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Evaluation of an Electrostatic Precipitator for Control of Emissions From a Copper Smelter Reverberatory Furnace

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EVALUATION OF AN ELECTROSTATIC PRECIPITATOR FOR CONTROL OF EMISSIONS FROM A COPPER SMELTER REVERBERATORY FURNACE

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report presents the findings of an investigation of air pollutant emissions from the reverberatory furnace pollution control system at a primary copper smelter. The study was performed to assess the degree of particulate emissions control and control problems associated with the application of electrostatic precipitators in the nonferrous metals production industry. The results are being used within the Agency's Office of Research and Development as part of a larger effort to define the potential environmental impact of emissions from this industry segment and the need for improved controls. The findings will also be useful to other Agency components and the industry in dealing with environmental control problems. The Metals and Inorganic Chemicals Branch of the Industrial Pollution Control Division should be contacted for any additional information desired concerning this program.

David G. Stephan
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ABSTRACT

This report describes tests to evaluate the performance of an electrostatic precipitator installed on a copper reverberatory furnace. Particle size measurements were made with modified Brink cascade impactors in order to calculate the ESP fractional efficiency. The particle size distributions at the inlet and outlet were both found to be biomodal. The overall mass median diameter of the inlet distribution was greater than 10 μm. The SRI-EPA computer model was used to simulate the ESP performance. Values of the mass collection efficiency were found by instack filters to be 96.7%, and by cascade impactors to be 96.6%. The computer model predicted an overall efficiency to be 96.8%, which is also the design efficiency.

The particulate matter was found to be very cohesive and hygroscopic, and the composition (color) varied from impactor stage to stage. There was no evidence of electrical problems due to particle resistivity or space charge.

Simultaneous testing was also carried out by Radian Corporation, Austin, Texas. Results of the Radian study are included in a report "Trace Element Study at a Primary Copper Smelter, Vol. I and II" (EPA-600/2-70-065a and -065b, March 1978). An evaluation of another such control system (installed at a different smelter) entitled "Performance Evaluation of an Electrostatic Precipitator Installed on a Copper Smelter Reverberatory Furnace", EPA-600/2-79-119, was published in June, 1979.

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FIGURES

FIGURES (Cont'd.)

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SECTION 1

SUMMARY AND CONCLUSIONS

Tests were performed on July 9 and 10, 1976 to measure the fractional collection efficiency of a Joy-Western Precipitation electrostatic precipitator installed on a copper reverberatory furnace.

From qualitative observations of cascade impactor stage catches it was determined that the particulate emissions are very cohesive, hygroscopic, and very likely inhomogeneous in composition with respect to particle size. The mass median diameter of the inlet particle size distribution was greater than 10 μm. The inlet particle size distributions were bimodel with one component having a mass median diameter less than 1 μm.

The electrical operating data indicate that the ESP was in good mechanical alignment and electrical condition. The overall collection efficiency, measured by instack filters operating at stack temperatures (∿300°C) was 96.7%. The overall collection efficiency calculated from cascade impactor data was 96.6%. The theoretical collection efficiency, predicted by the SRI-EPA computer model, was 96.8%. The design efficiency was 96.8%.

A potential source of trouble with the application of ESP's to sources of very fine particulate is suppression of the corona current by a particulate space charge. Although some reduction in current was observed at the ESP inlet, the degree of suppression was not large. This can be attributed to the fact that the particles were larger than expected, and the concentration was rather low.

1. The mass collection efficiency at gas conditions agreed with the theoretical and expected behavior of the device. The measured efficiency and design efficiency were identical within experimental error.

2. The power supply voltage vs current characteristics suggest that the electrode system was in good mechanical alignment.

3. Particulate resistivity was not limiting the operating characteristics of the collector.

4. The gas velocity distribution, as reported by Radian, was good in the inlet and outlet sampling planes.

5. There was an apparent difference in the chemical composition with respect to particle size.

6. A significant variation in sulfur oxide concentration occurred with time.

7. No significant change in electrostatic precipitator operation was deemed to be necessary for optimal operation.

SECTION 2

INTRODUCTION

Southern Research Institute worked in cooperation with the Radian Corporation to evaluate the performance of an electrostatic precipitator installed on a copper reverberatory furnace. In this particular test, Southern Research personnel conducted measurements of the inlet and outlet particle size distribution and voltage-current characteristics of the electrostatic precipitator. A computer simulation of the ESP performance was made using the computer systems model developed at SRI under the sponsorship of the EPA Industrial Environmental Research Laboratory at Research Triangle Park, N.C.

Section 3 contains a description of the ESP and a discussion of the experimental procedures which were used to make measurements of the particle size distributions. Section 4 contains reduced data from the particle size distribution measurements, and a comparison of the measured efficiency with that predicted by the computer model. All of the data taken with the Brink impactors is contained in Section 5, the Appendix. Section 5 also contains a more detailed summary of the procedures which were used to obtain particle size information with the Brink impactors.

SECTION 3

EXPERIMENTAL PROCEDURES AND DISCUSSION

DESCRIPTION OF THE ELECTROSTATIC PRECIPITATOR

Figure 1 is a schematic which shows the overall dimensions and electrical sectionalization of the Joy-Western electrostatic precipitator (ESP) used to control the emissions from a reverberatory furnace. Table 1 summarizes the descriptive parameters of the ESP.

The electrostatic precipitator is physically divided in the center such that two independent gas flow paths are provided. No data are available pertaining to turning vanes, baffles or gas distribution plates.

The power supply control cabinets are equipped with primary voltage and current meters. Measurements of the secondary voltage values were made by installing temporary voltage dividers. Series resistors of 26Ω, previously installed by Joy-Western, were used to monitor the currents. The circuits used to measure the secondary currents and voltages are shown in Figure 2.

Operating values for the primary and secondary currents and voltages were monitored throughout the tests. Power set C was operated in the manual mode because the automatic control system was inoperative. The manual settings were kept at near optimum values during the tests by SRI personnel. Sets A and B were operated in the automatic mode. At the conclusion of the particulate collection efficiency tests, complete V-I characteristics were measured for all three electrical power sets. (Repair to power set C would have caused a delay in the test program).

Values for the operating current and voltage which were recorded during the efficiency tests are shown in Table 2. These values were recorded at approximately 1 hour intervals, but for periods where the input power did not fluctuate from the average by more than five percent, only the average is included.

The electrical operating data indicate that the ESP was in good condition. Although the inlet section, set C, could

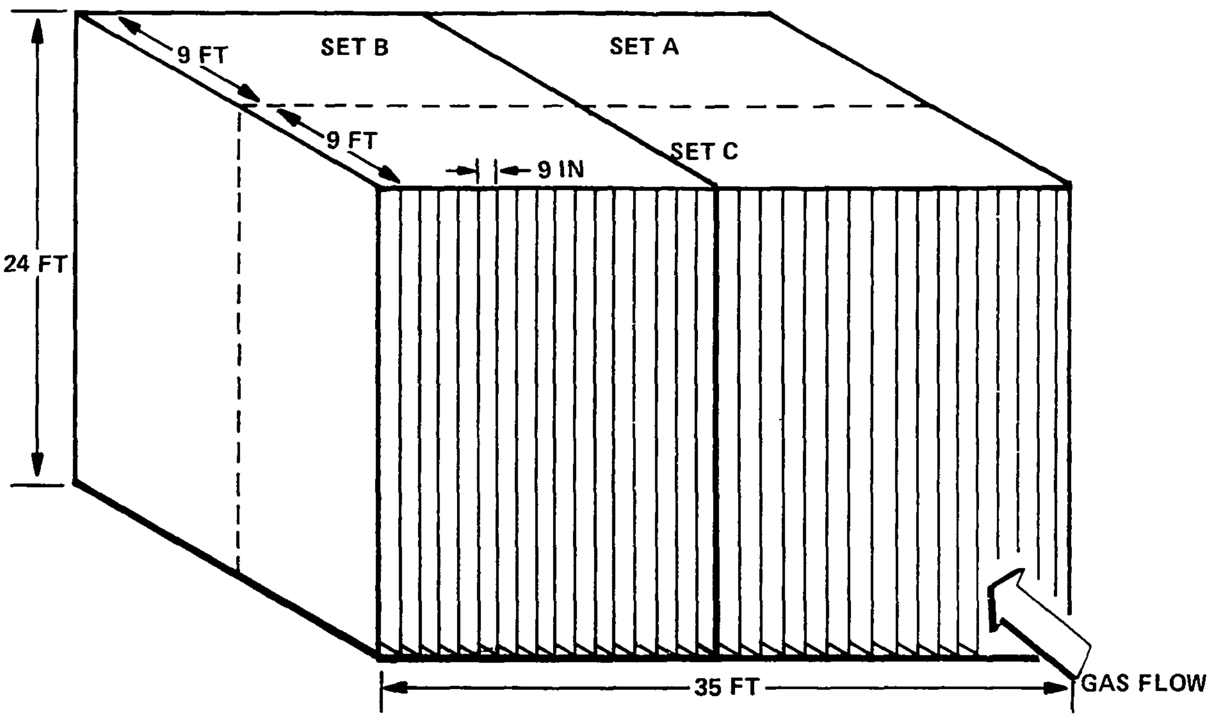
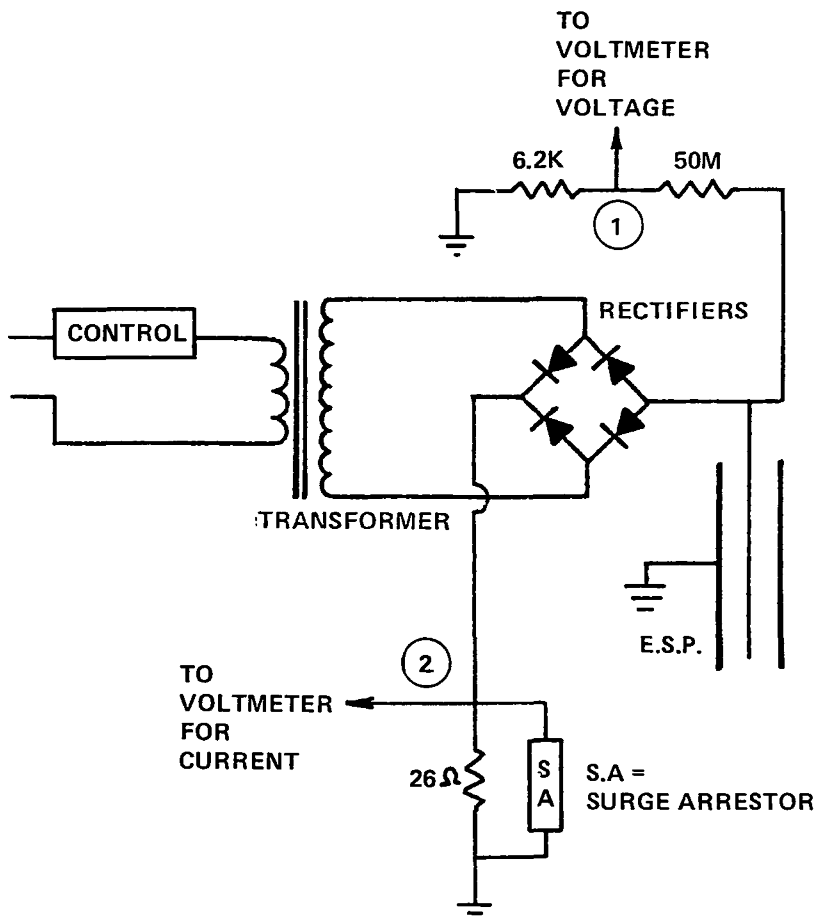


Figure 1. Approximate Dimensions of the Active Area of the Electrostatic Precipitator

TABLE 1. ELECTROSTATIC PRECIPITATOR DESCRIPTIVE PARAMETERS FOR A REVERBERATORY FURNACE

ITEM	ENGLISH	METRIC
Collection electrode area (A)(total-2 ESP)	39744 ft^2	3692.4 m^2
Inlet set area (power set C)	19872 ft^2	1846.2 m^2
Outlet set area (power set A)	9936 ft^2	923.0 m^2
Outlet set area (power set B)	9936 ft^2	923.0 m^2
Collection electrode spacing	9 in.	0.229 m
Corona electrode diameter (round wire)	0.1055 in.	2.7 mm
Collection electrode dimension	9 ft x 24 ft	2.74 x 7.32 m
Number of gas passages (total - 2 ESP)	46	
Gas passage length (active)	18 ft	5.49 mm
Volume flow rate design (V)*	150,000 acfm	70.8 m^3/sec
Design temperature	600-700°F	315-371°C
Design efficiency	96.83%	
Design precipitation rate parameter (w)	0.21 ft/sec	6.5 cm/sec
Specific collection electrode area (A/V)	265 ft^2/thousand cfm	52 m^2/m^3/sec

* Note - these conditions were within 5% of the actual measured flows during the test period. The temperature and efficiencies were approximately the same.



1. SECONDARY VOLTAGE = $V_1 \times \frac{50 \times 10^6 + 6.2 \times 10^3}{6.2 \times 10^3} = 8.1 \times 10^3\ V_1$

2. SECONDARY CURRENT = $\frac{V_2}{26}$

Figure 2. Circuits Used to Measure Electrical Operating Characteristics of the Electrostatic Precipitator

TABLE 2. POWER SUPPLY LOG, REVERBERATORY FURNACE, ESP

Date	Time	Set	Voltage, Primary (KV)	Current, Primary (V)	Power (kW)	Voltage, Secondary (kV)	Current, Secondary (mA)	Power (kW)	Current Density µA/ft²	Current Density mA/m²	Comments
7-8-76	7:00	A	210	80	16.8	32.0	231	7.4	24.0	.25	
		B	220	70	15.4	32.5	261	8.5	27.0	.28	
		C	260	90	23.4	36.0	281	10.1	14.9	.15	
	7:10	A	230	125	28.8	33.5	378	12.7	40.1	.41	
		B	280	175	49.0	36.3	584	21.2	61.9	.63	
		C	280	135	37.8	36.4	420	15.3	22.3	.23	
	9:00-10:40	A	250	160	40.0	35.5	515	18.3	54.6	.56	
		B	290	165	47.9	36.8	600	22.1	63.6	.65	
		C	290	140	40.6	37.1	505	18.7	26.8	.27	
	11:30-1:00	A	245	155	38.0	35.0	480	16.8	50.9	.52	
		B	280	165	46.2	36.0	560	20.2	50.9	.61	
		C	290	135	39.2	37.1	505	18.7	26.8	.27	
7-9-76	7:00-1:00	A	260	155	40.3	36.5	530	19.3	56.3	.57	
		B	290	165	47.9	36.8	579	21.3	61.4	.63	
		C	290	110	31.9	37.3	393	14.7	20.8	.21	
7-10-76	5:00-7:30	A	250	155	38.8	35.0	543	19.0	57.5	.59	
		B	285	165	47.0	37.5	552	20.7	58.5	.60	
		C	280	120	33.6	37.0	408	15.1	21.6	.22	
	8:00	A	240	125	30.0	34.5	409	14.1	43.3	.44	Upset relates to charging furnace
		C	255	125	31.9	35.5	386	13.7	40.9	.42	
		C	280	120	33.6	37.0	408	15.1	21.6	.22	
	8:07-12:00	A	265	165	43.7	36.5	562	20.5	59.6	.61	Normal
		B	300	170	51.0	38.5	571	22.0	60.5	.62	
		C	300	155	45.0	38.5	556	21.4	29.5	.30	

only be operated at a considerably lower current density than the outlet section sets A and B; this behavior is normal and can be explained in terms of a space charge effect. For cases of moderate and heavy mass loading, a space charge consisting of charged fine particles exists in the interelectrode space and causes a suppression of the corona current. Downstream sections are subjected to a lower concentration of uncollected particulate and usually can be operated at higher current densities.

The power supply designs were considered to be adequate in that the automatic control system operated with some sparking at currents below the current rating of the power supplies. The TR Set ratings are 1100 ma for sets A and B and 1400 ma for set C. Therefore, the power supply ratings were adequate.

The current suppression related to the space charge effect can be explained in terms of a reduced effective mobility of the charge carriers. If the entire current is carried by gas molecules, then the total current flow is caused by ionic motion. However, when significant electrical charge is attached to particulate matter, the velocity of which is much less than that for ions, the phenomenon of space charge suppression of current occurs.

Tables 3, 4, and 5, and Figure 3 contain data showing the complete voltage-current characteristics for the ESP. Again, these curves are normal, and show no indication of any high resistivity problem nor a severe space charge problem.

GAS VELOCITY DISTRIBUTION

It was initially intended to conduct gas velocity distribution measurements within the internal portion of the electrostatic precipitator. It was not possible to make this measurement because the anticipated reverberatory furnace shutdown did not occur. Therefore, the only gas velocity measurement was made in the inlet and outlet plenum areas. These data were reported by Radian.

The computer system projection suggested that the gas velocity distribution within the unit was acceptable.

COLLECTION ELECTRODE DESIGN

No discussion was included about the specific design of the collection electrode system. No data were available that could be used to show that any particular electrode design is superior to another.

Each individual equipment supplier provides the design that they feel best applies to their device. In the absence of definite supporting data, no general comment was warranted

TABLE 3. VOLTAGE VS. CURRENT VALUES FOR ELECTROSTATIC PRECIPITATOR INSTALLED ON A REVERBERATORY FURNACE

(Plate area 9936 ft^2)

Power Set A

V_{pri} (V)	I_{pri} (A)	Power (kW)	V_{sec} (kV)	I_{sec} (mA)	Power (kW)	Eff %	Current Density $\mu A/ft^2$	mA/m^2
260	170	44.2	36.5	573	20.9	47	57.7	.62
250	150	37.5	35.5	515	18.3	49	51.8	.56
225	110	24.8	33.0	344	11.4	46	34.6	.37
200	75	15.0	31.2	212	6.6	44	21.3	.23
185	50	9.3	29.6	131	3.9	42	13.2	.14
175	40	7.0	29.2	102	3.0	43	10.3	.11
160	30	4.8	28.1	67	1.9	39	6.7	.07
150	25	3.8	26.5	40	1.0	28	4.0	
125	10	1.3	23.7	9	0.2	17	0.9	
100			22.3	3			0.3	

TABLE 4. VOLTAGE VS. CURRENT VALUES FOR ELECTROSTATIC PRECIPITATOR INSTALLED ON A REVERBERATORY FURNACE

(Plate area 9936 ft^2)

Power Set B

V_{pri}(V)	I_{pri}(A)	Power(kW)	V_{sec}(kV)	I_{sec}(mA)	Power(kW)	Eff %	Current Density $\mu A/ft^2$	mA/m^2
290	175	50.7	36.8	621	22.9	45	62.5	.67
275	167	45.9	36.1	565	20.4	44	56.9	.61
250	120	30.0	33.8	378	12.8	43	38.0	.40
235	90	21.1	32.1	285	9.1	43	28.7	.31
225	65	14.6	31.7	254	8.1	55	25.6	.28
200	40	8.0	29.9	148	4.4	55	14.9	.16
185	30	5.5	28.8	107	3.1	56	10.8	.12
175	20	3.5	28.5	86	2.5	70	8.7	.09
145	10	1.5	24.4	21	0.5		2.1	
125	0		23.1	14			1.4	
100			19.8	4			0.4	

TABLE 5. VOLTAGE VS. CURRENT VALUES FOR ELECTROSTATIC PRECIPITATOR INSTALLED ON A REVERBERATORY FURNACE

(Plate area 19872 ft^2)

Power Set C

V_{pri}(V)	I_{pri}(A)	Power(kW)	V_{sec}(kV)	I_{sec}(mA)	Power(kW)	Eff %	Current Density μA/ft^2	mA/m^2
320	190	60.8	39.0	730	28.5	47	36.79	.40
300	160	48.0	37.8	585	22.1	46	29.4	.32
275	110	30.2	36.1	379	13.7	45	19.1	.21
250	75	18.8	34.7	235	8.2	43	11.8	.13
225	45	10.1	33.4	135	4.5	45	6.8	.07
200	25	5.0	32.0	68	2.2	44	3.4	.04
175	10	1.75	29.8	32	1.0	54	1.6	.02
160	0		28.3	15			0.8	
125			23.5	5			0.2	
100			17.5	1			0.05	

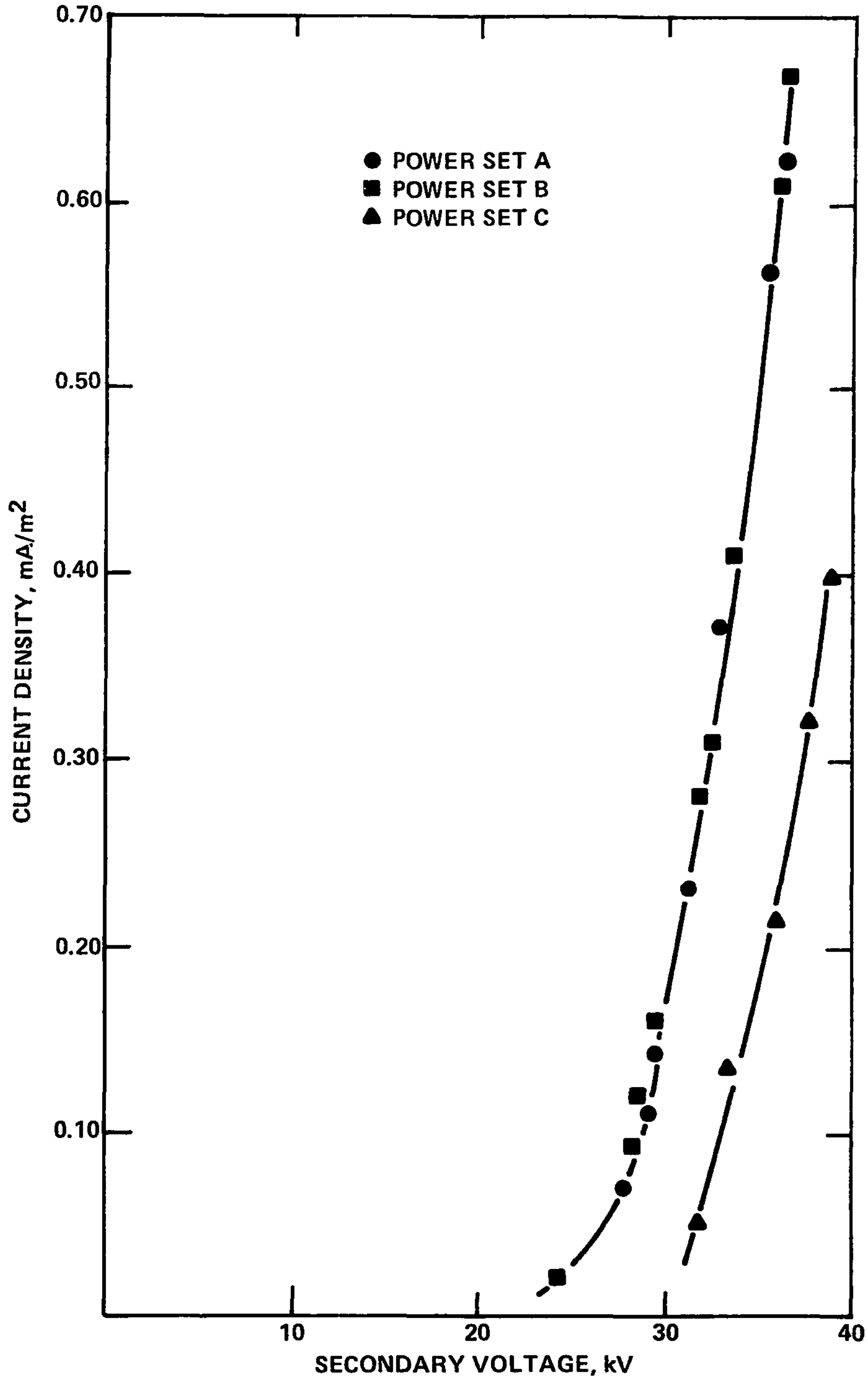


Figure 3. Voltage - Current Characteristics of the Three ESP Power Sets

for an individual design.

MAINTENANCE AND OPERATION

The behavior of the electrostatic precipitator was considered to be good. The plant had a maintenance man assigned to the Electrostatic Precipitator Control Room. He repeatedly checked the power supply readings and noted the general conditions of the unit. The material collected by the electrostatic precipitator was moved by screw conveyors into a storage bin for recycling through the smelter. No particular problems were noted with the system.

The particular maintenance and operation program that is followed by individual plants is formulated between the equipment user and supplier. These programs range from complete inspection and repair carried out at specified intervals to no maintenance work until a significant failure occurs. In many cases, electrostatic precipitators may operate satisfactorily for several years with little or no maintenance required while in others, extensive maintenance is required. Each supplier and user decides what is correct for each installation. The program followed at the test smelter seemed to be adequate because the electrostatic precipitator appeared to be in good operating condition.

PARTICLE SIZE MEASUREMENTS

Cascade impactors were used to measure the size distribution of particles suspended in the flue gas at the ESP inlet and outlet in order to characterize the particulate and to measure the collection efficiency vs. particle size. Brink cascade impactors, modified and calibrated at SRI, were chosen for this application because their low sampling rate allows longer sampling times and better averaging of emissions during process changes. Figure 4 shows the sampling train that was used during these tests.

On-site pretest investigations were done during the week of June 28 in order to determine the extent to which gas phase reactions between the rather high SO_x constituent of the effluent gas and glass fiber collection substrates and filters might interfere with the tests. The results from these tests indicate that the Reeve Angel 934AH material was sufficiently inert to allow confidence in the subsequent test data. A secondary purpose of the pretest was to provide an estimate of the sampling time required to obtain a weighable sample without overloading the impactor stages. Data for the efficiency tests were obtained on July 9 and 10.

Section 5, the Appendix, contains a more detailed description of the procedures that were used to collect impactor samples,

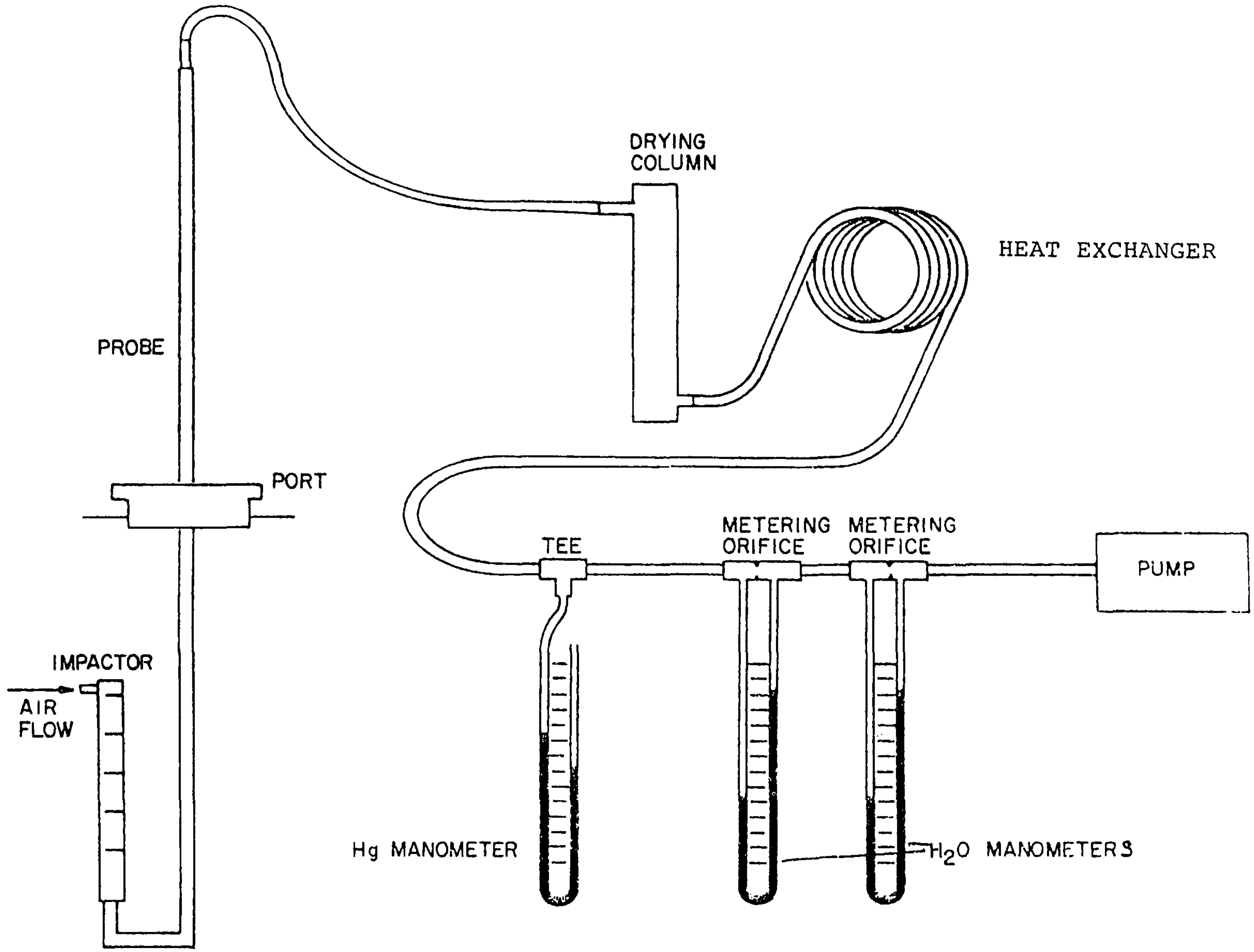


Figure 4. Sampling setup for the Brink Impactor using redundant calibrated orifice flowmeters.

and all of the data are tabulated there.

The term "particle size" is somewhat ambiguous if the particle shape is irregular, or if the mass density is unknown or inhomogeneous. Fortunately, many particles created by condensation are spherical and the diameter is used to measure size. If the particles are spherical, and the density is known, cascade impactors yield information on the actual physical size. If the shape and density are unknown, particle size is generally reported in terms of "aerodynamic diameter". The aerodynamic diameter of a particle is related to its behavior in a gas and is defined as the diameter of a sphere of unit density with the same settling velocity as the particle of interest. Cascade impactors measure the aerodynamic diameter directly. (See the Appendix for detailed discussion).

Since the aerosol of interest was a condensation product, and an approximate density of 3.58 gm/cm^3 was given by the plant personnel, all the particle size distributions reported here are based on the physical or Stokes diameter. Figure 5 is a curve relating aerodynamic diameters to physical diameters for a mass density of 3.58 gm/cm^3. This curve can be used to change any of the particle diameters reported here to an aerodynamic basis.

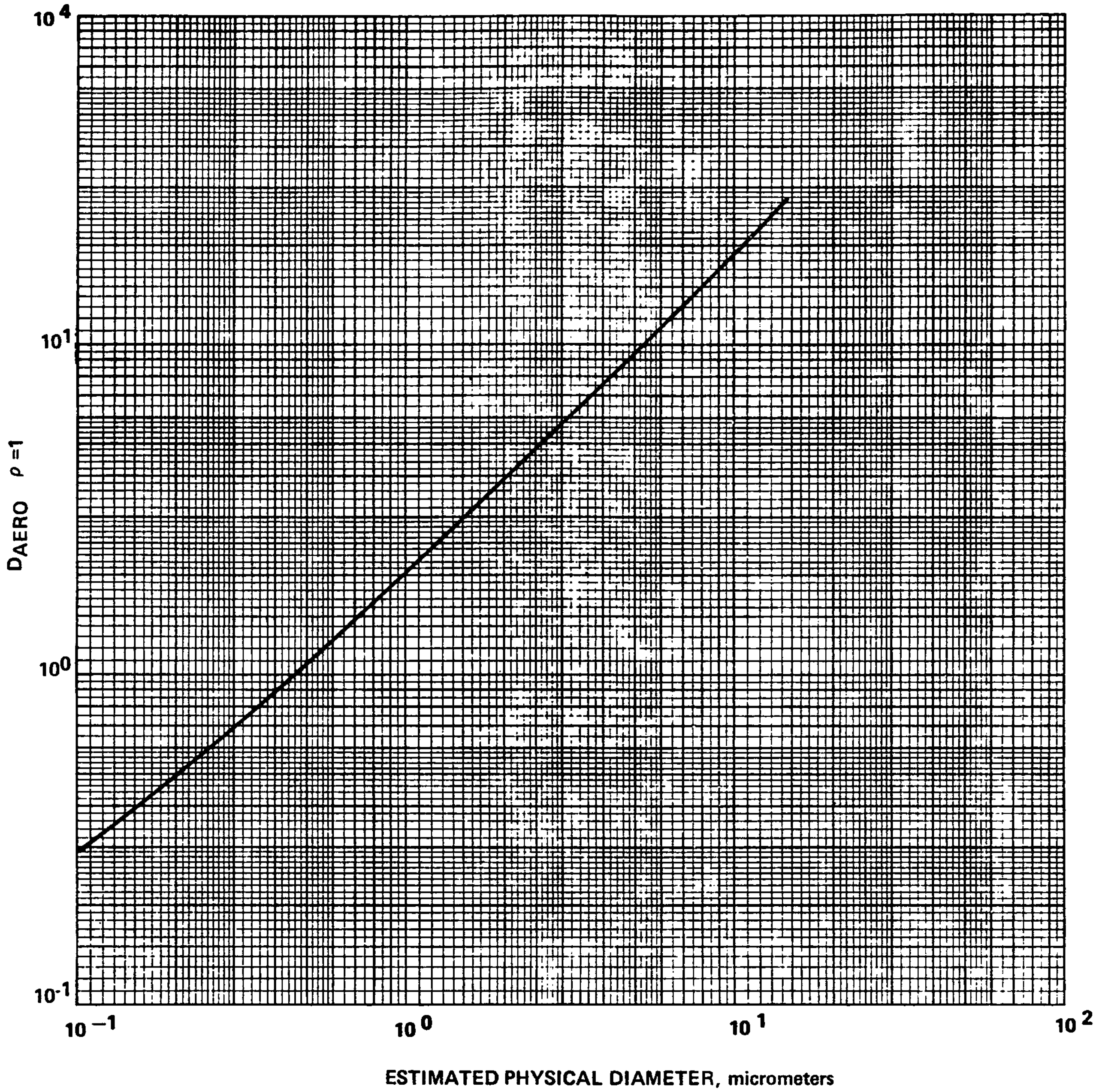


Figure 5. Plot of Aerodynamic Diameter (Density = 1.0 gm/cm^3) versus Physical or Stokes Diameter (Density = 3.58 gm/cm^3).

SECTION 4

TEST RESULTS

PARTICLE SIZE DISTRIBUTIONS

Six measurements of the particle size distribution were made at the inlet and three at the outlet during thest tests. The inlet data are shown plotted as cumulative mass loading vs. particle diameter in Figures 6 through 11 and the outlet data in Figures 12 through 14. Although the impactors have no size resolution above ten micrometers, a single point is shown at the extreme right hand side of each graph. This corresponds to the total particulate mass loading measured by that test. The data for the first outlet run, shown in Figure 12, is of questionable validity because the filter and substrates for this test were found to be wet upon dissassembling the impactor. This probably occurred as a result of condensed water within the probe accidentally running back into the impactor after it was removed from the duct.

Figure 15 shows the averaged inlet size distribution plotted as cumulative mass versus particle diameter. Figure 16 shows the averaged outlet data. Figures 17 and 18 are the averaged inlet and outlet size distributions plotted as cumulative percent of the total particulate loading versus particle diameter.

The averaged particle size distributions are all plotted with 90% confidence limits shown. The confidence limits are rather large, primarily for three reasons: 1) there were a small number of samples taken, 2) the source fluctuations introduced scatter, and 3) the collected particles clung together to form conical deposits underneath the impactor jets. These deposits quickly grew large enough to plug the jets if sampling times were too long. Thus, smaller sampling times than desirable were used and the weighing accuracy was limited.

The inlet distribution is bimodal with a fine particle mode having a mass median diameter of approximately 0.8 micrometers. Approximately 22% of the mass is contained in particles with diameters smaller than 10 micrometers. The overall mass median diameter of the inlet particle size distribution is greater than 10 micrometers.

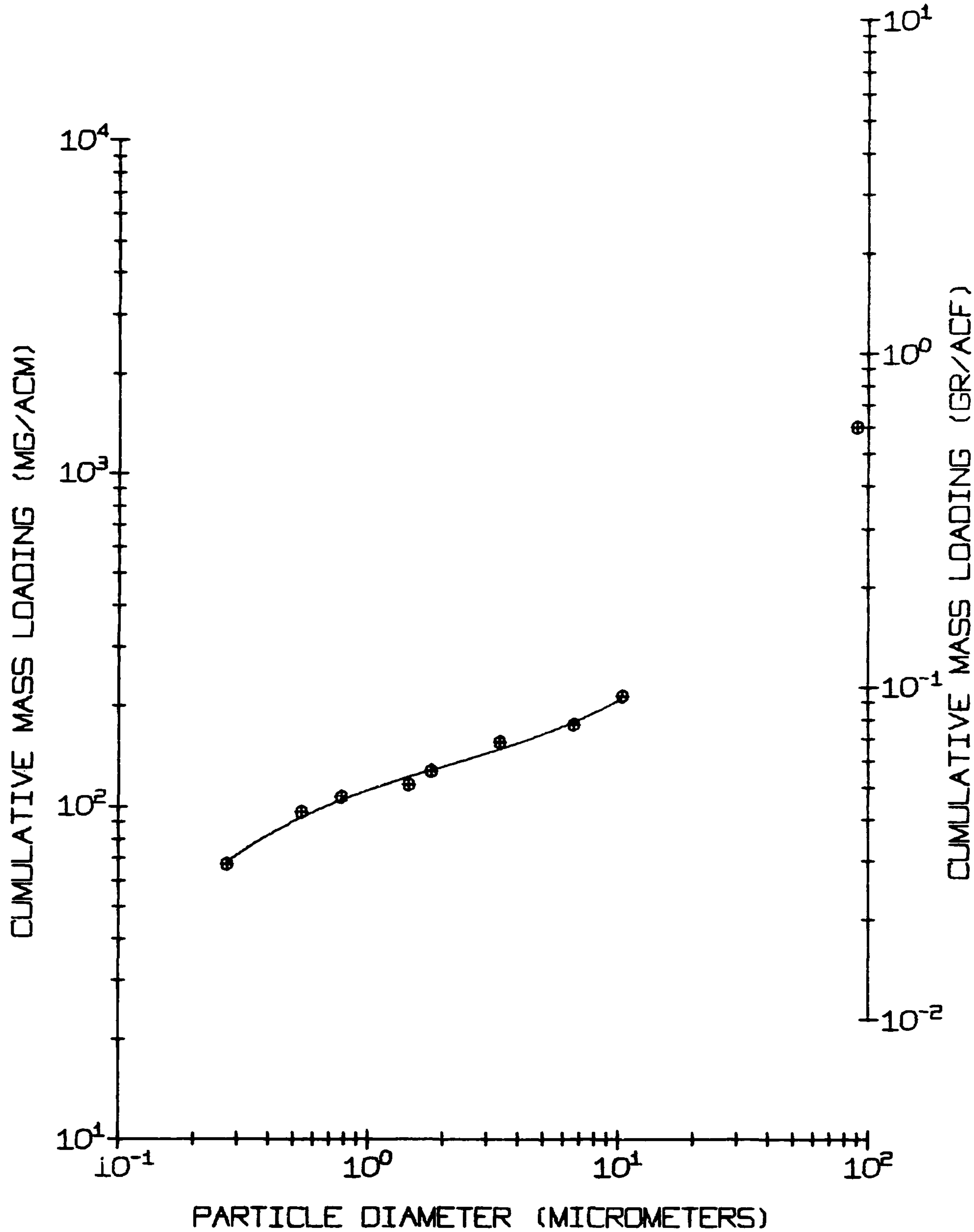


Figure 6. Inlet Particulate Loading Versus Particle Diameter Measured on July 9 at 0720 HRS in Port 4 of West Pantleg. Density = 3.58 gm/cm^3.

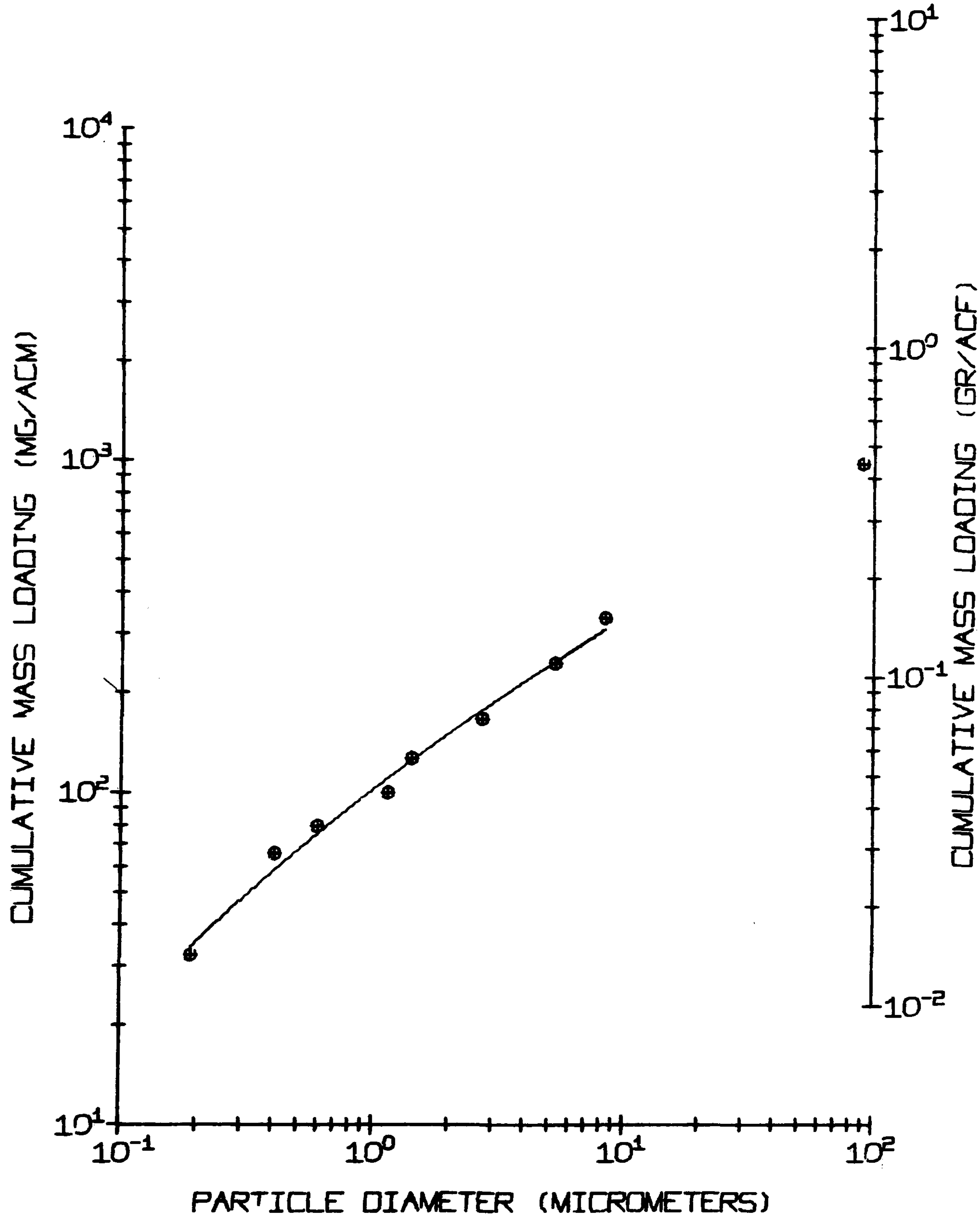


Figure 7. Inlet Particulate Loading Versus Particle Diameter Measured on July 9 at 1200 HRS in Port 4 of East Pantleg. Density = 3.58 gm/cm^3.

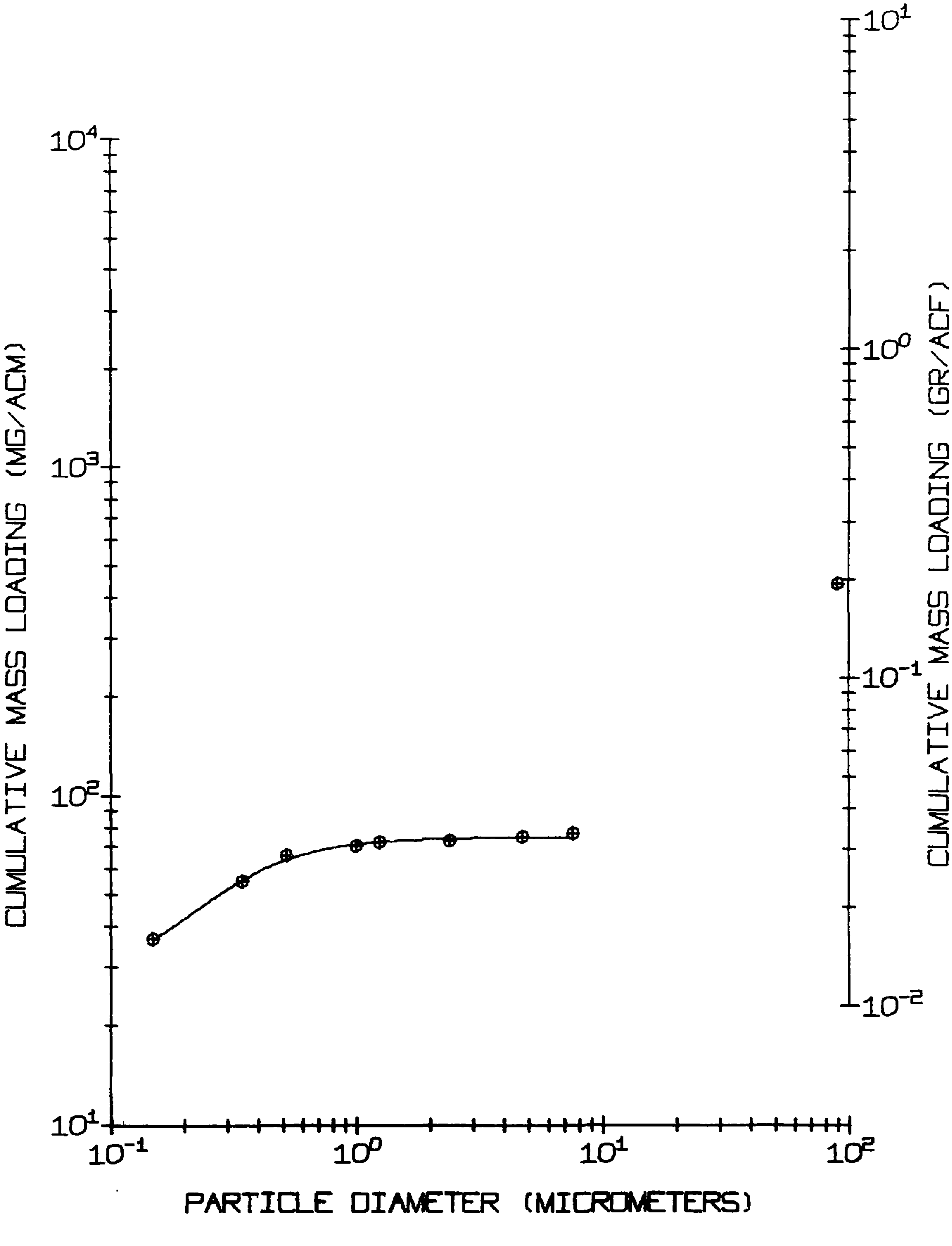


Figure 8. Inlet Particulate Loading Versus Particle Diameter Measured on July 9 at 0700 HRS in Port 3 of West Pantleg. Density = 3.58 gm/cm^3.

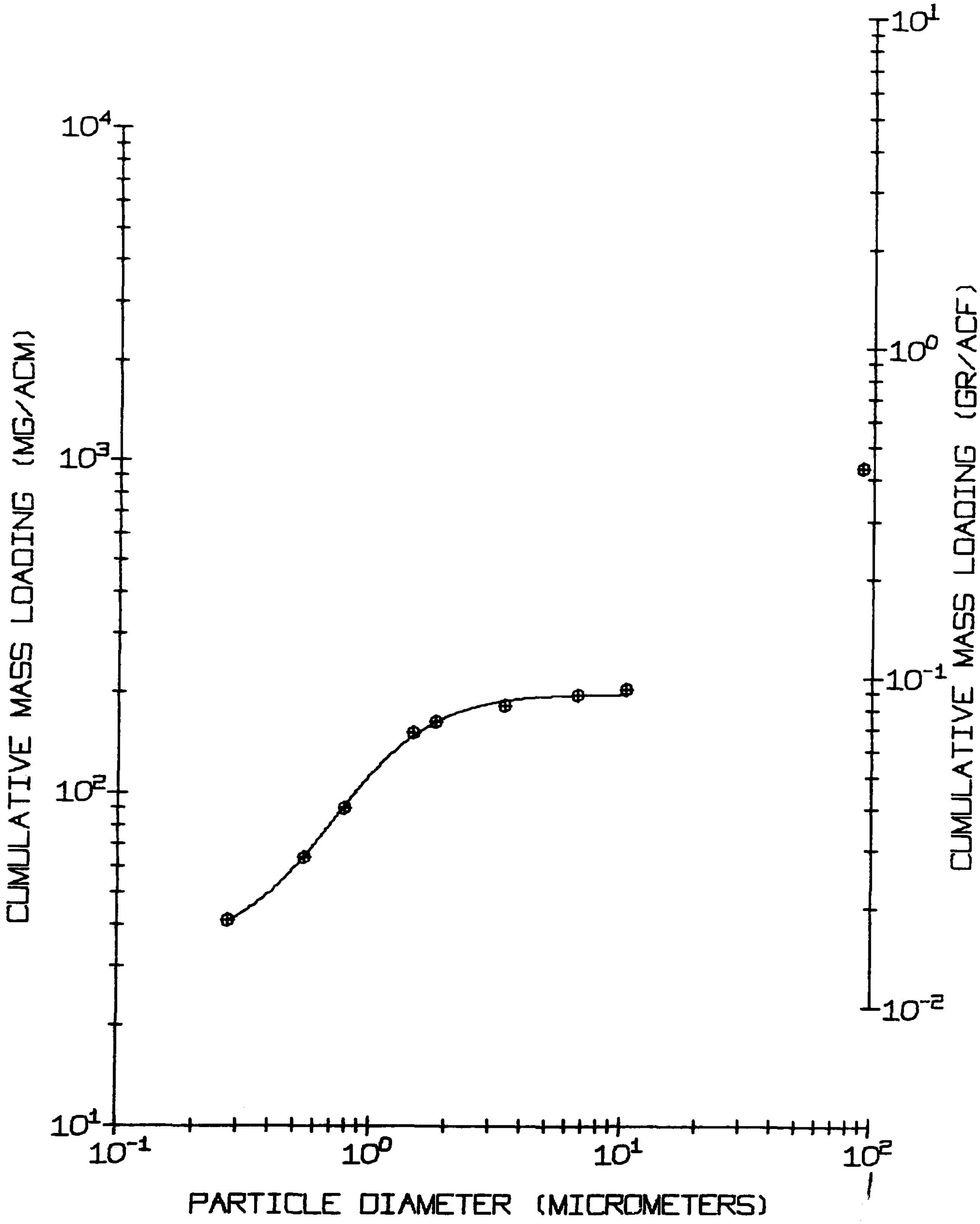


Figure 9. Inlet Particulate Loading Versus Particle Diameter Measured on July 9 at 1135 HRS in Port 3 of East Pantleg. Density = 3.58 gm/cm^3.

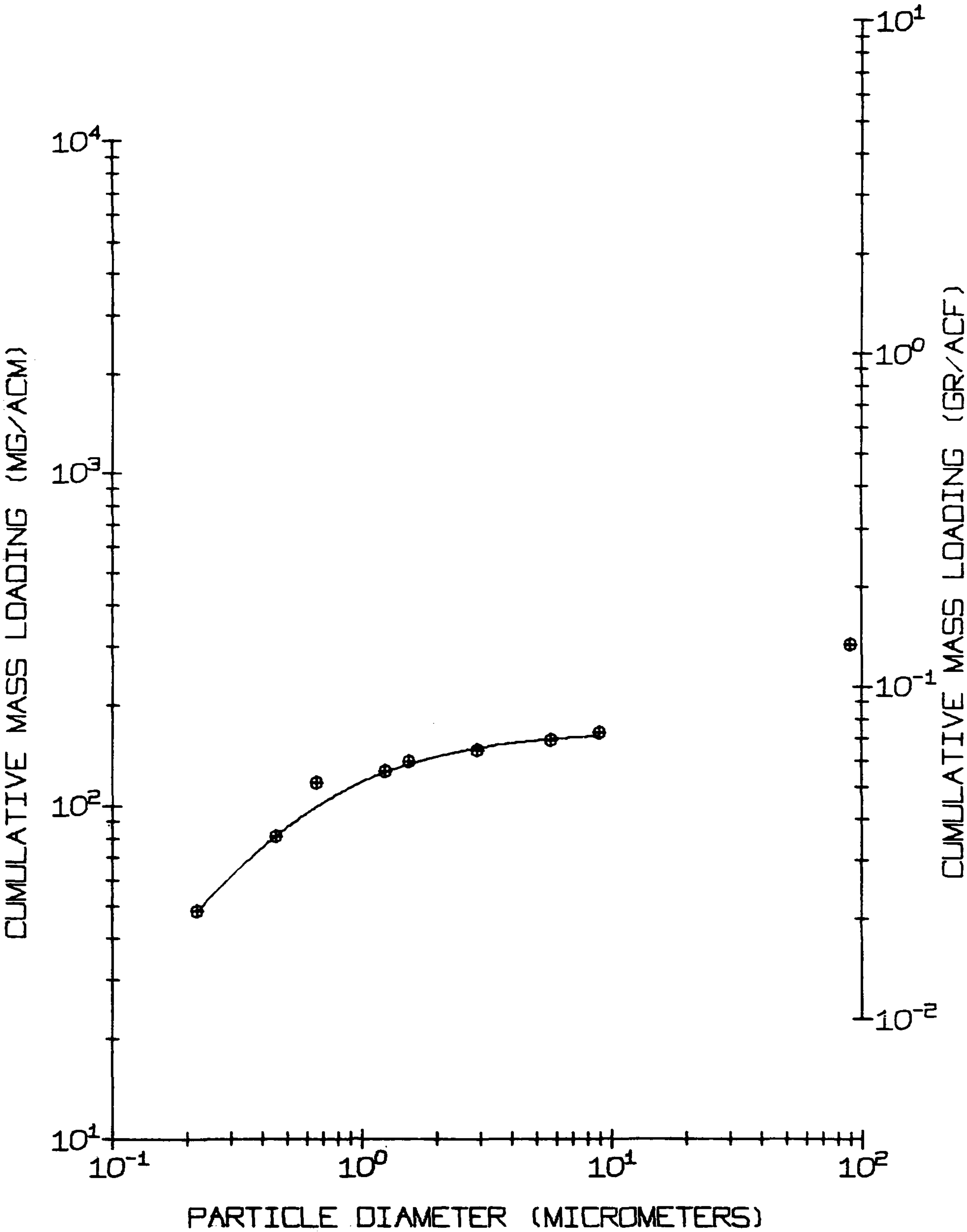


Figure 10. Inlet Particulate Loading Versus Particle Diameter Measured on July 10 at 0640 HRS in Port 3 of East Pantleg. Density = 3.58 gm/cm^3.

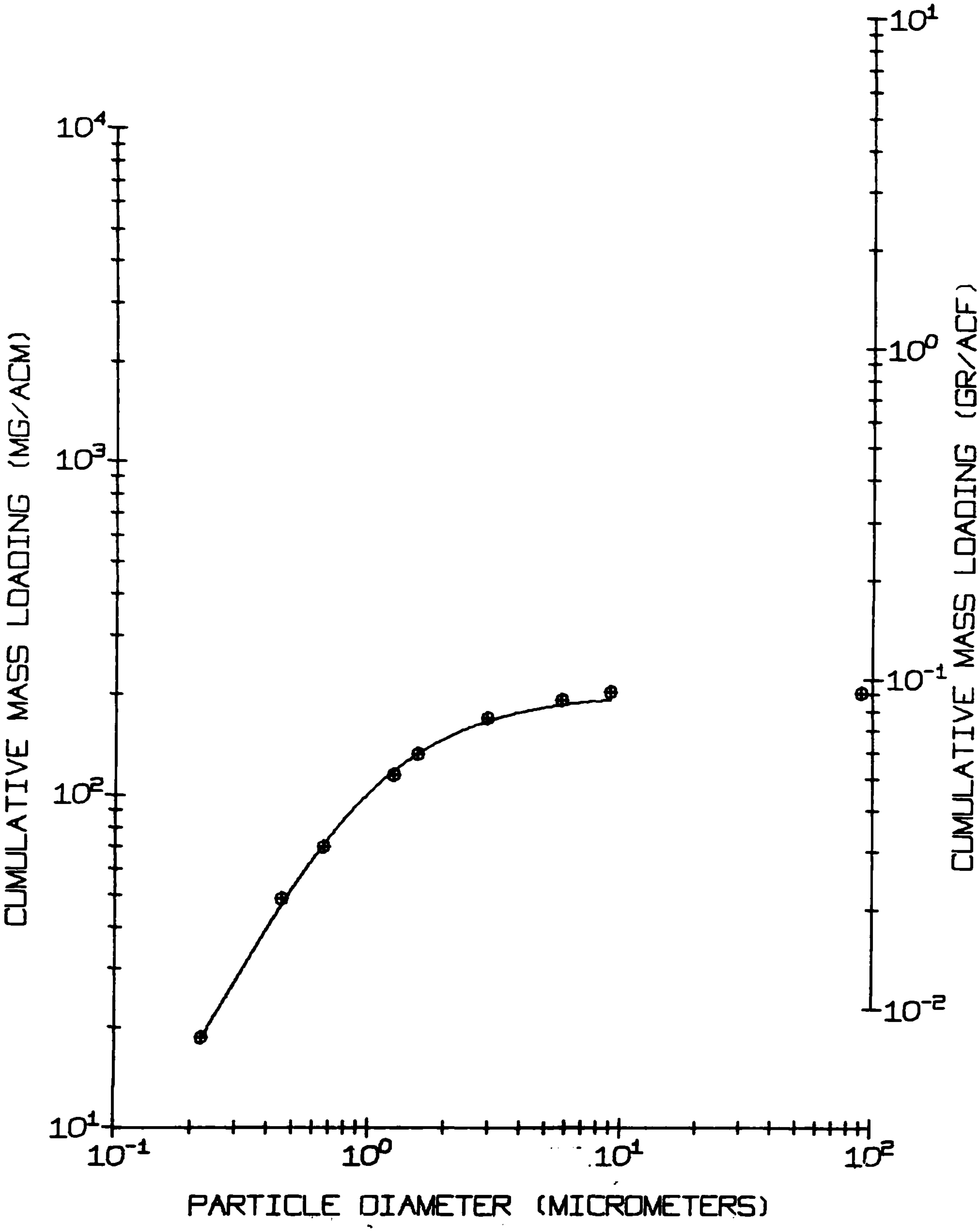


Figure 11. Inlet Particulate Loading Versus Particle Diameter Measured on July 10 at 1000 HRS in Port 3 of West Pantleg. Density = 3.58 gm/cm^3.

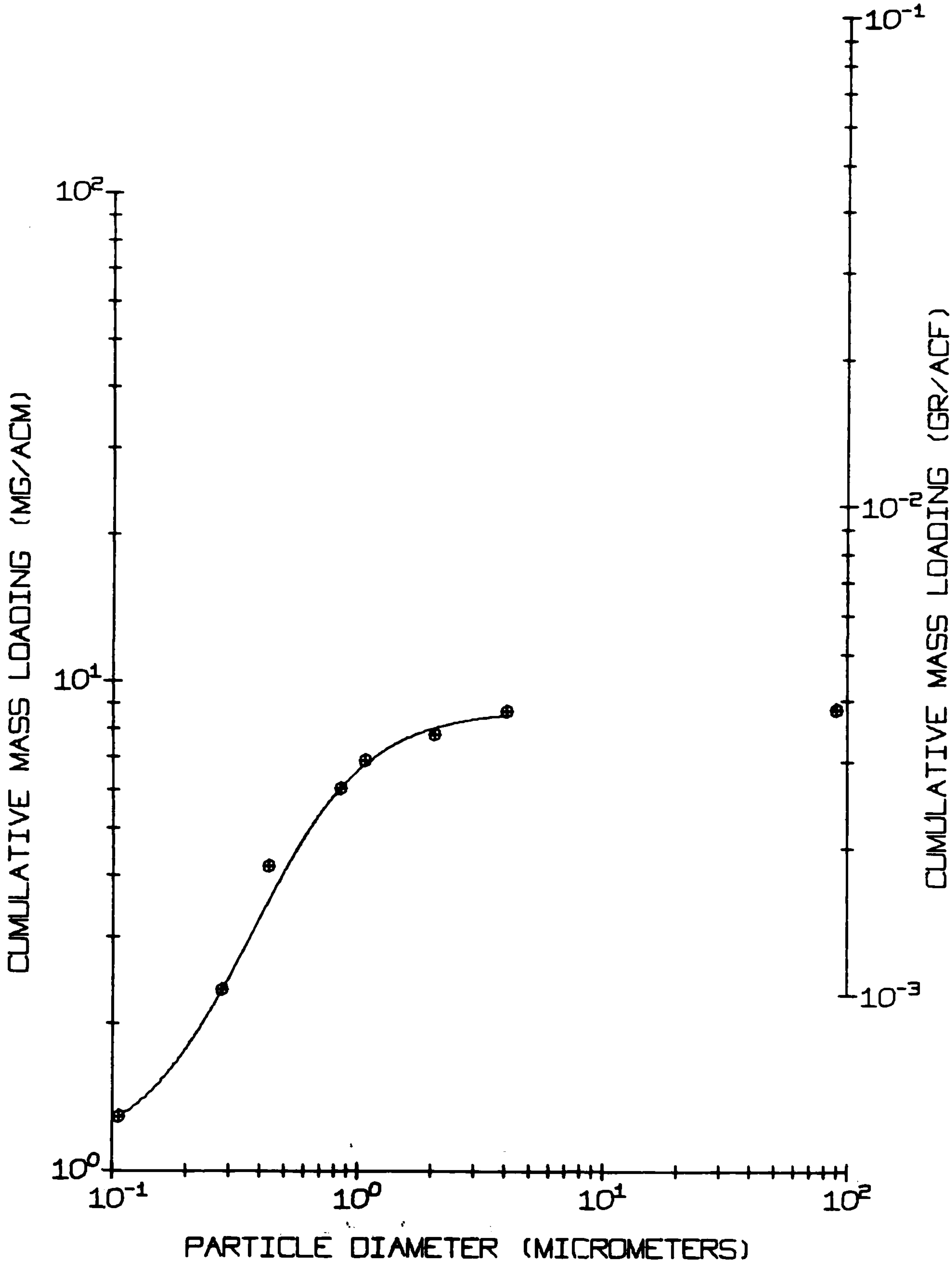


Figure 12. Outlet Particulate Loading Versus Particle Diameter Measured on July 9 at 0720 HRS in Port 1. Density = 3.58 gm/cm³.

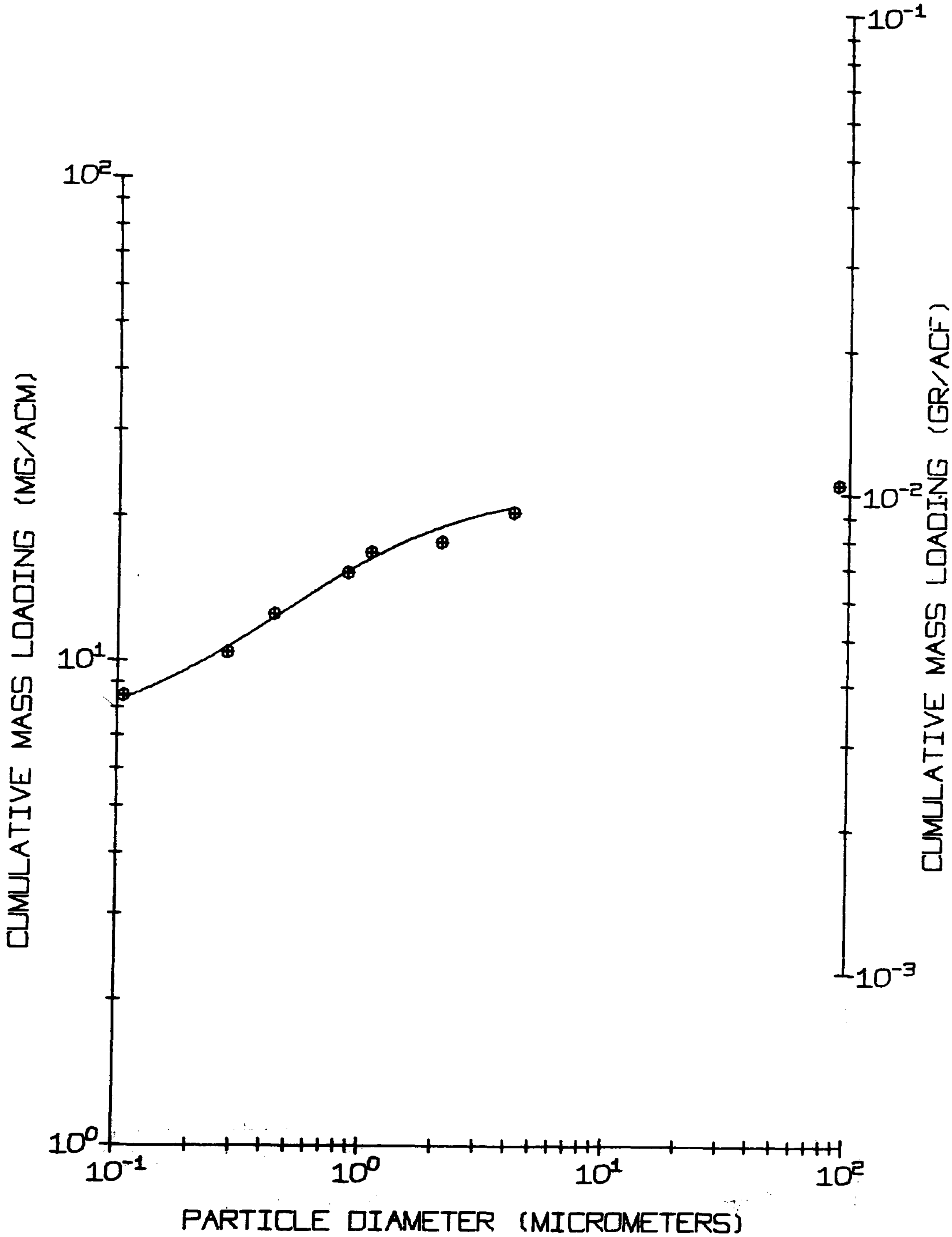


Figure 13. Outlet Particulate Loading Versus Particle Diameter Measured on July 9 at 1500 HRS in Port 3. Density of 3.58 gm/cm³.

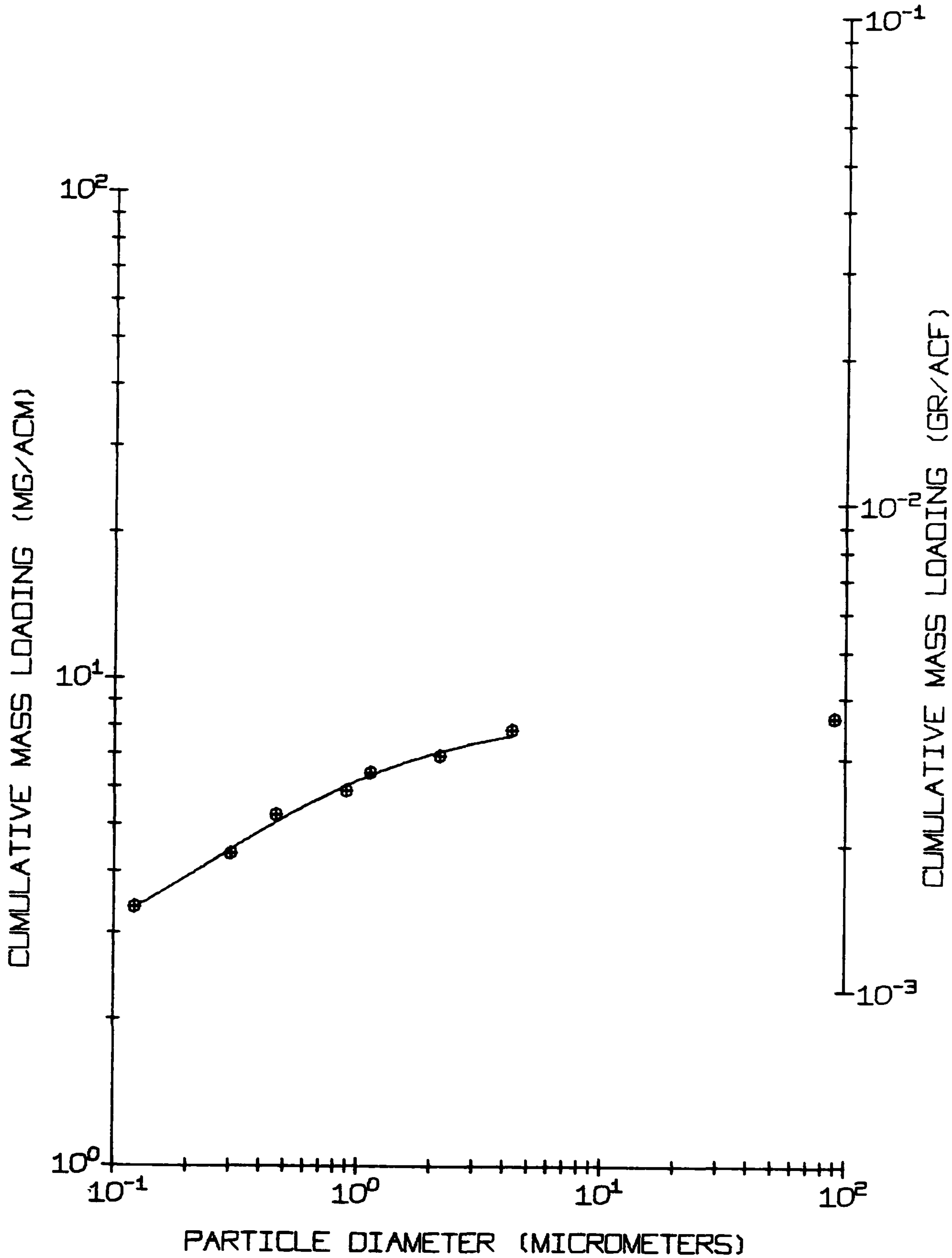


Figure 14. Outlet Particulate Loading Versus Particle Diameter Measured on July 10 at 0635 HRS in Port 3. Density = 3.58 gm/cm^3.

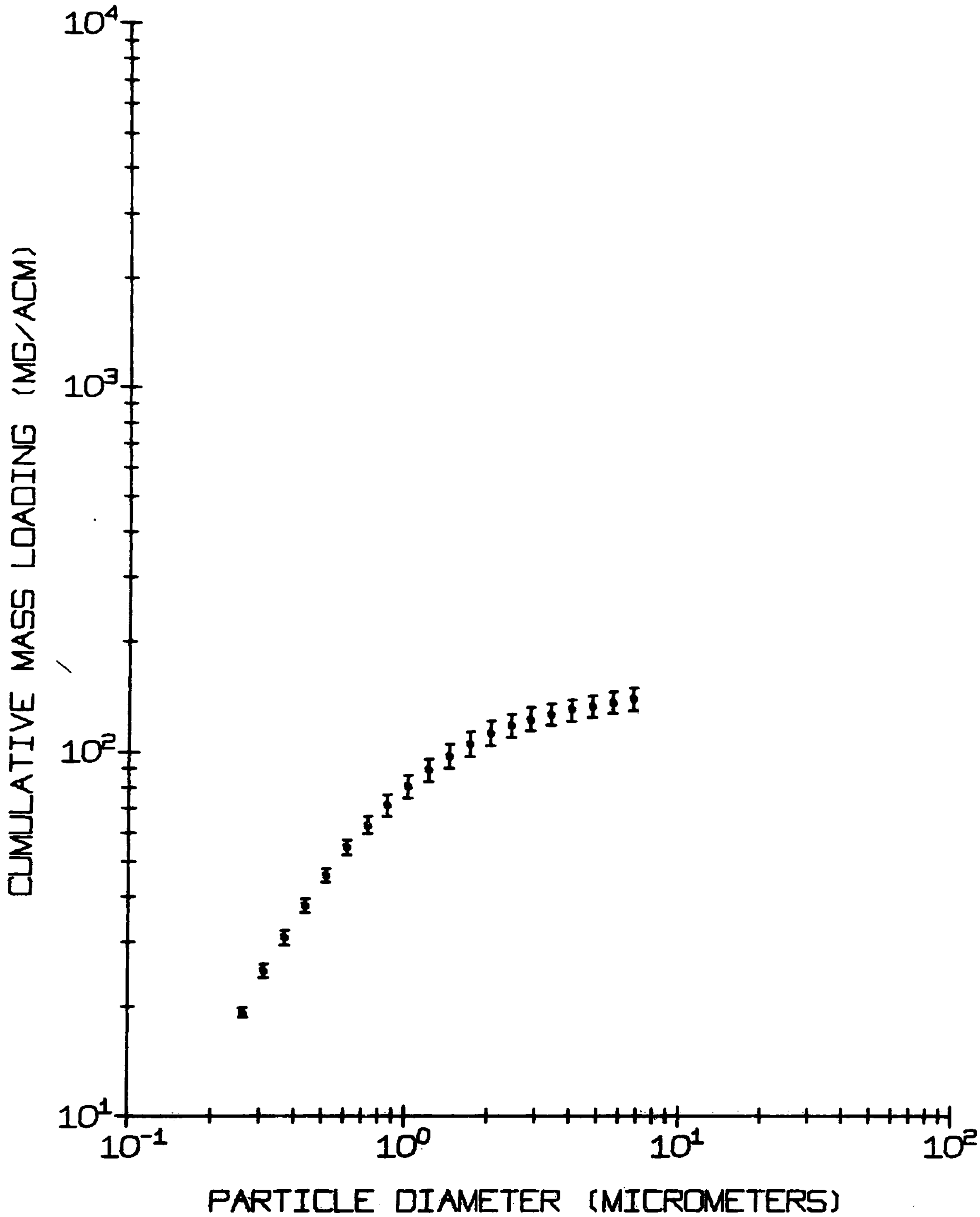


Figure 15 Average Cumulative Mass Loading Versus Particle Diameter for all Inlet Impactor Tests.

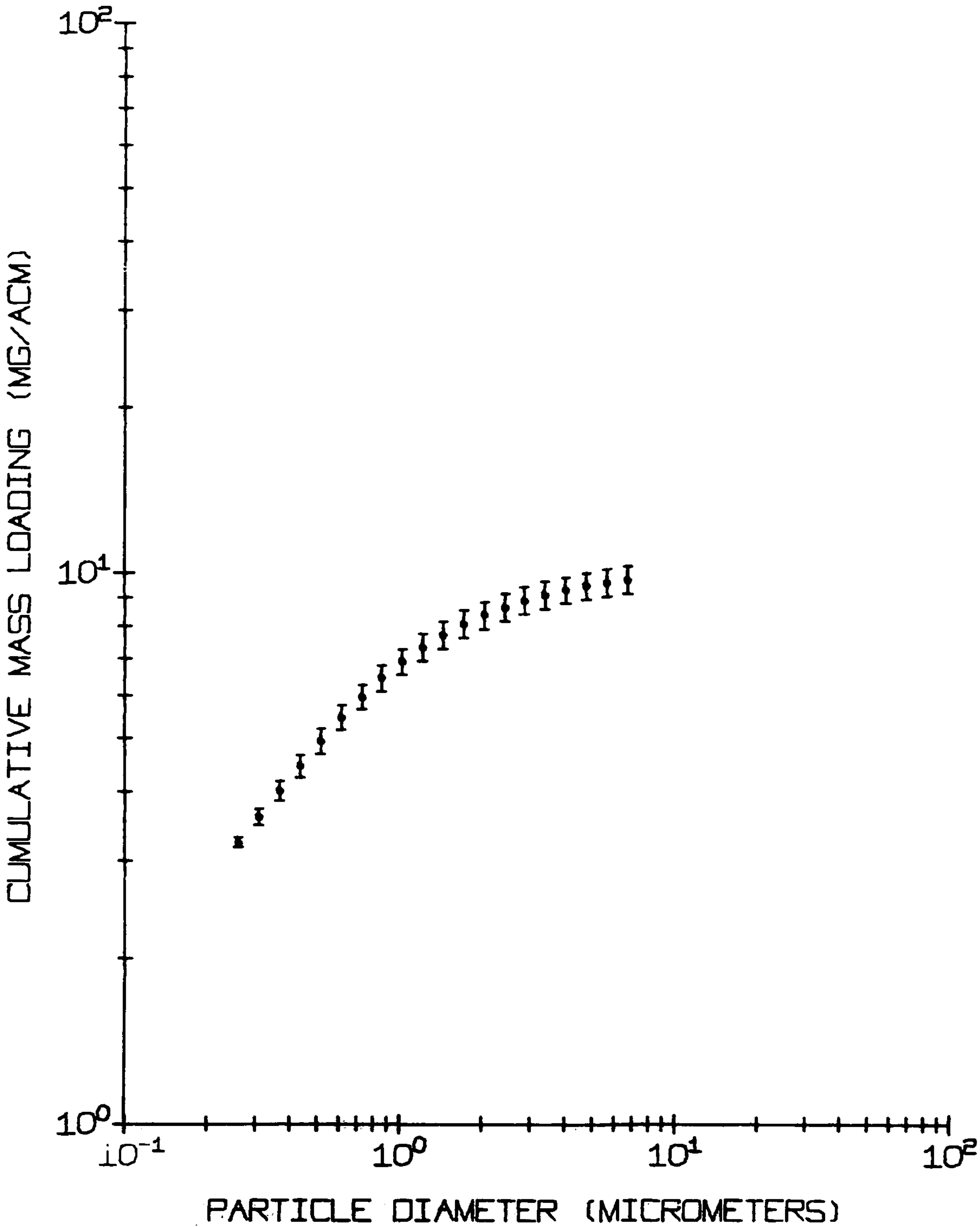


Figure 16 Average Cumulative Mass Loading Versus Particle Diameter for all Outlet Impactor Tests.

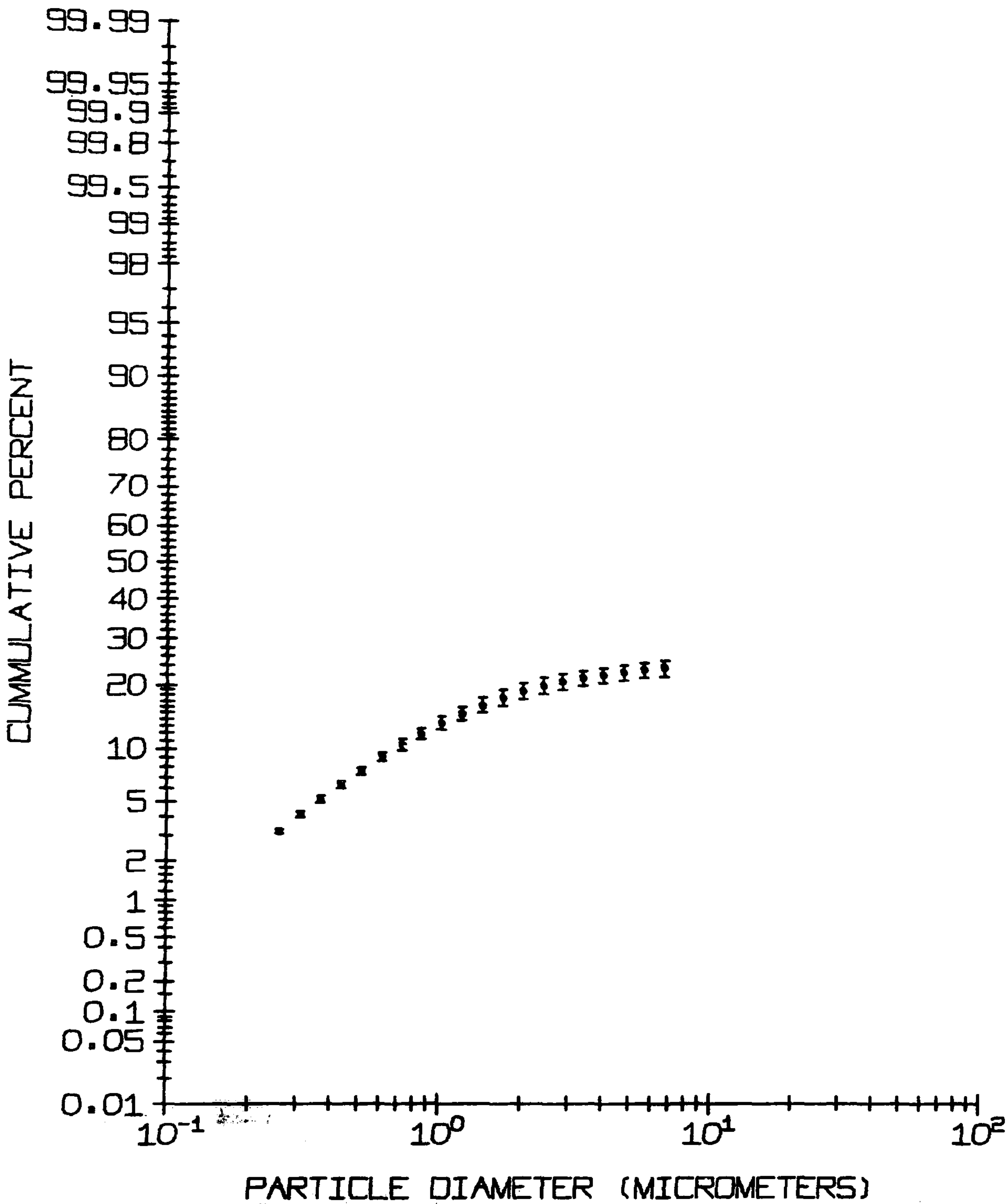


Figure 17 Inlet Size Distribution on a Cumulative Percentage versus Particle Size Basis.

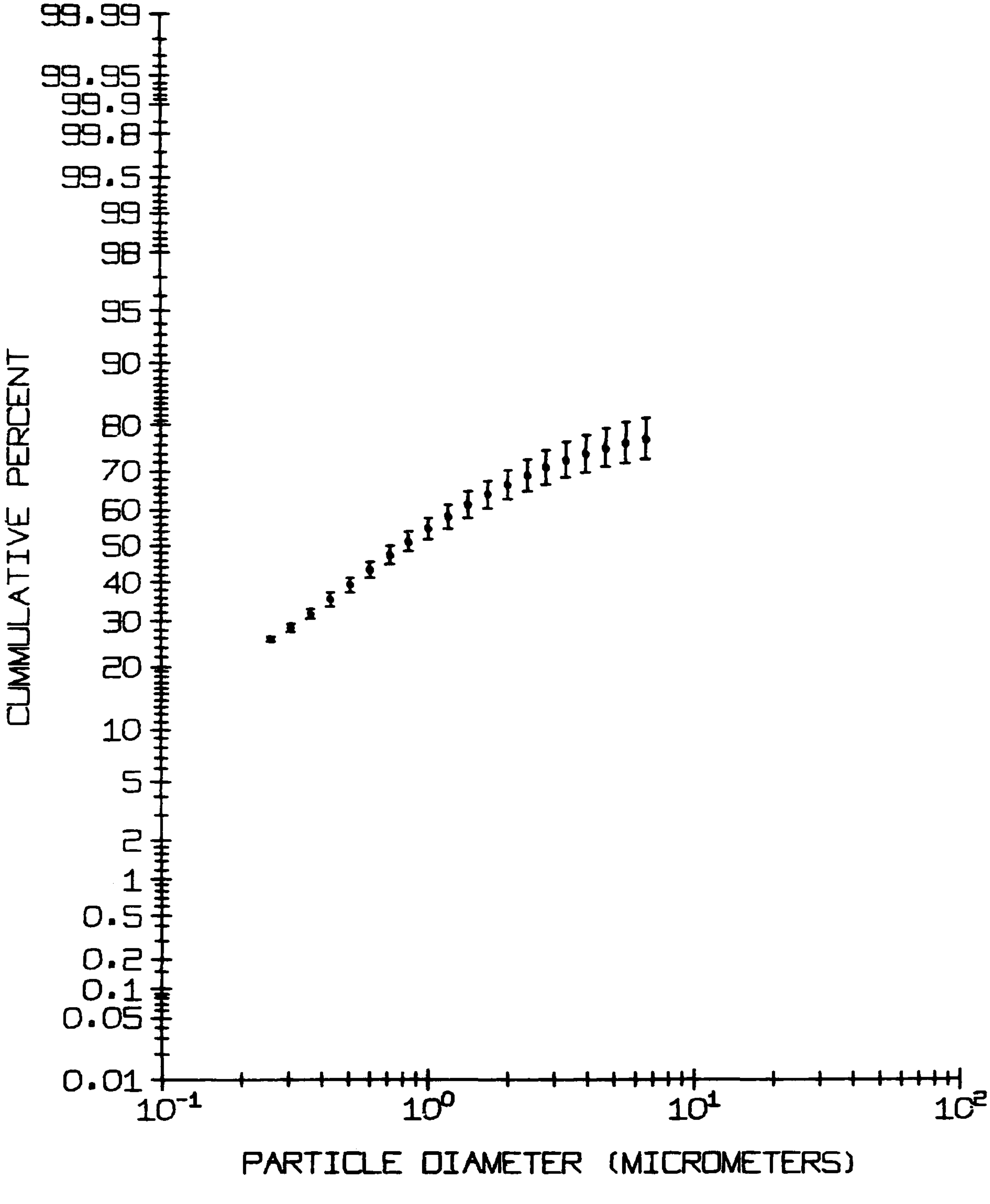


Figure 18 Outlet Size Distributions on a Cumulative Percentage versus Particle Size Basis.

— Curves are fitted through the data points as shown in Figures 6 through 14 in order to permit automatic calculation of averages and the fractional efficiency. The computer data analysis also yields tabular data and this is contained in Section 5.

During the tests it was observed that some of the impactor catches appeared to be hygroscopic. This was indicated by rapid weight increases of the various impactor stage catches when the samples were removed from desiccators. Also, the color of the particles was different from stage to stage within the impactor, indicating that the chemical composition of the particles was inhomogenuous with respect to size. If this is true, the value of 3.58 gm/cm^3 which was used to calculate the particle sizes may not really be appropriate for the entire range of sizes. Recent research conducted by the Kennecott Copper Corporation suggests that the particles contained in the aerosol effluent from copper smelters consists of at least two fractions, a one-to-ten micrometer size refractory dust and a less-than-one micrometer component of "sticky" condensation fume.[1] Thus, it is probable that the composition, size and concentration of the aerosol all change with time. Under such conditions, long term sampling or suitable averaging of the data is necessary to obtain data which accurately represent the emissions.

PARTIUCLATE MASS CONCENTRATION

In addition to the particulate mass concentration measurements made with cascade impactors by SRI personnel, the Radian Corporation test personnel made measurements concurrently using instack filters. A summary of these data are included in Table 6. In general, impactor data are less reliable than mass trains for obtaining mass concentration data because of the inability to do isokinetic traverses. The degree of agreement between the averaged impactor data and the mass trains which is shown in Table 6 is normal for sources where the emissions and gas velocity are not stable.

The mass emission data were provided by the Radian Corporation from tests conducted simultaneously with those by S.R.I. Our analyses were based on inlet and outlet loadings with terms of mass per unit volume. The total emission in pounds per hour determined from the Radian test is 12 pounds per hour. These data are found in EPA Report 600/2-78-065a & b, "Trace Element Study at a Primary Smelter".

SULFUR OXIDE CONCENTRATION

Sulfur oxide samples were collected at the outlet of the electrostatic precipitator on August 9 and 10, 1976. The sampling system consisted of a heated, glass-lined sampling probe with a quartz wool filter, a condenser, and a fritted bubbler

TABLE 6. MASS CONCENTRATION AND EFFICIENCY

DATE	MASS CONCENTRATION				EFFICIENCY	
	Inlet mg/DSCM		Outlet mg/DSCM		%	
	Impactor	Mass Train	Impactor	Mass Train	Impactor	Mass Train
7/9/76	1146	1407	41	48	96.4	96.6
7/10/76	641	1304	21	41	96.7	96.8

containing a 3% hydrogen peroxide solution. A dry test meter preceded by a Drierite tower was used to measure the volume of stack gas sampled.

The water-jacketed condenser was maintained at a temperature of 60 to 90°C to remove the sulfuric acid from the gas stream while passing the sulfur dioxide and water vapor. The sulfur dioxide was absorbed and converted to sulfuric acid in the peroxide bubbler. An acid-base titration with 0.1N NaOH and brom-phenol blue indicator was used to determine the sulfuric acid content of each sample.

Since the sulfur oxide content of the stack gas might be expected to vary during a charging cycle, an attempt was made to collect samples immediately before and after the furnace was charged. The results are shown in Table 7.

TABLE 7. SULFUR OXIDE CONCENTRATION

Date	Sampling Rate l/min	Furnace Charge Cycle	% By Volume SO_2	% By Volume SO_3
7/9	3.2	after	1.0	0.024
	2.9	before	0.42	0.019
7/10	2.4	after	0.73	0.018
	1.9	before	0.63	0.025
	1.0	after	1.7	0.067

Based on very limited data, it appeared that sulfur oxide concentrations in the stack gas were highly variable. Since the efficiency of the condenser had not been previously evaluated in this type of environment, the reliability of the SO_3 data cannot be verified. There was no reason to suspect the accuracy of the SO_2 measurements, however.

There is some question as to the applicability of this method to the nonferrous metal industry, as it is currently used. The indicated SO_3 concentration appears to be somewhat dependent upon the sampling rate, suggesting that perhaps insufficient retention time is allowed in the condenser for the significantly higher SO_3 concentration than encountered in power station effluent gas streams.

ESP COLLECTION EFFICIENCY

ESP collection efficiency is normally reported two ways. The overall mass efficiency, irrespective of particle size, is frequently used for purposes of design and guarantees.

Fractional efficiency, or efficiency versus particle size, is more meaningful for research and development purposes because both theories and experiments indicate a strong dependence of efficiency upon the particle size distribution. In general, one expects a "U shaped" fractional efficiency curve with a minimum near 0.2 or 0.3 μm diameter.

Figure 19 shows measured and calculated fractional efficiency curves for the Joy-Western ESP. The theoretical curve was generated by the SRI-EPA computer model, which was developed under Contract No. 68-07-0265. Averaged "normal" operating conditions of the ESP for this specific installation were used as input data. The theoretical curve shown in Figure 19 was predicted for ideal conditions; i.e., no corrections were made for rapping losses, poor velocity distribution, or gas bypassing the active areas.

Rapping reentrainment losses are an important nonideal feature of full scale ESP behavior and normally constitute a substantial percentage of the penetration. As previously mentioned, however, the particles caught on the impactor stages tended to adhere to one another, forming large agglomerates. Agglomeration on the ESP plates would minimize rapping losses and justifies our approximation of neglecting such losses in the computer simulation.

The experimental points in Figure 19 were taken from the averaged inlet and outlet particle size distributions. The confidence limits were calculated in such a way as to represent outer bounds.

The fractional efficiencies indicated in Figure 19 compares the measured with that computed from the ESP model. The ESP model did not include any estimate for rapping entrainment. Therefore, the material reentrained during rapping is expected to consist of agglomerates of previously collected material. There is a discrepancy between the measured and predicted values for particles larger than about 3-5 microns. This is indicated by the hyphen predicted efficiency for particles larger than about 5 microns.

The measured and calculated overall mass collection efficiencies are shown in Table 8. The agreement along the measured, calculated, and design efficiencies indicated that the ESP was performing well.

One can also deduce that the particulate emissions from this copper smelter present no resistivity problems. Rapping losses are not yet defined. It was not possible to assess the potential impact of space charge suppression of the corona by fine particles because the emissions were, on the average, rather low in particulate concentration.

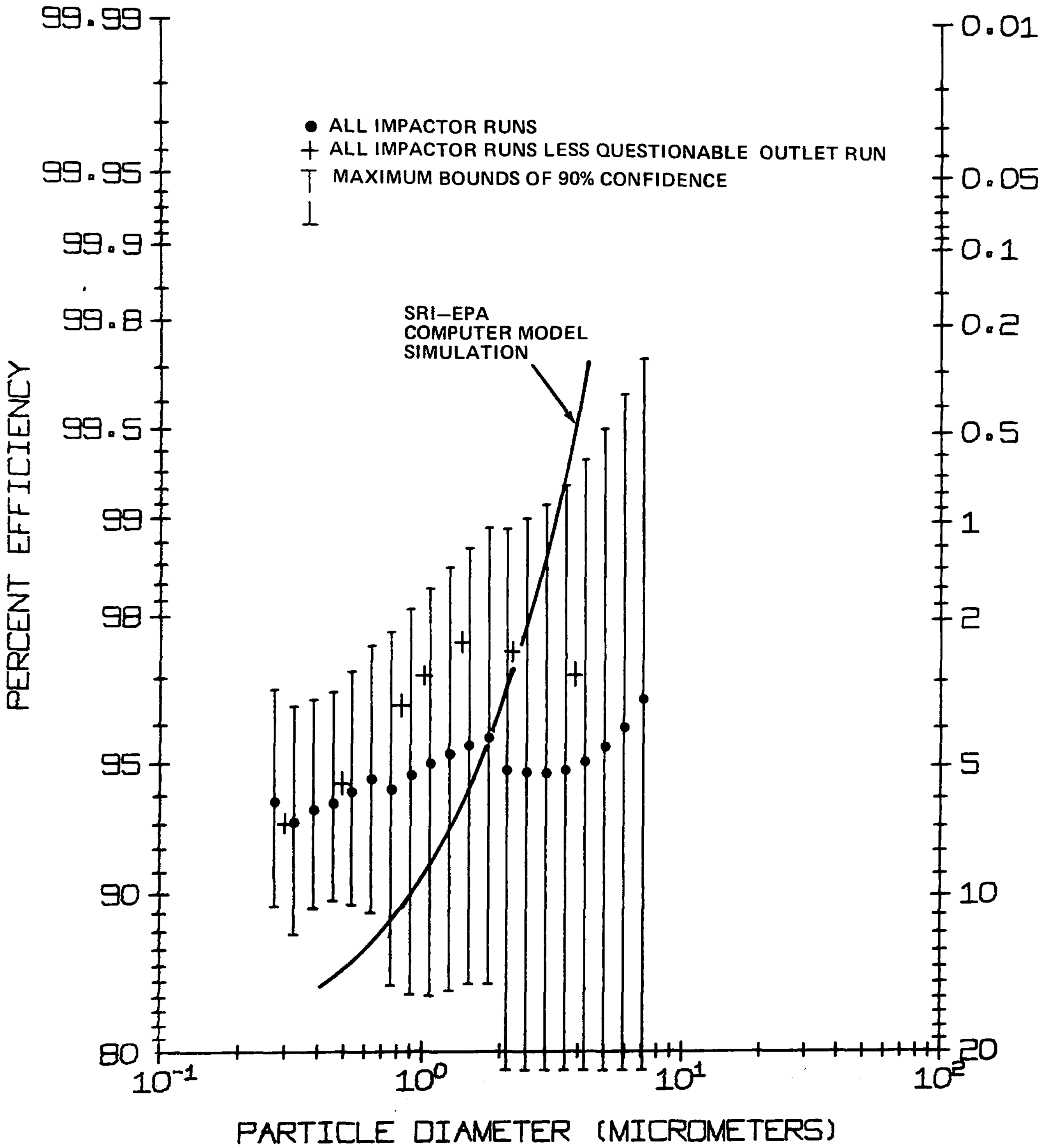


Figure 19 Measured and Theoretical Fractional Efficiency Curves for the Electrostatic Precipitator.

TABLE 8. OVERALL MASS COLLECTION EFFICIENCY

Mass Trains (Radian Corp.)	Impactors	Computer Simulation	Design
96.7%	96.6%	96.8%	96.8%

The total emissions from a reverberatory furnace consist of particulate and gaseous emissions. The electrostatic precipitator is only useful for collecting particulate matter with a significant collection efficiency. Therefore, only that material that exists as a particulate is expected to be collected by the device. Any material that exists in the gas phase at the operating temperature of the electrostatic precipitator will pass through the unit with essentially no removal.

Therefore, the collection efficiency measured for a given installation will depend upon the type of measurement system utilized. If the purpose for the study is to determine the operating characteristic of a control device, the measurement should be made with instrumentation operating at the gas conditions. This assures that the mass loading and particle size distribution data represent the conditions that exist in the control device. This measurement, however, provides no information about condensables or what might be particulate at other conditions of temperature and pressure.

The analysis presented in this report is based on the in-stack measurement conditions since the purpose for the test was to evaluate the control device. The total emissions, determined by the Radian Corporation, are included in a report "Trace Element Study at a Primary Copper Smelter, Vol. I and II" (EPA-600/2-70-065a and -065b, March 1978).

APPENDIX

PROCEDURES AND DATA FOR IMPACTOR TESTS

BRINK IMPACTOR OPERATING PROCEDURES

Pretest

Before every test of an unfamiliar source, it is SRI's practice to perform preliminary testing. Surveys of the site are made in order to determine the accessibility and suitability of sampling ports, platforms, and electrical power. Provisions are made for any special adapters or sampling procedures. Approximate mass loadings are determined, and potential substrate reactions with the flue gas are checked. Such interfering reactions can cause weight changes in the substrates and backup filters and thus confuse the results from particulate catches.

During the pretest period, both blank and particulate impactor tests were made. For blank runs the impactors are prepared as in an actual run except that a Gelman 47mm filter holder with glass fiber filter is attached to the impactor inlet. The impactor is then inserted into the sampling port and operated as if a normal particle size distribution measurement were being made. After the run the impactor is disassembled, the substrates are removed, examined, desiccated for 24 hours, and weighed. The observed weight gains from these tests and blank tests made during the main test period are used as quality control monitors for the particulate sampling runs.

Sampling Procedures--

Modified Brink cascade impactors were used at the ESP inlet and outlet. The Brink impactor was selected because its low flow rate allows relatively long sampling times, long enough in this instance to sample throughout at least one furnace cycle. Our procedures are specific for this test and could be slightly different for other sources.

The impactors were purchased from Monsanto Envirochem as five stage units. We have designed and added a precollector cyclone and two additional stages. Also, we always operate the impactors at a flowrate which is much lower than the manufacturer's design flowrate. No cyclones were used at the ESP outlet because of the relatively low concentration of large particles.

Impactor flowrates cannot be modulated during a test to maintain isokinesticity, thus traverses were approximated by taking discrete samples at several points in the ducts. The nozzle diameters were selected so that the sampling velocity was equal to the average flue gas velocity at the particular sampling point. Redundant orifice meters were used to set and monitor the sample flowrate, as shown in Figure 4.

Normally, the length of the sampling time is dictated by the mass loading and particle size distribution. Tests subsequent to the first have sampling times adjusted such that no single stage, excluding a cyclone if one is used, contains more than 10 mg. of mass. For these tests, however, the sampling times were cut short by particle buildup which plugged the impactor jets, and undesirably small samples were obtained.

Due to the necessity for high weighing accuracy and the restriction of low tare capacity for the precision electronic microbalance, greased foil or glass fiber collection substrates are used with almost all impactors. Greases have been found to be unstable at temperatures higher than 400°F, thus glass fiber substrates were used for this test.

Backup filters are used to collect the fine particles which pass the last impactor stage. One-inch diameter circular discs are placed under the last spring in the outlet stage of the impactor. The filter is protected by a teflon washer and a second filter disc is placed behind the actual filter to act as a support.

The impactors were carefully loaded with the preweighed collection substrates, assembled, and tightened with pipe wrenches to make certain that the asbestos gaskets were seated. Appropriate nozzles were selected for isokinetic sampling.

The impactors were mounted on probes and placed in the duct with the nozzles pointed downstream for 45 minutes before sampling began, to allow them to heat to the gas temperature. No supplementary heating was used.

For accurate weighing of collected material, a balance with a sensitivity of at least 0.05 milligrams is required. This is especially true for the lower stages of the Brink Impactor where collection of 0.3 mg. or less is not uncommon. The balance must also be insensitive to vibration if it is to be used. This balance is highly accurate and is insensitive to vibrations. A container of Drierite (anhydrous $CaSO_4$) is placed in the weighing chamber of the balance to keep moisture uptake to a minimum during weighing operations and a 500 mc.

Polonium-210 strip is mounted in the weighing compartment for electrostatic charge neutralization.

The balance was calibrated daily with precision calibration weights furnished by Cahn. Reference and control weights were also checked periodically throughout the test series. The reference weights are standard tare weights while the controls are impaction substrates which were identical to those actually used in the impactor runs.

Data Reduction

D_{50} cut points are determined by the conditions at which an impactor was run. The determination of particle size distributions from the mass loadings begins with the calculation of D_{50}'s for each stage, using an iterative solution of the following two equations:

$$D_{50} = \left(K_s \frac{\mu D_c^3 P_s}{\rho_p Q_I P_o C} \right)^{1/2}$$

and,

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

where D_{50} = the stage cut point (μm),
μ = gas viscosity (poise),
D_c = stage jet diameter (cm),
P_s = local pressure at jet stage (atm),
ρ_p = particle density (gm/cm^3),
Q_I = impactor flow rate (cfm),
P_o = gas pressure at impactor inlet (atm),
C = Cunningham Correction Factor,
L = Gas mean free path (cm), and
K_s = Stage calibration constant, proportional to (50% efficiency Stokes No.)$^{1/2}$ for that stage. The value of K_s for each stage is determined by an empirical calibration.

The viscosity of the gas is calculated using a method presented by C. R. Wilke in a paper entitled, "A Viscosity Equation for Gas Mixtures" in the Journal of Chemical Physics, 8(4), April 1950, p. 517.

These cut points are calculated by means of a computer program. The size parameters used are approximate (Stokes') diameter, based on estimated true particle densities, or aerodynamic diameters, based on the behavior of unit density spheres. Aerodynamic diameter is the diameter of a unit denisty sphere with the same settling velocity as the particle in question. The aerodynamic diameter is calculated by giving ρ_p the value of 1.0 gm/cm^3 in the D_{50} formula.

The data are presented on a cumulative basis by summing the mass on all the collection stages and backup filter, and plotting the fraction of the mass below a given size versus size. This is frequently done on special log-probability paper. This paper is especially convenient for log normal distributions, but semi-log paper may be preferable for interpretation, especially if the distribution is not log normal. In general, cumulative distributions are more difficult to interpret than differential plots. The abscissa is the logarithm of the particle diameter, and the ordinate is the percentage smaller than this size. The value of the ordinate at a given $(D_{50})_n$ is

$$\text{Percent less than stated size} = \frac{\sum_{t=o}^{n} dM_t}{\sum_{t=o}^{N} dM_t} \times 100\%$$

where t = o corresponds to the filter, and
t = N corresponds to the coarsest jet or cyclone.

In addition, the data are presented as differential particle size distributions. For this purpose it is assumed that all of the mass caught upon an impaction stage consists of material having aerodynamic diameters equal to, or greater than the D_{50} for that stage, and less than the D_{50} for the next higher stage. For the first stage (or cyclone), it is assumed that all the material caught has aerodynamic diameters greater than, or equal to the D_{50} for that stage (or cyclone), but less than or equal to the size of the largest particle present. The latter size is determined by microscopic examination of the material caught on the stage.

Because the intervals between the stage D_{50}'s are usually logarithmically related, and to minimize scaling problems, the differential partice size distributions are plotted on log-log or semi-log paper with

$$\frac{dM}{d\ (\log D)}$$

as the ordinate and D_{geo} as the abscissa. (D_{geo} is the geometric mean of D_1 and D_2.) The mass on stage "n" is designated by dM_n. The d (log D) associated with dM_n is log $D_{50})n+1$-log $(D_{50})n$. The total mass having diameters between $(D_{50})n$ is equal to the area under the curve

$$\text{Mass} = \sum_{t=m}^{n} \frac{dM_t}{\log (D_{50})_{t+1} - \log (D_{50})_t} \cdot \left[\log (D_{50})_{t+1} - \log (D_{50})_t\right]$$

or

$$\text{Mass} = \int_{D_m}^{D_n} \frac{dM}{d(\log D)} \cdot d(\log D)$$

for a continuum.

The procedure outlined above describes the construction of a histogram. A smooth curve is drawn through the points, yielding an approximation to the real particle size distribution. Such a curve is needed to calculate fractional efficiencies of control devices if the D_{50}'s differ between inlet and outlet measurements. The accuracy of the approximation is limited by the number of points, and by the basic inaccuracy of neglecting the non-ideal behavior of the impactors, especially the non-ideal overlapping efficiencies for adjacent stages.

Dividing dM/dlogD of an outlet run at a particle size by the dM/dlogD from its comparable inlet run at the same size gives the fractional penetration through the control device of that size particle. The fractional penetration subtracted from unity is the fractional efficiency of the control device.

DATA

Table 9 shows the weight changes measured for the blank Brink impactor runs. The glass fiber substrate material used was Reeve Angel 934AH. Our experience with this material has shown that weight changes due to flue gas gas phase reactions are usually small, especially when "preconditioned" by exposure to flue gas prior to an actual run. Another pre-conditioning

TABLE 9. BRINK IMPACTOR BLANK RUNS*

SUBSTRATE WEIGHT CHANGE FOR EXPOSURE TO FLUE GAS

Run Number	7	5	8	6	13	16	4	
Substrate Set	A1	A2	A3	A4	A5	A6	J11	
Type of Conditioning	H_2SO_4 wash	H_2SO_4 wash	None	None	In-situ	In-situ	In situ	
Run Time	15 min	15 min	30 min	15 min	15 min	15 min	60 min	
Run Date	6/30	6/29	6/30	6/29	6/30	7/1	7/10	
SO	-0.07 mg change	+0.01 mg change	+0.04 mg change	+0.07 mg change	-0.01 mg change	-0.03 mg change	+0.06 mg change	
S1	-0.09	+0.02	+0.05	+0.10	+0.00	-0.02	-0.07	
S2	-0.05	+0.08	+0.04	+0.07	-0.01	-0.03	-0.02	
S3	+0.01	+0.11	+0.03	+0.06	+0.01	-0.02	-0.05	
S4	-0.09	+0.01	+0.02	+0.06	-0.01	-0.04	-0.01	
S5	-0.19	+0.04	+0.01	+0.03	+0.00	-0.02	-0.03	
S6	+0.02	+0.01	Lost	+0.03	-0.03	-0.05	-0.03	
SF	-0.06	-0.06	Lost	+0.15	-0.11	-0.23	-0.17	
SF'	-0.27	-0.09	Lost	+0.17	-0.08	-0.11	-0.06	
SO - S6	$\bar{x}$=-0.01	σ=0.08	$\bar{x}$=0.05	σ=0.02	$\bar{x}$=-0.02	σ=0.02	$\bar{x}$=-0.02	σ=0.04
SF - SF'	$\bar{x}$=-0.12	σ=0.10	$\bar{x}$=0.16	σ=0.01	$\bar{x}$=-0.13	σ=0.07	$\bar{x}$=-0.12	σ=0.08
SO - SF'	$\bar{x}$=-0.04	σ=0.09	$\bar{x}$=0.06	σ=0.05	$\bar{x}$=-0.04	σ=0.06	$\bar{x}$=-0.04	σ=0.06

*Reeve Angel 934AH substrate material.

agent which could offer promise is sulfuric acid, since flue gas induced weight gains are found to be sulfate compounds.[2] Substrate sets A1 and A2 were washed in sulfuric acid followed by a thorough rinse. The weight changes recorded in Table 9 are listed stage by stage, from "stage zero", to SF', which is backup filter number two. Averages, and standard deviations about those averages, are given for stages zero through backup filter two. Impactor substrates for stages zero through six typically weigh 14 milligrams apiece and backup filters normally average about 32 milligrams apiece.

Outline of Data Reduction Procedures

1. Calculate D_{50}'s.
2. Convert Stage Weights To MG/ACM or MG/DSCM.
3. Plot Cumulative Size Distribution. $\sum_{t=o}^{n} M_t$ vs. $(D_{50})_{t+1}$
4. Plot Cumulative % Size Distribution. $\% < D_{50}$ vs. D_{50}
5. Plot Differential Size Distribution. $(dM/d \log D)_n$ vs. $\sqrt{D_i \cdot D_{i+1}}$
6. Calculate Penetration. $\frac{dM/d \log D, \text{ Outlet}}{dM/d \log D, \text{ Inlet}}$

Based on the results of these tests, unconditioned substrates were used for all the impactor tests on July 9 and 10.

Table 10 through 27 contain computer reduced data for all inlet and outlet impactor runs on July 9 and 10. The first line of the printout gives the run location, the run number, the run date, the start time, the port number, and pantleg designation as indicated below.

I-1	07-09-76	0720	4	West
Location: I-Inlet O-Outlet / Run Number	Date	Start Time	Port Number	Pantleg Designation

The data are reduced assuming particle densities of 1.0 (aerodynamic) and 3.58 gm/cm^3, and complete printouts are included for each assumed density.

TABLE 10.

I-1 07-09-76 0720 4WEST

IMPACTOR FLOWRATE = 0,029 ACFM   IMPACTOR TEMPERATURE = 650,0 F = 343,3 C   SAMPLING DURATION = 30,00 MIN

IMPACTOR PRESSURE DROP = 0,6 IN, OF HG   STACK TEMPERATURE = 650,0 F = 343,3 C

ASSUMED PARTICLE DENSITY = 3,58 GM/CU,CM,   STACK PRESSURE = 28,15 IN, OF HG   MAX, PARTICLE DIAMETER = 100,0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 6,40   CO = 0,00   N2 = 71,36   O2 = 5,50   H2O = 15,00

CALC, MASS LOADING = 6,0346E-01 GR/ACF   1,5607E+00 GR/DNCF   1,3809E+03 MG/ACM   3,5714E+03 MG/DNCM

IMPACTOR STAGE	CYC	S0	S1	S2	S3	S4	S5	S6	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8	9
D50 (MICROMETERS)	10,48	6,66	3,40	1,80	1,46	0,79	0,54	0,27	
MASS (MILLIGRAMS)	28,72	0,96	0,48	0,70	0,29	0,25	0,24	0,73	1,65
MG/DNCM/STAGE	3,01E+03	1,01E+02	5,04E+01	7,35E+01	3,04E+01	2,62E+01	2,52E+01	7,66E+01	1,73E+02
CUM, PERCENT OF MASS SMALLER THAN D50	15,58	12,76	11,35	9,29	8,44	7,71	7,00	4,86	
CUM, (MG/ACM) SMALLER THAN D50	2,15E+02	1,76E+02	1,57E+02	1,28E+02	1,17E+02	1,06E+02	9,67E+01	6,70E+01	
CUM, (MG/DNCM) SMALLER THAN D50	5,57E+02	4,56E+02	4,05E+02	3,32E+02	3,01E+02	2,75E+02	2,50E+02	1,73E+02	
CUM, (GR/ACF) SMALLER THAN D50	9,40E-02	7,70E-02	6,85E-02	5,61E-02	5,09E-02	4,65E-02	4,22E-02	2,93E-02	
CUM, (GR/DNCF) SMALLER THAN D50	2,43E-01	1,99E-01	1,77E-01	1,45E-01	1,32E-01	1,20E-01	1,09E-01	7,58E-02	
GEO, MEAN DIA, (MICROMETERS)	3,24E+01	8,35E+00	4,76E+00	2,48E+00	1,62E+00	1,07E+00	6,52E-01	3,85E-01	1,93E-01
DM/DLOGD (MG/DNCM)	3,08E+03	5,11E+02	1,73E+02	2,67E+02	3,33E+02	9,74E+01	1,55E+02	2,58E+02	5,75E+02
DN/DLOGD (NO, PARTICLES/DNCM)	4,84E+07	4,68E+08	8,56E+08	9,35E+09	4,14E+10	4,21E+10	2,99E+11	2,42E+12	4,26E+13

NORMAL (ENGINEERING STANDARD) CONDITIONS ARE 21 DEG C AND 760MM HG,

TABLE 11.

I-1 07-09-76 0720 4WEST

IMPACTOR FLOWRATE = 0,029 ACFM   IMPACTOR TEMPERATURE = 650,0 F = 343,3 C   SAMPLING DURATION = 30,00 MIN

IMPACTOR PRESSURE DROP = 0,6 IN, OF HG   STACK TEMPERATURE = 650,0 F = 343,3 C

ASSUMED PARTICLE DENSITY = 1,00 GM/CU,CM,   STACK PRESSURE = 28,15 IN, OF HG   MAX, PARTICLE DIAMETER = 189,2 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 6,40   CO = 0,00   N2 = 71,36   O2 = 5,50   H2O = 15,00

CALC, MASS LOADING = 6,0346E-01 GR/ACF   1,5607E+00 GR/DNCF   1,3809E+03 MG/ACM   3,5714E+03 MG/DNCM

IMPACTOR STAGE	CYC	S0	S1	S2	S3	S4	S5	S6	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8	9
D50 (MICROMETERS)	19,83	12,75	6,60	3,57	2,92	1,64	1,17	0,66	
MASS (MILLIGRAMS)	28,72	0,96	0,48	0,70	0,29	0,25	0,24	0,73	1,65
MG/DNCM/STAGE	3,01E+03	1,01E+02	5,04E+01	7,35E+01	3,04E+01	2,62E+01	2,52E+01	7,66E+01	1,73E+02
CUM, PERCENT OF MASS SMALLER THAN D50	15,58	12,76	11,35	9,29	8,44	7,71	7,00	4,86	
CUM, (MG/ACM) SMALLER THAN D50	2,15E+02	1,76E+02	1,57E+02	1,28E+02	1,17E+02	1,06E+02	9,67E+01	6,70E+01	
CUM, (MG/DNCM) SMALLER THAN D50	5,57E+02	4,56E+02	4,05E+02	3,32E+02	3,01E+02	2,75E+02	2,50E+02	1,73E+02	
CUM, (GR/ACF) SMALLER THAN D50	9,40E-02	7,70E-02	6,85E-02	5,61E-02	5,09E-02	4,65E-02	4,22E-02	2,93E-02	
CUM, (GR/DNCF) SMALLER THAN D50	2,43E-01	1,99E-01	1,77E-01	1,45E-01	1,32E-01	1,20E-01	1,09E-01	7,58E-02	
GEO, MEAN DIA, (MICROMETERS)	6,13E+01	1,59E+01	9,17E+00	4,85E+00	3,23E+00	2,19E+00	1,39E+00	8,78E-01	4,65E-01
DM/DLOGD (MG/DNCM)	3,08E+03	5,26E+02	1,76E+02	2,75E+02	3,49E+02	1,05E+02	1,74E+02	3,04E+02	5,75E+02
DN/DLOGD (NO, PARTICLES/DNCM)	2,56E+07	2,50E+08	4,35E+08	4,60E+09	1,98E+10	1,91E+10	1,25E+11	8,58E+11	1,09E+13

NORMAL (ENGINEERING STANDARD) CONDITIONS ARE 21 DEG C AND 760MM HG,

TABLE 12.

I=2 07=09=76 0700 3WEST

IMPACTOR FLOWRATE = 0,056 ACFM   IMPACTOR TEMPERATURE = 650,0 F = 343,3 C   SAMPLING DURATION = 20,00 MIN

IMPACTOR PRESSURE DROP = 2,2 IN, OF HG   STACK TEMPERATURE = 650,0 F = 343,3 C

ASSUMED PARTICLE DENSITY = 3,58 GM/CU,CM,   STACK PRESSURE = 28,20 IN, OF HG   MAX, PARTICLE DIAMETER = 100,0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 6,40   CO = 0,00   N2 = 71,36   O2 = 5,50   H2O = 15,00

CALC, MASS LOADING = 1,9415E=01 GR/ACF   5,0121E=01 GR/DNCF   4,4427E+02 MG/ACM   1,1469E+03 MG/DNCM

IMPACTOR STAGE	CYC	S0	S1	S2	S3	S4	S5	S6	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8	9
D50 (MICROMETERS)	7,54	4,74	2,40	1,25	1,01	0,52	0,34	0,15	
MASS (MILLIGRAMS)	11,65	0,07	0,05	0,02	0,06	0,16	0,34	0,58	1,16
MG/DNCM/STAGE	9,48E+02	5,70E+00	4,07E+00	1,63E+00	4,88E+00	1,30E+01	2,77E+01	4,72E+01	9,44E+01
CUM, PERCENT OF MASS SMALLER THAN D50	17,32	16,83	16,47	16,33	15,90	14,77	12,35	8,24	
CUM, (MG/ACM) SMALLER THAN D50	7,70E+01	7,48E+01	7,32E+01	7,25E+01	7,07E+01	6,56E+01	5,49E+01	3,66E+01	
CUM, (MG/DNCM) SMALLER THAN D50	1,99E+02	1,93E+02	1,89E+02	1,87E+02	1,82E+02	1,69E+02	1,42E+02	9,45E+01	
CUM, (GR/ACF) SMALLER THAN D50	3,36E=02	3,27E=02	3,20E=02	3,17E=02	3,09E=02	2,87E=02	2,40E=02	1,60E=02	
CUM, (GR/DNCF) SMALLER THAN D50	8,68E=02	8,43E=02	8,26E=02	8,18E=02	7,97E=02	7,40E=02	6,19E=02	4,13E=02	
GEO, MEAN DIA, (MICROMETERS)	2,75E+01	5,98E+00	3,37E+00	1,73E+00	1,12E+00	7,22E=01	4,21E=01	2,25E=01	1,04E=01
DM/DLOGD (MG/DNCM)	8,45E+02	2,82E+01	1,38E+01	5,76E+00	5,13E+01	4,53E+01	1,53E+02	1,30E+02	3,14E+02
DN/DLOGD (NO, PARTICLES/DNCM)	2,18E+07	7,05E+07	1,91E+08	5,90E+08	1,94E+10	6,43E+10	1,09E+12	6,08E+12	1,47E+14

NORMAL (ENGINEERING STANDARD) CONDITIONS ARE 21 DEG C AND 760MM HG,

TABLE 13.

I-2 07-09-76 0700 3WEST

IMPACTOR FLOWRATE = 0,056 ACFM   IMPACTOR TEMPERATURE = 650,0 F = 343,3 C   SAMPLING DURATION = 20,00 MIN

IMPACTOR PRESSURE DROP = 2,2 IN, OF HG   STACK TEMPERATURE = 650,0 F = 343,3 C

ASSUMED PARTICLE DENSITY = 1,00 GM/CU,CM,   STACK PRESSURE = 28,20 IN, OF HG   MAX, PARTICLE DIAMETER = 189,2 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 6,40   CO = 0,00   N2 = 71,36   O2 = 5,50   H2O = 15,00

CALC, MASS LOADING = 1,9415E-01 GR/ACF   5,0121E-01 GR/DNCF   4,4427E+02 MG/ACM   1,1469E+03 MG/DNCM

IMPACTOR STAGE	CYC	S0	S1	S2	S3	S4	S5	S6	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8	9
D50 (MICROMETERS)	14,27	9,13	4,70	2,52	2,05	1,13	0,79	0,40	
MASS (MILLIGRAMS)	11,65	0,07	0,05	0,02	0,06	0,16	0,34	0,58	1,16
MG/DNCM/STAGE	9,48E+02	5,70E+00	4,07E+00	1,63E+00	4,88E+00	1,30E+01	2,77E+01	4,72E+01	9,44E+01
CUM, PERCENT OF MASS SMALLER THAN D50	17,32	16,83	16,47	16,33	15,90	14,77	12,35	8,24	
CUM, (MG/ACM) SMALLER THAN D50	7,70E+01	7,48E+01	7,32E+01	7,25E+01	7,07E+01	6,56E+01	5,49E+01	3,66E+01	
CUM, (MG/DNCM) SMALLER THAN D50	1,99E+02	1,93E+02	1,89E+02	1,87E+02	1,82E+02	1,69E+02	1,42E+02	9,45E+01	
CUM, (GR/ACF) SMALLER THAN D50	3,36E-02	3,27E-02	3,20E-02	3,17E-02	3,09E-02	2,87E-02	2,40E-02	1,60E-02	
CUM, (GR/DNCF) SMALLER THAN D50	8,68E-02	8,43E-02	8,26E-02	8,18E-02	7,97E-02	7,40E-02	6,19E-02	4,13E-02	
GEO, MEAN DIA, (MICROMETERS)	5,20E+01	1,14E+01	6,55E+00	3,44E+00	2,27E+00	1,52E+00	9,46E-01	5,62E-01	2,82E-01
DM/DLOGD (MG/DNCM)	8,45E+02	2,94E+01	1,41E+01	6,02E+00	5,48E+01	5,02E+01	1,80E+02	1,59E+02	3,14E+02
DN/DLOGD (NO, PARTICLES/DNCM)	1,15E+07	3,77E+07	9,60E+07	2,82E+08	8,91E+09	2,72E+10	4,05E+11	1,70E+12	2,66E+13

NORMAL (ENGINEERING STANDARD) CONDITIONS ARE 21 DEG C AND 760MM HG,

TABLE 14.

I-3 07-09-76 1135 3EAST

IMPACTOR FLOWRATE = 0,029 ACFM   IMPACTOR TEMPERATURE = 625,0 F = 329,4 C   SAMPLING DURATION = 30,00 MIN

IMPACTOR PRESSURE DROP = 0,6 IN, OF HG   STACK TEMPERATURE = 625,0 F = 329,4 C

ASSUMED PARTICLE DENSITY = 3,58 GM/CU,CM,   STACK PRESSURE = 28,20 IN, OF HG   MAX, PARTICLE DIAMETER = 100,0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 6,40   CO = 0,00   N2 = 71,36   O2 = 5,50   H2O = 15,00

CALC, MASS LOADING = 4,3317E-01 GR/ACF   1,0931E+00 GR/DNCF   9,9124E+02 MG/ACM   2,5014E+03 MG/DNCM

IMPACTOR STAGE	CYC	S0	S1	S2	S3	S4	S5	S6	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8	9
D50 (MICROMETERS)	10,39	6,60	3,38	1,79	1,45	0,78	0,54	0,27	
MASS (MILLIGRAMS)	19,24	0,24	0,38	0,49	0,29	1,54	0,66	0,56	1,02
MG/DNCM/STAGE	1,97E+03	2,46E+01	3,89E+01	5,02E+01	2,97E+01	1,58E+02	6,76E+01	5,74E+01	1,04E+02
CUM, PERCENT OF MASS SMALLER THAN D50	21,22	20,23	18,68	16,67	15,48	9,18	6,48	4,18	
CUM, (MG/ACM) SMALLER THAN D50	2,10E+02	2,01E+02	1,85E+02	1,65E+02	1,53E+02	9,10E+01	6,42E+01	4,15E+01	
CUM, (MG/DNCM) SMALLER THAN D50	5,31E+02	5,06E+02	4,67E+02	4,17E+02	3,87E+02	2,30E+02	1,62E+02	1,05E+02	
CUM, (GR/ACF) SMALLER THAN D50	9,19E-02	8,76E-02	8,09E-02	7,22E-02	6,71E-02	3,98E-02	2,80E-02	1,81E-02	
CUM, (GR/DNCF) SMALLER THAN D50	2,32E-01	2,21E-01	2,04E-01	1,82E-01	1,69E-01	1,00E-01	7,08E-02	4,57E-02	
GEO, MEAN DIA, (MICROMETERS)	3,22E+01	8,28E+00	4,72E+00	2,46E+00	1,61E+00	1,07E+00	6,50E-01	3,84E-01	1,93E-01
DM/DLOGD (MG/DNCM)	2,00E+03	1,25E+02	1,34E+02	1,83E+02	3,26E+02	5,87E+02	4,19E+02	1,94E+02	3,47E+02
DN/DLOGD (NO, PARTICLES/DNCM)	3,19E+07	1,17E+08	6,77E+08	6,53E+09	4,13E+10	2,58E+11	8,12E+11	1,82E+12	2,56E+13

NORMAL (ENGINEERING STANDARD) CONDITIONS ARE 21 DEG C AND 760MM HG,

TABLE 15.

I-3 07-09-76 1135 3EAST

IMPACTOR FLOWRATE = 0,029 ACFM IMPACTOR TEMPERATURE = 625,0 F = 329,4 C SAMPLING DURATION = 30,00 MIN

IMPACTOR PRESSURE DROP = 0,6 IN, OF HG STACK TEMPERATURE = 625,0 F = 329,4 C

ASSUMED PARTICLE DENSITY = 1,00 GM/CU,CM, STACK PRESSURE = 28,20 IN, OF HG MAX, PARTICLE DIAMETER = 189,2 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 6,40 CO = 0,00 N2 = 71,36 O2 = 5,50 H2O = 15,00

CALC, MASS LOADING = 4,3317E-01 GR/ACF 1,0931E+00 GR/DNCF 9,9124E+02 MG/ACM 2,5014E+03 MG/DNCM

IMPACTOR STAGE	CYC	S0	S1	S2	S3	S4	S5	S6	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8	9
D50 (MICROMETERS)	19,67	12,65	6,55	3,54	2,90	1,63	1,17	0,66	
MASS (MILLIGRAMS)	19,24	0,24	0,38	0,49	0,29	1,54	0,66	0,56	1,02
MG/DNCM/STAGE	1,97E+03	2,46E+01	3,89E+01	5,02E+01	2,97E+01	1,58E+02	6,76E+01	5,74E+01	1,04E+02
CUM, PERCENT OF MASS SMALLER THAN D50	21,22	20,23	18,68	16,67	15,48	9,18	6,48	4,18	
CUM, (MG/ACM) SMALLER THAN D50	2,10E+02	2,01E+02	1,85E+02	1,65E+02	1,53E+02	9,10E+01	6,42E+01	4,15E+01	
CUM, (MG/DNCM) SMALLER THAN D50	5,31E+02	5,06E+02	4,67E+02	4,17E+02	3,87E+02	2,30E+02	1,62E+02	1,05E+02	
CUM, (GR/ACF) SMALLER THAN D50	9,19E-02	8,76E-02	8,09E-02	7,22E-02	6,71E-02	3,98E-02	2,80E-02	1,81E-02	
CUM, (GR/DNCF) SMALLER THAN D50	2,32E-01	2,21E-01	2,04E-01	1,82E-01	1,69E-01	1,00E-01	7,08E-02	4,57E-02	
GEO, MEAN DIA, (MICROMETERS)	6,10E+01	1,58E+01	9,10E+00	4,82E+00	3,20E+00	2,17E+00	1,38E+00	8,75E-01	4,63E-01
DM/DLOGD (MG/DNCM)	2,00E+03	1,28E+02	1,36E+02	1,88E+02	3,41E+02	6,29E+02	4,68E+02	2,29E+02	3,47E+02
DN/DLOGD (NO, PARTICLES/DNCM)	1,69E+07	6,24E+07	3,45E+08	3,22E+09	1,98E+10	1,17E+11	3,41E+11	6,53E+11	6,67E+12

NORMAL (ENGINEERING STANDARD) CONDITIONS ARE 21 DEG C AND 760MM HG,

TABLE 16.

I-4 07-09-76 1200 4EAST

IMPACTOR FLOWRATE = 0,044 ACFM   IMPACTOR TEMPERATURE = 625,0 F = 329,4 C   SAMPLING DURATION = 30,00 MIN

IMPACTOR PRESSURE DROP = 1,4 IN, OF HG   STACK TEMPERATURE = 625,0 F = 329,4 C

ASSUMED PARTICLE DENSITY = 3,58 GM/CU,CM,   STACK PRESSURE = 28,20 IN, OF HG   MAX, PARTICLE DIAMETER = 100,0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 6,40   CO = 0,00   N2 = 71,36   O2 = 5,50   H2O = 15,00

CALC, MASS LOADING = 4,4567E-01 GR/ACF   1,1246E+00 GR/DNCF   1,0198E+03 MG/ACM   2,5735E+03 MG/DNCM

IMPACTOR STAGE	CYC	S0	S1	S2	S3	S4	S5	S6	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8	9
D50 (MICROMETERS)	8,44	5,33	2,71	1,43	1,15	0,60	0,41	0,19	
MASS (MILLIGRAMS)	25,26	3,59	2,95	1,52	1,05	0,77	0,51	1,26	1,21
MG/DNCM/STAGE	1,71E+03	2,42E+02	1,99E+02	1,03E+02	7,09E+01	5,20E+01	3,44E+01	8,51E+01	8,17E+01
CUM, PERCENT OF MASS SMALLER THAN D50	33,74	24,32	16,58	12,60	9,84	7,82	6,48	3,18	
CUM, (MG/ACM) SMALLER THAN D50	3,44E+02	2,48E+02	1,69E+02	1,28E+02	1,00E+02	7,98E+01	6,61E+01	3,24E+01	
CUM, (MG/DNCM) SMALLER THAN D50	8,68E+02	6,26E+02	4,27E+02	3,24E+02	2,53E+02	2,01E+02	1,67E+02	8,18E+01	
CUM, (GR/ACF) SMALLER THAN D50	1,50E-01	1,08E-01	7,39E-02	5,61E-02	4,39E-02	3,49E-02	2,89E-02	1,42E-02	
CUM, (GR/DNCF) SMALLER THAN D50	3,79E-01	2,74E-01	1,87E-01	1,42E-01	1,11E-01	8,80E-02	7,29E-02	3,58E-02	
GEO, MEAN DIA, (MICROMETERS)	2,90E+01	6,71E+00	3,80E+00	1,97E+00	1,28E+00	8,34E-01	4,96E-01	2,78E-01	1,34E-01
DM/DLOGD (MG/DNCM)	1,59E+03	1,21E+03	6,78E+02	3,67E+02	7,59E+02	1,86E+02	2,01E+02	2,57E+02	2,71E+02
DN/DLOGD (NO, PARTICLES/DNCM)	3,46E+07	2,15E+09	6,59E+09	2,58E+10	1,93E+11	1,72E+11	8,76E+11	6,37E+12	5,96E+13

NORMAL (ENGINEERING STANDARD) CONDITIONS ARE 21 DEG C AND 760MM HG.

TABLE 17.

I-4 07-09-76 1200 4EAST

IMPACTOR FLOWRATE = 0,044 ACFM   IMPACTOR TEMPERATURE = 625,0 F = 329,4 C   SAMPLING DURATION = 30,00 MIN

IMPACTOR PRESSURE DROP = 1,4 IN, OF HG   STACK TEMPERATURE = 625,0 F = 329,4 C

ASSUMED PARTICLE DENSITY = 1,00 GM/CU,CM,   STACK PRESSURE = 28,20 IN, OF HG   MAX, PARTICLE DIAMETER = 189,2 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 6,40   CO = 0,00   N2 = 71,36   O2 = 5,50   H2O = 15,00

CALC, MASS LOADING = 4,4567E-01 GR/ACF   1,1246E+00 GR/DNCF   1,0198E+03 MG/ACM   2,5735E+03 MG/DNCM

IMPACTOR STAGE	CYC	S0	S1	S2	S3	S4	S5	S6	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8	9
D50 (MICROMETERS)	15,97	10,24	5,28	2,84	2,32	1,29	0,91	0,49	
MASS (MILLIGRAMS)	25,26	3,59	2,95	1,52	1,05	0,77	0,51	1,26	1,21
MG/DNCM/STAGE	1,71E+03	2,42E+02	1,99E+02	1,03E+02	7,09E+01	5,20E+01	3,44E+01	8,51E+01	8,17E+01
CUM, PERCENT OF MASS SMALLER THAN D50	33,74	24,32	16,58	12,60	9,84	7,82	6,48	3,18	
CUM, (MG/ACM) SMALLER THAN D50	3,44E+02	2,48E+02	1,69E+02	1,28E+02	1,00E+02	7,98E+01	6,61E+01	3,24E+01	
CUM, (MG/DNCM) SMALLER THAN D50	8,68E+02	6,26E+02	4,27E+02	3,24E+02	2,53E+02	2,01E+02	1,67E+02	8,18E+01	
CUM, (GR/ACF) SMALLER THAN D50	1,50E-01	1,08E-01	7,39E-02	5,61E-02	4,39E-02	3,49E-02	2,89E-02	1,42E-02	
CUM, (GR/DNCF) SMALLER THAN D50	3,79E-01	2,74E-01	1,87E-01	1,42E-01	1,11E-01	8,80E-02	7,29E-02	3,58E-02	
GEO, MEAN DIA, (MICROMETERS)	5,50E+01	1,28E+01	7,35E+00	3,88E+00	2,57E+00	1,73E+00	1,09E+00	6,67E-01	3,44E-01
DM/DLOGD (MG/DNCM)	1,59E+03	1,26E+03	6,93E+02	3,82E+02	8,03E+02	2,04E+02	2,30E+02	3,11E+02	2,71E+02
DN/DLOGD (NO, PARTICLES/DNCM)	1,83E+07	1,15E+09	3,33E+09	1,25E+10	9,05E+10	7,51E+10	3,44E+11	2,00E+12	1,27E+13

NORMAL (ENGINEERING STANDARD) CONDITIONS ARE 21 DEG C AND 760MM HG,

TABLE 18.

I-5 7-10-76 0640 3EAST

IMPACTOR FLOWRATE = 0,038 ACFM IMPACTOR TEMPERATURE = 615,0 F = 323,9 C SAMPLING DURATION = 30,00 MIN

IMPACTOR PRESSURE DROP = 1,1 IN, OF HG STACK TEMPERATURE = 615,0 F = 323,9 C

ASSUMED PARTICLE DENSITY = 3,58 GM/CU,CM, STACK PRESSURE = 28,28 IN, OF HG MAX, PARTICLE DIAMETER = 100,0 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 6,40 CO = 0,00 N2 = 71,36 O2 = 5,50 H2O = 15,00

CALC, MASS LOADING = 1,3402E-01 GR/ACF 3,3412E-01 GR/DNCF 3,0668E+02 MG/ACM 7,6458E+02 MG/DNCM

IMPACTOR STAGE	CYC	S0	S1	S2	S3	S4	S5	S6	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8	9
D50 (MICROMETERS)	9,05	5,73	2,92	1,54	1,25	0,66	0,45	0,22	
MASS (MILLIGRAMS)	4,55	0,25	0,35	0,36	0,29	0,30	1,18	1,06	1,56
MG/DNCM/STAGE	3,51E+02	1,93E+01	2,70E+01	2,78E+01	2,24E+01	2,32E+01	9,11E+01	8,19E+01	1,20E+02
CUM, PERCENT OF MASS SMALLER THAN D50	54,05	51,52	47,98	44,35	41,42	38,39	26,47	15,76	
CUM, (MG/ACM) SMALLER THAN D50	1,66E+02	1,58E+02	1,47E+02	1,36E+02	1,27E+02	1,18E+02	8,12E+01	4,83E+01	
CUM, (MG/DNCM) SMALLER THAN D50	4,13E+02	3,94E+02	3,67E+02	3,39E+02	3,17E+02	2,94E+02	2,02E+02	1,21E+02	
CUM, (GR/ACF) SMALLER THAN D50	7,24E-02	6,90E-02	6,43E-02	5,94E-02	5,55E-02	5,14E-02	3,55E-02	2,11E-02	
CUM, (GR/DNCF) SMALLER THAN D50	1,81E-01	1,72E-01	1,60E-01	1,48E-01	1,38E-01	1,28E-01	8,84E-02	5,27E-02	
GEO, MEAN DIA, (MICROMETERS)	3,01E+01	7,20E+00	4,09E+00	2,12E+00	1,39E+00	9,09E-01	5,47E-01	3,14E-01	1,54E-01
DM/DLOGD (MG/DNCM)	3,37E+02	9,73E+01	9,24E+01	1,00E+02	2,42E+02	8,44E+01	5,45E+02	2,59E+02	4,00E+02
DN/DLOGD (NO, PARTICLES/DNCM)	6,60E+06	1,39E+08	7,20E+08	5,59E+09	4,85E+10	6,00E+10	1,78E+12	4,49E+12	5,83E+13

NORMAL (ENGINEERING STANDARD) CONDITIONS ARE 21 DEG C AND 760MM HG,

TABLE 19.

I-5 7-10-76 0640 3EAST

IMPACTOR FLOWRATE = 0,038 ACFM IMPACTOR TEMPERATURE = 615,0 F = 323,9 C SAMPLING DURATION = 30,00 MIN

IMPACTOR PRESSURE DROP = 1,1 IN, OF HG STACK TEMPERATURE = 615,0 F = 323,9 C

ASSUMED PARTICLE DENSITY = 1,00 GM/CU,CM, STACK PRESSURE = 28,28 IN, OF HG MAX, PARTICLE DIAMETER = 189,2 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 6,40 CO = 0,00 N2 = 71,36 O2 = 5,50 H2O = 15,00

CALC, MASS LOADING = 1,3402E-01 GR/ACF 3,3412E-01 GR/DNCF 3,0668E+02 MG/ACM 7,6458E+02 MG/DNCM

IMPACTOR STAGE	CYC	S0	S1	S2	S3	S4	S5	S6	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8	9
D50 (MICROMETERS)	17,12	10,99	5,68	3,06	2,50	1,40	1,00	0,54	
MASS (MILLIGRAMS)	4,55	0,25	0,35	0,36	0,29	0,30	1,18	1,06	1,56
MG/DNCM/STAGE	3,51E+02	1,93E+01	2,70E+01	2,78E+01	2,24E+01	2,32E+01	9,11E+01	8,19E+01	1,20E+02
CUM, PERCENT OF MASS SMALLER THAN D50	54,05	51,52	47,98	44,35	41,42	38,39	26,47	15,76	
CUM, (MG/ACM) SMALLER THAN D50	1,66E+02	1,58E+02	1,47E+02	1,36E+02	1,27E+02	1,18E+02	8,12E+01	4,83E+01	
CUM, (MG/DNCM) SMALLER THAN D50	4,13E+02	3,94E+02	3,67E+02	3,39E+02	3,17E+02	2,94E+02	2,02E+02	1,21E+02	
CUM, (GR/ACF) SMALLER THAN D50	7,24E-02	6,90E-02	6,43E-02	5,94E-02	5,55E-02	5,14E-02	3,55E-02	2,11E-02	
CUM, (GR/DNCF) SMALLER THAN D50	1,81E-01	1,72E-01	1,60E-01	1,48E-01	1,38E-01	1,28E-01	8,84E-02	5,27E-02	
GEO, MEAN DIA, (MICROMETERS)	5,69E+01	1,37E+01	7,90E+00	4,17E+00	2,77E+00	1,87E+00	1,18E+00	7,35E-01	3,84E-01
DM/DLOGD (MG/DNCM)	3,37E+02	1,00E+02	9,42E+01	1,04E+02	2,55E+02	9,15E+01	6,19E+02	3,11E+02	4,00E+02
DN/DLOGD (NO, PARTICLES/DNCM)	3,49E+06	7,42E+07	3,65E+08	2,73E+09	2,29E+10	2,67E+10	7,20E+11	1,49E+12	1,35E+13

NORMAL (ENGINEERING STANDARD) CONDITIONS ARE 21 DEG C AND 760MM HG,

TABLE 20.

I-7 07-01-76 1000 3WEST

IMPACTOR FLOWRATE = 0,038 ACFM IMPACTOR TEMPERATURE = 615,0 F = 323,9 C SAMPLING DURATION = 20,00 MIN

IMPACTOR PRESSURE DROP = 1,1 IN, OF HG STACK TEMPERATURE = 615,0 F = 323,9 C

ASSUMED PARTICLE DENSITY = 3,58 GM/CU,CM, STACK PRESSURE = 28,28 IN, OF HG MAX, PARTICLE DIAMETER = 100,0 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 6,40 CO = 0,00 N2 = 71,36 O2 = 5,50 H2O = 15,00

CALC, MASS LOADING = 9,0767E-02 GR/ACF 2,2629E-01 GR/DNCF 2,0771E+02 MG/ACM 5,1783E+02 MG/DNCM

IMPACTOR STAGE	CYC	S0	S1	S2	S3	S4	S5	S6	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8	9
D50 (MICROMETERS)	9,05	5,73	2,92	1,54	1,25	0,66	0,45	0,22	
MASS (MILLIGRAMS)	0,00	0,27	0,49	0,83	0,40	0,97	0,46	0,65	0,40
MG/DNCM/STAGE	0,00E-01	3,13E+01	5,68E+01	9,62E+01	4,63E+01	1,12E+02	5,33E+01	7,53E+01	4,63E+01
CUM, PERCENT OF MASS SMALLER THAN D50	100,00	93,96	83,00	64,43	55,49	33,79	23,49	8,95	
CUM, (MG/ACM) SMALLER THAN D50	2,08E+02	1,95E+02	1,72E+02	1,34E+02	1,15E+02	7,02E+01	4,88E+01	1,86E+01	
CUM, (MG/DNCM) SMALLER THAN D50	5,18E+02	4,87E+02	4,30E+02	3,34E+02	2,87E+02	1,75E+02	1,22E+02	4,64E+01	
CUM, (GR/ACF) SMALLER THAN D50	9,08E-02	8,53E-02	7,53E-02	5,85E-02	5,04E-02	3,07E-02	2,13E-02	8,13E-03	
CUM, (GR/DNCF) SMALLER THAN D50	2,26E-01	2,13E-01	1,88E-01	1,46E-01	1,26E-01	7,65E-02	5,32E-02	2,03E-02	
GEO, MEAN DIA, (MICROMETERS)	3,01E+01	7,20E+00	4,09E+00	2,12E+00	1,39E+00	9,09E-01	5,47E-01	3,14E-01	1,54E-01
DM/DLOGD (MG/DNCM)	0,00E-01	1,58E+02	1,94E+02	3,47E+02	5,01E+02	4,09E+02	3,19E+02	2,39E+02	1,54E+02
DN/DLOGD (NO, PARTICLES/DNCM)	0,00E-01	2,25E+08	1,51E+09	1,93E+10	1,00E+11	2,91E+11	1,04E+12	4,13E+12	2,24E+13

NORMAL (ENGINEERING STANDARD) CONDITIONS ARE 21 DEG C AND 760MM HG,

TABLE 21.

I-7 07-01-76 1000 3WEST

IMPACTOR FLOWRATE = 0.038 ACFM   IMPACTOR TEMPERATURE = 615.0 F = 323.9 C   SAMPLING DURATION = 20.00 MIN

IMPACTOR PRESSURE DROP = 1.1 IN. OF HG   STACK TEMPERATURE = 615.0 F = 323.9 C

ASSUMED PARTICLE DENSITY = 1.00 GM/CU.CM.   STACK PRESSURE = 28.28 IN. OF HG   MAX. PARTICLE DIAMETER = 189.2 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 6.40   CO = 0.00   N2 = 71.36   O2 = 5.50   H2O = 15.00

CALC. MASS LOADING = 9.0767E-02 GR/ACF   2.2629E-01 GR/DNCF   2.0771E+02 MG/ACM   5.1783E+02 MG/DNCM

IMPACTOR STAGE	CYC	S0	S1	S2	S3	S4	S5	S6	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8	9
D50 (MICROMETERS)	17.12	10.99	5.68	3.06	2.50	1.40	1.00	0.54	
MASS (MILLIGRAMS)	0.00	0.27	0.49	0.83	0.40	0.97	0.46	0.65	0.40
MG/DNCM/STAGE	0.00E-01	3.13E+01	5.68E+01	9.62E+01	4.63E+01	1.12E+02	5.33E+01	7.53E+01	4.63E+01
CUM. PERCENT OF MASS SMALLER THAN D50	100.00	93.96	83.00	64.43	55.49	33.79	23.49	8.95	
CUM. (MG/ACM) SMALLER THAN D50	2.08E+02	1.95E+02	1.72E+02	1.34E+02	1.15E+02	7.02E+01	4.88E+01	1.86E+01	
CUM. (MG/DNCM) SMALLER THAN D50	5.18E+02	4.87E+02	4.30E+02	3.34E+02	2.87E+02	1.75E+02	1.22E+02	4.64E+01	
CUM. (GR/ACF) SMALLER THAN D50	9.08E-02	8.53E-02	7.53E-02	5.85E-02	5.04E-02	3.07E-02	2.13E-02	8.13E-03	
CUM. (GR/DNCF) SMALLER THAN D50	2.26E-01	2.13E-01	1.88E-01	1.46E-01	1.26E-01	7.65E-02	5.32E-02	2.03E-02	
GEO. MEAN DIA. (MICROMETERS)	5.69E+01	1.37E+01	7.90E+00	4.17E+00	2.77E+00	1.87E+00	1.18E+00	7.35E-01	3.84E-01
DM/DLOGD (MG/DNCM)	0.00E-01	1.63E+02	1.98E+02	3.59E+02	5.28E+02	4.44E+02	3.62E+02	2.86E+02	1.54E+02
DN/DLOGD (NO. PARTICLES/DNCM)	0.00E-01	1.20E+08	7.66E+08	9.44E+09	4.74E+10	1.29E+11	4.21E+11	1.37E+12	5.20E+12

NORMAL (ENGINEERING STANDARD) CONDITIONS ARE 21 DEG C AND 760MM HG.
STOP 000000

TABLE 22.

O-1B 07-09-76 0720 1PORT

IMPACTOR FLOWRATE = 0,073 ACFM — IMPACTOR TEMPERATURE = 650,0 F = 343,3 C — SAMPLING DURATION = 60,00 MIN

IMPACTOR PRESSURE DROP = 3,8 IN. OF HG — STACK TEMPERATURE = 650,0 F = 343,3 C

ASSUMED PARTICLE DENSITY = 3,58 GM/CU.CM. — STACK PRESSURE = 28,20 IN. OF HG — MAX. PARTICLE DIAMETER = 100,0 MICROMETERS

GAS COMPOSITION (PERCENT) — CO2 = 6,40 — CO = 0,00 — N2 = 71,36 — O2 = 5,50 — H2O = 15,00

CALC. MASS LOADING = 1,0324E-02 GR/ACF — 2,6651E-02 GR/DNCF — 2,3624E+01 MG/ACM — 6,0987E+01 MG/DNCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	S6	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	4,13	2,08	1,08	0,86	0,43	0,28	0,11	
MASS (MILLIGRAMS)	0,41	0,34	0,09	0,18	0,35	0,26	0,25	1,05
MG/DNCM/STAGE	8,53E+00	7,08E+00	1,6[illegible]+00	3,75E+00	7,29E+00	5,41E+00	5,20E+00	2,19E+01
CUM. PERCENT OF MASS SMALLER THAN D50	1,00E+02	8,60E+01	7,44E+01	7,13E+01	6,52E+01	5,32E+01	4,44E+01	
CUM. (MG/ACM) SMALLER THAN D50	2,03E+01	1,76E+01	1,69E+01	1,54E+01	1,26E+01	1,05E+01	8,47E+00	
CUM. (MG/DNCM) SMALLER THAN D50	5,25E+01	4,54E+01	4,35E+01	3,98E+01	3,25E+01	2,71E+01	2,19E+01	
CUM. (GR/ACF) SMALLER THAN D50	8,88E-03	7,68E-03	7,36E-03	6,73E-03	5,50E-03	4,58E-03	3,70E-03	
CUM. (GR/DNCF) SMALLER THAN D50	2,29E-02	1,98E-02	1,90E-02	1,74E-02	1,42E-02	1,18E-02	9,55E-03	
GEO. MEAN DIA. (MICROMETERS)	2,03E+01	2,93E+00	1,50E+00	9,61E-01	6,10E-01	3,47E-01	1,72E-01	7,51E-02
DM/DLOGD (MG/DNCM)	6,17E+00	2,38E+01	6,53E+00	3,84E+01	2,45E+01	2,83E+01	1,24E+01	7,26E+01
DN/DLOGD (NO. PARTICLES/DNCM)	3,92E+05	5,04E+08	1,04E+09	2,31E+10	5,76E+10	3,60E+11	1,30E+12	9,16E+13

NORMAL (ENGINEERING STANDARD) CONDITIONS ARE 21 DEG C AND 760MM HG.

TABLE 23.

O-1B 07-09-76 0720 1PORT

IMPACTOR FLOWRATE = 0,073 ACFM   IMPACTOR TEMPERATURE = 650,0 F = 343,3 C   SAMPLING DURATION = 60,00 MIN

IMPACTOR PRESSURE DROP = 3,8 IN, OF HG   STACK TEMPERATURE = 650,0 F = 343,3 C

ASSUMED PARTICLE DENSITY = 1,00 GM/CU,CM,   STACK PRESSURE = 28,20 IN, OF HG   MAX, PARTICLE DIAMETER = 189,2 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 6,40   CO = 0,00   N2 = 71,36   O2 = 5,50   H2O = 15,00

CALC, MASS LOADING = 1,0324E-02 GR/ACF   2,6651E-02 GR/DNCF   2,3624E+01 MG/ACM   6,0987E+01 MG/DNCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	S6	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	7,97	4,09	2,18	1,78	0,97	0,67	0,31	
MASS (MILLIGRAMS)	0,41	0,34	0,09	0,18	0,35	0,26	0,25	1,05
MG/DNCM/STAGE	8,53E+00	7,08E+00	1,87E+00	3,75E+00	7,29E+00	5,41E+00	5,20E+00	2,19E+01
CUM, PERCENT OF MASS SMALLER THAN D50	1,00E+02	8,60E+01	7,44E+01	7,13E+01	6,52E+01	5,32E+01	4,44E+01	
CUM, (MG/ACM) SMALLER THAN D50	2,03E+01	1,76E+01	1,69E+01	1,54E+01	1,26E+01	1,05E+01	8,47E+00	
CUM, (MG/DNCM) SMALLER THAN D50	5,25E+01	4,54E+01	4,35E+01	3,98E+01	3,25E+01	2,71E+01	2,19E+01	
CUM, (GR/ACF) SMALLER THAN D50	8,88E-03	7,68E-03	7,36E-03	6,73E-03	5,50E-03	4,58E-03	3,70E-03	
CUM, (GR/DNCF) SMALLER THAN D50	2,29E-02	1,98E-02	1,90E-02	1,74E-02	1,42E-02	1,18E-02	9,55E-03	
GEO, MEAN DIA, (MICROMETERS)	3,88E+01	5,71E+00	2,99E+00	1,97E+00	1,31E+00	8,04E-01	4,52E-01	2,16E-01
DM/DLOGD (MG/DNCM)	6,21E+00	2,44E+01	6,87E+00	4,16E+01	2,76E+01	3,37E+01	1,53E+01	7,26E+01
DN/DLOGD (NO, PARTICLES/DNCM)	2,02E+05	2,50E+08	4,91E+08	1,04E+10	2,34E+10	1,24E+11	3,17E+11	1,38E+13

NORMAL (ENGINEERING STANDARD) CONDITIONS ARE 21 DEG C AND 760MM HG,

TABLE 24.

O-28 07-09-76 1500 3PORT

IMPACTOR FLOWRATE = 0,073 ACFM   IMPACTOR TEMPERATURE = 620,0 F = 326,7 C   SAMPLING DURATION = 60,00 MIN

IMPACTOR PRESSURE DROP = 3,9 IN, OF HG   STACK TEMPERATURE = 620,0 F = 326,7 C

ASSUMED PARTICLE DENSITY = 3,58 GM/CU,CM,   STACK PRESSURE = 28,25 IN, OF HG   MAX, PARTICLE DIAMETER = 100,0 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 6,40   CO = 0,00   N2 = 71,36   O2 = 5,50   H2O = 15,00

CALC, MASS LOADING = 3,8405E-03 GR/ACF   9,6295E-03 GR/DNCF   8,7883E+00 MG/ACM   2,2036E+01 MG/DNCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	S6	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	4,09	2,06	1,07	0,85	0,43	0,28	0,11	
MASS (MILLIGRAMS)	0,01	0,11	0,11	0,11	0,23	0,23	0,13	0,16
MG/DNCM/STAGE	2,02E-01	2,22E+00	2,22E+00	2,22E+00	4,65E+00	4,65E+00	2,63E+00	3,23E+00
CUM, PERCENT OF MASS SMALLER THAN D50	1,00E+02	9,91E+01	8,90E+01	7,89E+01	6,88E+01	4,77E+01	2,66E+01	
CUM, (MG/ACM) SMALLER THAN D50	8,71E+00	7,82E+00	6,93E+00	6,05E+00	4,19E+00	2,34E+00	1,29E+00	
CUM, (MG/DNCM) SMALLER THAN D50	2,18E+01	1,96E+01	1,74E+01	1,52E+01	1,05E+01	5,86E+00	3,24E+00	
CUM, (GR/ACF) SMALLER THAN D50	3,81E-03	3,42E-03	3,03E-03	2,64E-03	1,83E-03	1,02E-03	5,64E-04	
CUM, (GR/DNCF) SMALLER THAN D50	9,54E-03	8,57E-03	7,60E-03	6,63E-03	4,59E-03	2,56E-03	1,41E-03	
GEO, MEAN DIA, (MICROMETERS)	2,02E+01	2,91E+00	1,48E+00	9,56E-01	6,08E-01	3,48E-01	1,72E-01	7,52E-02
DM/DLOGD (MG/DNCM)	1,46E-01	7,48E+00	7,78E+00	2,29E+01	1,57E+01	2,45E+01	6,27E+00	1,07E+01
DN/DLOGD (NO, PARTICLES/DNCM)	9,39E+03	1,63E+08	1,27E+09	1,40E+10	3,73E+10	3,11E+11	6,52E+11	1,35E+13

NORMAL (ENGINEERING STANDARD) CONDITIONS ARE 21 DEG C AND 760MM HG,

O-2R 07-09-76 1500 SPORT

TABLE 25.

IMPACTOR FLOWRATE = 0,073 ACFM   IMPACTOR TEMPERATURE = 620,0 F = 326,7 C   SAMPLING DURATION = 60,00 MIN

IMPACTOR PRESSURE DROP = 3,9 IN, OF HG   STACK TEMPERATURE = 620,0 F = 326,7 C

ASSUMED PARTICLE DENSITY = 1,00 GM/CU,CM,   STACK PRESSURE = 28,25 IN, OF HG   MAX, PARTICLE DIAMETER = 189,2 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 6,40   CO = 0,00   N2 = 71,36   O2 = 5,50   H2O = 15,00

CALC, MASS LOADING = 3,8405E-03 GR/ACF   9,6295E-03 GR/DNCF   8,7883E+00 MG/ACM   2,2036E+01 MG/DNCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	S6	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	7,90	4,05	2,17	1,76	0,96	0,67	0,30	
MASS (MILLIGRAMS)	0,01	0,11	0,11	0,11	0,23	0,23	0,13	0,16
MG/DNCM/STAGE	2,02E-01	2,22E+00	2,22E+00	2,22E+00	4,65E+00	4,65E+00	2,63E+00	3,23E+00
CUM, PERCENT OF MASS SMALLER THAN D50	1,00E+02	9,91E+01	8,90E+01	7,89E+01	6,88E+01	4,77E+01	2,66E+01	
CUM, (MG/ACM) SMALLER THAN D50	8,71E+00	7,82E+00	6,93E+00	6,05E+00	4,19E+00	2,34E+00	1,29E+00	
CUM, (MG/DNCM) SMALLER THAN D50	2,18E+01	1,96E+01	1,74E+01	1,52E+01	1,05E+01	5,86E+00	3,24E+00	
CUM, (GR/ACF) SMALLER THAN D50	3,81E-03	3,42E-03	3,03E-03	2,64E-03	1,83E-03	1,02E-03	5,64E-04	
CUM, (GR/DNCF) SMALLER THAN D50	9,54E-03	8,57E-03	7,60E-03	6,63E-03	4,59E-03	2,56E-03	1,41E-03	
GEO, MEAN DIA, (MICROMETERS)	3,87E+01	5,66E+00	2,96E+00	1,95E+00	1,30E+00	8,00E-01	4,50E-01	2,15E-01
DM/DLOGD (MG/DNCM)	1,47E-01	7,68E+00	8,17E+00	2,47E+01	1,77E+01	2,91E+01	7,74E+00	1,07E+01
DN/DLOGD (NO, PARTICLES/DNCM)	4,85E+03	8,10E+07	5,99E+08	6,33E+09	1,53E+10	1,09E+11	1,62E+11	2,05E+12

NORMAL (ENGINEERING STANDARD) CONDITIONS ARE 21 DEG C AND 760MM HG,

TABLE 26.

O-3B 07-10-76 0635 3PORT

IMPACTOR FLOWRATE = 0,066 ACFM IMPACTOR TEMPERATURE = 615,0 F = 323,9 C SAMPLING DURATION = 60,00 MIN

IMPACTOR PRESSURE DROP = 3,2 IN, OF HG STACK TEMPERATURE = 615,0 F = 323,9 C

ASSUMED PARTICLE DENSITY = 3,58 GM/CU,CM, STACK PRESSURE = 28,28 IN, OF HG MAX, PARTICLE DIAMETER = 100,0 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 6,40 CO = 0,00 N2 = 71,36 O2 = 5,50 H2O = 15,00

CALC, MASS LOADING = 3,6632E-03 GR/ACF 9,1329E-03 GR/DNCF 8,3828E+00 MG/ACM 2,0899E+01 MG/DNCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	S6	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	4,31	2,18	1,13	0,91	0,46	0,30	0,12	
MASS (MILLIGRAMS)	0,06	0,10	0,06	0,06	0,07	0,10	0,11	0,38
MG/DNCM/STAGE	1,33E+00	2,22E+00	1,33E+00	1,33E+00	1,56E+00	2,22E+00	2,45E+00	8,45E+00
CUM, PERCENT OF MASS SMALLER THAN D50	1,00E+02	9,36E+01	8,30E+01	7,66E+01	7,02E+01	6,28E+01	5,21E+01	
CUM, (MG/ACM) SMALLER THAN D50	7,85E+00	6,96E+00	6,42E+00	5,89E+00	5,26E+00	4,37E+00	3,39E+00	
CUM, (MG/DNCM) SMALLER THAN D50	1,96E+01	1,73E+01	1,60E+01	1,47E+01	1,31E+01	1,09E+01	8,45E+00	
CUM, (GR/ACF) SMALLER THAN D50	3,43E-03	3,04E-03	2,81E-03	2,57E-03	2,30E-03	1,91E-03	1,48E-03	
CUM, (GR/DNCF) SMALLER THAN D50	8,55E-03	7,58E-03	7,00E-03	6,41E-03	5,73E-03	4,76E-03	3,69E-03	
GEO, MEAN DIA, (MICROMETERS)	2,08E+01	3,06E+00	1,57E+00	1,01E+00	6,48E-01	3,74E-01	1,92E-01	8,64E-02
DM/DLOGD (MG/DNCM)	9,77E-01	7,50E+00	4,69E+00	1,39E+01	5,34E+00	1,20E+01	6,20E+00	2,81E+01
DN/DLOGD (NO, PARTICLES/DNCM)	5,83E+04	1,39E+08	6,48E+08	7,13E+09	1,05E+10	1,22E+11	4,66E+11	2,33E+13

NORMAL (ENGINEERING STANDARD) CONDITIONS ARE 21 DEG C AND 760MM HG,

TABLE 27.

0-38 07-10-76 0635 3PORT

IMPACTOR FLOWRATE = 0,066 ACFM   IMPACTOR TEMPERATURE = 615,0 F = 323,9 C   SAMPLING DURATION = 60,00 MIN

IMPACTOR PRESSURE DROP = 3,2 IN, OF HG   STACK TEMPERATURE = 615,0 F = 323,9 C

ASSUMED PARTICLE DENSITY = 1,00 GM/CU,CM,   STACK PRESSURE = 28,28 IN, OF HG   MAX, PARTICLE DIAMETER = 189,2 MICROMETERS

GAS COMPOSITION (PERCENT)   CO2 = 6,40   CO = 0,00   N2 = 71,36   O2 = 5,50   H2O = 15,00

CALC, MASS LOADING = 3,6632E-03 GR/ACF   9,1329E-03 GR/DNCF   8,3828E+00 MG/ACM   2,0899E+01 MG/DNCM

IMPACTOR STAGE	S0	S1	S2	S3	S4	S5	S6	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	8,30	4,27	2,28	1,86	1,02	0,71	0,34	
MASS (MILLIGRAMS)	0,06	0,10	0,06	0,06	0,07	0,10	0,11	0,38
MG/DNCM/STAGE	1,33E+00	2,22E+00	1,33E+00	1,33E+00	1,56E+00	2,22E+00	2,45E+00	8,45E+00
CUM, PERCENT OF MASS SMALLER THAN D50	1,00E+02	9,36E+01	8,30E+01	7,66E+01	7,02E+01	6,28E+01	5,21E+01	
CUM, (MG/ACM) SMALLER THAN D50	7,85E+00	6,96E+00	6,42E+00	5,89E+00	5,26E+00	4,37E+00	3,39E+00	
CUM, (MG/DNCM) SMALLER THAN D50	1,96E+01	1,73E+01	1,60E+01	1,47E+01	1,31E+01	1,09E+01	8,45E+00	
CUM, (GR/ACF) SMALLER THAN D50	3,43E-03	3,04E-03	2,81E-03	2,57E-03	2,30E-03	1,91E-03	1,48E-03	
CUM, (GR/DNCF) SMALLER THAN D50	8,55E-03	7,58E-03	7,00E-03	6,41E-03	5,73E-03	4,76E-03	3,69E-03	
GEO, MEAN DIA, (MICROMETERS)	3,96E+01	5,95E+00	3,12E+00	2,06E+00	1,38E+00	8,51E-01	4,91E-01	2,41E-01
DM/DLOGD (MG/DNCM)	9,82E-01	7,69E+00	4,92E+00	1,49E+01	5,96E+00	1,42E+01	7,65E+00	2,81E+01
DN/DLOGD (NO, PARTICLES/DNCM)	3,01E+04	6,97E+07	3,09E+08	3,25E+09	4,37E+09	4,40E+10	1,23E+11	3,85E+12

NORMAL (ENGINEERING STANDARD) CONDITIONS ARE 21 DEG C AND 760MM HG.

STOP 000000

REFERENCES

1. Tayler, Paul L., Characterization of Copper Smelter Flue Dust, APCA Paper 76-24.3, presented at the 1976 Annual Meeting of the Air Pollution Control Association.

2. Smith, Wallace B., et al, Particulate Sizing Techniques for Control Device Evaluation, Appendix A., U.S. Environmental Protection Agency Report EPA-650/2-74-102a prepared by Southern Research Institute under Contract No. 68-02-0273.

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15. SUPPLEMENTARY NOTES

Project Officer: John O. Burckle

16. ABSTRACT

This report describes tests to evaluate the performance of an electrostatic precipitator installed on a copper reverberatory furnace. Particle size measurements were made with modified Brink cascade impactors in order to calculate the ESP fractional efficiency. The particle size distributions at the inlet and outlet were both found to be bimodal. The overall mass median diameter of the inlet distribution was greater than 10 μm. The SRI-EPA computer model was used to simulate the ESP performance. Values of the mass collection efficiency were found by instack filters to be 96.7%, and by cascade impactors to be 96.6%. The computer model predicted an overall efficiency to be 96.8%, which is also the design efficiency. The particulate matter was found to be very cohesive and hygroscopic, and the composition (color) varied from impactor stage to stage. There was no evidence of electrical problems due to particle resistivity or space charge. Simultaneous testing was also carried out by Radian Corporation, Austin, Texas. Results of the Radian study are included in a report "Trace Element Study at a Primary Copper Smelter, Vol. I and II" (EPA-600/2-70-065a and - 065b, March 1978).

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Exhaust Emissions Smelting Trace Elements Pollution	Copper Smelter Reverberatory Furnace Particulate Emission Electrostatic Precipitator Field Test Fractional Efficiency	13B

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