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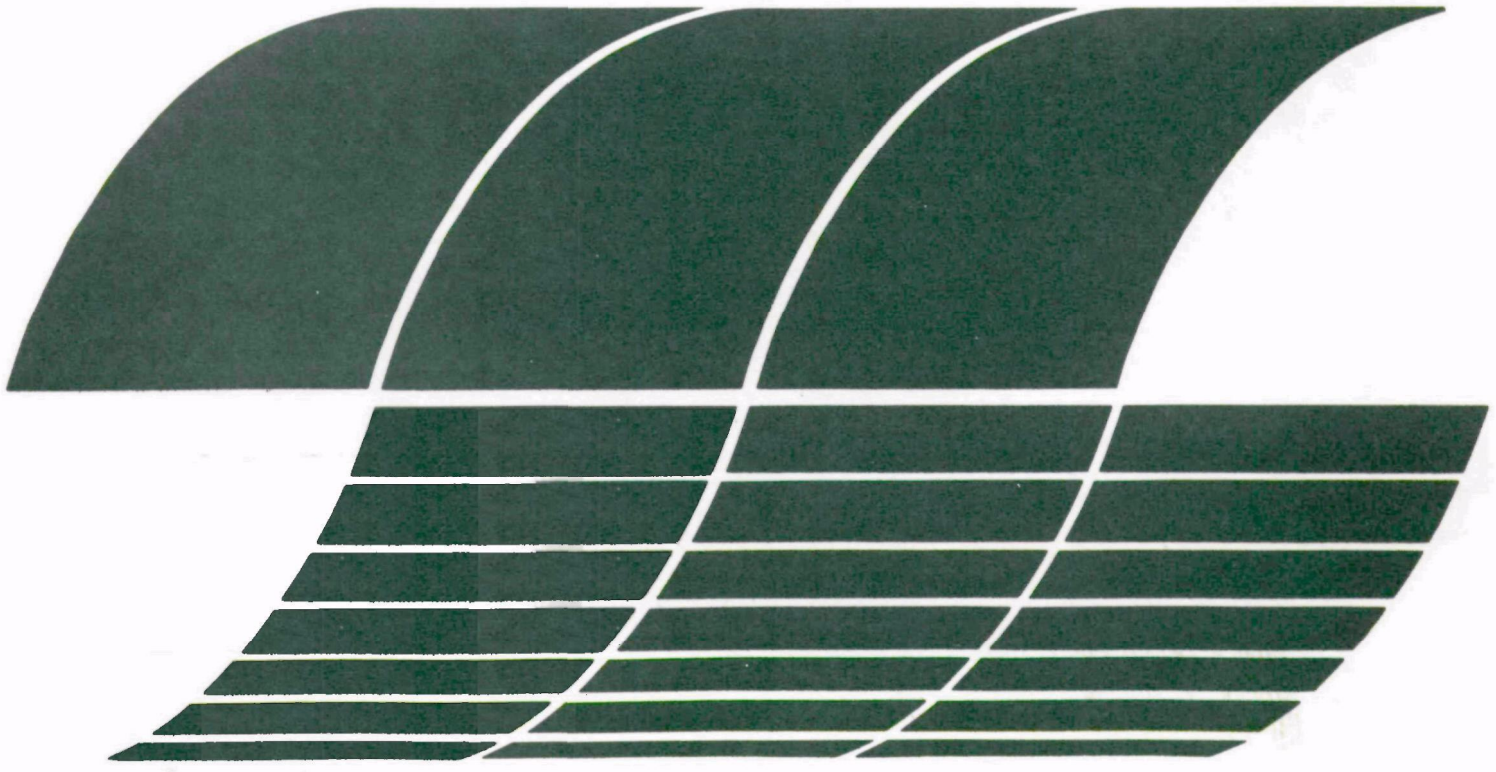
CEA Variable-Throat Venturi Scrubber Evaluation

Interagency Energy/Environment R&D Program Report



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CEA Variable-Throat Venturi Scrubber Evaluation

by

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SECTION I

CONCLUSIONS

This evaluation was one of a series of studies being conducted by the Industrial Environmental Research Laboratory of the Environmental Protection Agency to identify and test novel devices which are capable of high efficiency collection of particulates. The test methods used may not have been consistent with compliance-type methods, but were state-of-the-art techniques for measuring mass and fractional efficiency using standard mass train and inertial, electrical, and optical methods.

The overall collection efficiency of the CEA variable throat venturi scrubber, determined by conventional (Method 17) techniques on a pulverized coal fired power boiler producing particulate having a mass median diameter of about 20 μm, ranged from 99.12 to 99.50 during three days of testing. The venturi pressure drop ranged from 44.5 cm w.c. to 48.3 cm w.c. Measured fractional efficiencies were about 5% at 0.06 μm, 25% at 0.1 μm, 40% at 0.20 μm, 50% at 0.5 μm, 98.4% at 1.0 μm, and 99.99% at 2 μm. The system energy usage during the tests was approximately 7200 joules/DNCM. SO_2 collection efficiency ranged from 76.5% to 85.6%.

A comparison of the performance of the CEA scrubber with that of conventional scrubbers of various types is shown in Figure 14.

The results of this comparison indicate that the scrubber tested performed about the same as a well designed conventional venturi scrubber operating at the same pressure drop.

SECTION II

INTRODUCTION

This report presents results of tests conducted by Southern Research Institute to determine the capability of the C.E.A. variable throat venturi scrubber to collect fine particles. The goals of the tests were to determine the overall mass efficiency and the fractional efficiency of the scrubber when operating under normal conditions in controlling the emissions from a pulverized coal fired power boiler.

Figure 1 is a schematic of the power boiler and scrubber systems showing the inlet and outlet sampling locations. The tests were conducted on one of the three identical scrubber modules which are operated in parallel to control SO_2 and particulate emissions from the power boiler. The three modules are independently controlled with respect to liquor flows and venturi pressure drop. Pressure drops across the venturis are regulated by adjusting the position of the "plumb bob" shown in Figure 1, thereby increasing or decreasing the cross sectional area of the venturi throat. Throughout these tests, with the exception of one brief period, the pressure drop across the venturi on the module being tested was held at 46 ± 2 cm w.c.. Gas temperatures at the scrubber inlet ranged from 129°C to

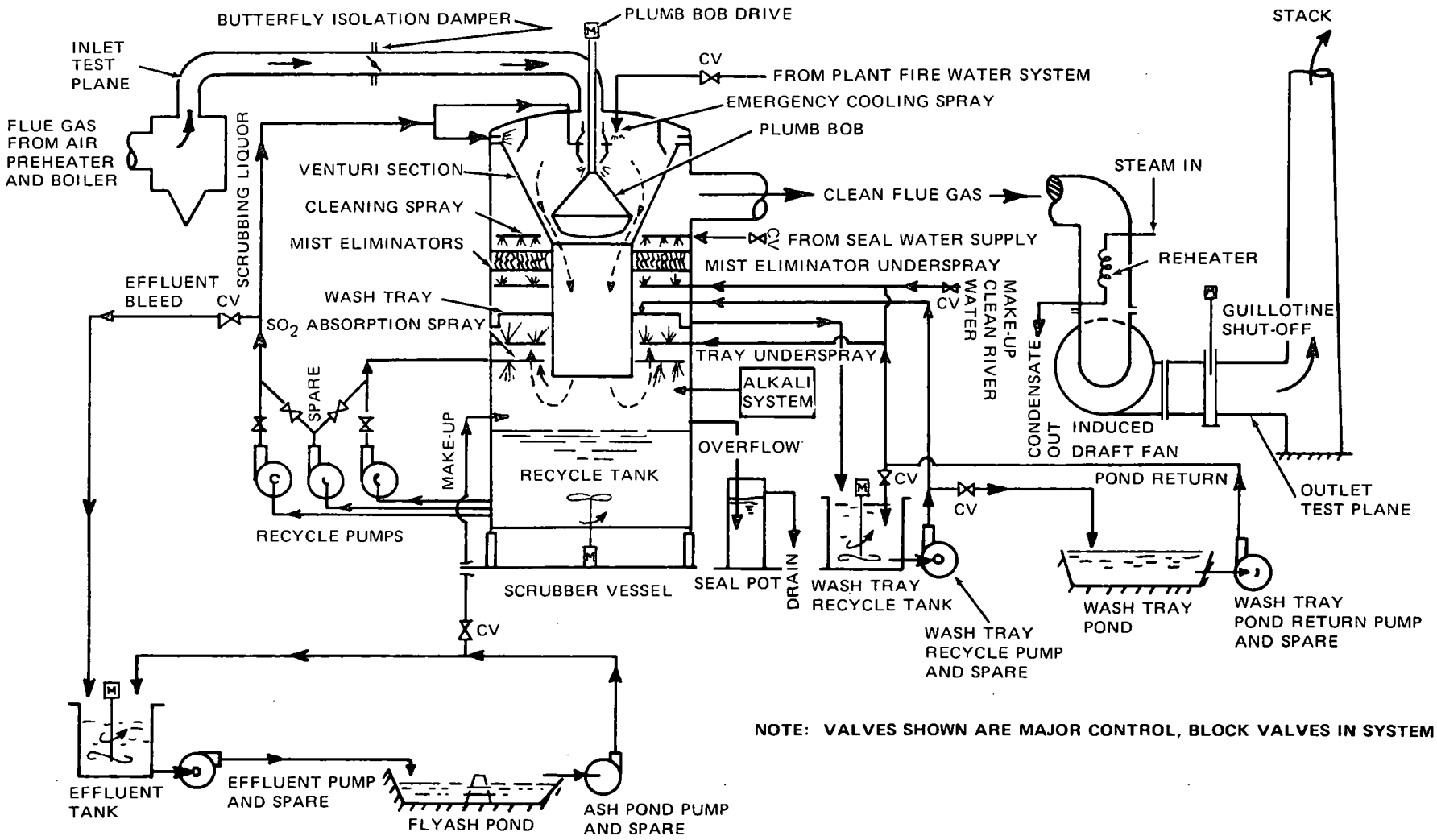

Figure 1. Simplified scrubber flow diagram.

137°C. The scrubber exit gas temperatures ranged from 57°C to 60°C and temperatures at the outlet test plane ranged from 94°C to 99°C. The temperature rise between the scrubber exit and the outlet mass sampling location results from a flue gas reheat system and the action of the fan, both of which are located between the scrubber outlet and the sampling plane. The gas flow handled by the scrubber throughout the tests was approximately 130 DNCM/sec (280,000 DSCFM).

Testing took place on May 17, 18, 19, and 20, 1977, with some preliminary testing on May 16. Except for a brief period on May 20, the unit was operated at relatively constant conditions of gas flow and pressure drop. A planned series of tests at other pressure drops was cancelled because of a forced shutdown of the unit being tested which resulted from malfunctions in the turbine and boiler.

SECTION III

DISCUSSION

A total of four measurement techniques were used during the tests. These were: (1) electrical mobility techniques using a Thermosystems Model 3030 Electrical Aerosol Analyzer for determining concentration and size distribution on a number basis for particles having sizes between 0.01 μm and 0.3 μm, (2) optical techniques to determine concentrations and size distributions for particles having diameters between approximately 0.5 μm and 2.0 μm, (3) inertial techniques using cascade impactors for determining concentrations and size distributions on a mass basis for particles having sizes between approximately 0.5 μm and 5.0 μm, and (4) standard mass train (Method 17) measurements for determining total inlet and outlet mass loadings and emission rates.

Description of the Scrubber

The scrubber, which was illustrated in Figure 1, is made up in a modular fashion with three modules required for treating the flue gases from each of the station's 360 MW units. Each module is comprised of a variable throat venturi section for particulate and sulfur dioxide collection followed by a spray type absorption section for further sulfur dioxide removal.

The spray type absorber is followed by a wash tray for reducing the concentration of suspended and dissolved solids in the entrained liquors and is followed in turn by a chevron type mist eliminator. A reheater is used between the scrubber and the induced draft fan to prevent condensation downstream of the scrubber, and to raise the temperature of the exhaust gases from the scrubber to that necessary for obtaining sufficient gas buoyancy for discharge through the stack. The venturi sections have a designed pressure drop range of 30.5 cm (12 in.) to 50.8 cm (20 in.) w.c. with a nominal operating pressure drop of 43 cm (17 in.) w.c.. Design L/G rates are 2.0 ℓ/m^3 (15 gal/1000 CF) in the venturi section and 2.41 ℓ/m^3 (18 gal/1000 CF) in the absorber section.

High alkali metal oxides content in the fly ash permitted the scrubber to be designed to use a recirculating slurry of flyash for SO_2 removal. The system operates with a slurry having a pH of 5.0 to 5.6 containing 12 percent solids by weight. The pH is controlled by the addition of small amounts of lime as required. The scrubber design parameters are given in Table 1. A more complete description of the scrubber is given in Appendix A.

Table 1

Design Parameters For The CEA Variable Throat Venturi Scrubber
(Colstrip Application)

Venturi Pressure Drop	43.2 cm w.c. (17 in.)
Venturi L/G	2 ℓ/m (15 gal/1000 ACF, saturated)
Absorption Spray L/G	2.41 ℓ/m (18 gal/1000 ACF, saturated)
% suspended solids in recirculating slurry, by weight	12%
Residence time in the recycle tank	8 minutes
Gas velocity in mist eliminator zone	2.65 m/sec (8.7 ft/sec)
Wash tray pressure drop	9.65 cm w.c. (3.8 in.)
Mist eliminator pressure drop	2.5 cm w.c. (1 in.)
Reheat pressure drop	5.6 cm w.c. (2.2 in.)
Total system pressure drop (including reheat)	64.8 cm w.c. (25.5 in.)
Total scrubber pressure drop (less reheat)	55.4 cm w.c. (21.8 in.)

Method 17 Results and Overall Collection Efficiencies

Method 17 data were obtained on four days of testing with the first days' test intended as a preliminary run rather than an actual data run. However, the preliminary run data appears to be sufficiently useful as to warrant its inclusion in this report. Including the preliminary run, a total of 6 pairs of inlet and outlet tests were performed.

The data obtained by Method 17 are summarized in Tables 2 and 3. The overall collection efficiencies for each of the pairs of tests are given in Table 4. Two values are shown for the outlet mass loadings for tests 3, 4, 5, and 6 in Table 3 and for the efficiencies calculated for those tests in Table 4. The reasons for the two sets of values are based on the information contained in Table 5, which shows the values for the particulate catches in the outlet Method 17 data and corresponding outlet impactor data. The catch data for each run is broken down into two components, the material caught in the nozzle and that which passed through the nozzle and was caught downstream of it.

The Method 17 runs and the impactor runs were made using virtually identical "buttonhook" nozzles and at very nearly the same flow rates (isokinetic at all points for the Method 17 runs and near isokinetic fixed flow rates for the impactor runs). The sampling times differed slightly; most of the Method 17 times were 96 min while most of the impactor sampling times were 80 minutes. Note that the weights for the material caught downstream of the

Table 2

CEA Variable Throat Venturi Test
Inlet Mass Data

Run Number	1*	2*	3	4	5	6**
Date	5-16-77	5-17-77	5-18-77	5-18-77	5-19-77	5-19-77
Time	1715	1455	1235	1545	0825	1245
Moisture, %	10.30	11.62	10.25	10.87	11.86	12.26
Gas Temperature, °C	134	132	129	129	137	133
°F	274	269	265	264	278	272
Volumetric Flow, m^3/sec	208.6	201.3	233.9	236.9	238.8	227.6
ACFM	442,000	426,500	495,500	502,000	506,000	482,300
Volumetric Flow, DNCM/s	116.5	110.3	131.9	132.9	130.1	124.4
DSCFM	247,700	233,600	279,500	281,500	275,600	263,500
Concentration, grams/ACM	2.0184	2.8325	3.3097	3.4820	3.5145	3.5829
Concentration, grams/DNCM	3.6145	5.1701	5.8663	6.2079	6.4512	6.5546
Isokinetic, %	107.62	105.85	104.23	108.62	103.79	103.56

* Used points for 10 ft. stack
**Test cut short by 3 points (6 minutes) due to boiler shutdown.

Table 3

CEA Variable Throat Venturi
Outlet Mass Train Data

Run Number	1*	2	3	4	5	6
Data	5-16-77	5-17-77	5-18-77	5-18-77	5-19-77	5-19-77
Time	1700	1315		1500	0830	1300
Moisture, %	14.01	19.45	17.37	16.53	18.70	18.15
Gas Temperature,						
°C	99.4	94.4	96.1	96.1	96.1	96.1
°F	211	202	205	205	205	205
Volumetric						
Flow, M^3/s	194.9	224.8	238.9	273.8	237.8	239.3
ACFM	413,000	476,200	506,200	579,300	503,800	507,000
Volumetric						
Flow, DNM^3/s	118.4	128.4	140.0	162.1	137.3	139.3
DSCFM	250,800	171,100	196,700	343,500	290,900	295,200
Concentration,						
mg/ACM Raw	26.09	25.86	75.97	63.39	68.42	44.62
Corrected**	26.09	25.86	19.66	21.52	24.23	19.23
Concentration,						
mg/DNCM Raw	42.79	45.31	129.75	106.87	118.31	76.66
Corrected**	42.79	45.31	33.58	36.28	41.90	33.04
Isokinetic, %	105.71	113.99	106.40	106.76	103.91	104.66

* Nozzle changed in middle of test. One traverse point omitted.
**For explanation of corrected concentrations see text.

Table 4

CEA Variable Throat Venturi Scrubber Efficiencies From Mass Train Data

Run No.	Date	Efficiency (%)	Revised** Efficiency (%)
1*	5-16-77	98.82	98.82
2*	5-17-77	99.12	99.12
3	5-18-77	97.79	99.43
4	5-18-77	98.28	99.42
5	5-19-77	97.18	99.35
6	5-19-77	98.83	99.50

* Calculated efficiencies for runs 1 and 2 are probably not reliable because of the sampling errors noted in Tables 2 and 3.

**For explanation of revised efficiencies see text.

Table 5

Comparison Of Mass Train and Impactor Catches
(All catch weights in milligrams, adjusted to equal sampling times)

Date	16	17	18	19	20
Item	Catch Weight				
Method 17 Nozzle	.37	1.52	59.53 50.99	45.65 26.99	
Impactor Nozzle		2.74 2.58 6.81	3.66 1.83 2.15	0.44 0.55 1.27	0.67 0.27 1.61
Method 17 Filter	31.6	25.6	19.5 24.7	23.4 18.7	
Impactor Substrates and Filter	29.56	14.83 38.64 52.41	14.60 21.43 22.52	16.28 17.78 19.97	17.71 14.62 20.51

nozzles are quite consistent for each system and are rather close in average value when adjusted to the same sampling time. Furthermore, the nozzle catch weights for the impactors were consistently about 0.5 to 3.0 mg. This agrees well with the Method 17 nozzle catch weights for the first two days of sampling. On the other hand, the nozzle catch weights for the Method 17 runs on the third and fourth days of testing were very much higher than those of the impactors and the previous two days' Method 17 results.

It was thus concluded that the nozzle washes for the Method 17 tests on the third and fourth days of testing were somehow contaminated and that they should be omitted from the analysis. The corrected Method 17 results and the corrected overall mass efficiencies shown in Tables 2 and 4 are based on the Method 17 filter catches to which nominal nozzle catch weights have been added. These nominal nozzle catch weights were based on the impactor nozzle catch weights. These corrected results are believed to be fairly reliable values of the Method 17 outlet tests. The overall collection efficiency of the scrubber on this source under the conditions of operation tested is thus found to be approximately 99.4 percent.

Although the total combined emissions from the three scrubber modules used for SO_x and particulate removal from the Unit 1 flue gases were not measured, estimates of these emissions can be made by assuming that the three modules were performing identically and were processing equal gas volumes. If these

assumptions are made one can estimate the particulate emissions in terms of pounds of particulate per million BTU thermal input. Such estimates were made for the data from the tests on 5/17, 5/18 and 5/19 and the results are shown in Table 6.

Cascade Impactor Results

Inertial sizing was accomplished using modified Brink impactors for inlet measurements and University of Washington Mark III impactors for outlet measurements. Sampling was done in both cases at near isokinetic flow rates, thus errors due to deviations from isokinetic sampling should be of little consequence. All impactors used in this program were calibrated at SoRI using the methods described in EPA publications 600/2-76-280 and 600/2-77-004.

The impactor data are summarized in Figures 2 through 8. Figures 2 and 3 present averaged inlet and outlet size distributions, respectively, on a cumulative percentage (by mass) basis versus aerodynamic particle diameter. Figures 4 and 5 show the same data on a cumulative mass concentration basis and Figures 6 and 7 show the data on a differential mass basis. Figure 8 shows the fractional efficiency curve as a function of aerodynamic particle diameter as derived from the inlet and outlet data that were presented in the previous figures. The fractional efficiency curve is shown in the following section as a function of Stoke's diameter together with the efficiency curves derived

Table 6

Estimated Particulate Emissions, lbs/MMBTU

Date	Unit Load MW	MMBTU/hour	Module C Gas Flow DSCFM	Corrected* Mass Loading, grains/DSCF	Emissions lbs/hour Module C	Combined Estimated Total Emissions, lbs/hour (=3x module c emissions)	Total Emissions, lb/MMBTU
5/17	330	3100	272000	0.0198	46.16	138.5	0.045
5/18	350	3290	297000	0.0147	37.42	112.3	0.034
5/18	355	3340	343000	0.0159	46.75	140.2	0.042
5/19	355	3340	291000	0.0183	45.65	136.9	0.041
5/19	355	3340	295000	0.0144	36.41	109.2	0.033

*For explanation of corrected mass loadings see text.

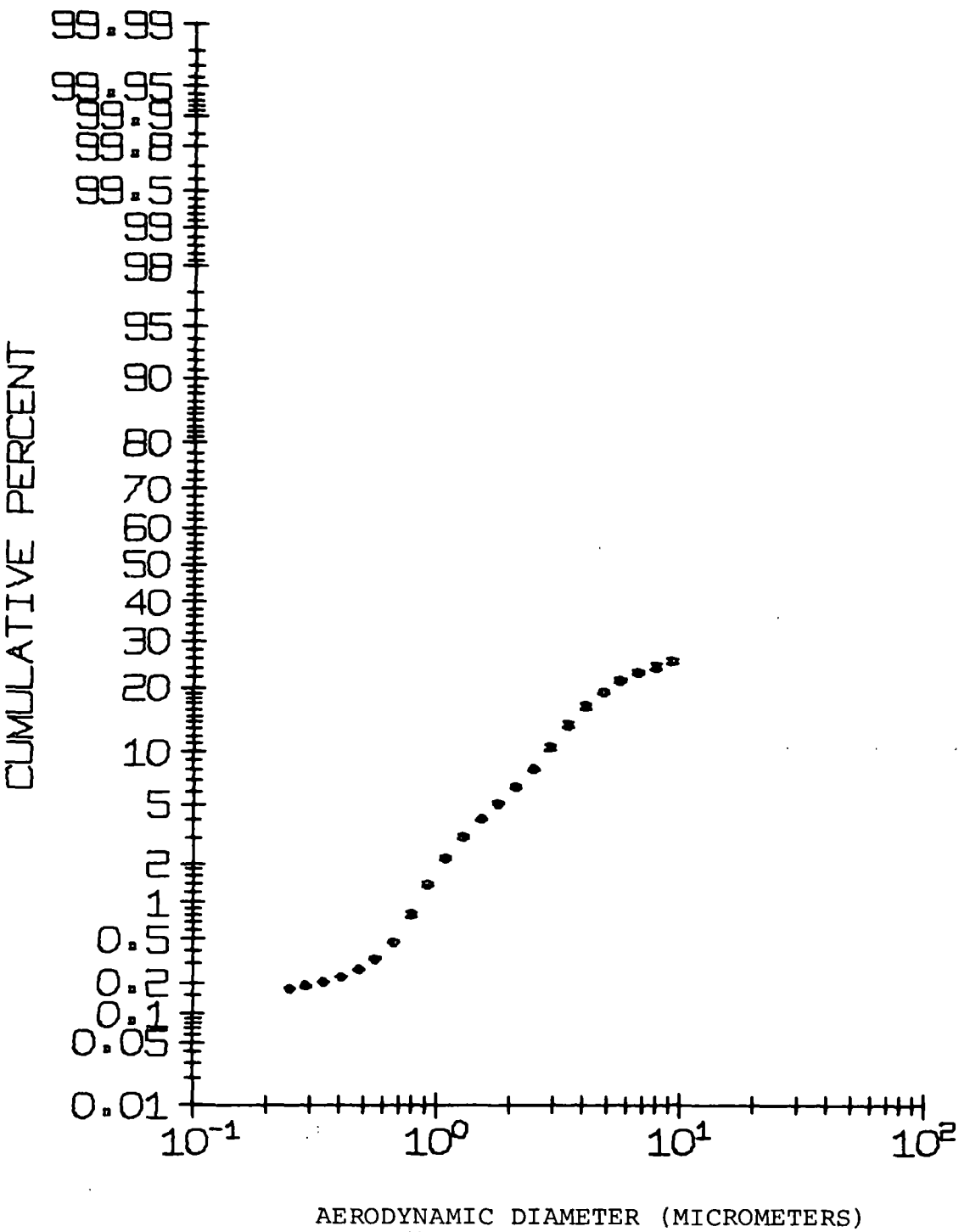

Figure 2. Average inlet particle size distribution from cascade impactor data on a cumulative percent by mass basis.

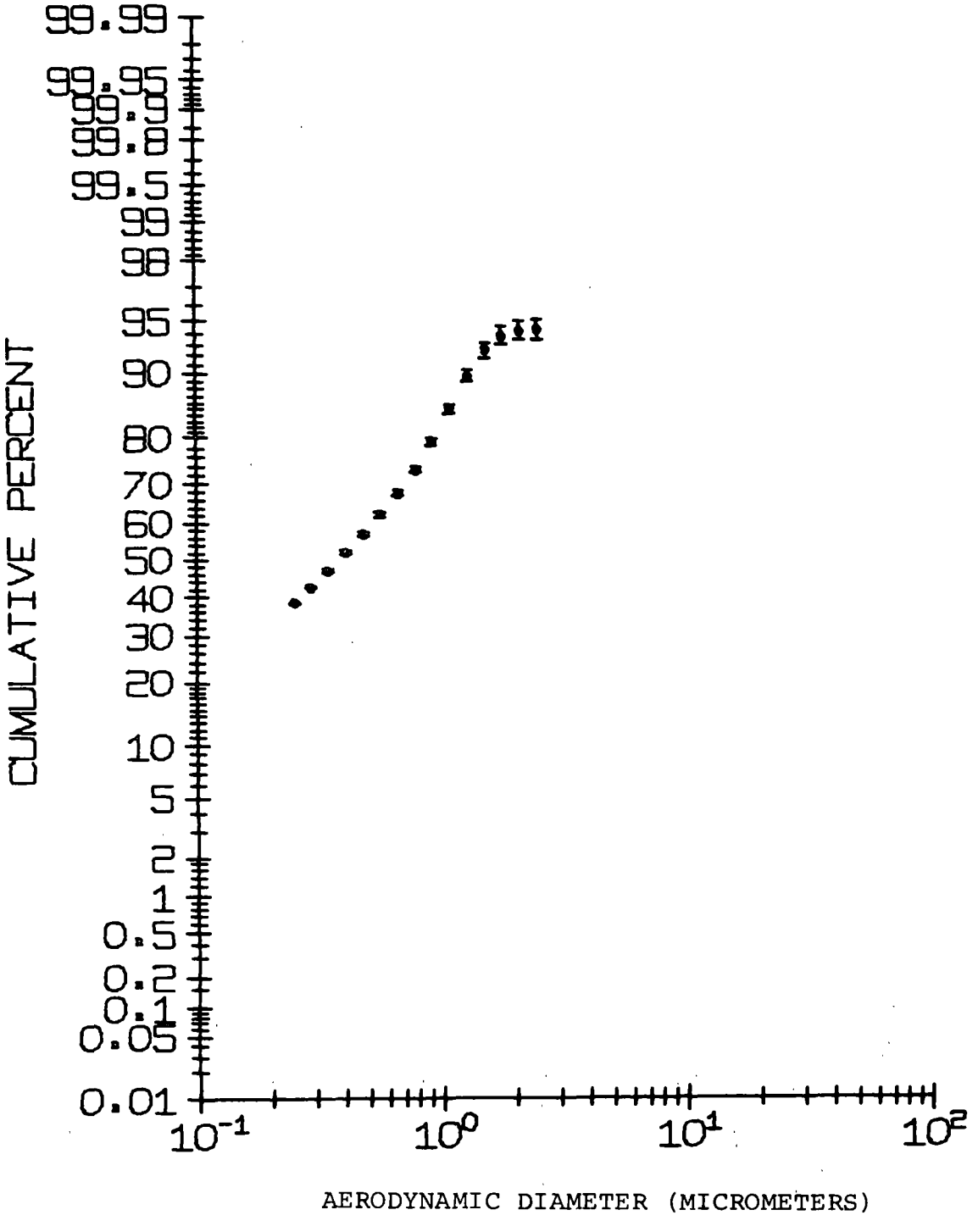

Figure 3. Average outlet particle size distribution from cascade impactor data on a cumulative percent by mass basis.

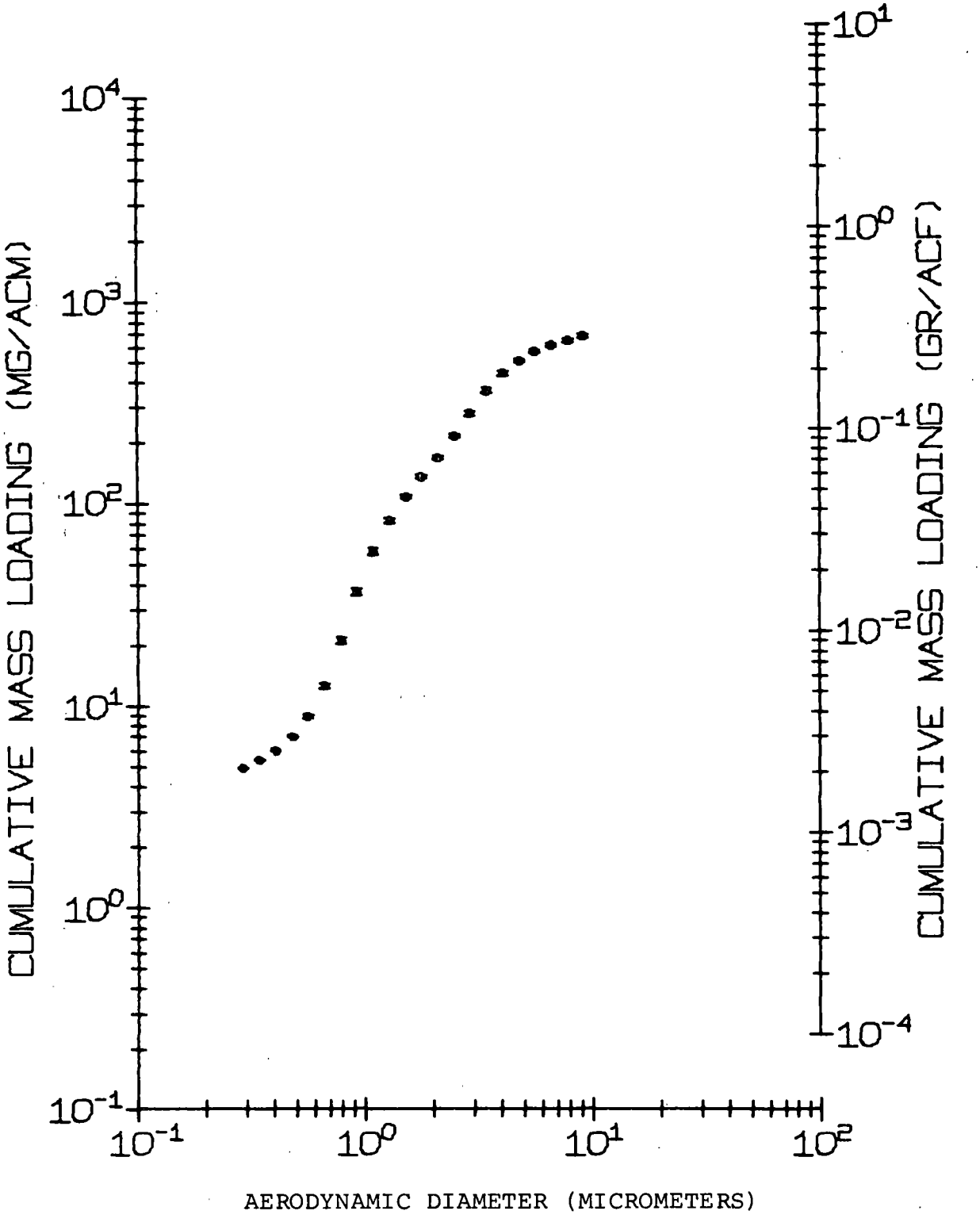

Figure 4. Average inlet particle size distribution on a cumulative mass concentration basis from cascade impactor data.

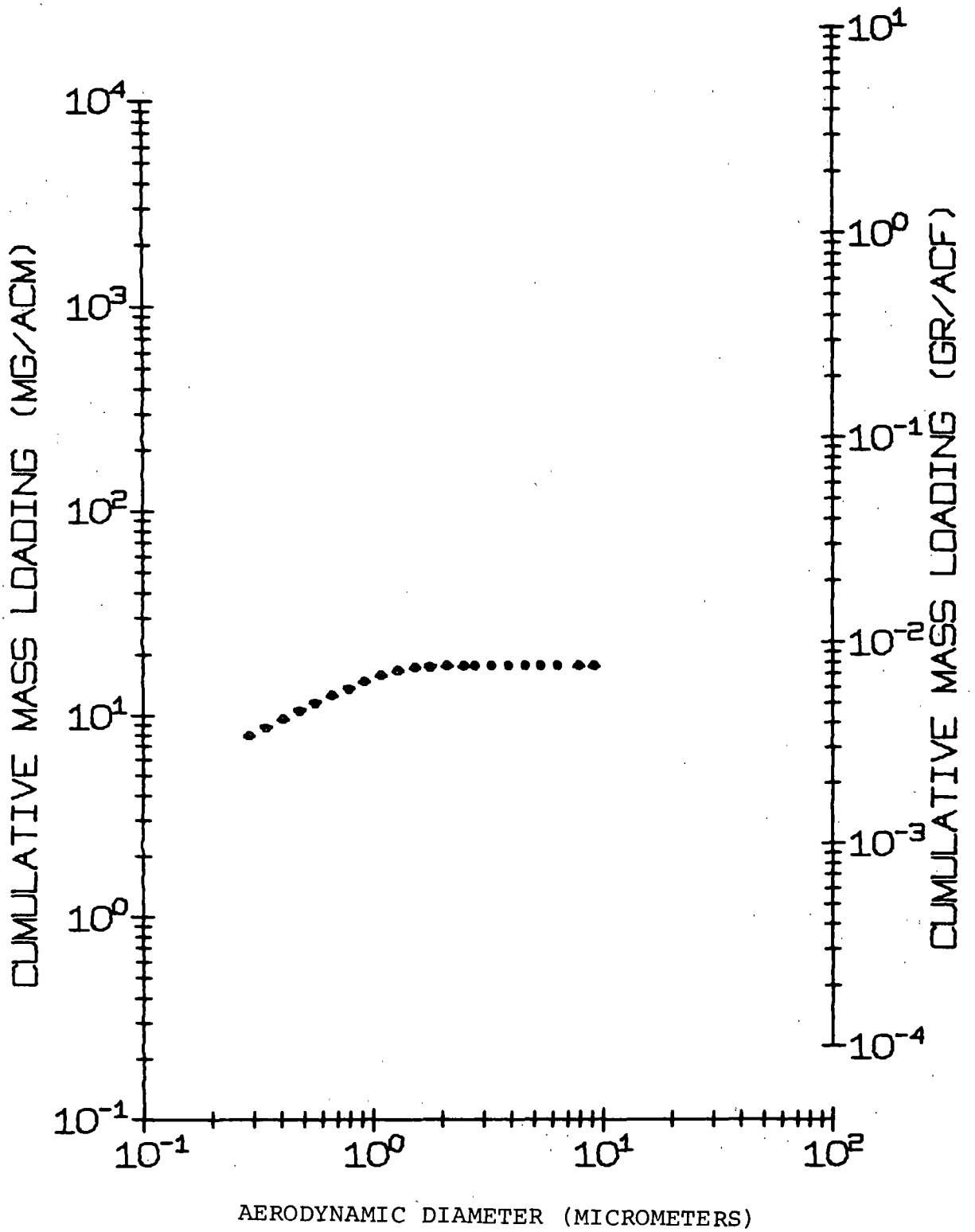

Figure 5. Average outlet particle size distribution on a cumulative mass concentration basis from cascade impactor data.

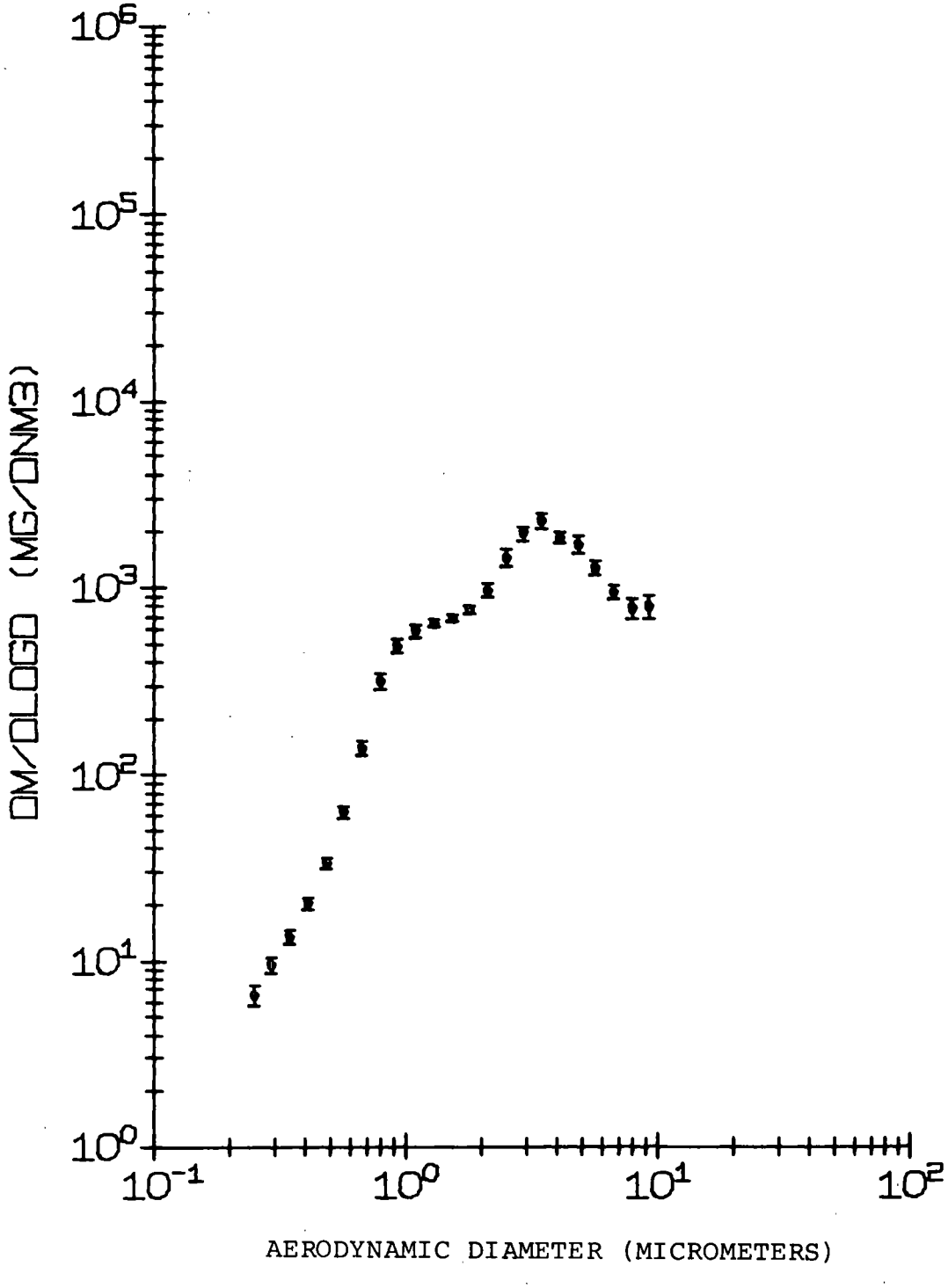

Figure 6. Average inlet particle size distribution on a differential mass basis from cascade impactor data.

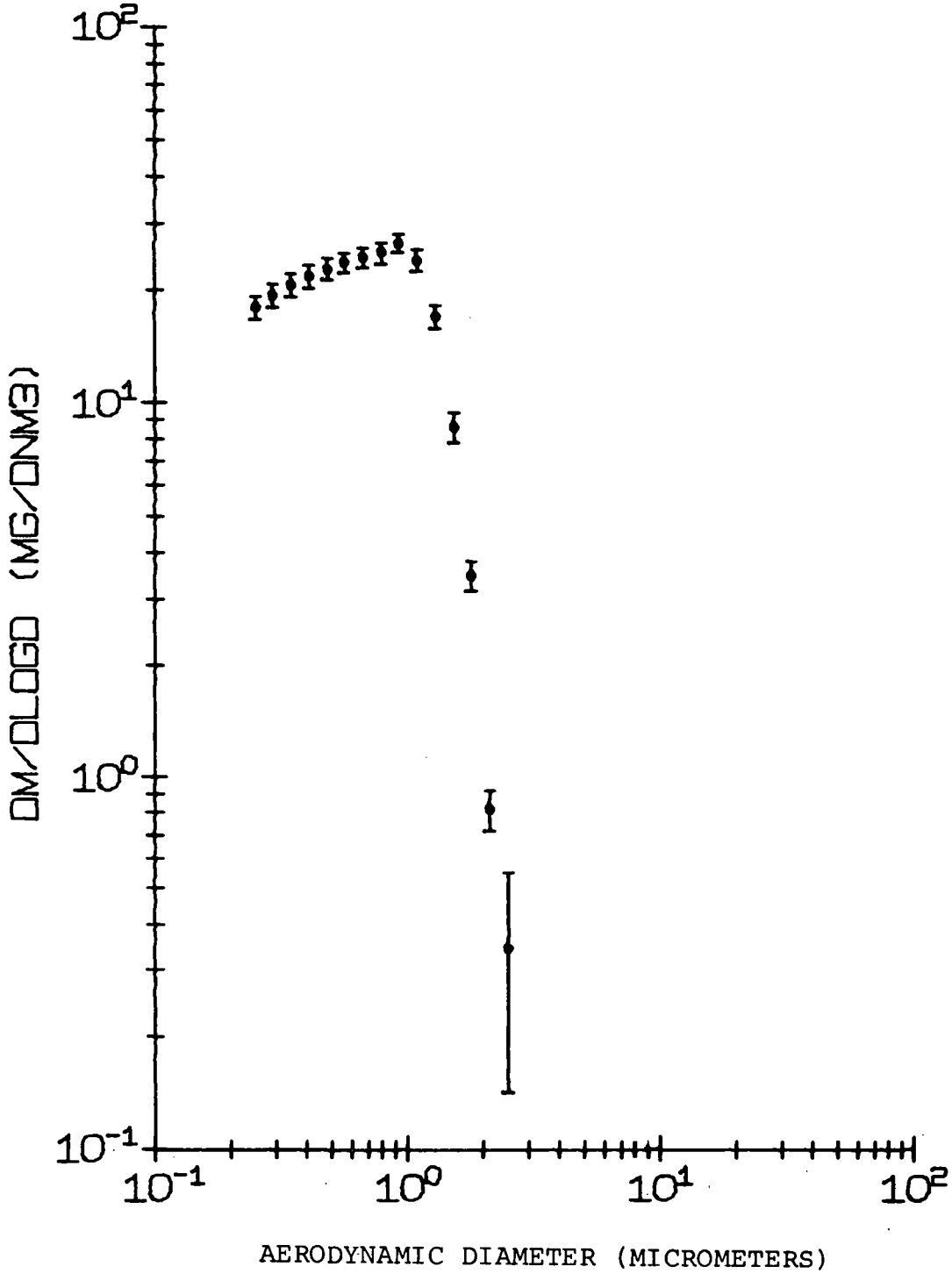

Figure 7. Average outlet particle size distribution on a differential mass basis from cascade impactor data.

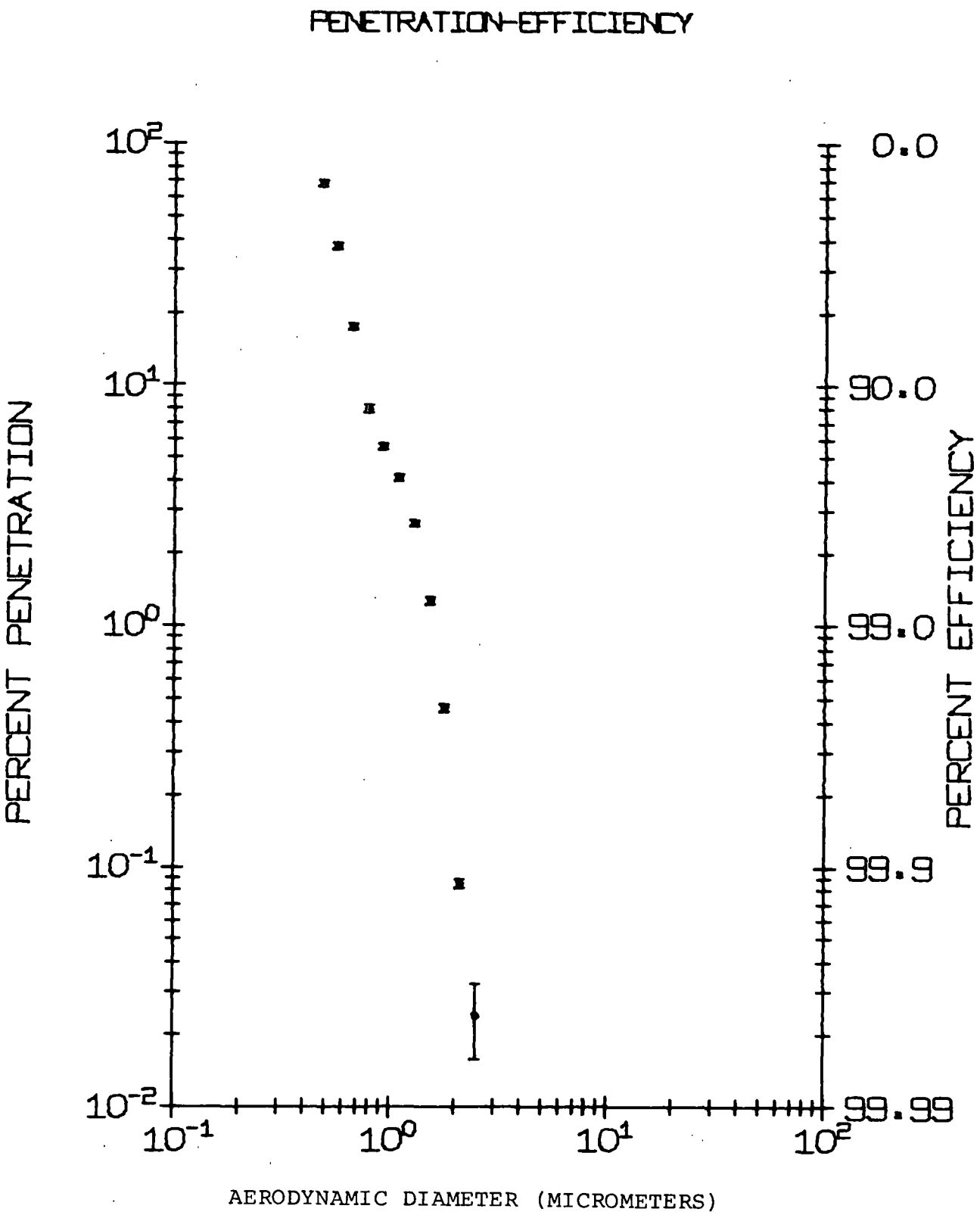

Figure 8. Fractional efficiency curve on an aerodynamic particle diameter basis for the CEA variable throat venturi scrubber operating at a venturi pressure drop of 48 cm (19 in.) w.c..

from the ultrafine particulate data. The scrubber was operating at a venturi pressure drop of about 48 cm w.c. throughout the impactor test periods.

Ultrafine Particulate Data

Measurements of the concentration and size distribution of ultrafine particulates were made using a Thermosystems Model 3030 Electrical Aerosol Analyzer (EAA) and a Royco Model 241 Optical Single Particle Counter.

The EAA provides size distribution and concentration data on a number basis for particles having diameters between approximately 0.01 μM and 0.3 μM. The optical counter provides similar data in the range from approximately 0.3 to 2 μM. Both instruments require extensive sample dilution and conditioning when used to sample flue gases. The sample extraction and dilution system used in these tests is described in a forthcoming EPA report on Contract 68-02-2114, Task VIII. Dilution factors of about 150:1 were used at both the inlet and outlet during these tests.

In order to insure that condensation effects were minimal, and that the particles were dry as measured, the diluent air was dried and filtered, and diffusional dryers were utilized in the lines carrying the diluted samples to the instruments.

Because only one set of instruments and dilution system was available it was not possible to obtain simultaneous inlet and outlet data for the ultrafine particulates. The system was first installed at the scrubber inlet and all inlet data was obtained on May 17. The equipment was then moved to the outlet and outlet data were obtained on May 19 and 20. For the purposes of calculating fractional efficiencies the assumption was made that the process was sufficiently stable that the inlet data, as obtained above, were a valid representation of that which would have obtained during the time the outlet measurements were made.

Inlet data were obtained with the optical counter in two size channels--0.35 to 0.60 μM and 0.60 to 2.0 μM. However, an instrument malfunction resulted in outlet data being obtained only in the 0.6 to 2.0 μM size interval with this method.

Inlet size distributions on a cumulative concentration by number basis are shown in Figure 9. Outlet size distributions on a similar basis are shown in Figure 10 for the normal scrubber operating condition (48 cm w.c. venturi pressure drop). Figure 11 shows the fractional efficiencies for ultrafine particles. Also shown in Figure 11 are the fractional efficiencies as a function of Stoke's diameter, obtained from the impactor data.

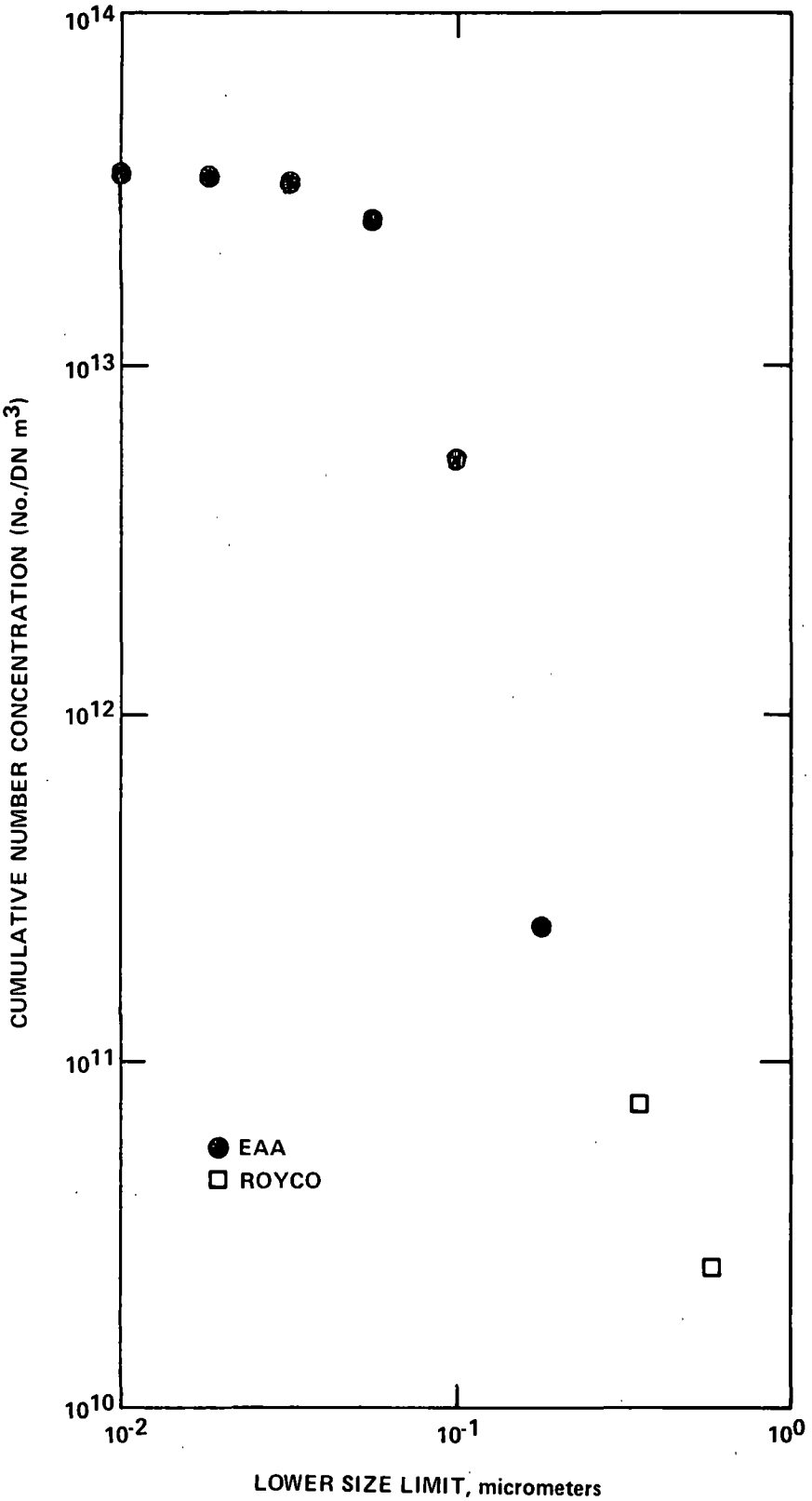

Figure 9. Scrubber inlet particle size distribution from electrical aerosol analyser and Royco optical particle counter data.

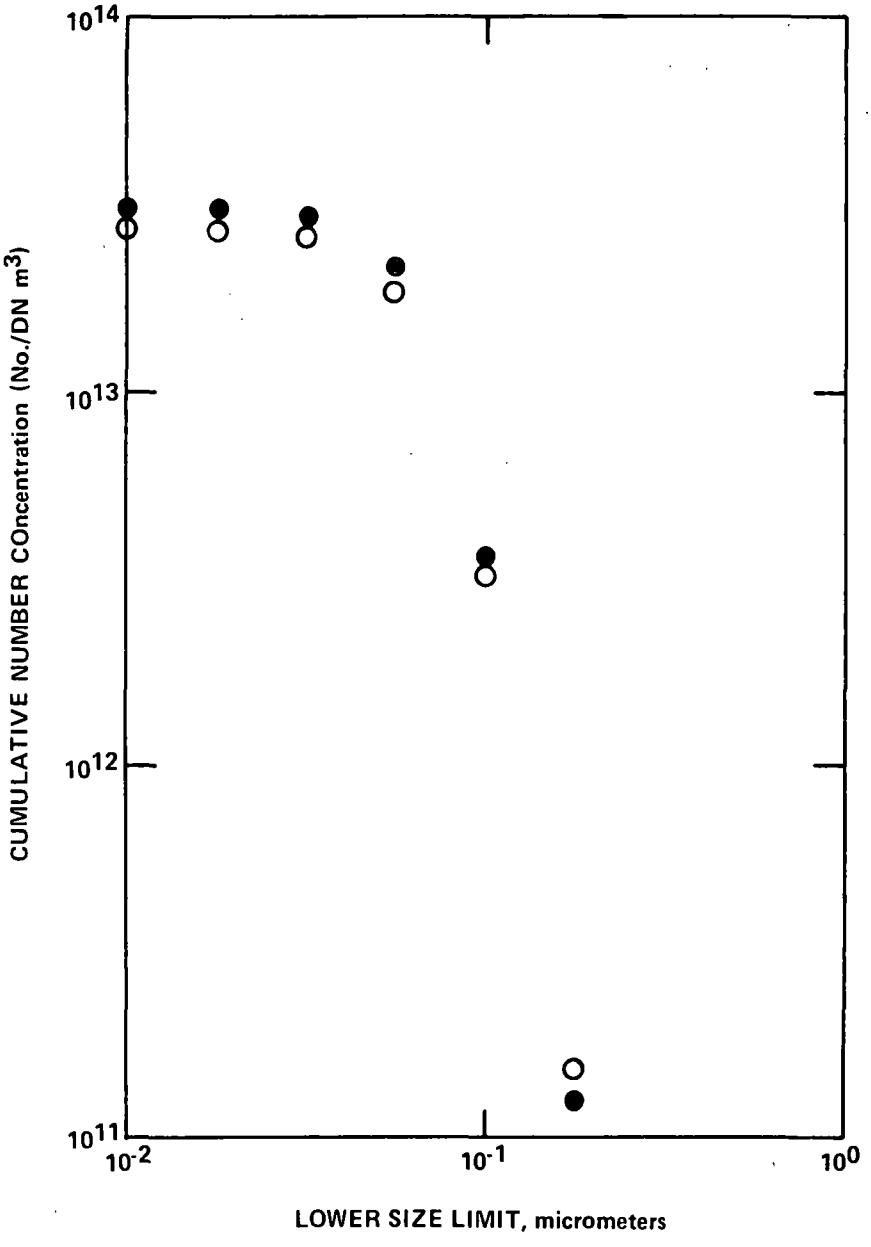

Figure 10. Scrubber outlet particle size distribution from electrical aerosol analyser data.

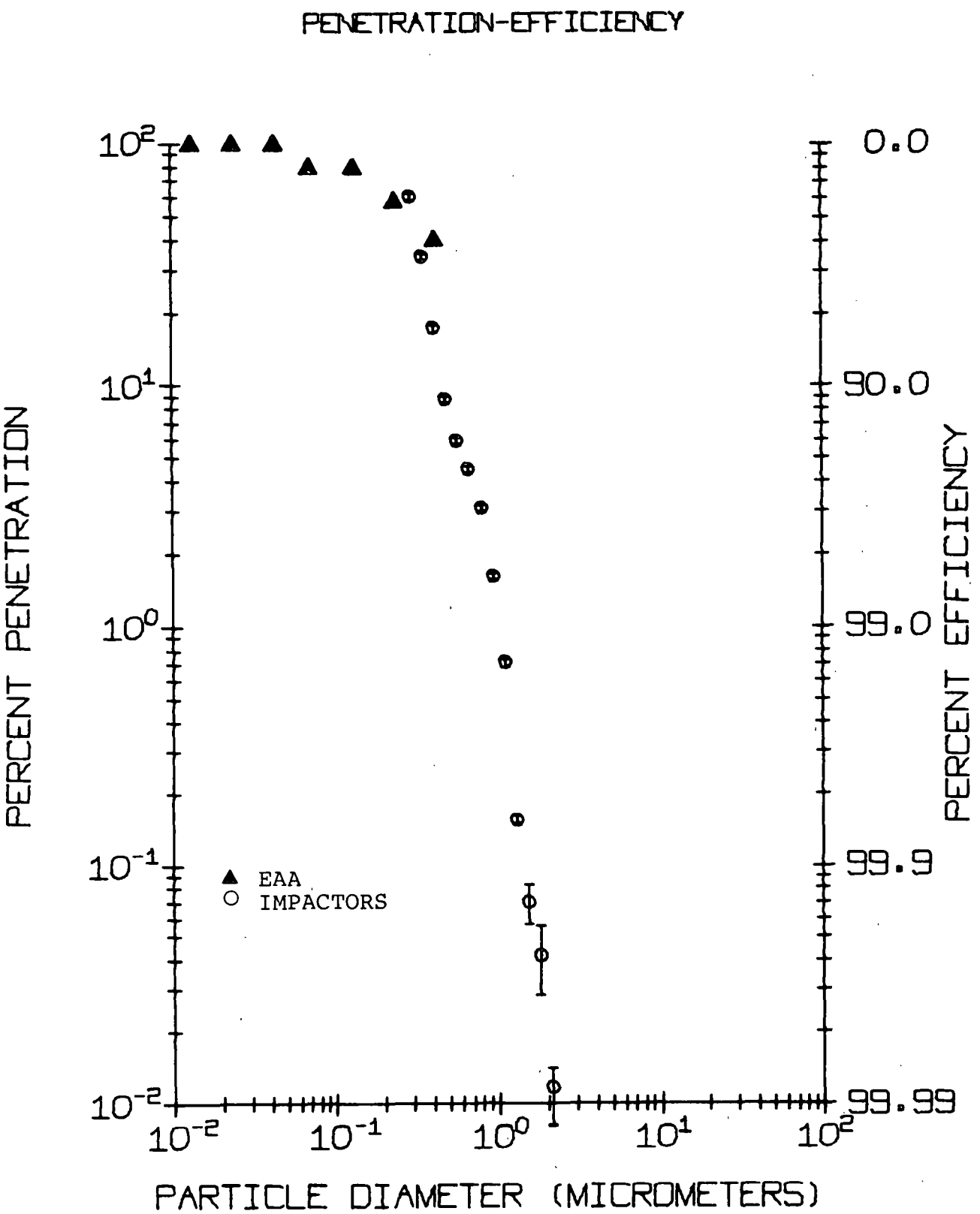

Figure 11. Fractional efficiencies based on electrical mobility and optical methods shown on a "physical" diameter basis. Also shown are fractional efficiencies from the cascade impactor data on a basis of Stoke 's diameters.

The scrubber was operated at venturi pressure drops of 31, 36, 41, 46, and 51 cm w.c. for a brief period at each condition on May 21, during which time the outlet concentrations were monitored with the EAA and the optical counter. No significant concentration changes were noted in the EAA data over this range of pressure drops, however, the optical counter data did show significant changes. In the 2 μM to 4 μM size interval, a 50% reduction in concentration was obtained by increasing the venturi pressure drop from 31 to 51 cm w.c. and a 35% reduction in concentration occurred in the 0.6 μm to 2.0 μm particle diameter range. These relative concentration changes are shown in Figure 12.

Stack gas opacity measurements of the combined effluent from the three parallel modules showed a dramatic reduction in opacity when the module C venturi pressure drop was taken up to 51 cm w.c. as illustrated in Figure 13. (Modules A and B were being operated at constant venturi pressure drops of 49 cm and 48 cm w.c., respectively during this time).

Table 7 summarizes the scrubber operating conditions throughout the test period. The liquid to gas ratio in the venturi portion of the scrubber during the tests was typically about 3.3 ℓ/DNCM.

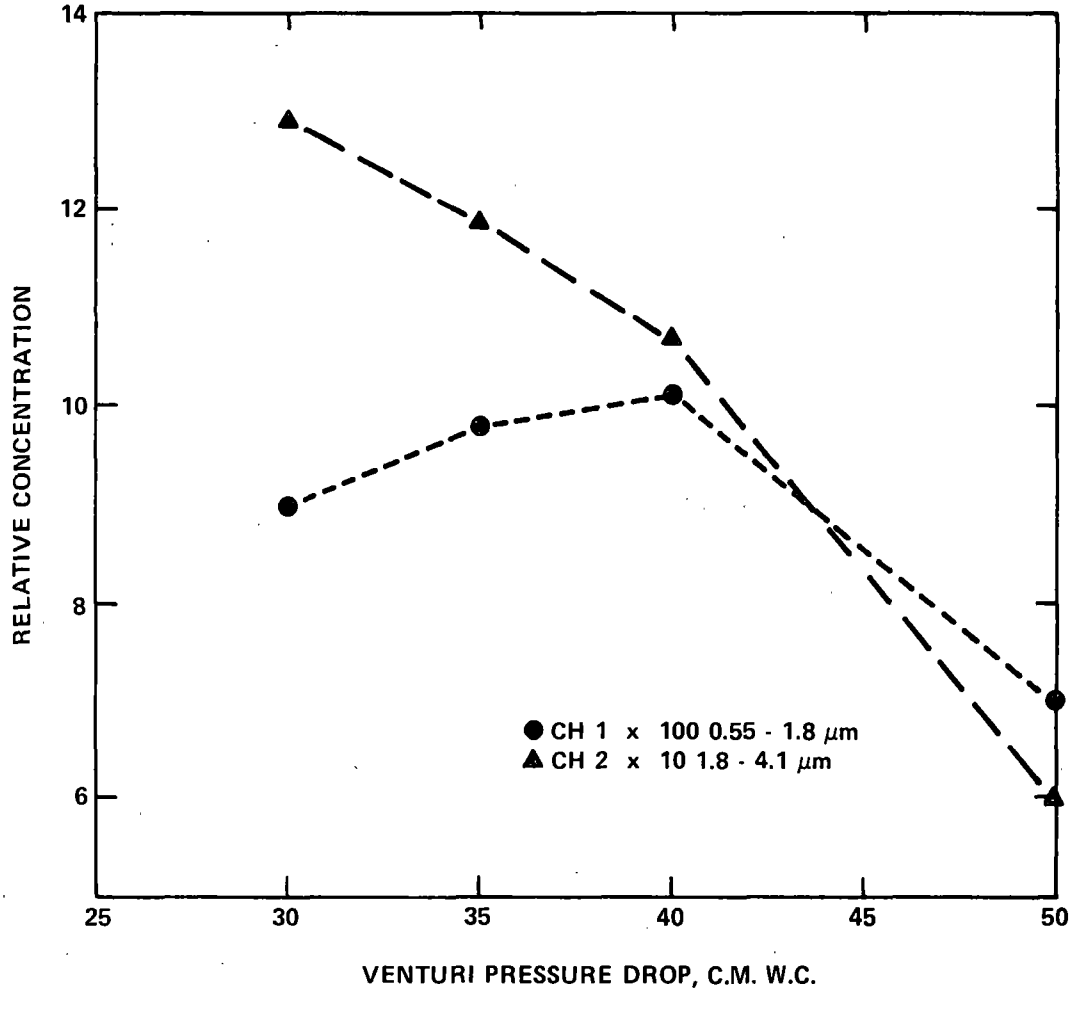

Figure 12. Relative outlet particulate concentrations in two size ranges as functions of venturi pressure drop.

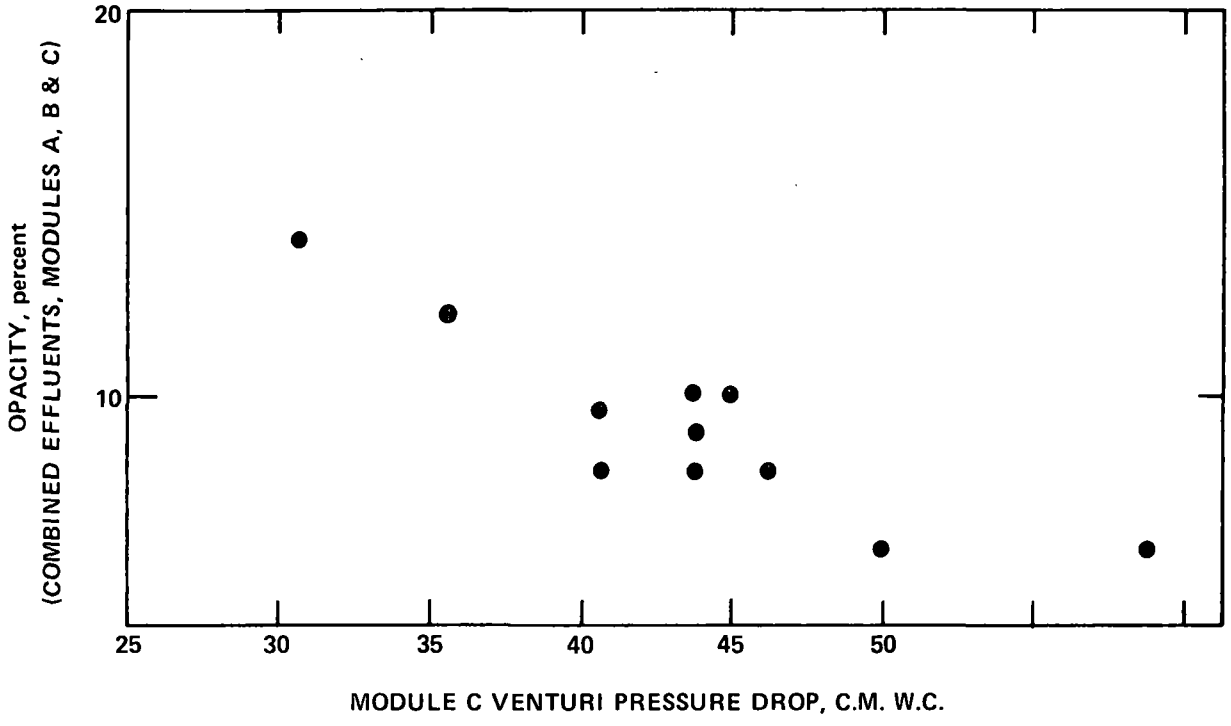

Figure 13. Opacity of combined emissions from three scrubber modules as a function of venturi pressure drop of one module with the remaining two modules operating at fixed pressure drops of approximately 48 cm W.C.

Table 7

Scrubber Operating Conditions

Date	Unit Load, MW	Measured Gas Flow, DNCM/s		Plumb Bob Position, % of Travel	Venturi Δ P, cm w.c.	Temperatures, °C				Liquor Flows, ℓpm					
		Inlet	Outlet			Scrubber Inlet	Scrubber Outlet	Reheat Outlet	Fan Outlet	Upper Spray	Middle Spray	Absorption Spray	Mist Film Under Spray	Wash Tray Under Spray	Wash Tray Feed
5/17	330	110	128	54	44.5	132	60	79	94	15900	10200	22700	570	1170	3600
5/18	350	132	140	58	46.4	129	58	78	96	15000	9370	24400	570	1060	2900
5/18	355	133	162	62	46.4	129	57	78	96	18200	11360	19870	570	1170	2800
5/19	355	130	137	61	46.4	131	59	78	96	17600	10790	24600	625	1170	3220
5/19	355	124	139	61	47.0	133	57	74	96	17500	10600	24200	625	1190	2840
5/20	290	(106)[1]	(113)[1]	53	45.7	129	56	82	93	17800	10600	25700	530	1170	3220
5/20	348	(127)[1]	(136)[1]	65	45.1	129	52	82	93	17600	11700	25000	570	950	3220

	Liquor pH	% Suspended Solids
5/17	4.3	11.4
5/18	4.7	15.2
5/18	4.7	16.4
5/19	4.7	14.3
5/19	4.6	13.4
5/20	N.A.	N.A.
5/20	N.A.	N.A.

[1]Based on partial traverse and scaling from previous days.

The performance of the CEA variable throat venturi scrubber is compared with the performance of several types of conventional scrubbers, including conventional venturi scrubbers, in Figure 14 using the "cut diameter" method described by Calvert (1974) J. APCA, 24:929. This method is based on the idea that the most significant single parameter to define the performance of a scrubber is the particle diameter for which the collection efficiency is 0.5 (50%).

SO_2 concentrations and collection efficiencies were also measured during the test program. Results of these measurements are given in Table 8, from which it can be seen that typically the SO_2 collection efficiency is about 80%.

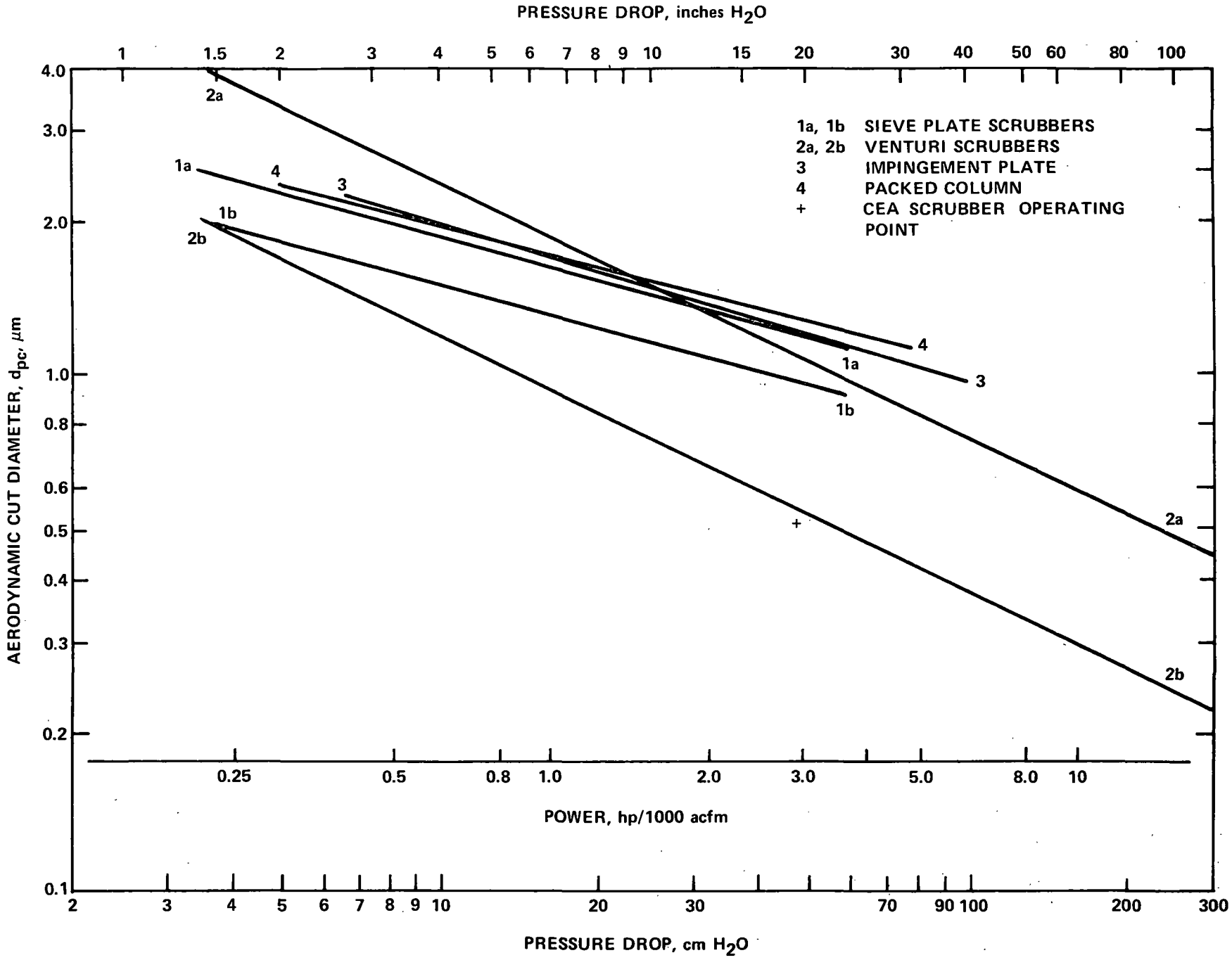

Figure 14. Comparison of the CEA variable throat venturi scrubber performance with that of other conventional scrubbers, after Calvert (1974) JAPCA 24:929.

Table 8

Colstrip Power Plant
Scrubber SO_2 Removal Efficiency

Date	Inlet SO_2 Concentration (ppm)	Reheater Outlet SO_2 Concentration (ppm)	SO_2 Removal Efficiency (%)
5-17-77	658	130	80.2
5-18-77	525	103	80.4
5-19-77	553	130	76.5
5-20-77	625	90	85.6

APPENDIX A

MANUFACTURER'S DESCRIPTION OF SCRUBBER OPERATION

APPENDIX A. DESCRIPTION OF THE CEA VARIABLE THROAT VENTURI SCRUBBER: COLSTRIP FLUE GAS CLEANING SYSTEM*

The flue gas cleaning system (Figure 1) now in operation on the two Colstrip 360 MW units is unique in that a wet scrubbing system is used for both particulate and SO_2 control and captured ash provides the alkalinity for the SO_2 removal.

The system currently installed on the two 360 MW Units 1 and 2 is illustrated in Figures A1 and A2. The hot flue gas leaving the boiler is cooled in the heat recovery air heater and enters the flue gas scrubbing system at about 300°F. Each scrubber module, as shown in simplified drawing in Figure A2, consists of a downflow venturi scrubber centered within an upflow spray tower contactor. The venturi is equipped with a variable throat to maintain constant pressure drop at variable loads. In the venturi the scrubbing liquid is finely dispersed by the high velocity flue gas and serves to efficiently wet and trap the particulate fly ash. In the spray tower the gas contacts a recycle spray of absorption slurry. The slurry from the venturi and the spray contacter is collected and held in the base of the scrubber and recirculated at an L/G rate

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*Taken from a paper by C. Grimm, J. Z. Abrams, W. W. Leffmann, I. A. Raben, and C. Lamatia. Presented at the 1977 National Meeting of the AIChE.

THE MONTANA POWER CO. PUGET SOUND POWER & LIGHT
2 - 360 MW COLSTRIP UNITS 1 & 2

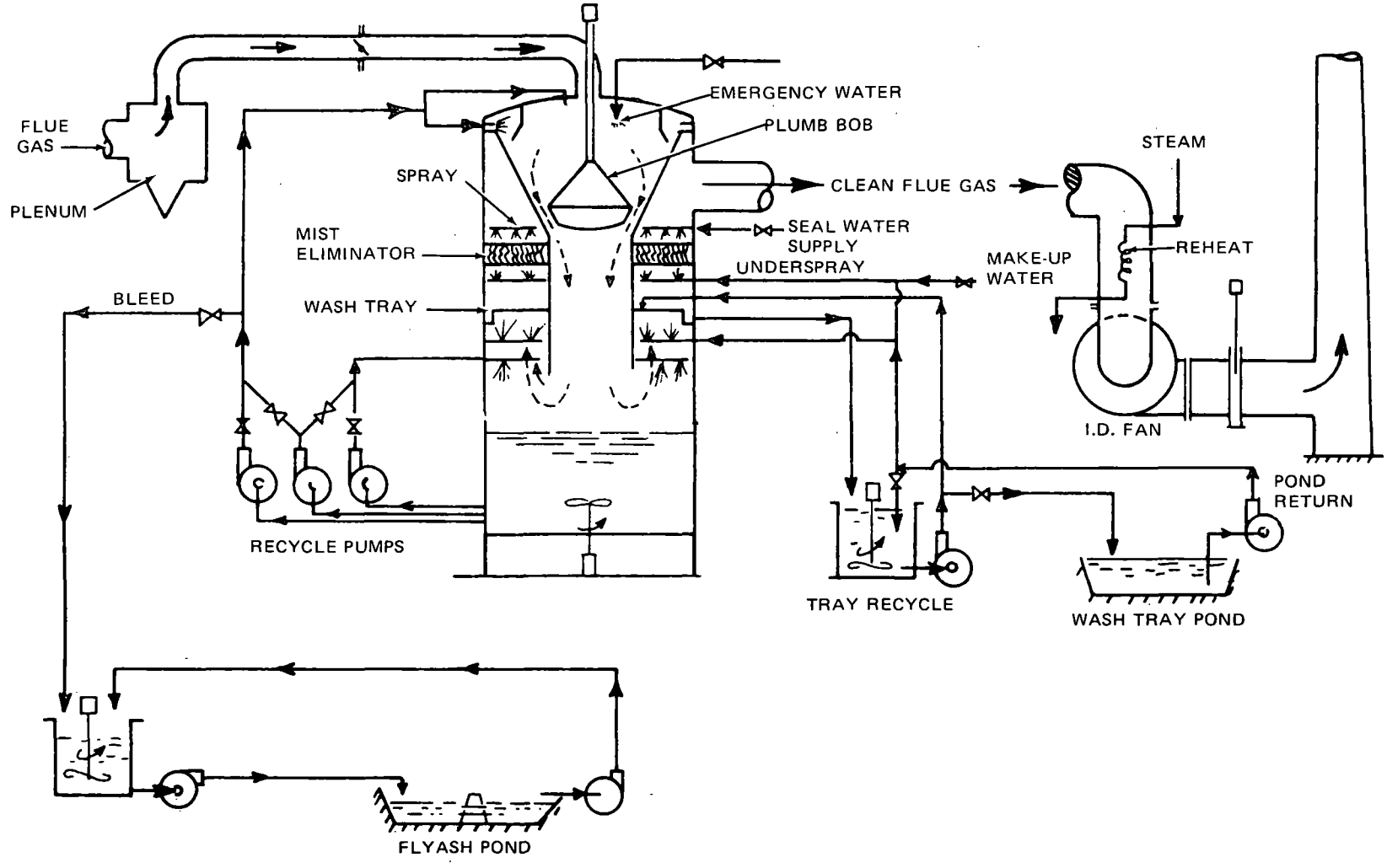

FIGURE A1. THE MOTANA POWER CO. – PUGET SOUND AND LIGHT
COLSTRIP UNITS 1 AND 2 – (360 MW EACH) FLUE GAS CLEANING SYSTEM.

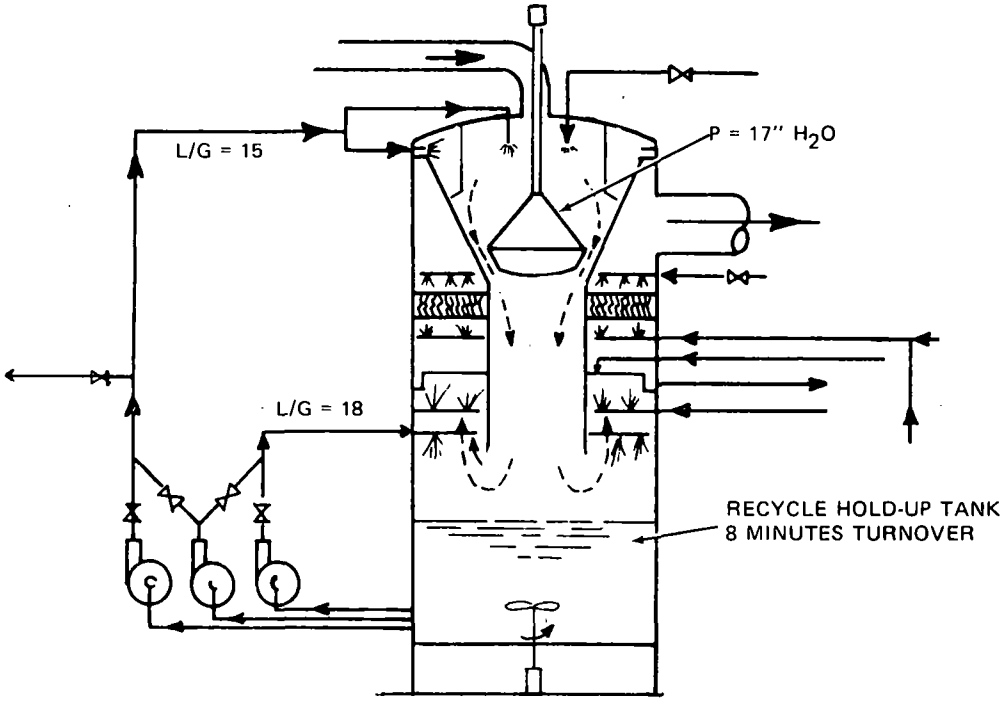

FIGURE A2. COLSTRIP SCRUBBER MODULE.

of 15 (gal/1000 ft^3) for the venturi and 18 (gal/1000 ft^3) for the absorber spray. An agitator in the scrubber base serves to maintain suspension of the fly ash and solid reaction products. Slurry is bled from the recycle to maintain a 12% suspended solids concentration. Slaked quick lime is added as lime slurry only if needed to augment the fly ash alkali and maintain the desired slurry pH.

Each scrubber module is designed to clean 120 MW of equivalent gas flow under normal conditions and 144 MW under emergency conditions. (i.e., when one module is down, the two in operation will clean the amount of flue gas generated at 80% of boiler design load.)

The treated gas leaving the spray section passes through the water wash tray which serves to trap and dilute the entrainment. The gas leaving the washtray passes through a chevron demister followed by a mesh pad demister and leaves the absorption section water-saturated and cooled to the saturation temperature of about 120°F.

To preclude condensation in the fan and stack, and improve the gas buoyancy, the cooled gas from the scrubber is reheated 50 to 75°F by a steam-heated exchanger. The warmed gas then passes through the dry induced draft fans and is discharged to the atmosphere from the top of a 500 foot stack.

As shown in Figure A1 the slurry discharged from the absorption loop is passed to an intermediate retention pond where the solids settle and from which the clarified water is returned to the absorption system. At intermittent intervals (currently only during the warm summer months), a floating dredge is used to reclaim the settled solids from the intermediate settling pond and transport them as a 30% slurry by pipeline to the remotely located permanent disposal pond. Decanted water (supernate) from the disposal pond is returned, also intermittently, through the same slurry pipeline to the intermediate pond for recycle to the absorption system. No stabilization of the sludge is required and a closed water loop is maintained.

Fresh water is added to the absorption system in an amount equivalent to that evaporated into the warm gas stream plus that retained in the waste sludge. This fresh makeup water is introduced to the system as dilution water for minimizing the calcium saturation level in the mist eliminator washwater. This washwater is trapped by and withdrawn from the washtray and circulated to a small pond where entrained solids are separated. A portion of the water from this pond is returned and used to wash the undersurface of the washtray. Another portion of the flow is diluted with the fresh makeup water, and used for bottom wash of the mist eliminator.

The scrubber has been free of scale while the pH of the recycle liquid remains in the expected range. Corrosion problems in the reheater and demister plugging have not been experienced with the installation.

EPA method stack emission tests have been run numerous times on both units during 1976. Table A1 shows the results of sulfur dioxide, particulate and NO_x tests along with the requirements of the NSPS, the vendor's scrubber guarantee, and the results as projected from pilot plant experience. Table A2 contains data on the fuel and ash specifications and this may be compared with coal data contained in Table A1. The test data are for emission only - no inlet measurements have been made. The results over the first year of plant operation agree well with the pilot plant data. The test data show the plant emissions are well below the guarantee and the federal standards.

Table A3 compares scrubber availability and plant load for the two units during the time period September 1975 through December 1976. Note the definition of scrubber availability below the table. These generating plants have no bypass capability around the air pollution control system.

Table A1

Emission Test Results - EPA Method

					SO_2			PARTICULATE			NO_x	
					LB/HR	PPM	LB/MMBtu	LB/HR	LB/MMBtu	%OPAC	LB/HR	LB/MMBtu
1.	Required by NSPS (358 MW)				4063	510	1.2	339	0.10	20	2370	0.7
2.	Scrubber Guarantee (358 MW)				3386	425	1.0	207	0.06	-	(1)	(1)
3.	Projected from Pilot Plant (358 MW)											
	a) 0.78%S (760 PPM), 8.19% Ash				1394	185	0.41	130	.038	20	2370	0.7
	b) 1.0%S (965 PPM), 12.58% Ash				2071	260	0.61	184	.054	20	2370	0.7
4.	UNIT 1 TESTS:											
		COAL AS RECD.										
	Date	GEN MW	%Sul.	%Ash	Btu/LB.							
	2/76	353	0.83	9.03	8638	1464	197	0.44	90.1	.027	10 (3)	880	0.26
	4/76	210	0.71	7.79	8861	420	87	0.21	57.3	.029	14 (2)	738	0.38
	7/76	184	0.64	8.49	8807	241	52	0.14	53.6	.031	15 (2)	695	0.40
	9/76	186	0.62	7.93	8633	255	56	0.14	60.5	.035	11 (2)	646	0.37
	12/76	223	0.94	8.54	8394	898	154	0.43	67.2	.032	15 (2)	662	0.31
5.	UNIT 2 TESTS:											
	10/76	331	0.56	7.96	8368	1231	178	0.39	83.4	.028	11 (2)	862	0.28
	11/76	327	0.59	7.86	8484	664	83	0.21	85.9	.028	10 (2)	934	0.30
	12/76	324	0.64	7.87	8690	780	98	0.25	105.7	.034	16 (2)	784	0.25

Notes: 1. NO_x Emissions guaranteed by boiler supplier only, equal to NSPS.
2. Avg. EDC monitor opacity.
3. Qualified observer.

Table A2

Fuel And Ash As Described
In Specifications

COAL:	Average, As Received
Moisture	23.87%
Volatile Matter	28.59%
Fixed Carbon	38.96%
Ash	8.59% (Max. 12.58%, Min. 6.1%)
Heating Value	8843 Btu/lb. (Min. 8162 Btu/lb.)
Sulfur	.777% (Max. 1.0% Min. 0.4%)

ASH: (Estimated composition, sulfur trioxide-free basis)

SiO_2	41.60%
Al_2O_3	22.42%
TiO_2	0.79%
Fe_2O_3	5.44%
CaO	21.90%
MgO	4.95%
Na_2O	0.31%
K_2O	0.13%
P_2O_5	0.41%
(balance unidentified)	

Later fly ash data varies slightly from above as follows:

LEACHED IN H_2O (1% Fly Ash)

pH	11.8
Conductivity	4.150
Total Dissolved Solids	930 ppm
Calcium	396 ppm
Magnesium	0 ppm
Chloride	15 ppm
Sulfate (SO_4=)	30 ppm

LEACHED IN HCl

% Acid insolubles (SiO_2)	57.59
% Calcium as CaO	22.00
% Magnesium as MgO	1.27
% Aluminum As Al_2O_3	15.59
% Iron as Fe_2O_3	4.97
% Sulfate as SO_4	0.71
% Carbonate as CO_3	0.70

Table A3

Scrubber Availability
Vs. Plant Load

	Monthly Capacity Factor %		No. Days On Line		Avg. MW for Days On Line		Scrubber Availability %	
UNIT	1	2	1	2	1	2	1	2
Sept. 1975	0.5		3		50			
Oct.	19.4		19		139			
Nov.	42.2		24		203			
Dec.	59.9		30		239			
Jan. 1976	63.8		28		265		90.0	
Feb.	65.4		26		273		98.0	
Mar.	57.0		24		277		97.6	
Apr.	49.9		28		219		74.2	
May	26.0	1.3	14	3	210	66	96.8	100.0
Jun.	0.0	23.2	0	16	0	171	-	99.7
Jul.	28.0	19.5	20	13	167	180	93.2	98.7
Aug.	37.8	13.0	23	10	194	162	94.7	95.8
Se t.	64.5	64.6	30	30	239	232	88.6	98.3
Oct.	73.1	77.0	30	31	281	298	79.9	90.3
Nov.	55.6	79.7	30	30	225	303	62.7	94.7
Dec.	67.2	82.3	31	31	249	297	73.8	92.5

Note: Scrubber availability = total module hours available divided by three times the number of hours in month. May through August base is days in operation because of extended scheduled outages.

Development Of The Process Concept

The successful operation of the Colstrip system as described above represents the culmination of an extensive development program carried out jointly by the architect engineer, Bechtel Power Corp., the scrubber system supplier, Combustion Equipment Associates, Inc. (CEA), and the power plant owners, Montana Power Company and Puget Sound Power & Light Company.

Previous experience with Colstrip coal at the J. E. Corrette Station in Billings was limited to particulate removal only, and this was effected by use of an electrostatic precipitator. This experience revealed serious problems in performance which were attributed to the high resistivity characteristics of the low-sulfur coal.

A study was made by Bechtel of the possible options for meeting particulate and SO_2 removal standards. The owners chose a design level of 1.0 lbs. of SO_2 /MM Btu - less than the NSPS level of 1.2, and substantially below the state requirements.

A detailed chemical analysis of the fly ash (see Table 2) revealed that it contained alkali metal oxides in an amount theoretically sufficient to react with and adsorb the sulfur dioxide produced by the coal combustion. Laboratory experiments simulating absorption condtions revealed that this alkalinity

was only usable under low pH absorption conditions (<5.6). It also revealed that absorption under these low pH conditions would result in extensive oxidation of the absorbed SO_2 producing calcium sulfate rather than calcium sulfite as the predominant reaction product.

Continued laboratory tests were conducted by Bechtel to determine the process conditions under which the alkalinity of the fly ash could be utilized while at the same time accommodating the scaling potential of the calcium sulfate. The conditions selected were a pH of 5 to 5.6, low enough for alkali utilization and high enough for adequate SO_2 absorption capability. The other, and perhaps the key operating factor, was the use of a high level of suspended solids in the absorption slurry (12 to 15% by weight, of which some 3-4% is calcium sulfate formed in the absorption). This provided a high concentration of calcium sulfate seed crystals to promote desupersaturation. A long residence time for the recycle slurry in a stirred tank external to the scrubber was also proposed to ensure alkali utilization and to provide crystallization of calcium sulfate under controlled and non-scaling conditions. A slurry holdup of 8-10 hours was selected based on bleed rate.

The above two conditions, i.e., low slurry pH and long contact with the oxygen-containing flue gas, provided substan-

tially complete oxidation. This high oxidation was shown to improve the disposal characteristics of the waste sludge produced.

APPENDIX B

IMPACTOR DATA

Table B1

Inlet Impactor Blank Run Data[1]

Date	5/17	5/18	5/19	5/20	5/17
Run No.	5	9	16	20	Control[2]
Flow rate, alpm	1.36	1.33	1.33	1.44	0
Sample duration, minutes	30	30	30	30	0
Stage/Weight gain mg					
0	0.10	0.04	0.08	0.06	0.05
1	0.12	0.10	0.07	0.04	0.05
2	0.12	0.07	0.01	0.10	0.07
3	0.13	0.03	0.06	0.05	0.04
4	0.09	0.05	0.06	0.05	0.04
5	0.07	0.06	0.00	0.07	0.03
6	0.08	-0.01	0.04	0.10	0.09
F	0.06	0.14	0.16	0.11	0.06

[1]Substrates were acid washed Reeve Angel 934 AH glass fiber filter media. Prepared in accordance to the procedures specified in EPA Report 600/7-700-060.

[2]This control run was handled identically in all respects to blank runs with the exception that no gas was actually pulled through the impactor and thus represents a measure of the weighing precision.

Table B2

Outlet Impactor Blank Run Data[1]

Date	5/17	5/18	5/19	5/20
Run No.	5	9	11	16
Flowrate, a&pm	14	14	11	11
Sample duration, minutes	80	80	80	80
Stage/Weight Gain, mg				
1	0.02	1.10[2]	0.19	0.28[2]
2	-0.02	0.09	0.02	0.06
3	-0.02	0.15	0.09	0.04
4	0.05	0.10	0.17	0.03
5	0.07	0.10	0.05	0.03
6	0.09	0.13	0.09	0.08
7	0.06	0.11	0.03	0.05
F	0.06	0.04	0.11	0.17

[1]Substrates were stainless steel shim stock coated with Apiezon H grease.

[2]Outliers

CPPI-02 5-17-77 PORT-03 1457 INLET SAMPLE MODIFIED BRINK CASCADE IMPACTOR NUMBER - C

IMPACTOR FLOWRATE = 0.039 ACFM IMPACTOR TEMPERATURE = 270.0 F = 132.2 C SAMPLING DURATION = 30.00 MIN

IMPACTOR PRESSURE DROP = 1.7 IN. OF HG STACK TEMPERATURE = 270.0 F = 132.2 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 25.48 IN. OF HG MAX. PARTICLE DIAMETER = 58.3 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 14.62 CO = 0.00 N2 = 70.21 O2 = 2.18 H2O = 13.00

CALC. MASS LOADING = 5.1908E-01 GR/ACF 9.5269E-01 GR/DNCF 1.1878E+03 MG/ACM 2.1801E+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)	9.65	5.85	3.18	1.99	1.52	0.63	0.45	0.20	
MASS (MILLIGRAMS)	21.73	1.02	1.93	4.70	4.18	3.73	1.30	0.21	0.15
MG/DNCM/STAGE	1.23E+03	5.79E+01	1.09E+02	2.67E+02	2.37E+02	2.12E+02	7.38E+01	1.19E+01	8.51E+00
CUM. PERCENT OF MASS SMALLER THAN D50	44.21	41.59	36.64	24.57	13.84	4.26	0.92	0.39	
CUM. (MG/ACM) SMALLER THAN D50	5.25E+02	4.94E+02	4.35E+02	2.92E+02	1.64E+02	5.06E+01	1.10E+01	4.57E+00	
CUM. (MG/DNCM) SMALLER THAN D50	9.64E+02	9.07E+02	7.99E+02	5.36E+02	3.02E+02	9.29E+01	2.01E+01	8.40E+00	
CUM. (GR/ACF) SMALLER THAN D50	2.29E-01	2.16E-01	1.90E-01	1.28E-01	7.18E-02	2.21E-02	4.80E-03	2.00E-03	
CUM. (GR/DNCF) SMALLER THAN D50	4.21E-01	3.96E-01	3.49E-01	2.34E-01	1.32E-01	4.06E-02	8.81E-03	3.67E-03	
GEO. MEAN DIA. (MICROMETERS)	2.37E+01	7.51E+00	4.31E+00	2.51E+00	1.74E+00	9.78E-01	5.35E-01	3.09E-01	1.45E-01
DM/DLOGD (MG/DNCM)	1.58E+03	2.67E+02	4.13E+02	1.31E+03	2.01E+03	5.56E+02	5.14E+02	3.45E+01	2.83E+01
DN/DLOGD (NO. PARTICLES/DNCM)	9.82E+07	5.22E+08	4.27E+09	6.86E+10	3.18E+11	4.92E+11	2.79E+12	1.01E+12	7.71E+12

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	14.63	8.93	4.88	3.08	2.36	1.01	0.74	0.36	
GEO. MEAN DIA. (MICROMETERS)	3.60E+01	1.14E+01	6.60E+00	3.87E+00	2.69E+00	1.54E+00	8.67E-01	5.20E-01	2.58E-01
DM/DLOGD (MG/DNCM)	1.58E+03	2.70E+02	4.16E+02	1.33E+03	2.05E+03	5.76E+02	5.50E+02	3.86E+01	2.83E+01
DN/DLOGD (NO. PARTICLES/DNCM)	6.48E+07	3.45E+08	2.77E+09	4.39E+10	2.00E+11	2.99E+11	1.61E+12	5.22E+11	3.15E+12

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

SQUARE ROOTS OF PSI BY STAGE	0.322	0.322	0.351	0.388	0.330	0.350	0.273
HOLE DIAMETERS BY STAGE (CENTIMETERS)	0.3658	0.2460	0.1724	0.1360	0.0896	0.0719	0.0589

CPPI-03 5-17-77 PORT-01 1545 INLET SAMPLE MODIFIED BRINK CASCADE IMPACTOR NUMBER = 0

IMPACTOR FLOWRATE = 0.050 ACFM IMPACTOR TEMPERATURE = 270.0 F = 132.2 C SAMPLING DURATION = 30.00 MIN

IMPACTOR PRESSURE DROP = 2.8 IN. OF HG STACK TEMPERATURE = 270.0 F = 132.2 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 25.48 IN. OF HG MAX. PARTICLE DIAMETER = 58.3 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 14.62 CO = 0.00 N2 = 70.21 O2 = 2.18 H2O = 13.00

CALC. MASS LOADING = 9.7882E-01 GR/ACF 1.7965E+00 GR/DNCF 2.2399E+03 MG/ACM 4.1109E+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)	8.45	4.90	2.77	1.79	1.20	0.51	0.38	0.10	
MASS (MILLIGRAMS)	59.66	2.44	11.37	8.79	6.42	4.67	2.11	0.24	0.01
MG/DNCM/STAGE	2.60E+03	1.06E+02	4.95E+02	3.83E+02	2.80E+02	2.03E+02	9.19E+01	1.04E+01	4.35E-01
CUM. PERCENT OF MASS SMALLER THAN D50	37.67	35.12	23.24	14.05	7.35	2.47	0.26	0.01	
CUM. (MG/ACM) SMALLER THAN D50	8.44E+02	7.87E+02	5.20E+02	3.15E+02	1.65E+02	5.52E+01	5.85E+00	2.34E-01	
CUM. (MG/DNCM) SMALLER THAN D50	1.55E+03	1.44E+03	9.55E+02	5.78E+02	3.02E+02	1.01E+02	1.07E+01	4.30E-01	
CUM. (GR/ACF) SMALLER THAN D50	3.69E-01	3.44E-01	2.27E-01	1.38E-01	7.19E-02	2.41E-02	2.56E-03	1.02E-04	
CUM. (GR/DNCF) SMALLER THAN D50	6.77E-01	6.31E-01	4.17E-01	2.52E-01	1.32E-01	4.43E-02	4.69E-03	1.88E-04	
GEO. MEAN DIA. (MICROMETERS)	2.22E+01	6.44E+00	3.69E+00	2.23E+00	1.47E+00	7.87E-01	4.44E-01	1.94E-01	6.91E-02
DM/DLOGD (MG/DNCM)	3.10E+03	4.49E+02	2.00E+03	2.02E+03	1.62E+03	5.58E+02	7.19E+02	1.76E+01	1.45E+00
DN/DLOGD (NO. PARTICLES/DNCM)	2.35E+08	1.40E+09	3.31E+10	1.52E+11	4.25E+11	9.42E+11	6.81E+12	2.01E+12	3.64E+12

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	12.82	7.50	4.26	2.77	1.88	0.84	0.64	0.19	
GEO. MEAN DIA. (MICROMETERS)	3.37E+01	9.80E+00	5.65E+00	3.44E+00	2.28E+00	1.25E+00	7.29E-01	3.48E-01	1.35E-01
DM/DLOGD (MG/DNCM)	3.10E+03	4.56E+02	2.02E+03	2.05E+03	1.66E+03	5.78E+02	7.80E+02	1.99E+01	1.45E+00
DN/DLOGD (NO. PARTICLES/DNCM)	1.55E+08	9.25E+08	2.13E+10	9.66E+10	2.66E+11	5.61E+11	3.84E+12	9.01E+11	1.13E+12

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

SQUARE ROOTS OF PST BY STAGE	0.322	0.322	0.346	0.354	0.297	0.337	0.226
HOLE DIAMETERS BY STAGE (CENTIMETERS)	0.3560	0.2461	0.1778	0.1368	0.0937	0.0739	0.0550

CPPI-06 5-18-77 PORT-04 1350 INLET SAMPLE MODIFIED BRINK CASCADE IMPACTOR NUMBER = 0

IMPACTOR FLOWRATE = 0.047 ACFM IMPACTOR TEMPERATURE = 270.0 F = 132.2 C SAMPLING DURATION = 30.00 MIN

IMPACTOR PRESSURE DROP = 2.5 IN. OF HG STACK TEMPERATURE = 270.0 F = 132.2 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 25.50 IN. OF HG MAX. PARTICLE DIAMETER = 58.3 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 13.28 CO = 0.00 N2 = 71.67 O2 = 4.75 H2O = 10.30

CALC. MASS LOADING = 1.1711E+00 GR/ACF 2.0830E+00 GR/DNCF 2.6798E+03 MG/ACM 4.7666E+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)	8.83	5.13	2.90	1.87	1.26	0.54	0.40	0.11	
MASS (MILLIGRAMS)	63.47	5.20	3.41	25.66	3.06	4.49	0.95	0.21	0.09
MG/DNCM/STAGE	2.88E+03	2.36E+02	1.55E+02	1.16E+03	1.39E+02	2.04E+02	4.31E+01	9.52E+00	4.08E+00
CUM. PERCENT OF MASS SMALLER THAN D50	40.43	35.55	32.34	8.26	5.39	1.17	0.28	0.08	
CUM. (MG/ACM) SMALLER THAN D50	1.08E+03	9.53E+02	8.67E+02	2.21E+02	1.44E+02	3.14E+01	7.55E+00	2.26E+00	
CUM. (MG/DNCM) SMALLER THAN D50	1.93E+03	1.69E+03	1.54E+03	3.94E+02	2.57E+02	5.59E+01	1.34E+01	4.03E+00	
CUM. (GR/ACF) SMALLER THAN D50	4.73E-01	4.16E-01	3.79E-01	9.67E-02	6.31E-02	1.37E-02	3.30E-03	9.89E-04	
CUM. (GR/DNCF) SMALLER THAN D50	8.42E-01	7.40E-01	6.74E-01	1.72E-01	1.12E-01	2.44E-02	5.87E-03	1.76E-03	
GEO. MEAN DIA. (MICROMETERS)	2.27E+01	6.73E+00	3.85E+00	2.33E+00	1.54E+00	8.26E-01	4.68E-01	2.08E-01	7.56E-02
DM/DLOGD (MG/DNCM)	3.51E+03	9.99E+02	6.24E+02	6.14E+03	8.04E+02	5.56E+02	3.41E+02	1.65E+01	1.36E+01
DN/DLOGD (NO. PARTICLES/DNCM)	2.50E+08	2.72E+09	9.05E+09	4.03E+11	1.84E+11	8.19E+11	2.76E+12	1.52E+12	2.61E+13

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	13.39	7.83	4.45	2.90	1.97	0.88	0.67	0.21	
GEO. MEAN DIA. (MICROMETERS)	3.44E+01	1.02E+01	5.91E+00	3.59E+00	2.39E+00	1.31E+00	7.66E-01	3.72E-01	1.46E-01
DM/DLOGD (MG/DNCM)	3.51E+03	1.01E+03	6.30E+02	6.24E+03	8.23E+02	5.80E+02	3.69E+02	1.86E+01	1.36E+01
DN/DLOGD (NO. PARTICLES/DNCM)	1.65E+08	1.80E+09	5.84E+09	2.57E+11	1.16E+11	4.90E+11	1.57E+12	6.92E+11	8.35E+12

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

SQUARE ROOTS OF PSI BY STAGE	0.322	0.322	0.346	0.354	0.297	0.337	0.226	
HOLE DIAMETERS BY STAGE (CENTIMETERS)	0.3560	0.2461	0.1778	0.1368	0.0937	0.0739	0.0550	

CPPI-07 5-18-77 PORT-C4 1102 INLET SAMPLE MODIFIED BRINK CASCADE IMPACTOR NUMBER = 8

IMPACTOR FLOWRATE = 0.034 ACFM IMPACTOR TEMPERATURE = 270.0 F = 132.2 C SAMPLING DURATION = 30.00 MIN

IMPACTOR PRESSURE DROP = 1.3 IN. OF HG STACK TEMPERATURE = 270.0 F = 132.2 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 25.50 IN. OF HG MAX. PARTICLE DIAMETER = 58.3 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 13.28 CO = 0.00 N2 = 71.67 O2 = 4.75 H2O = 10.30

CALC. MASS LOADING = 4.6282E-01 GR/ACF 8.2323E-01 GR/DNCF 1.0591E+03 MG/ACM 1.8838E+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)	10.34	6.18	3.31	2.15	1.38	0.64	0.48	0.11	
MASS (MILLIGRAMS)	14.70	0.96	1.88	4.72	2.45	3.75	1.82	0.23	0.17
MG/DNCM/STAGE	9.15E+02	5.97E+01	1.17E+02	2.94E+02	1.52E+02	2.33E+02	1.13E+02	1.43E+01	1.06E+01
CUM. PERCENT OF MASS SMALLER THAN D50	52.09	48.96	42.83	27.44	19.46	7.24	1.30	0.55	
CUM. (MG/ACM) SMALLER THAN D50	5.52E+02	5.18E+02	4.54E+02	2.91E+02	2.06E+02	7.66E+01	1.38E+01	5.87E+00	
CUM. (MG/DNCM) SMALLER THAN D50	9.81E+02	9.22E+02	8.07E+02	5.17E+02	3.67E+02	1.36E+02	2.46E+01	1.04E+01	
CUM. (GR/ACF) SMALLER THAN D50	2.41E-01	2.27E-01	1.98E-01	1.27E-01	9.01E-02	3.35E-02	6.03E-03	2.56E-03	
CUM. (GR/DNCF) SMALLER THAN D50	4.29E-01	4.03E-01	3.53E-01	2.26E-01	1.60E-01	5.96E-02	1.07E-02	4.56E-03	
GEO. MEAN DIA. (MICROMETERS)	2.46E+01	7.99E+00	4.52E+00	2.67E+00	1.73E+00	9.43E-01	5.58E-01	2.26E-01	7.43E-02
DM/DLOGD (MG/DNCM)	1.22E+03	2.67E+02	4.33E+02	1.57E+03	7.92E+02	7.02E+02	9.24E+02	2.15E+01	3.51E+01
DN/DLOGD (NO. PARTICLES/DNCM)	6.83E+07	4.34E+08	3.88E+09	6.84E+10	1.28E+11	6.95E+11	4.41E+12	1.56E+12	7.13E+13

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	15.69	9.43	5.08	3.32	2.15	1.03	0.79	0.20	
GEO. MEAN DIA. (MICROMETERS)	3.72E+01	1.22E+01	6.92E+00	4.11E+00	2.68E+00	1.49E+00	9.03E-01	4.00E-01	1.43E-01
DM/DLOGD (MG/DNCM)	1.22E+03	2.70E+02	4.36E+02	1.59E+03	8.09E+02	7.29E+02	9.86E+02	2.41E+01	3.51E+01
DN/DLOGD (NO. PARTICLES/DNCM)	4.50E+07	2.87E+08	2.51E+09	4.38E+10	8.06E+10	4.21E+11	2.56E+12	7.22E+11	2.31E+13

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

SQUARE ROOTS OF PST BY STAGE	0.322	0.322	0.349	0.330	0.302	0.345	0.175
HOLE DIAMETERS BY STAGE (CENTIMETERS)	0.3618	0.2414	0.1737	0.1366	0.0918	0.0719	0.0566

CPPI-08 5-18-77 PORT-D2 1146 INLET SAMPLE MODIFIED BRINK CASCADE IMPACTOR NUMBER = C

IMPACTOR FLOWRATE = 0.045 ACFM IMPACTOR TEMPERATURE = 270.0 F = 132.2 C SAMPLING DURATION = 30.00 MIN

IMPACTOR PRESSURE DROP = 2.3 IN. OF HG STACK TEMPERATURE = 270.0 F = 132.2 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 25.50 IN. OF HG MAX. PARTICLE DIAMETER = 58.3 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 13.28 CO = 0.00 N2 = 71.67 O2 = 4.75 H2O = 10.30

CALC. MASS LOADING = 1.1758E+00 GR/ACF 2.0915E+00 GR/DNCF 2.6907E+03 MG/ACM 4.7860E+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)	9.00	5.45	2.96	1.85	1.41	0.58	0.41	0.18	
MASS (MILLIGRAMS)	59.38	5.84	5.26	14.62	10.72	5.69	1.05	0.13	0.17
MG/DNCM/STAGE	2.80E+03	2.75E+02	2.48E+02	6.90E+02	5.06E+02	2.68E+02	4.95E+01	6.13E+00	8.02E+00
CUM. PERCENT OF MASS SMALLER THAN D50	42.27	36.59	31.48	17.27	6.84	1.31	0.29	0.17	
CUM. (MG/ACM) SMALLER THAN D50	1.14E+03	9.85E+02	8.47E+02	4.65E+02	1.84E+02	3.53E+01	7.85E+00	4.45E+00	
CUM. (MG/DNCM) SMALLER THAN D50	2.02E+03	1.75E+03	1.51E+03	8.26E+02	3.28E+02	6.28E+01	1.40E+01	7.91E+00	
CUM. (GR/ACF) SMALLER THAN D50	4.97E-01	4.30E-01	3.70E-01	2.03E-01	8.05E-02	1.54E-02	3.43E-03	1.94E-03	
CUM. (GR/DNCF) SMALLER THAN D50	8.80E-01	7.65E-01	6.58E-01	3.61E-01	1.43E-01	2.74E-02	6.10E-03	3.46E-03	
GEO. MEAN DIA. (MICROMETERS)	2.29E+01	7.01E+00	4.01E+00	2.34E+00	1.61E+00	9.04E-01	4.90E-01	2.71E-01	1.26E-01
DM/DLOGD (MG/DNCM)	3.45E+03	1.26E+03	9.33E+02	3.39E+03	4.26E+03	6.97E+02	3.37E+02	1.67E+01	2.66E+01
DN/DLOGD (NO. PARTICLES/DNCM)	2.38E+08	3.05E+09	1.20E+10	2.20E+11	8.43E+11	7.85E+11	2.38E+12	6.96E+11	1.11E+13

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	13.65	8.33	4.54	2.86	2.19	0.94	0.68	0.32	
GEO. MEAN DIA. (MICROMETERS)	3.47E+01	1.07E+01	6.15E+00	3.61E+00	2.50E+00	1.43E+00	7.99E-01	4.70E-01	2.29E-01
DM/DLOGD (MG/DNCM)	3.45E+03	1.28E+03	9.42E+02	3.44E+03	4.36E+03	7.26E+02	3.63E+02	1.89E+01	2.66E+01
DN/DLOGD (NO. PARTICLES/DNCM)	1.57E+08	2.02E+09	7.73E+09	1.40E+11	5.30E+11	4.73E+11	1.36E+12	3.47E+11	4.26E+12

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

SQUARE ROOTS OF PSI BY STAGE	0.322	0.322	0.351	0.388	0.330	0.350	0.273	
HOLE DIAMETERS BY STAGE (CENTIMETERS)	0.3658	0.2460	0.1724	0.1360	0.0896	0.0719	0.0589	

CPPI-10 5-18-77 PORT-C1 1813 INLET SAMPLE MODIFIED BRINK CASCADE IMPACTOR NUMBER = C

IMPACTOR FLOWRATE = 0.045 ACFM IMPACTOR TEMPERATURE = 270.0 F = 132.2 C SAMPLING DURATION = 30.00 MIN

IMPACTOR PRESSURE DROP = 2.3 IN. OF HG STACK TEMPERATURE = 270.0 F = 132.2 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 25.50 IN. OF HG MAX. PARTICLE DIAMETER = 58.3 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 13.28 CO = 0.00 N2 = 71.67 O2 = 4.75 H2O = 10.30

CALC. MASS LOADING = 1.8176E+00 GR/ACF 3.2329E+00 GR/DNCF 4.1592E+03 MG/ACM 7.3980E+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)	8.99	5.45	2.95	1.85	1.41	0.58	0.41	0.18	
MASS (MILLIGRAMS)	125.36	8.76	6.85	8.54	4.79	3.79	0.90	0.16	0.20
MG/DNCM/STAGE	5.90E+03	4.12E+02	3.22E+02	4.02E+02	2.25E+02	1.78E+02	4.24E+01	7.53E+00	9.41E+00
CUM. PERCENT OF MASS SMALLER THAN D50	21.33	15.83	11.53	6.18	3.17	0.79	0.23	0.13	
CUM. (MG/ACM) SMALLER THAN D50	8.87E+02	6.59E+02	4.80E+02	2.57E+02	1.32E+02	3.29E+01	9.40E+00	5.22E+00	
CUM. (MG/DNCM) SMALLER THAN D50	1.58E+03	1.17E+03	8.53E+02	4.57E+02	2.34E+02	5.85E+01	1.67E+01	9.29E+00	
CUM. (GR/ACF) SMALLER THAN D50	3.88E-01	2.88E-01	2.10E-01	1.12E-01	5.76E-02	1.44E-02	4.11E-03	2.28E-03	
CUM. (GR/DNCF) SMALLER THAN D50	6.90E-01	5.12E-01	3.73E-01	2.00E-01	1.02E-01	2.56E-02	7.30E-03	4.06E-03	
GEO. MEAN DIA. (MICROMETERS)	2.29E+01	7.00E+00	4.01E+00	2.34E+00	1.61E+00	9.02E-01	4.89E-01	2.71E-01	1.26E-01
DM/DLOGD (MG/DNCM)	7.27E+03	1.89E+03	1.21E+03	1.97E+03	1.90E+03	4.63E+02	2.88E+02	2.05E+01	3.13E+01
DN/DLOGD (NO. PARTICLES/DNCM)	5.03E+08	4.58E+09	1.56E+10	1.29E+11	3.77E+11	5.24E+11	2.04E+12	8.58E+11	1.31E+13

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	13.64	8.32	4.54	2.86	2.19	0.93	0.68	0.32	
GEO. MEAN DIA. (MICROMETERS)	3.47E+01	1.07E+01	6.14E+00	3.60E+00	2.50E+00	1.43E+00	7.98E-01	4.69E-01	2.28E-01
DM/DLOGD (MG/DNCM)	7.27E+03	1.92E+03	1.22E+03	2.01E+03	1.94E+03	4.82E+02	3.10E+02	2.31E+01	3.13E+01
DN/DLOGD (NO. PARTICLES/DNCM)	3.31E+08	3.03E+09	1.01E+10	8.20E+10	2.37E+11	3.15E+11	1.17E+12	4.28E+11	5.03E+12

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

SQUARE ROOTS OF PSI BY STAGE	0.322	0.322	0.351	0.388	0.330	0.350	0.273
HOLE DIAMETERS BY STAGE (CENTIMETERS)	0.3658	0.2460	0.1724	0.1360	0.0896	0.0719	0.0589

CPPI-11 5-18-77 PORT-C3 1850 INLET SAMPLE MODIFIED BRINK CASCADE IMPACTOR NUMBER = 8

IMPACTOR FLOWRATE = 0.029 ACFM IMPACTOR TEMPERATURE = 270.0 F = 132.2 C SAMPLING DURATION = 30.00 MIN

IMPACTOR PRESSURE DROP = 0.9 IN. OF HG STACK TEMPERATURE = 270.0 F = 132.2 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 25.50 IN. OF HG MAX. PARTICLE DIAMETER = 58.3 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 13.28 CO = 0.00 N2 = 71.67 O2 = 4.75 H2O = 10.30

CALC. MASS LOADING = 7.2288E-01 GR/ACF 1.2858E+00 GR/DNCF 1.6542E+03 MG/ACM 2.9423E+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)	11.29	6.75	3.63	2.36	1.52	0.71	0.54	0.12	
MASS (MILLIGRAMS)	26.97	1.70	2.05	2.27	3.43	2.64	0.85	0.19	0.09
MG/DNCM/STAGE	2.00E+03	1.26E+02	1.52E+02	1.68E+02	2.55E+02	1.96E+02	6.31E+01	1.41E+01	6.68E+00
CUM. PERCENT OF MASS SMALLER THAN D50	32.89	28.66	23.56	17.91	9.38	2.81	0.70	0.22	
CUM. (MG/ACM) SMALLER THAN D50	5.44E+02	4.74E+02	3.90E+02	2.96E+02	1.55E+02	4.65E+01	1.15E+01	3.70E+00	
CUM. (MG/DNCM) SMALLER THAN D50	9.68E+02	8.43E+02	6.93E+02	5.27E+02	2.76E+02	8.27E+01	2.05E+01	6.59E+00	
CUM. (GR/ACF) SMALLER THAN D50	2.38E-01	2.07E-01	1.70E-01	1.30E-01	6.78E-02	2.03E-02	5.04E-03	1.62E-03	
CUM. (GR/DNCF) SMALLER THAN D50	4.23E-01	3.69E-01	3.03E-01	2.30E-01	1.21E-01	3.62E-02	8.96E-03	2.88E-03	
GEO. MEAN DIA. (MICROMETERS)	2.57E+01	8.73E+00	4.95E+00	2.93E+00	1.89E+00	1.04E+00	6.20E-01	2.59E-01	8.78E-02
DM/DLOGD (MG/DNCM)	2.81E+03	5.65E+02	5.64E+02	9.03E+02	1.33E+03	5.95E+02	5.25E+02	2.21E+01	2.22E+01
DN/DLOGD (NO. PARTICLES/DNCM)	1.38E+08	7.04E+08	3.86E+09	2.99E+10	1.62E+11	4.39E+11	1.83E+12	1.09E+12	2.72E+13

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	17.13	10.30	5.56	3.64	2.36	1.14	0.87	0.23	
GEO. MEAN DIA. (MICROMETERS)	3.89E+01	1.33E+01	7.57E+00	4.50E+00	2.93E+00	1.64E+00	9.97E-01	4.52E-01	1.65E-01
DM/DLOGD (MG/DNCM)	2.81E+03	5.72E+02	5.68E+02	9.15E+02	1.35E+03	6.16E+02	5.57E+02	2.46E+01	2.22E+01
DN/DLOGD (NO. PARTICLES/DNCM)	9.10E+07	4.66E+08	2.50E+09	1.92E+10	1.03E+11	2.68E+11	1.07E+12	5.08E+11	9.39E+12

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

SQUARE ROOTS OF PSI BY STAGE	0.322	0.322	0.349	0.330	0.302	0.345	0.175
HOLE DIAMETERS BY STAGE (CENTIMETERS)	0.3618	0.2414	0.1737	0.1366	0.0918	0.0719	0.0566

CPPI-13 5-19-77 PORT-01 1015 INLET SAMPLE MODIFIED BRINK CASCADE IMPACTOR NUMBER = C

IMPACTOR FLOWRATE = 0.050 ACFM IMPACTOR TEMPERATURE = 270.0 F = 132.2 C SAMPLING DURATION = 30.00 MIN

IMPACTOR PRESSURE DROP = 2.8 IN. OF HG STACK TEMPERATURE = 270.0 F = 132.2 C

ASSUMED PARTICLE DENSITY = 2.50 GM/CU.CM. STACK PRESSURE = 25.69 IN. OF HG MAX. PARTICLE DIAMETER = 58.3 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 14.00 CO = 0.00 N2 = 70.79 O2 = 2.71 H2O = 12.50

CALC. MASS LOADING = 9.7790E-01 GR/ACF 1.7699E+00 GR/DNCF 2.2378E+03 MG/ACM 4.0502E+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)	8.46	5.12	2.77	1.73	1.32	0.54	0.38	0.16	
MASS (MILLIGRAMS)	59.34	7.98	6.67	9.93	5.23	4.97	0.98	0.35	0.36
MG/DNCM/STAGE	2.54E+03	3.42E+02	2.86E+02	4.25E+02	2.24E+02	2.13E+02	4.20E+01	1.50E+01	1.54E+01
CUM. PERCENT OF MASS SMALLER THAN D50	38.06	29.74	22.77	12.41	6.95	1.76	0.74	0.38	
CUM. (MG/ACM) SMALLER THAN D50	8.52E+02	6.65E+02	5.10E+02	2.78E+02	1.56E+02	3.95E+01	1.66E+01	8.41E+00	
CUM. (MG/DNCM) SMALLER THAN D50	1.54E+03	1.20E+03	9.22E+02	5.03E+02	2.82E+02	7.14E+01	3.00E+01	1.52E+01	
CUM. (GR/ACF) SMALLER THAN D50	3.72E-01	2.91E-01	2.23E-01	1.21E-01	6.80E-02	1.72E-02	7.25E-03	3.67E-03	
CUM. (GR/DNCF) SMALLER THAN D50	6.74E-01	5.26E-01	4.03E-01	2.20E-01	1.23E-01	3.12E-02	1.31E-02	6.65E-03	
GEO. MEAN DIA. (MICROMETERS)	2.22E+01	6.58E+00	3.76E+00	2.19E+00	1.51E+00	8.43E-01	4.55E-01	2.46E-01	1.12E-01
DM/DLOGD (MG/DNCM)	3.03E+03	1.57E+03	1.07E+03	2.08E+03	1.88E+03	5.50E+02	2.81E+02	3.90E+01	5.12E+01
DN/DLOGD (NO. PARTICLES/DNCM)	2.30E+08	4.57E+09	1.67E+10	1.65E+11	4.54E+11	7.62E+11	2.49E+12	2.18E+12	3.06E+13

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	12.82	7.82	4.26	2.68	2.05	0.87	0.64	0.29	
GEO. MEAN DIA. (MICROMETERS)	3.37E+01	1.00E+01	5.77E+00	3.38E+00	2.35E+00	1.34E+00	7.45E-01	4.30E-01	2.06E-01
DM/DLOGD (MG/DNCM)	3.03E+03	1.59E+03	1.08E+03	2.12E+03	1.93E+03	5.74E+02	3.04E+02	4.42E+01	5.12E+01
DN/DLOGD (NO. PARTICLES/DNCM)	1.52E+08	3.03E+09	1.08E+10	1.05E+11	2.85E+11	4.57E+11	1.41E+12	1.06E+12	1.12E+13

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

SQUARE ROOTS OF PSI BY STAGE	0.322	0.322	0.351	0.388	0.330	0.350	0.273
HOLE DIAMETERS BY STAGE (CENTIMETERS)	0.3658	0.2460	0.1724	0.1360	0.0896	0.0719	0.0589

CPPI-14 5-19-77 PORT-C2 1052 INLET SAMPLE MODIFIED BRINK CASCADE IMPACTOR NUMBER = 0

IMPACTOR FLOWRATE = 0.045 ACFM IMPACTOR TEMPERATURE = 270.0 F = 132.2 C SAMPLING DURATION = 30.00 MIN

IMPACTOR PRESSURE DROP = 2.3 IN. OF HG STACK TEMPERATURE = 270.0 F = 132.2 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 25.69 IN. OF HG MAX. PARTICLE DIAMETER = 58.3 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 14.00 CO = 0.00 N2 = 70.79 O2 = 2.71 H2O = 12.50

CALC. MASS LOADING = 1.7637E+00 GR/ACF 3.1923E+00 GR/DNCF 4.0360E+03 MG/ACM 7.3050E+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)	8.91	5.18	2.93	1.89	1.27	0.55	0.41	0.11	
MASS (MILLIGRAMS)	132.40	3.95	6.63	5.84	2.68	2.99	0.84	0.19	0.14
MG/DNCM/STAGE	6.30E+03	1.88E+02	3.15E+02	2.78E+02	1.27E+02	1.42E+02	4.00E+01	9.04E+00	6.66E+00
CUM. PERCENT OF MASS SMALLER THAN D50	14.94	12.41	8.15	4.39	2.67	0.75	0.21	0.09	
CUM. (MG/ACM) SMALLER THAN D50	6.03E+02	5.01E+02	3.29E+02	1.77E+02	1.08E+02	3.03E+01	8.56E+00	3.63E+00	
CUM. (MG/DNCM) SMALLER THAN D50	1.09E+03	9.06E+02	5.95E+02	3.21E+02	1.95E+02	5.49E+01	1.55E+01	6.57E+00	
CUM. (GR/ACF) SMALLER THAN D50	2.64E-01	2.19E-01	1.44E-01	7.75E-02	4.71E-02	1.33E-02	3.74E-03	1.59E-03	
CUM. (GR/DNCF) SMALLER THAN D50	4.77E-01	3.96E-01	2.60E-01	1.40E-01	8.53E-02	2.40E-02	6.77E-03	2.87E-03	
GEO. MEAN DIA. (MICROMETERS)	2.28E+01	6.79E+00	3.89E+00	2.35E+00	1.55E+00	8.36E-01	4.76E-01	2.14E-01	7.84E-02
DM/DLOGD (MG/DNCM)	7.72E+03	7.97E+02	1.27E+03	1.47E+03	7.40E+02	3.89E+02	3.19E+02	1.59E+01	2.21E+01
DN/DLOGD (NO. PARTICLES/DNCM)	5.41E+08	2.11E+09	1.79E+10	9.35E+10	1.64E+11	5.53E+11	2.46E+12	1.35E+12	3.82E+13

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	13.51	7.91	4.50	2.93	1.99	0.89	0.68	0.21	
GEO. MEAN DIA. (MICROMETERS)	3.46E+01	1.03E+01	5.96E+00	3.63E+00	2.41E+00	1.33E+00	7.76E-01	3.80E-01	1.50E-01
DM/DLOGD (MG/DNCM)	7.72E+03	8.08E+02	1.29E+03	1.49E+03	7.57E+02	4.06E+02	3.44E+02	1.79E+01	2.21E+01
DN/DLOGD (NO. PARTICLES/DNCM)	3.57E+08	1.40E+09	1.16E+10	5.96E+10	1.03E+11	3.31E+11	1.40E+12	6.24E+11	1.25E+13

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

SQUARE ROOTS OF PST BY STAGE	0.322	0.322	0.346	0.354	0.297	0.337	0.226
HOLE DIAMETERS BY STAGE (CENTIMETERS)	0.3560	0.2461	0.1778	0.1368	0.0937	0.0739	0.0550

CPPI-15 5-19-77 PORT-02 1150 INLET SAMPLE MODIFIED BRINK CASCADE IMPACTOR NUMBER = 8

IMPACTOR FLOWRATE = 0.047 ACFM IMPACTOR TEMPERATURE = 270.0 F = 132.2 C SAMPLING DURATION = 30.00 MIN

IMPACTOR PRESSURE DROP = 2.4 IN. OF HG STACK TEMPERATURE = 270.0 F = 132.2 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 25.69 IN. OF HG MAX. PARTICLE DIAMETER = 58.3 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 14.00 CO = 0.00 N2 = 70.79 O2 = 2.71 H2O = 12.50

CALC. MASS LOADING = 1.3832E+00 GR/ACF 2.5035E+00 GR/DNCF 3.1652E+03 MG/ACM 5.7289E+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)	8.79	5.23	2.80	1.81	1.16	0.53	0.40	0.07	
MASS (MILLIGRAMS)	99.29	3.49	5.12	7.04	5.36	3.82	1.16	0.21	0.08
MG/DNCM/STAGE	4.59E+03	1.61E+02	2.37E+02	3.26E+02	2.48E+02	1.77E+02	5.36E+01	9.71E+00	3.70E+00
CUM. PERCENT OF MASS SMALLER THAN D50	20.93	18.15	14.07	8.47	4.20	1.15	0.23	0.06	
CUM. (MG/ACM) SMALLER THAN D50	6.62E+02	5.74E+02	4.45E+02	2.68E+02	1.33E+02	3.65E+01	7.31E+00	2.02E+00	
CUM. (MG/DNCM) SMALLER THAN D50	1.20E+03	1.04E+03	8.06E+02	4.85E+02	2.40E+02	6.62E+01	1.32E+01	3.65E+00	
CUM. (GR/ACF) SMALLER THAN D50	2.89E-01	2.51E-01	1.95E-01	1.17E-01	5.81E-02	1.60E-02	3.19E-03	8.81E-04	
CUM. (GR/DNCF) SMALLER THAN D50	5.24E-01	4.54E-01	3.52E-01	2.12E-01	1.05E-01	2.89E-02	5.78E-03	1.59E-03	
GEO. MEAN DIA. (MICROMETERS)	2.26E+01	6.78E+00	3.83E+00	2.25E+00	1.45E+00	7.85E-01	4.58E-01	1.72E-01	5.27E-02
DM/DLOGD (MG/DNCM)	5.59E+03	7.17E+02	8.72E+02	1.73E+03	1.27E+03	5.21E+02	4.18E+02	1.34E+01	1.23E+01
DN/DLOGD (NO. PARTICLES/DNCM)	4.00E+08	1.91E+09	1.29E+10	1.25E+11	3.47E+11	8.96E+11	3.61E+12	2.20E+12	6.96E+13

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	13.32	7.99	4.30	2.81	1.81	0.86	0.65	0.15	
GEO. MEAN DIA. (MICROMETERS)	3.43E+01	1.03E+01	5.86E+00	3.48E+00	2.26E+00	1.25E+00	7.50E-01	3.13E-01	1.06E-01
DM/DLOGD (MG/DNCM)	5.59E+03	7.27E+02	8.81E+02	1.76E+03	1.31E+03	5.45E+02	4.52E+02	1.51E+01	1.23E+01
DN/DLOGD (NO. PARTICLES/DNCM)	2.64E+08	1.26E+09	8.34E+09	7.99E+10	2.17E+11	5.35E+11	2.05E+12	9.46E+11	1.99E+13

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

SQUARE ROOTS OF PSI BY STAGE	0.322	0.322	0.349	0.330	0.302	0.345	0.175
HOLE DIAMETERS BY STAGE (CENTIMETERS)	0.3618	0.2414	0.1737	0.1366	0.0918	0.0719	0.0566

CPPI-17 5-20-77 PORT-C3 1130 INLET SAMPLE MODIFIED BRINK CASCADE IMPACTOR NUMBER = D

IMPACTOR FLOWRATE = 0.045 ACFM IMPACTOR TEMPERATURE = 270.0 F = 132.2 C SAMPLING DURATION = 30.00 MIN

IMPACTOR PRESSURE DROP = 2.3 IN. OF HG STACK TEMPERATURE = 270.0 F = 132.2 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 25.69 IN. OF HG MAX. PARTICLE DIAMETER = 58.3 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 12.70 CO = 0.00 N2 = 72.68 O2 = 2.82 H2O = 11.80

CALC. MASS LOADING = 8.1080E-01 GR/ACF 1.4559E+00 GR/DNCF 1.8554E+03 MG/ACM 3.3315E+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)	8.94	5.19	2.94	1.90	1.28	0.55	0.41	0.11	
MASS (MILLIGRAMS)	47.12	4.92	3.06	6.37	5.24	2.96	1.51	0.09	0.13
MG/DNCM/STAGE	2.23E+03	2.33E+02	1.45E+02	3.01E+02	2.48E+02	1.40E+02	7.14E+01	4.26E+00	6.15E+00
CUM. PERCENT OF MASS SMALLER THAN D50	34.01	27.11	22.83	13.91	6.57	2.42	0.31	0.18	
CUM. (MG/ACM) SMALLER THAN D50	6.31E+02	5.03E+02	4.24E+02	2.58E+02	1.22E+02	4.50E+01	5.72E+00	3.38E+00	
CUM. (MG/DNCM) SMALLER THAN D50	1.13E+03	9.03E+02	7.61E+02	4.63E+02	2.19E+02	8.07E+01	1.03E+01	6.07E+00	
CUM. (GR/ACF) SMALLER THAN D50	2.76E-01	2.20E-01	1.85E-01	1.13E-01	5.33E-02	1.96E-02	2.50E-03	1.48E-03	
CUM. (GR/DNCF) SMALLER THAN D50	4.95E-01	3.95E-01	3.32E-01	2.02E-01	9.56E-02	3.53E-02	4.49E-03	2.65E-03	
GEO. MEAN DIA. (MICROMETERS)	2.28E+01	6.81E+00	3.90E+00	2.36E+00	1.56E+00	8.39E-01	4.77E-01	2.14E-01	7.86E-02
DM/DLOGD (MG/DNCM)	2.74E+03	9.87E+02	5.84E+02	1.59E+03	1.44E+03	3.83E+02	5.70E+02	7.47E+00	2.04E+01
DN/DLOGD (NO. PARTICLES/DNCM)	1.91E+08	2.59E+09	8.16E+09	1.00E+11	3.16E+11	5.39E+11	4.37E+12	6.32E+11	3.50E+13

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	13.55	7.93	4.51	2.94	1.99	0.89	0.68	0.21	
GEO. MEAN DIA. (MICROMETERS)	3.46E+01	1.04E+01	5.98E+00	3.64E+00	2.42E+00	1.33E+00	7.78E-01	3.81E-01	1.51E-01
DM/DLOGD (MG/DNCM)	2.74E+03	1.00E+03	5.90E+02	1.62E+03	1.47E+03	4.00E+02	6.15E+02	8.43E+00	2.04E+01
DN/DLOGD (NO. PARTICLES/DNCM)	1.26E+08	1.71E+09	5.37E+09	6.61E+10	1.98E+11	3.23E+11	2.49E+12	2.91E+11	1.14E+13

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

SQUARE ROOTS OF PST BY STAGE	0.322	0.322	0.346	0.354	0.297	0.337	0.226
HOLE DIAMETERS BY STAGE (CENTIMETERS)	0.3560	0.2461	0.1778	0.1368	0.0937	0.0739	0.0550

CPPI-1A 5-20-77 PORT-D3 1243 INLET SAMPLE MODIFIED BRINK CASCADE IMPACTOR NUMBER = C

IMPACTOR FLOWRATE = 0.035 ACFM IMPACTOR TEMPERATURE = 270.0 F = 132.2 C SAMPLING DURATION = 30.00 MIN

IMPACTOR PRESSURE DROP = 1.3 IN. OF HG STACK TEMPERATURE = 270.0 F = 132.2 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 25.69 IN. OF HG MAX. PARTICLE DIAMETER = 58.3 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 12.70 CO = 0.00 N2 = 72.68 O2 = 2.82 H2O = 11.80

CALC. MASS LOADING = 7.9252E-01 GR/ACF 1.4230E+00 GR/DNCF 1.8136E+03 MG/ACM 3.2564E+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)	10.21	6.20	3.37	2.11	1.61	0.67	0.49	0.23	
MASS (MILLIGRAMS)	34.48	2.92	2.67	4.71	4.23	3.16	1.03	0.11	0.15
MG/DNCM/STAGE	2.13E+03	1.80E+02	1.65E+02	2.91E+02	2.61E+02	1.95E+02	6.36E+01	6.79E+00	9.26E+00
CUM. PERCENT OF MASS SMALLER THAN D50	35.50	30.04	25.05	16.24	8.32	2.41	0.49	0.28	
CUM. (MG/ACM) SMALLER THAN D50	6.44E+02	5.45E+02	4.54E+02	2.94E+02	1.51E+02	4.38E+01	8.82E+00	5.09E+00	
CUM. (MG/DNCM) SMALLER THAN D50	1.16E+03	9.78E+02	8.16E+02	5.29E+02	2.71E+02	7.86E+01	1.58E+01	9.14E+00	
CUM. (GR/ACF) SMALLER THAN D50	2.81E-01	2.38E-01	1.99E-01	1.29E-01	6.60E-02	1.91E-02	3.85E-03	2.22E-03	
CUM. (GR/DNCF) SMALLER THAN D50	5.05E-01	4.27E-01	3.56E-01	2.31E-01	1.18E-01	3.43E-02	6.92E-03	3.99E-03	
GEO. MEAN DIA. (MICROMETERS)	2.44E+01	7.96E+00	4.57E+00	2.67E+00	1.85E+00	1.04E+00	5.73E-01	3.32E-01	1.60E-01
DM/DLOGD (MG/DNCM)	2.81E+03	8.32E+02	6.22E+02	1.44E+03	2.22E+03	5.15E+02	4.50E+02	2.04E+01	3.08E+01
DN/DLOGD (NO. PARTICLES/DNCM)	1.61E+08	1.37E+09	5.41E+09	6.28E+10	2.93E+11	3.78E+11	1.98E+12	4.64E+11	6.26E+12

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	15.49	9.46	5.17	3.26	2.50	1.08	0.79	0.40	
GEO. MEAN DIA. (MICROMETERS)	3.70E+01	1.21E+01	6.99E+00	4.11E+00	2.86E+00	1.64E+00	9.25E-01	5.61E-01	2.81E-01
DM/DLOGD (MG/DNCM)	2.81E+03	8.43E+02	6.27E+02	1.46E+03	2.26E+03	5.33E+02	4.78E+02	2.26E+01	3.08E+01
DN/DLOGD (NO. PARTICLES/DNCM)	1.06E+08	9.07E+08	3.50E+09	4.02E+10	1.85E+11	2.30E+11	1.16E+12	2.44E+11	2.65E+12

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

SQUARE ROOTS OF PSI BY STAGE	0.322	0.322	0.351	0.388	0.330	0.350	0.273
HOLE DIAMETERS BY STAGE (CENTIMETERS)	0.3658	0.2460	0.1724	0.1360	0.0896	0.0719	0.0589

CPPI-19 5-20-77 PORT-C1 1320 INLET SAMPLE MODIFIED BRINK CASCADE IMPACTOR NUMBER = 8

IMPACTOR FLOWRATE = 0.051 ACFM IMPACTOR TEMPERATURE = 270.0 F = 132.2 C SAMPLING DURATION = 30.00 MIN

IMPACTOR PRESSURE DROP = 2.9 IN. OF HG STACK TEMPERATURE = 270.0 F = 132.2 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 25.69 IN. OF HG MAX. PARTICLE DIAMETER = 58.3 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 12.70 CO = 0.00 N2 = 72.68 O2 = 2.82 H2O = 11.80

CALC. MASS LOADING = 2.3936E+00 GR/ACF 4.2980E+00 GR/DNCF 5.4774E+03 MG/ACM 9.8352E+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)	8.41	5.00	2.67	1.73	1.10	0.50	0.37	0.07	
MASS (MILLIGRAMS)	187.49	13.10	12.69	14.69	4.44	4.50	0.92	0.20	0.21
MG/DNCM/STAGE	7.85E+03	5.48E+02	5.31E+02	6.15E+02	1.86E+02	1.88E+02	3.85E+01	8.37E+00	8.79E+00
CUM. PERCENT OF MASS SMALLER THAN D50	21.30	15.80	10.48	4.31	2.45	0.56	0.17	0.09	
CUM. (MG/ACM) SMALLER THAN D50	1.17E+03	8.66E+02	5.74E+02	2.36E+02	1.34E+02	3.06E+01	9.43E+00	4.83E+00	
CUM. (MG/DNCM) SMALLER THAN D50	2.10E+03	1.55E+03	1.03E+03	4.24E+02	2.41E+02	5.49E+01	1.69E+01	8.67E+00	
CUM. (GR/ACF) SMALLER THAN D50	5.10E-01	3.78E-01	2.51E-01	1.03E-01	5.86E-02	1.34E-02	4.12E-03	2.11E-03	
CUM. (GR/DNCF) SMALLER THAN D50	9.16E-01	6.79E-01	4.50E-01	1.85E-01	1.05E-01	2.40E-02	7.40E-03	3.79E-03	
GEO. MEAN DIA. (MICROMETERS)	2.21E+01	6.48E+00	3.66E+00	2.15E+00	1.38E+00	7.45E-01	4.32E-01	1.57E-01	4.69E-02
DM/DLOGD (MG/DNCM)	9.33E+03	2.43E+03	1.95E+03	3.26E+03	9.52E+02	5.51E+02	2.95E+02	1.12E+01	2.92E+01
DN/DLOGD (NO. PARTICLES/DNCM)	7.14E+08	7.40E+09	3.32E+10	2.72E+11	2.99E+11	1.11E+12	3.03E+12	2.39E+12	2.35E+14

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	12.75	7.64	4.11	2.68	1.73	0.82	0.62	0.13	
GEO. MEAN DIA. (MICROMETERS)	3.36E+01	9.87E+00	5.61E+00	3.32E+00	2.15E+00	1.19E+00	7.11E-01	2.89E-01	9.53E-02
DM/DLOGD (MG/DNCM)	9.33E+03	2.47E+03	1.97E+03	3.31E+03	9.76E+02	5.78E+02	3.20E+02	1.26E+01	2.92E+01
DN/DLOGD (NO. PARTICLES/DNCM)	4.71E+08	4.90E+09	2.14E+10	1.73E+11	1.87E+11	6.57E+11	1.70E+12	1.00E+12	6.44E+13

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

SQUARE ROOTS OF PSI BY STAGE	0.322	0.322	0.349	0.330	0.302	0.345	0.175
HOLE DIAMETERS BY STAGE (CENTIMETERS)	0.3618	0.2414	0.1737	0.1366	0.0918	0.0719	0.0566

CPPO-3 5-17-77 PORT-1 1530 OUTLET SAMPLE U. OF W. MARK III SOURCE TEST IMPACTOR NO. = A

IMPACTOR FLOWRATE = 0.560 ACFM IMPACTOR TEMPERATURE = 202.0 F = 94.4 C SAMPLING DURATION = 80.00 MIN

IMPACTOR PRESSURE DROP = 1.4 IN. OF HG STACK TEMPERATURE = 202.0 F = 94.4 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 26.50 IN. OF HG MAX. PARTICLE DIAMETER = 40.2 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 12.00 CO = 0.00 N2 = 64.52 O2 = 4.03 H2O = 19.45

CALC. MASS LOADING = 1.1643E-02 GR/ACF 2.0123E-02 GR/DNCF 2.6644E+01 MG/ACM 4.6049E+01 MG/DNCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	7.33	7.32	3.27	1.14	0.72	0.40	0.17	
MASS (MILLIGRAMS)	2.26	0.00	0.01	0.42	2.42	6.34	5.99	16.36
MG/DSCM/STAGE	3.12E+00	0.00E-01	1.38E-02	5.80E-01	3.34E+00	8.76E+00	8.27E+00	2.26E+01
CUM. PERCENT OF MASS SMALLER THAN D50	93.31	93.31	93.28	92.04	84.88	66.12	48.40	
CUM. (MG/ACM) SMALLER THAN D50	2.49E+01	2.49E+01	2.49E+01	2.45E+01	2.26E+01	1.76E+01	1.29E+01	
CUM. (MG/DNCM) SMALLER THAN D50	4.30E+01	4.30E+01	4.30E+01	4.24E+01	3.91E+01	3.04E+01	2.23E+01	
CUM. (GR/ACF) SMALLER THAN D50	1.09E-02	1.09E-02	1.09E-02	1.07E-02	9.88E-03	7.70E-03	5.64E-03	
CUM. (GR/DNCF) SMALLER THAN D50	1.88E-02	1.88E-02	1.88E-02	1.85E-02	1.71E-02	1.33E-02	9.74E-03	
GEO. MEAN DIA. (MICROMETERS)	1.72E+01	7.33E+00	4.89E+00	1.93E+00	9.05E-01	5.33E-01	2.57E-01	1.18E-01
DM/DLOGD (MG/DNCM)	4.22E+00	0.00E-01	3.95E-02	1.27E+00	1.65E+01	3.40E+01	2.20E+01	7.50E+01
DN/DLOGD (NO. PARTICLES/DNCM)	6.93E+05	0.00E-01	2.80E+05	1.46E+08	1.85E+10	1.86E+11	1.07E+12	3.82E+13

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	11.17	11.15	5.01	1.78	1.13	0.65	0.30	
GEO. MEAN DIA. (MICROMETERS)	2.61E+01	1.12E+01	7.47E+00	2.99E+00	1.42E+00	8.58E-01	4.39E-01	2.10E-01
DM/DLOGD (MG/DNCM)	4.23E+00	0.00E-01	3.97E-02	1.29E+00	1.71E+01	3.61E+01	2.44E+01	7.50E+01
DN/DLOGD (NO. PARTICLES/DNCM)	4.55E+05	0.00E-01	1.82E+05	9.26E+07	1.14E+10	1.09E+11	5.50E+11	1.54E+13

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

SQUARE ROOTS OF PSI BY STAGE	0.144	0.330	0.371	0.271	0.308	0.373	0.349
HOLE DIAMETERS BY STAGE (CENTIMETERS)	1.8237	0.5768	0.2501	0.0808	0.0524	0.0333	0.0245

CPPO-4 5-17-77 PORT-3 1515 OUTLET SAMPLE U. OF W. MARK III SOURCE TEST IMPACTOR NO. = C

IMPACTOR FLOWRATE = 0.330 ACFM IMPACTOR TEMPERATURE = 202.0 F = 94.4 C SAMPLING DURATION = 32.00 MIN

IMPACTOR PRESSURE DROP = 0.5 IN. OF HG STACK TEMPERATURE = 202.0 F = 94.4 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 26.50 IN. OF HG MAX. PARTICLE DIAMETER = 40.2 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 12.00 CO = 0.00 N2 = 64.52 O2 = 4.03 H2O = 19.45

CALC. MASS LOADING = 2.7913E-02 GR/ACF 4.8242E-02 GR/DNCF 6.3874E+01 MG/ACM 1.1039E+02 MG/DNCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	9.58	9.83	4.18	1.80	0.94	0.66	0.24	
MASS (MILLIGRAMS)	2.35	0.02	0.01	0.18	3.45	3.90	2.88	6.31
MG/DSCM/STAGE	1.38E+01	1.17E-01	5.86E-02	1.05E+00	2.02E+01	2.28E+01	1.69E+01	3.70E+01
CUM. PERCENT OF MASS SMALLER THAN D50	87.70	87.59	87.54	86.60	68.53	48.12	33.04	
CUM. (MG/ACM) SMALLER THAN D50	5.60E+01	5.59E+01	5.59E+01	5.53E+01	4.38E+01	3.07E+01	2.11E+01	
CUM. (MG/DNCM) SMALLER THAN D50	9.68E+01	9.67E+01	9.66E+01	9.56E+01	7.57E+01	5.31E+01	3.65E+01	
CUM. (GR/ACF) SMALLER THAN D50	2.45E-02	2.44E-02	2.44E-02	2.42E-02	1.91E-02	1.34E-02	9.22E-03	
CUM. (GR/DNCF) SMALLER THAN D50	4.23E-02	4.23E-02	4.22E-02	4.18E-02	3.31E-02	2.32E-02	1.59E-02	
GEO. MEAN DIA. (MICROMETERS)	1.96E+01	9.71E+00	6.41E+00	2.75E+00	1.30E+00	7.88E-01	4.01E-01	1.72E-01
DM/DLOGD (MG/DNCM)	2.21E+01	-1.04E+01	1.58E-01	2.89E+00	7.16E+01	1.48E+02	3.90E+01	1.23E+02
DN/DLOGD (NO. PARTICLES/DNCM)	2.43E+06	-9.41E+06	4.97E+05	1.16E+08	2.69E+10	2.51E+11	5.02E+11	1.99E+13

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	14.58	14.96	6.39	2.78	1.48	1.05	0.42	
GEO. MEAN DIA. (MICROMETERS)	2.98E+01	1.48E+01	9.78E+00	4.22E+00	2.03E+00	1.24E+00	6.60E-01	2.94E-01
DM/DLOGD (MG/DNCM)	2.22E+01	-1.04E+01	1.58E-01	2.92E+00	7.33E+01	1.54E+02	4.20E+01	1.23E+02
DN/DLOGD (NO. PARTICLES/DNCM)	1.60E+06	-6.17E+06	3.24E+05	7.44E+07	1.68E+10	1.53E+11	2.79E+11	9.22E+12

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

SQUARE ROOTS OF PSI BY STAGE	0.144	0.330	0.371	0.320	0.295	0.363	0.312
HOLE DIAMETERS BY STAGE (CENTIMETERS)	1.8237	0.5874	0.2459	0.0807	0.0532	0.0376	0.0260

CPPO-6 5-18-77 PORT-1,2 1335 INLET SAMPLE U. OF W. MARK III SOURCE TEST IMPACTOR NO. = A

IMPACTOR FLOWRATE = 0.310 ACFM IMPACTOR TEMPERATURE = 205.0 F = 96.1 C SAMPLING DURATION = 80.00 MIN

IMPACTOR PRESSURE DROP = 0.4 IN. OF HG STACK TEMPERATURE = 205.0 F = 96.1 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 26.66 IN. OF HG MAX. PARTICLE DIAMETER = 40.2 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 11.79 CO = 0.00 N2 = 67.69 O2 = 3.57 H2O = 16.95

CALC. MASS LOADING = 9.1225E-03 GR/ACF 1.5269E-02 GR/DNCF 2.0875E+01 MG/ACM 3.4941E+01 MG/DNCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	9.95	9.94	4.46	1.58	1.00	0.58	0.26	
MASS (MILLIGRAMS)	3.06	0.00	0.00	0.00	0.02	1.37	2.67	7.54
MG/DSCM/STAGE	7.39E+00	0.00E-01	0.00E-01	0.00E-01	4.83E-02	3.31E+00	6.45E+00	1.82E+01
CUM. PERCENT OF MASS SMALLER THAN D50	79.13	79.13	79.13	79.13	78.99	69.65	51.43	
CUM. (MG/ACM) SMALLER THAN D50	1.65E+01	1.65E+01	1.65E+01	1.65E+01	1.65E+01	1.45E+01	1.07E+01	
CUM. (MG/DNCM) SMALLER THAN D50	2.76E+01	2.76E+01	2.76E+01	2.76E+01	2.76E+01	2.43E+01	1.80E+01	
CUM. (GR/ACF) SMALLER THAN D50	7.22E-03	7.22E-03	7.22E-03	7.22E-03	7.21E-03	6.35E-03	4.69E-03	
CUM. (GR/DNCF) SMALLER THAN D50	1.21E-02	1.21E-02	1.21E-02	1.21E-02	1.21E-02	1.06E-02	7.85E-03	
GEO. MEAN DIA. (MICROMETERS)	2.00E+01	9.95E+00	6.66E+00	2.65E+00	1.26E+00	7.61E-01	3.91E-01	1.87E-01
DM/DLOGD (MG/DNCM)	1.22E+01	0.00E-01	0.00E-01	0.00E-01	2.46E-01	1.38E+01	1.90E+01	6.05E+01
DN/DLOGD (NO. PARTICLES/DNCM)	1.27E+06	0.00E-01	0.00E-01	0.00E-01	1.02E+08	2.60E+10	2.65E+11	7.67E+12

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	15.15	15.12	6.81	2.44	1.57	0.92	0.45	
GEO. MEAN DIA. (MICROMETERS)	3.04E+01	1.51E+01	1.01E+01	4.08E+00	1.96E+00	1.20E+00	6.43E-01	3.17E-01
DM/DLOGD (MG/DNCM)	1.22E+01	0.00E-01	0.00E-01	0.00E-01	2.52E-01	1.43E+01	2.06E+01	6.05E+01
DN/DLOGD (NO. PARTICLES/DNCM)	8.32E+05	0.00E-01	0.00E-01	0.00E-01	6.41E+07	1.57E+10	1.48E+11	3.64E+12

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

SQUARE ROOTS OF PSI BY STAGE	0.144	0.330	0.371	0.271	0.308	0.373	0.349
HOLE DIAMETERS BY STAGE (CENTIMETERS)	1.8237	0.5768	0.2501	0.0808	0.0524	0.0333	0.0245

CPPO-7 5-18-77 PORT-4,5 1331 INLET SAMPLE U. OF W. MARK III SOURCE TEST IMPACTOR NO. = D

IMPACTOR FLOWRATE = 0.450 ACFM IMPACTOR TEMPERATURE = 205.0 F = 96.1 C SAMPLING DURATION = 78.00 MIN

IMPACTOR PRESSURE DROP = 0.9 IN. OF HG STACK TEMPERATURE = 205.0 F = 96.1 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 26.66 IN. OF HG MAX. PARTICLE DIAMETER = 40.2 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 11.79 CO = 0.00 N2 = 67.69 O2 = 3.57 H2O = 16.95

CALC. MASS LOADING = 6.7094E-03 GR/ACF 1.1230E-02 GR/DNCF 1.5353E+01 MG/ACM 2.5698E+01 MG/DNCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	8.24	8.18	3.71	1.49	0.78	0.48	0.18	
MASS (MILLIGRAMS)	2.10	0.00	0.00	0.04	0.48	1.19	4.16	7.29
MG/DSCM/STAGE	3.58E+00	0.00E-01	0.00E-01	6.83E-02	8.19E-01	2.03E+00	7.10E+00	1.24E+01
CUM. PERCENT OF MASS SMALLER THAN D50	86.24	86.24	86.24	89.98	82.83	75.03	47.77	
CUM. (MG/ACM) SMALLER THAN D50	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.27E+01	1.15E+01	7.33E+00	
CUM. (MG/DNCM) SMALLER THAN D50	2.22E+01	2.22E+01	2.22E+01	2.21E+01	2.13E+01	1.93E+01	1.23E+01	
CUM. (GR/ACF) SMALLER THAN D50	5.79E-03	5.79E-03	5.79E-03	5.77E-03	5.56E-03	5.03E-03	3.21E-03	
CUM. (GR/DNCF) SMALLER THAN D50	9.68E-03	9.68E-03	9.68E-03	9.66E-03	9.30E-03	8.43E-03	5.36E-03	
GEO. MEAN DIA. (MICROMETERS)	1.82E+01	8.21E+00	5.51E+00	2.35E+00	1.08E+00	6.08E-01	2.90E-01	1.25E-01
DM/DLOGD (MG/DNCM)	5.21E+00	0.00E-01	0.00E-01	1.73E-01	2.89E+00	9.52E+00	1.66E+01	4.13E+01
DN/DLOGD (NO. PARTICLES/DNCM)	7.17E+05	0.00E-01	0.00E-01	1.10E+07	1.92E+09	3.51E+10	5.61E+11	1.74E+13

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	12.55	12.45	5.67	2.31	1.23	0.77	0.31	
GEO. MEAN DIA. (MICROMETERS)	2.77E+01	1.25E+01	8.41E+00	3.62E+00	1.68E+00	9.71E-01	4.91E-01	2.22E-01
DM/DLOGD (MG/DNCM)	5.22E+00	0.00E-01	0.00E-01	1.75E-01	2.97E+00	1.00F+01	1.82F+01	4.13E+01
DN/DLOGD (NO. PARTICLES/DNCM)	4.71E+05	0.00E-01	0.00E-01	7.03F+06	1.19F+09	2.09E+10	2.94E+11	7.23E+12

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

SQUARE ROOTS OF PSI BY STAGE	0.144	0.330	0.371	0.319	0.321	0.389	0.354
HOLE DIAMETERS BY STAGE (CENTIMETERS)	1.8237	0.5743	0.2512	0.0793	0.0495	0.0330	0.0229

CPPD-8 5-18-77 PORT-3,6 1330 INLET SAMPLE U. OF W. MARK III SOURCE TEST IMPACTOR NO. = C

IMPACTOR FLOWRATE = 0.410 ACFM IMPACTOR TEMPERATURE = 205.0 F = 96.1 C SAMPLING DURATION = 78.00 MIN

IMPACTOR PRESSURE DROP = 0.8 IN. OF HG STACK TEMPERATURE = 205.0 F = 96.1 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 26.66 IN. OF HG MAX. PARTICLE DIAMETER = 40.2 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 11.79 CO = 0.00 N2 = 67.69 O2 = 3.57 H2O = 16.95

CALC. MASS LOADING = 9.3569E-03 GR/ACF 1.5662E-02 GR/DNCF 2.1412E+01 MG/ACM 3.5839E+01 MG/DNCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	8.64	8.87	3.76	1.62	0.84	0.58	0.21	
MASS (MILLIGRAMS)	1.83	0.00	0.08	0.14	0.38	2.67	6.73	7.56
MG/DSCM/STAGE	3.43E+00	0.00E-01	1.50E-01	2.62E-01	7.12E-01	5.00E+00	1.26E+01	1.42E+01
CUM. PERCENT OF MASS SMALLER THAN D50	90.56	90.56	90.15	89.43	87.47	73.70	38.99	
CUM. (MG/ACM) SMALLER THAN D50	1.94E+01	1.94E+01	1.93E+01	1.91E+01	1.87E+01	1.58E+01	8.35E+00	
CUM. (MG/DNCM) SMALLER THAN D50	3.25E+01	3.25E+01	3.23E+01	3.20E+01	3.13E+01	2.64E+01	1.40E+01	
CUM. (GR/ACF) SMALLER THAN D50	8.47E-03	8.47E-03	8.44E-03	8.37E-03	8.18E-03	6.90E-03	3.65E-03	
CUM. (GR/DNCF) SMALLER THAN D50	1.42E-02	1.42E-02	1.41E-02	1.40E-02	1.37E-02	1.15E-02	6.11E-03	
GEO. MEAN DIA. (MICROMETERS)	1.86E+01	8.76E+00	5.78E+00	2.47E+00	1.17E+00	7.01E-01	3.50E-01	1.48E-01
DM/DLOGD (MG/DNCM)	5.14E+00	0.00E-01	4.03E-01	7.16E-01	2.50E+00	3.17E+01	2.83E+01	4.70E+01
DN/DLOGD (NO. PARTICLES/DNCM)	6.59E+05	0.00E-01	1.73E+06	3.95E+07	1.31E+09	7.63E+10	5.49E+11	1.21E+13

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	13.16	13.50	5.76	2.50	1.32	0.93	0.36	
GEO. MEAN DIA. (MICROMETERS)	2.83E+01	1.33E+01	8.82E+00	3.80E+00	1.82E+00	1.11E+00	5.82E-01	2.57E-01
DM/DLOGD (MG/DNCM)	5.15E+00	0.00E-01	4.05E-01	7.25E-01	2.57E+00	3.31E+01	3.07E+01	4.70E+01
DN/DLOGD (NO. PARTICLES/DNCM)	4.33E+05	0.00E-01	1.13E+06	2.53E+07	8.13E+08	4.61E+10	2.98E+11	5.31E+12

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

SQUARE ROOTS OF PSI BY STAGE	0.144	0.330	0.371	0.320	0.295	0.363	0.312
HOLE DIAMETERS BY STAGE (CENTIMETERS)	1.8237	0.5874	0.2459	0.0807	0.0532	0.0376	0.0260

CPPO-10 5-19-77 PORT-2 1059 INLET SAMPLE U. OF W. MARK III SOURCE TEST IMPACTOR NO. = A

IMPACTOR FLOWRATE = 0.320 ACFM IMPACTOR TEMPERATURE = 205.0 F = 96.1 C SAMPLING DURATION = 80.00 MIN

IMPACTOR PRESSURE DROP = 0.5 IN. OF HG STACK TEMPERATURE = 205.0 F = 96.1 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 26.69 IN. OF HG MAX. PARTICLE DIAMETER = 40.2 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 11.59 CO = 0.00 N2 = 66.01 O2 = 4.00 H2O = 18.40

CALC. MASS LOADING = 8.0538E-03 GR/ACF 1.3705E-02 GR/DNCF 1.8430E+01 MG/ACM 3.1361E+01 MG/DNCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	9.77	9.76	4.38	1.55	0.98	0.57	0.26	
MASS (MILLIGRAMS)	0.45	0.00	0.00	0.00	0.00	1.70	2.85	8.36
MG/DSCM/STAGE	1.07E+00	0.00E-01	0.00E-01	0.00E-01	0.00E-01	4.04E+00	6.78E+00	1.99E+01
CUM. PERCENT OF MASS SMALLER THAN D50	96.63	96.63	96.63	96.63	96.63	83.91	62.57	
CUM. (MG/ACM) SMALLER THAN D50	1.78E+01	1.78E+01	1.78E+01	1.78E+01	1.78E+01	1.55E+01	1.15E+01	
CUM. (MG/DNCM) SMALLER THAN D50	3.03E+01	3.03E+01	3.03E+01	3.03E+01	3.03E+01	2.63E+01	1.96E+01	
CUM. (GR/ACF) SMALLER THAN D50	7.78E-03	7.78E-03	7.78E-03	7.78E-03	7.78E-03	6.76E-03	5.04E-03	
CUM. (GR/DNCF) SMALLER THAN D50	1.32E-02	1.32E-02	1.32E-02	1.32E-02	1.32E-02	1.15E-02	8.58E-03	
GEO. MEAN DIA. (MICROMETERS)	1.98E+01	9.76E+00	6.53E+00	2.60E+00	1.23E+00	7.46E-01	3.82E-01	1.83E-01
DM/DLOGD (MG/DNCM)	1.74E+00	0.00E-01	0.00E-01	0.00E-01	0.00E-01	1.68E+01	1.99E+01	6.61E+01
DN/DLOGD (NO. PARTICLES/DNCM)	1.86E+05	0.00E-01	0.00E-01	0.00E-01	0.00E-01	3.37E+10	2.97E+11	9.01E+12

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	14.87	14.85	6.69	2.40	1.54	0.90	0.44	
GEO. MEAN DIA. (MICROMETERS)	3.01E+01	1.49E+01	9.96E+00	4.00E+00	1.92E+00	1.18E+00	6.29E-01	3.10E-01
DM/DLOGD (MG/DNCM)	1.75E+00	0.00E-01	0.00E-01	0.00E-01	0.00E-01	1.75E+01	2.16E+01	6.61E+01
DN/DLOGD (NO. PARTICLES/DNCM)	1.22E+05	0.00E-01	0.00E-01	0.00E-01	0.00E-01	2.04E+10	1.65E+11	4.29E+12

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

SQUARE ROOTS OF PST BY STAGE	0.144	0.330	0.371	0.271	0.308	0.373	0.349	
HOLE DIAMETERS BY STAGE (CENTIMETERS)	1.8237	0.5768	0.2501	0.0808	0.0524	0.0333	0.0245	

CPPO-12 5-19-77 PORT-3,6 1055 INLET SAMPLE U. OF W. MARK III SOURCE TEST IMPACTOR NO. = C

IMPACTOR FLOWRATE = 0.350 ACFM IMPACTOR TEMPERATURE = 205.0 F = 96.1 C SAMPLING DURATION = 80.00 MIN

IMPACTOR PRESSURE DROP = 0.5 IN. OF HG STACK TEMPERATURE = 205.0 F = 96.1 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 26.69 IN. OF HG MAX. PARTICLE DIAMETER = 40.2 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 11.59 CO = 0.00 N2 = 66.01 O2 = 4.00 H2O = 18.40

CALC. MASS LOADING = 8.1185E-03 GR/ACF 1.3815E-02 GR/DNCF 1.8578E+01 MG/ACM 3.1613E+01 MG/DNCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	9.34	9.59	4.07	1.76	0.92	0.64	0.23	
MASS (MILLIGRAMS)	0.28	0.00	0.00	0.04	0.14	1.23	6.19	6.85
MG/DSCM/STAGE	6.09E-01	0.00E-01	0.00E-01	8.70E-02	3.05E-01	2.68E+00	1.35E+01	1.49E+01
CUM. PERCENT OF MASS SMALLER THAN D50	98.10	98.10	98.10	97.83	96.88	88.53	46.50	
CUM. (MG/ACM) SMALLER THAN D50	1.82E+01	1.82E+01	1.82E+01	1.82E+01	1.80E+01	1.64E+01	8.64E+00	
CUM. (MG/DNCM) SMALLER THAN D50	3.10E+01	3.10E+01	3.10E+01	3.09E+01	3.06E+01	2.80E+01	1.47E+01	
CUM. (GR/ACF) SMALLER THAN D50	7.96E-03	7.96E-03	7.96E-03	7.94E-03	7.87E-03	7.19E-03	3.78E-03	
CUM. (GR/DNCF) SMALLER THAN D50	1.36E-02	1.36E-02	1.36E-02	1.35E-02	1.34E-02	1.22E-02	6.42E-03	
GEO. MEAN DIA. (MICROMETERS)	1.94E+01	9.46E+00	6.25E+00	2.67E+00	1.27E+00	7.66E-01	3.88E-01	1.66E-01
DM/DLOGD (MG/DNCM)	9.61E-01	0.00E-01	0.00E-01	2.38E-01	1.08E+00	1.72E+01	3.09E+01	4.95E+01
DN/DLOGD (NO. PARTICLES/DNCM)	1.10E+05	0.00E-01	0.00E-01	1.03E+07	4.39E+08	3.19E+10	4.40E+11	8.97E+12

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	14.21	14.59	6.23	2.71	1.44	1.02	0.40	
GEO. MEAN DIA. (MICROMETERS)	2.94E+01	1.44E+01	9.53E+00	4.11E+00	1.97E+00	1.21E+00	6.40E-01	2.84E-01
DM/DLOGD (MG/DNCM)	9.63E-01	0.00E-01	0.00E-01	2.41E-01	1.10E+00	1.79E+01	3.34E+01	4.95E+01
DN/DLOGD (NO. PARTICLES/DNCM)	7.21E+04	0.00E-01	0.00E-01	6.64E+06	2.74E+08	1.94E+10	2.43E+11	4.11E+12

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

SQUARE ROOTS OF PSI BY STAGE	0.144	0.330	0.371	0.320	0.295	0.363	0.312
HOLE DIAMETERS BY STAGE (CENTIMETERS)	1.8237	0.5874	0.2459	0.0807	0.0532	0.0376	0.0260

CPPO-13 5-19-77 PORT-4,5 1057 INLET SAMPLE U. OF W. MARK III SOURCE TEST IMPACTOR NO. = D

IMPACTOR FLOWRATE = 0.430 ACFM IMPACTOR TEMPERATURE = 205.0 F = 96.1 C SAMPLING DURATION = 80.00 MIN

IMPACTOR PRESSURE DROP = 0.8 IN. OF HG STACK TEMPERATURE = 205.0 F = 96.1 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 26.69 IN. OF HG MAX. PARTICLE DIAMETER = 40.2 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 11.59 CO = 0.00 N2 = 66.01 O2 = 4.00 H2O = 18.40

CALC. MASS LOADING = 7.6534E-03 GR/ACF 1.3023E-02 GR/DNCF 1.7514E+01 MG/ACM 2.9802E+01 MG/DNCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	8.42	8.35	3.79	1.53	0.80	0.49	0.18	
MASS (MILLIGRAMS)	0.89	0.00	0.00	0.00	0.26	3.34	3.92	8.65
MG/DSCM/STAGE	1.58E+00	0.00E-01	0.00E-01	0.00E-01	4.60E-01	5.91E+00	6.94E+00	1.53E+01
CUM. PERCENT OF MASS SMALLER THAN D50	94.78	94.78	94.78	94.78	93.26	73.68	50.70	
CUM. (MG/ACM) SMALLER THAN D50	1.66E+01	1.66E+01	1.66E+01	1.66E+01	1.63E+01	1.29E+01	8.88E+00	
CUM. (MG/DNCM) SMALLER THAN D50	2.82E+01	2.82E+01	2.82E+01	2.82E+01	2.78E+01	2.20E+01	1.51E+01	
CUM. (GR/ACF) SMALLER THAN D50	7.25E-03	7.25E-03	7.25E-03	7.25E-03	7.14E-03	5.64E-03	3.88E-03	
CUM. (GR/DNCF) SMALLER THAN D50	1.23E-02	1.23E-02	1.23E-02	1.23E-02	1.21E-02	9.60E-03	6.60E-03	
GEO. MEAN DIA. (MICROMETERS)	1.84E+01	8.38E+00	5.62E+00	2.40E+00	1.10E+00	6.23E-01	2.99E-01	1.30E-01
DM/DLOGD (MG/DNCM)	2.32E+00	0.00E-01	0.00E-01	0.00E-01	1.63E+00	2.79E+01	1.63E+01	5.09E+01
DN/DLOGD (NO. PARTICLES/DNCM)	3.10E+05	0.00E-01	0.00E-01	0.00E-01	1.01E+09	9.56E+10	5.05E+11	1.93E+13

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	12.81	12.71	5.79	2.36	1.25	0.79	0.32	
GEO. MEAN DIA. (MICROMETERS)	2.79E+01	1.28E+01	8.58E+00	3.70E+00	1.72E+00	9.94E-01	5.05E-01	2.29E-01
DM/DLOGD (MG/DNCM)	2.33E+00	0.00E-01	0.00E-01	0.00E-01	1.67E+00	2.93E+01	1.79E+01	5.09E+01
DN/DLOGD (NO. PARTICLES/DNCM)	2.03E+05	0.00E-01	0.00E-01	0.00E-01	6.26E+08	5.70E+10	2.67E+11	8.14E+12

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

SQUARE ROOTS OF PSI BY STAGE	0.144	0.330	0.371	0.319	0.321	0.389	0.354
HOLE DIAMETERS BY STAGE (CENTIMETERS)	1.8237	0.5743	0.2512	0.0793	0.0495	0.0330	0.0229

CPPO-14 5-20-77 PORT-5,6 1135 INLET SAMPLE U. OF W. MARK III SOURCE TEST IMPACTOR NO. = C

IMPACTOR FLOWRATE = 0.340 ACFM IMPACTOR TEMPERATURE = 205.0 F = 96.1 C SAMPLING DURATION = 80.00 MIN

IMPACTOR PRESSURE DROP = 0.5 IN. OF HG STACK TEMPERATURE = 205.0 F = 96.1 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 26.68 IN. OF HG MAX. PARTICLE DIAMETER = 40.2 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 11.37 CO = 0.00 N2 = 68.37 O2 = 4.46 H2O = 15.80

CALC. MASS LOADING = 8.3176E-03 GR/ACF 1.3722E-02 GR/DNCF 1.9034E+01 MG/ACM 3.1400E+01 MG/DNCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	9.53	9.78	4.16	1.79	0.94	0.66	0.24	
MASS (MILLIGRAMS)	0.55	0.00	0.02	0.00	0.16	2.20	5.02	6.71
MG/DSCM/STAGE	1.19E+00	0.00E-01	4.34E-02	0.00E-01	3.47E-01	4.78E+00	1.09E+01	1.46E+01
CUM. PERCENT OF MASS SMALLER THAN D50	96.25	96.25	96.11	96.11	95.02	80.01	45.77	
CUM. (MG/ACM) SMALLER THAN D50	1.83E+01	1.83E+01	1.83E+01	1.83E+01	1.81E+01	1.52E+01	8.71E+00	
CUM. (MG/DNCM) SMALLER THAN D50	3.02E+01	3.02E+01	3.02E+01	3.02E+01	2.98E+01	2.51E+01	1.44E+01	
CUM. (GR/ACF) SMALLER THAN D50	8.01E-03	8.01E-03	7.99E-03	7.99E-03	7.90E-03	6.66E-03	3.81E-03	
CUM. (GR/DNCF) SMALLER THAN D50	1.32E-02	1.32E-02	1.32E-02	1.32E-02	1.30E-02	1.10E-02	6.28E-03	
GEO. MEAN DIA. (MICROMETERS)	1.96E+01	9.66E+00	6.38E+00	2.73E+00	1.30E+00	7.83E-01	3.97E-01	1.70E-01
DM/DLOGD (MG/DNCM)	1.91E+00	0.00E-01	1.17E-01	0.00E-01	1.23E+00	3.09E+01	2.51E+01	4.84E+01
DN/DLOGD (NO. PARTICLES/DNCM)	2.11E+05	0.00E-01	3.74E+05	0.00E-01	4.70E+08	5.34E+10	3.32E+11	8.11E+12

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	14.51	14.89	6.36	2.77	1.47	1.04	0.41	
GEO. MEAN DIA. (MICROMETERS)	2.97E+01	1.47E+01	9.73E+00	4.19E+00	2.01E+00	1.24E+00	6.55E-01	2.91E-01
DM/DLOGD (MG/DNCM)	1.91E+00	0.00E-01	1.17E-01	0.00E-01	1.26E+00	3.21E+01	2.71E+01	4.84E+01
DN/DLOGD (NO. PARTICLES/DNCM)	1.39E+05	0.00E-01	2.44E+05	0.00E-01	2.94E+08	3.25E+10	1.84E+11	3.74E+12

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

SQUARE ROOTS OF PSI BY STAGE	0.144	0.330	0.371	0.320	0.295	0.363	0.312
HOLE DIAMETERS BY STAGE (CENTIMETERS)	1.8237	0.5874	0.2459	0.0807	0.0532	0.0376	0.0260

CPPO-15 5-20-77 PORT-2 1140 INLET SAMPLE U. OF W. MARK III SOURCE TEST IMPACTOR NO. = A

IMPACTOR FLOWRATE = 0.296 ACFM IMPACTOR TEMPERATURE = 205.0 F = 96.1 C SAMPLING DURATION = 94.00 MIN

IMPACTOR PRESSURE DROP = 0.4 IN. OF HG STACK TEMPERATURE = 205.0 F = 96.1 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 26.68 IN. OF HG MAX. PARTICLE DIAMETER = 40.2 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 11.37 CO = 0.00 N2 = 68.37 O2 = 4.46 H2O = 15.80

CALC. MASS LOADING = 7.7206E-03 GR/ACF 1.2737E-02 GR/DNCF 1.7667E+01 MG/ACM 2.9146E+01 MG/DNCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	10.22	10.21	4.58	1.62	1.03	0.60	0.27	
MASS (MILLIGRAMS)	0.18	0.07	0.00	0.02	0.01	2.11	2.88	8.65
MG/DSCM/STAGE	3.82E-01	1.49E-01	0.00E-01	4.24E-02	2.12E-02	4.48E+00	6.11E+00	1.84E+01
CUM. PERCENT OF MASS SMALLER THAN D50	98.71	98.20	98.20	98.06	97.99	82.83	62.14	
CUM. (MG/ACM) SMALLER THAN D50	1.74E+01	1.74E+01	1.74E+01	1.73E+01	1.73E+01	1.46E+01	1.10E+01	
CUM. (MG/DNCM) SMALLER THAN D50	2.88E+01	2.86E+01	2.86E+01	2.86E+01	2.86E+01	2.41E+01	1.81E+01	
CUM. (GR/ACF) SMALLER THAN D50	7.62E-03	7.58E-03	7.58E-03	7.57E-03	7.57E-03	6.40E-03	4.80E-03	
CUM. (GR/DNCF) SMALLER THAN D50	1.26E-02	1.25E-02	1.25E-02	1.25E-02	1.25E-02	1.05E-02	7.91E-03	
GEO. MEAN DIA. (MICROMETERS)	2.03E+01	1.02E+01	6.84E+00	2.73E+00	1.29E+00	7.84E-01	4.04E-01	1.94E-01
DM/DLOGD (MG/DNCM)	6.42E-01	2.19E+02	0.00E-01	9.42E-02	1.08E-01	1.87E+01	1.82E+01	6.10E+01
DN/DLOGD (NO. PARTICLES/DNCM)	6.40E+04	1.71E+08	0.00E-01	3.86E+06	4.14E+07	3.23E+10	2.29E+11	6.96E+12

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	15.55	15.53	7.00	2.51	1.61	0.95	0.46	
GEO. MEAN DIA. (MICROMETERS)	3.08E+01	1.55E+01	1.04E+01	4.19E+00	2.01E+00	1.24E+00	6.62E-01	3.27E-01
DM/DLOGD (MG/DNCM)	6.44E-01	2.19E+02	0.00E-01	9.53E-02	1.11E-01	1.95E+01	1.96E+01	6.10E+01
DN/DLOGD (NO. PARTICLES/DNCM)	4.21E+04	1.12E+08	0.00E-01	2.48E+06	2.60E+07	1.96E+10	1.28E+11	3.33E+12

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

SQUARE ROOTS OF PSI BY STAGE	0.144	0.330	0.371	0.271	0.308	0.373	0.349	
HOLE DIAMETERS BY STAGE (CENTIMETERS)	1.8237	0.5768	0.2501	0.0808	0.0524	0.0333	0.0245	

CPPO-17 5-20-77 PORT-4,5 1137 INLET SAMPLE U. OF W. MARK III SOURCE TEST IMPACTOR NO. = D

IMPACTOR FLOWRATE = 0.418 ACFM IMPACTOR TEMPERATURE = 205.0 F = 96.1 C SAMPLING DURATION = 80.00 MIN

IMPACTOR PRESSURE DROP = 0.8 IN. OF HG STACK TEMPERATURE = 205.0 F = 96.1 C

ASSUMED PARTICLE DENSITY = 2.30 GM/CU.CM. STACK PRESSURE = 26.68 IN. OF HG MAX. PARTICLE DIAMETER = 40.2 MICROMETERS

GAS COMPOSITION (PERCENT) CO2 = 11.37 CO = 0.00 N2 = 68.37 O2 = 4.46 H2O = 15.80

CALC. MASS LOADING = 8.2192E-03 GR/ACF 1.3559E-02 GR/DNCF 1.8808E+01 MG/ACM 3.1028E+01 MG/DNCM

IMPACTOR STAGE	S1	S2	S3	S4	S5	S6	S7	FILTER
STAGE INDEX NUMBER	1	2	3	4	5	6	7	8
D50 (MICROMETERS)	8.59	8.52	3.86	1.56	0.81	0.50	0.19	
MASS (MILLIGRAMS)	1.36	0.00	0.00	0.14	0.26	3.60	3.81	8.64
MG/DSCM/STAGE	2.40E+00	0.00E-01	0.00E-01	2.47E-01	4.59E-01	6.36E+00	6.73E+00	1.53E+01
CUM. PERCENT OF MASS SMALLER THAN D50	92.36	92.36	92.36	91.58	90.12	69.90	48.51	
CUM. (MG/ACM) SMALLER THAN D50	1.74E+01	1.74E+01	1.74E+01	1.72E+01	1.69E+01	1.31E+01	9.12E+00	
CUM. (MG/DNCM) SMALLER THAN D50	2.87E+01	2.87E+01	2.87E+01	2.84E+01	2.80E+01	2.17E+01	1.51E+01	
CUM. (GR/ACF) SMALLER THAN D50	7.59E-03	7.59E-03	7.59E-03	7.53E-03	7.41E-03	5.75E-03	3.99E-03	
CUM. (GR/DNCF) SMALLER THAN D50	1.25E-02	1.25E-02	1.25E-02	1.24E-02	1.22E-02	9.48E-03	6.58E-03	
GEO. MEAN DIA. (MICROMETERS)	1.86E+01	8.55E+00	5.74E+00	2.45E+00	1.13E+00	6.37E-01	3.07E-01	1.33E-01
DM/DLOGD (MG/DNCM)	3.58E+00	0.00E-01	0.00E-01	6.27E-01	1.62E+00	3.01E+01	1.59E+01	5.07E+01
DN/DLOGD (NO. PARTICLES/DNCM)	4.64E+05	0.00E-01	0.00E-01	3.52E+07	9.45E+08	9.64E+10	4.56E+11	1.77E+13

AERODYNAMIC DIAMETERS ARE CALCULATED HERE ACCORDING TO THE TASK GROUP ON LUNG DYNAMICS DEFINITION

D50 (MICROMETERS)	13.07	12.97	5.91	2.41	1.28	0.81	0.33	
GEO. MEAN DIA. (MICROMETERS)	2.82E+01	1.30E+01	8.76E+00	3.78E+00	1.76E+00	1.02E+00	5.16E-01	2.34E-01
DM/DLOGD (MG/DNCM)	3.59E+00	0.00E-01	0.00E-01	6.35E-01	1.67E+00	3.16E+01	1.74E+01	5.07E+01
DN/DLOGD (NO. PARTICLES/DNCM)	3.05E+05	0.00E-01	0.00E-01	2.25E+07	5.87E+08	5.76E+10	2.42E+11	7.53E+12

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

SQUARE ROOTS OF PSI BY STAGE	0.144	0.330	0.371	0.319	0.321	0.389	0.354
HOLE DIAMETERS BY STAGE (CENTIMETERS)	1.8237	0.5743	0.2512	0.0793	0.0495	0.0330	0.0229

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

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EPA-600/7-78-094		

4. TITLE AND SUBTITLE	5. REPORT DATE
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	6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Joseph D. McCain	SORI-EAS-78-348 3765-SR

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15. SUPPLEMENTARY NOTES IERL-RTP project officer is Dale L. Harmon, Mail Drop 61, 919/541-2925.

16. ABSTRACT The report gives detailed results of fractional and overall mass efficiency tests of a Combustion Equipment Associates (CEA) variable-throat venturi scrubber. The tests were performed on a full-scale scrubber used for controlling particles and SOx emissions from a pulverized-coal-fired utility boiler. Total flue gas particulate mass concentrations were determined at the scrubber inlet and outlet by conventional techniques. Inlet and outlet particulate concentrations as functions of size were determined on a mass basis using cascade impactors for sizes from about 0.3 to 5 micrometers, and on a number basis for sizes smaller than about 1 micrometer using optical and electrical mobility techniques. The report describes the scrubber, measurement methods, inlet and outlet size distribution data, and fractional efficiencies.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Boilers	Pollution Control	13B 13A
Dust Control	Measurement	Stationary Sources	
Gas Scrubbing	Efficiency	Particulates	07A, 13H
Venturi Tubes			14B
Scrubbers			13I
Coal			21D

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
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	Unclassified	

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