Background Report Reference

AP-42 Section Number: 8.12

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Title: Emission Test Report: F.M.C., Green River, Wyoming

US EPA

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May 1979

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5.16

United States Environmental Protection Agency

Office of Air Quality Planning and Standards
Research Triangle Park NC 27711

EMB Report 79-SOD-2
May 1979

Air

EPA

Sodium Carbonate

~~Section 5.16~~

~~Reference #33~~

Emission Test Rep…
F. M. C.
Green River, Wyoming

United States Environmental Protection Agency
Emission Measurement Branch
Mail Drop 13
Research Triangle Park, North Carolina 27711

FINAL REPORT

Emission Test Program: Sodium Carbonate Manufacturing Plant

Conducted at

F.M.C. Corporation
Green River, Wyoming 82935

Contract Number 68-02-2819

Task Assignment 14

Project Number 79-SOD-2

York Project Number 1-9517-14

March 11, 1980

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STATEMENT OF CONFIDENTIALITY

All data pertaining to temperature, moisture and actual flow rates of the inlets tested have been deemed confidential by the F.M.C. Corporation. Due to this fact, these data have been deleted from the final report and put under separate cover. Pending determination by E.P.A. of the confidentiality of these data, they have been submitted as described to us for official entry into our confidential files.

1.0 INTRODUCTION

York Research Corporation (YRC) under contract #68-02-2819 was requested by the United States Environmental Protection Agency (USEPA) to perform an emission test program at a Sodium Carbonate manufacturing plant. The test program was conducted at the F.M.C. Corporation plant, located in Green River, Wyoming. Sampling was performed from May 14, 1979 to May 19, 1979.

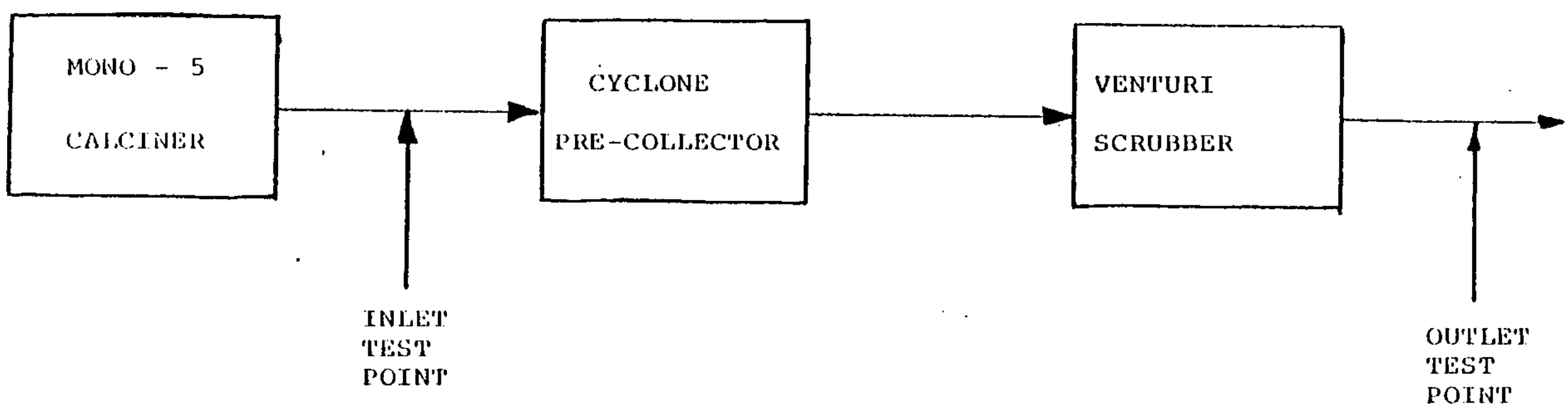
The sampling locations included:

- Mono-5 Inlet
- Mono-5 Outlet
- NS-6 Dryer Inlet
- NS-6 Dryer Outlet
- NS-3 Calciner Inlet
- NS-3 Calciner Outlet

Figures 1-1 to 1-3 show the sampling locations in the process. Samples were collected for solid particulate, organics and particle size distribution at each test location. The objective of the test program was to determine the emission levels of controlled sodium carbonate industry.

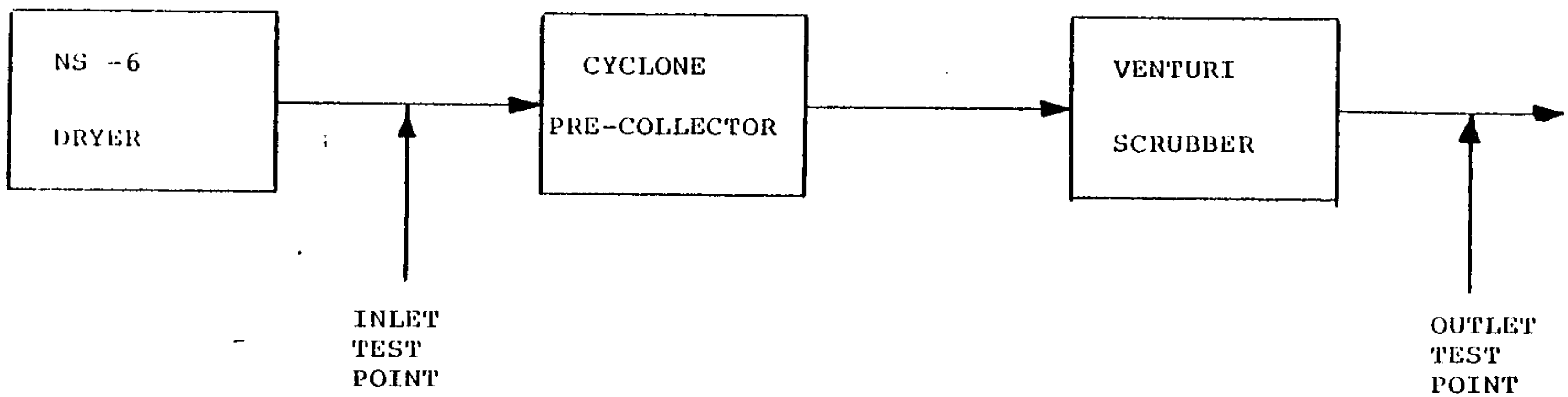
The test team consisted of the following individuals:

Name	Affiliation	Title
Dennis P. Holzschuh	USEPA	Technical Manager
Roger A. Kniskern	YRC	Project Manager
William J. Cesareo	YRC	Test Engineer
John Breger	YRC	Test Engineer
Keith Synnestvedt	YRC	Test Technician
Albert Burton	YRC	Test Technician
Laurie Behr	YRC	Test Technician
Joseph Kuntz	YRC	Chemical Technician
Bruce Wuebber	YRC	Test Technician



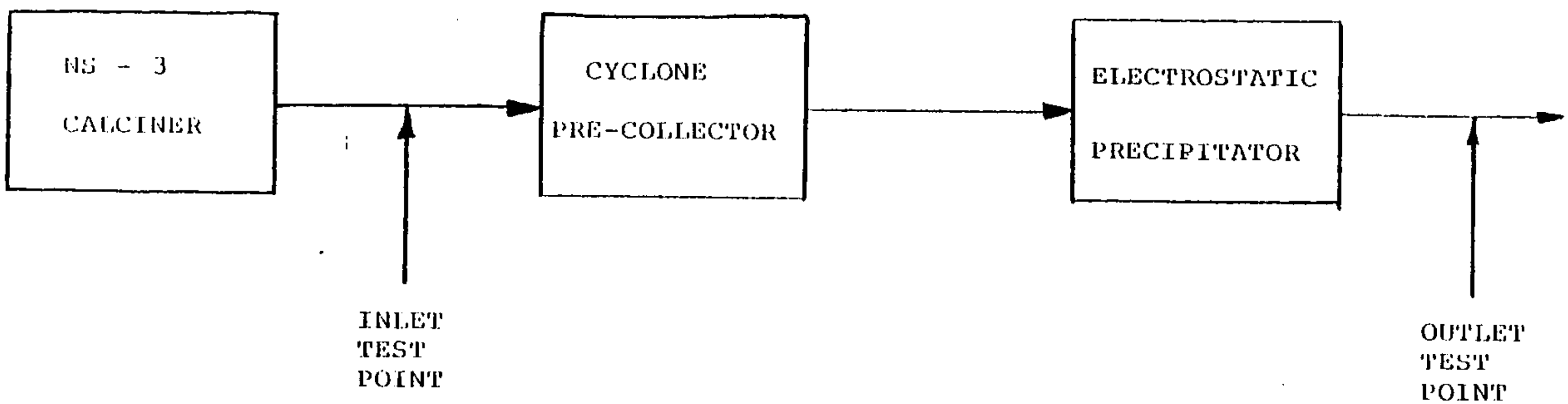
MONO - 5 CALCINER PROCESS DIAGRAM

FIGURE 1-1



NS - 6 DRYER PROCESS DIAGRAM

FIGURE 1-2



NS-3 CALCINER PROCESS DIAGRAM

FIGURE 1-3

2.0 SUMMARY AND DISCUSSION OF TEST RESULTS

Tables 2-1 through 2-18 and Figures 2-1 through 2-10 summarize the results of the emission test program. These tables present the results of tests for the following parameters:

- Particulate
- Particle Size Distribution
- Visible Emissions
- Organics

Sample analysis for all parameters were performed at YRC laboratories in Stamford, Connecticut or Denver, Colorado with the exception of organics. A portable gas chromatograph with a flame ionization detector was set up at the test site for analysis of organic samples. The particulate concentration at each of the three inlet test locations were extremely high. This contributed to nozzle, filter, probe and pitot tube plugging. All pitot readings were taken after each line was purged with air.

The following table details the isokinetic ratio results of the particulate tests conducted at each location.

Test No.	1	2	3
Mono-5 Inlet	97.6	97.9	111.1
Mono-5 Outlet	107.6	107.8	108.4
NS-6 Inlet	72.6	68.8	76.2
NS-6 Outlet	99.2	99.9	94.9
NS-3 Inlet	78.1	93.2	104.4
NS-3 Outlet	94.9	103.3	108.3

Several inlet tests failed to meet the isokinetic requirement (100±10%) of the reference method.

Anisokinetic conditions can fall into two categories:

- The velocity in the nozzle greater than the velocity in the stack ($V_n > V_s$)
- The velocity in the nozzle less than the velocity in the stack ($V_n < V_s$)

In the case of $V_n > V_s$ the measured concentration of particulate is less than the actual concentration in the stack gas. This is due to the inertial properties of the larger particles - they tend to pass the nozzle while the gas and the smaller particles are drawn into the nozzle. As a result, fewer particles are collected per unit volume. Conversely, in the case of $V_n < V_s$ the measured concentration of particulate is greater than the actual concentration in the stack gas. This is again due to the inertial properties of the smaller particles - they tend to pass the nozzle while the larger particles are drawn into the nozzle. As a result, more particles are collected per unit volume. This being the case, it is important to sample isokinetically in streams where there are predominantly large particle.

Correction factors for anisokinetic sampling are shown in Exhibit A. The following tables detail the test results corrected for anisokinetic sampling.

Exhibit A

Appendix C

Errors due to Anisokinetic Sampling

Failure to withdraw a sample from a flowing stream at the same velocity as that which exists locally in the stream will result in nonrepresentative sampling. If the sampling rate is much higher than the local stream velocity, a greater fraction of smaller rather than larger particles will be drawn into the probe. If sampling is much lower than the stream velocity, large particles will be impacted into the collecting probe.

Although theoretical and experimental data are available, a comprehensive study of these errors has not been made. The data is almost entirely empirical and reflects different techniques using different particles. The influence of probe shape and size has yet to be fully evaluated.

In Table C1 the errors due to anisokinetic sampling rates are given, which represent data composited from several workers' experiments.[4]

Particles used in the studies yielding the data shown were coal dust, dibutyl phthalate, and fungus spores, all of which are relatively low density materials, ranging from 1.3 for coal dust to about 1 or somewhat less for the spores. Since particle density will materially increase the inertial effects, the sampling error could be considerably larger than the tabled values for a given particle size. The last column

[4]GREEN, H. L.; LANE, W. R. *Particulate Clouds: Dusts, Smokes, and Mists.* London: E. and F. N. Spon, Ltd. 1964, 2nd ed. p 272.

Table C1

Ratio of Observed to Actual Concentration of Particles when Sampled at Various Fractions and Multiples of Isokinetic Flow

$\frac{U}{U_o} = \frac{\text{Probe inlet velocity}}{\text{Duct velocity}}$	$\frac{C}{C_o} = \frac{\text{Observed concentration in sample}}{\text{Actual concentration}}$					Limit for Very Large Particles
	$d_p = 4\mu m$	$d_p = 12\mu m$	$d_p = 17\mu m$	$d_p = 31\mu m$	$d_p = 37\mu m$	
0.5	1.06	1.14	1.20	1.33	1.46	2.00
0.6	1.03	1.09	1.13	1.23	1.41	1.67
0.7	1.02	1.05	1.08	1.14	1.32	1.44
0.8	1.01	1.02	1.04	1.06	1.16	1.25
0.9	1.00	1.01	1.01	1.03	1.07	1.11
1.0	1.00	1.00	1.00	1.00	1.00	1.00
1.1	0.99	0.98	0.98	0.95	0.93	0.90
1.2	0.98	0.96	0.95	0.92	0.87	0.83
1.3	0.97	0.94	0.94	0.85	0.84	0.77
1.4	0.97	0.92	0.93	0.83	0.81	0.72
1.5	0.96	0.89	0.93	*	0.76	0.67
1.6	0.95	0.83	*	*	0.74	0.63
1.7	0.94	0.78	*	*	0.71	0.59
1.8	0.92	0.72	*	*	0.68	0.55
1.9	[illegible]	0.65	*	*	0.66	0.53
2.0	0.86	*	*	*	0.64	0.50

*Data does not cover this range.

of the table shows the limit of the concentration ratio for very large or dense particles. If the sampling probe inlet velocity is only 50 percent of the duct velocity and all large (or dense) particles in the projected area of the probe inlet are impacted into the probe, twice as many will be collected as should have been. Similarly, should the sampling probe inlet velocity be twice the duct velocity and the particle inertia be such that only those particles approaching in the projected area of the probe are collected, then the observed concentration would be one-half the actual concentration.

It must be remembered that particles generated by most natural processes vary widely in size, and the sampling error will be the composite effect of all particle sizes present.

Mono-5

Test No.	1	2	3
Inlet Particulate Concentration (gr/SCFD)			
Measured	72.84011	109.49157	114.86092
Correction Factor	1.00	1.00	0.8923
Actual	72.84011	109.49157	128.72455
Outlet Particulate Concentration (gr/SCFD)			
Measured	0.09353	0.12157	0.11740
Correction Factor	1.00	1.00	1.00
Actual	0.09353	0.12157	0.11740
Scrubber Efficiency(%)			
Based on Measured	99.87	99.89	99.90
Based on Actual	99.87	99.89	99.91

NS-6

Test No.	1	2	3
Inlet Particulate Concentration (gr/SCFD)			
Measured	39.65347	19.28181	18.26509
Correction Factor	1.3984	1.4676	1.3408
Actual	28.35631	13.13833	13.62253
Outlet Particulate Concentration (gr/SCFD)			
Measured	0.04935	0.01703	0.00655
Correction Factor	1.00	1.00	1.00
Actual	0.04935	0.01703	0.00655
Scrubber Efficiency(%)			
Based on Measured	99.88	99.91	99.96
Based on Actual	99.83	99.87	99.95

NS-3

Test No.	1	2	3
Inlet Particulate Concentration (gr/SCFD)			
Measured	103.5689	94.32048	77.54809
Correction Factor	1.3104	1.00	1.00
Actual	79.03610	94.32048	77.54809
Outlet Particulate Concentration (gr/SCFD)			
Measured	0.09322	0.12319	0.08193
Correction Factor	1.00	1.00	1.00
Actual	0.09322	0.12319	0.08193
Scrubber Efficiency (%)			
Based on Measured	99.91	99.87	99.89
Based on Actual	99.88	99.87	99.89

The correction factor was applied as follows:

$$Fc = \frac{C}{Ca}$$

where

Fc = correction factor

C = measured concentration

Ca = actual concentration

therefore

$$Ca = \frac{C}{Fc}$$

The correction factor for the inlet concentrations was for large particles since the Bahco analysis showed approximately 50% of the particles at each location to be greater than 44 microns.

Correcting for anisokinetic sampling increased the scrubber efficiency for test 3 at Mono-5 by 0.03%, decreased the scrubber efficiency at NS-6 by an average of 0.033 %, and decreased the scrubber efficiency for test 1 at NS-3 by 0.03%.

Particle size tests were performed using an Andersen cascade impactor at each test location except the NS-6 dryer outlet. No sample was collected at the NS-6 dryer outlet due to the high moisture content of the gas stream. Sufficient sample was collected at the inlet such that an aliquot from each test was taken and composited for a sieve and Bahco particle size analysis. It is not feasible to conduct a particle size analysis on any outlet filters because of the small amount of particulate. Any scraping of the filter would bias the particle size by introducing fiberglass material into the sample, also any extraction of the filter by use of solvents such as water would dissolve the particulate matter and the subsequent crystallization would not be representative of actual test conditions.

TABLE 2.1

Summary of Removal Efficiency

Test No.	Test Location	Removal Efficiency(%)
1	Mono-5	99.87
2	Mono-5	99.88
3	Mono-5	99.90
1	NS-6 Dryer	99.98
2	NS-6 Dryer	99.91
3	NS-6 Dryer	99.96
1	NS-3 Calciner	99.90
2	NS-3 Calciner	99.86
3	NS-3 Calciner	99.86

TABLE 2-2

Summary of Emission Test Results

Mono-5 Inlet

(English Units)

Test No.	1	2	3	Average
General Data				
Date	5/15/79	5/15/79	5/17/79	--
Time	0925	1345	0810	--
Isokinetic Ratio(%)	97.6	97.9	111.1	102.2
Gas Data				
Velocity (fps)				
Flow (SCFMD)				
Temperature (°F)				
Moisture (%)				
Particulate Emissions				
Gr/SCFD	72.84011	109.49157	114.86092	99.06420
Lb/hour	39517.36	48624.06	44010.36	44050.59
Organics				
ppm	917	2587	--	1752

*

* Refer to page -iii- Statement of Confidentiality

TABLE 2-3

Summary of Emission Test Results

Mono-5 Inlet

(Metric Units)

Test No.	1	2	3	Average
General Data				
Date	5/15	5/15	5/17	--
Time	0925	1345	0810	--
Isokinetic Ratio(%)	97.6	97.9	111.1	102.2
Gas Data				*
Velocity (mps)				
Flow (dnm^3/min)				
Temperature (^{o}C)				
Moisture (%)				
Particulate Emissions				
Mg/nm^3	166685.7	250558.09	262845.19	226696.33
Kg/hr	17925.07	22055.88	19963.10	19981.35

* Refer to page -iii- Statement of Confidentiality

TABLE 2-4

Summary of Emission Test Results
Mono-5 Outlet
(English Units)

Test No.	1	2	3	Average
General Data				
Date	5/15/79	5/15/79	5/17/79	--
Time	0930	1337	0800	--
Isokinetic Ratio(%)	107.6	107.8	108.4	107.9
Gas Data				
Velocity (fps)	85.889	87.228	87.103	86.740
Flow (SCFMD)	47308.	44343.	43707.	45119.
Temperature (^{o}F)	152.5	168.8	150.0	157.1
Moisture (%)	32.8	36.4	38.6	36.0
Particulate Emissions				
Gr/SCFD	0.09353	0.12157	0.11740	0.11083
Lb/Hour	37.93	46.21	43.98	42.71
Organics				
ppm	154	261	--	207.5

TABLE 2-5

Summary of Emission Test Results
Mono-5 Outlet
(Metric Units)

Test No.	1	2	3	Average
General Data				
Date	5/15	5/15	5/17	--
Time	0930	1337	0800	--
Isokinetic Ratio (%)	107.6	107.8	108.4	107.9
Gas Data				
Velocity (mps)	26.179	26.587	26.549	26.438
Flow (dnm^3/min)	1340	1256	1238	1278
Temperature (^{o}C)	66.9	76.0	65.6	69.5
Moisture (%)	32.8	36.4	38.6	36.0
Particulate Emissions				
Mg/nm^3	214.03	278.20	268.67	253.63
Kg/Hour	17.20	20.96	19.95	19.37

TABLE 2-6

Summary of Emission Test Results
NS-6 Dryer Inlet
(English Units)

Test No.	1	2	3	Average
General Data				
Date	5/18/79	5/18/79	5/18/79	--
Time	0835	1220	1530	--
Isokinetic Ratio (%)	72.6	68.8	76.2	72.5
Gas Data				*
Velocity (fps)				
Flow (SCFMD)				
Temperature (^{o}F)				
Moisture (%)				
Particulate Emissions				
Gr/SCFD	39.65347	19.28181	18.26509	25.73346
Lb/Hour	26082.05	11853.49	11501.76	16479.10
Organics				
ppm	25	88	--	56.5

* Refer to page -iii- Statement of Confidentiality

TABLE 2-7

Summary of Emission Test Results
NS-6 Dryer Inlet
(Metric Units)

Test No.	1	2	3	Average
General Data				
Date	5/18	5/18	5/18	--
Time	0835	1220	1530	--
Isokinetic Ratio (%)	72.6	68.8	76.2	72.5
Gas Data				
Velocity (mps)				
Flow (dnm^3/min)				
Temperature (^oC)				
Moisture (%)				
Particulate Emissions				
Mg/nm^3	90742.13	44124.07	41797.43	58887.88
Kg/Hour	11830.82	5376.74	5217.20	7474.92

*

* Refer to page -iii- Statement of Confidentiality

TABLE 2-8

Summary of Emission Test Results
NS-6 Dryer Outlet
(English Units)

Test No.	1	2	3	Average
General Data				
Date	5/18/79	5/18/79	5/18/79	--
Time	0841	1220	1520	--
Isokinetic Ratio (%)	99.2	99.9	94.9	98.0
Gas Data				
Velocity (fps)	67.157	64.228	62.754	64.713
Flow (SCFMD)	43330.	41987.	43323.	42880.
Temperature (^{o}F)	165.0	168.6	142.1	158.6
Moisture (%)	31.3	30.0	29.2	30.2
Particulate Emissions				
Gr/SCFD	0.04935	0.01703	0.00655	0.02431
Lb/Hour	18.33	6.13	2.43	8.96
Organics				
ppm	103	72	--	87.5

TABLE 2-9

Summary of Emission Test Results
NS-6 Dryer Outlet
(Metric Units)

Test No.	1	2	3	Average
General Data				
Date	5/18	5/18	5/18	--
Time	0841	1220	1520	--
Isokinetic Ratio (%)	99.2	99.9	94.9	98.0
Gas Data				
Velocity (mps)	20.470	19.577	19.127	19.725
Flow (dnm^3/min)	1227.	1189.	1227.	1214.
Temperature (^oC)	73.9	75.9	61.2	70.3
Moisture (%)	31.3	30.0	29.2	30.2
Particulate Emissions				
Mg/nm^3	112.93	38.97	14.99	55.63
Kg/Hour	8.31	2.78	1.10	4.07

TABLE 2-10

Summary of Emission Test Results
NS-3 Calciner Inlet
(English Units)

Test No.	1	2	3	Average
General Data				
Date	5/19/79	5/19/79	5/19/79	--
Time	1015	1430	1710	--
Isokinetic Ratio (%)	78.1	93.2	104.4	91.9
Gas Data				
Velocity (fps)				*
Flow (SCFMD)				
Temperature (^{o}F)				
Moisture (%)				
Particulate Emissions				
Gr/SCFD	103.5689	94.32048	77.54809	91.81252
Lb/Hour	93577.33	83311.77	57897.52	78262.20
Organics				
ppm	47	178	222	149

* Refer to page -iii- Statement of Confidentiality

TABLE 2-11

Summary of Emission Test Results
NS-3 Calciner Inlet
(Metric Units)

Test No.	1	2	3	Average
General Data				
Date	5/19	5/19	5/19	--
Time	1015	1430	1710	--
Isokinetic Ratio (%)	78.1	93.2	104.4	91.9
Gas Data				*
Velocity (mps)				
Flow (dnm^3/min)				
Temperature (^oC)				
Moisture (%)				
Particulate Emissions				
Mg/nm^3	237004.9	215840.91	177459.33	210101.75
Kg/Hour	42446.68	37790.21	26262.31	35499.73

* Refer to page -iii- Statement of Confidentiality

TABLE 2-12

Summary of Emission Test Results
NS-3 Calciner Outlet
(English Units)

Test No.	1	2	3	Average
General Data				
Date	5/19/79	5/19/79	5/19/79	--
Time	1014	1420	1710	--
Isokinetic Ratio (%)	94.9	103.3	108.3	102.2
Gas Data				
Velocity (fps)	82.721	82.004	78.364	81.030
Flow (SCFMD)	85421.	84751.	76372.	82181.
Temperature (^{o}F)	400.8	400.9	401.1	401.0
Moisture (%)	30.4	30.4	34.3	31.7
Particulate Emissions				
Gr/SCFD	0.09322	0.12319	0.08193	0.09944
Lb/Hour	68.25	89.49	53.63	70.46
Organics				
ppm	361	314	--	337.5

TABLE 2-13

Summary of Emission Test Results
NS-3 Calciner Outlet
(Metric Units)

Test No.	1	2	3	Average
General Data				
Date	5/19	5/19	5/19	--
Time	1014	1420	1710	--
Isokinetic Ratio (%)	94.9	103.3	108.3	102.2
Gas Data				
Velocity (mps)	25.213	24.995	23.885	24.689
Flow (dnm^3/min)	2419.	2400.	2163.	2327.
Temperature (^{o}C)	204.9	205.0	205.1	205.0
Moisture (%)	30.4	30.4	34.3	31.7
Particulate Emissions				
Mg/nm^3	213.31	281.90	187.48	227.56
Kg/Hour	30.96	40.59	24.33	31.96

TABLE 2-14

Summary of Opacity Observations

Mono-5

1340 - 1440

5/15/79

Six Minute Interval	Average Opacity (%)
1	50
2	40
3	45
4	50
5	45
6	40
7	40
8	40
9	38
10	38

TABLE 2-15

Summary of Opacity Observations

NS-6

1203 - 1303

5/19/79

Six Minute Interval	Average Opacity (%)
1	6
2	7
3	7
4	7
5	9
6	8
7	8
8	10
9	8
10	7

TABLE 2-16

Summary of Opacity Observations

NS-6

1410 - 1510

5/18/79

Six Minute Interval	Average Opacity (%)
1	10
2	8
3	7
4	9
5	6
6	9
7	10
8	8
9	7
10	8

TABLE 2-17

Summary of Opacity Observations
NS-3 Dryer
1532 - 1632
5/19/79

Six Minute Interval	Average Opacity (%)
1	13
2	12
3	13
4	17
5	16
6	24
7	17
8	10
9	9
10	13

TABLE 2-18

Summary of Opacity Observations

NS-3 Dryer

0945 - 1045

5/19/79

Six Minute Interval	Average Opacity (%)
1	12
2	13
3	14
4	14
5	13
6	14
7	12
8	11
9	12
10	12

PARTICLE SIZE DISTRIBUTION

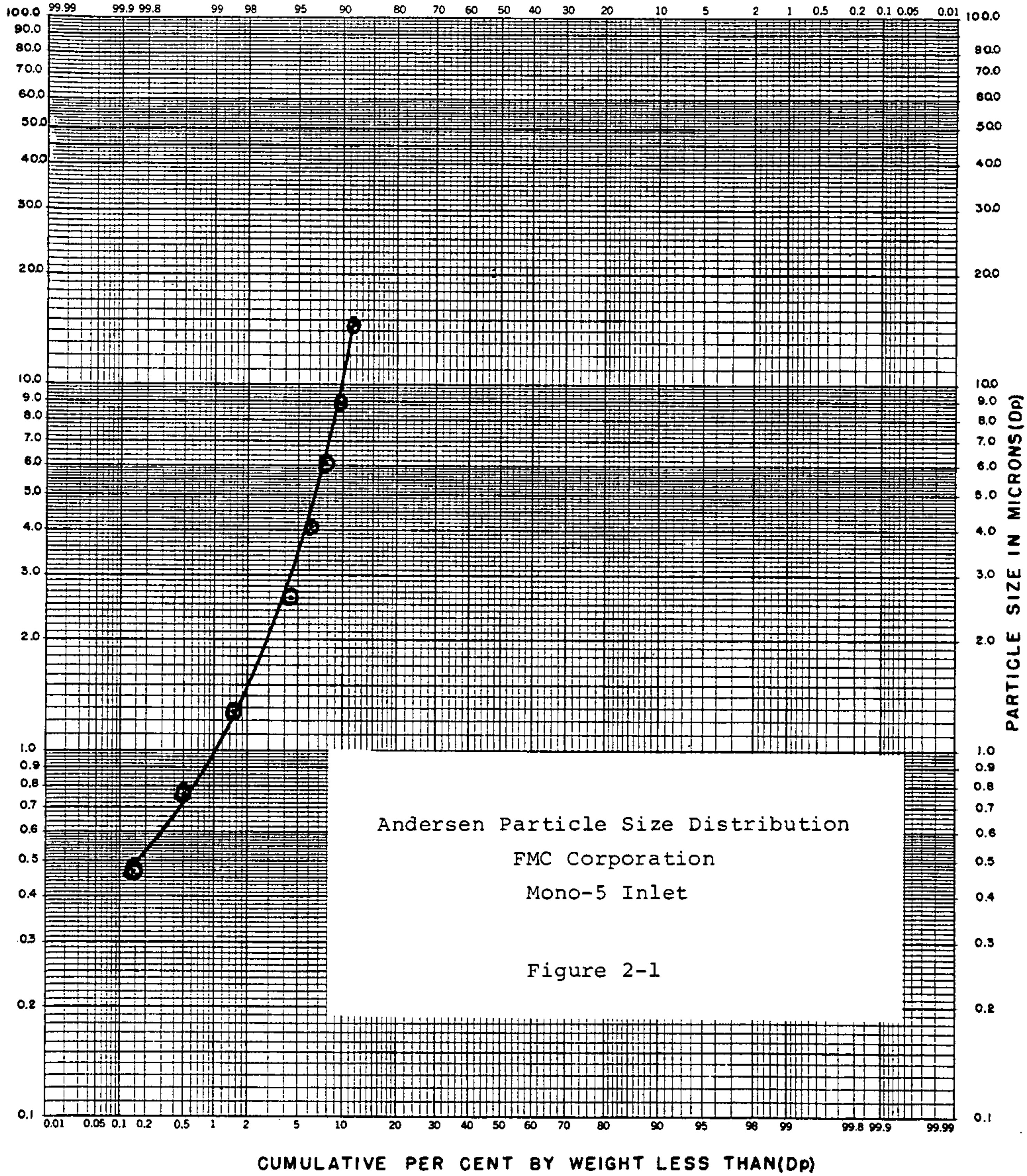


Figure 2-1

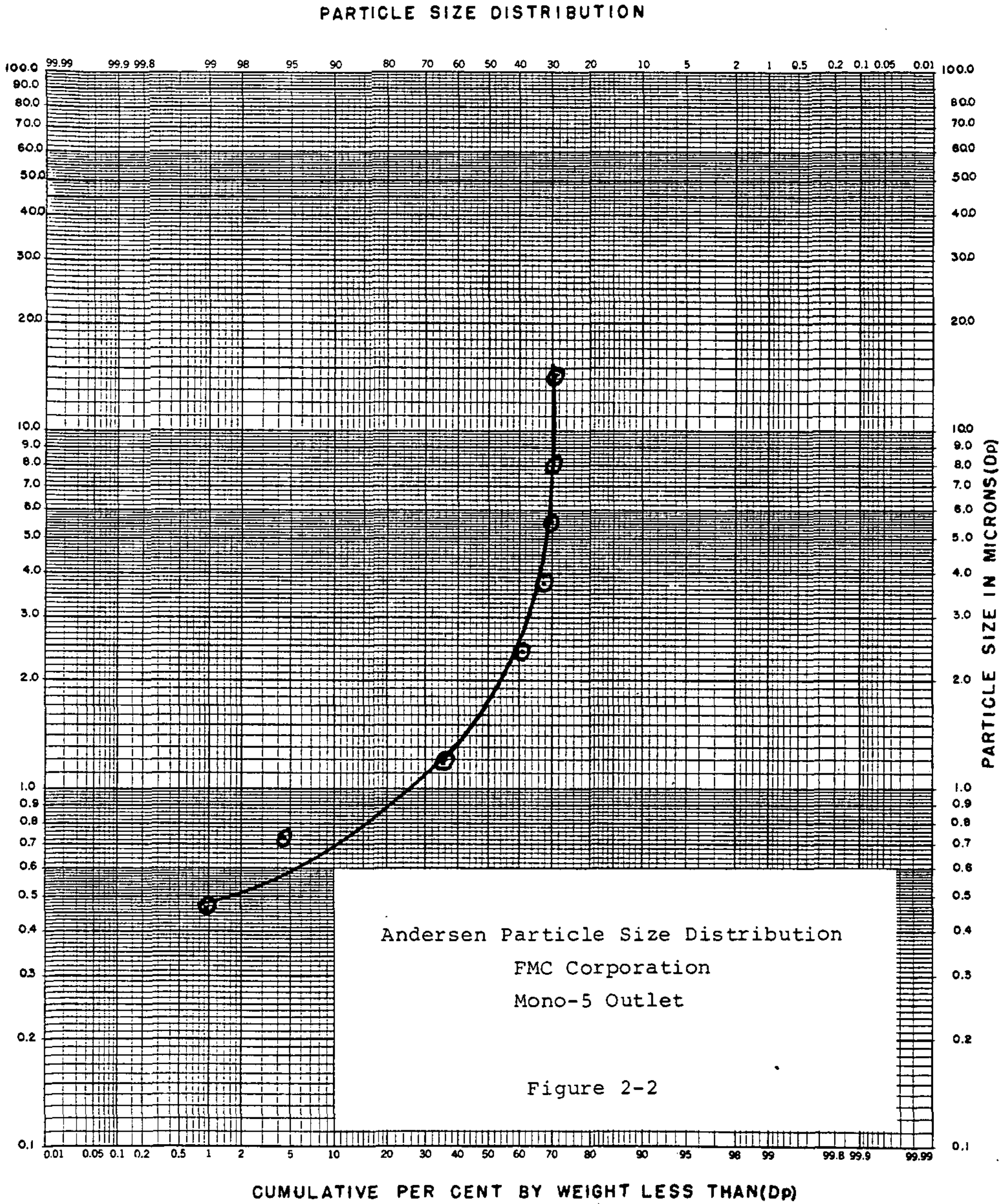

PARTICLE SIZE DISTRIBUTION
PARTICLE SIZE IN MICRONS(Dp)
CUMULATIVE PER CENT BY WEIGHT LESS THAN(Dp)
Andersen Particle Size Distribution
FMC Corporation
Mono-5 Outlet

Figure 2-2

PARTICLE SIZE DISTRIBUTION

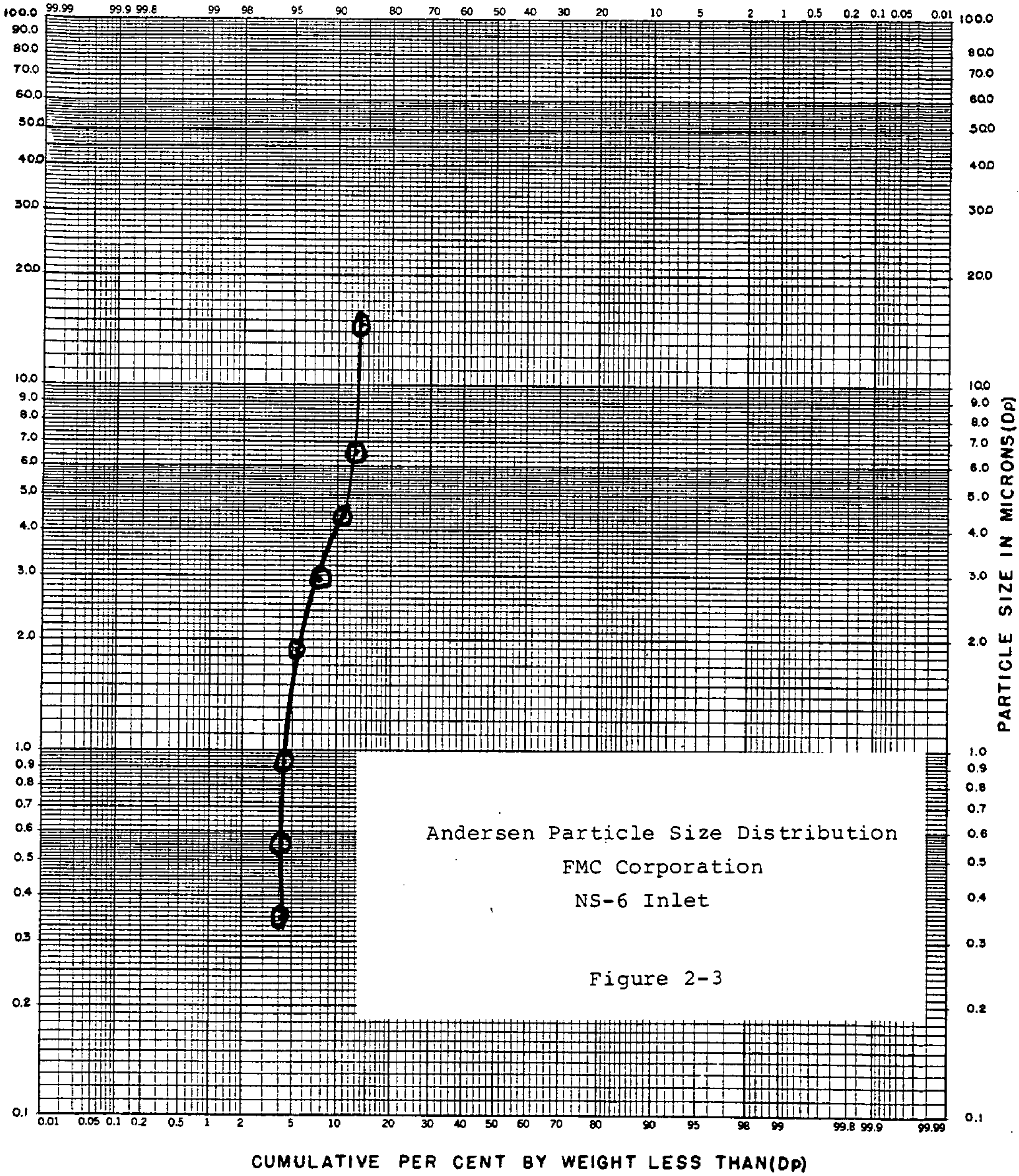
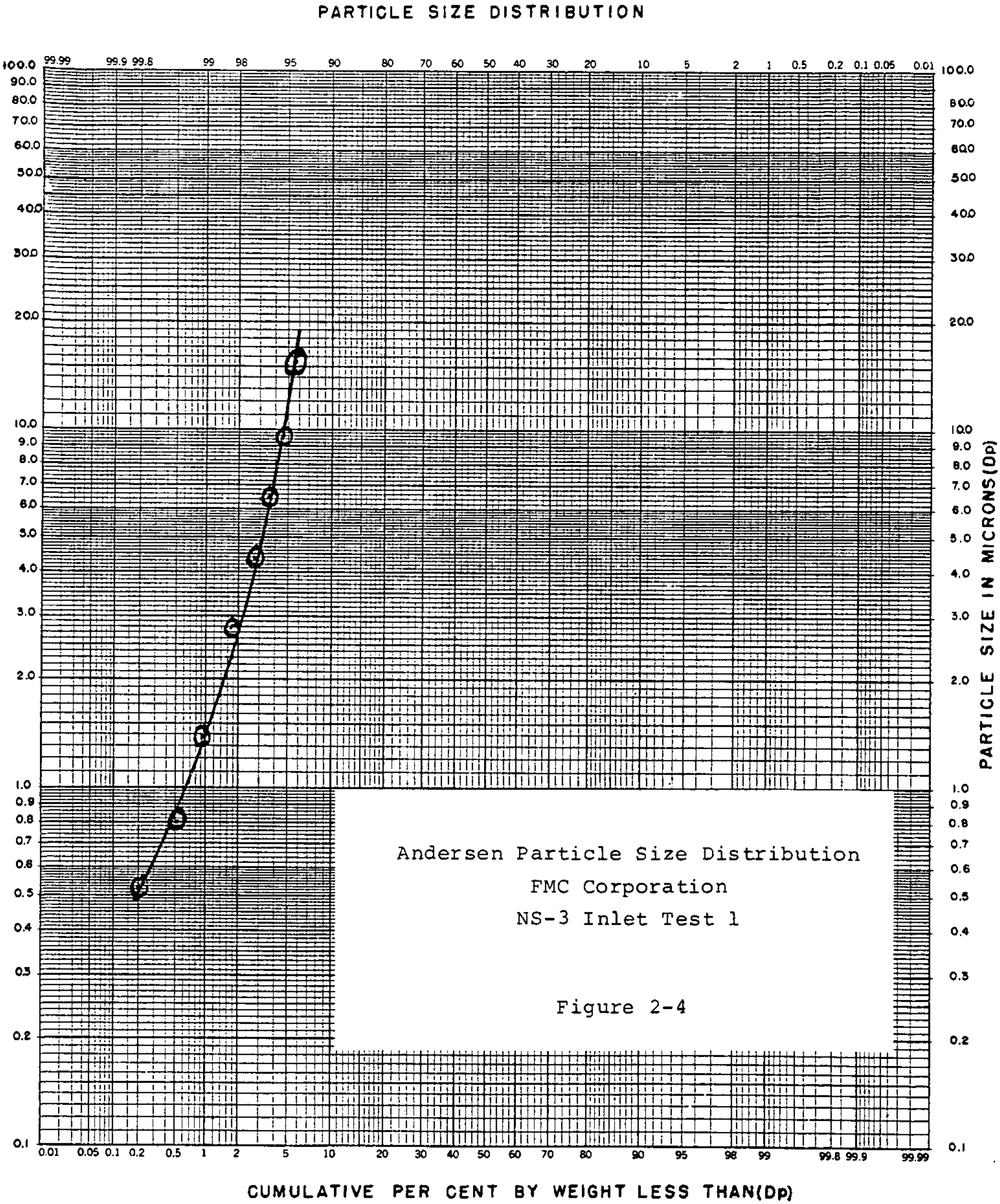
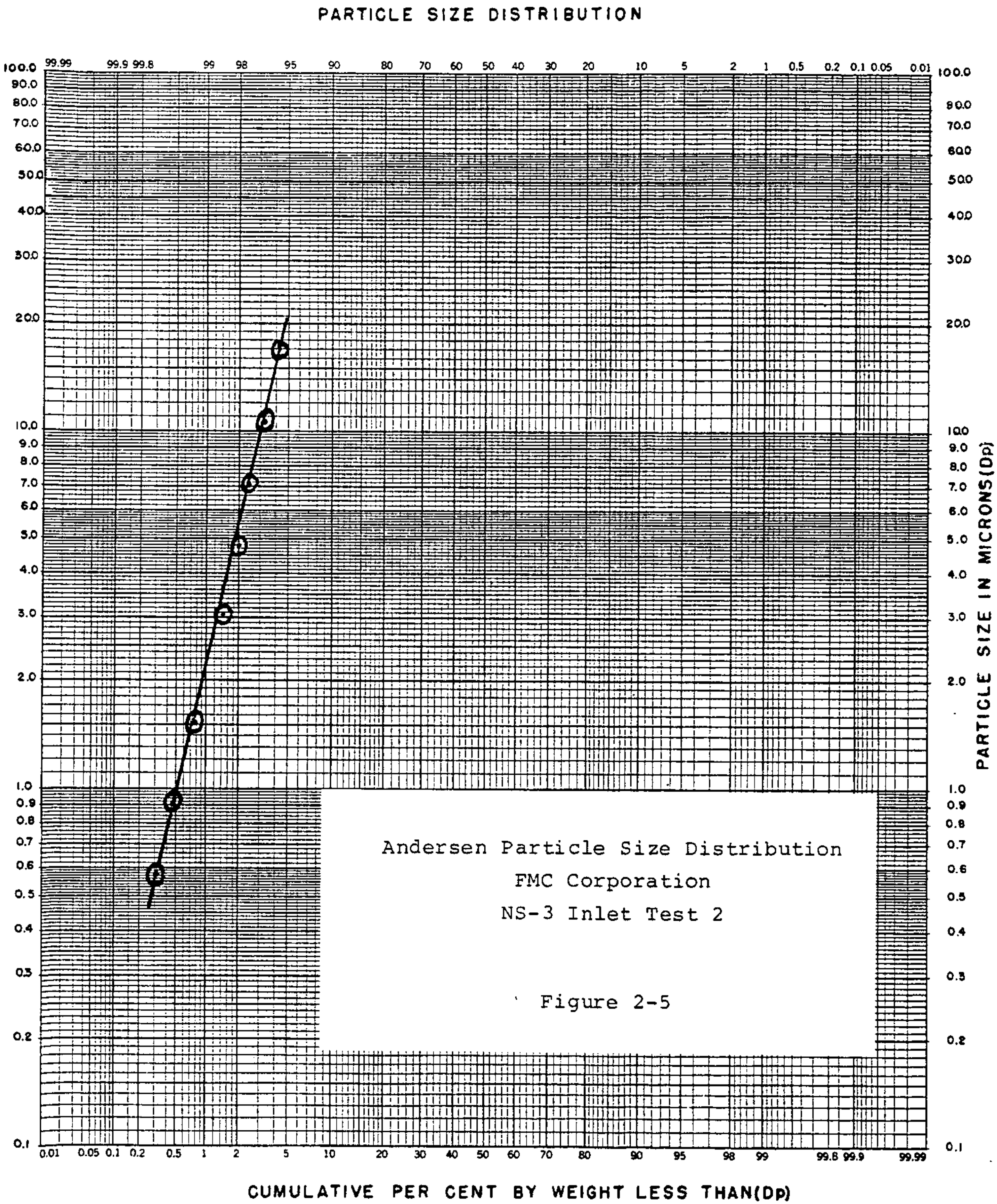


Figure 2-3



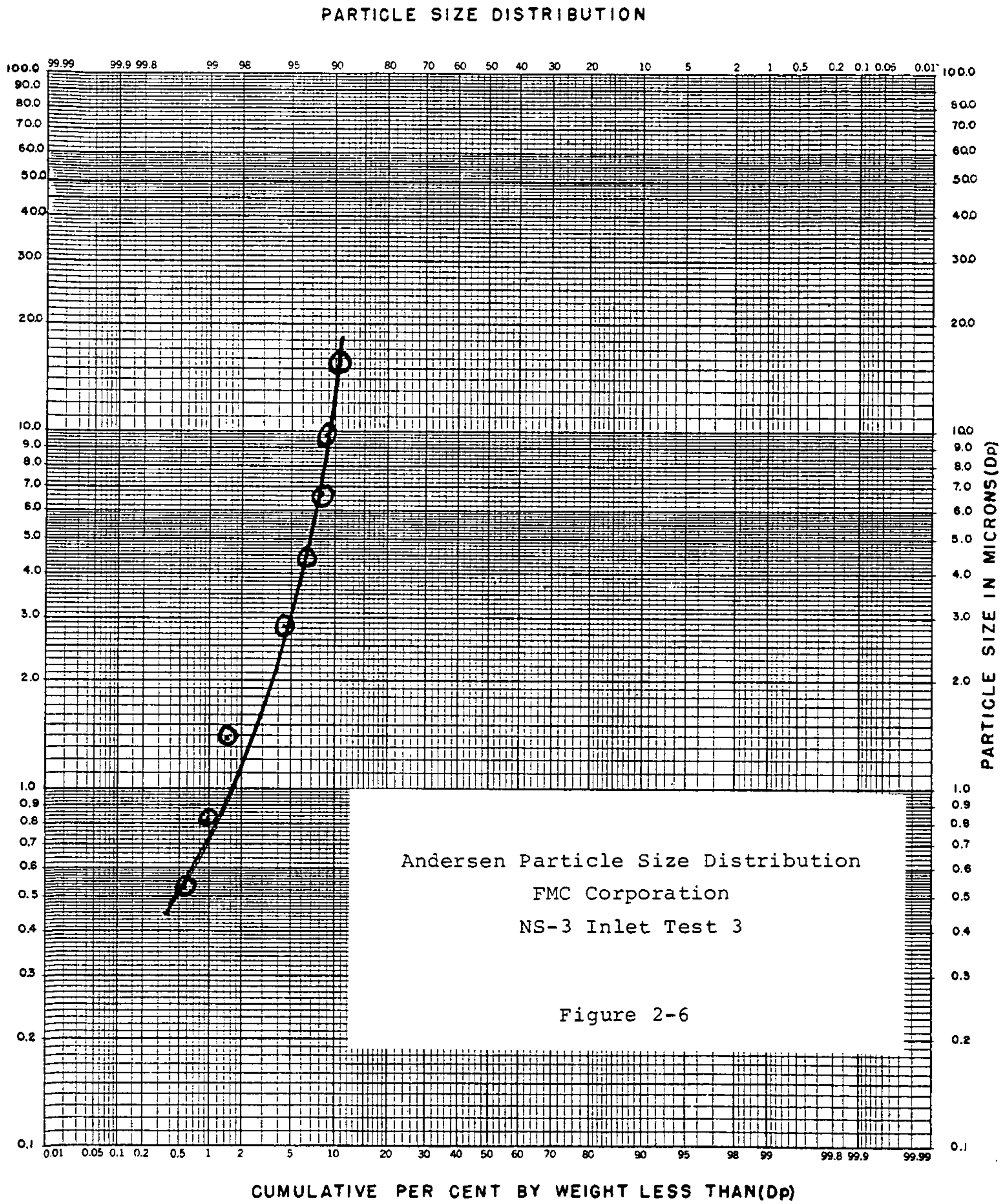
Andersen Particle Size Distribution
FMC Corporation
NS-3 Inlet Test 1

Figure 2-4



Andersen Particle Size Distribution
FMC Corporation
NS-3 Inlet Test 2

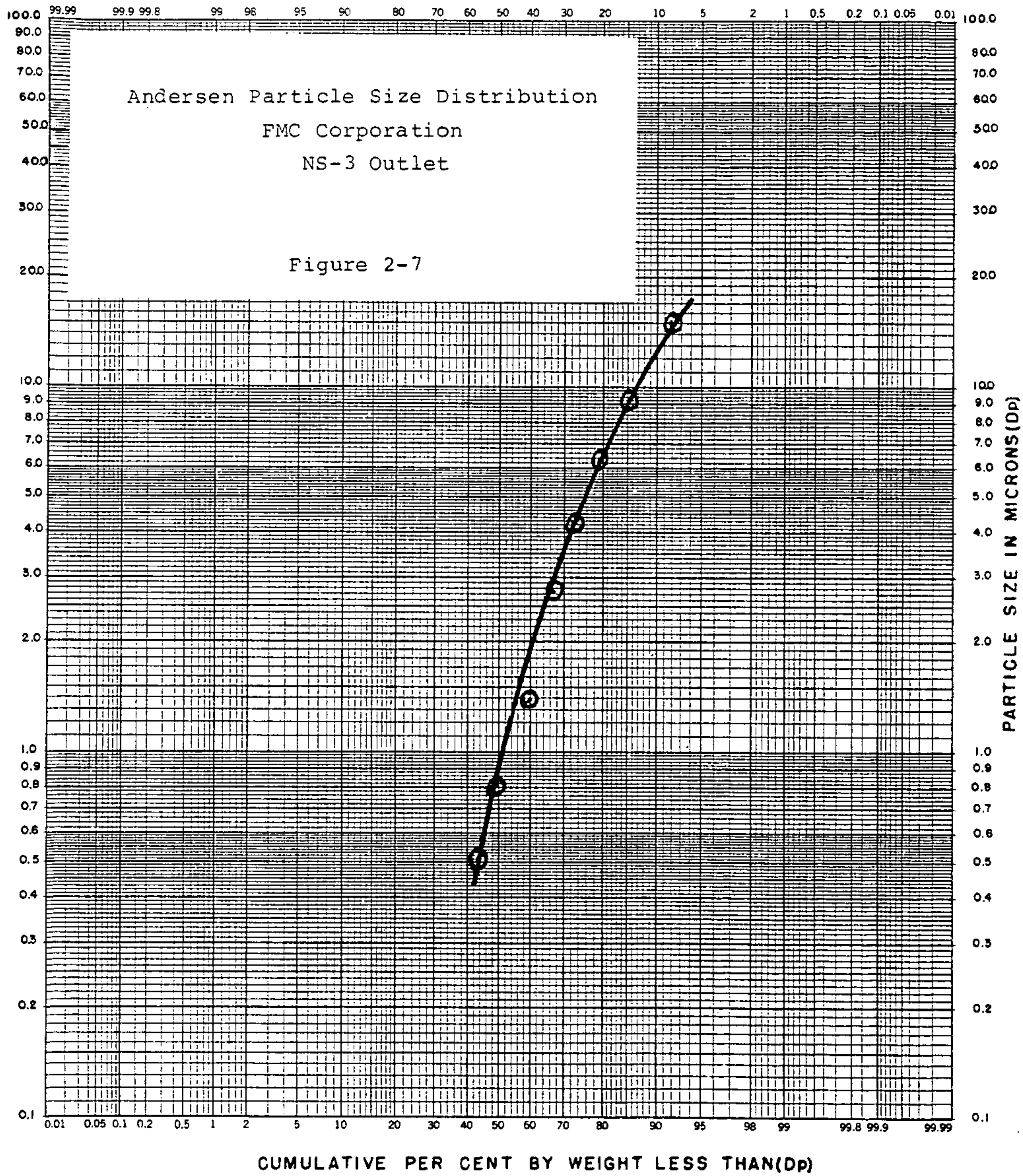
Figure 2-5

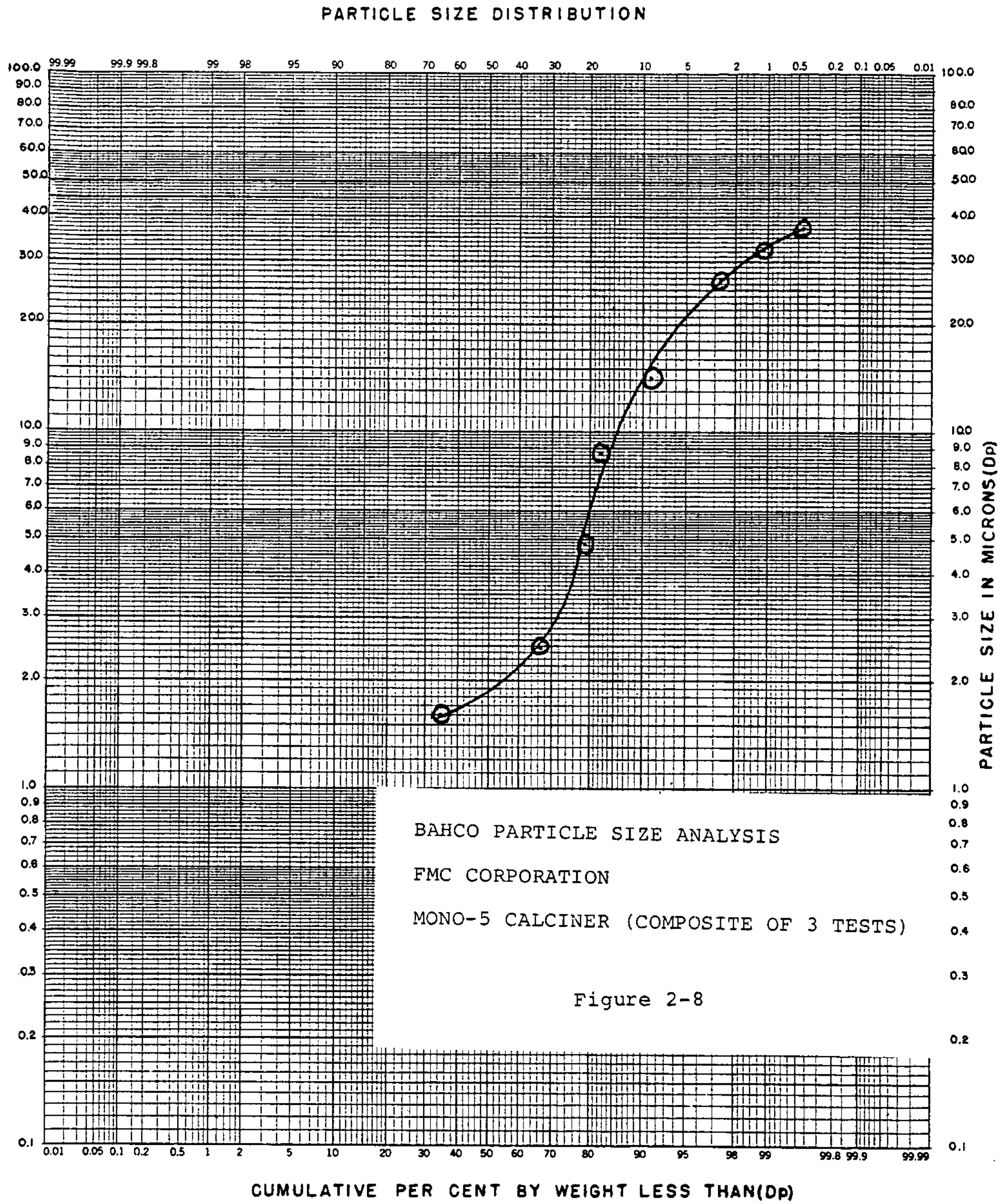


Andersen Particle Size Distribution
FMC Corporation
NS-3 Inlet Test 3

Figure 2-6

PARTICLE SIZE DISTRIBUTION





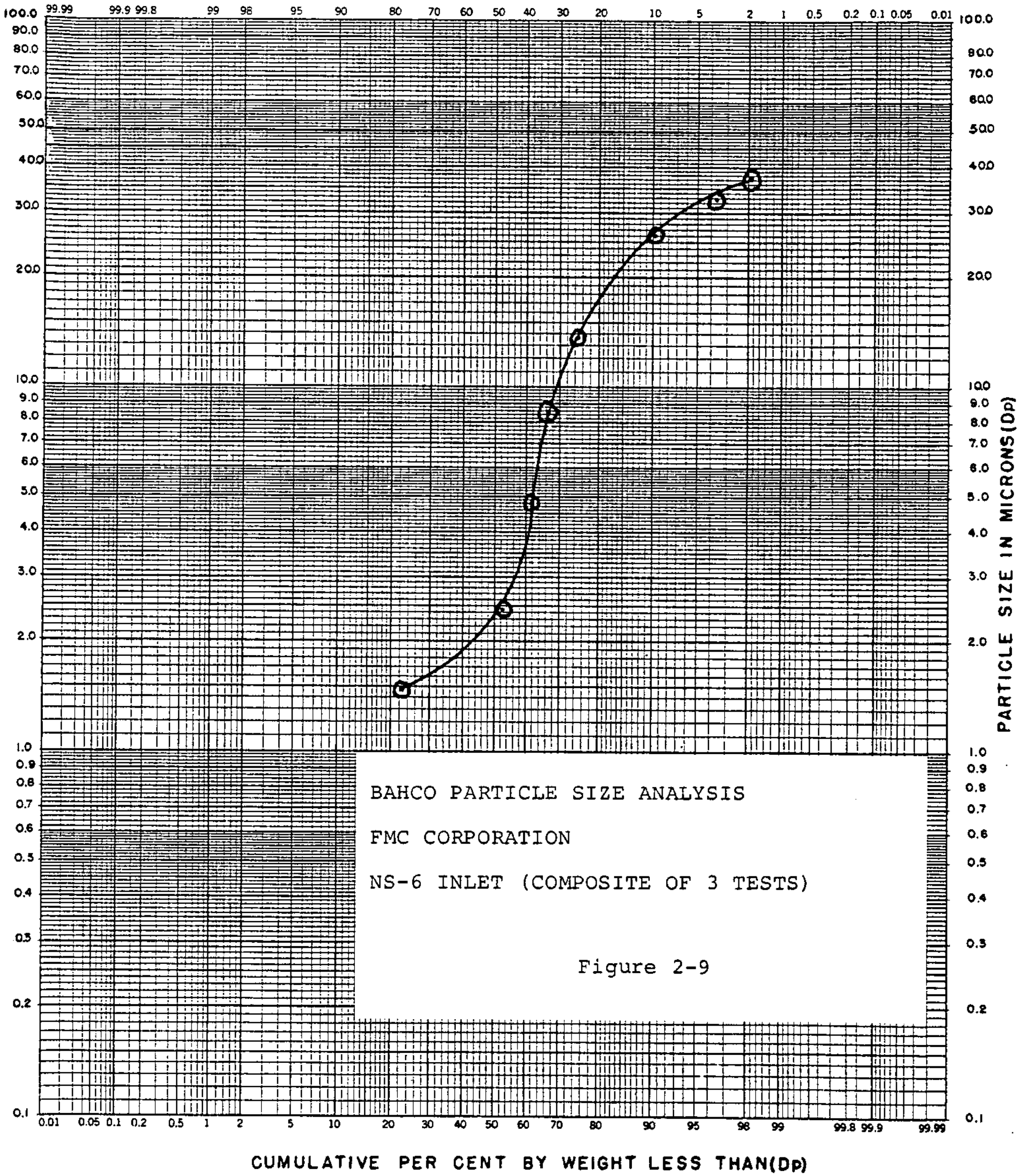
BAHCO PARTICLE SIZE ANALYSIS

FMC CORPORATION

MONO-5 CALCINER (COMPOSITE OF 3 TESTS)

Figure 2-8

PARTICLE SIZE DISTRIBUTION



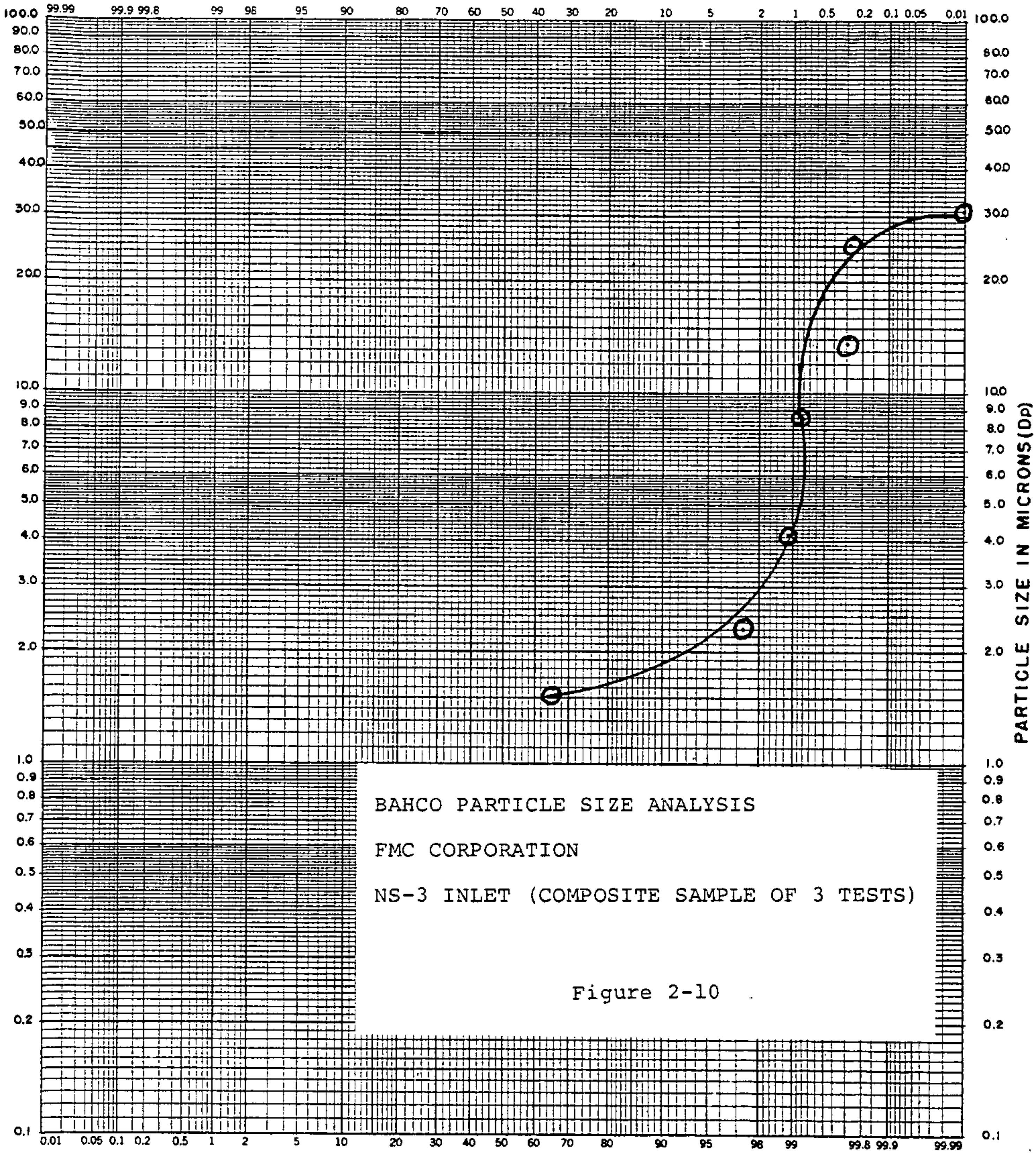
BAHCO PARTICLE SIZE ANALYSIS

FMC CORPORATION

NS-6 INLET (COMPOSITE OF 3 TESTS)

Figure 2-9

PARTICLE SIZE DISTRIBUTION



CUMULATIVE PER CENT BY WEIGHT LESS THAN(Dp)

Figure 2-10

3.0 SAMPLING METHODS

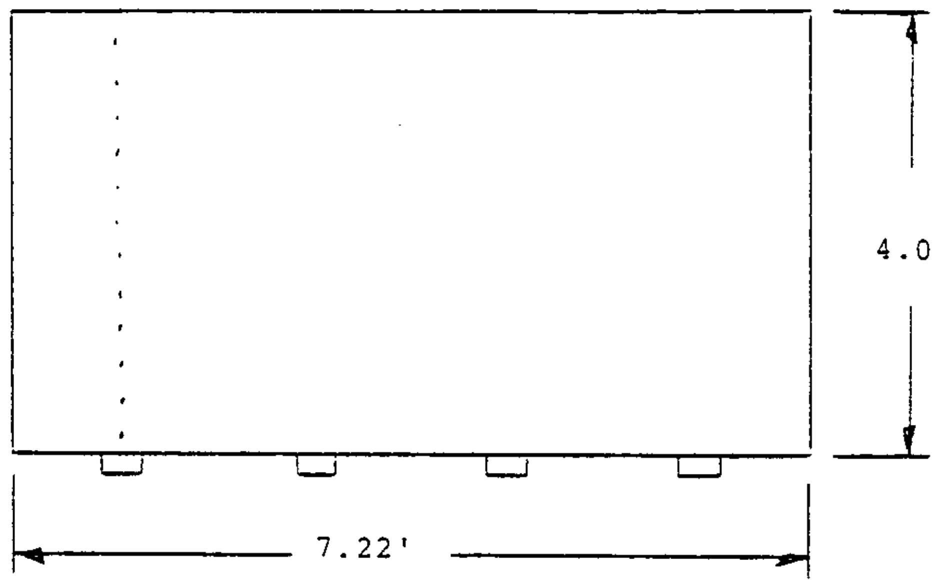
3.1 Test Port Locations and Sampling Point Determination

The location of the test ports and sampling points at each location was determined in accordance with guidelines outlined in EPA Method 1 (Sample and Velocity Traverses for Stationary Sources).

The sampling ports at the Mono-5 Calciner Inlet are located in the ductwork between the calciner outlet and the cyclone inlet (Figure 4-1). The duct is 4.03 feet by 7.22 feet at this location. Four sampling ports are located on the bottom of the duct. Method 1 requires a 48 point traverse but due to the extremely high grain loading which caused several filter changes and plugging of the nozzle, 24 points were sampled at two minutes each, resulting in a total test time of 48 minutes.

The sampling ports at the Mono-5 Calciner Outlet are located in the stack which vents the exhaust gases from the scrubber to the atmosphere. Two sample ports are installed 90^{o} apart. The stack diameter is 60 inches at this location (Figure 4-2) and 12 traverse points were sampled at 5 minutes each resulting in a total test time of 60 minutes.

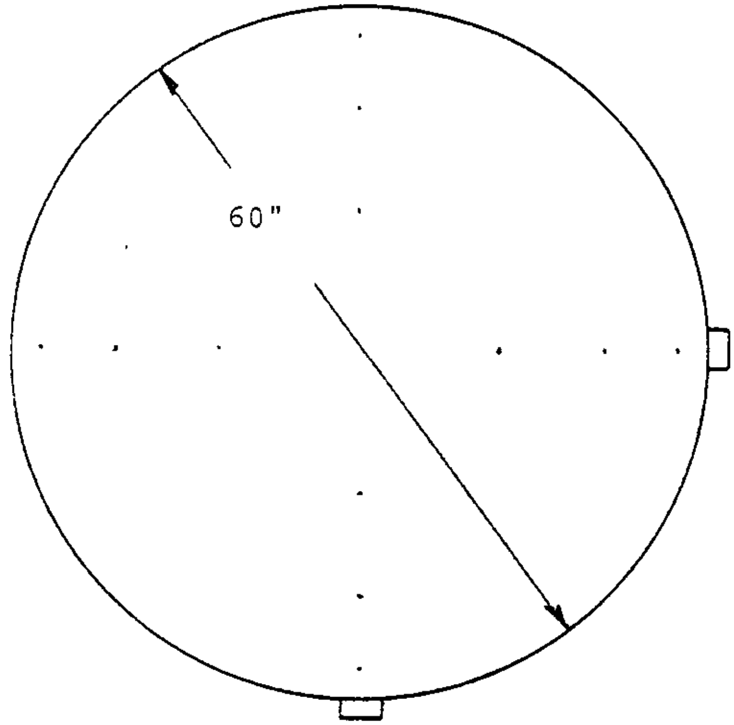
Sampling ports at the NS-6 Dryer Cyclone Inlet are located in the ductwork between the dryer outlet and the cyclone inlet. The duct dimensions are 9.104 feet by 4.76 feet (Figure 4-3). Six sampling ports are located in the bottom of the duct. Originally, all six ports were to be sampled, but due to obstructions inside one duct and obstructions by permanent scaffolding, only four ports could be utilized. Again, because of the extremely high grain loading, 24 points were sampled at two minutes each resulting in a total test time of 48 minutes.



SAMPLING POINT	DISTANCE FROM STACK WALL (INCHES)
1	2.02
2	6.05
3	10.08
4	14.11
5	18.14
6	22.17
7	26.20
8	30.23
9	34.26
10	38.29
11	42.32
12	46.35

MONO-5 CALCINER CYCLONE INLET SAMPLING POINT LOCATIONS

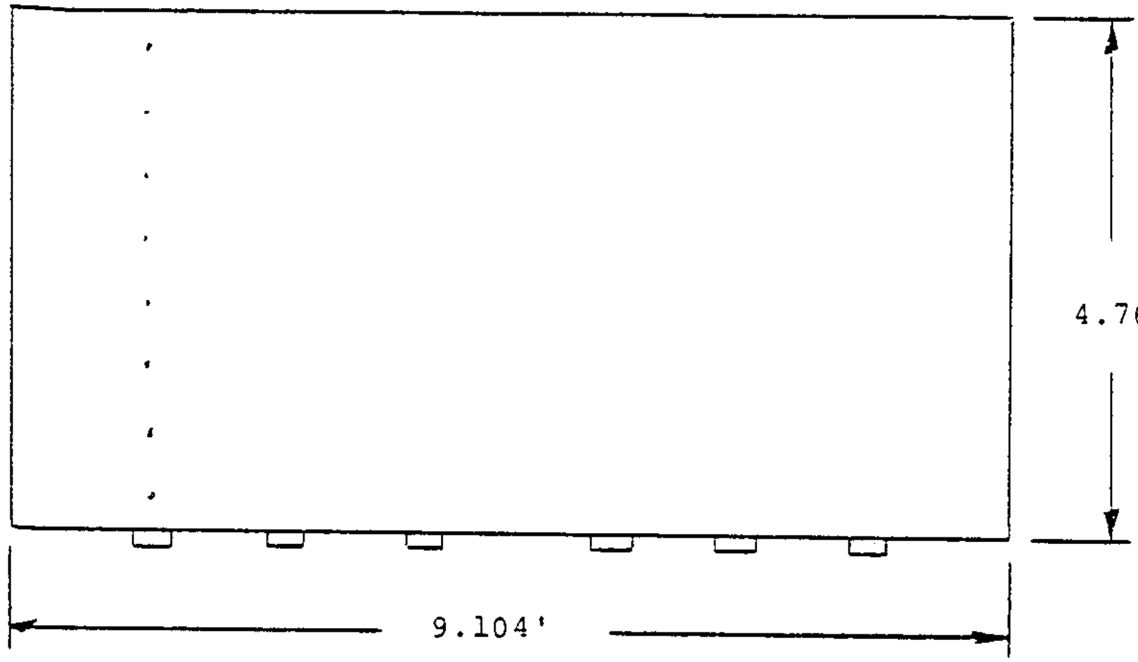
FIGURE 4-1



SAMPLING POINT	DISTANCE FROM STACK WALL (INCHES)
1	2.64
2	8.82
3	17.70
4	42.30
5	51.18
6	57.36

MONO-5 CALCINER SCRUBBER OUTLET SAMPLING POINT LOCATION

FIGURE 4-2



SAMPLING POINT	DISTANCE FROM STACK WALL (INCHES)
1	3.57
2	10.71
3	17.85
4	24.99
5	32.13
6	39.27
7	46.41
8	53.55

NS-6 DRYER CYCLONE INLET SAMPLING POINT LOCATIONS

FIGURE 4-3

The sampling ports at the NS-6 Dryer Scrubber Outlet are located in the stack which vents the exhaust gases from the scrubber to the atmosphere. The two sampling ports are installed (90° apart) at which the diameter is 77 inches. Six traverse points were sampled in each port for five minutes each resulting in a test time of 60 minutes (Figure 4-4).

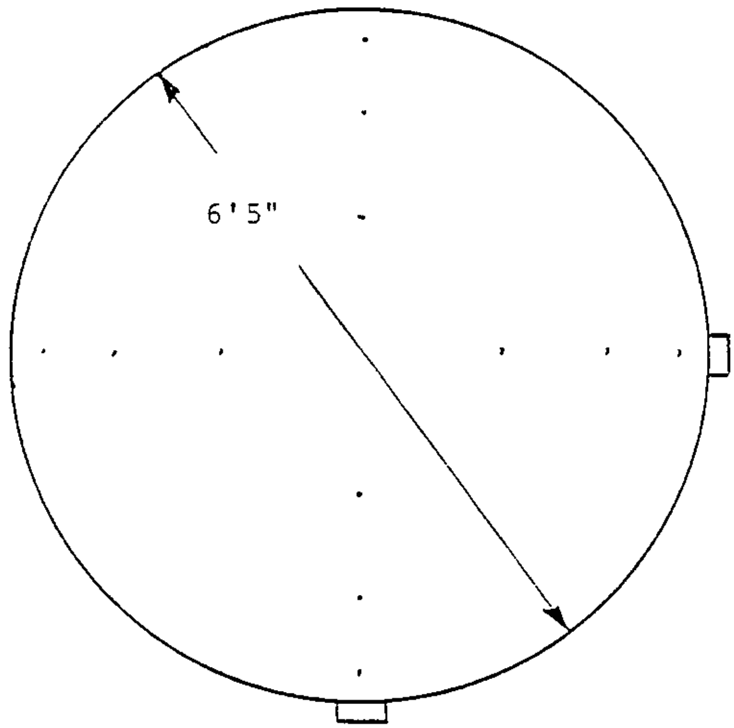
The sampling ports at the NS-3 Calciner Cyclone Inlet are located in the ductwork between the calciner outlet and the cyclone inlets. Four sampling ports are located on the side of the duct. The dimensions at this location are 8.032 feet by 8.115 feet. Thirty sampling points were used due to the high grain loading and sampled two minutes each for a total test time of sixty minutes (Figure 4-5).

The sampling ports of the NS-3 Calciner Dryer Outlet are located 90° apart in the stack which vents the exhaust gases from the precipitator to the atmosphere. The stack dimensions at this location is 96 inches ID. Forty-eight sampling points were used and each point was sampled for two minutes, resulting in a test time of ninety-six minutes (Figure 4-6).

3.2 Gas Velocity

The gas velocity at each location was determined in accordance with guidelines outlined in EPA Method 2 (Determination of Stack Gas Velocity and Volumetric Flow Rate).

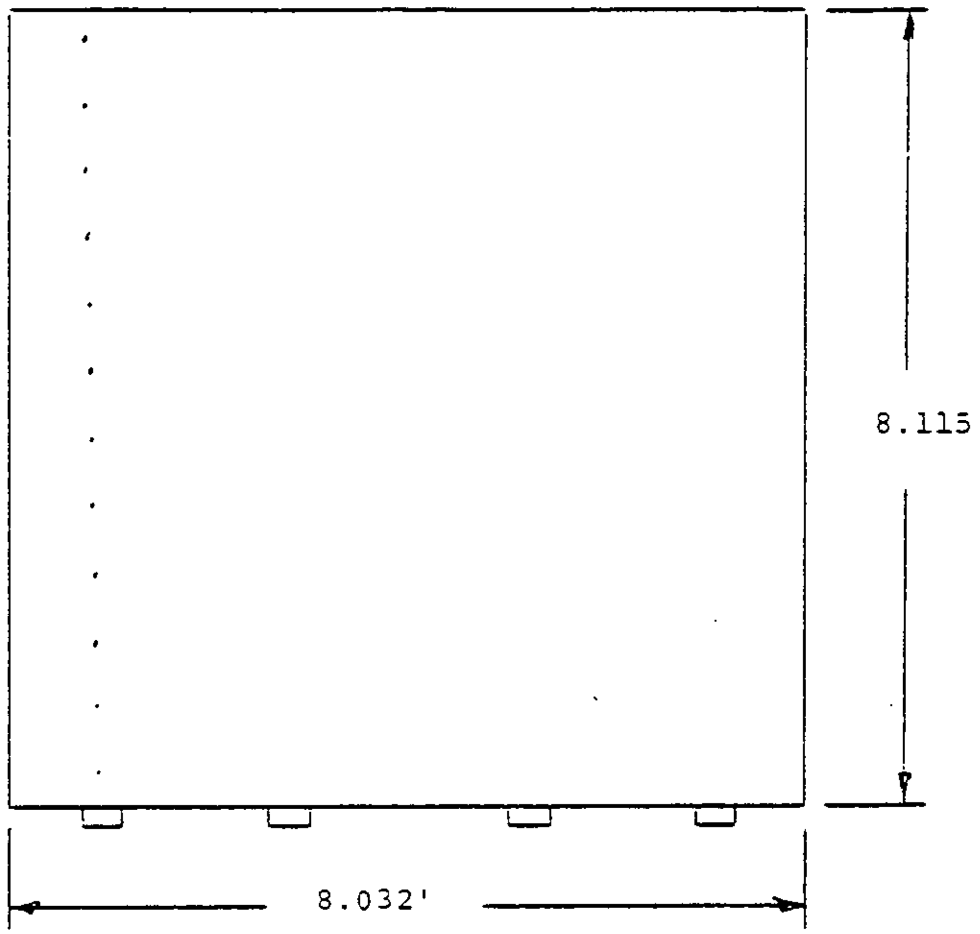
A precalibrated type "S" pitot tube and thermocouple were rigidly attached to each sampling probe. The velocity pressure was measured on an inclined manometer, and the temperature on a pyrometer. Readings were recorded at each traverse point.



SAMPLING POINT	DISTANCE FROM STACK WALL (INCHES)
1	3.43
2	11.47
3	23.01
4	55.00
5	66.53
6	74.57

NS-6 DRYER SCRUBBER OUTLET SAMPLING POINT LOCATIONS

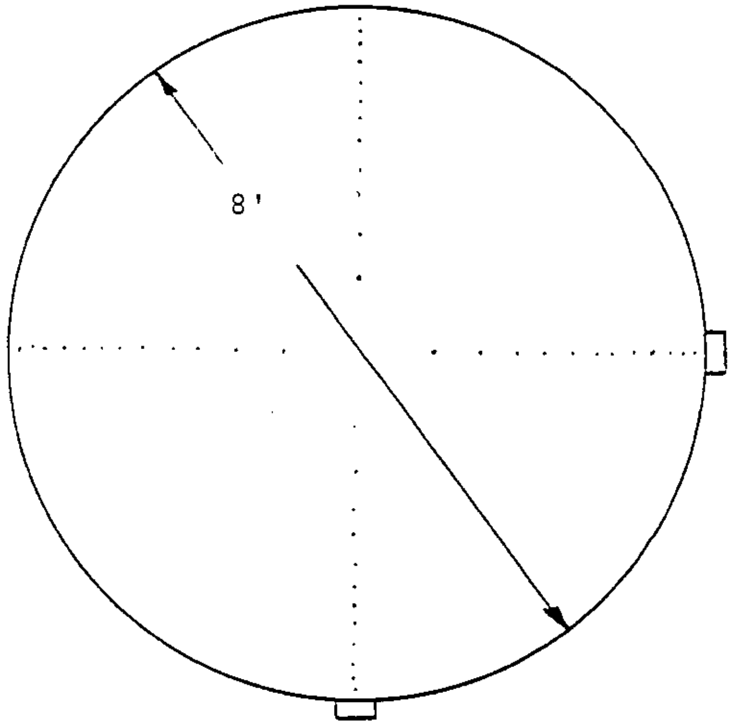
FIGURE 4-4



SAMPLING POINT	DISTANCE FROM DUCT WALL (INCHES
1	4.06
2	12.17
3	20.29
4	28.40
5	36.52
6	44.63
7	52.75
8	60.86
9	68.98
10	77.09
11	85.21
12	93.32

NS-3 CALCINER CYCLONE INLET SAMPLING POINT LOCATIONS

FIGURE 4-5



SAMPLING POINT	DISTANCE FROM STACK WALL (INCHES)
1	1.06
2	3.07
3	5.28
4	7.58
5	10.08
6	12.67
7	15.46
8	18.62
9	22.08
10	26.11
11	31.01
12	38.21
13	57.79
14	64.99
15	69.89
16	73.92
17	77.38
18	80.54
19	83.33
20	85.92
21	88.42
22	90.72
23	92.93
24	94.94

NS-3 CALCINER CYCLONE OUTLET SAMPLING POINT LOCATION

FIGURE 4-6

3.3 Gas Composition

The gas composition was determined in accordance with guidelines outlined in EPA Method 3 (Gas Analysis for Carbon Dioxide, Oxygen, Excess Air and Dry Molecular Weight). Since there is no combustion involved in the process, the gas composition at each test location was assumed to be air. A check was made with a Fyrite analyzer for carbon dioxide and oxygen content.

3.4 Particulate

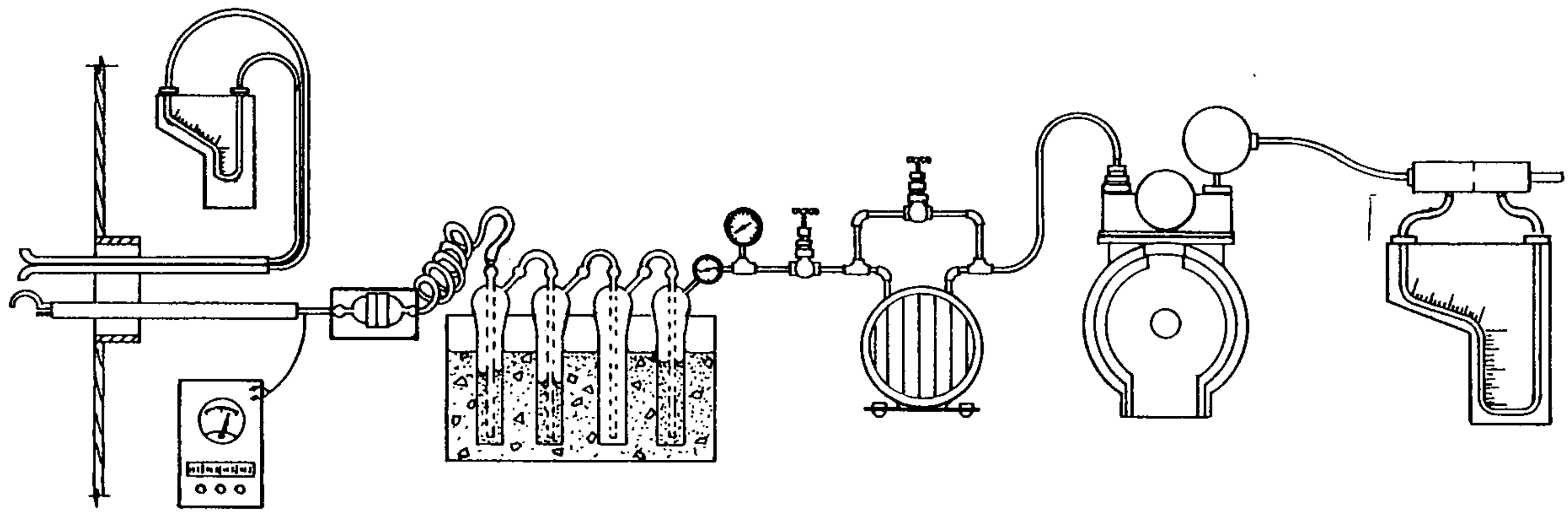
The particulate concentrations were determined in accordance with guidelines outlined in EPA Method 5 (Determination of Particulate Emissions from Stationary Sources).

The sampling train consisted of a nozzle, stainless steel probe, heated sample box which contained the filter, impingers, vacuum pump, dry gas meter and calibrated orifice (Figure 4-7). The nozzle was rigidly connected to the probe and the probe consisted of 5/8 inch O.D. tubing which was wrapped with heater tape to prevent condensation. Attached to the probe was an "S" type pitot tube and thermocouple used for monitoring the velocity pressure and temperature. The probe and heater box were attached to the impinger train by means of a flexible sample line.

The impinger train consisted of five Greenburg-Smith impingers connected in series. The first impinger was modified by replacing the impinger tip with a blank stem. This impinger was initially filled with 100 milliliters of distilled water. The second impinger was a standard Greenburg-Smith impinger containing 100 milliliters of distilled water. The third and fourth impingers were identical to the first and were left dry while the fifth contained 300 grams of indicating type silica gel.

Figure 4-7

MODIFIED PARTICULATE SAMPLING TRAIN



From the fifth impinger the effluent stream flowed through a check valve, flexible rubber vacuum tubing, a vacuum gauge, a needle valve, a leakless vacuum pump and a dry gas meter.

A calibrated orifice completed the train and was used to measure instantaneous flow rates. The dual manometer across the calibrated orifice was an inclined vertical type graduated in hundreths of an inch of water from 0 to 1.0 inch and in tenths from 1 to 10 inches.

During the test the following data was recorded at each traverse point:

- Traverse point
- Sampling time
- Clock time
- Gas meter reading (cf)
- Velocity pressure (in. H_2O)
- Orifice pressure drop (in. H_2O)
- Stack temperature ($^{\circ}F$)
- Dry gas meter temperature - inlet and outlet ($^{\circ}F$)
- Pump vacuum (in. Hg)
- Sample box temperature ($^{\circ}F$)
- Impinger temperature ($^{\circ}F$)

The relationship of ΔP reading with the ΔH reading is a function of the following variables:

- Orifice calibration factor
- Gas meter temperature
- Moisture content of flue gas
- Ratio of flue gas pressure to barometric pressure
- Stack temperature
- Sampling nozzle diameter

A nomograph was used to correlate all the above variables such that a direct relationship between ΔP and ΔH was determined by the sampler and isokinetic conditions could be maintained.

At the completion of the test the samples were recovered in the following manner:

Container #1 - The filter was removed from the filter holder and placed in its original container and sealed.

Container #2 - The nozzle, probe, cyclone bypass and front half filter holder were rinsed with acetone. The acetone was placed in a glass jar and sealed.

Container #3 - The silica gel was returned to its original container and sealed.

3.5 Organics

A gaseous sample was withdrawn from the source using a heated, glass lined stainless steel probe. Samples were drawn into a prepurged, evacuated, heated (to above the dew point of the sample gas) 250 ml glass grab flask until a positive pressure was obtained in the flask. The sample was injected into an AID model 621 portable Gas Chromatograph (GC) directly from the heated grab flask using the positive pressure obtained while sampling to fill the sample loop of the G.C. Two injections per flask were made to determine the reproducibility of the sample.

The samples were analyzed for Total Hydrocarbons, such as methane, by using a 1cc gas sample loop and a flame ionization detector. The column temperature was 125°C. The G.C. was standardized employing a range of certified analyzed methane standards prepared in helium.

Calculations:

S_F = the Sensitivity Factor

$$= \frac{\text{ppm standard}}{\text{Peak ht(mm) x (attenuation x range)}}$$

ppm total Hydrocarbons = S_F X peak ht(mm) of sample X (attenuation X range)

3.6 Particle Size Distribution

The particle size distribution samples were collected using an Andersen Cascade Impactor. The impactor consists of multiple stages which collect different particle sizes (Figure 4-8). Each stage consists of an orifice of a specific diameter above a collection plate. The orifice sizes of each stage are different and are arranged in descending order, the largest being stage 1. The sampling system was set up as shown in Figure 4-9. The stack conditions were determined and the sample was extracted isokinetically.

As the sample flows through each orifice, and is deflected off a glass fiber substrate filter placed on the collection plate, particles of a specific size become impacted on the substrate while the remaining particles entrained in the gas stream proceed to the next collection stage. The range of particle sizes retained on the substrate varies according to the velocity of the gas (as determined by the sampling rate and orifice diameter), the gas viscosity and the particle density. Since the orifices are arranged in descending diameters, the gas velocity increases and the particle size collected on each stage decreases.

During the sampling a cyclone preseparator was used to precut particles above 10 microns and avoid overloading the collection substrates. At the completion of each test the contents of the preseparator and an acetone wash were

ANDERSEN SAMPLING TRAIN

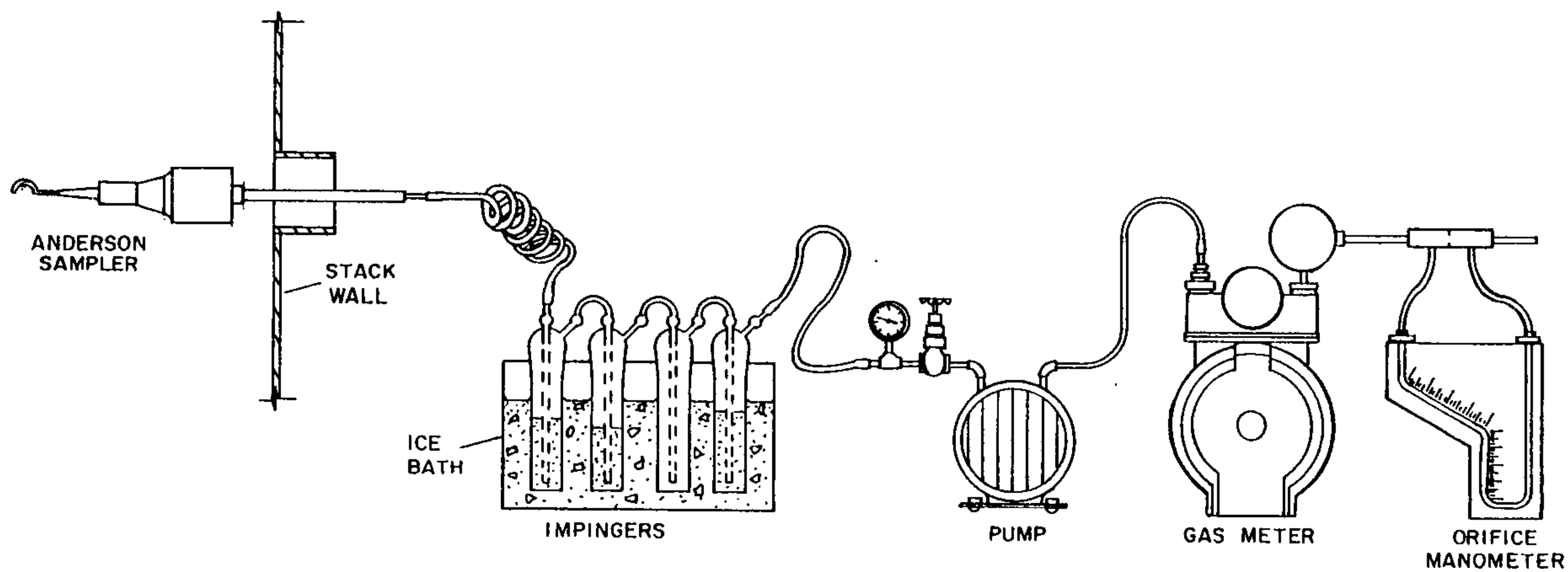


Figure 4-8

ANDERSEN STACK SAMPLER

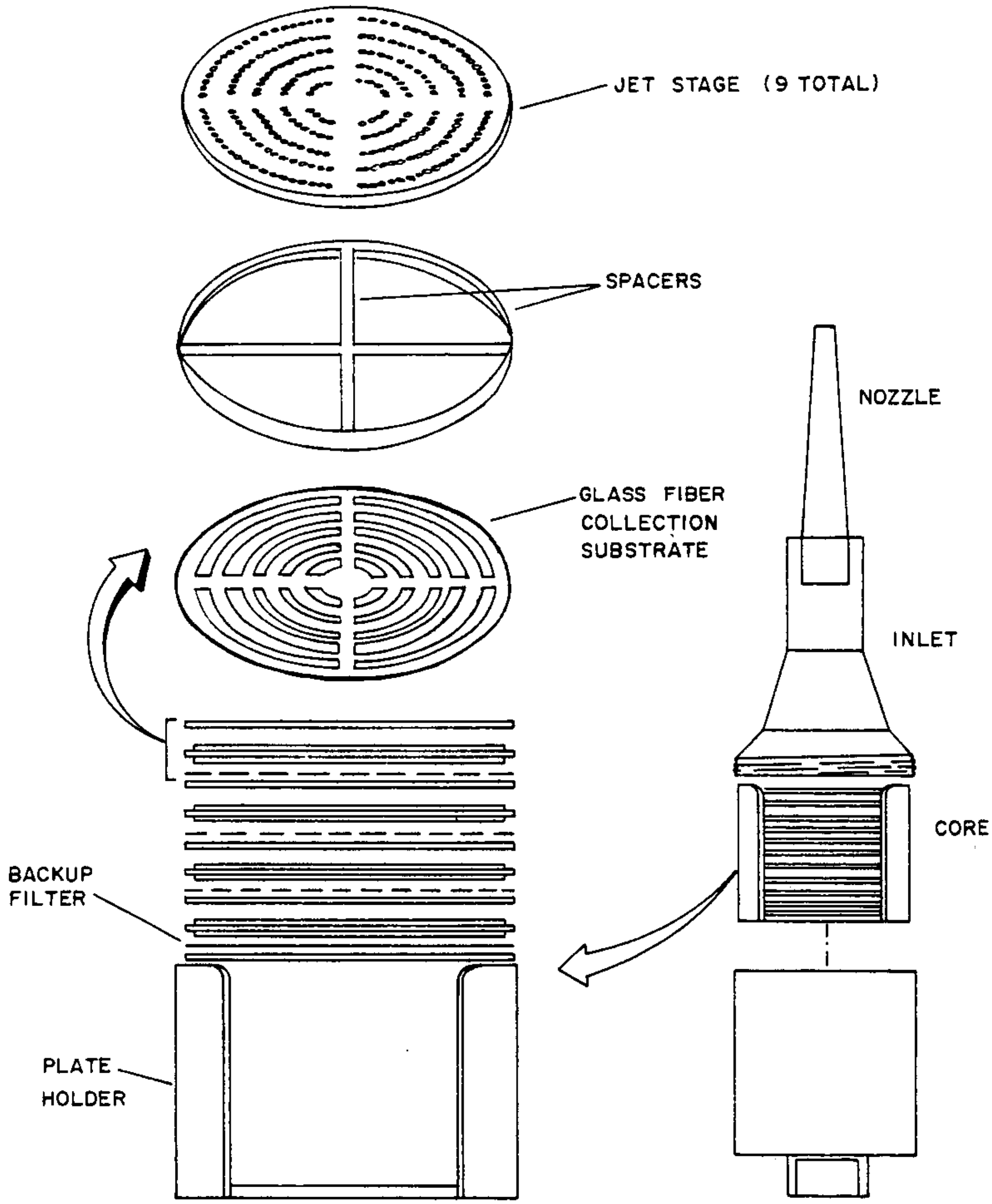


Figure 4-9

placed in a sample bottle. The glass fiber substrate filters were returned to their original containers and sealed.

3.7 Visible Emissions

The visible emissions were determined in accordance with guidelines outlined in EPA Method 9 (Visual Determination of the Opacity of Emissions from Stationary Sources).

4.0 ANALYTICAL PROCEDURES

4.1 Particulate

Each sample from the particulate test was analyzed in the following manner:

Container #1 - The filter was removed from its sealed container and placed on a tared watch glass. The filter and watch glass were dessicated with anhydrous $CaSO_4$ and weighed to a constant weight. The weight was recorded to the nearest 0.01 mg.

Container #2 - The acetone washings were transferred to a tared beaker. The acetone was then evaporated at ambient temperature and pressure, dessicated and weighed to a constant weight. The weight was recorded to the nearest 0.01 mg

Container #3 - The silica gel was weighed to the nearest 0.1 gram on a beam balance.

4.2 Particle Size Distribution

The fiberglass substrate filters were dessicated and weighed to a constant weight. The net weight gain was recorded to the nearest 0.01 mg.

The acetone rinse of the cyclone preseparator was transferred to a tared beaker. The beaker was heated to a temperature well below the boiling point until the water was evaporated. The beaker was then dessicated and weighed to a constant weight. The net weight gain was recorded to the nearest 0.01 mg.

Bahco analysis was also performed on certain locations due to the high moisture content restricting applicability of the Andersen Impactor.

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