTS

MASS CONCENTRATION AND GAS ANALYSIS

Table 1 presents results obtained from the mass train measurements at the inlet and outlet sampling locations. Acceptable data was not obtained at the inlet with the mass train during the sampling period November 17 through November 19, 1975. Therefore, a second measurement series was conducted on December 16 and 17, 1975. The second measurement series was conducted under essentially identical boiler operating conditions as was the earlier test program, and the mass train inlet data from this time period can therefore be used to calculate overall collection efficiency for the precipitator. Both impactor and mass train measurements were conducted at the inlet and outlet during the December test period.

The data in Table 1 indicate that boiler operation and precipitator performance were relatively stable during the two test periods. However, the outlet mass concentrations during the December sampling period were about 50% less than those determined during the previous month. Table 2, which compares impactor and mass train total particulate loadings, shows that fair agreement was obtained between results from the indicated measurement systems. Table 3 gives the average collection efficiency of the precipitator from the mass train data. The outlet flow volume is considered to be more accurate because of traversing difficulties which were encountered at the inlet sampling lcoation.

Gas composition data are presented in Table 4. The flue gas contains high water vapor concentrations and relatively low sulfur oxide levels.

VOLTAGE-CURRENT MEASUREMENTS

Figure 2 shows the secondary voltage and current relationships obtained as described in Section III. Operating values of current and voltage obtained during the sampling periods are given in Table 5. The voltage-current characteristics are typical of those exhibited by precipitators collecting dust with a low electrical resistivity. The indicated variation in current density from day to day may have been caused by varying thickness of "salt cake" on the electrodes, which would in turn vary the effective electrode spacing. A laboratory measurement of the resistivity of the "salt cake" collected in this precipitator was conducted in a gas environment with a volume composition of 15% H_2O, 5% O_2, 13% CO_2, 500 ppm SO_2, and the balance nitrogen. The measurement gave a resistivity value of 2.5×10^8 ohm cm at 200°C with an applied electric field of 2 kv/cm.

OPACITY MEASUREMENTS

The baseline opacity of the exit stack indicated by the Lear Siegler RM41p portable optical transmissometer was relatively stable at 1% during the November sampling period. Spikes in the transmissometer output, presumably caused by rapping puffs, were observed at intervals. The average opacity indicated for the spikes was about 2%.

PARTICLE SIZE MEASUREMENTS

Table 6 gives stage weights from U. of W. impactor blank and real runs using aluminum foil substrates. These data show that the blank weight gains are a small fraction of the gains obtained during the real runs. Analogous data from Andersen runs are presented in Table 7, and the data indicate that the blank weight gains experienced using conditioned glass fiber substrates were substantial. As a result of these weight gains, it was decided to base fractional efficiency calculations upon outlet data obtained with the U. of W. impactors. The blank data correction factor for the Andersen data was calculated by averaging stage weight gains. Any blank run determined to have large handling errors from substrates sticking to stage plates was deleted. A differential size distribution obtained with the corrected Andersen data at the outlet is presented in a subsequent portion of this discussion for comparative purposes only.

Figures 3 and 4 present cumulative inlet size distributions obtained with the Brink impactor at the inlet sampling location. Outlet cumulative distributions from the U. of W. data are given in Figures 5 and 6. These data are also presented on log-probability co-ordinates in Figure 7 through 10. The inlet size distribution data show that about 75% of the particulate mass entering the precipitator consists of particles smaller than 2.0 μm diameter, whereas about 55% of the particulate mass exiting the collector is smaller than 2.0 μm diameter.

Differential size distributions were computed, on both a mass and number basis from the size and concentration data obtained with the inertial impactors and the electrical aerosol analyzer. These differential distributions have been plotted in Figure 11 on a mass basis, and in Figure 12 on a number basis. The concentration of particles in the 1 to 2 μm diameter range at the inlet was so great that the optical particle counter was saturated at the highest dilution ratio attainable with the dilution system. Therefore, no useful efficiency information was obtained with this instrument.

A comparison of the differential size distributions obtained with the two measurement techniques (inertial and electrical mobility) indicates whether agreement was obtained in the regions of overlap. This method of presenting the data also indicates the size regions containing the greatest quantities of mass or number concentration. The impactor data presented in Figure 11 show that, for both the inlet and outlet locations, the greatest quantity of mass is contained in the 1 μm diameter region. Figure 11 also indicates poor agreement between the impactor distributions and those obtained with the electrical aerosol analyzer in the overlap regions. Since the disagreement occurs at both the inlet and outlet, possible causes are systematic losses of particles in the dilution system and gas-phase interference problems with the impactor back up filter. Figure 12 shows the manner in which the number distributions are skewed toward the smallest particle sizes. In both Figures 11 and 12, the bars represent ± one standard deviation from the mean.

Figure 13 contains outlet data from the Andersen runs corrected for the average blank weight changes. A comparison of this data with that from the U. of W. impactors in Figure 11 indicates that the U. of W. data sets appear to be more consistent.

Figure 14 presents fractional efficiency results obtained during the November sampling period with the electrical aerosol analyzer and the inertial impactors. Note that the EAA and the impactor show fair agreement in terms of collection efficiency in the region of overlap. Figure 14 also contains theoretical fractional efficiencies calculated from a mathematical model of the precipitator. These calculations will be discussed in the next section. Figure 15 gives the fractional efficiency data obtained with impactor measurements during the December sampling period. The error bars represent the range ± one standard deviation from the mean.

COMPARISON OF THEORETICAL AND MEASURED RESULTS

A mathematical model of electrostatic precipitation has been developed by Southern Research Institute under another contract for the Environmental Protection Agency.[1] This model has been

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[1]Gooch, J. P., Jack R. McDonald and Sabert Oglesby, Jr., "A Mathematical Model of Electrostatic Precipitation". EPA Report No. EPA-650/2-75-037 prepared under Contract No. 68-02-0265 by Southern Research Institute, Birmingham, Alabama, April 1975.

used to simulate the operating conditions and geometry of the precipitator on which this test series was conducted. Results from the simulation are shown in Table 8 and Figure 14. The operating conditions of November 19, 1975 were used in the model to obtain the fractional efficiency curve shown in Figure 14. In general it is expected that the theoretically calculated fractional and overall efficiency should be above the experimentally determined curve since most non-ideal effects which exist in an actual precipitator would tend to decrease the performance. However, it is clear from Table 8 and Figure 14 that the model is under-predicting the performance of this precipitator in the 0.10 to 1.5 μm diameter size range. The probable cause of disagreement between theoretical and measured efficiencies for larger particles is the reentrainment of particle agglomerates from electrode rapping. It is believed that a major contributing factor to the model's under-prediction of this unit's performance is the approximate procedure which is currently used in the model for estimating the effects of particulate space charge. The significance of particulate space charge is more pronounced for size distributions such as those measured at this installation, in which higher concentrations of fine particles are present than is the case for size distributions obtained at the inlet of ESP's installed on pulverized coal-fired boilers. Research is currently in progress with the objective of developing more accurate procedures for representing space charge effects.

ENERGY COSTS

The power consumption of the precipitator TR sets averaged 261 kw, or 2.1 kw/(m^3/sec). If power costs are $0.01 kwh, the energy costs for the TR sets would be about $63.00/day.

SECTION V
ACKNOWLEDGMENTS

The particle size measurements given in this report were conducted by members of the Physics Section.

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Table 1

Mass Train Results[1]

	INLET				OUTLET							
Run Number	1	2	3	4	1	2	3	4	5	1	2	3
Date	12/16/75	12/17/75	12/17/75	12/17/75	11/17/75	11/18/75	11/18/75	11/19/75	11/19/75	12/16/75	12/17/75	12/17/75
Stack Temp. °C	194	198	211	201	196	202	193	199	193	191	197	197
% Moisture	25.6	23.1	23.4	25.6	24.5	25.6	25.8	25.7	26.1	25.3	24.6	24.9
Velocity, m/sec	12.4	13.2	13.3	13.2	22.2	22.0	21.4	21.8	21.8	20.4	20.4	20.5
Volumetric Flow												
am^3/min	6415	6835	6874	6797	7864	7790	7572	7749	7717	7155	7186	7200
acfm	226533	241365	242753	240032	277728	275094	267384	273644	272537	252661	253758	254249
SDm^3/min	2985	3242	3160	3090	3745	3615	3568	3608	3614	3394	3373	3366
Concentration												
gm/SDm^3	12.4	14.08	12.2	13.8	0.011	0.009	0.009	0.011	0.009	0.0046	0.0046	0.0046
gm/am^3	5.76	6.68	5.63	6.32	0.0046	0.0046	0.0046	0.0046	0.0046	0.0023	0.0023	0.0023
gr/aft^3	2.52	2.92	2.46	2.76	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001
% Isokinetic Variation	102	100	102	105	97	101	101	104	102	97	105	101

[1] Standard condition defined as 1.0 atm and 21°C.

Table 2

Total Average Particulate Concentrations from Impactors and Mass Train

	Particulate Concentration, gm/am^3			
	INLET		OUTLET	
	Mass Train	Brink Impactor	Mass Train	U. of W. Impactor
11/17/75 through 11/19/75	-	5.35	0.0046	0.0059
12/16/75 through 12/17/75	6.10	4.55	0.0023	0.0027

Table 3

Average Electrostatic Precipitator Performance (Mass Train Data)

	Mass Collection Efficiency, %	Specific Collection Area, m^2/m^3/sec
11/17/75 through 11/19/75	99.92 (1)	110 (2)
12/16/75 through 12/17/75	99.96	118

(1) Based on inlet loading of 6.1 gm/am^3.

(2) Based on outlet volume flow rate.

Table 4

Gas Analysis
(Volume Compositions)

Date	SO_2,ppm	SO_3,ppm	H_2O%	O_2%	CO_2%
11/17	76	∿0	26.7	7.0	16.0
11/18	95	1.4	25.6	7.5	15.5
11/19	107	0.6	26.1	7.0	15.0

Table 5

Average Electrical Operating
Conditions During Sampling Periods

		Average Primary		Secondary		Current Density	
DATE	TR NO.	Volts	Amps	KV	MA	μA/ft²	nA/cm²
11/17/75	1	206	114.4	43.5	367	14.4	15.5
	2	218.8	177.4	44.4	660	25.9	27.9
	3	269	258	45.6	1084	42.6	45.8
	4	275.2	265.6	53	1136	44.6	48.0
	5	210	269.4	53.2	1149	45.1	48.5
	6	215.6	270.6	53	1125	44.2	47.6
	Average			48.8			38.9
11/18/75	1	195.6	91	42	299.4	11.8	12.7
	2	205.9	133	42.6	457.5	18	19.4
	3	263.75	212.5	43.5	860	33.8	36.4
	4	270.9	236.25	51	980.625	38.5	41.4
	5	203.75	229.75	50.5	932.5	36.6	39.4
	6	208.75	236.5	50.6	943.75	37.1	39.9
	Average			46.7			31.5

Table 5
(Continued)

Average Electrical Operating
Conditions During Sampling Periods

		Average Primary		Secondary		Current Density	
DATE	TR NO.	Volts	Amps	KV	MA	$\mu A/ft^2$	nA/cm^2
11/19/75	1	203.1	109.1	43	341.25	13.4	14.4
	2	201.25	142.9	43	498.1	19.6	21.1
	3	267.5	238.6	44.8	991.25	38.9	41.9
	4	268.4	242.75	51.6	1015.6	39.9	42.9
	5	196.9	223.5	50	897.5	35.2	37.9
	6	204.75	230.6	50.3	917.5	36.0	38.8
	Average			47.1			32.8
12/16/75	1	223.3	125	44.2	416.7	16.4	17.6
	2	176.7	117.7	41.8	390	15.3	16.5
	3	180	86.7	37.2	306.7	12.0	12.9
	4	255	266	53	1141.7	44.8	48.2
	5	235	265	52.8	1121.7	44	47.4
	6	227	262.3	52.2	1073.3	42.1	45.3
	Average			46.9			31.3
12/17/75	1	199.2	62.9	41.5	255	10	10.8
	2	190	106.2	41	341.7	13.4	14.4
	3	199.2	75.2	36.2	255	10	10.8
	4	270	245.3	51.8	1031.7	40.5	43.6
	5	245	262.5	52.6	1110	43.6	46.9
	6	234.2	263.3	52.3	1083.3	42.5	45.7
				45.9			28.7
Overall Average		224	194	47.1			32.6

Table 6

Outlet U. of W. Impactor Runs
Blank Runs and Real Runs

Run No.	SRO-7	SRO-3	SRO-4	SRO-12	SRO-9	SRO-13	SRO-18	SRO-16	SRO-17		
Date	11/17/75	11/17/75	11/17/75	11/18/75	11/18/75	11/18/75	11/19/75	11/19/75	11/19/75	12/17/75	12/17/75
Time	7:40	2:49	3:40	1:00	9:50	3:30	4:00	11:22	2:40		
Type of Run	Blank	Real	Real	Blank	Real	Real	Blank	Real	Real	Blank	Real
Run Time min.	48	48	48	50	48	96	96	72	96		
WEIGHT GAINS mg											
S0											
S1	.05	5.97	.84	.18	-.20	.72	.60	.53	1.01	.03	3.54
S2	.00	.87	.11	.08	.29	.37	.07	1.19	.27	.03	.12
S3	-.07	.89	.54	.09	.30	1.01	.06	.60	.80	-.03	.46
S4	-.06	.82	.31	.08	.18	.63	.07	.31	.58	.02	.23
S5	-.15	1.46	.71	.07	.94	2.04	.06	.75	1.64	.01	.61
S6	-.04	1.55	1.21	.01	1.57	2.85	.02	1.78	3.30	.02	1.75
S7	-.04	.19	.2	.06	.32	.46	.08	.85	.77	.03	1.03
SF	-.05	.18	.29	.06	.19	.35	-.02	.41	.74	-.07	.32

Average Blank Run Stage Weight Gain $\bar{x}$ = .03 mg
Standard Deviation σ = .06 mg

Table 7

Outlet Andersen Impactor Runs
Blank - Real Runs

Run No.	SRO-10[2]	SRO-5		SRO-15	SRO-14	
Date	11/18/75	11/17/75		11/19/75	11/19/75	
Time	10:43 am	6:00 pm		10:25 am	8:39 am	
Type of Run	Blank	Real	Corrected Real	Blank	Real	Corrected Real
Run Time	48 min	∿48 min		96 min	72 min	
Substrate	GFF[1]	GFF		GFF	GFF	
WEIGHT GAINS mg						
S0	.37	.72	.516	.18	.66	.439
S1	.24	.40	.196	.14	.34	.119
S2	.26	.53	.326	.31	1.62	1.399
S3	.19	.09	-.114[4]	.24	.14	-.081[4]
S4	.19	.38	.176	.26	.42	.199
S5	.07	1.43	1.226	.25	.62	.399
S6	1.17[3]	1.25	1.046	.02	1.53	1.309
S7	.11	.04	-.164[4]	.37	.50	.279
SF	.07	-.39[4]	-.594[4]	.22	-.14[4]	-.361[4]
$\bar{x}$	.204		$\bar{x}$	.221		
σ	.099		σ	.101		

[1]GFF = Glass Fiber Filter
[2]Blank run on 11/17/75 was unusable
[3]Deleted from average
[4]Negative weight gains entered as zero in data analysis

Table 8

Comparison of Computed and Measured
Mass Collection Efficiency

Date	Specific Collection Area $m^2/(m^3/sec)$	Collection Efficiency % From Model	Collection Efficiency % From Test Data
11/17/75	110	99.75	99.92
11/18/75	110	99.54	99.92
11/19/75	110	99.63	99.92
12/16/75	118	99.66	99.96
12/17/75	118	99.44	99.96

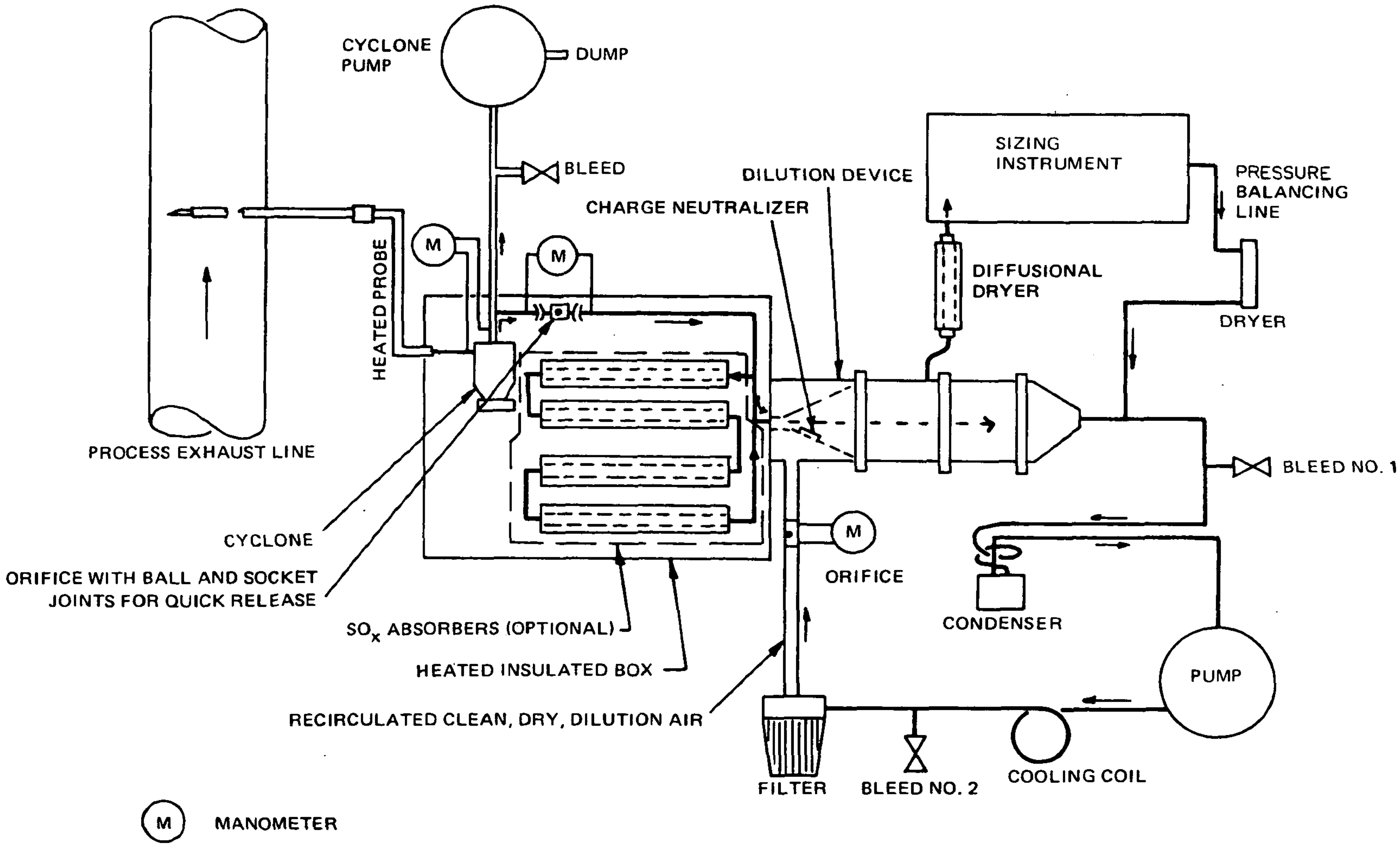


Figure 1. Sample Extraction-Dilution System

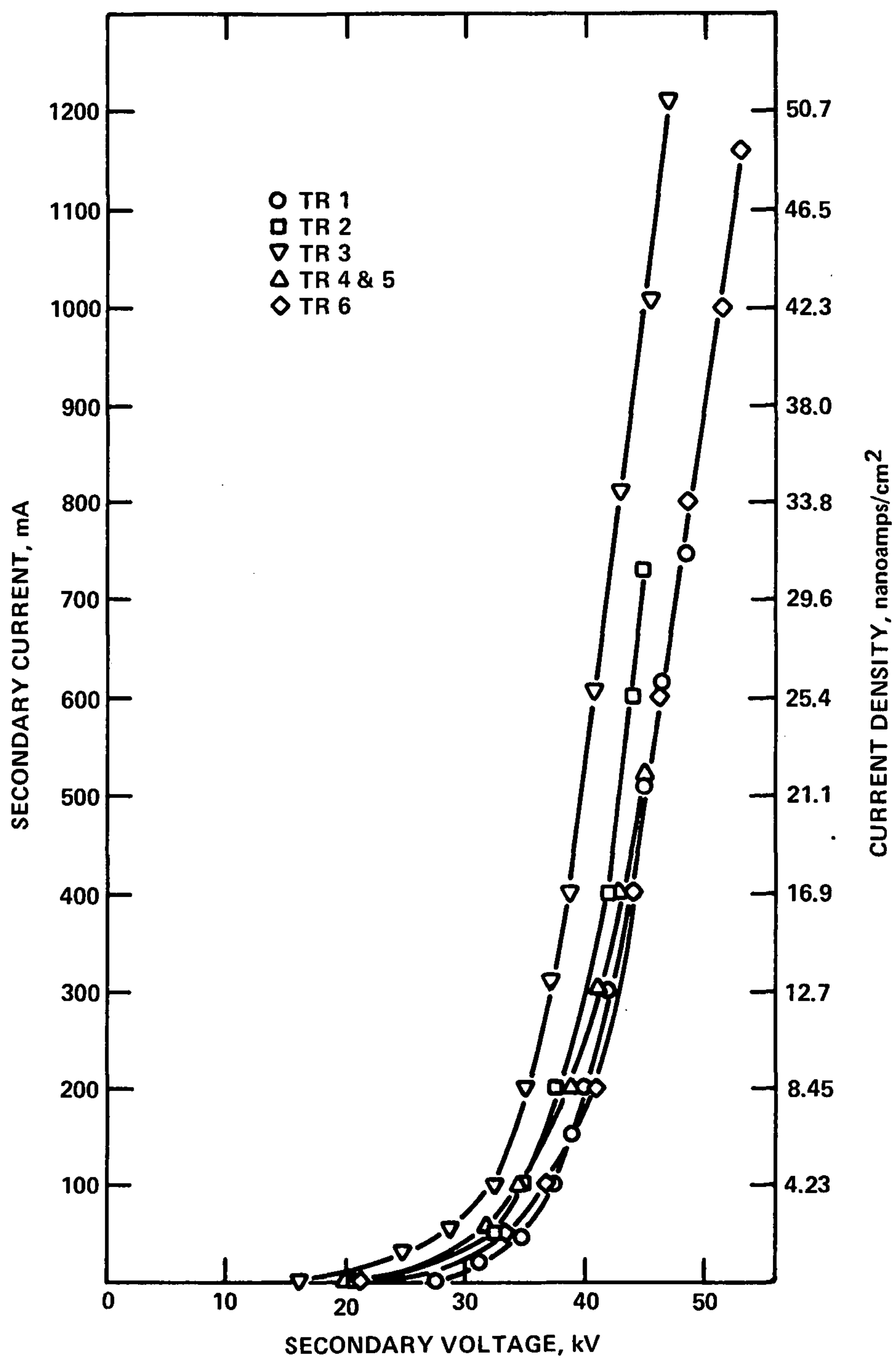


Figure 2. V-I Curves for #2 Unit Obtained on 11/13/75

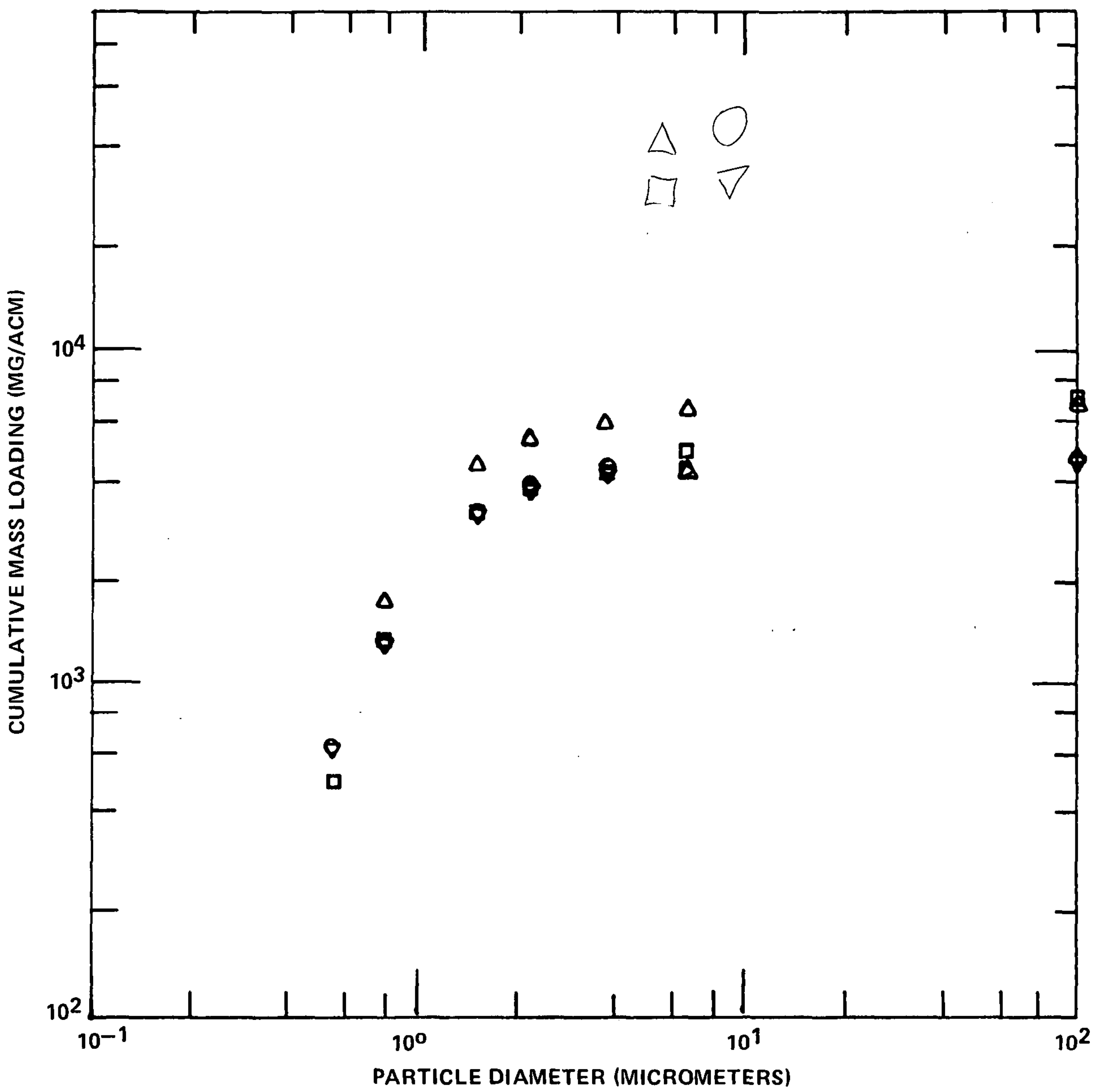


Figure 3. Inlet size distributions obtained with the Brink Impactors 11/19/75

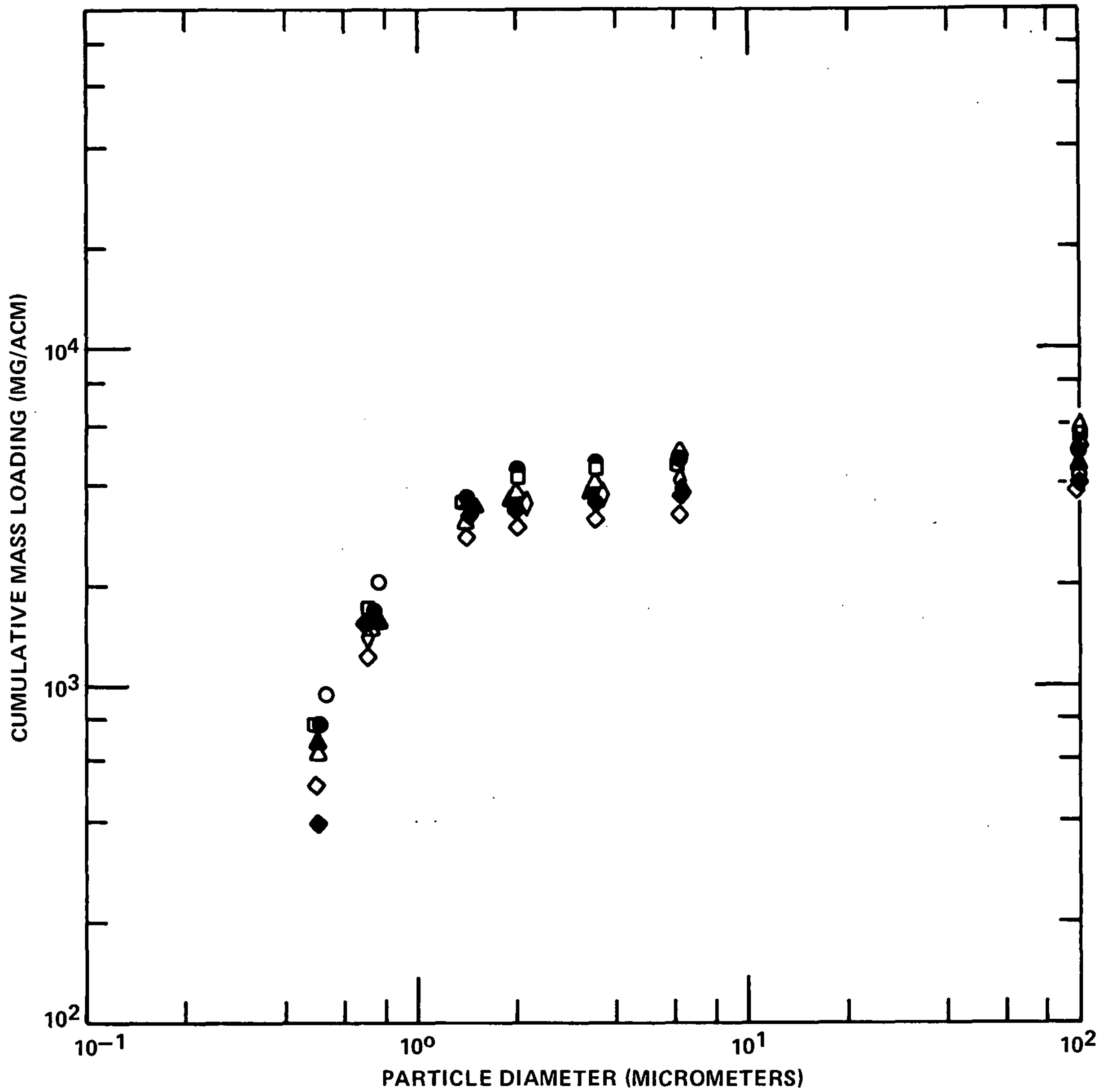


Figure 4. Inlet size distributions obtained with the Brink Impactors 12/16-17/75

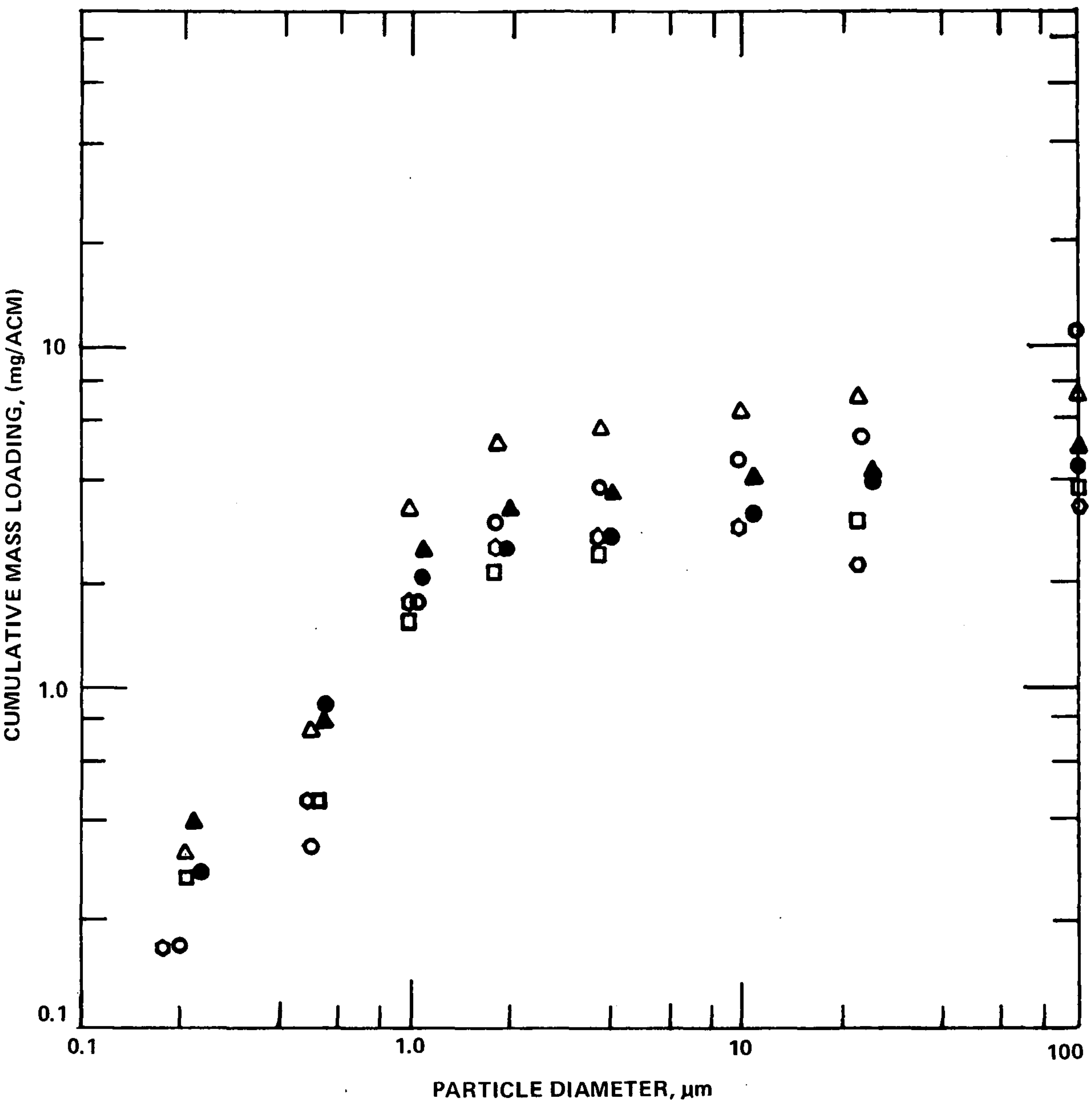


Figure 5. Outlet size distributions obtained with the U. of W. Impactors 11/17-19/75

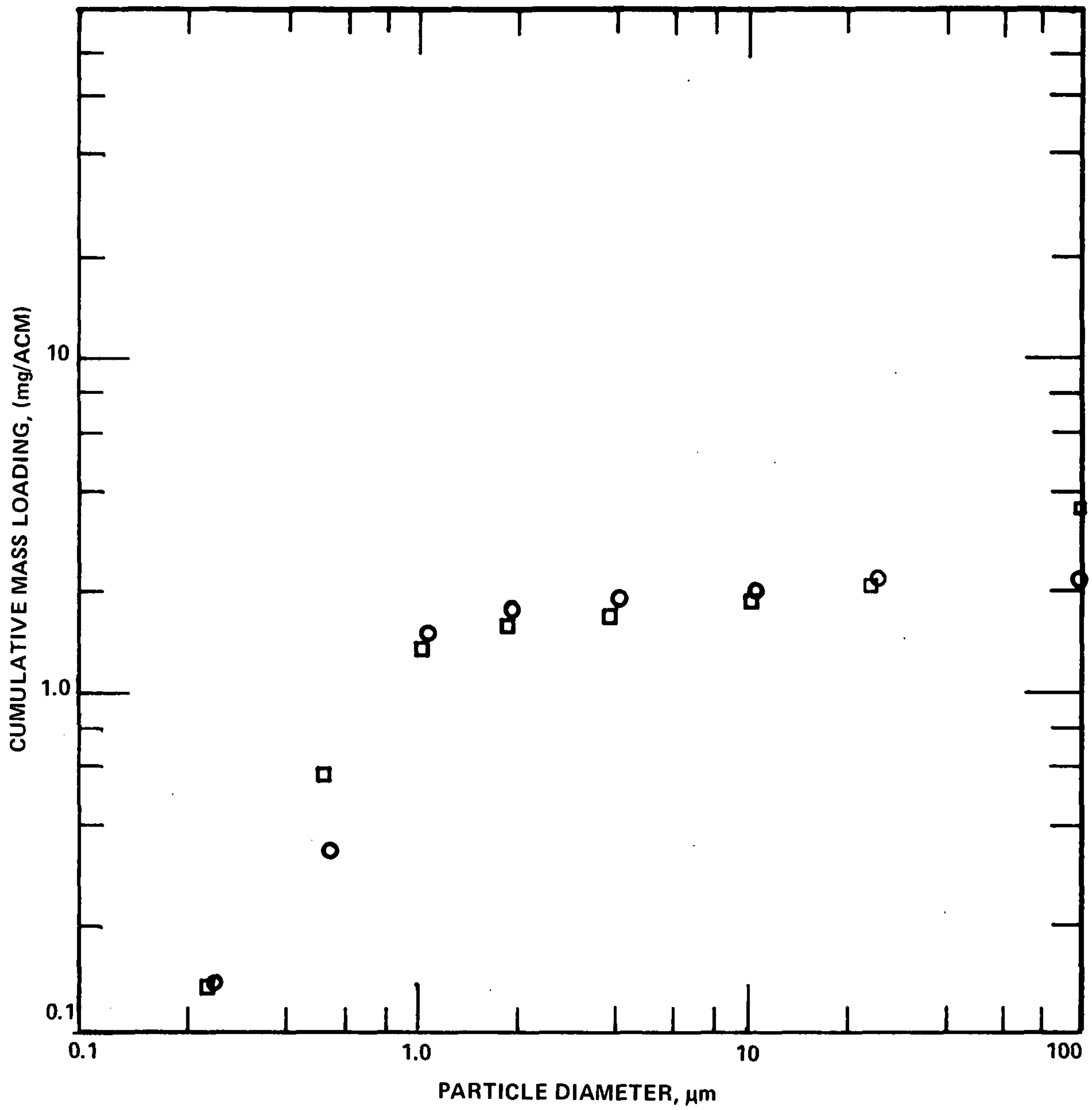


Figure 6. Outlet size distributions obtained with the U. of W. Impactors 12/16-17/75

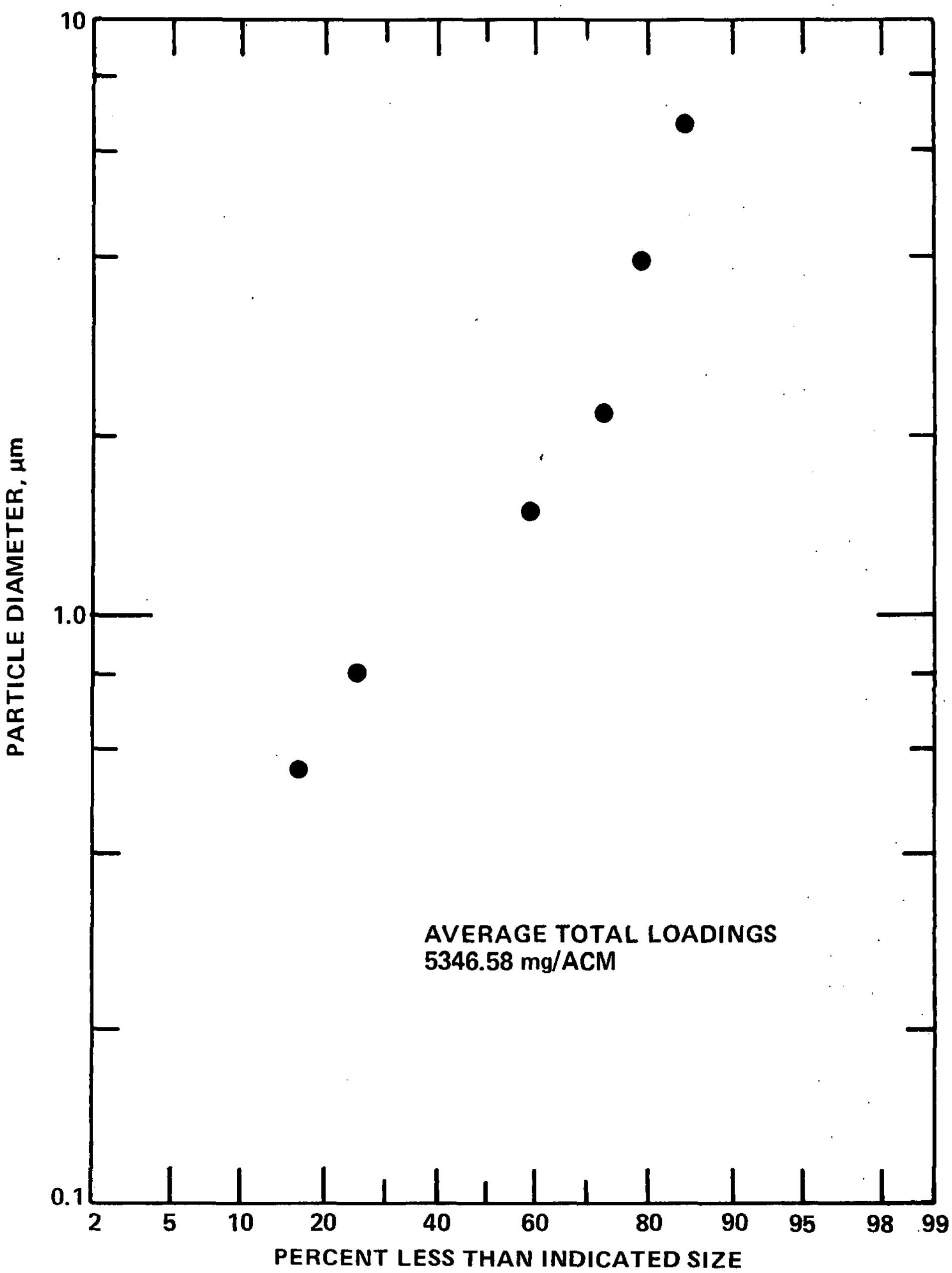


Figure 7. Inlet size distributions on log-probability co-ordinates 11/19/75

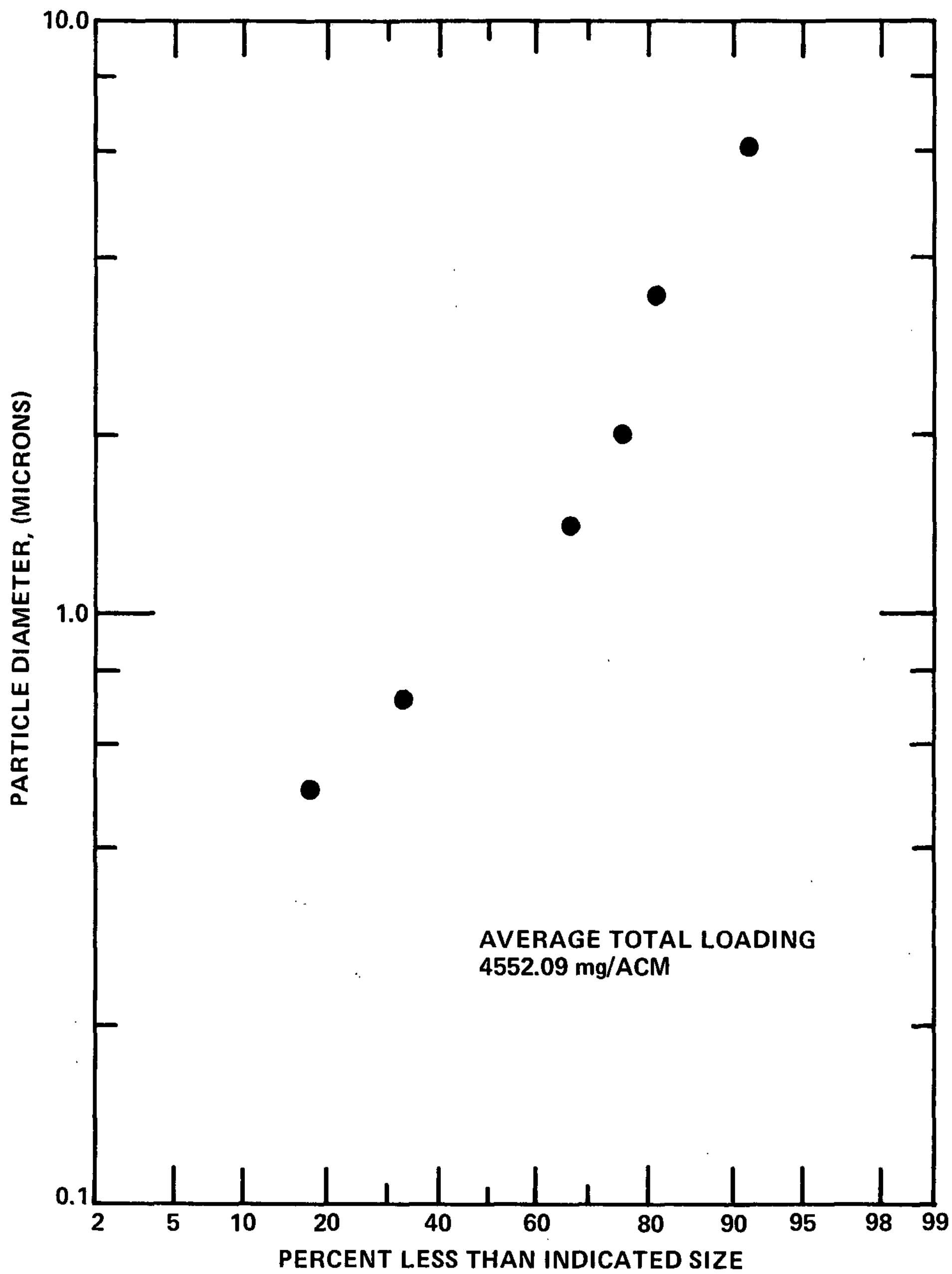


Figure 8. Inlet size distributions on log-probability co-ordinates 12/16-17/75

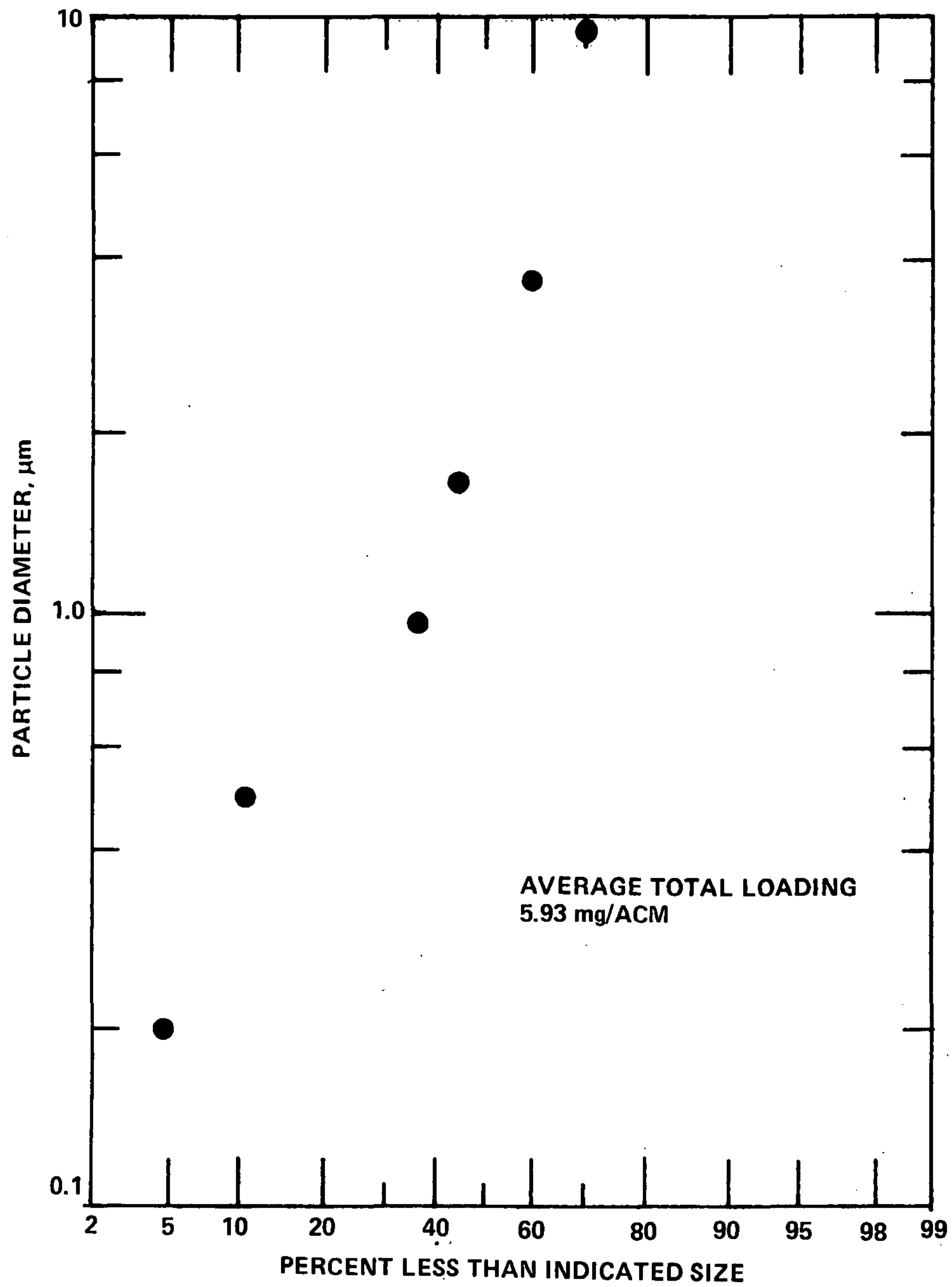


Figure 9. Outlet size distributions on log-probability co-ordinates 11/17-19/75

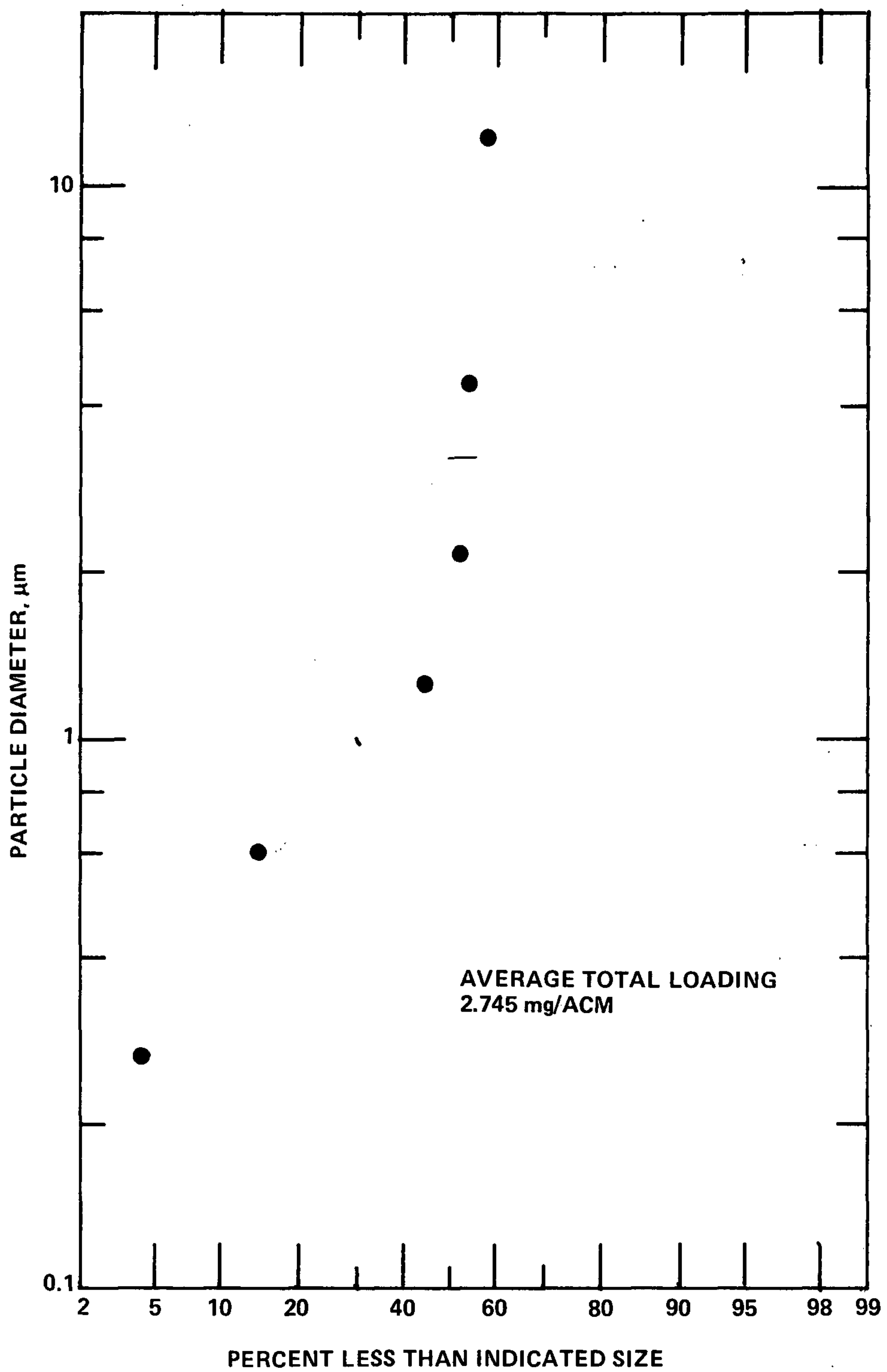


Figure 10. Outlet size distributions on log-probability co-ordinates 12/16-17/75

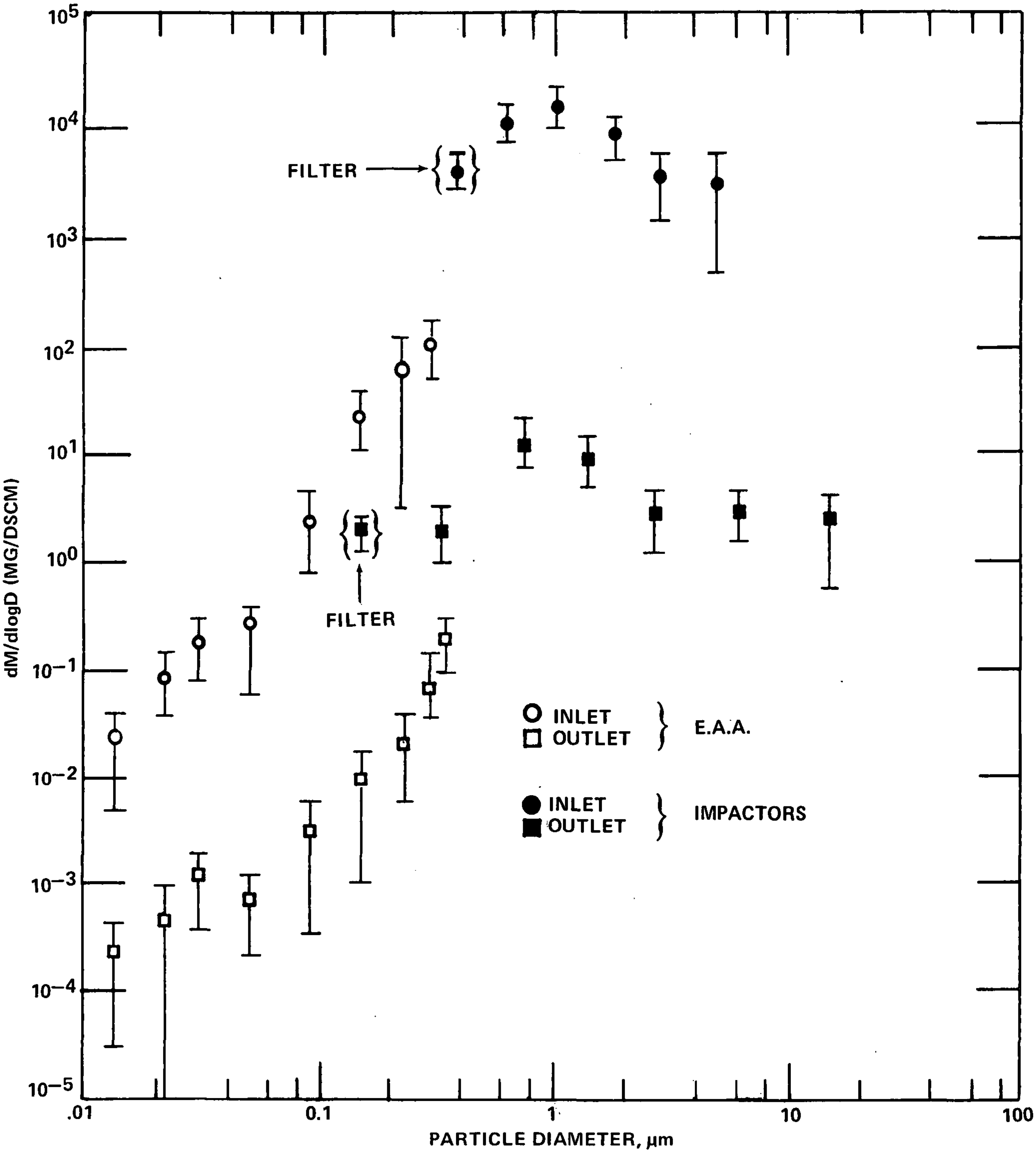


Figure 11. Inlet and Outlet differential mass distributions 11/17-19/75

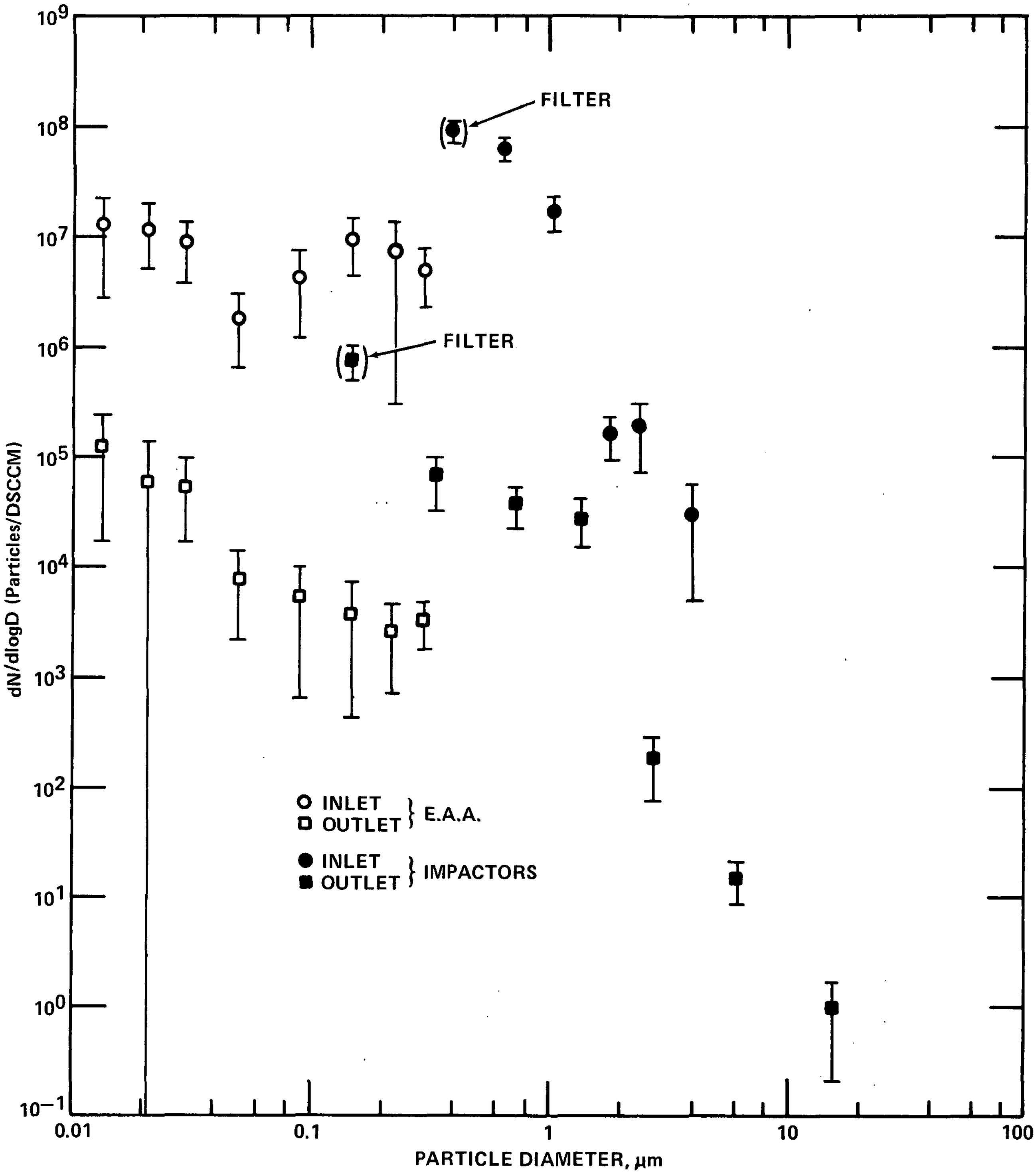


Figure 12. Inlet and Outlet differential number distributions 11/17-19/75

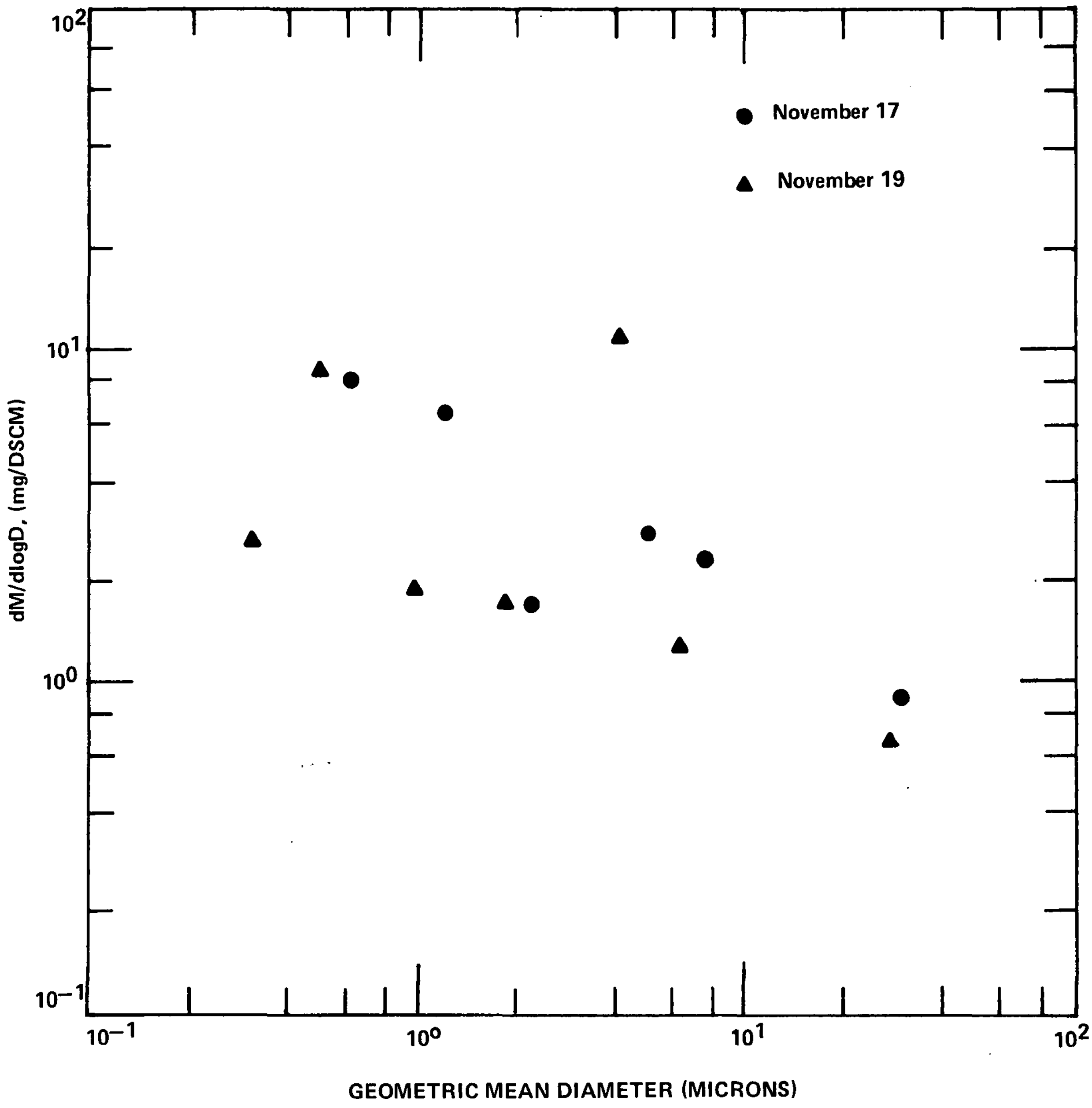


Figure 13. Outlet differential mass distribution from Andersen Impactors 11/17-19/75

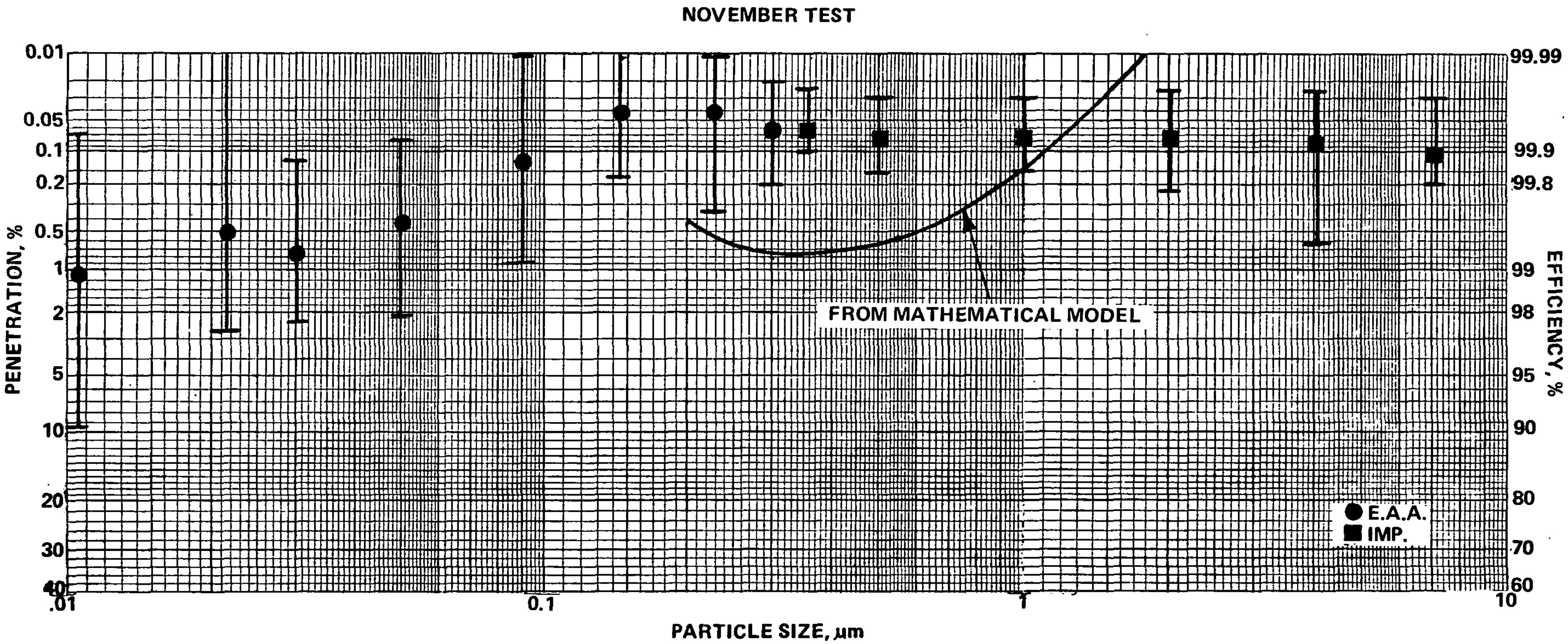


Figure 14. Measured and theoretically calculated fractional efficiency 11/17-19/75

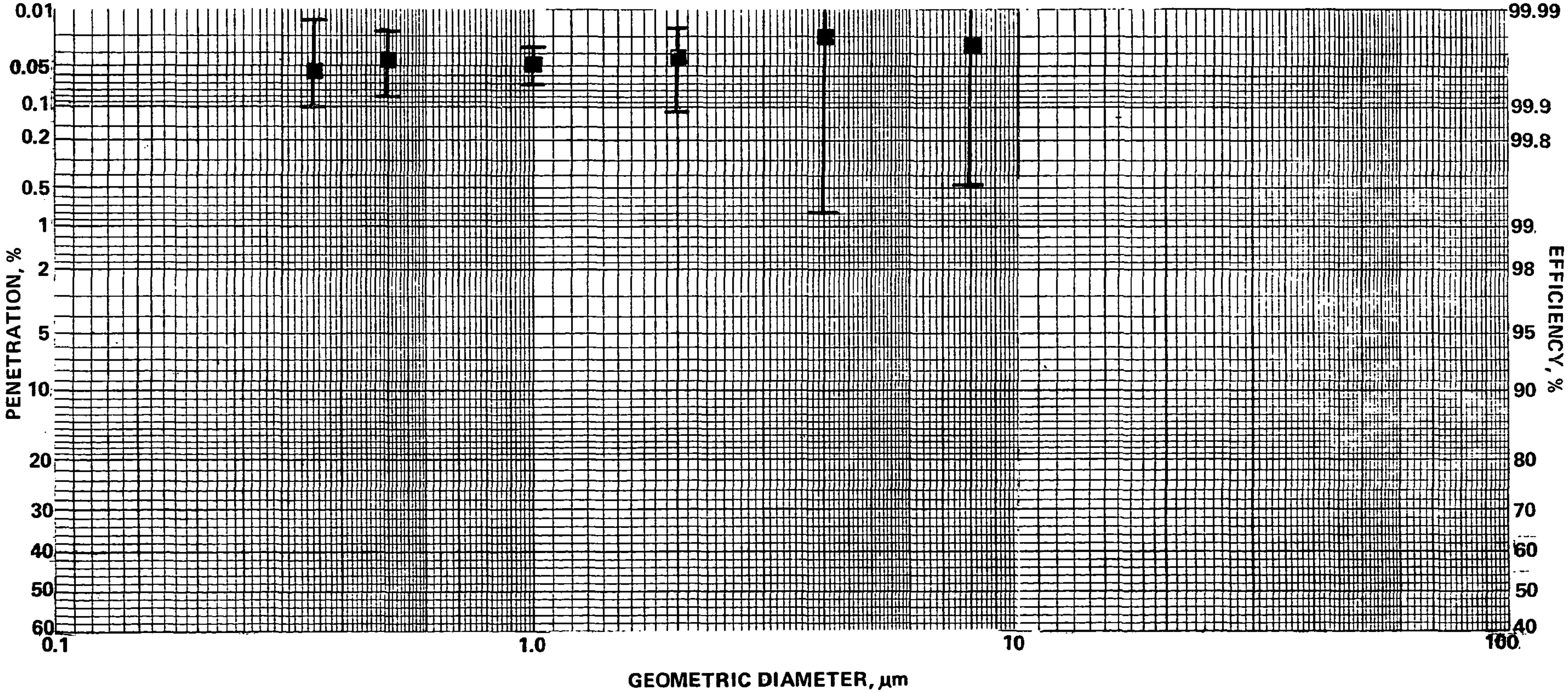


Figure 15. Impactor determined fractional efficiencies 12/16-17/75

APPENDIX

SAMPLE DATA REDUCTION CALCULATIONS FOR IMPACTOR (FINE) AND DIFFUSIONAL (ULTRAFINE) SIZING DATA

In this appendix we include information on how individual impactor stage weights and run data are used to obtain the cumulative mass distribution, $\Delta M/\Delta \log D$, $\Delta N/\Delta \log D$, and fractional efficiency information cited in this report. Next we give the computer print-outs for each impactor run. In a third section the data reduction scheme used for obtaining ultrafine particle size distribution data is explained. Finally, the ultrafine particle size distribution data recorded for this test are included. In this test ultrafine particle sizing data were obtained by electrical diffusional mobility analysis.

SAMPLE DATA REDUCTION CALCULATIONS

After an impactor run, it is necessary to obtain a particle size distribution from the mass loading on each stage. The conditions at which the impactor was run determine stage D_{50} cut points. These are calculated by an iterative solution of the following two equations:

(E1) $$D_{50} = 1.43 \times 10^{4} \left[\frac{\mu D_C{}^3 P_S\, X(I)}{\rho_p Q_I P_o C 472.0}\right]^{1/2}$$

(E2) $$C = 1 + \frac{2L}{D_{50} \times 10^{-4}} \left[1.23 + 0.41 \,\mathrm{Exp} \left[(-0.44 D_{50})/L \times 10^{-4}\right]\right]$$

where D_{50} = the stage cut point (μm),

μ = gas viscosity (poise),

D_c = stage jet diameter (cm),

P_s = local pressure at stage jet (atm),

ρ_p = particle density (gm/cm^3),

Q_I = impactor flow rate (cfm),

P_o = ambient pressure at impactor inlet (atm),

C = Cunningham Correction factor,

L = gas mean free path (cm), and

X(I) = number of holes per stage.

The easiest way to calculate these cut points is to write a computer program. Otherwise, it is a tedious process. The size parameter reported is either aerodynamic equivalent diameter, that is, diameter based on the settling velocity of unit density particles, or approximate physical diameter, based on a measurement of the true particle density. In either case, the particles are assumed to be spherical.

Certain of the values in equations E1 and E2 are calculated separately. A brief discussion of each of these calculations follows.

To find the viscosity of the flue gas, μ, the viscosity of the pure gas components of the flue gas must first be found. Viscosity is a function of temperature, and the temperature difference in different flue gases can be quite significant. The following equations (derived from curves fitted to viscosity data from the Handbook of Chemistry and Physics, Chemical Rubber Company Publisher, 54 Edition, 1973-1974, pp. F52-55), are used to find the viscosities of $CO_2(\mu_1)$, $CO(\mu_2)$, $N_2(\mu_3)$, $O_2(\mu_4)$ and $H_2O(\mu_5)$.

(E3) $\mu_1 = 138.494 + 0.499T - 0.267 \times 10^{-3}T^2 + 0.972 \times 10^{-7}T^3$

(E4) $\mu_2 = 165.763 + 0.442T - 0.213 \times 10^{-3}T^2$

(E5) $\mu_3 = 167.086 + 0.417T - 0.139 \times 10^{-3}T^2$

(E6) $\mu_4 = 190.187 + 0.558T - 0.336 \times 10^{-3}T^2 + 0.139 \times 10^{-6}T^3$

(E7) $\mu_5 = 87.800 + 0.374T + 0.238 \times 10^{-4}T^2$

where T is the temperature of the flue gas in degrees Celsius. The units of μ are 10^{-6} g/cm-sec. Next, these values of μ_1 through μ_5 are used in a general viscosity equation for a mixture of any number of components (See "A Viscosity Equation for Gas Mixtures" by C. R. Wilke, Journal of Chemical Physics, Volume 8, Number 4, April 1950, page 517) used to find the viscosity of the flue gas:

(E8) $$\mu = \sum_{i=1}^{n} \frac{\mu_i}{\left[1 + \frac{1}{X_i} \sum_{\substack{j=1 \\ j \neq i}}^{j=n} X_j \phi_{ij}\right]}$$

where ϕ_{ij} is given by the equation:

(E9) $$\phi_{ij} = \frac{\left[1 + (\mu_i/\mu_j)^{\frac{1}{2}} (M_j/M_i)^{\frac{1}{4}}\right]^2}{(4/\sqrt{2}) \left[1 + (M_i/M_j)\right]^{\frac{1}{2}}}$$

and

M = molecular weight of a component in the mixture,

X = mole fraction of a component in the mixture,

μ = viscosity, g/cm-sec; μ_1, μ_2, etc. refer to the pure components at the temperature and pressure of the mixture, μ is the viscosity of the mixture, and

ϕ = dimensionless constant defined above.

To find the pressure PS_i (in atmospheres) at each impactor stage i, the following equation is used:

(E10) $$PS_i = POA - (PI_i)(DP)$$

where POA is the gas pressure at the impactor inlet in atmospheres, PI_i is the fraction of impactor pressure drop at each stage i, and DP is the pressure drop across the impactor in atmospheres.

To find the gas mean free path L_i (in centimeters) for each impactor stage i, the following equation is used:

(E11) $$L_i = \frac{2\mu}{1.01325 \times 10^6 \, PS_i} \times \sqrt{\frac{8.3117 \times 10^7 \, T_k}{3 \, MM}}$$

where μ is the gas viscosity,

PS_i is the pressure at each impactor stage i,

T_k is the gas temperature at the impactor stage in degrees Kelvin, and

MM is the average molecular weight of the flue gas.

Procedures for presenting the particle size distribution in graphical and tabular form are outlined below. A sample computer printout is shown on page 53 which includes reduced data from a hypothetical test. It is assumed for this sample calculation that an Andersen Stack Sampler was used to collect the particulate.

Information obtained from the data log sheets for each test is printed at the top of the sheet. The maximum particle diameter is measured by examining the particles collected on the first stage (or first cyclone) through an optical microscope. Gas analysis samples are taken at the same time the impactor is run. The mass loading is calculated from the total mass of the particulate collected by the impactor and listed in four different units after the heading CALC. MASS LOADING. The units are defined as:

GR/ACF - grains per actual cubic foot of gas at stack conditions of temperature, pressure, and water content.

GR/DSCF - grains per dry standard cubic foot of gas at standard conditions of the gas. Standard conditions are defined as 0% water content, 70°F, and 29.92 inches of Hg.

MG/ACM - milligrams per actual cubic meter of gas at stack conditions of temperature, pressure, and water content.

MG/DSCM - milligrams per dry standard cubic meter of gas at standard conditions of the gas. Standard conditions are defined as 0% water content, 21°C and 760 mm of Hg.

Below these data the information pertinent to each stage is summarized in columnar form in order of decreasing particle size from left to right. Thus S1 is the first stage, S8 is the last stage, and FILTER is the back-up filter. If a cyclone was used, then to the left of S1 a column labelled CYC will appear and information relevant to the cyclone will be listed in this column. Beneath each impactor stage number is listed the corresponding stage index members, which also serve as identification for the stages. Directly beneath these listings is the stage cut point calculated from Equations E1 and E2 for the actual test conditions. It is labelled D_{50} and is given in micrometer units. The stage weights are likewise listed for the respective stages, labelled MASS and are in milligram units.

The mass loadings per unit volume of gas sampled indicated by the stage weights are labelled MG/DSCM/STAGE and are written in milligrams per dry standard cubic meter. The /STAGE indicates that it is not a cumulative. It is calculated for a particular stage j by the formula

$$\text{MG/DSCM/STAGE}_j = \frac{\text{MASS}_j}{\text{SAMPLING DURATION (minutes)}}$$

$$\times \frac{35.314667 \text{ cubic feet/cubic meter}}{\text{FLOWRATE (ACFM)}} \times \frac{\text{Absolute Stack Temperature}}{\text{Absolute Standard Temperature}}$$

$$\times \frac{\text{Absolute Standard Pressure}}{\text{Absolute Stack Pressure}} \times \frac{1}{(1\text{-Fraction of } H_2O)}$$

where absolute means the temperature and pressure are in absolute units-degrees Rankin or degrees Kelvin for temperature, and atmospheres, inches or millimeters of mercury for pressure.
For S1,

$$\text{MG/DSCM/STAGE}_1 = \frac{.72 \text{ mg}}{20 \text{ min.}} \times \frac{35.314667 \text{ cubic feet/cubic meter}}{0.500 \text{ ACFM}}$$

$$\times \frac{(400 + 460)^0\text{R}}{(70 + 460)^0\text{R}} \times \frac{29.92 \text{ in. Hg}}{26.50 \text{ in. Hg}} \times \frac{1}{(1.0 - 0.01)} = 4.71 \text{ mg/DSCM}$$

The subscripts indicate stage index numbers.

The percent of the mass of particles with diameters smaller than the corresponding D_{50} is called the CUMULATIVE PERCENT OF MASS SMALLER THAN D50. It is the cumulative mass at stage j divided by the toal mass collected on all the stages, and converted to a percentage:

$$\text{CUM }\%_j = \frac{\sum_{i=j+1}^{9} \text{MASS}_i}{\text{Total Mass}} \times 100$$

For example, for S6, the cumulative percent is given by

$$\text{CUM }\%_6 = \frac{\text{MASS}_7 + \text{MASS}_8 + \text{MASS}_9}{\text{Total Mass}} \times 100$$

$$= \frac{1.25 \text{ mg} + 0.04 \text{ mg} + 0.39 \text{ mg}}{5.24 \text{ mg}} \times 100 = 32.06\%$$

For S8, the mass of the particulate collected on the filter is used,

$$\text{CUM }\%_8 = \frac{\text{MASS}_9}{\text{Total Mass}} \times 100$$

$$= \frac{0.39 \text{ mg}}{5.24 \text{ mg}} \times 100$$

$$= 7.44\%$$

Note that the apparent error in the decimal places of the calculated percentages is due to using masses from the computer print-out which have been rounded off to two decimal places before printing.

The cumulative mass loading of particles smaller in diameter than the corresponding D_{50} in milligrams per actual cubic meter (CUM. (MG/ACM) SMALLER THAN D50) for a particular stage j is given by the formula

$$\text{CUM.(MG/ACM)}_j = \frac{\sum_{i=j+1}^{9} \text{MASS}_i}{\text{SAMPLING DURATION(min)}} \times \frac{35.314667 \text{ cubic feet/cubic meter}}{\text{FLOWRATE (ACFM)}}$$

From the information at the top of the computer print-out sheet, the flowrate is 0.500 actual cubic feet per minute (ACFM) and the sampling duration is 20.00 minutes. Therefore, for S4,

$$\text{CUM.(MG/ACM)}_4 = \frac{\text{MASS}_5 + \text{MASS}_6 + \text{MASS}_7 + \text{MASS}_8 + \text{MASS}_9}{20 \text{ minutes}}$$

$$\times \frac{35.314667 \text{ cubic feet/cubic meter}}{0.500 \text{ ACFM}} = 12.3 \text{ mg/ACM}$$

For S8, the mass of the particulate collected on the filter is again used,

$$\text{CUM.(MG/ACM)}_8 = \frac{\text{MASS}_9}{20 \text{ minutes}} \times \frac{35.314667 \text{ cubic feet/cubic meter}}{0.500 \text{ ACFM}}$$

$$= \frac{0.39 \text{ mg}}{20 \text{ minutes}} \times \frac{35.314667 \text{ cubic feet/cubic meter}}{0.500 \text{ ACFM}}$$

$$= 1.38 \text{ mg/ACM}$$

The cumulative mass loading of particles smaller in diameter than the corresponding D_{50} in grains per actual cubic foot (CUM. (GR/ACF) SMALLER THAN D50) for a particular stage j is given by the formula

$$\text{CUM.(GR/ACF)}_j = \frac{\text{CUM.(MG/ACM)}_j}{2.2883519 \frac{\text{grams/cubic meter}}{\text{grains/cubic foot}} \times 1000 \text{ mg/gram}}$$

For S7,

$$\text{CUM.(GR/ACF)}_7 = \frac{1.52 \text{ mg/ACM}}{2.2883519 \frac{\text{grams/cubic meter}}{\text{grains/cubic foot}} \times 1000 \text{ mg/gram}}$$

$$= 6.64 \times 10^{-4} \text{ grains/ACF}$$

The cumulative mass loading of particles smaller in diameter than the corresponding D_{50} in grains per dry standard cubic foot (CUM. (GR/DSCF) SMALLER THAN D50) is calculated to show what the above cumulative would be for one cubic foot of dry gas at 70°F and at a pressure of 29.92 inches of mercury. For a particular stage j,

$$\text{CUM.(GR/DSCF)}_j = \text{CUM.(GR/ACF)}_j$$

$$\times \frac{\text{Absolute Stack Temperature}}{\text{Absolute Standard Temperature}} \times \frac{\text{Absolute Standard Pressure}}{\text{Absolute Stack Pressure}}$$

$$\times \frac{1}{(1\text{-Fraction of } H_2O)}$$

where absolute means the temperature and pressure are in absolute units-degrees Rankin or degrees Kelvin for temperature, and atmospheres, inches or millimeters of mercury for pressure.

For S1,

$$\text{CUM.(GR/DSCF)}_1 = 6.96 \times 10^{-3} \text{ gr/ACF}$$

$$\times \frac{(400 + 460)\,^0\text{R}}{(70 + 460)\,^0\text{R}} \times \frac{29.92 \text{ in. Hg}}{26.50 \text{ in. Hg}} \times \frac{1}{(1.00-0.01)} = 1.29 \times 10^{-2} \text{ gr/DSCF}$$

The particle size distribution may be presented on a differential basis which is the slope of the cumulative curve. If we define the terms:

ΔM_j = MG/DSCM/STAGE$_j$ and

$(\Delta \log D)_j = \log_{10}(D50_{j-1}) - \log_{10}(D50_j)$ then

$$\left(\frac{\Delta M}{\Delta \log D}\right)_j = \frac{MG/DSCM/STAGE_j}{\log_{10}(D50_{j-1}) - \log_{10}(D50_j)} .$$

Since the computer printer does not contain Greek letters, the computer print-out sheet reads DM/DLOG D instead of $\Delta M/\Delta LOG\ D$.

For S6,

$$\left(\frac{\Delta M}{\Delta LOGD}\right)_6 = \frac{9.35 \text{ mg/DSCM}}{\log_{10}(2.22) - \log_{10}(1.29)} = 39.7 \text{ mg/DSCM}$$

Note that $\Delta M/\Delta LOGD$ has the dimensions of the numerator since the denominator is dimensionless. In the calculation for S1, a maximum particle diameter is used. For this example, MAX. PARTICLE DIAMETER = 100.0 microns.

$$\left(\frac{\Delta M}{\Delta LOGD}\right)_1 = \frac{4.71 \text{ mg/DSCM}}{\log_{10}(100) - \log_{10}(10.74)} = 4.86 \text{ mg/DSCM}$$

For the filter stage, the D50 is arbitrarily chosen to be one-half of the D_{50} for stage eight (S8). For this example, it is chosen to be 0.33 micrometers/2 = 0.165 micrometers. Thus,

$$\left(\frac{\Delta M}{\Delta LOGD}\right)_9 = \frac{2.55 \text{ mg/DSCM}}{\log_{10}(0.33) - \log_{10}(0.165)} = 8.47 \text{ mg/DSCM}$$

The geometric mean diameter in micrometers (GEO. MEAN DIA. (MICROMETERS)) for a particular stage j is given by the formula

$$\text{GEO. MEAN DIA.}_j = \sqrt{D50_j \times D50_{j-1}}$$

For S8,

$$\text{GEO. MEAN DIA.}_8 = \sqrt{0.33 \times 0.69} \text{ micrometers}$$
$$= 0.477 \text{ micrometers}$$

As in the ΔLOGD calculation, we again use the maximum particle diameter for the stage one calculation and one-half the D_{50} for stage eight for the filter stage calculation.

For S1,

$$\text{GEO. MEAN DIA.}_1 = \sqrt{10.74 \times 100.0} \text{ micrometers}$$
$$= 32.8 \text{ micrometers}$$

For the filter,

$$\text{GEO. MEAN DIA.}_9 = \sqrt{0.165 \times 0.33} \text{ micrometers}$$
$$= 0.23 \text{ micrometers}$$

A differential number distribution can also be derived. Since ΔM_j = MG/DSCM/STAGE$_j$ is the mass per unit volume for stage j then we can define ΔN_j as ΔN_j = NUMBER OF PARTICLES/DSCM/STAGE$_j$ or the number of particles per unit volume for stage j. Now ΔM_j and ΔN_j are related by the equation $\Delta M_j = \Delta N_j \times m_p$, where m_p is the average mass of the particles collected on one stage. Dividing both sides of the equation by $m_p \times \Delta$LOGD yields

$$\frac{(\Delta M/\Delta LOGD)_j}{m_p} = \left(\frac{\Delta N}{\Delta LOG\ D}\right)_j .$$

Now $m_p = \rho_p V_p$ where ρ_p is the assumed particle density and V_p is the average volume of one particle on one stage. To obtain m_p in milligram units when ρ_p is in grams per cubic centimeter and V_p is in cubic micrometers, certain conversion factors must be used. The complete formula, using the correct conversion factors and the expression $(4/3)\ (\pi)\ (d/2)^3$ for V_p where d is the geometric mean diameter in micrometers, is:

$$m_p = \rho_p \left(\frac{10^3 \text{ mg}}{1 \text{ gm}}\right) \left(\frac{4\pi}{3}\right)\left(\frac{d}{2}\right)^3 \left(\frac{10^{-12} \text{ cm}^3}{1 \text{ cubic micrometer}}\right) = 5.23599 \times 10^{-10}\ \rho_p d^3.$$

Therefore,

$$\left(\frac{\Delta N}{\Delta LOGD}\right)_j = \frac{(\Delta M/\Delta LOGD)_j}{5.23599 \times 10^{-10}\ \rho_p d^3}$$

where $\Delta M/\Delta LOGD$ is in units of mg/DSCM, ρ_p is in gm/cc, d is in microns, and $\Delta N/\Delta LOGD$ is in number of particles/DSCM.

For S3,

$$\left(\frac{\Delta N}{\Delta LOGD}\right)_3 = \frac{17.9 \text{ mg/DSCM}}{(5.23599 \times 10^{-10}) \times (1.35 \text{ gm/cc}) \times (7.96 \text{ microns})^3}$$

$$= 5.02 \times 10^7 \text{ particles/DSCM.}$$

For the filter stage

$$\left(\frac{\Delta N}{\Delta LOGD}\right)_9 = \frac{8.47 \text{ mg/DSCM}}{(5.23599 \times 10^{-10}) \times (1.35 \text{ gm/cc}) \times (0.231 \text{ microns})^3}$$

$$= 9.72 \times 10^{11} \text{ particles/DSCM}$$

The test data is usually classified according to sampling location (outlet or inlet), sampling time (day, week, etc.) and combustion chamber or pollution control device conditions (high or low sulfur coal for coal plants, normal or below normal fuel consumption, normal or below normal current density for electrostatic precipitators, etc.). When classified, all of the data taken in a single classification is usually averaged together and plotted on appropriate graph paper. For example, the $\Delta M/\Delta LOGD$ at a given geometric mean diameter or within a small range of geometric mean diameters might be averaged over all the tests performed in a day and plotted as ordinate and abscissa, respectively on log-log graph paper.

Error bars indicating standard deviation or confidence limits would be included on the graph. A Hewlett-Packard HP-25 calculator program is included which will calculate the average ($\overline{X}$), the standard deviation(S), the relative standard deviation ($S/\overline{X}$), a 90% or 95% confidence interval (CI), the lower confidence limit ($\overline{X}$ - CI or LCL), and the upper confidence limit ($\overline{X}$ + CI or UCL). Also included is some hypothetical data typical of Brink impactor samples giving the $\Delta M/\Delta LOGD$ and geometric mean diameter values for one day. The average and other programmed calculations have been listed underneath the data in this table and on page 55 a graph of the average $\Delta M/\Delta LOGD$ values $\pm$ one standard deviation versus the average of the geometric mean diameters is plotted on log-log graph paper. Note that the standard deviations for the geometric mean diameters were too small to be indicated on the graph. A smooth line was drawn through the ΔM/ΔLOGD data points and the upper and lower standard deviations. These curves are used to calculate the fractional efficiency.

On page 56 is a ΔM/ΔLOGD plot of hypothetical data from an Andersen impactor, which is normally used by SRI at the outlets of emission control devices while the Brink impactor is typically used at the inlets of those devices. It was assumed that the Andersen ΔM/ΔLOGD plot represented values obtained the same day as that of the Brink. Thus it was valid to find the efficiency of the control device by comparing the two plots. A set of particle sizes was chosen which would be used in deriving an average cumulative mass loading and the efficiency of the control device from the ΔM/ΔLOGD plots. The maximum and minimum particle sizes are chosen for which ΔM/ΔLOGD values are available in both the inlet and outlet ΔM/ΔLOGD distributions. These particle sizes are listed under the heading Geometric Mean Diameter on page 52.

Notice that by beginning the set with the particle size 0.500 micrometers, the data from the filter stages is not utilized. The reason the filter stage data is not included is that during the operation of a cascade impactor there is always a certain amount of particle bounce and reentrainment into the gas stream, and subsequent deposition on a lower stage. These particles are larger than most of the particles collected on the stage and thus in the lower stages, their mass can be a significant percentage of the total mass for that stage. The errors tend to be more significant for the fine particle end of the distribution and most significant of all for the filter. In addition, many filter media contain components which react chemically with constituents of flue gases (SO_2, for example). This gaseous reaction with the filter substrate can result in a change in the weight of the substrate even though the substrate was preconditioned. Again, substrate weight changes would usually be much more serious for the lower stages and back-up filter, whose particulate mass loadings are generally small. Also, the filter has a larger surface area than the substrates and is more thoroughly permeated by the gas going through it.

The filter stage weight, then, is likely to contain a larger error and may not be an accurate record of the concentration of small particles in the gas stream sampled. For this reason, the derived $\Delta M/\Delta LOGD$ value for the filter stage weights is often ignored especially if it exhibits any unusual characteristics. For more information on particle bounce and reentrainment see Particulate Sizing Techniques for Control Device Evaluation by Cushing, Lacey, McCain, and Smith, Final Report of EPA Contract No. 68-02-0273, to be published. For more information on substrate weight changes due to reactions with the components in a gas stream see Particulate Sizing Techniques for Control Device Evaluation by Cushing, Lacey, McCain, and Smith, August, 1975, Publication Number EPA-650/2-74-102a.

The percent penetration of a particular size particle is found by dividing the $\Delta M/\Delta LOGD$ for the outlet at that size by the $\Delta M/\Delta LOGD$ for the inlet at that same size, and multiplying the quotient by 100. The same is done using upper curve (where one standard deviation is added) for the outlet and lower curve (where one standard deviation is subtracted) for the inlet and vice versa from the $\Delta M/\Delta LOGD$ plots to obtain a set of penetration values which may be roughly interpreted as "upper and lower standard deviations for the percent penetration". The collection efficiency of the emission control device is 100% minus the percent penetration. The collection efficiency corresponding to various particle sizes is plotted on log-log probability graph paper on page 57.

Although cumulative mass loading data for each impactor test is presented in tabular form on the computer print-out sheet, a more accurate average cumulative mass loading is found by integrating the average ΔM/ΔLOGD curve. The equation below yields ΔM_i corresponding to a particular size interval (Geometric Mean Diameter) d_i to d_{i+1} from the values of ΔM/ΔLOGD at those particle sizes. These values are taken from the ΔM/ΔLOGD plots on pages 55 and 56 and listed opposite the corresponding geometric mean diameters and identification numbers i on the table on page 52.

$$\Delta M_i = \frac{(\Delta M/\Delta LOGD)_i + (\Delta M/\Delta LOGD)_{i-1}}{2} \times \log_{10}\left(\frac{d_i}{d_{i-1}}\right)$$

Next the ΔM_i's are progressively summed to obtain the cumulative mass loading. Upper and lower 90% confidence limits are found by similar integrations of the upper and lower 90% confidence limits of the ΔM/ΔLOGD plots. A table listing ΔM/ΔLOGD, percent penetration, and cumulative mass loading values and their corresponding standard deviations for each size d_i is found on page 52. There is no value of the cumulative for d_1 because there is no valid $(\Delta M/\Delta LOGD)_0$ value due to particle bounce, etc. Thus the cumulative mass loadings plotted are cumulatives for particles larger than the D_{50} of the last impactor stage. Plots of cumulative mass loading for the inlet and percent efficiency of the emissions control device are found on pages 54 and 57.

HP-25 Program Form

Title Mean, Standard Deviation, 90/95% Confidence Interval Page 1 of 2

Switch to PRGM mode, press [f] [PRGM], then key in the program.

DISPLAY LINE	DISPLAY CODE	KEY ENTRY	X	Y	Z	T	COMMENTS
00							
01	14 21	f $\bar{x}$					
02	23 04	STO 4					
03	74	R/S					
04	14 22	fs					
05	23 05	STO 5					
06	74	R/S					
07	24 04	RCL 4					
08	71	÷					
09	74	R/S					
10	24 05	RCL 5					
11	24 03	RCL 3					
12	14 02	f$\sqrt{x}$					
13	71	÷					
14	24 03	RCL 3					
15	01	1					
16	41	−					
17	24 02	RCL 2					
18	14 03	f y^x					
19	24 01	RCL 1					
20	61	X					
21	24 00	RCL 0					
22	51	+					
23	61	X					
24	23 05	STO 5					
25	74	R/S					
26	24 04	RCL 4					
27	24 05	RCL 5					
28	41	−					
29	74	R/S					
30	24 04	RCL 4					
31	24 05	RCL 5					
32	51	+					
33	74	R/S					
34	00	0					
35	23 03	STO 3					
36	23 04	STO 4					
37	23 05	STO 5					
38	23 06	STO 6					
39	23 07	STO 7					
40	13 00	GTO 00					
41							
42							
43							
44							
45							
46							
47							
48							
49							

REGISTERS	
R_0	
R_1	
R_2	
R_3	n
R_4	$\bar{x}$
R_5	s_1 C.I.
R_6	Σx^2
R_7	Σx

HP-25 Program Form

Title Mean, Standard Deviation, 90/95% Confidence Interval Page 2 of 2

Programmer Joseph D. McCain

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS				OUTPUT DATA/UNITS
1	Initialize		f PRGM	f REG			
2a	For 90% C.I.	1.645	STO 0				
		2.60481	STO 1				
		1.18553	CHS	STO 2			
2b	For 95% C.I.	1.96	STO 0				
		5.5495	STO 1				
		1.34635	CHS	STO 2			
3	Enter values x_i						
	for i = 1, N:	x_i	Σ+				i
	if error in x_i:		fLASTx	f Σ-			
4a	Calculate mean		R/S				$\bar{x}$
b	Cal. standard devia-		R/S				s
	tion						
c	Cal. relative std.		R/S				$s/\bar{x}$
	deviation						
d	Cal. confidence		R/S				C.I.
	interval						
e	Cal. lower confidence		R/S				LCL
	limit						
f	Cal. upper confidence		R/S				UCL
	limit						
5	To determine effect						
	of omitting a point,						
	x_m, from data set:	x_m	fΣ-	GTO 00			
	and go to step 4.						
6	To abandon calculation						
	during step 4:		GTO 34	R/S			
	and go to step 3.						
7	For new data set						
	after step 4f (UCL):		R/S				

and go to step 3.

Hypothetical Data - Brink Impactor

Test		CYC	S0	S1	S2	S3	S4	S5	S6	SF
1	ΔM/ΔLOGD*	3770	2630	1010	1190	1060	503	279	75.1	92.8
2	ΔM/ΔLOGD	3960	1500	866	991	1410	398	300	28.3	77.7
3	ΔM/ΔLOGD	3540	1720	1080	1080	913	452	163	41.5	104
4	ΔM/ΔLOGD	3410	2680	1130	1200	907	347	236	41.9	111
5	ΔM/ΔLOGD	3260	2910	1180	1310	1560	321	165	21.5	99.4
6	ΔM/ΔLOGD	3830	3050	1160	1380	1180	326	142	40.5	68.0
	ΔM/ΔLOGD Average	3630	2420	1070	1190	1170	391	214	41.5	92.2
	Standard Deviation	269	646	118	143	267	74.0	66.8	18.5	16.4
	Relative Std. Dev.	0.074	0.267	0.110	0.120	0.228	0.189	0.312	0.445	0.178
90% Confidence Interval		223	536	97.5	119	222	61.4	55.4	15.3	13.6
Lower Confidence Limit		3410	1880	973	1070	950	330	159	26.2	78.6
Upper Condidence Limit		3850	2950	1170	1310	1390	453	270	56.8	106
1	Geo. Mean Dia.	43.0	9.25	5.86	3.40	2.18	1.31	0.804	0.506	0.270
2	Geo. Mean Dia.	43.0	9.26	5.87	3.40	2.18	1.31	0.806	0.504	0.260
3	Geo. Mean Dia.	42.2	8.92	5.65	3.28	2.10	1.27	0.770	0.480	0.250
4	Geo. Mean Dia.	42.1	8.87	5.62	3.25	2.08	1.25	0.766	0.476	0.246
5	Geo. Mean Dia.	41.0	8.42	5.33	3.09	1.97	1.19	0.726	0.451	0.233
6	Geo. Mean Dia.	41.0	8.41	5.33	3.09	1.97	1.19	0.725	0.451	0.233
	Geo. Mean Dia. Average	42.1	8.86	5.61	3.25	2.08	1.25	0.766	0.478	0.249
	Standard Deviation	0.898	0.377	0.240	0.139	0.0944	0.0543	.0356	.0242	.0147
	Relative Std. Dev.	0.0214	0.0426	0.0428	0.0429	0.0454	0.0433	.0465	.0506	.0592
90% Confidence Interval		0.745	0.313	0.199	0.116	0.0783	0.0450	.0295	.0201	.0122
Lower Confidence Limit		41.3	8.54	5.41	3.14	2.00	1.21	.737	.460	.237
Upper Confidence Limit		42.8	9.17	5.81	3.37	2.16	1.30	.796	.498	.261

*NOTE: ΔM/ΔLOGD in units of mg/DSCM.
Geometric Mean Diameter in units of micrometers.

Hypothetical Data

i	Geometric Mean Diameter (Micrometers)		Outlet ΔM/ΔLOGD (mg/DSCM)	Inlet ΔM/ΔLOGD (mg/DSCM)	Percent Penetration	Inlet Cumulative Mass Loading (mg/DSCM)
1	0.500	$\bar{x}$	2.95	49.5	5.96	
		[1]$\bar{x} + 1\sigma$	5.27	79.0	19.5	
		[2]$\bar{x} - 1\sigma$	0.635	27.0	0.80	
2	0.800	$\bar{x}$	6.40	227	2.82	28.2
		$\bar{x} + 1\sigma$	8.70	310	5.47	39.7
		$\bar{x} - 1\sigma$	4.05	159	1.31	19.0
3	1.28	$\bar{x}$	7.40	410	1.80	93.2
		$\bar{x} + 1\sigma$	10.2	510	3.11	123
		$\bar{x} - 1\sigma$	4.99	328	0.98	68.7
4	2.05	$\bar{x}$	9.30	1170	0.79	254
		$\bar{x} + 1\sigma$	13.0	1437	1.49	322
		$\bar{x} - 1\sigma$	6.00	870	0.42	191
5	3.28	$\bar{x}$	13.2	1150	1.15	491
		$\bar{x} + 1\sigma$	19.0	1320	1.81	603
		$\bar{x} - 1\sigma$	7.20	1047	0.69	387
6	5.24	$\bar{x}$	12.8	1040	1.23	715
		$\bar{x} + 1\sigma$	18.8	1190	1.96	860
		$\bar{x} - 1\sigma$	6.90	960	0.58	591
7	8.39	$\bar{x}$	10.7	2280	0.47	1054
		$\bar{x} + 1\sigma$	15.3	2820	0.92	1269
		$\bar{x} - 1\sigma$	5.80	1660	0.21	859
8	13.4	$\bar{x}$	7.60	3000	0.25	1592
		$\bar{x} + 1\sigma$	10.6	3600	0.43	1924
		$\bar{x} - 1\sigma$	4.00	2490	0.11	1282
9	21.5	$\bar{x}$	4.50	3460	0.13	2252
		$\bar{x} + 1\sigma$	6.00	3880	0.20	2688
		$\bar{x} - 1\sigma$	2.55	3020	0.07	1845

[1]Average value plus one standard deviation
[2]Average value minus one standard deviation

HYPOTHETICAL ANDERSEN

IMPACTOR FLOWRATE = 0,500 ACFM   IMPACTOR TEMPERATURE = 400,0 F = 204,4 C   SAMPLING DURATION = 20,00 MIN

IMPACTOR PRESSURE DROP = 1,5 IN, OF HG   STACK TEMPERATURE = 400,0 F = 204,4 C

ASSUMED PARTICLE DENSITY = 1,35 GM/CU,CM,   STACK PRESSURE = 26,50 IN, OF HG   MAX, PARTICLE DIAMETER = 100,0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 0,95   CO = 0,00   N2 = 76,53   O2 = 20,53   H2O = 1,00

CALC, MASS LOADING = 8,0711E-03 GR/ACF   1,4948E-02 GR/DSCF   1,8470E+01 MG/ACM   3,4207E+01 MG/DSCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	S8	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8	9
D50 (MICROMETERS)	10,74	9,95	6,36	4,19	2,22	1,29	0,69	0,33	
MASS (MILLIGRAMS)	0,72	0,40	0,53	0,09	0,38	1,43	1,25	0,04	0,39
MG/DSCM/STAGE	4,71E+00	2,62E+00	3,47E+00	5,89E-01	2,49E+00	9,35E+00	8,18E+00	2,62E-01	2,55E+00
CUM, PERCENT OF MASS SMALLER THAN D50	86,24	78,59	68,46	66,74	59,47	32,13	8,23	7,46	
CUM, (MG/ACM) SMALLER THAN D50	1,59E+01	1,45E+01	1,26E+01	1,23E+01	1,10E+01	5,93E+00	1,52E+00	1,38E+00	
CUM, (GR/ACF) SMALLER THAN D50	6,96E-03	6,34E-03	5,53E-03	5,39E-03	4,80E-03	2,59E-03	6,64E-04	6,02E-04	
CUM, (GR/DSCF) SMALLER THAN D50	1,29E-02	1,17E-02	1,02E-02	9,98E-03	8,89E-03	4,80E-03	1,23E-03	1,12E-03	
GEO, MEAN DIA, (MICROMETERS)	3,28E+01	1,03E+01	7,96E+00	5,17E+00	3,05E+00	1,69E+00	9,43E-01	4,74E-01	2,31E-01
DM/DLOGD (MG/DSCM)	4,86E+00	7,94E+01	1,79E+01	3,25E+00	8,99E+00	3,99E+01	2,98E+01	8,09E-01	8,47E+00
DN/DLOGD (NO, PARTICLES/DSCM)	1,95E+05	1,02E+08	5,01E+07	3,33E+07	4,48E+08	1,16E+10	5,03E+10	1,08E+10	9,74E+11

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

HYPOTHETICAL DATA - BRINK IMPACTOR

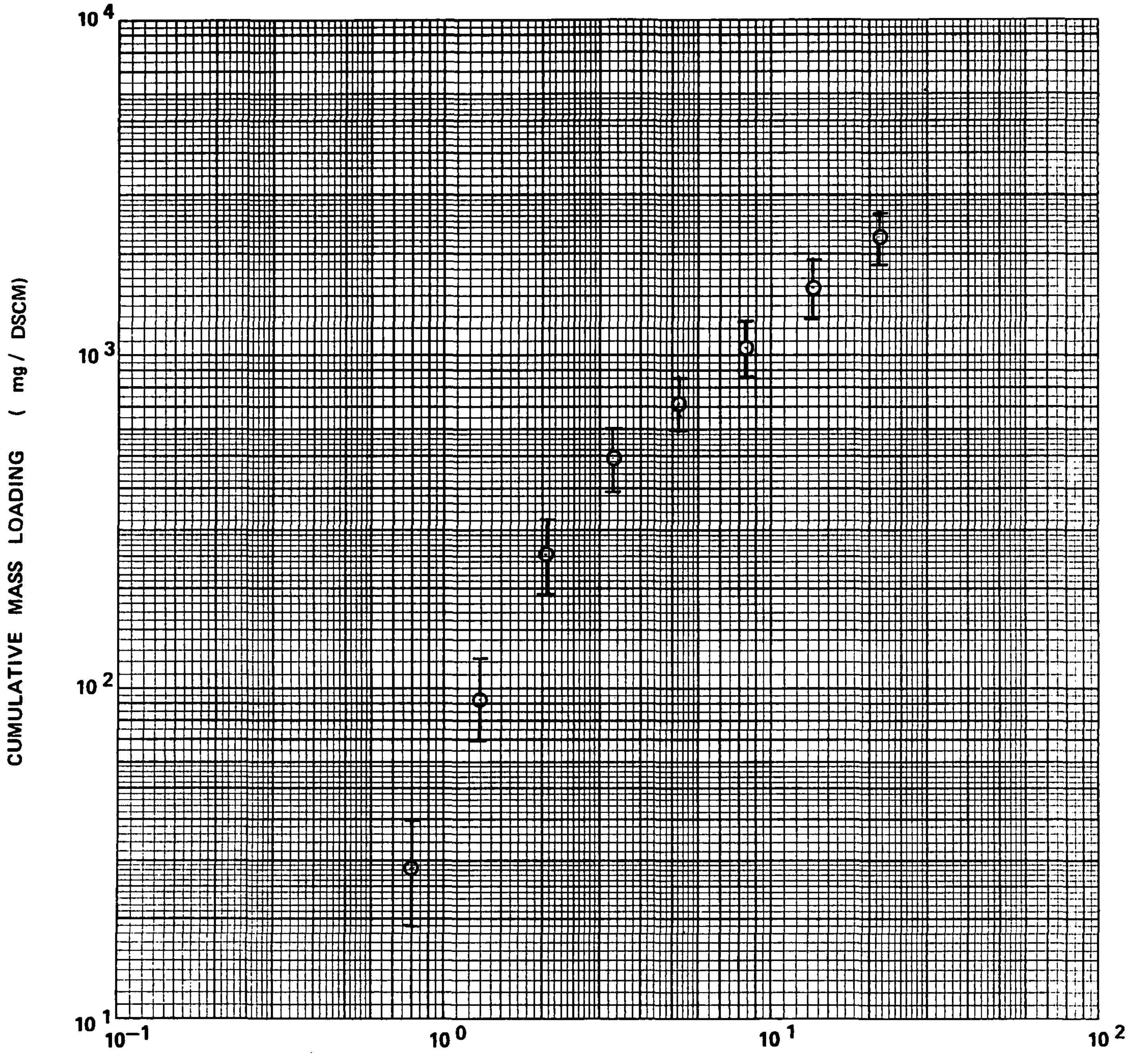
SITE ____________________

LOCATION ________________

DATE ____________________

ASSUMED PARTICLE DENSITY = 1.35 gm / cm^3

ERROR BARS INDICATE ONE STANDARD DEVIATION



HYPOTHETICAL DATA - BRINK IMPACTOR

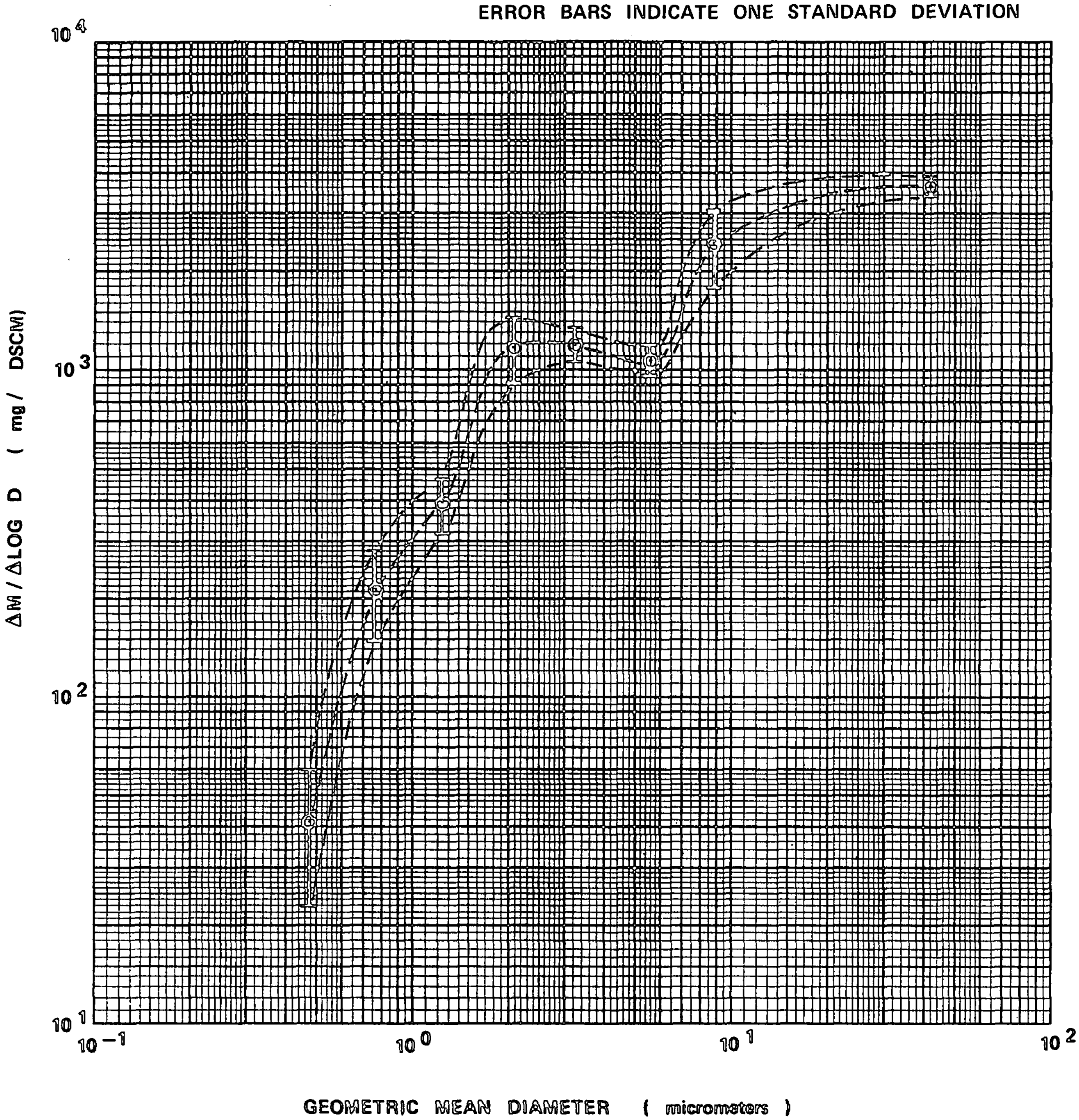
SITE ____________________

LOCATION ________________

DATE ____________________

ASSUMED PARTICLE DENSITY = 1.35 gm / cm^3

ERROR BARS INDICATE ONE STANDARD DEVIATION

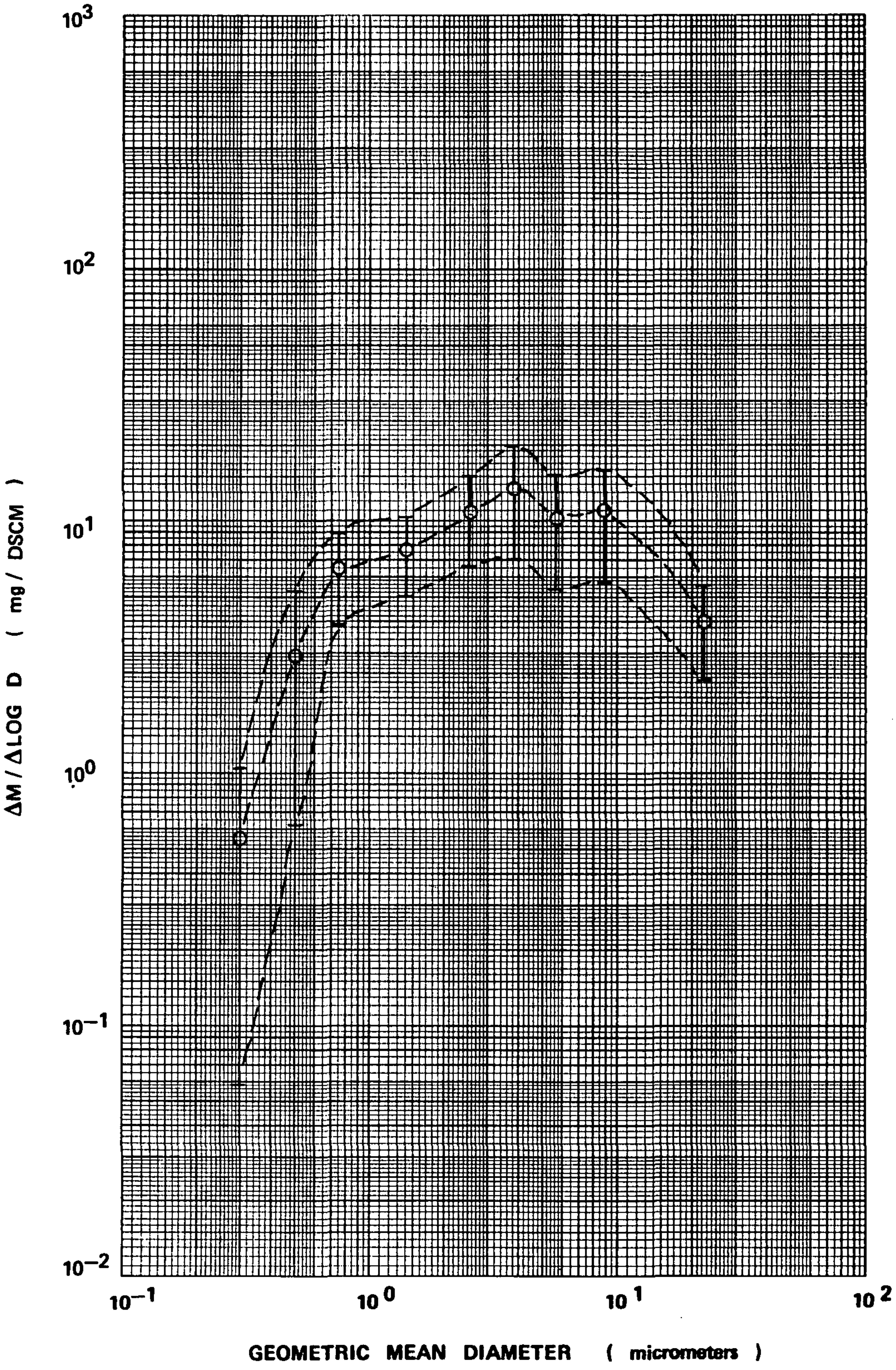


HYPOTHETICAL DATA - ANDERSEN IMPACTOR

SITE ____________________

LOCATION ____________________ ASSUMED PARTICLE DENSITY = 1.35 gm / cm^3

DATE ____________________ ERROR BARS INDICATE ONE STANDARD DEVIATION



SITE ____________________

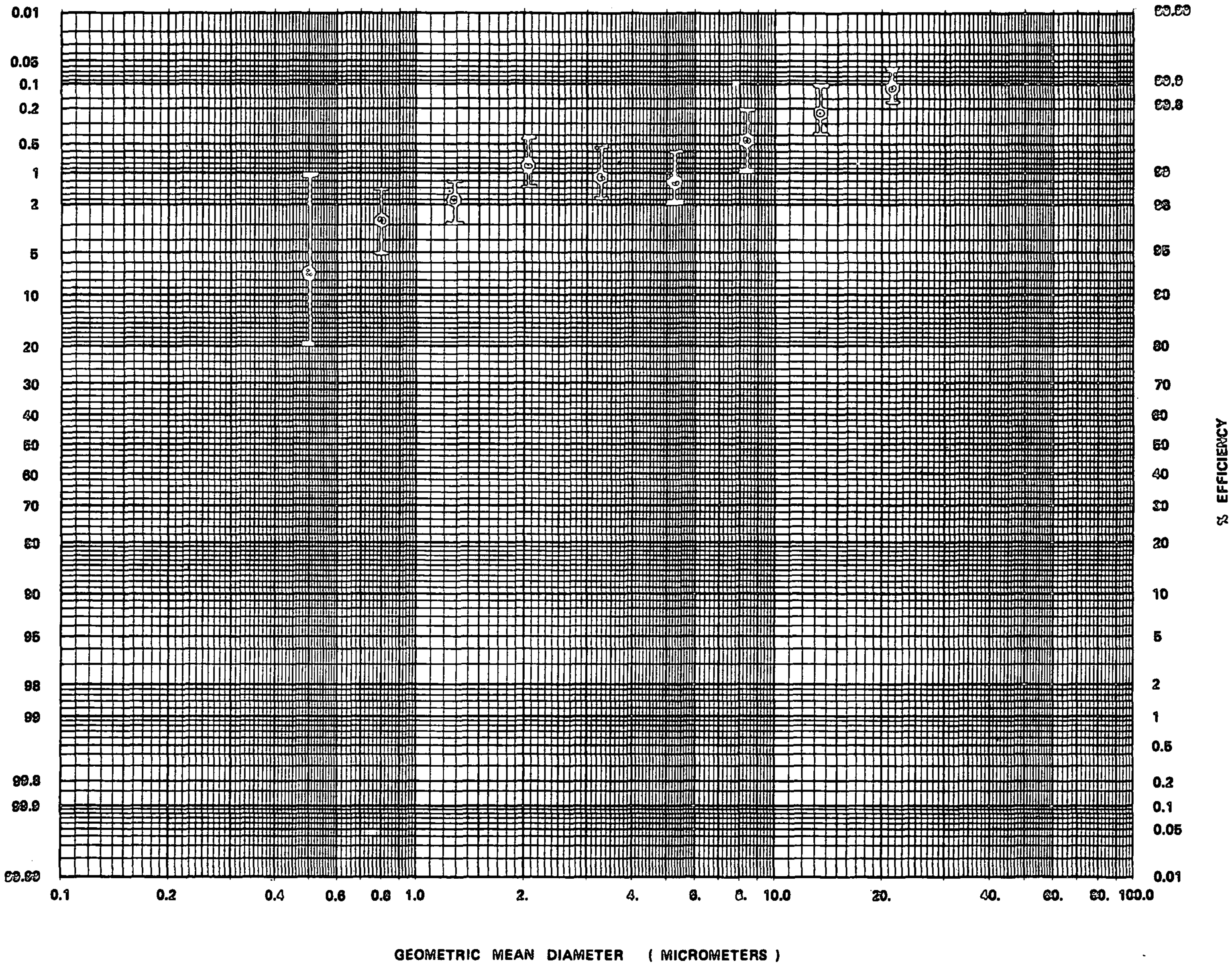
LOCATION ____________________

DATE ____________________

HYPOTHETICAL DATA

NOTE

ERROR BARS DERIVED FROM ONE STANDARD DEVIATION INDICATED ON INLET AND OUTLET ΔM/ΔLOG D CURVES



IN #4

SRI-4 11-17-75 1000 PURT-1

IMPACTOR FLOWRATE = 0.079 ACFM   IMPACTOR TEMPERATURE = 400.0 F = 204.4 C   SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 3.0 IN. OF HG   STACK TEMPERATURE = 400.0 F = 204.4 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM.   STACK PRESSURE = 30.08 IN. OF HG   MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 15.50   CO = 0.00   N2 = 49.10   O2 = 7.50   H2O = 26.10

CALC. MASS LOADING = 5.7496E+00 GR/ACF   1.2399E+01 GR/DSCF   1.3157E+04 MG/ACM   2.8373E+04 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.25	3.54	2.08	1.43	0.74	0.52	
MASS (MILLIGRAMS)	1.08	0.36	1.22	0.88	5.58	18.60	1.75
MG/DSCM/STAGE	1.04E+03	3.47E+02	1.17E+03	8.47E+02	5.37E+03	1.79E+04	1.68E+03
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	9.63E+01	9.51E+01	9.10E+01	8.80E+01	6.91E+01	
CUM. (MG/ACM) SMALLER THAN D50	1.27E+04	1.25E+04	1.20E+04	1.16E+04	9.09E+03	7.82E+02	
CUM. (GR/ACF) SMALLER THAN D50	5.54E+00	5.47E+00	5.23E+00	5.06E+00	3.97E+00	3.42E-01	
CUM. (GR/DSCF) SMALLER THAN D50	1.19E+01	1.18E+01	1.13E+01	1.09E+01	8.56E+00	7.37E-01	
GEO. MEAN DIA. (MICROMETERS)	2.50E+01	4.70E+00	2.71E+00	1.73E+00	1.03E+00	6.20E-01	3.67E-01
DM/DLOGD (MG/DSCM)	8.64E+02	1.40E+03	5.09E+03	5.23E+03	1.88E+04	1.16E+05	5.60E+03
DN/DLOGD (NO. PARTICLES/DSCM)	7.23E+07	1.76E+10	3.34E+11	1.33E+12	2.25E+13	6.35E+14	1.48E+14

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN #5

SRI-5 11-18-75 1112 PORT-2

IMPACTOR FLOWRATE = 0.071 ACFM   IMPACTOR TEMPERATURE = 400.0 F = 204.4 C   SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 3.0 IN. OF HG   STACK TEMPERATURE = 400.0 F = 204.4 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM.   STACK PRESSURE = 30.15 IN. OF HG   MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 15.50   CO = 0.00   N2 = 49.10   O2 = 7.50   H2O = 26.10

CALC. MASS LOADING = 1.6039E+00 GR/ACF   3.4508E+00 GR/DSCF   3.6703E+03 MG/ACM   7.8966E+03 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.60	3.73	2.20	1.52	0.79	0.55	
MASS (MILLIGRAMS)	0.63	0.21	0.20	0.49	3.38	2.04	0.45
MG/DSCM/STAGE	6.72E+02	2.24E+02	2.13E+02	5.23E+02	3.61E+03	2.18E+03	4.80E+02
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	9.15E+01	8.87E+01	8.60E+01	7.93E+01	3.37E+01	
CUM. (MG/ACM) SMALLER THAN D50	3.36E+03	3.25E+03	3.15E+03	2.91E+03	1.24E+03	2.23E+02	
CUM. (GR/ACF) SMALLER THAN D50	1.47E+00	1.42E+00	1.38E+00	1.27E+00	5.40E-01	9.76E-02	
CUM. (GR/DSCF) SMALLER THAN D50	3.16E+00	3.06E+00	2.97E+00	2.74E+00	1.16E+00	2.10E-01	
GEO. MEAN DIA. (MICROMETERS)	2.57E+01	4.96E+00	2.86E+00	1.82E+00	1.09E+00	6.60E-01	3.91E-01
DM/DLOGD (MG/DSCM)	5.69E+02	9.07E+02	9.26E+02	3.24E+03	1.27E+04	1.42E+04	1.60E+03
DN/DLOGD (NO. PARTICLES/DSCM)	4.40E+07	9.70E+09	5.15E+10	6.98E+11	1.27E+13	6.47E+13	3.49E+13

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN #6

SRI-6 11-18-75 12:35 PORT-1

IMPACTOR FLOWRATE = 0.072 ACFM   IMPACTOR TEMPERATURE = 400.0 F = 204.4 C   SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 2.6 IN. OF HG   STACK TEMPERATURE = 400.0 F = 204.4 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM.   STACK PRESSURE = 30.15 IN. OF HG   MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 15.50   CO = 0.00   N2 = 49.10   O2 = 7.50   H2O = 26.10

CALC. MASS LOADING = 2.0232E+00 GR/ACF   4.3529E+00 GR/DSCF   4.6298E+03 MG/ACM   9.9609E+03 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.57	3.72	2.19	1.51	0.78	0.55	
MASS (MILLIGRAMS)	1.04	0.72	0.48	0.74	3.71	1.90	0.81
MG/DSCM/STAGE	1.10E+03	7.63E+02	5.09E+02	7.84E+02	3.93E+03	2.01E+03	8.58E+02
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	8.89E+01	8.13E+01	7.62E+01	6.83E+01	2.88E+01	
CUM. (MG/ACM) SMALLER THAN D50	4.12E+03	3.76E+03	3.53E+03	3.16E+03	1.33E+03	3.99E+02	
CUM. (GR/ACF) SMALLER THAN D50	1.80E+00	1.64E+00	1.54E+00	1.38E+00	5.83E-01	1.74E-01	
CUM. (GR/DSCF) SMALLER THAN D50	3.87E+00	3.54E+00	3.32E+00	2.97E+00	1.26E+00	3.75E-01	
GEO. MEAN DIA. (MICROMETERS)	2.56E+01	4.95E+00	2.85E+00	1.82E+00	1.09E+00	6.58E-01	3.90E-01
DM/DLOGD (MG/DSCM)	9.32E+02	3.09E+03	2.21E+03	4.86E+03	1.38E+04	1.32E+04	2.85E+03
DN/DLOGD (NO. PARTICLES/DSCM)	7.24E+07	3.34E+10	1.24E+11	1.06E+12	1.40E+13	6.06E+13	6.28E+13

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN #7

SRI-7 11-18-75 2:40 PORT-5

IMPACTOR FLOWRATE = 0.072 ACFM   IMPACTOR TEMPERATURE = 400.0 F = 204.4 C   SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 2.3 IN. OF HG   STACK TEMPERATURE = 400.0 F = 204.4 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM.   STACK PRESSURE = 30.15 IN. OF HG   MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 15.50   CO = 0.00   N2 = 49.10   O2 = 7.50   H2O = 26.10

CALC. MASS LOADING = 2.4722E+00 GR/ACF   5.3188E+00 GR/DSCF   5.6572E+03 MG/ACM   1.2171E+04 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.55	3.71	2.18	1.51	0.78	0.55	
MASS (MILLIGRAMS)	1.10	0.54	0.31	0.86	5.29	1.76	1.69
MG/DSCM/STAGE	1.16E+03	5.69E+02	3.27E+02	9.06E+02	5.57E+03	1.85E+03	1.78E+03
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	9.05E+01	8.58E+01	8.31E+01	7.57E+01	2.99E+01	
CUM. (MG/ACM) SMALLER THAN D50	5.12E+03	4.85E+03	4.70E+03	4.28E+03	1.69E+03	8.28E+02	
CUM. (GR/ACF) SMALLER THAN D50	2.24E+00	2.12E+00	2.05E+00	1.87E+00	7.39E-01	3.62E-01	
CUM. (GR/DSCF) SMALLER THAN D50	4.81E+00	4.56E+00	4.42E+00	4.03E+00	1.59E+00	7.79E-01	
GEO. MEAN DIA. (MICROMETERS)	2.56E+01	4.93E+00	2.85E+00	1.81E+00	1.09E+00	6.56E-01	3.89E-01
DM/DLOGD (MG/DSCM)	9.79E+02	2.30E+03	1.42E+03	5.62E+03	1.96E+04	1.22E+04	5.92E+03
DN/DLOGD (NO. PARTICLES/DSCM)	7.64E+07	2.51E+10	8.04E+10	1.23E+12	2.01E+13	5.63E+13	1.31E+14

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN #8

SRI-8 11-18-75 4:40 PORT-1

IMPACTOR FLOWRATE = 0.067 ACFM   IMPACTOR TEMPERATURE = 393.0 F = 200.6 C   SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 6.0 IN. OF HG   STACK TEMPERATURE = 393.0 F = 200.6 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM.   STACK PRESSURE = 30.16 IN. OF HG   MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 15.50   CO = 0.00   N2 = 49.10   O2 = 7.50   H2O = 26.10

CALC. MASS LOADING = 2.1964E+00 GR/ACF   4.6855E+00 GR/DSCF   5.0261E+03 MG/ACM   1.0722E+04 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.78	3.84	2.26	1.56	0.81	0.57	
MASS (MILLIGRAMS)	3.82	1.39	0.21	0.98	2.58	0.34	0.23
MG/DSCM/STAGE	4.29E+03	1.56E+03	2.36E+02	1.10E+03	2.90E+03	3.82E+02	2.58E+02
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	6.00E+01	4.55E+01	4.33E+01	3.30E+01	5.97E+00	
CUM. (MG/ACM) SMALLER THAN D50	3.02E+03	2.28E+03	2.17E+03	1.66E+03	3.00E+02	1.21E+02	
CUM. (GR/ACF) SMALLER THAN D50	1.32E+00	9.98E-01	9.50E-01	7.25E-01	1.31E-01	5.30E-02	
CUM. (GR/DSCF) SMALLER THAN D50	2.81E+00	2.13E+00	2.03E+00	1.55E+00	2.80E-01	1.13E-01	
GEO. MEAN DIA. (MICROMETERS)	2.60E+01	5.10E+00	2.94E+00	1.88E+00	1.12E+00	6.77E-01	4.00E-01
DM/DLOGD (MG/DSCM)	3.67E+03	6.32E+03	1.02E+03	6.83E+03	1.02E+04	2.45E+03	8.58E+02
DN/DLOGD (NO. PARTICLES/DSCM)	2.72E+08	6.23E+10	5.25E+10	1.35E+12	9.40E+12	1.03E+13	1.75E+13

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

INLET ST, REGIS COMPANY 11-19-75 RUN - 9,10,11,13,14

IMPACTOR FLOWRATE = 0,073 ACFM   IMPACTOR TEMPERATURE = 410,0 F = 210,0 C   SAMPLING DURATION = 1,00 MIN

IMPACTOR PRESSURE DROP = 2,5 IN, OF HG   STACK TEMPERATURE = 410,0 F = 210,0 C

ASSUMED PARTICLE DENSITY = 1,46 GM/CU,CM,   STACK PRESSURE = 30,10 IN, OF HG   MAX, PARTICLE DIAMETER = 100,0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 15,50   CO = 0,00   N2 = 49,10   O2 = 7,50   H2O = 26,10

CALC, MASS LOADING = 2,0773E+00 GR/ACF   4,5287E+00 GR/DSCF   4,7535E+03 MG/ACM   1,0363E+04 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6,52	3,69	2,17	1,50	0,78	0,55	
MASS (MILLIGRAMS)	1,37	0,79	0,59	0,42	4,07	1,68	0,96
MG/DSCM/STAGE	1,44E+03	8,29E+02	6,19E+02	4,41E+02	4,27E+03	1,76E+03	1,01E+03
CUM, PERCENT OF MASS SMALLER THAN D50	1,00E+02	8,61E+01	7,81E+01	7,22E+01	6,79E+01	2,67E+01	
CUM, (MG/ACM) SMALLER THAN D50	4,09E+03	3,71E+03	3,43E+03	3,23E+03	1,27E+03	4,62E+02	
CUM, (GR/ACF) SMALLER THAN D50	1,79E+00	1,62E+00	1,50E+00	1,41E+00	5,55E-01	2,02E-01	
CUM, (GR/DSCF) SMALLER THAN D50	3,90E+00	3,54E+00	3,27E+00	3,08E+00	1,21E+00	4,40E-01	
GEO, MEAN DIA, (MICROMETERS)	2,55E+01	4,91E+00	2,83E+00	1,80E+00	1,08E+00	6,51E-01	3,86E-01
DM/DLOGD (MG/DSCM)	1,21E+03	3,35E+03	2,68E+03	2,73E+03	1,50E+04	1,15E+04	3,35E+03
DN/DLOGD (NO, PARTICLES/DSCM)	9,52E+07	3,71E+10	1,55E+11	6,09E+11	1,56E+13	5,46E+13	7,63E+13

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN #10

SRI-10 11-19-75 10:00 PORT-4

IMPACTOR FLOWRATE = 0.072 ACFM IMPACTOR TEMPERATURE = 410.0 F = 210.0 C SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 3.1 IN. OF HG STACK TEMPERATURE = 410.0 F = 210.0 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM. STACK PRESSURE = 30.10 IN. OF HG MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 15.50 CO = 0.00 N2 = 49.10 O2 = 7.50 H2O = 26.10

CALC. MASS LOADING = 2.4990E+00 GR/ACF 5.4481E+00 GR/DSCF 5.7185E+03 MG/ACM 1.2467E+04 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.57	3.72	2.19	1.51	0.78	0.55	
MASS (MILLIGRAMS)	6.54	0.47	0.29	0.21	0.94	2.26	1.03
MG/DSCM/STAGE	6.95E+03	4.99E+02	3.08E+02	2.23E+02	9.98E+02	2.40E+03	1.09E+03
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	4.43E+01	4.03E+01	3.78E+01	3.60E+01	2.80E+01	
CUM. (MG/ACM) SMALLER THAN D50	2.53E+03	2.30E+03	2.16E+03	2.06E+03	1.60E+03	5.02E+02	
CUM. (GR/ACF) SMALLER THAN D50	1.11E+00	1.01E+00	9.45E-01	9.01E-01	7.00E-01	2.19E-01	
CUM. (GR/DSCF) SMALLER THAN D50	2.41E+00	2.20E+00	2.06E+00	1.96E+00	1.53E+00	4.78E-01	
GEO. MEAN DIA. (MICROMETERS)	2.56E+01	4.94E+00	2.85E+00	1.81E+00	1.08E+00	6.54E-01	3.88E-01
DM/DLOGD (MG/DSCM)	5.87E+03	2.02E+03	1.34E+03	1.38E+03	3.50E+03	1.56E+04	3.63E+03
DN/DLOGD (NO. PARTICLES/DSCM)	4.57E+08	2.19E+10	7.55E+10	3.02E+11	3.59E+12	7.28E+13	8.16E+13

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN # 11

SRI-11 11-19-75 11:45 PORT-1

IMPACTOR FLOWRATE = 0.074 ACFM   IMPACTOR TEMPERATURE = 410.0 F = 210.0 C   SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 2.3 IN. OF HG   STACK TEMPERATURE = 410.0 F = 210.0 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM.   STACK PRESSURE = 30.10 IN. OF HG   MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 15.50   CO = 0.00   N2 = 49.10   O2 = 7.50   H2O = 26.10

CALC. MASS LOADING = 1.2371E+00 GR/ACF   2.6971E+00 GR/DSCF   2.8309E+03 MG/ACM   6.1718E+03 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.52	3.69	2.17	1.49	0.78	0.54	
MASS (MILLIGRAMS)	0.32	1.06	0.29	0.25	0.97	1.67	1.34
MG/DSCM/STAGE	3.35E+02	1.11E+03	3.03E+02	2.62E+02	1.01E+03	1.75E+03	1.40E+03
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	9.46E+01	7.66E+01	7.17E+01	6.75E+01	5.10E+01	
CUM. (MG/ACM) SMALLER THAN D50	2.68E+03	2.17E+03	2.03E+03	1.91E+03	1.44E+03	6.43E+02	
CUM. (GR/ACF) SMALLER THAN D50	1.17E+00	9.48E-01	8.87E-01	8.35E-01	6.31E-01	2.81E-01	
CUM. (GR/DSCF) SMALLER THAN D50	2.55E+00	2.07E+00	1.93E+00	1.82E+00	1.38E+00	6.13E-01	
GEO. MEAN DIA. (MICROMETERS)	2.55E+01	4.90E+00	2.83E+00	1.80E+00	1.08E+00	6.50E-01	3.85E-01
DM/DLOGD (MG/DSCM)	2.82E+02	4.49E+03	1.32E+03	1.62E+03	3.56E+03	1.14E+04	4.66E+03
DN/DLOGD (NO. PARTICLES/DSCM)	2.22E+07	4.98E+10	7.61E+10	3.63E+11	3.73E+12	5.44E+13	1.06E+14

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

/N # 12

SRI-12 11-19-75 1115 PORT-6

IMPACTOR FLOWRATE = 0.073 ACFM   IMPACTOR TEMPERATURE = 410.0 F = 210.0 C   SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 2.5 IN. OF HG   STACK TEMPERATURE = 410.0 F = 210.0 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM.   STACK PRESSURE = 30.10 IN. OF HG   MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 15.50   CO = 0.00   N2 = 49.10   O2 = 7.50   H2O = 26.10

CALC. MASS LOADING = 1.9138E+00 GR/ACF   4.1723E+00 GR/DSCF   4.3794E+03 MG/ACM   9.5476E+03 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.53	3.70	2.17	1.50	0.78	0.55	
MASS (MILLIGRAMS)	0.61	0.89	0.29	0.69	2.78	2.59	1.24
MG/DSCM/STAGE	6.41E+02	9.35E+02	3.05E+02	7.25E+02	2.92E+03	2.72E+03	1.30E+03
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	9.33E+01	8.35E+01	8.03E+01	7.27E+01	4.21E+01	
CUM. (MG/ACM) SMALLER THAN D50	4.09E+03	3.66E+03	3.52E+03	3.18E+03	1.85E+03	5.98E+02	
CUM. (GR/ACF) SMALLER THAN D50	1.79E+00	1.60E+00	1.54E+00	1.39E+00	8.06E-01	2.61E-01	
CUM. (GR/DSCF) SMALLER THAN D50	3.89E+00	3.48E+00	3.35E+00	3.03E+00	1.76E+00	5.69E-01	
GEO. MEAN DIA. (MICROMETERS)	2.56E+01	4.91E+00	2.83E+00	1.80E+00	1.08E+00	6.51E-01	3.86E-01
DM/DLOGD (MG/DSCM)	5.41E+02	3.78E+03	1.32E+03	4.48E+03	1.02E+04	1.77E+04	4.33E+03
DN/DLOGD (NO. PARTICLES/DSCM)	4.24E+07	4.17E+10	7.59E+10	9.99E+11	1.07E+13	8.41E+13	9.84E+13

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN #15

SRI-15 11-19-75

IMPACTOR FLOWRATE = 0.072 ACFM IMPACTOR TEMPERATURE = 400.0 F = 204.4 C SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 2.7 IN. OF HG STACK TEMPERATURE = 400.0 F = 204.4 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM. STACK PRESSURE = 30.10 IN. OF HG MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 15.50 CO = 0.00 N2 = 49.10 O2 = 7.50 H2O = 26.10

CALC. MASS LOADING = 3.1698E+00 GR/ACF 6.8312E+00 GR/DSCF 7.2537E+03 MG/ACM 1.5632E+04 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.55	3.71	2.18	1.50	0.78	0.55	
MASS (MILLIGRAMS)	4.54	1.24	1.10	1.16	4.07	1.71	1.01
MG/DSCM/STAGE	4.79E+03	1.31E+03	1.16E+03	1.22E+03	4.29E+03	1.80E+03	1.06E+03
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	6.94E+01	6.10E+01	5.36E+01	4.58E+01	1.83E+01	
CUM. (MG/ACM) SMALLER THAN D50	5.03E+03	4.43E+03	3.89E+03	3.32E+03	1.33E+03	4.94E+02	
CUM. (GR/ACF) SMALLER THAN D50	2.20E+00	1.93E+00	1.70E+00	1.45E+00	5.82E-01	2.16E-01	
CUM. (GR/DSCF) SMALLER THAN D50	4.74E+00	4.17E+00	3.66E+00	3.13E+00	1.25E+00	4.66E-01	
GEO. MEAN DIA. (MICROMETERS)	2.56E+01	4.93E+00	2.84E+00	1.81E+00	1.08E+00	6.55E-01	3.88E-01
DM/DLOGD (MG/DSCM)	4.04E+03	5.29E+03	5.03E+03	7.57E+03	1.51E+04	1.18E+04	3.54E+03
DN/DLOGD (NO. PARTICLES/DSCM)	3.15E+08	5.78E+10	2.86E+11	1.67E+12	1.55E+13	5.49E+13	7.91E+13

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN #16

SRI-16 11-19-75 5:25 PORT-5

IMPACTOR FLOWRATE = 0.073 ACFM   IMPACTOR TEMPERATURE = 400.0 F = 204.4 C   SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 2.4 IN. OF HG   STACK TEMPERATURE = 400.0 F = 204.4 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM.   STACK PRESSURE = 30.10 IN. OF HG   MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 15.50   CO = 0.00   N2 = 49.10   O2 = 7.50   H2O = 26.10

CALC. MASS LOADING = 2.9738E+00 GR/ACF   6.4087E+00 GR/DSCF   6.8051E+03 MG/ACM   1.4665E+04 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.53	3.70	2.17	1.50	0.78	0.55	
MASS (MILLIGRAMS)	0.08	1.28	1.30	1.79	5.91	2.36	1.27
MG/DSCM/STAGE	8.39E+01	1.34E+03	1.36E+03	1.88E+03	6.20E+03	2.47E+03	1.33E+03
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	9.94E+01	9.03E+01	8.10E+01	6.82E+01	2.60E+01	
CUM. (MG/ACM) SMALLER THAN D50	6.77E+03	6.14E+03	5.51E+03	4.64E+03	1.77E+03	6.18E+02	
CUM. (GR/ACF) SMALLER THAN D50	2.96E+00	2.68E+00	2.41E+00	2.03E+00	7.72E-01	2.70E-01	
CUM. (GR/DSCF) SMALLER THAN D50	6.37E+00	5.79E+00	5.19E+00	4.37E+00	1.66E+00	5.82E-01	
GEO. MEAN DIA. (MICROMETERS)	2.56E+01	4.91E+00	2.84E+00	1.81E+00	1.08E+00	6.53E-01	3.87E-01
DM/DLOGD (MG/DSCM)	7.08E+01	5.43E+03	5.91E+03	1.16E+04	2.18E+04	1.62E+04	4.42E+03
DN/DLOGD (NO. PARTICLES/DSCM)	5.55E+06	5.99E+10	3.39E+11	2.58E+12	2.26E+13	7.60E+13	9.95E+13

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN #17

SRI-17 11-19-75 6:15 PORT-3

IMPACTOR FLOWRATE = 0.073 ACFM   IMPACTOR TEMPERATURE = 400.0 F = 204.4 C   SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 2.4 IN. OF HG   STACK TEMPERATURE = 400.0 F = 204.4 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM.   STACK PRESSURE = 30.10 IN. OF HG   MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 15.50   CO = 0.00   N2 = 49.10   O2 = 7.50   H2O = 26.10

CALC. MASS LOADING = 2.0782E+00 GR/ACF   4.4786E+00 GR/DSCF   4.7556E+03 MG/ACM   1.0248E+04 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.53	3.70	2.17	1.50	0.78	0.55	
MASS (MILLIGRAMS)	0.67	0.22	0.50	1.58	3.99	1.50	1.33
MG/DSCM/STAGE	7.01E+02	2.30E+02	5.23E+02	1.65E+03	4.18E+03	1.57E+03	1.39E+03
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	9.32E+01	9.09E+01	8.58E+01	6.97E+01	2.89E+01	
CUM. (MG/ACM) SMALLER THAN D50	4.43E+03	4.32E+03	4.08E+03	3.31E+03	1.37E+03	6.46E+02	
CUM. (GR/ACF) SMALLER THAN D50	1.94E+00	1.89E+00	1.78E+00	1.45E+00	6.01E-01	2.82E-01	
CUM. (GR/DSCF) SMALLER THAN D50	4.17E+00	4.07E+00	3.84E+00	3.12E+00	1.29E+00	6.09E-01	
GEO. MEAN DIA. (MICROMETERS)	2.55E+01	4.91E+00	2.83E+00	1.80E+00	1.08E+00	6.53E-01	3.87E-01
DM/DLOGD (MG/DSCM)	5.92E+02	9.32E+02	2.27E+03	1.02E+04	1.47E+04	1.03E+04	4.63E+03
DN/DLOGD (NO. PARTICLES/DSCM)	4.64E+07	1.03E+10	1.31E+11	2.28E+12	1.52E+13	4.84E+13	1.04E+14

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

111 # 18

SRI-18 11-19-75 6:15 PORT-2

IMPACTOR FLOWRATE = 0.072 ACFM   IMPACTOR TEMPERATURE = 395.0 F = 201.7 C   SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 2.4 IN. OF HG   STACK TEMPERATURE = 395.0 F = 201.7 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM.   STACK PRESSURE = 30.10 IN. OF HG   MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 15.50   CO = 0.00   N2 = 49.10   O2 = 7.50   H2O = 26.10

CALC. MASS LOADING = 2.1324E+00 GR/ACF   4.5686E+00 GR/DSCF   4.8796E+03 MG/ACM   1.0455E+04 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.53	3.70	2.18	1.50	0.78	0.55	
MASS (MILLIGRAMS)	0.85	0.49	0.59	1.26	4.05	1.49	1.26
MG/DSCM/STAGE	8.90E+02	5.13E+02	6.17E+02	1.32E+03	4.24E+03	1.56E+03	1.32E+03
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	9.15E+01	8.66E+01	8.07E+01	6.81E+01	2.75E+01	
CUM. (MG/ACM) SMALLER THAN D50	4.46E+03	4.23E+03	3.94E+03	3.32E+03	1.34E+03	6.16E+02	
CUM. (GR/ACF) SMALLER THAN D50	1.95E+00	1.85E+00	1.72E+00	1.45E+00	5.87E-01	2.69E-01	
CUM. (GR/DSCF) SMALLER THAN D50	4.18E+00	3.96E+00	3.69E+00	3.11E+00	1.26E+00	5.76E-01	
GEO. MEAN DIA. (MICROMETERS)	2.56E+01	4.91E+00	2.84E+00	1.81E+00	1.08E+00	6.54E-01	3.88E-01
DM/DLOGD (MG/DSCM)	7.51E+02	2.08E+03	2.68E+03	8.17E+03	1.49E+04	1.02E+04	4.38E+03
DN/DLOGD (NO. PARTICLES/DSCM)	5.88E+07	2.29E+10	1.54E+11	1.81E+12	1.54E+13	4.79E+13	9.82E+13

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN #19

SRI-1 12-16-75 1420 PORT-1

IMPACTOR FLOWRATE = 0,072 ACFM   IMPACTOR TEMPERATURE = 382,0 F = 194,4 C   SAMPLING DURATION = 1,00 MIN

IMPACTOR PRESSURE DROP = 3,7 IN, OF HG   STACK TEMPERATURE = 382,0 F = 194,4 C

ASSUMED PARTICLE DENSITY = 1,46 GM/CU,CM,   STACK PRESSURE = 30,00 IN, OF HG   MAX, PARTICLE DIAMETER = 100,0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 8,57   CO = 0,00   N2 = 39,86   O2 = 7,08   H2O = 25,50

CALC, MASS LOADING = 1,8583E+00 GR/ACF   3,9022E+00 GR/DSCF   4,2524E+03 MG/ACM   8,9295E+03 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6,43	3,63	2,13	1,47	0,76	0,53	
MASS (MILLIGRAMS)	1,07	0,19	0,26	0,34	2,71	2,22	1,94
MG/DSCM/STAGE	1,09E+03	1,94E+02	2,66E+02	3,48E+02	2,77E+03	2,27E+03	1,98E+03
CUM, PERCENT OF MASS SMALLER THAN D50	1,00E+02	8,77E+01	8,56E+01	8,26E+01	7,87E+01	4,77E+01	
CUM, (MG/ACM) SMALLER THAN D50	3,73E+03	3,64E+03	3,51E+03	3,35E+03	2,03E+03	9,45E+02	
CUM, (GR/ACF) SMALLER THAN D50	1,63E+00	1,59E+00	1,53E+00	1,46E+00	8,86E-01	4,13E-01	
CUM, (GR/DSCF) SMALLER THAN D50	3,42E+00	3,34E+00	3,22E+00	3,07E+00	1,86E+00	8,67E-01	
GEO, MEAN DIA, (MICROMETERS)	2,54E+01	4,83E+00	2,78E+00	1,77E+00	1,05E+00	6,31E-01	3,72E-01
DM/DLOGD (MG/DSCM)	9,18E+02	7,85E+02	1,15E+03	2,14E+03	9,62E+03	1,44E+04	6,59E+03
DN/DLOGD (NO, PARTICLES/DSCM)	7,37E+07	9,09E+09	6,97E+10	5,06E+11	1,08E+13	7,54E+13	1,67E+14

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN #20

SRI-2 12-16-75 1455 PORT-2

IMPACTOR FLOWRATE = 0.080 ACFM   IMPACTOR TEMPERATURE = 382.0 F = 194.4 C   SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 2.0 IN. OF HG   STACK TEMPERATURE = 382.0 F = 194.4 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM.   STACK PRESSURE = 30.00 IN. OF HG   MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 8.57   CO = 0.00   N2 = 39.86   O2 = 7.08   H2O = 25.50

CALC. MASS LOADING = 2.4499E+00 GR/ACF   5.1445E+00 GR/DSCF   5.6062E+03 MG/ACM   1.1772E+04 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.11	3.45	2.02	1.39	0.72	0.50	
MASS (MILLIGRAMS)	2.54	0.38	0.53	1.17	4.35	2.00	1.73
MG/DSCM/STAGE	2.35E+03	3.52E+02	4.91E+02	1.08E+03	4.03E+03	1.85E+03	1.60E+03
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	8.00E+01	7.70E+01	7.28E+01	6.36E+01	2.94E+01	
CUM. (MG/ACM) SMALLER THAN D50	4.49E+03	4.32E+03	4.08E+03	3.57E+03	1.65E+03	7.64E+02	
CUM. (GR/ACF) SMALLER THAN D50	1.96E+00	1.89E+00	1.78E+00	1.56E+00	7.20E-01	3.34E-01	
CUM. (GR/DSCF) SMALLER THAN D50	4.12E+00	3.96E+00	3.75E+00	3.27E+00	1.51E+00	7.01E-01	
GEO. MEAN DIA. (MICROMETERS)	2.47E+01	4.59E+00	2.64E+00	1.68E+00	9.98E-01	5.97E-01	3.53E-01
DM/DLOGD (MG/DSCM)	1.94E+03	1.42E+03	2.12E+03	6.66E+03	1.39E+04	1.18E+04	5.33E+03
DN/DLOGD (NO. PARTICLES/DSCM)	1.68E+08	1.92E+10	1.50E+11	1.84E+12	1.84E+13	7.28E+13	1.59E+14

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN#21

SRI-3 12-16-75 1741 PORT-5

IMPACTOR FLOWRATE = 0.079 ACFM   IMPACTOR TEMPERATURE = 382.0 F = 194.4 C   SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 2.6 IN. OF HG   STACK TEMPERATURE = 382.0 F = 194.4 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM.   STACK PRESSURE = 29.85 IN. OF HG   MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 8.57   CO = 0.00   N2 = 39.86   O2 = 7.08   H2O = 25.50

CALC. MASS LOADING = 1.6468E+00 GR/ACF   3.4754E+00 GR/DSCF   3.7684E+03 MG/ACM   7.9530E+03 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.15	3.48	2.04	1.40	0.72	0.50	
MASS (MILLIGRAMS)	0.55	0.29	0.30	0.36	3.45	2.07	1.41
MG/DSCM/STAGE	5.19E+02	2.74E+02	2.83E+02	3.40E+02	3.25E+03	1.95E+03	1.33E+03
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	9.35E+01	9.00E+01	8.65E+01	8.22E+01	4.13E+01	
CUM. (MG/ACM) SMALLER THAN D50	3.52E+03	3.39E+03	3.26E+03	3.10E+03	1.56E+03	6.30E+02	
CUM. (GR/ACF) SMALLER THAN D50	1.54E+00	1.48E+00	1.42E+00	1.35E+00	6.80E-01	2.76E-01	
CUM. (GR/DSCF) SMALLER THAN D50	3.25E+00	3.13E+00	3.01E+00	2.86E+00	1.43E+00	5.81E-01	
GEO. MEAN DIA. (MICROMETERS)	2.48E+01	4.62E+00	2.66E+00	1.69E+00	1.00E+00	6.00E-01	3.54E-01
DM/DLOGD (MG/DSCM)	4.28E+02	1.10E+03	1.22E+03	2.08E+03	1.13E+04	1.24E+04	4.42E+03
DN/DLOGD (NO. PARTICLES/DSCM)	3.67E+07	1.46E+10	8.47E+10	5.66E+11	1.46E+13	7.52E+13	1.30E+14

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN #22

SRI-4 12-16-75 1750 PORT-6

IMPACTOR FLOWRATE = 0,075 ACFM | IMPACTOR TEMPERATURE = 382,0 F = 194,4 C | SAMPLING DURATION = 1,00 MIN

IMPACTOR PRESSURE DROP = 2,8 IN, OF HG | STACK TEMPERATURE = 382,0 F = 194,4 C

ASSUMED PARTICLE DENSITY = 1,46 GM/CU,CM, | STACK PRESSURE = 29,85 IN, OF HG | MAX, PARTICLE DIAMETER = 100,0 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 8,57 CO = 0,00 N2 = 39,86 O2 = 7,08 H2O = 25,50

CALC, MASS LOADING = 2,5988E+00 GR/ACF 5,4847E+00 GR/DSCF 5,9470E+03 MG/ACM 1,2551E+04 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6,32	3,57	2,09	1,44	0,74	0,52	
MASS (MILLIGRAMS)	0,61	3,00	0,42	1,77	3,52	1,89	1,42
MG/DSCM/STAGE	6,06E+02	2,98E+03	4,17E+02	1,76E+03	3,50E+03	1,88E+03	1,41E+03
CUM, PERCENT OF MASS SMALLER THAN D50	1,00E+02	9,52E+01	7,14E+01	6,81E+01	5,41E+01	2,62E+01	
CUM, (MG/ACM) SMALLER THAN D50	5,66E+03	4,25E+03	4,05E+03	3,22E+03	1,56E+03	6,69E+02	
CUM, (GR/ACF) SMALLER THAN D50	2,47E+00	1,86E+00	1,77E+00	1,41E+00	6,81E-01	2,92E-01	
CUM, (GR/DSCF) SMALLER THAN D50	5,22E+00	3,92E+00	3,73E+00	2,97E+00	1,44E+00	6,17E-01	
GEO, MEAN DIA, (MICROMETERS)	2,51E+01	4,75E+00	2,73E+00	1,74E+00	1,03E+00	6,19E-01	3,65E-01
DM/DLOGD (MG/DSCM)	5,05E+02	1,20E+04	1,80E+03	1,08E+04	1,21E+04	1,20E+04	4,69E+03
DN/DLOGD (NO, PARTICLES/DSCM)	4,16E+07	1,47E+11	1,15E+11	2,70E+12	1,44E+13	6,62E+13	1,26E+14

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN #23

SRI-5 12-17-75 1220 PORT-1

IMPACTOR FLOWRATE = 0.080 ACFM IMPACTOR TEMPERATURE = 389.0 F = 198.3 C SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 3.5 IN. OF HG STACK TEMPERATURE = 389.0 F = 198.3 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM. STACK PRESSURE = 29.83 IN. OF HG MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 9.67 CO = 0.00 N2 = 40.83 O2 = 4.84 H2O = 25.61

CALC. MASS LOADING = 7.8512E-01 GR/ACF 1.6743E+00 GR/DSCF 1.7966E+03 MG/ACM 3.8315E+03 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.11	3.45	2.02	1.39	0.71	0.49	
MASS (MILLIGRAMS)	0.25	0.27	0.22	0.26	0.75	1.38	0.94
MG/DSCM/STAGE	2.35E+02	2.54E+02	2.07E+02	2.45E+02	7.06E+02	1.30E+03	8.85E+02
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	9.39E+01	8.72E+01	8.18E+01	7.54E+01	5.70E+01	
CUM. (MG/ACM) SMALLER THAN D50	1.69E+03	1.57E+03	1.47E+03	1.36E+03	1.02E+03	4.15E+02	
CUM. (GR/ACF) SMALLER THAN D50	7.37E-01	6.85E-01	6.42E-01	5.92E-01	4.48E-01	1.81E-01	
CUM. (GR/DSCF) SMALLER THAN D50	1.57E+00	1.46E+00	1.37E+00	1.26E+00	9.54E-01	3.87E-01	
GEO. MEAN DIA. (MICROMETERS)	2.47E+01	4.59E+00	2.64E+00	1.68E+00	9.96E-01	5.94E-01	3.50E-01
DM/DLOGD (MG/DSCM)	1.94E+02	1.02E+03	8.93E+02	1.50E+03	2.43E+03	8.18E+03	2.94E+03
DN/DLOGD (NO. PARTICLES/DSCM)	1.68E+07	1.38E+10	6.32E+10	4.16E+11	3.23E+12	5.11E+13	8.98E+13

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN #24

SRI-6 12-17-75 1225 PORT-2

IMPACTOR FLOWRATE = 0.080 ACFM   IMPACTOR TEMPERATURE = 389.0 F = 198.3 C   SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 2.7 IN. OF HG   STACK TEMPERATURE = 389.0 F = 198.3 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM.   STACK PRESSURE = 29.83 IN. OF HG   MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 9.67   CO = 0.00   N2 = 40.83   O2 = 4.84   H2O = 25.61

CALC. MASS LOADING = 1.9541E+00 GR/ACF   4.1673E+00 GR/DSCF   4.4717E+03 MG/ACM   9.5363E+03 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.11	3.45	2.02	1.39	0.71	0.50	
MASS (MILLIGRAMS)	1.94	0.30	0.48	0.64	3.45	2.44	0.88
MG/DSCM/STAGE	1.83E+03	2.82E+02	4.52E+02	6.02E+02	3.25E+03	2.30E+03	8.28E+02
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	8.09E+01	7.79E+01	7.32E+01	6.68E+01	3.28E+01	
CUM. (MG/ACM) SMALLER THAN D50	3.62E+03	3.48E+03	3.27E+03	2.99E+03	1.47E+03	3.89E+02	
CUM. (GR/ACF) SMALLER THAN D50	1.58E+00	1.52E+00	1.43E+00	1.31E+00	6.41E-01	1.70E-01	
CUM. (GR/DSCF) SMALLER THAN D50	3.37E+00	3.25E+00	3.05E+00	2.79E+00	1.37E+00	3.62E-01	
GEO. MEAN DIA. (MICROMETERS)	2.47E+01	4.60E+00	2.64E+00	1.68E+00	9.96E-01	5.95E-01	3.51E-01
DM/DLOGD (MG/DSCM)	1.50E+03	1.14E+03	1.95E+03	3.69E+03	1.12E+04	1.46E+04	2.75E+03
DN/DLOGD (NO. PARTICLES/DSCM)	1.30E+08	1.54E+10	1.38E+11	1.02E+12	1.48E+13	9.04E+13	8.33E+13

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN # 25

SRI-7 12-17-75 1530 PORT-3

IMPACTOR FLOWRATE = 0,080 ACFM IMPACTOR TEMPERATURE = 389,0 F = 198,3 C SAMPLING DURATION = 1,00 MIN

IMPACTOR PRESSURE DROP = 2,5 IN, OF HG STACK TEMPERATURE = 389,0 F = 198,3 C

ASSUMED PARTICLE DENSITY = 1,46 GM/CU,CM, STACK PRESSURE = 29,83 IN, OF HG MAX, PARTICLE DIAMETER = 100,0 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 9,67 CO = 0,00 N2 = 40,83 O2 = 4,84 H2O = 25,61

CALC, MASS LOADING = 2,5483E+00 GR/ACF 5,4344E+00 GR/DSCF 5,8313E+03 MG/ACM 1,2436E+04 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6,11	3,45	2,02	1,39	0,71	0,50	
MASS (MILLIGRAMS)	3,90	0,63	0,51	1,31	3,71	1,71	1,44
MG/DSCM/STAGE	3,67E+03	5,93E+02	4,80E+02	1,23E+03	3,49E+03	1,61E+03	1,36E+03
CUM, PERCENT OF MASS SMALLER THAN D50	1,00E+02	7,05E+01	6,57E+01	6,19E+01	5,19E+01	2,39E+01	
CUM, (MG/ACM) SMALLER THAN D50	4,11E+03	3,83E+03	3,61E+03	3,03E+03	1,39E+03	6,36E+02	
CUM, (GR/ACF) SMALLER THAN D50	1,80E+00	1,67E+00	1,58E+00	1,32E+00	6,08E-01	2,78E-01	
CUM, (GR/DSCF) SMALLER THAN D50	3,83E+00	3,57E+00	3,36E+00	2,82E+00	1,30E+00	5,93E-01	
GEO, MEAN DIA, (MICROMETERS)	2,47E+01	4,60E+00	2,64E+00	1,68E+00	9,96E-01	5,96E-01	3,51E-01
DM/DLOGD (MG/DSCM)	3,03E+03	2,39E+03	2,07E+03	7,56E+03	1,21E+04	1,02E+04	4,50E+03
DN/DLOGD (NO, PARTICLES/DSCM)	2,62E+08	3,22E+10	1,46E+11	2,09E+12	1,60E+13	6,33E+13	1,36E+14

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN # 26

SRI-8 12-17-75 1545 PORT-4

IMPACTOR FLOWRATE = 0.080 ACFM IMPACTOR TEMPERATURE = 389.0 F = 198.3 C SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 2.3 IN. OF HG STACK TEMPERATURE = 389.0 F = 198.3 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM. STACK PRESSURE = 29.83 IN. OF HG MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 9.67 CO = 0.00 N2 = 40.83 O2 = 4.84 H2O = 25.61

CALC. MASS LOADING = 1.8056E+00 GR/ACF 3.8506E+00 GR/DSCF 4.1318E+03 MG/ACM 8.8114E+03 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.11	3.45	2.02	1.39	0.71	0.50	
MASS (MILLIGRAMS)	2.09	0.18	0.31	0.62	3.47	1.56	1.13
MG/DSCM/STAGE	1.97E+03	1.69E+02	2.92E+02	5.84E+02	3.27E+03	1.47E+03	1.06E+03
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	7.77E+01	7.58E+01	7.24E+01	6.58E+01	2.87E+01	
CUM. (MG/ACM) SMALLER THAN D50	3.21E+03	3.13E+03	2.99E+03	2.72E+03	1.19E+03	4.99E+02	
CUM. (GR/ACF) SMALLER THAN D50	1.40E+00	1.37E+00	1.31E+00	1.19E+00	5.19E-01	2.18E-01	
CUM. (GR/DSCF) SMALLER THAN D50	2.99E+00	2.92E+00	2.79E+00	2.53E+00	1.11E+00	4.65E-01	
GEO. MEAN DIA. (MICROMETERS)	2.47E+01	4.60E+00	2.64E+00	1.68E+00	9.96E-01	5.96E-01	3.52E-01
DM/DLOGD (MG/DSCM)	1.62E+03	6.83E+02	1.26E+03	3.58E+03	1.13E+04	9.34E+03	3.53E+03
DN/DLOGD (NO. PARTICLES/DSCM)	1.40E+08	9.21E+09	8.90E+10	9.91E+11	1.49E+13	5.78E+13	1.06E+14

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN #27

SRI-9 12-17-75 1705 PORT-6

IMPACTOR FLOWRATE = 0.080 ACFM IMPACTOR TEMPERATURE = 389.0 F = 198.3 C SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 2.6 IN. OF HG STACK TEMPERATURE = 389.0 F = 198.3 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM. STACK PRESSURE = 29.83 IN. OF HG MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 9.67 CO = 0.00 N2 = 40.83 O2 = 4.84 H2O = 25.61

CALC. MASS LOADING = 1.1632E+00 GR/ACF 2.4807E+00 GR/DSCF 2.6618E+03 MG/ACM 5.6766E+03 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.11	3.45	2.02	1.39	0.71	0.50	
MASS (MILLIGRAMS)	0.60	0.14	0.23	0.36	2.60	1.14	0.96
MG/DSCM/STAGE	5.65E+02	1.32E+02	2.17E+02	3.39E+02	2.45E+03	1.07E+03	9.04E+02
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	9.01E+01	8.77E+01	8.39E+01	7.79E+01	3.48E+01	
CUM. (MG/ACM) SMALLER THAN D50	2.40E+03	2.34E+03	2.23E+03	2.07E+03	9.27E+02	4.24E+02	
CUM. (GR/ACF) SMALLER THAN D50	1.05E+00	1.02E+00	9.76E-01	9.07E-01	4.05E-01	1.85E-01	
CUM. (GR/DSCF) SMALLER THAN D50	2.23E+00	2.18E+00	2.08E+00	1.93E+00	8.64E-01	3.95E-01	
GEO. MEAN DIA. (MICROMETERS)	2.47E+01	4.60E+00	2.64E+00	1.68E+00	9.96E-01	5.95E-01	3.51E-01
DM/DLOGD (MG/DSCM)	4.65E+02	5.31E+02	9.33E+02	2.08E+03	8.45E+03	6.81E+03	3.00E+03
DN/DLOGD (NO. PARTICLES/DSCM)	4.03E+07	7.16E+09	6.60E+10	5.76E+11	1.12E+13	4.22E+13	9.07E+13

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN #28

SRI-10 12-17-75 1840 PORT-5

IMPACTOR FLOWRATE = 0.080 ACFM   IMPACTOR TEMPERATURE = 389.0 F = 198.3 C   SAMPLING DURATION = 1.00 MIN

IMPACTOR PRESSURE DROP = 3.0 IN. OF HG   STACK TEMPERATURE = 389.0 F = 198.3 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM.   STACK PRESSURE = 29.83 IN. OF HG   MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 9.67   CO = 0.00   N2 = 40.83   O2 = 4.84   H2O = 25.61

CALC. MASS LOADING = 4.7956E+00 GR/ACF   1.0227E+01 GR/DSCF   1.0974E+04 MG/ACM   2.3403E+04 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6.11	3.45	2.02	1.39	0.71	0.50	
MASS (MILLIGRAMS)	8.68	7.23	1.40	0.90	3.22	2.12	1.31
MG/DSCM/STAGE	8.17E+03	6.81E+03	1.32E+03	8.47E+02	3.03E+03	2.00E+03	1.23E+03
CUM. PERCENT OF MASS SMALLER THAN D50	1.00E+02	6.51E+01	3.60E+01	3.04E+01	2.68E+01	1.38E+01	
CUM. (MG/ACM) SMALLER THAN D50	7.14E+03	3.95E+03	3.33E+03	2.94E+03	1.51E+03	5.79E+02	
CUM. (GR/ACF) SMALLER THAN D50	3.12E+00	1.73E+00	1.46E+00	1.28E+00	6.62E-01	2.53E-01	
CUM. (GR/DSCF) SMALLER THAN D50	6.66E+00	3.68E+00	3.11E+00	2.74E+00	1.41E+00	5.39E-01	
GEO. MEAN DIA. (MICROMETERS)	2.47E+01	4.60E+00	2.64E+00	1.68E+00	9.96E-01	5.95E-01	3.51E-01
DM/DLOGD (MG/DSCM)	6.73E+03	2.74E+04	5.68E+03	5.19E+03	1.05E+04	1.26E+04	4.10E+03
DN/DLOGD (NO. PARTICLES/DSCM)	5.83E+08	3.70E+11	4.02E+11	1.44E+12	1.38E+13	7.85E+13	1.24E+14

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

IN #29

SRI-11 12-17-75 1912 PORT-3

IMPACTOR FLOWRATE = 0,080 ACFM IMPACTOR TEMPERATURE = 389,0 F = 198,3 C SAMPLING DURATION = 1,00 MIN

IMPACTOR PRESSURE DROP = 2,7 IN, OF HG STACK TEMPERATURE = 389,0 F = 198,3 C

ASSUMED PARTICLE DENSITY = 1,46 GM/CU,CM, STACK PRESSURE = 29,83 IN, OF HG MAX, PARTICLE DIAMETER = 100,0 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 9,67 CO = 0,00 N2 = 40,83 O2 = 4,84 H2O = 25,61

CALC, MASS LOADING = 2,1933E+00 GR/ACF 4,6775E+00 GR/DSCF 5,0191E+03 MG/ACM 1,0704E+04 MG/DSCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7
D50 (MICROMETERS)	6,11	3,45	2,02	1,39	0,71	0,50	
MASS (MILLIGRAMS)	0,63	0,32	0,61	1,78	4,52	1,77	1,74
MG/DSCM/STAGE	5,93E+02	3,01E+02	5,74E+02	1,68E+03	4,26E+03	1,67E+03	1,64E+03
CUM, PERCENT OF MASS SMALLER THAN D50	1,00E+02	9,45E+01	9,16E+01	8,63E+01	7,06E+01	3,09E+01	
CUM, (MG/ACM) SMALLER THAN D50	4,74E+03	4,60E+03	4,33E+03	3,54E+03	1,55E+03	7,68E+02	
CUM, (GR/ACF) SMALLER THAN D50	2,07E+00	2,01E+00	1,89E+00	1,55E+00	6,77E-01	3,36E-01	
CUM, (GR/DSCF) SMALLER THAN D50	4,42E+00	4,29E+00	4,04E+00	3,30E+00	1,44E+00	7,16E-01	
GEO, MEAN DIA, (MICROMETERS)	2,47E+01	4,60E+00	2,64E+00	1,68E+00	9,96E-01	5,95E-01	3,51E-01
DM/DLOGD (MG/DSCM)	4,89E+02	1,21E+03	2,48E+03	1,03E+04	1,47E+04	1,06E+04	5,44E+03
DN/DLOGD (NO, PARTICLES/DSCM)	4,23E+07	1,64E+10	1,75E+11	2,85E+12	1,94E+13	6,56E+13	1,65E+14

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760MM HG

SRO-1 11-15-75 11:30 PORT - 2N

IMPACTOR FLOWRATE = 0.395 ACFM IMPACTOR TEMPERATURE = 400.0 F = 204.4 C SAMPLING DURATION = 48.00 MIN

IMPACTOR PRESSURE DROP = 6.0 IN. OF HG STACK TEMPERATURE = 400.0 F = 204.4 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM. STACK PRESSURE = 30.10 IN. OF HG MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 15.50 CO = 0.00 N2 = 49.10 O2 = 7.50 H2O = 26.10

CALC. MASS LOADING = 5.1227E-03 GR/ACF 1.1040E-02 GR/DSCF 1.1722E+01 MG/ACM 2.5262E+01 MG/DSCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	31.59	13.78	5.25	2.58	1.43	0.75	0.31	
MASS (MILLIGRAMS)	0.75	0.79	0.40	0.57	1.17	0.86	0.98	0.78
MG/DSCM/STAGE	3.05E+00	3.21E+00	1.63E+00	2.32E+00	4.76E+00	3.50E+00	3.98E+00	3.17E+00
CUM. PERCENT OF MASS SMALLER THAN D50	88.10	75.56	69.21	60.16	41.59	27.94	12.39	
CUM. (MG/ACM) SAMLLER THAN D50	1.03E+01	8.86E+00	8.11E+00	7.05E+00	4.88E+00	3.28E+00	1.45E+00	
CUM. (GR/ACF) SMALLER THAN D50	4.51E-03	3.87E-03	3.55E-03	3.08E-03	2.13E-03	1.43E-03	6.34E-04	
CUM. (GR/DSCF) SMALLER THAN D50	9.73E-03	8.34E-03	7.64E-03	6.64E-03	4.59E-03	3.08E-03	1.37E-03	
GEO. MEAN DIA. (MICROMETERS)	5.62E+01	2.09E+01	8.51E+00	3.69E+00	1.93E+00	1.04E+00	4.81E-01	2.19E-01
DM/DLOGD (MG/DSCM)	6.09E+00	8.91E+00	3.88E+00	7.52E+00	1.86E+01	1.24E+01	1.04E+01	1.05E+01
DN/DLOGD (NO. PARTICLES/DSCM)	4.49E+04	1.28E+06	8.24E+06	1.97E+08	3.41E+09	1.46E+10	1.22E+11	1.31E+12

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760 MM HG

SRO-2 11-15-75 11:30 PORT - 2W

IMPACTOR FLOWRATE = 1.154 ACFM   IMPACTOR TEMPERATURE = 365.0 F = 185.0 C   SAMPLING DURATION = 48.00 MIN

IMPACTOR PRESSURE DROP = 7.0 IN. OF HG   STACK TEMPERATURE = 365.0 F = 185.0 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM.   STACK PRESSURE = 30.08 IN. OF HG   MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 15.50   CO = 0.00   N2 = 49.10   O2 = 7.50   H2O = 26.10

CALC. MASS LOADING = 8.4801E-03 GR/ACF   1.7542E-02 GR/DSCF   1.9405E+01 MG/ACM   4.0143E+01 MG/DSCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	18.12	7.88	2.98	1.45	0.79	0.39	0.13	
MASS (MILLIGRAMS)	23.37	0.38	0.69	1.50	0.54	1.47	1.91	0.57
MG/DSCM/STAGE	3.12E+01	5.08E-01	9.23E-01	2.01E+00	7.22E-01	1.97E+00	2.55E+00	7.62E-01
CUM. PERCENT OF MASS SMALLER THAN D50	23.21	21.96	19.69	14.76	12.99	8.15	1.88	
CUM. (MG/ACM) SAMLLER THAN D50	4.50E+00	4.26E+00	3.82E+00	2.86E+00	2.52E+00	1.58E+00	3.64E-01	
CUM. (GR/ACF) SMALLER THAN D50	1.97E-03	1.86E-03	1.67E-03	1.25E-03	1.10E-03	6.92E-04	1.59E-04	
CUM. (GR/DSCF) SMALLER THAN D50	4.07E-03	3.85E-03	3.45E-03	2.59E-03	2.28E-03	1.43E-03	3.29E-04	
GEO. MEAN DIA. (MICROMETERS)	4.26E+01	1.20E+01	4.85E+00	2.08E+00	1.07E+00	5.54E-01	2.26E-01	9.22E-02
DM/DLOGD (MG/DSCM)	4.21E+01	1.41E+00	2.18E+00	6.38E+00	2.72E+00	6.49E+00	5.36E+00	2.53E+00
DN/DLOGD (NO. PARTICLES/DSCM)	7.14E+05	1.08E+06	2.51E+07	9.34E+08	2.95E+09	4.99E+10	6.09E+11	4.23E+12

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760 MM HG

OUT #3

SRO-3 11-17-75 2:49 PORT - 2W

IMPACTOR FLOWRATE = 0.779 ACFM   IMPACTOR TEMPERATURE = 365.0 F = 185.0 C   SAMPLING DURATION = 48.00 MIN

IMPACTOR PRESSURE DROP = 4.4 IN. OF HG   STACK TEMPERATURE = 365.0 F = 185.0 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM.   STACK PRESSURE = 30.08 IN. OF HG   MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 15.50   CO = 0.00   N2 = 49.10   O2 = 7.50   H2O = 26.10

CALC. MASS LOADING = 4.9250E-03 GR/ACF   1.0188E-02 GR/DSCF   1.1270E+01 MG/ACM   2.3314E+01 MG/DSCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	22.08	9.62	3.65	1.78	0.98	0.50	0.20	
MASS (MILLIGRAMS)	5.97	0.87	0.89	0.82	1.46	1.55	0.19	0.18
MG/DSCM/STAGE	1.18E+01	1.72E+00	1.76E+00	1.62E+00	2.89E+00	3.07E+00	3.76E-01	3.57E-01
CUM. PERCENT OF MASS SMALLER THAN D50	49.96	42.67	35.21	28.34	16.10	3.11	1.51	
CUM. (MG/ACM) SAMLLER THAN D50	5.63E+00	4.81E+00	3.97E+00	3.19E+00	1.81E+00	3.50E-01	1.71E-01	
CUM. (GR/ACF) SMALLER THAN D50	2.46E-03	2.10E-03	1.73E-03	1.40E-03	7.93E-04	1.53E-04	7.46E-05	
CUM. (GR/DSCF) SMALLER THAN D50	5.09E-03	4.35E-03	3.59E-03	2.89E-03	1.64E-03	3.16E-04	1.54E-04	
GEO. MEAN DIA. (MICROMETERS)	4.70E+01	1.46E+01	5.93E+00	2.55E+00	1.32E+00	6.97E-01	3.19E-01	1.45E-01
DM/DLOGD (MG/DSCM)	1.80E+01	4.77E+00	4.19E+00	5.22E+00	1.11E+01	1.05E+01	9.77E-01	1.18E+00
DN/DLOGD (NO. PARTICLES/DSCM)	2.27E+05	2.02E+06	2.63E+07	4.11E+08	6.31E+09	4.04E+10	3.93E+10	5.10E+11

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760 MM HG

OUT #4

SRO-4 11-17-75 3:40 PORT - 2N

IMPACTOR FLOWRATE = 0.792 ACFM   IMPACTOR TEMPERATURE = 370.0 F = 187.8 C   SAMPLING DURATION = 48.00 MIN

IMPACTOR PRESSURE DROP = 3.6 IN. OF HG   STACK TEMPERATURE = 370.0 F = 187.8 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM.   STACK PRESSURE = 30.08 IN. OF HG   MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 15.50   CO = 0.00   N2 = 49.10   O2 = 7.50   H2O = 26.10

CALC. MASS LOADING = 1.7086E-03 GR/ACF   3.5559E-03 GR/DSCF   3.9098E+00 MG/ACM   8.1372E+00 MG/DSCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	21.95	9.56	3.63	1.77	0.97	0.49	0.21	
MASS (MILLIGRAMS)	0.84	0.11	0.54	0.31	0.71	1.21	0.20	0.29
MG/DSCM/STAGE	1.65E+00	2.16E-01	1.06E+00	6.07E-01	1.39E+00	2.37E+00	3.92E-01	5.68E-01
CUM. PERCENT OF MASS SMALLER THAN D50	80.05	77.44	64.61	57.25	40.39	11.64	6.89	
CUM. (MG/ACM) SAMLLER THAN D50	3.13E+00	3.03E+00	2.53E+00	2.24E+00	1.58E+00	4.55E-01	2.70E-01	
CUM. (GR/ACF) SMALLER THAN D50	1.37E-03	1.32E-03	1.10E-03	9.78E-04	6.90E-04	1.99E-04	1.18E-04	
CUM. (GR/DSCF) SMALLER THAN D50	2.85E-03	2.75E-03	2.30E-03	2.04E-03	1.44E-03	4.14E-04	2.45E-04	
GEO. MEAN DIA. (MICROMETERS)	4.69E+01	1.45E+01	5.89E+00	2.53E+00	1.31E+00	6.92E-01	3.22E-01	1.48E-01
DM/DLOGD (MG/DSCM)	2.50E+00	5.97E-01	2.51E+00	1.95E+00	5.33E+00	8.06E+00	1.06E+00	1.89E+00
DN/DLOGD (NO. PARTICLES/DSCM)	3.18E+04	2.57E+05	1.61E+07	1.57E+08	3.10E+09	3.19E+10	4.15E+10	7.55E+11

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760 MM HG

Outlet # 5

SRO-9 11-18-75 9:50 PORT - 2N,2W

IMPACTOR FLOWRATE = 0,832 ACFM IMPACTOR TEMPERATURE = 412,0 F = 211,1 C SAMPLING DURATION = 48,00 MIN

IMPACTOR PRESSURE DROP = 5,7 IN, OF HG STACK TEMPERATURE = 412,0 F = 211,1 C

ASSUMED PARTICLE DENSITY = 1,46 GM/CU,CM, STACK PRESSURE = 30,16 IN, OF HG MAX, PARTICLE DIAMETER = 100,0 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 15,50 CO = 0,00 N2 = 49,10 O2 = 7,50 H2O = 26,10

CALC, MASS LOADING = 1,5411E-03 GR/ACF 3,3608E-03 GR/DSCF 3,5266E+00 MG/ACM 7,6907E+00 MG/DSCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	21,87	9,52	3,61	1,76	0,96	0,48	0,18	
MASS (MILLIGRAMS)	0,20	0,29	0,30	0,18	0,94	1,57	0,32	0,19
MG/DSCM/STAGE	3,91E-01	5,67E-01	5,86E-01	3,52E-01	1,84E+00	3,07E+00	6,25E-01	3,71E-01
CUM, PERCENT OF MASS SMALLER THAN D50	94,99	87,72	80,21	75,69	52,14	12,79	4,77	
CUM, (MG/ACM) SAMLLER THAN D50	3,35E+00	3,09E+00	2,83E+00	2,67E+00	1,84E+00	4,51E-01	1,68E-01	
CUM, (GR/ACF) SMALLER THAN D50	1,46E-03	1,35E-03	1,24E-03	1,17E-03	8,03E-04	1,97E-04	7,35E-05	
CUM, (GR/DSCF) SMALLER THAN D50	3,19E-03	2,95E-03	2,70E-03	2,54E-03	1,75E-03	4,30E-04	1,60E-04	
GEO, MEAN DIA, (MICROMETERS)	4,68E+01	1,44E+01	5,86E+00	2,52E+00	1,30E+00	6,82E-01	2,97E-01	1,29E-01
DM/DLOGD (MG/DSCM)	5,92E-01	1,57E+00	1,39E+00	1,13E+00	7,00E+00	1,03E+01	1,47E+00	1,23E+00
DN/DLOGD (NO, PARTICLES/DSCM)	7,57E+03	6,83E+05	9,04E+06	9,23E+07	4,18E+09	4,26E+10	7,35E+10	7,56E+11

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760 MM HG

out # 6

SRO-13 11-18-75 3:30 PORT - 2N,2W

IMPACTOR FLOWRATE = 0.787 ACFM IMPACTOR TEMPERATURE = 385.0 F = 196.1 C SAMPLING DURATION = 48.00 MIN

IMPACTOR PRESSURE DROP = 4.2 IN. OF HG STACK TEMPERATURE = 385.0 F = 196.1 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM. STACK PRESSURE = 30.16 IN. OF HG MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 15.50 CO = 0.00 N2 = 49.10 O2 = 7.50 H2O = 26.10

CALC. MASS LOADING = 3.4421E-03 GR/ACF 7.2739E-03 GR/DSCF 7.8767E+00 MG/ACM 1.6645E+01 MG/DSCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	22.18	9.66	3.66	1.79	0.98	0.50	0.21	
MASS (MILLIGRAMS)	0.72	0.37	1.01	0.63	2.04	2.85	0.46	0.35
MG/DSCM/STAGE	1.44E+00	7.41E-01	2.02E+00	1.26E+00	4.08E+00	5.70E+00	9.21E-01	7.00E-01
CUM. PERCENT OF MASS SMALLER THAN D50	91.46	87.07	75.09	67.62	43.42	9.61	4.16	
CUM. (MG/ACM) SAMLLER THAN D50	7.20E+00	6.86E+00	5.91E+00	5.33E+00	3.42E+00	7.57E-01	3.27E-01	
CUM. (GR/ACF) SMALLER THAN D50	3.15E-03	3.00E-03	2.58E-03	2.33E-03	1.49E-03	3.31E-04	1.43E-04	
CUM. (GR/DSCF) SMALLER THAN D50	6.65E-03	6.33E-03	5.46E-03	4.92E-03	3.16E-03	6.99E-04	3.02E-04	
GEO. MEAN DIA. (MICROMETERS)	4.71E+01	1.46E+01	5.95E+00	2.56E+00	1.32E+00	6.98E-01	3.20E-01	1.45E-01
DM/DLOGD (MG/DSCM)	2.20E+00	2.05E+00	4.80E+00	4.04E+00	1.56E+01	1.94E+01	2.40E+00	2.33E+00
DN/DLOGD (NO. PARTICLES/DSCM)	2.76E+04	8.55E+05	2.98E+07	3.16E+08	8.82E+09	7.46E+10	9.61E+10	9.94E+11

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760 MM HG

OUT #7

SRO-16 11-19-75 11:22 PORT - 2N,2W

IMPACTOR FLOWRATE = 0,698 ACFM   IMPACTOR TEMPERATURE = 395,0 F = 201,7 C   SAMPLING DURATION = 72,00 MIN

IMPACTOR PRESSURE DROP = 3,3 IN, OF HG   STACK TEMPERATURE = 395,0 F = 201,7 C

ASSUMED PARTICLE DENSITY = 1,46 GM/CU.CM,   STACK PRESSURE = 30,10 IN, OF HG   MAX, PARTICLE DIAMETER = 100,0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 15,50   CO = 0,00   N2 = 49,10   O2 = 7,50   H2O = 26,10

CALC, MASS LOADING = 1,9709E-03 GR/ACF   4,2226E-03 GR/DSCF   4,5100E+00 MG/ACM   9,6627E+00 MG/DSCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	23,68	10,32	3,92	1,91	1,05	0,54	0,23	
MASS (MILLIGRAMS)	0,53	1,19	0,60	0,31	0,75	1,78	0,85	0,41
MG/DSCM/STAGE	8,09E-01	1,82E+00	9,15E-01	4,73E-01	1,14E+00	2,72E+00	1,30E+00	6,25E-01
CUM, PERCENT OF MASS SMALLER THAN D50	91,75	73,21	63,87	59,04	47,36	19,63	6,39	
CUM, (MG/ACM) SAMLLER THAN D50	4,14E+00	3,30E+00	2,88E+00	2,66E+00	2,14E+00	8,85E-01	2,88E-01	
CUM, (GR/ACF) SMALLER THAN D50	1,81E-03	1,44E-03	1,26E-03	1,16E-03	9,33E-04	3,87E-04	1,26E-04	
CUM, (GR/DSCF) SMALLER THAN D50	3,87E-03	3,09E-03	2,70E-03	2,49E-03	2,00E-03	8,29E-04	2,70E-04	
GEO, MEAN DIA, (MICROMETERS)	4,87E+01	1,56E+01	6,36E+00	2,74E+00	1,42E+00	7,50E-01	3,54E-01	1,65E-01
DM/DLOGD (MG/DSCM)	1,29E+00	5,03E+00	2,18E+00	1,52E+00	4,39E+00	9,29E+00	3,60E+00	2,08E+00
DN/DLOGD (NO, PARTICLES/DSCM)	1,47E+04	1,72E+06	1,11E+07	9,69E+07	2,02E+09	2,88E+10	1,06E+11	6,01E+11

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760 MM HG

OUT # 8

SRO-17 11-19-75 2:40 PORT - 2N,2W

IMPACTOR FLOWRATE = 0.681 ACFM IMPACTOR TEMPERATURE = 395.0 F = 201.7 C SAMPLING DURATION = 96.00 MIN

IMPACTOR PRESSURE DROP = 4.8 IN. OF HG STACK TEMPERATURE = 395.0 F = 201.7 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM. STACK PRESSURE = 30.10 IN. OF HG MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 15.50 CO = 0.00 N2 = 49.10 O2 = 7.50 H2O = 26.10

CALC. MASS LOADING = 2.1502E-03 GR/ACF 4.6067E-03 GR/DSCF 4.9203E+00 MG/ACM 1.0542E+01 MG/DSCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	23.98	10.45	3.97	1.94	1.06	0.54	0.22	
MASS (MILLIGRAMS)	1.01	0.27	0.80	0.58	1.64	3.30	0.77	0.74
MG/DSCM/STAGE	1.18E+00	3.17E-01	9.38E-01	6.80E-01	1.92E+00	3.87E+00	9.03E-01	8.68E-01
CUM. PERCENT OF MASS SMALLER THAN D50	88.92	85.95	77.17	70.81	52.80	16.58	8.13	
CUM. (MG/ACM) SAMLLER THAN D50	4.38E+00	4.23E+00	3.80E+00	3.48E+00	2.60E+00	8.16E-01	4.00E-01	
CUM. (GR/ACF) SMALLER THAN D50	1.91E-03	1.85E-03	1.66E-03	1.52E-03	1.14E-03	3.56E-04	1.75E-04	
CUM. (GR/DSCF) SMALLER THAN D50	4.10E-03	3.96E-03	3.56E-03	3.26E-03	2.43E-03	7.64E-04	3.74E-04	
GEO. MEAN DIA. (MICROMETERS)	4.90E+01	1.58E+01	6.44E+00	2.77E+00	1.44E+00	7.61E-01	3.47E-01	1.56E-01
DM/DLOGD (MG/DSCM)	1.91E+00	8.78E-01	2.23E+00	2.19E+00	7.39E+00	1.33E+01	2.31E+00	2.88E+00
DN/DLOGD (NO. PARTICLES/DSCM)	2.13E+04	2.89E+05	1.09E+07	1.34E+08	3.26E+09	3.94E+10	7.25E+10	9.84E+11

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760 MM HG

OUT # 9

SRO-2 12-16-75 1616 PORT - 2N

IMPACTOR FLOWRATE = 0,626 ACFM IMPACTOR TEMPERATURE = 370,0 F = 187,8 C SAMPLING DURATION = 66,00 MIN

IMPACTOR PRESSURE DROP = 3,6 IN, OF HG STACK TEMPERATURE = 370,0 F = 187,8 C

ASSUMED PARTICLE DENSITY = 1,46 GM/CU,CM, STACK PRESSURE = 30,00 IN, OF HG MAX, PARTICLE DIAMETER = 100,0 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 8,57 CO = 0,00 N2 = 39,86 O2 = 7,08 H2O = 25,50

CALC, MASS LOADING = 9,1483E-04 GR/ACF 1,8937E-03 GR/DSCF 2,0935E+00 MG/ACM 4,3333E+00 MG/DSCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	24,62	10,72	4,07	1,98	1,09	0,55	0,24	
MASS (MILLIGRAMS)	0,03	0,19	0,11	0,06	0,33	1,34	0,23	0,16
MG/DSCM/STAGE	5,38E-02	3,41E-01	1,97E-01	1,08E-01	5,92E-01	2,40E+00	4,12E-01	2,87E-01
CUM, PERCENT OF MASS SMALLER THAN D50	98,78	91,03	86,54	84,09	70,62	15,92	6,54	
CUM, (MG/ACM) SAMLLER THAN D50	2,07E+00	1,91E+00	1,81E+00	1,76E+00	1,48E+00	3,33E-01	1,37E-01	
CUM, (GR/ACF) SMALLER THAN D50	9,04E-04	8,33E-04	7,92E-04	7,69E-04	6,46E-04	1,46E-04	5,98E-05	
CUM, (GR/DSCF) SMALLER THAN D50	1,87E-03	1,72E-03	1,64E-03	1,59E-03	1,34E-03	3,02E-04	1,24E-04	
GEO, MEAN DIA, (MICROMETERS)	4,96E+01	1,62E+01	6,60E+00	2,84E+00	1,47E+00	7,75E-01	3,60E-01	1,66E-01
DM/DLOGD (MG/DSCM)	8,83E-02	9,44E-01	4,69E-01	3,45E-01	2,27E+00	8,17E+00	1,11E+00	9,53E-01
DN/DLOGD (NO, PARTICLES/DSCM)	9,46E+02	2,88E+05	2,13E+06	1,97E+07	9,34E+08	2,29E+10	3,10E+10	2,71E+11

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760 MM HG

OUT # 10

SRO-4 12-17-75 1800 PORT - 2N,2W

IMPACTOR FLOWRATE = 0.697 ACFM IMPACTOR TEMPERATURE = 390.0 F = 198.9 C SAMPLING DURATION = 120.00 MIN

IMPACTOR PRESSURE DROP = 2.6 IN. OF HG STACK TEMPERATURE = 390.0 F = 198.9 C

ASSUMED PARTICLE DENSITY = 1.46 GM/CU.CM. STACK PRESSURE = 29.79 IN. OF HG MAX. PARTICLE DIAMETER = 100.0 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 9.67 CO = 0.00 N2 = 40.83 O2 = 4.84 H2O = 25.61

CALC. MASS LOADING = 1.4861E-03 GR/ACF 3.1772E-03 GR/DSCF 3.4007E+00 MG/ACM 7.2705E+00 MG/DSCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	23.45	10.21	3.87	1.88	1.03	0.52	0.23	
MASS (MILLIGRAMS)	3.54	0.12	0.46	0.23	0.61	1.75	1.03	0.32
MG/DSCM/STAGE	3.24E+00	1.10E-01	4.21E-01	2.10E-01	5.58E-01	1.60E+00	9.42E-01	2.93E-01
CUM. PERCENT OF MASS SMALLER THAN D50	56.08	54.60	48.89	46.03	38.47	16.75	3.98	
CUM. (MG/ACM) SAMLLER THAN D50	1.91E+00	1.86E+00	1.66E+00	1.57E+00	1.31E+00	5.70E-01	1.35E-01	
CUM. (GR/ACF) SMALLER THAN D50	8.33E-04	8.11E-04	7.27E-04	6.84E-04	5.72E-04	2.49E-04	5.91E-05	
CUM. (GR/DSCF) SMALLER THAN D50	1.78E-03	1.73E-03	1.55E-03	1.46E-03	1.22E-03	5.32E-04	1.26E-04	
GEO. MEAN DIA. (MICROMETERS)	4.84E+01	1.55E+01	6.28E+00	2.70E+00	1.39E+00	7.30E-01	3.42E-01	1.60E-01
DM/DLOGD (MG/DSCM)	5.14E+00	3.04E-01	9.98E-01	6.73E-01	2.12E+00	5.38E+00	2.61E+00	9.72E-01
DN/DLOGD (NO. PARTICLES/DSCM)	5.92E+04	1.07E+05	5.26E+06	4.48E+07	1.03E+09	1.81E+10	8.54E+10	3.12E+11

NORMAL OR STANDARD CONDITIONS ARE 21 DEG C AND 760 MM HG

SAMPLE CALCULATION FOR DATA REDUCTION OF ULTRAFINE PARTICLE SIZE MEASUREMENTS

INSTRUMENTATION

A Thermo-Systems Inc. Model 3030 Electrical Aerosol Size Analyzer (EAA) with a 0.0032 μm to 0.360 μm range at the operating conditions used ($N_o t = 7 \times 10^6$ at 4.0×10^{-9} amperes ionizer current and 50 volts ionizer voltage) was used to determine concentration vs size information in the ultrafine size range.

PROCEDURES

Once the equipment has been set up as shown schematically in Figure 1, the flows were adjusted through the sample orifice and the dilution air orifice, to obtain the desired dilution factor. The EAA was placed in an automatic scan mode and the current readings for each channel were manually recorded. At the beginning of each day the internal calibration points and flows through the EAA were checked, as described in the instrument manual. These were also periodically rechecked throughout the day. The optional SOx absorbers and the cyclone pump shown in Figure 1 were not used in this test.

The theory of operation and basic equations for the EAA have been given by Liu *et al*[1] and calibration of the Model 3030 EAA has been done by Liu and Pui[2] which revises the previous calibration. Table 1 shows these revised calibration constants in a data reduction format. The calibration by Liu suggested the use of a calibration matrix; however typical source fluctuations in industrial processes generally negate any potential advantage of such refinements. Table 1 is essentially self-explanatory. The heading "D_p,μm" (column 3) is the particle diameter in microns. A value of 0.0100 means that the center rod voltage is such that all particles of 0.0100 μm diameter and smaller are collected in the analyzer tube while larger particles penetrate to the current collecting filter where an electrometer measures the total current carried by the unprecipitated particles. This current represents the charges on all particles larger

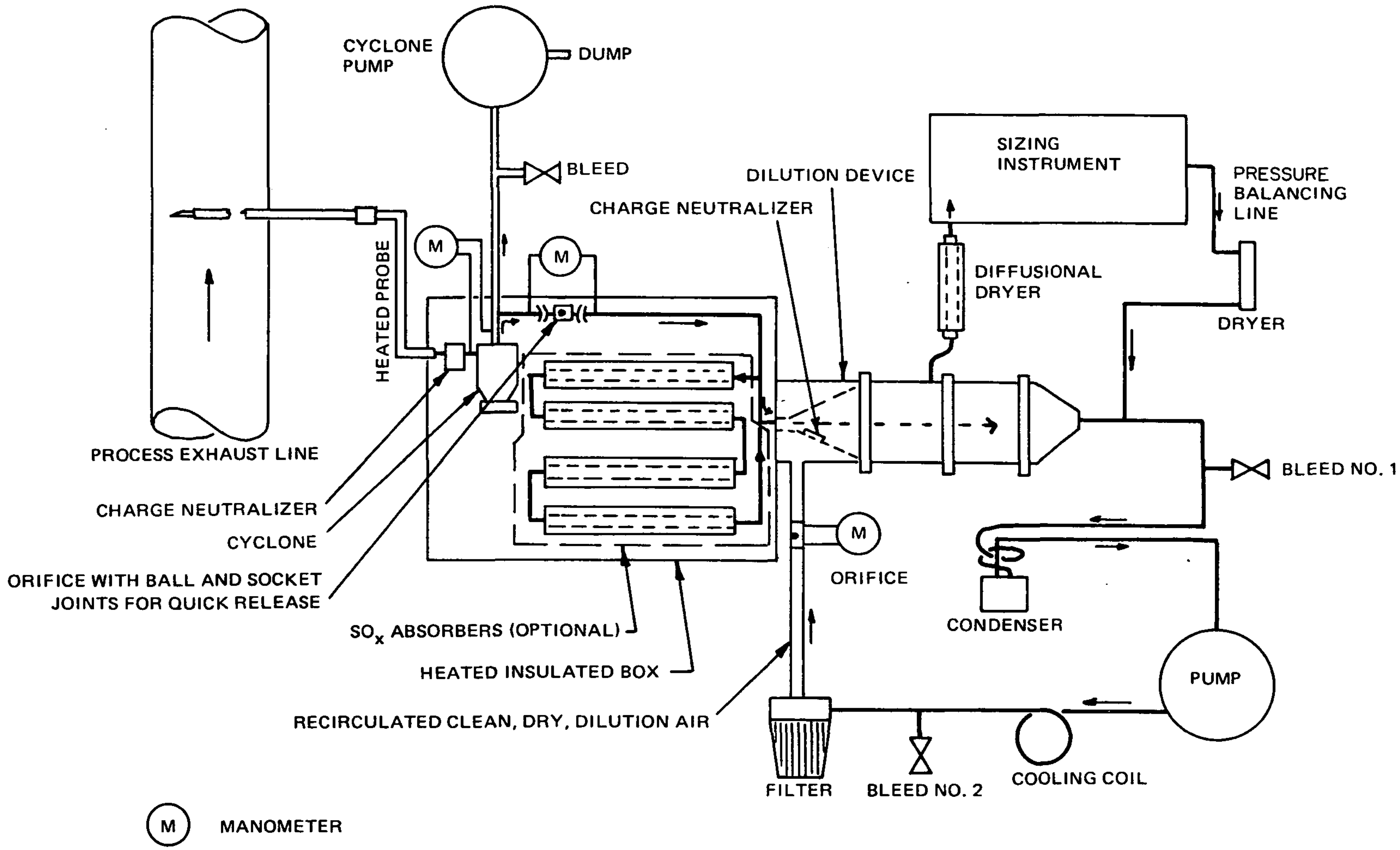


Figure 1. Sample Extraction-Dilution System

Table 1

EAA (Model 3030) Data Reduction Form
Concentration, Cumulative Concentration, and dN/d log D from Scan No. ____
for DF = _____

1	2	3	4	5	6	7	8	9	10	11	12
Channel No.	Collector Voltage	D_p, μm	D_{pi}, μm	ΔN/ΔI	$\Delta \log D_p$	I, pA	ΔI, pA	ΔN	ΔN_s	ΣN_s	$\Delta N_s/\Delta \log D$
3	196	0.0100				____					
			0.0133	4.76×10^5	0.250		____	____	____	____	____
4	593	0.0178				____					
			0.0215	2.33×10^5	0.165		____	____	____	____	____
5	1,220	0.026				____					
			0.0306	1.47×10^5	0.141		____	____	____	____	____
6	2,183	0.036				____					
			0.0502	8.33×10^4	0.289		____	____	____	____	____
7	3,515	0.070				____					
			0.0917	4.26×10^4	0.234		____	____	____	____	____
8	5,387	0.120				____					
			0.149	2.47×10^4	0.188		____	____	____	____	____
9	7,152	0.185				____					
			0.219	1.56×10^4	0.148		____	____	____	____	____
10	8,642	0.260				____					
			0.306	1.10×10^4	0.141		____	____	____	____	____
11	9,647	0.360				____					

than 0.0100 μm. This measured current is the basic output of the Model 3030.

The fourth column (D_{pi}, μm) is the geometric mean diameter of the particles represented by the current difference of two successive steps (Channel No.'s). For example, the difference in current for the 0.0100 μm cut-off and the current for the 0.0178 μm cut-off is the total current collected from particles between these sizes, or rather for a mean diameter of 0.0133 μm. The current differences are entered in column 8 headed "ΔI,pA" (picoAmps).

The fifth column gives the revised calibration factor (based on the calibration by Liu and Pui) for each of the eight size bands. These factors are in units of particles per cm^3 per picoAmpere. Multiplying this size specific current sensitivity, ΔN/ΔI, (column 5) by the current difference, ΔI, (column 8) gives the total number of particles, ΔN (in units of particles per cm^3) within this size band (column 4). Columns 6 and 12 are used for ΔN/ΔLogD information calculated from the number distribution in column 10. Column 11 is used for cumulative concentrations, corrected for dilution to normal conditions with a dilution factor (DF).

The basic data from the EAA is cumulative current for each of nine channels (column 7). One must then take the differences of the current readings for successive channels (column 8) in order to find ΔN, etc. These ΔI values are multiplied by a series of constants ($\Delta N/\Delta I_i$, DF_j) to arrive at ΔN_s (concentration in stack corrected to dry, standard conditions). While a single scan will be made at a constant dilution, different scans may be made at different dilutions. To simplify the arithmetic, we form the product $\alpha_i = \Delta I_{i,j} \times DF_j$ and average all such inlet (outlet) products for the same size band. This average is used in Table 2 to calculate ΔN_s, cumulative concentration, and ΔN/ΔLogD for each size band. When Table 2 is used the data reduction is as follows:

Table 2

EAA (Model 3030) Data Reduction Form
Concentration, Cumulative Concentration, and ΔN/ΔlogD
From Average $\bar{\alpha}$ for Condition ____________

1 Channel No.	2 Collector Voltage	3 D_p, μm	4 D_{pi}, μm	5 ΔN/ΔI	6 $\Delta \log D_p$	7 $\bar{\alpha}$	8 ΔN_s	9 $\Sigma \Delta N_s$	10 $\Delta N_s/\Delta \log D$
3	196	0.0100							
			0.0133	4.76×10^5	0.250	____	____	____	____
4	593	0.0178							
			0.0215	2.33×10^5	0.165	____	____	____	____
5	1,220	0.026							
			0.0306	1.47×10^5	0.141	____	____	____	____
6	2,183	0.036							
			0.0502	8.33×10^4	0.289	____	____	____	____
7	3,515	0.070							
			0.0917	4.26×10^4	0.234	____	____	____	____
8	5,387	0.120							
			0.149	2.47×10^4	0.188	____	____	____	____
9	7,152	0.185							
			0.219	1.56×10^4	0.148	____	____	____	____
10	8,642	0.260							
			0.306	1.10×10^4	0.141	____	____	____	____
11	9.647	0.360							

SUMMARY OF THE CALCULATION FORMAT

STEP 1

Calculate all dilution factors (DF_j), inlet and outlet.

STEP 2

Calculate current differences ($\Delta I_{i,j}$) from adjacent channels and average the α_i products ($\alpha_i = \Delta I_{i,j} \times DF_j$) for the same size band for all scans taken at the inlet (outlet). Calculate standard deviations for each α_i. Note: the i subscript denotes size and the j subscript denotes dilution setting.

STEP 3

Using α_i and Table 2 calculate "number concentration" (ΔN_s), "average cumulative concentration of all particles having diameter greater than the indicated size" ($\Sigma \Delta N_s$), and "$\Delta N/\Delta$LogD" for each size band for the inlet (outlet).

STEP 4

Plot "Cumulative Concentration vs. Size" for inlet (outlet).

STEP 5

Plot $\Delta N/\Delta$LogD with plus and minus one standard deviation error bars inlet (outlet).

STEP 6

Calculate and plot efficiency vs. size with plus and minus one standard deviation error bars.

SAMPLE CALCULATION FOLLOWING THE CALCULATION FORMAT

STEP 1

Calculate all dilution factors (DF_j; corrected to normal conditions: 70°F (21°C) and 29.92 inches of mercury pressure (760 Torr)).

The flow through a calibrated orifice is given by

$$Q = k\sqrt{\frac{T \times \Delta P}{P}}$$

where Q is the actual flow through the orifice

T is the orifice temperature

P is the pressure at the high side of the orifice

ΔP is the pressure drop across the orifice

and k is a constant of proportionality for a limited range of ΔP values.

The flow rate, Q_N, connected to normal (standard) conditions of temperature, T_N, and pressure, P_N is given by:

$$Q_N = \left(\frac{P}{P_N}\right)\left(\frac{T_N}{T}\right) Q$$

The constant of proportionality, k, is found from the calibration data thusly:

$$k = Q_c \sqrt{\frac{P_c}{T_c \times \Delta P_c}}$$

Where the subscript c refers to calibration conditions of flow, pressure, pressure drop, and temperature.

By collecting constants we tabulate a single constant (C_N) for each orifice so that

$$Q_N = C_N \sqrt{\frac{P \times \Delta P}{T}}$$

where

$$C_N = \left(\frac{T_N}{P_N}\right) \quad Q_c \sqrt{\frac{P_c}{T_c \times \Delta P_c}}$$

For example:

If for the .029 orifice, an actual flow rate (Q_c) of 1.526 liters per minute were measured for a pressure drop (ΔP_c) of 10 inches H_2O at temperature (T_c) 537°R and pressure (P_c) 29.40 inches mercury

$$C_N \text{ (for .029 orifice)} = \left(\frac{530°R}{29.92"Hg}\right) (1.526 \text{ lpm}) \sqrt{\frac{29.40"Hg}{(537°R)\ (10"H_2O)}}$$

$$= 2.00 \text{ (for Q in lpm)}$$

By definition the dilution factor (DF) is the ratio of the total flow ($Q_D + Q_S$) divided by the sample flow (Q_S):

thus
$$DF = \frac{Q_D}{Q_S} + 1$$

or

$$DF = \frac{C_{N,D}\sqrt{\dfrac{(P_D)\quad(\Delta P_D)}{T_D}}}{C_{N,S}\sqrt{\dfrac{(P_S)\quad(\Delta P_S)}{T_S}}} + 1$$

where the subscripts D and S denote dilution air orifice and sample air orifice respectively.

The diagram in Figure 2 will help illustrate how the pressures P_S and P_D are determined.

P_S then is: $P_S = P_{AMB} + \Delta P_7 + \Delta P_s$

and P_D is: $P_D = P_{AMB} + \Delta P_{DU} - \Delta P_{CY}$

where P_{AMB} = ambient absolute pressure

and ΔP_7 = differential pressure between the internal diluter pressure and ambient (negative when the diluter is negative to ambient)

ΔP_{DU} = differential pressure, duct to ambient (negative when duct is negative to ambient)

ΔP_{CY} = pressure drop across the cyclone

The calculation of DF is done using a programmable calculator (HP-25) and the following format is used to collectively restate the data values for direct input to the calculator each time a different DF is calculated.

ΔPs	T_{DI}	P_A
ΔP_D	T_{DU}	C_S
ΔP_7	P_S	DF =

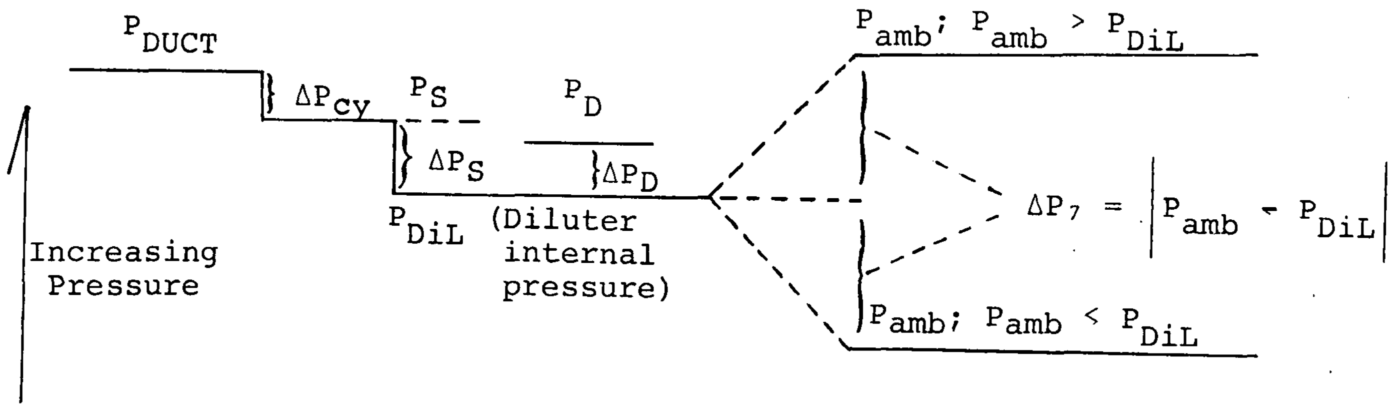


Figure 2. Diagrammatic representation of pressure drops in the ultrafine particle sizing system.

Note: ΔP_S, ΔP_D, and ΔP_7 and in inches H_2O, T_{DI}, and T_{DU} are in °R ($T_{DU} = T_S$), P_S and P_A are in inches Hg, $C_S = C_{N,S}$ and is for Q in lpm ($C_{N,D}$ = 590 is programmed in the calculator).

Typical data may be recorded as follows (for Q in NLPM):
Inlet, Friday (13 May, 1976), Dilution air orifice DA

26.34	329	45	-25.5	48
P_A	T_{DU}	T_{DI}	ΔP_{DU}	T_{AF}

TIME	OR	CAL
3:15 pm	.029	
(6.7, 3.2, -30) .5		

where P_A = ambient pressure (P_{AMB}) in "Hg
T_{DU} = temperature of the flue gas (Note: $T_S - T_{DU}$) in °F
T_{DI} = temperature of the dilution air orifice (T_D) in °F
T_A = ambient temperature in °F
TIME is the time at which these variables were recorded
OR is the sample air orifice identification number
CAL is a reminder to check the calibrations adjustments on all instruments

The following format is also used in conjunction with the data logging stamp:

(ΔP_S, ΔP_D, ΔP_7) ΔP_{CY} where all drops are in "H_2O

From calibration tables for our orifices, Table 3, we have

.029 orifice; $C_{N,S}$ = 3.70

and dilution air orifice, DA, $C_{N,D}$ = 590 (in program) thus:

ΔP_S 6.7	T_{DI} 505	P_A 26.34
ΔP_D 3.2	T_{DU} 789	C_S 2.00
ΔP_7 -30	PS 24.5	DF = 255

Table 3

ORIFICE CONSTANTS

#	2 Dot Set	3 Dot Set
.120	45	52
.082	14	16
.059	5.9	5.9
.042	3.7	3.3
.029	2.0	1.5
.021K	.96	.78
.021L	.82	—
.014K	.37	.45
.014L	.48	—
DA		590

or

$$DF = \frac{590 \sqrt{\dfrac{(24.4\ \text{"Hg})\ (3.2\ \text{"}H_2O)}{(505°R)}}}{2.00 \sqrt{\dfrac{(24.5\ \text{"Hg})\ (6.7\ \text{"}H_2O)}{(789°R)}}} + 1 = 255$$

$$\text{for } P_D = 26.34\text{"Hg} + \left(\frac{-30\text{"}H_2O + 3.2\text{"}H_2O}{13.6\ \text{"}H_2O/\text{"Hg}}\right) = 24.4\text{"Hg}$$

$$P_S = 26.34\text{"Hg} + \left(\frac{-25.5\text{"}H_2O - .5\text{"}H_2O}{13.6\ \text{"}H_2O/\text{"Hg}}\right) = 24.5\text{"Hg}$$

STEP 2

Calculate current differences ($\Delta I_{i,}j$) from adjacent channels and average the α_i products for the same size band for all scans taken at the inlet (outlet). Calculate standard deviations for each $\overline{\alpha_i}$:

The α_i product is given by the following:

$$\alpha_i = \Delta I_{i,j} \times DF_j$$

where i denotes the size band and j denotes the dilution value.

SAMPLE CALCULATION (FOR ILLUSTRATION ONLY)

Find $\overline{\alpha_i}$ for the ten scans given in Table 4 made at two different dilutions.

For channels 3-4 we have:

Scan #1: $\alpha_{3-4,1}$ = (.135)(255) pA

2: $\alpha_{3-4,1}$ = (.124)(255) pA

3: $\alpha_{3-4,1}$ = (.132)(255) pA

.

.

Table 4[1]

EAA Current Readings (I, in picoamps and Dilution Factors)
for this Sample Calculation: Hypothetical Inlet Data

ID #	Time	CH 3	CH 4	CH 5	CH 6	CH 7	CH 8	CH 9	CH 10	CH 11	Dilution Factor[2]
	Friday 12/4/75										
1	1:30p	2.869	2.734	2.519	2.227	1.362	.682	.242	.102	.020	255
2	1:32	2.835	2.711	2.495	2.205	1.344	.669	.220	.075	-.010	255
3	1:34	2.841	2.709	2.500	2.200	1.340	.655	.218	.081	.001	255
4	1:36	2.859	2.722	2.522	2.235	1.368	.676	.226	.096	.010	255
5	1:38	2.866	2.740	2.530	2.251	1.381	.714	.279	.137	.052	255
6	1:40	2.866	2.736	2.531	2.238	1.378	.698	.255	.115	.033	255
7	1:45	6.477	6.188	5.716	5.056	3.111	1.575	.565	.243	.053	113
8	1:47	6.580	6.288	5.818	5.153	3.233	1.613	.510	.195	.010	113
9	1:49	6.377	6.087	5.620	4.960	3.021	1.526	.537	.227	.032	113
10	1:51	6.390	6.094	5.614	4.956	3.006	1.467	.492	.187	.005	113

1. .029 Orifice; ΔP_{DUCT} = 25.5 "Hg, ΔP_{cy} = 0.5 "H_2O

2. For Runs 1 - 6, ΔP_S = 6.7 "H_2O T_{DI} = 505°R P_A = 26.34 "Hg
ΔP_D = 3.2 "H_2O T_{DU} = 789°R C_S = 2.00
ΔP_7 = -30 "H_2O P_S = 24.5 "Hg
For Runs 7 - 10, ΔP_S = 9.7 "H_2O T_{DI} = 505°R P_A = 26.34 "Hg
ΔP_D = 3.2 "H_2O T_{DU} = 789°R C_S = 3.70
ΔP_7 = - 41 "H_2O P_S = 24.5 "Hg

$$9: \quad \alpha_{3-4,2} = (.290)(113) \text{ pA}$$
$$10: \quad \alpha_{3-4,2} = (.296)(113) \text{ pA}$$

thus $\bar{\alpha}_{3-4}$ = 33.179 pA; n = 10 and σ = .997.
In a similar manner we can find α_{4-5}, α_{5-6}, ..., α_{10-11}.

A Hewlett-Packard HP-25 calculator program (included in the discussion of the impactor data reduction) has been written to calculate the error estimates given on graphs of the data points. Given a set of data, this program calculates the average ($\bar{X}$), the standard deviation (S), the relative standard deviation ($S/\bar{X}$), a 90% or 95% confidence interval (CI), the lower confidence limit ($\bar{X}$-CI or LCL), and the upper confidence limit ($\bar{X}$+CI or UCL).

Thus the mean plus and minus one standard deviation for α_{3-4} is

$$\alpha_{3-4} = (33.179 \pm 0.997) \text{ pA}$$

or

$$\alpha_{3-4} = (33.2 \pm 1.0) \text{ pA}$$

STEP 3

Using $\bar{\alpha}_i$ and Table 2 calculate "number concentration" (ΔN_S), "average cumulative concentration ..." ($\Sigma\Delta N_S$), and "$\Delta N_S/\Delta \text{Log} D$" for each size band for the inlet (outlet).

Table 5 shows these calculations for the sample data of Table 4. Column 7 is $\bar{\alpha}$ as shown in Step 2. Column 8 is the product of columns 7 and 5. Column 9 is the summation of 8 for all sizes "equal to or greater than the indicated size". Column 10 is column 5 times column 7 divided by column 6.

STEP 4

Plot cumulative concentration vs. size for inlet (outlet). For the sample data set of Table 4 this would be the concentrations in Table 5 column 9 plotted against the sizes in column 4. No error bars are used.

Table 5

EAA (Model 3030) Data Reduction Form
Concentration, Cumulative Concentration, and $\Delta N/\Delta \log D$
From Average ΔI for Condition Inlet
(Sample Calculation)

1	2	3	4	5	6	7	8	9	10
Channel No.	Collector Voltage	D_p, μm	D_{pi}, μm	$\Delta N/\Delta I$	$\Delta \log D_p$	$\bar{\alpha}$	ΔN_s	$\Sigma \Delta N_s$	$\Delta N_s/\Delta \text{Log} D$
							$\times 10^6$	$\times 10^6$	$\times 10^6$
3	196	0.0100							
			0.0133	4.76×10^5	0.250	33.2±1.0	15.8±.5	68.4	63.2±1.9
4	593	0.0178							
			0.0215	2.33×10^5	0.165	53.3±1.2	12.4±.3	52.6	75.3±1.7
5	1,220	0.026							
			0.0306	1.47×10^5	0.141	74.3±1.4	10.9±.2	40.2	77.5±1.5
6	2,183	0.036							
			0.0502	8.33×10^4	0.289	219.8±1.3	18.3±.1	29.3	63.4±.4
7	3,515	0.070							
			0.0917	4.26×10^4	0.234	174±3.9	7.41±.2	11.0	31.7±.7
8	5,387	0.120							
			0.149	2.47×10^4	0.188	114±4.1	2.82±.1	3.61	15.0±.5
9	7,152	0.185							
			0.219	1.56×10^4	0.148	35.4±1.1	.552±.02	.785	3.73±.1
10	8,642	0.260							
			0.306	1.10×10^4	0.141	21.2±.6	.233±.007	.233	1.65±.05
11	9,647	0.360							

STEP 5

Plot N/ LogD with plus or minus one standard deviation error bars for the inlet (outlet).

For the sample data set of Table 4 this would be the concentrations in Table 5, column 10 plotted against the sizes in column 4. The upper error bar is the value plus the standard deviation. The lower error bar is the value minus the standard deviation. For $\bar{\alpha}_{3-4}$ in Table 4 we would have $\bar{\alpha}_{3-4} = 33.2 \pm 1.0$ thus

$$\Delta N_s/\Delta \text{LogD} = \frac{33.2 \times 4.76 \times 10^5}{.250} \pm \frac{1.0 \times 4.76 \times 10^5}{.250}$$

$$= (63.2 \pm 1.9) \times 10^6$$

STEP 6

Calculate and plot efficiency vs. size with plus or minus one standard deviation error bars:

The efficiency of the control device is given by the following:

$$\text{Eff} = \left(1 - \frac{\text{Outlet N/ LogD}}{\text{Inlet N/ LogD}}\right) \times 100\%$$

Sample Calculation:

If, for 0.0133 μm particles, the

$$\text{Inlet } \Delta N_s/\Delta \text{LogD} = (63.2 \pm 1.9) \times 10^6$$

and

$$\text{Outlet } \Delta N_s/\Delta \text{LogD} = (8.85 \pm .23) \times 10^5$$

$$\text{Eff} = 1 - \frac{8.85 \times 10^5}{63.2 \times 10^6} \times 100 = 98.6\%$$

the upper limit (UL_E) and lower limit (LL_E) are given by

$$UL_E = 1 - \frac{\text{Outlet} - \sigma}{\text{Inlet} + \sigma} \times 100\% = 1 - \frac{8.62 \times 10^5}{65.1 \times 10^6} \times 100\% = 98.7\%$$

$$LL_E = 1 - \frac{\text{Outlet} + \sigma}{\text{Inlet} - \sigma} \times 100\% = 1 - \frac{9.08 \times 10^5}{61.3 \times 10^6} \times 100\% = 98.5\%$$

Efficiencies with upper and lower limits are calculated for each of the eight sizes in column 4 from the inlet and outlet $\Delta N_S/\Delta \text{LogD}$ values in column 10.

The following data were taken with the ultrafine sampling system described previously. These data were taken during November, 1975 at a Kraft recovery boiler.

INLET

CHANNEL	3	4	5	6	7	8	9	10	11
11:40AM 11/18/75 1									
BKGND DATA	0.005	0.005	0.005	0.004	0.004	0.003	0.003	0.003	0.003
	0.005	0.005	0.004	0.004	0.004	0.004	0.003	0.003	0.003
	0.005	0.005	0.005	0.005	0.004	0.003	0.003	0.003	0.003
	0.005	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003

ΔP_S 9.5 T_{DI} 541 P_A 30.15

ΔP_D 3.3 T_{DU} 900 C_S 3.7

ΔP_7 -10.3 P_S 30.65 DF = 120.2

INLET

CHANNEL	3	4	5	6	7	8	9	10	11
12:15PM 11/18/75 2									
DATA	4.927	4.998	4.978	4.818	4.654	4.482	3.339	1.704	0.828
	4.238	4.275	4.199	3.900	3.904	3.678	2.781	1.389	0.980
	4.452	4.446	4.344	4.243	4.177	3.880	2.861	1.438	0.683
	3.854	3.820	3.750	3.731	3.720	3.574	2.520	1.237	0.584
	5.145	5.011	4.951	4.969	4.996	4.606	3.430	1.750	0.856
	4.685	4.601	4.591	4.282	4.107	3.916	3.019	1.517	0.722

ΔP_S 4.5 T_{DI} 541 P_A 30.15

ΔP_D 3.2 T_{DU} 910 C_S 5.9

ΔP_7 -7.2 P_S 30.65 DF = 108.9

INLET

CHANNEL	3	4	5	6	7	8	9	10	11
1:40PM 11/18/75 3									
DATA	3.545	3.556	3.439	3.602	3.581	3.412	2.910	1.016	0.491
	3.086	3.090	3.038	2.930	2.861	9.999	0.000	9.999	0.000
	3.836	3.879	3.889	3.734	3.498	3.314	2.328	9.999	0.000
	3.110	3.093	3.111	3.115	2.912	2.741	1.934	0.735	0.311
	4.036	3.977	3.963	3.678	3.755	3.624	2.600	1.083	0.458

ΔP_S 8.3 T_{DI} 536 P_A 30.15

ΔP_D 2.4 T_{DU} 895 C_S 3.3

ΔP_7 -11.0 P_S 30.65 DF = 122.9

INLET

CHANNEL	3	4	5	6	7	8	9	10	11
3:15PM 11/18/75 4									
DATA	1.417	1.370	1.427	1.486	1.477	1.410	0.960	0.351	0.125
	1.912	1.898	1.956	1.977	1.874	1.708	1.158	0.405	0.153
	1.880	1.951	1.869	1.783	1.815	1.727	1.158	0.408	0.153
	1.769	1.708	1.650	1.528	1.503	1.428	0.928	0.314	0.108
	1.382	1.365	9.999	1.348	1.278	1.182	9.999	0.000	9.999
	1.148	1.214	1.177	0.963	9.999	0.618	0.453	0.168	0.051

ΔP_S 8.3 T_{DI} 536 P_A 30.15

ΔP_D 2.8 T_{DU} 850 C_S 16

ΔP_7 -19.1 P_S 30.65 DF = 27.2

INLET

CHANNEL	3	4	5	6	7	8	9	10	11
4:55PM 11/18/75 5									
DATA	6.167	6.190	6.595	5.876	5.712	4.713	1.249	0.093	0.007
	6.380	6.184	6.056	6.889	6.949	5.672	1.336	0.119	0.011
	6.622	6.623	6.611	6.197	6.382	5.435	1.715	0.181	0.017
	7.220	7.362	7.058	7.077	6.988	5.916	1.677	0.223	0.037

ΔP_S 8.1 T_{DI} 536 P_A 30.15

ΔP_D 2.7 T_{DU} 850 C_S 14

ΔP_7 -17.9 P_S 30.65 DF = 30.8

INLET

CHANNEL	3	4	5	6	7	8	9	10	11
01:10PM 11/19/75 6									
DATA	3.840	4.039	3.973	3.798	3.681	2.245	0.295	0.012	-0.010
	4.012	3.827	4.137	3.915	3.992	3.022	0.512	0.038	-0.007
	3.785	3.857	3.880	3.797	3.490	2.559	0.469	0.030	-0.005
	3.905	3.687	3.786	3.651	3.651	3.085	0.829	0.065	0.002

ΔP_S 3.9 T_{DI} 528 P_A 30.1

ΔP_D 3.2 T_{DU} 855 C_S 45

ΔP_7 -23.0 P_S 29.6 **DF = 15.87**

OUTLET

CHANNEL	3	4	5	6	7	8	9	10	11
8:45AM 11/19/75 7									
DATA	-0.165	-0.170	-0.169	-0.183	-0.186	-0.191	-0.195	-0.198	-0.201
	-0.023	-0.028	-0.032	-0.039	-0.041	-0.045	-0.051	-0.055	-0.058
	-0.066	-0.075	-0.080	-0.086	-0.089	-0.095	-0.101	-0.106	-0.110
	-0.102	-0.114	-0.119	-0.123	-0.126	9.999	0.000	-0.135	-0.138
	-0.135	-0.140	-0.142	-0.141	-0.145	-0.148	-0.153	-0.159	-0.164

ΔP_S 3.5 T_{DI} 528 P_A 30.1

ΔP_D 3.2 T_{DU} 850 C_S 52

ΔP_7 -22.5 P_S 29.6 **DF = 14.55**

OUTLET

CHANNEL	3	4	5	6	7	8	9	10	11
9:20AM 11/19/75 8									
DATA	-0.157	-0.159	-0.160	-0.160	-9.159	-0.159	-0.159	-0.160	-0.164
	-0.150	-0.156	-0.156	-0.150	-0.157	-0.160	-0.162	-0.164	-0.165
	-0.122	-0.137	-0.153	-0.146	-0.154	-0.157	-0.161	-0.162	-0.162
	-0.154	-0.154	-0.153	-0.146	-0.148	-0.146	-0.150	-0.144	-0.147
	-0.163	-0.162	-0.162	-0.162	-0.165	-0.163	-0.162	-0.167	-0.169
	-0.149	-0.157	-0.163	-0.165	-0.168	-0.169	-0.169	-0.171	-0.175
	-0.072	-0.109	-0.146	-0.147	-0.999	-0.154	-0.156	-0.158	-0.159

ΔP_S 3.3 T_{DI} 528 P_A 30.1

ΔP_D 3.2 T_{DU} 855 C_S 52

ΔP_7 -22.5 P_S 29.6 **DF = 14.95**

OUTLET

CHANNEL	3	4	5	6	7	8	9	10	11
9:50AM 11/19/75 9									
DATA	-0.158	-0.158	-0.158	-0.159	-0.160	-0.161	-0.163	-0.163	-0.166
	-0.168	-0.169	-0.172	-0.171	-0.167	-0.163	-0.161	-0.162	-0.162
	-0.166	-0.166	-0.166	-0.167	-0.167	-0.168	-0.169	-0.173	-0.175
	-0.152	-0.161	-0.163	-0.166	-0.166	-0.167	-0.167	-0.170	-0.171
	-0.148	-0.147	-0.144	-0.146	-0.147	-0.149	-0.150	-0.150	-0.149

ΔP_S 3.3 T_{DI} 538 P_A 30.1

ΔP_D 3.2 T_{DU} 840 C_S 52

ΔP_7 -22.5 P_S 29.6 **DF = 14.74**

OUTLET

9:55AM 11/19/75 10

CHANNEL	3	4	5	6	7	8	9	10	11
DATA	-0.156	-0.152	-0.157	-0.162	-0.165	-0.168	-0.170	-0.174	-0.175
	-0.174	-0.174	-0.174	-0.175	-0.175	-0.177	-0.177	-0.180	-0.180
	-0.176	-0.180	-0.179	-0.180	-0.181	-0.182	-0.999	-0.187	-0.999

ΔP_S 3.6 T_{DI} 538 P_A 30.1

ΔP_D 3.2 T_{DU} 840 C_S 45

ΔP_7 -22.5 P_S 29.6 **DF = 16.36**

OUTLET

10:30AM 11/19/75 11

CHANNEL	3	4	5	6	7	8	9	10	11
DATA	-0.075	-0.075	-0.075	-0.075	-0.076	-0.073	-0.073	-0.074	-0.076
	-0.075	-0.078	-0.079	-0.078	-0.079	0.000	-0.080	-0.081	-0.082
	-0.074	-0.077	-0.073	-0.076	-0.078	-0.078	-0.079	-0.081	-0.080

ΔP_S 3.2 T_{DI} 548 P_A 30.1

ΔP_D 3.0 T_{DU} 830 C_S 45

ΔP_7 -21.2 P_S 29.6 **DF = 16.51**

OUTLET

11:30AM 11/19/75 12

CHANNEL	3	4	5	6	7	8	9	10	11
DATA	-0.051	-0.052	-0.055	-0.053	-0.052	-0.052	-0.053	-0.055	-0.056
	-0.044	-0.049	-0.050	-0.049	-0.050	-0.049	-0.051	-0.053	-0.054
	-0.050	-0.051	-0.050	-0.050	-0.050	-0.050	-0.052	-0.053	-0.053
	-0.049	-0.049	-0.050	-0.050	-0.051	-0.050	-0.051	-0.054	-0.054
	-0.049	-0.048	-0.049	-0.048	-0.049	-0.049	-0.050	-0.051	-0.053
	-0.048	-0.048	-0.048	-0.048	-0.049	-0.050	-0.051	-0.052	-0.053
	-0.046	-0.046	-0.048	-0.047	-0.048	-0.049	-0.049	-0.050	-0.052
	-0.046	-0.045	-0.045	-0.047	-0.045	-0.046	-0.047	-0.047	-0.048
	-0.043	-0.044	-0.045	-0.046	-0.046	0.000	-0.047	-0.048	-0.049
	-0.040	-0.042	-0.041	-0.042	0.000	-0.043	-0.045	-0.047	-0.047

ΔP_S 3.4 T_{DI} 540 P_A 30.1
ΔP_D 3.5 T_{DU} 840 C_S 45
ΔP_7 −29.92 P_S 29.6 DF = 17.18

OUTLET

12:00PM 11/19/75 13

CHANNEL	3	4	5	6	7	8	9	10	11
DATA	-0.060	-0.060	-0.061	-0.061	-0.061	-0.062	-0.064	-0.065	-0.066
	-0.056	-0.056	-0.057	-0.058	-0.060	-0.061	-0.061	-0.063	-0.063
	-0.053	-0.054	-0.053	-0.053	-0.055	-0.055	-0.055	-0.058	-0.059
	-0.048	-0.049	-0.050	-0.051	-0.052	-0.052	-0.053	-0.055	-0.055

INLET

12:10PM 11/19/75 14

CHANNEL	3	4	5	6	7	8	9	10	11
BKGND	-0.022	-0.021	-0.021	-0.021	-0.021	-0.020	-0.021	-0.020	-0.020
DATA	-0.019	-0.018	-0.019	-0.018	-0.019	-0.018	-0.018	-0.019	-0.019
	-0.018	-0.017	-0.018	-0.017	-0.017	-0.019	-0.018	-0.021	-0.018

ΔP_S 4.5 T_{DI} 540 P_A 30.1
ΔP_D 3.2 T_{DU} 830 C_S .45
ΔP_7 -4.1 P_S 30.6 DF = 13.58.99

INLET

2:11PM 11/19/75 15

CHANNEL	3	4	5	6	7	8	9	10	11
DATA	0.005	0.006	0.003	0.000	-0.001	-0.003	-0.006	-0.012	-0.016
	0.148	0.139	0.129	0.107	0.112	0.109	0.097	0.075	0.052
	0.089	0.080	0.082	0.056	0.065	0.086	0.080	0.064	0.046
	0.065	0.051	0.063	0.063	0.064	0.058	0.059	0.046	0.025
	0.048	0.048	0.035	0.035	0.031	0.030	0.019	0.005	0.001

ΔP_S 6.8 T_{DI} 540 P_A 30.1

ΔP_D 3.2 T_{DU} 830 C_S .37

ΔP_7 -7.8 P_S 30.6 DF = 1338.46

INLET

CHANNEL	3	4	5	6	7	8	9	10	11
2:35PM 11/19/75 16									
DATA	0,313	0,273	0,303	0,303	0,268	0,258	0,255	0,158	0,079
	0,355	0,336	0,347	0,317	0,325	0,274	0,204	0,151	0,999
	0,351	0,345	0,374	0,333	0,323	0,323	0,290	0,220	0,161
	0,376	0,360	0,318	0,320	0,312	0,315	0,304	0,234	0,168
	0,341	0,329	0,318	0,326	0,334	0,319	0,308	0,221	0,171
	0,329	0,318	0,317	0,320	0,336	0,318	0,307	0,223	0,162
	0,325	0,328	0,320	0,315	0,307	0,334	0,291	0,233	0,153
	0,336	0,341	0,335	0,336	0,343	0,337	0,312	0,237	0,167

ΔP_S 5.8 T_{DI} 540 P_A 30.1

ΔP_D 3.3 T_{DU} 860 C_S .78

ΔP_7 -6.3 P_S 30.6 DF = 712.51

INLET

CHANNEL	3	4	5	6	7	8	9	10	11
2:37PM 11/19/75 17									
DATA	0,603	0,565	0,545	0,513	0,447	0,442	0,307	0,173	0,106
	0,717	0,688	0,659	0,643	0,641	0,617	0,533	0,386	0,260
	0,839	0,830	0,832	0,804	0,805	0,772	0,642	0,437	0,308
	0,858	0,840	0,818	0,814	0,815	0,763	0,695	0,518	0,347
	0,959	0,918	0,898	0,897	0,909	0,874	0,763	0,552	0,365
	0,899	0,899	0,878	0,885	0,871	0,850	0,726	0,554	0,377

STOP 000000

REFERENCES

1. Liu, B. Y. H., Whitby, K. T. and Pui, D. Y. H., "A Portable Electric Aerosol Analyzer for Size Distribution Measurement of Submicron Aerosols", presented at the 66th Annual Meeting of the Air Pollution Control Association, Paper No. 73-283 (June 1973).

2. Liu, B. Y. H., and Pui, D. Y. H., "On the Performance of the Electrical Aerosol Analyzer," J. Aerosol Science, 6, pp. 249-64, (1975).

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

1. REPORT NO. EPA-600/2-76-141	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Particulate Collection Efficiency Measurements on an Electrostatic Precipitator Installed on a Paper Mill Recovery Boiler		5. REPORT DATE May 1976 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Larry G. Felix John P. Gooch and G.H. Marchant, Jr.		8. PERFORMING ORGANIZATION REPORT NO. SORI-EAS-76-091 3540-1
9. PERFORMING ORGANIZATION NAME AND ADDRESS Southern Research Institute 2000 Ninth Avenue South Birmingham, Alabama 35205		10. PROGRAM ELEMENT NO. 1AB012; ROAP 21ADL-027 11. CONTRACT/GRANT NO. 68-02-2114, Task 1
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15. SUPPLEMENTARY NOTES IERL-RTP Project Officer for this report is L.E. Sparks, Mail Drop 61, Ext 2925.

16. ABSTRACT The report gives results of fractional and overall collection efficiency measurements of an electrostatic precipitator collecting 'salt cake' from a Kraft recovery boiler. Mass median diameter of the particulate entering the collector was approximately 1.0 micrometers; minimum average collection efficiency in the 0.1-2.0 micrometer diameter range was 99.92%. Size distributions at the precipitator inlet and outlet were measured with cascade impactors and an electrical aerosol analyzer. Overall mass efficiency measurements, based on a mass train with an in-stack filter, ranged from 99.92 to 99.96%. Fair agreement was obtained between the total mass loadings obtained with the mass trains and the impactors. Average precipitator operating conditions during the test period were: secondary voltage, 47.1 kV; current density, 32.6 x 10 to the minus 9th power amps/sq cm; specific collecting area, 114 sq m/(cu m/sec); temperature, 198C; and gas velocity, 0.76 m/sec.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution	Air Pollution Control	13B
Dust	Stationary Sources	11G
Measurement	Particulate	14B
Electrostatic Precipitators	Collection Efficiency	
Paper Mills	Recovery Boilers	
Sulfate Pulping	Salt Cake	13H,07A

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