Note: This is a reference cited in *AP 42, Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources.* AP42 is located on the EPA web site at www.epa.gov/ttn/chief/ap42/

The file name refers to the reference number, the AP42 chapter and section. The file name "ref02_c01s02.pdf" would mean the reference is from AP42 chapter 1 section 2. The reference may be from a previous version of the section and no longer cited. The primary source should always be checked.

United States
Environmental Protection
Agency

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

EMB Report 83-CDR-1
October 1983

Air

EPA

10448

Ref. No. 5

AP-42 Section 11.5
Reference 5
Report Sect.
Reference

Calciners and Dryers

Emission Test Report A. P. Green Company Mexico, Missouri

United States
Environmental Protection
Agency

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

EMB Report 83-CDR-1
October 1983

Air

EPA

10448

Calciners and Dryers

Emission Test Report A. P. Green Company Mexico, Missouri

NSPS DEVELOPMENT
PARTICULATE AND PARTICLE SIZE EMISSIONS TESTING
ROTARY CALCINER/COOLER

A.P. GREEN REFRACTORIES COMPANY
MEXICO, MISSOURI
OCTOBER 17-21, 1983

Compiled by:

TRC Environmental Consultants, Inc.
800 Connecticut Blvd.
East Hartford, Connecticut 06108

68-02-3543
Work Assignment No. 8
TRC Project No. 2177-E84
EMB Report No. 83-CDR-1

Task Manager

Dennis Holzschuh
Emission Measurement Branch
Emissions Standards and Engineering Division
Research Triangle Park, N. C., 27711

OFFICE OF AIR QUALITY PLANNING AND STANDARDS
OFFICE OF AIR, NOISE, AND RADIATION
U. S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, N. C., 27711

PREFACE

The work herein was conducted by personnel from TRC Environmental Consultants, Inc. (TRC), The Radian Corporation, AP Green Refractories Company in Mexico, Missouri, and the U.S. Environmental Protection Agency (EPA).

The scope of work, issued under EPA Contract No. 68-02-3543, Work Assignment No. 8, was under the supervision of the TRC Work Assignment Manager, Mr. Eugene A. Brackbill. Mr. Leigh A. Gammie of TRC served as Field Team Leader and was responsible for summarizing the test and analytical data in this report. Sample analyses were performed in Mexico, Missouri under the direction of Ms. Ellen M. Scanlon and at the TRC laboratory in East Hartford, Connecticut under the direction of Mr. Samuel S. Cha.

Radian personnel were responsible for monitoring the process operations during the testing program and for preparing Section 3.0 (Process Description and Operation).

Personnel of the AP Green Refractories Company whose assistance and guidance contributed greatly to the success of the test program included Mr. Glen E. Werner, Chemist, Environmental Control and Mr. Robert E. Besalke, Manager, Environmental Control.

Mr. Dennis Holzschuh, Office of Air Quality Planning and Standards, Emission Measurement Branch, EPA, served as Technical Manager and was responsible for coordinating the emission test program.

Further information relating to this test program can be found in the "Site Test Plan for NSPS Development, Particulate and Particle Size Emissions Testing, Rotary Calciner, AP Green Refractories Company, Mexico, Missouri" prepared August 1983 and in Appendix H.

TABLE OF CONTENTS

SECTION		PAGE
	PREFACE	ii
1.0	INTRODUCTION	
1.1	Background	1
1.2	Brief Process Description	1
1.3	Measurement Program	2
1.3.1	Rotary Calciner Multiclone Inlet	4
1.3.2	Rotary Calciner Venturi Scrubber Outlet	4
1.3.3	Rotary Calciner Inlet	4
1.3.4	Rotary Cooler Outlet	5
1.3.5	Blank Evaluations	5
1.4	Particle Size Distribution Measurements	5
1.4.1	Analysis	5
1.4.2	Data Reduction	6
1.5	Description of Report Sections	6
		7
2.0	SUMMARY OF RESULTS	
2.1	Rotary Calciner - Particulate Matter Tests	8
2.2	Rotary Calciner - Particle Size Tests	8
2.2.1	Multiclone Inlet - Test Parameter Summary	13
2.2.2	Venturi Scrubber Outlet - Test Parameter Summary	13
2.3	Impactor Data at Interpolated Particle Diameters	17
2.3.1	Rotary Calciner - Multiclone Inlet	19
2.3.2	Rotary Calciner - Venturi Scrubber Outlet	19
2.4	Comparative Data Analysis	23
2.4.1	Rotary Calciner - Multiclone Inlet	23
2.4.2	Rotary Calciner - Venturi Scrubber Outlet	23
2.5	Averaged Distributions for Tests 1, 2, and 3	29
2.6	Comparison of Cumulative Percent Less than 10 microns	29
2.7	Visible Emissions	29
2.8	Fugitive Emissions	36
2.9	Sieve and Moisture Analysis-Feed and Product Material	36
2.9.1	Feed Material	41
2.9.2	Product Material	41
2.9.3	Trace Metals Analysis	41
		41
3.0	PROCESS DESCRIPTION AND OPERATION	
3.1	General	45
3.2	Calcining Process	45
3.2.1	Raw Material	45
3.2.2	Rotary Calciner	45
3.2.3	Calciner Design Capacity	46
3.2.4	Calciner Exhaust Gases	46
3.2.5	Storage	46
3.3	Process Conditions During Testing	49
3.3.1	Monitoring Procedures	49
3.3.2	Production Rates	49
		51
4.0	SCOPE OF THE SAMPLING PROGRAM BY SITE	56
4.1	Multiclone Inlet - Particulate Matter Tests	56

TABLE OF CONTENTS
(continued)

SECTION		PAGE
4.2	Multiclone Inlet - Particle Sizing Tests	56
4.3	Venturi Scrubber Outlet - Particulate Matter Tests	59
4.4	Venturi Scrubber Outlet - Particle Sizing Tests	59
4.5	Venturi Scrubber Outlet - Opacity Observations	63
4.6	Rotary Calciner Inlet Transfer Point	63
4.7	Rotary Cooler Outlet Transfer Point	63
5.0	SAMPLING AND ANALYTICAL METHODS	67
5.1	Preliminary Measurements	67
5.2	Particulate Matter Tests	68
5.3	Gas Analysis	71
5.4	Particle Size Tests	71
5.4.1	Sample Recovery	75
5.4.2	Sample Drying and Weighing	76
5.4.3	Data Reduction	77
5.5	Plume Opacity - Venturi Scrubber Outlet	77
5.6	Fugitive Emissions - Rotary Calciner Inlet	77
5.7	Feed and Product Material - Grab Samples	77
6.0	QUALITY ASSURANCE	79
6.1	Introduction	79
6.2	Sampling Train Components	79
6.3	Pre-Separators and Cascade Impactors - Particle Size Tests	79
6.4	Sample Collection Substrates - Particle Size Tests	80
6.5	Substrate Weighing - Particle Size Tests	80
6.6	Blank Sample - Particle Size Test	81
6.7	Sample Recovery	81
6.8	EPA Method 3	82
APPENDICES		
A	PARTICULATE DATA SUMMARIES	83
A.1	Multiclone Inlet	84
A.2	Venturi Scrubber Outlet	89
B	PADRE DATA SUMMARIES	99
B.1	Multiclone Inlet	100
B.2	Venturi Scrubber Outlet	107
C	FIELD DATA SHEETS	115
C.1	Multiclone Inlet - Method 5	116
C.2	Multiclone Inlet - Method 3	128
C.3	Multiclone Inlet - Particle Size	133
C.4	Venturi Scrubber Outlet - Method 5	146
C.5	Venturi Scrubber Outlet - Method 3	153

TABLE OF CONTENTS
(continued)

APPENDICES

			PAGE
	C.6	Venturi Scrubber Outlet - Particle Size	157
	C.7	Visible Emissions	164
	C.8	Fugitive Emissions	173
D		FILTER WEIGHT DATA	176
	D.1	Particulate Tests	176
	D.2	Particle Size Tests	184
E		SAMPLING EQUIPMENT CALIBRATION DATA	194
	E.1	Particulate Sampling Train	195
	E.2	Particle Size Sampling Train	207
F		PROCESS SAMPLES, LABORATORY SIEVE ANALYSIS/MOISTURE CONTENT	214
G		BLANK EVALUATION RESULTS	221
H		SCOPE OF WORK	224
I		PROJECT PARTICIPANTS	236
J		PADRE'S USER GUIDE	238
K		CHAIN OF CUSTODY FORMS	284

LIST OF FIGURES

FIGURE		PAGE
1-1	Overhead View-Rotary Kiln/Cooler AP Green Refractories Mexico, Missouri	3
2-1	Inlet and Outlet Particle Size Distributions Based upon Interpolated Diameters, Test 1	33
2-2	Inlet and Outlet Particle Size Distributions Based upon Interpolated Diameters, Test 2	34
2-3	Inlet and Outlet Particle Size Distributions Based upon Interpolated Diameters, Test 3	35
3-1	Partial Flow Diagram for Fire Clay Plant	47
4-1	Overhead View-Rotary Kiln/Cooler, AP Green Refractories, Mexico, Missouri	57
4-2	Inlet Sampling Location, AP Green Refractories, Mexico, Missouri	58
4-3	Particle Size Tests, Inlet Sampling Location, AP Green Refractories, Mexico, Missouri	60
4-4	Outlet Sampling Location, AP Green Refractories, Mexico, Missouri	61
4-5	Particle Size Tests, Outlet Sampling Location, AP Green Refractories, Mexico, Missouri	62
4-6	Overhead View-Rotary Kiln/Cooler, AP Green Refractories Mexico, Missouri	64
4-7	Raw Material, Grab Sample Location, AP Green Refractories Mexico, Missouri	65
4-8	Overhead View-Indoor Inlet Raw Material Transfer Point, Fugitive Emissions Inspection, AP Green Refractories, Mexico, Missouri	66
5-1	Modified EPA Particulate Sampling Train, August 18, 1977, Federal Register	69
5-2	Integrated Bag Sampling Train	72
5-3	Particle Size Distribution Sampling Train	73

LIST OF TABLES

TABLE		PAGE
2-1	Summary of Results EPA Method 5 Tests Inlet to Multiclone and Outlet from Venturi Scrubber	9
2-1a	Summary of Results EPA Method 5 Tests Inlet to Multiclone.	10
2-1b	Summary of Results EPA Method 5 Tests Inlet to Multiclone and Outlet from Venturi Scrubber	11
2-1c	Summary of Results EPA Method 5 Tests Inlet to Multiclone .	12
2-2	Summary of Test Parameters Particle Size Distribution Measurement Tests Inlet to Multiclone - Test 1	14
2-3	Summary of Test Parameters Particle Size Distribution Measurement Tests Inlet to Multiclone - Test 2	15
2-4	Summary of Test Parameters Particle Size Distribution Measurement Tests Inlet to Multiclone - Test 3	16
2-5	Summary of Test Parameters Particle Size Distribution Measurement Tests Outlet from Venturi Scrubber, AP Green Refractories Company, Mexico, Missouri	18
2-6	Impactor Data Summary at Interpolated Particle Diameters Particle Size Distribution Tests, AP Green Refractories Company, Rotary Calciner, Inlet to Multiclone, Mexico, Missouri	20
2-7	Impactor Data Summary at Interpolated Particle Diameters Particle Size Distribution Tests, AP Green Refractories Company, Rotary Calciner, Inlet to Multiclone, Mexico, Missouri	21
2-8	Impactor Data Summary at Interpolated Particle Diameters Particle Size Distribution Tests, AP Green Refractories Company, Rotary Calciner, Inlet to Multiclone, Mexico, Missouri	22
2-9	Impactor Data Summary at Interpolated Particle Diameters Particle Size Distribution Tests, AP Green Refractories Company, Rotary Calciner, Outlet from Venturi Scrubber, Mexico, Missouri	24
2-10	Comparative CPLT* Data for Test 1, Particle Size Distribution Tests, AP Green Refractories Company, Rotary Calciner, Outlet from Venturi Scrubber, Mexico, Missouri	25
2-11	Comparative CPLT* Data for Test 2, Particle Size Distribution Tests, AP Green Refractories Company, Rotary Calciner, Inlet to Multiclone, Mexico, Missouri .	

LIST OF TABLES
(Continued)

TABLE		PAGE
2-12	Comparative CPLT* Data for Test 3, Particle Size Distribution Tests, AP Green Refractories Company, Rotary Calciner, Inlet to Multiclone, Mexico, Missouri, October 21, 1983	28
2-13	Comparative CPLT* Data for Test 1, Particle Size Distribution Tests, AP Green Refractories Company, Rotary Calciner, Inlet to Multiclone and Outlet from Venturi Scrubber, Mexico, Missouri, October 18, 1983 . .	30
2-14	Comparative CPLT* Data for Test 2, Particle Size Distribution Tests, AP Green Refractories Company, Rotary Calciner, Inlet to Multiclone and Outlet from Venturi Scrubber, Mexico, Missouri, October 20, 1983 . .	31
2-15	Comparative CPLT* Data for Test 3, Particle Size Distribution Tests, AP Green Refractories Company, Rotary Calciner, Inlet to Multiclone and Outlet from Venturi Scrubber, Mexico, Missouri, October 21, 1983 . .	32
2-16	Comparison of Cumulative Percent Less Than 10 um, Particle Size Distribution Tests, AP Green Refractories Company, Rotary Calciner, Inlet to Multiclone and Outlet from Venturi Scrubber, Mexico, Missouri	37
2-17	Visible Emissions Observations at the Rotary Calciner - Venturi Scrubber Outlet, AP Green Refractories Company, Mexico, Missouri	38
2-18	Fugitive Emissions Observations at the Rotary Calciner - Hopper Inlet, AP Green Refractories Company, Mexico, Missouri	40
2-19	Feed Material Samples, Sieve Analysis/Moisture Content, AP Green Refractories Company, Mexico, Missouri	42
2-20	Product Material Samples, Sieve Analysis/Moisture Content, AP Green Refractories Company, Mexico, Missouri	43
2-21	Trace Metals Analytical Results Impinger Reagents and Method 5 Filters	44
3-1	Data for the Clay Calciner at A.P. Green Refractories Company, Mexico, Missouri	48
3-2	Data for Emission Control Equipment for the Calciner/Cooler at A.P. Green Refractories Company, Mexico, Missouri . . .	50
3-3	Operating Conditions --Run No. 1-- , October 18, 1983 . . .	52

LIST OF TABLES
(Continued)

TABLE		PAGE
3-4	Operating Conditions --Run No. 2--, October 20, 1983	53
3-5	Operating Conditions --Run No. 3--, October 21, 1983	54
4-1	Visible Emissions Observation Locations, A.P. Green Refractories Company, Venturi Scrubber Outlet Stack, Mexico, Missouri	63

1.0 INTRODUCTION

1.1 Background

The United States Environmental Protection Agency (EPA) is developing a new source performance standard (NSPS) for the generic source category of calciners and dryers. The primary focus will be control particulate matter (PM) emissions. Because of the interest and emphasis upon limiting ambient air concentrations of inhalable particulates, EPA is also planning to collect emission data relative to particle size distributions and the emission fraction with an equivalent aerodynamic diameter equal to or less than 10 micrometers (μm). This fraction is designated as the PM_{10} category.

EPA's Emission Standards and Engineering Division (ESED) selected the AP Green Refractories Company plant in Mexico, Missouri as a site for an emission test program. This plant utilizes a rotary calciner for drying various types of clays used in manufacturing refractory brick. This facility is considered to employ process and emission control technology representative of dryers and calciners in the clay industry. The collected data will be used to develop controlled and uncontrolled emission rates. The particle size data may be used to develop additional regulations for PM_{10}. The test program was designed to provide a portion of the emission data base required for NSPS for processes associated with clay industries.

EPA engaged TRC to measure particulate concentrations, emission rates, mass flowrates, particle size distributions, and plume opacities at the rotary calciner and its associated air pollution control equipment. All measurements made at this facility were performed during times of normal production process operation as described in Section 3.0, Process Description and Operations.

1.3 Measurement Program

The measurement program was conducted at the AP Green Refractories Company facility in Mexico, Missouri during the week of October 17-21, 1983. The emission tests were designed to characterize uncontrolled and controlled emissions from the rotary calciner/cooler pollution control equipment and to determine particle size distribution.

TRC personnel were responsible for sampling and analyzing process emissions. Concurrently, Radian was responsible for monitoring pertinent process operation parameters. The components of the measuring program were as follows:

1.3.1 Rotary Calciner Multiclone Inlet

Particulate Matter Tests

Three tests run concurrently with the venturi scrubber outlet tests.

Particle Size Distribution Tests

Three tests run simultaneously with the particulate matter tests.

1.3.2 Rotary Calciner Venturi Scrubber Outlet

Particulate Matter Tests

Three tests run concurrently with the multiclone inlet tests.

Particle Size Distribution Tests

Three tests run simultaneously with the particulate matter tests.

Visible Emissions

The opacity of the scrubber outlet plume was monitored during the particulate matter tests.

Pressure Drop Across Scrubber

The gas pressure drop across the scrubber was measured periodically during each particulate matter test.

1.3.3 Rotary Calciner Inlet

Raw Material Samples

Grab samples of the raw material (feed) clay were collected periodically, during each particulate matter test. These samples were subsequently subjected to moisture content and sieve analyses.

Fugitive Emissions

Fugitive emission inspections were performed during the particulate matter tests. Inspections were conducted at the point in which the raw material entered the hopper inlet.

1.3.4 Rotary Cooler Outlet

Product Samples

Grab samples of the finished product were collected periodically, during each particulate matter test. These samples were subsequently subjected to moisture content and sieve analyses.

1.3.5 Blank Evaluations

At the completion of the emission tests, a cascade impactor was assembled and charged as if ready to perform a test. The unexposed cascade impactor was recovered and each individual filter weighed in order to establish proper laboratory clean-up technique.

1.4 Particle Size Distribution Measurement

Particle size distribution measurements were performed using cascade impactors with a pre-separator ahead of the impactor. TRC used the new style Andersen right angle inlet pre-separator.

Testing was performed in general accordance with the procedures developed by EPA's Industrial Environmental Research Laboratory (IERL). The IERL.

document describing these procedures is currently in draft form. The generalized sampling scheme employed had seven steps:

1. The pre-separator and impactor were assembled and leak checked. This was performed at the field laboratory site which was remote from the sampling site.

2. The sampling train was assembled and leak checked.

3. The pre-separator/impactor assembly was positioned in the exhaust stream with the nozzle perpendicular to the flow streamlines. The purpose of this step was to preheat the pre-separator/impactor assembly to exhaust stream temperature.

4. After the pre-separator/impactor reached exhaust stream temperature, the assembly was rotated to orient the nozzle parallel to the flow streamlines. Sampling began immediately thereafter.

5. At the end of the specified sampling time period, the sample flow was shut off and the pre-separator/impactor assembly was withdrawn from the exhaust stream.

6. The pre-separator/impactor assembly was then purged with ambient air to remove any free or condensed moisture which may have collected within the impactor.

7. After completion of the purge, the sampling train was disassembled. The pre-separator/impactor assembly was then transported to the field laboratory for disassembly and sample recovery.

1.4.1 Analysis

The analysis portion of this program consisted of recovering the collected particulate sample fractions from the pre-separator and each stage of the cascade impactor. These sample fractions were then weighed. All sample dish and impactor substrate weighings were performed at the field laboratory. These included both the pre-test (tare) and collected sample weighings.

1.4.2 Data Reduction

Data reduction for the particle size distribution measurement tests used EPA's Particulate Data Reduction System (PADRE). PADRE is an interactive computer program used to enter, reduce and analyze cascade impactor data for particle size distributions. PADRE can be used to store, review, edit, and analyze data, and, through a variety of data checks, to identify suspect or invalid data. Impactor stage cut-points (D_{50}) are calculated and cumulative and differential mass concentrations are determined and interpolated to standard diameters. PADRE performs data reduction using three definitions of particle diameter: (1) physical (Stokes's), (2) aerodynamic or Task Group on Lung Dynamics (TGLD), and (3) aerodynamic impaction (Mercer's). The aerodynamic impaction definition was used for the data developed by these tests. Data entry was performed using a portable terminal connected via telephone modem hook-up to the National Computer Center (NCC) in Research Triangle Park, North Carolina.

1.5 Description Of Report Sections

The remaining sections of this report present the Summary of Results (Section 2), Process Description and Operations (Section 3), Scope of the Sampling Program by Site (Section 4), Sampling and Analytical Methods (Section 5), and Quality Assurance (Section 6). Descriptions of methods and procedures, field and laboratory data, and calculations are presented in the various appendices, as noted in the Table of Contents.

2.0 SUMMARY OF RESULTS

This section presents summary tables of results and narrative on the emission tests conducted during the week of October 17-21, 1983 at the AP Green Refractories Company facility in Mexico, Missouri. Testing was performed on emissions entering the rotary calciner multiclone inlet and exiting the venturi scrubber outlet.

EPA Method 5 samples were analyzed at the TRC laboratory in East Hartford, Connecticut. Particle size samples were analyzed at the TRC field laboratory located in the motel room (Mexico, Missouri).

2.1 Rotary Calciner - Particulate Matter Tests

Inlet To Multiclone and Outlet From Venturi Scrubber

A summary of particulate uncontrolled and controlled emissions from the rotary calciner is shown in Table 2-1. The average venturi scrubber removal efficiency is 99.9 percent. Table 2-1a presents a data summary for a fourth test run at the inlet location only. This test was run due to a high isokinetic sampling rate (118%) generated during the first test run. The results from Table 2-1a were not included in the overall averaging in Table 2-1; instead the results are presented for informational purposes only. At the completion of Test 1 (inlet location), TRC and the EPA task manager agreed to change the sampling procedure at this location in order to maintain proper isokinetic sampling. The changes are listed below:

1. Decrease sampling points from 49 (seven points per port) to 28 (four points per port).

2. Increase sampling time from 2 minutes per point to 4 minutes per point.

TABLE 2-1

SUMMARY OF RESULTS
EPA METHOD 5 TESTS
INLET TO MULTICLONE AND OUTLET FROM VENTURI SCRUBBER
AP GREEN REFRACTORIES COMPANY
MEXICO, MISSOURI

Run Number	1		2		3		Average	
Date	10/18/83		10/20/83		10/21/83			
Time	1053---1528	1048---1514	1025---1415	0955---1450	0915---1120	0908---1236		
Location	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Volume of Gas Sampled (ACF)	21.80	110.62	40.69	105.30	39.99	117.47	34.16	111.13
Volume of Gas Sampled (DSCF)[1]	22.08	110.34	41.58	104.53	40.83	116.42	34.83	110.43
Volumetric Flowrate (ACFM)[2]	40000	17000	41000	17000	41000	18000	41000	17000
Volumetric Flowrate (DSCFM)[3]	13000	12000	13000	12000	13000	12000	13000	12000
Percent Moisture By Volume	18.5	20.2	21.1	19.4	21.8	19.8	20.5	19.8
Average Duct Temperature (°F)	853	143	842	144	851	145	849	144
Percent Oxygen (Dry)	11.2	12.2	11.3	13.0	10.4	12.7	11.0	12.6
Percent Carbon Dioxide (Dry)	5.8	4.8	5.5	4.4	6.0	4.6	5.8	4.6
Molecular Weight (Duct)	27.27	26.98	26.94	27.04	26.89	27.0	27.03	27.01
Particulate Collected (Mg)[4]	11269.44	86.18	28280.88	37.84	23800.54	40.53	21116.95	54.85
Particulate Concentration (Grains/DSCF)	7.87	0.012	10.5	0.0056	9.03	0.0054	9.14	0.0077
Emission Rate (Pounds)/Hour)	869.7	1.23	1150.2	0.57	964.4	0.57	994.8	0.79
Percent Isokinetics	118.7	107.7	106.4	102.3	106.8	102.1	110.6	104.4
Percent Removal Efficiency[5]	99.86		99.95		99.94		99.92	

1 Dry standard cubic feet @ 68°F, 29.92 inches Hg.
2 Actual cubic feet per minute.
3 Dry standard cubic feet per minute.
4 Milligrams (nozzle, probe, and filter catch).
5 Efficiency = $\left(\frac{\text{Inlet (lb/hr - outlet (lb/hr)}}{\text{(Inlet (lb/hr))}}\right)100$

TABLE 2-1a

SUMMARY OF RESULTS
EPA METHOD 5 TESTS
INLET TO MULTICLONE
AP GREEN REFRACTORIES COMPANY
MEXICO, MISSOURI

Run Number	4
Date	10/21/83
Time	1205---1426
Location	Inlet
Volume of Gas Sampled (ACF)	40.94
Volume of Gas Sampled (DSCF)[1]	41.04
Volumetric Flowrate (ACFM)[2]	42000
Volumetric Flowrate (DSCFM)[3]	13000
Percent Moisture By Volume	20.6
Average Duct Temperature (°F)	837
Percent Oxygen (Dry)	11.5
Percent Carbon Dioxide (Dry)	5.2
Molecular Weight (Duct)	26.96
Particulate Collected (Mg)[4]	20584.52
Particulate Concentration (Grains/DSCF)	7.77
Emission Rate (Pounds)/Hour)	874.8
Percent Isokinetic	101.8

1 Dry standard cubic feet @ 68°F, 29.92 inches Hg.
2 Actual cubic feet per minute.
3 Dry standard cubic feet per minute.
4 Milligrams (nozzle, probe, and filter catch).

TABLE 2-1b (metric)

SUMMARY OF RESULTS
EPA METHOD 5 TESTS
INLET TO MULTICLONE AND OUTLET FROM VENTURI SCRUBBER
AP GREEN REFRACTORIES COMPANY
MEXICO, MISSOURI

Run Number	1		2		3		Average	
Date	10/18/83		10/20/83		10/21/83			
Time	1053---1528	1048---1514	1025---1415	0955---1450	0915---1120	0908---1236		
Location	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Volume of Gas Sampled (AM^3)	0.62	3.13	1.15	2.98	1.13	3.33	0.97	3.15
Volume of Gas Sampled (NM^3)[1]	0.63	3.12	1.18	2.96	1.16	3.30	0.99	3.13
Volumetric Flowrate (M^3/Min)[2]	1133	481	1161	481	1161	510	1152	491
Volumetric Flowrate (NM^3/Min)[3]	365	340	368	340	368	340	367	340
Percent Moisture By Volume	18.5	20.2	21.1	19.4	21.8	19.8	20.5	19.8
Average Duct Temperature (^oC)	456	62	450	62	455	63	454	62
Percent Oxygen (Dry)	11.2	12.2	11.3	13.0	10.4	12.7	11.0	12.6
Percent Carbon Dioxide (Dry)	5.8	4.8	5.5	4.4	6.0	4.6	5.8	4.6
Molecular Weight (Duct)	27.27	26.98	26.94	27.04	26.89	27.0	27.03	27.01
Particulate Collected (Mg)[4]	11269.44	86.18	28280.88	37.84	23800.54	40.53	21116.95	54.85
Particulate Concentration (Mg/NM^3)	18020.77	27.46	24027.69	12.77	20663.82	12.29	20915.53	17.51
Emission Rate (Gm/Hr)[5]	3.94×10^5	5.58×10^2	5.22×10^5	2.57×10^2	4.37×10^5	2.60×10^2	4.51×10^5	3.58×10^2
Percent Isokinetics	110.7	107.7	106.4	102.3	106.8	102.1	110.6	104.0
Percent Removal Efficiency[6]	99.86		99.95		99.94		99.92	

1 Normal cubic meters @ 20^oC, 760 mm Hg.
2 Actual cubic meters per minute.
3 Normal cubic meters per minute.
4 Milligrams (nozzle, probe, and filter catch).
5 Grams Per Hour
6 Efficiency = $\left(\frac{\text{inlet (gm/hr)} - \text{outlet (gm/hr)}}{\text{inlet (gm/hr)}}\right)100$

TABLE 2-1c (metric)

SUMMARY OF RESULTS
EPA METHOD 5 TESTS
INLET TO MULTICLONE
AP GREEN REFRACTORIES COMPANY
MEXICO, MISSOURI

Run Number	4
Date	10/21/83
Time	1205---1426
Location	Inlet
Volume of Gas Sampled (AM^3)	1.16
Volume of Gas Sampled (NM^3)	1.16
Volumetric Flowrate (M^3/Min)	1189
Volumetric Flowrate (NM^3/Min)	368
Percent Moisture By Volume	20.6
Average Duct Temperature (°C)	447
Percent Oxygen (Dry)	11.5
Percent Carbon Dioxide (Dry)	5.2
Molecular Weight (Duct)	26.96
Particulate Collected (Mg)[4]	20584.52
Particulate Concentration (Mg/NM^3)	17780.49
Emission Rate (Gm/Hr)[5]	3.97×10^5
Percent Isokinetics	101.8

1 Normal cubic meters @ 20°C, 760 mm Hg.
2 Actual cubic meters per minute.
3 Normal cubic meters per minute.
4 Milligrams (nozzle, probe, and filter catch).
5 Grams per hour.

With the decrease in sampling points, volumetric flowrates still remained consistent throughout the four inlet tests.

The venturi scrubber outlet particulate concentration and emission rate for Test 1 is approximately double that of Tests 2 and 3. At this time there is no known explanation.

2.2 Rotary Calciner - Particle Size Tests

2.2.1 Multiclone Inlet - Test Parameter Summary

Tables 2-2, 2-3, and 2-4 present a summary of the three tests performed at the inlet location. All tests were run in conjunction with the inlet particulate tests and simultaneously with the outlet tests. Prior to each particle size test, gas stream velocity, temperature, and static pressure measurements were performed at the four predetermined sampling points. An average velocity was calculated; this average velocity was then used to set the sample flow rate for all four sampling points.

Actual moisture determination for each particle size run was not performed. The "volume of water collected" was determined by back calculating using the following equation:

$$\left(\frac{\text{Water Collected During Method 5 Test}}{\text{Method 5 Sample Volume (acf)}}\right) \times \left(\frac{X}{\text{Particle Size Sample Volume (acf)}}\right)$$

where:

X = water collected during particle size run

It should be noted that on Table 2-2 and all other tables standard (normal) conditions have been defined as 70°F and 29.92 inches of mercury instead of the 68°F and 29.92 inches of mercury normally associated with emission measurement calculations. This variation conforms to the standard conditions definition incorporated by the PADRE program.

TABLE 2-2

SUMMARY OF TEST PARAMETERS
PARTICLE SIZE DISTRIBUTION MEASUREMENT TESTS
INLET TO MULTICLONE
AP GREEN REFRACTORIES COMPANY
MEXICO, MISSOURI

Test Number	1	1	1	1
Run Number	P3/P1*	P3/P2	P5/P1**	P5/P2
Date	10-18-83	10-18-83	10-18-83	10-18-83
Start Time	1145	1240	1505	1538
Duration (Min.)	0.25	1	2	2
Ambient Pressure (Inches Hg)	29.42	29.42	29.42	29.42
Stack Pressure (Inches H_2O)	-0.69	-0.69	-0.69	-0.69
Stack Temperature (°F)	860	872	830	830
Percent Carbon Dioxide (Dry)	5.8	5.8	5.8	5.8
Percent Oxygen (Dry)	11.2	11.2	11.2	11.2
Percent Moisture	18.5	18.5	18.5	18.5
Molecular Weight (Duct)	27.27	27.27	27.27	27.27
Stack Gas Velocity (Ft/Sec)[1]	50.0	50.0	50.0	50.0
Impactor Temperature (°F)	860	872	830	830
Impactor Flow Rate (ACFM)[2]	0.219	0.586	0.582	0.596
Nozzle Diameter (Inches)	0.1891	0.1892	0.1891	0.1891
Dry Gas Meter Temperature (°F)	60	65	67	67
Dry Gas Meter Cal. Factor	1.01	1.01	1.01	1.01
Orifice Pressure Drop (Inches H_2O)	0.13	0.13	0.13	0.13
Volume Water Collected (ml)	0.24	0.91	1.87	1.91
Sample Volume (ACF)	0.049	0.186	0.383	0.392
Sample Volume (NCF)[3]	0.050	0.187	0.383	0.392
Percent Isokinetics	105.7	100.3	99.8	102.1

1 Feet per second.
2 Actual cubic feet per minute.
3 Normal cubic feet @ 70° F, 29.92 inches Hg.

* Port 3/Point 1
** Port 5/Point 1

Note: Particle size distributions are based upon an assumed particulate density of 1 gram/cc; actual particulate density is 2.65 to 3.00 grams/cc.

TABLE 2-3

SUMMARY OF TEST PARAMETERS
PARTICLE SIZE DISTRIBUTION MEASUREMENT TESTS
INLET TO MULTICLONE
AP GREEN REFRACTORIES COMPANY
MEXICO, MISSOURI

Test Number	2	2	2	2
Run Number	P3/P1	P5/P1	P5/P2	P3/P2
Date	10-20-83	10-20-83	10-20-83	10-20-83
Start Time	1015	1105	1312	1426
Duration (Min.)	2	2	2	2
Ambient Pressure (Inches Hg)	29.32	29.32	29.32	29.32
Stack Pressure (Inches H_2O)	-0.60	-0.60	-0.60	-0.60
Stack Temperature (°F)	855	850	830	840
Percent Carbon Dioxide (Dry)	5.5	5.5	5.5	5.5
Percent Oxygen (Dry)	11.3	11.3	11.3	11.3
Percent Moisture	21.1	21.1	21.1	21.1
Molecular Weight (Duct)	26.94	26.94	26.94	26.94
Stack Gas Velocity (Ft/Sec)[1]	50.0	50.0	50.0	50.0
Impactor Temperature (°F)	855	849	827	832
Impactor Flow Rate (ACFM)[2]	0.663	0.604	0.623	0.636
Nozzle Diameter (Inches)	0.1891	0.1892	0.1891	0.1892
Dry Gas Meter Temperature (°F)	63	61	61	60
Dry Gas Meter Cal. Factor	1.01	1.01	1.01	1.01
Orifice Pressure Drop (Inches H_2O)	0.15	0.135	0.135	0.135
Volume Water Collected (ml)	2.38	2.18	2.28	2.31
Sample Volume (ACF)	0.411	0.375	0.393	0.399
Sample Volume (NCF)[3]	0.412	0.378	0.396	0.403
Percent Isokinetics	113.7	103.7	107.1	109.5

1 Feet per second.
2 Actual cubic feet per minute.
3 Normal cubic feet @ 70° F, 29.92 inches Hg.

Note: Particle size distributions are based upon an assumed particulate density of 1 gram/cc; actual particulate density is 2.65 to 3.00 grams/cc.

TABLE 2-4

SUMMARY OF TEST PARAMETERS
PARTICLE SIZE DISTRIBUTION MEASUREMENT TESTS
INLET TO MULTICLONE
AP GREEN REFRACTORIES COMPANY
MEXICO, MISSOURI

Test Number	3	3	3	3
Run Number	P3/P1	P3/P2	P5/P1	P5/P2
Date	10-21-83	10-21-83	10-21-83	10-21-83
Start Time	0935	1030	1122	1235
Duration (Min.)	2	2	2	2
Ambient Pressure (Inches Hg)	29.18	29.18	29.18	29.18
Stack Pressure (Inches H_2O)	-0.65	-0.65	-0.65	-0.65
Stack Temperature (°F)	867	856	843	840
Percent Carbon Dioxide (Dry)	6.0	6.0	6.0	5.2
Percent Oxygen (Dry)	10.4	10.4	10.4	11.5
Percent Moisture	21.8	21.8	21.8	20.6
Molecular Weight (Duct)	26.89	26.89	26.89	26.96
Stack Gas Velocity (Ft/Sec)[1]	50.0	50.0	50.0	51.7
Impactor Temperature (°F)	865	855	843	840
Impactor Flow Rate (ACFM)[2]	0.655	0.695	0.663	0.666
Nozzle Diameter (Inches)	0.1891	0.1891	0.1891	0.1891
Dry Gas Meter Temperature (°F)	56	58	59	59
Dry Gas Meter Cal. Factor	1.01	1.01	1.01	1.01
Orifice Pressure Drop (Inches H_2O)	0.14	0.14	0.14	0.14
Volume Water Collected (ml)	2.39	2.56	2.47	2.30
Sample Volume (ACF)	0.394	0.423	0.408	0.417
Sample Volume (NCF)[3]	0.399	0.426	0.411	0.420
Percent Isokinetics	112.5	119.3	113.8	110.0

1 Feet per second.
2 Actual cubic feet per minute.
3 Normal cubic feet @ 70° F, 29.92 inches Hg.

Note: Particle size distributions are based upon an assumed particulate density of 1 gram/cc; actual particulate density is 2.65 to 3.00 grams/cc.

The sampling period for each point was two minutes in duration with the exception of the first two runs of Test 1. Run 1 of Test 1 was for 0.25 minutes. After a visual inspection of each individual impactor substrate, a decision was made to increase the sampling period to one (1) minute. TRC and the EPA task manager agreed that the increase in time would aid in the sampling technique (i.e., impactor flow rate, isokinetic sampling, and proper particulate weight gain on each substrate).

At the completion of the second run, on Test 1, each substrate was again visually inspected. The sample time of one (1) minute seemed a little to short regarding particulate weight gain on each substrate. In an effort to avoid an "underloading" problem on the substrates, the sample time was increased to two (2) minutes. The increase to two (2) minutes per sample point would further enhance the sampling technique.

Four (4) impactors were used for each test (one impactor per sample point). All tests were within the IERL prescribed isokinetic range of 100 $\pm$ 20 percent and were within the Andersen prescribed impactor flow rate range of 0.5 to 0.75 actual cubic feet per minute (acfm). Run 1 of Test 1 had a low impactor flow rate (0.22 acfm); this was probably due to the very short sampling time of 0.25 minutes.

2.2.2 Venturi Scrubber Outlet - Test Parameter Summary

Table 2.5 presents a summary of the three tests performed at the outlet location. One impactor was used for each test (one impactor per four sample points). All tests were run in conjunction with the outlet particulate tests and simultaneously with the inlet tests. Velocity measurements, sample flow rate determination, and moisture determination were performed in the same manner as the inlet particle size tests.

Due to the low particulate loadings at the outlet sampling location, a change was made between Test 1 and Test 2. Impactor nozzle diameters were

TABLE 2-5

SUMMARY OF TEST PARAMETERS
PARTICLE SIZE DISTRIBUTION MEASUREMENT TESTS
OUTLET FROM VENTURI SCRUBBER
AP GREEN REFRACTORIES COMPANY
MEXICO, MISSOURI

Test Number	1	2	3
Run Number	5	5	5
Date	10-18-83	10-20-83	10-21-83
Start Time	1045	0955	0910
Duration (Min.)	240	240	240
Ambient Pressure (Inches Hg)	29.39	29.23	29.12
Stack Pressure (Inches H_2O)	-0.17	-0.19	-0.22
Stack Temperature (^oF)	134	136	135
Percent Carbon Dioxide (Dry)	4.8	4.4	4.6
Percent Oxygen (Dry)	12.2	13.0	12.7
Percent Moisture	20.2	19.4	19.8
Molecular Weight (Duct)	26.98	27.04	27.00
Stack Gas Velocity (Ft/Sec)[1]	36.7	36.7	38.3
Impactor Temperature (^oF)	134	136	134
Impactor Flow Rate (ACFM)[2]	0.525	0.785	0.793
Nozzle Diameter (Inches)	0.1891	0.250	0.250
Dry Gas Meter Temperature (^oF)	64	60	58
Dry Gas Meter Cal. Factor	1.01	1.01	1.01
Orifice Pressure Drop (Inches H_2O)	0.99	0.99	0.99
Volume Water Collected (ml)	464.7	665.1	680.2
Sample Volume (ACF)	86.43	130.72	131.34
Sample Volume (NCF)[3]	86.94	131.79	132.43
Percent Isokinetics	120.5	104.3	101.0

1 Feet per second.
2 Actual cubic feet per minute.
3 Normal cubic feet @ 70^o F, 29.92 inches Hg.

Note: Particle size distributions are based upon an assumed particulate density of 1 gram/cc; actual particulate density is 2.65 to 3.00 grams/cc.

increased from a 0.1891 inch to 0.250 inch. This change in nozzle size increased the sampled volumes and impactor flowrates to a more desirable level. The increase in sample volume also allowed for a more measurable weight gain on each substrate.

2.3 Impactor Data at Interpolated Particle Diameters

A particularly useful feature of EPA's Particulate Data Reduction System (PADRE) is its ability to provide comparable data for several runs by interpolating the particle size distribution data to a common set of standard particle diameters. These diameters are 20.0, 15.0, 10.0, 6.0, 2.5, 1.25, 1.00, 0.625, 0.30, and 0.10 µm. However, the interpolation is performed only within the range of actual measured data. That is, if the smallest cut-point at which the sample is collected is 1.00 µm, no values at the small standard diameters can be interpolated.

2.3.1 Rotary Calciner - Multiclone Inlet

Tables 2-6, 2-7, and 2-8 present summaries of the impactor data for Tests 1, 2, and 3, respectively, on a "cumulative percent mass less than the interpolated diameter" (CPLT) basis. The following nomenclature was used for each run number:

P3/P1 - Port 3/Point 1
P3/P2 - Port 3/Point 2
P5/P1 - Port 5/Point 1
P5/P2 - Port 5/Point 2

Port 3 was located above the centerline of the rectangular horizontal duct and Port 5 was located below the centerline. Four runs were performed per test at the inlet location. Each run had its own impactor assembly (i.e., four impactors were used per test).

TABLE 2-6

IMPACTOR DATA SUMMARY AT INTERPOLATED PARTICLE DIAMETERS
PARTICLE SIZE DISTRIBUTION TESTS
AP GREEN REFRACTORIES COMPANY
ROTARY CALCINER
INLET TO MULTICLONE
MEXICO, MISSOURI

Test Number		1		
Run Number	P3/P1	P3/P2	P5/P1	P5/P2
Date	10-18-83	10-18-83	10-18-83	10-18-83
Start Time	1145	1240	1505	1538
Duration (Min.)	0.25	1	2	2
Interpolated Diameter (µm)	Cumulative Percent Mass Less Than Interpolated Diameter			
20.00	40.36	40.80	40.98	59.74
15.00	28.22	28.43	28.41	47.89
10.00	17.30	16.78	16.18	31.18
6.00	8.92	7.45	5.88	10.90
2.50	4.76	2.25	1.34	1.71
1.25	3.42	1.28	1.07	0.50
1.00	3.15	0.74	0.59	0.18

Note: Particle size distributions are based upon an assumed particulate density of 1 gram/cc; actual particulate density is 2.65 to 3.00 grams/cc.

TABLE 2-7

IMPACTOR DATA SUMMARY AT INTERPOLATED PARTICLE DIAMETERS
PARTICLE SIZE DISTRIBUTION TESTS
AP GREEN REFRACTORIES COMPANY
ROTARY CALCINER
INLET TO MULTICLONE
MEXICO, MISSOURI

Test Number				
Run Number			2	
Date	P3/P1	P5/P1	P5/P2	P3/P2
Start Time	10-20-83	10-20-83	10-20-83	10-20-83
Duration (Min.)	1015	1105	1312	1426
	2	2	2	2

Interpolated Diameter (μm)	Cumulative Percent Mass Less Than Interpolated Diameter			
20.00	67.98	45.32	48.24	50.16
15.00	57.31	33.15	36.01	38.14
10.00	40.85	20.46	22.17	24.21
6.00	19.82	8.74	8.16	9.78
2.50	4.82	3.52	1.14	1.85
1.25	1.27	1.89	0.20	0.46
1.00	0.61	1.31	0.06	0.26

Note: Particle size distributions are based upon an assumed particulate density of 1 gram/cc; actual particulate density is 2.65 to 3.00 grams/cc.

TABLE 2-8

IMPACTOR DATA SUMMARY AT INTERPOLATED PARTICLE DIAMETERS
PARTICLE SIZE DISTRIBUTION TESTS
AP GREEN REFRACTORIES COMPANY
ROTARY CALCINER
INLET TO MULTICLONE
MEXICO, MISSOURI

Test Number	3			
Run Number	P3/P1	P3/P2	P5/P1	P5/P2
Date	10-21-83	10-21-83	10-21-83	10-21-83
Start Time	0935	1030	1122	1235
Duration (Min.)	2	2	2	2
Interpolated Diameter (µm)	**Cumulative Percent Mass Less Than Interpolated Diameter**			
20.00	65.52	57.92	56.25	50.79
15.00	53.55	46.20	44.65	38.90
10.00	37.50	30.45	29.74	25.09
6.00	17.61	12.03	12.86	10.73
2.50	3.41	1.71	3.08	2.23
1.25	0.44	0.59	1.19	1.03
1.00	0.34	0.34	0.82	0.67

Note: Particle size distributions are based upon an assumed particulate density of 1 gram/cc; actual particulate density is 2.65 to 3.00 grams/cc.

2.3.2 Rotary Calciner - Venturi Scrubber Outlet

Table 2-9 presents the summary of the impactor data for Tests 1, 2, and 3 on a "cumulative percent mass less than the interpolated diameter" (CPLT) basis.

Only one run was performed per test at the outlet location. The same impactor assembly was used for all four sampling points.

2.4 Comparative Data Analysis

The preceding section provided impactor data of standard particle diameters which allowed an evaluation of the results from individual runs. This section presents a comparative data analysis including basic statistics. Data presented in this section were developed using PADRE's data comparison routine. This routine permits comparison of data for two or more runs of a specified test as identified by a site code and date. For example:

1. The four runs performed during Test 1 (inlet) can be compared.
2. Test 1 (outlet) can not be compared to Test 2 (outlet) because of the different site code and date.

Therefore, the comparative data analyses are presented on an individual test basis.

2.4.1 Rotary Calciner - Multiclone Inlet

Table 2-10 presents the comparative CPLT data for runs performed on October 18, 1983. Comparison of minimum and maximum CPLT of all interpolated diameters shows a wide range. At 10 μm the CPLT ranges from 31.18 percent to 16.18 percent. This wide range is also reflected by the calculated relative standard deviation (RDS = standard deviation divided by the mean, times 100)

TABLE 2-9

IMPACTOR DATA SUMMARY AT INTERPOLATED PARTICLE DIAMETERS
PARTICLE SIZE DISTRIBUTION TESTS
AP GREEN REFRACTORIES COMPANY
ROTARY CALCINER
OUTLET FROM VENTURI SCRUBBER
MEXICO, MISSOURI

Test Number	1	2	3
Run Number	1	1	1
Date	10-18-83	10-20-83	10-21-83
Start Time	1045	0955	0910
Duration (Min.)	240	240	240
Interpolated Diameter (μm)	Cumulative Percent Mass Less Than Interpolated Diameter		
20.00	78.2	99.0	96.1
15.00	63.6	88.6	89.9
10.00	60.5	66.0	81.9
6.00	58.6	44.9	62.1
2.50	58.6	34.9	43.8
1.25	56.2	31.9	39.6
1.00	45.8	21.8	24.3
0.63	0	0	0

Note: Particle size distributions are based upon an assumed particulate density of 1 gram/cc; actual particulate density is 2.65 to 3.00 grams/cc.

TABLE 2-10

COMPARATIVE CPLT* DATA FOR TEST 1
PARTICLE SIZE DISTRIBUTION TESTS
AP GREEN REFRACTORIES COMPANY
ROTARY CALCINER
INLET TO MULTICLONE
MEXICO, MISSOURI
OCTOBER 18, 1983

Interpolated Diameter (μm)[1]	20.00	15.00	10.00	6.00	2.50	1.25	1.00
Run Number	Cumulative Percent Less Than Interpolated Diameter						
P3/P1	40.36	28.22	17.30	8.92	4.76	3.42	3.15
P3/P2	40.80	28.43	16.78	7.45	2.25	1.28	0.74
P5/P1	40.98	28.41	16.18	5.88	1.34	1.07	0.59
P5/P2	59.74	47.89	31.18	10.90	1.17	0.50	0.18
Minimum	40.36	28.22	16.18	5.88	1.34	0.50	0.18
Maxmum	59.74	47.89	31.18	10.90	4.76	3.42	3.15
Average	45.57	33.24	20.36	8.29	2.51	1.57	1.17
Standard Deviation	9.52	9.77	7.23	2.13	1.55	1.28	1.35
Relative Standard Deviation (%)	20.94	29.39	35.51	25.69	61.75	81.53	115.38

* Cumulative Percent Less Than
[1] Microns

Note: Particle size distributions are based upon an assumed particulate density of 1 gram/cc; actual particulate density is 2.65 to 3.00 grams/cc.

which is an indicator of precision. The RSD ranged from 115.38 percent at 1.00 μm to 20.94 percent at 20.0 μm and averaged 52.7 percent.

Table 2-11 presents the comparative CPLT data for the runs performed on October 20, 1983. Comparison of minimum and maximum CPLT at all interpolated diameters show a wide range. At 10 μm the CPLT ranges from 40.85 percent to 20.46 percent. The RSD at all interpolated diameters, except one 6.00 μm, are slightly smaller than those of the October 18, 1983 tests. RSD ranged from 98.21 percent at 1.00 μm to 17.07 percent at 20.0 μm and averaged 51.9 percent.

Table 2-12 presents the comparative CPLT data for the runs performed on October 21, 1983. It is notable that the RSD at all interpolated diameters are significantly smaller than those of the previous two tests. RSD ranged from 46.30 percent at 1.00 μm to 9.85 percent at 20.0 μm and averaged 26.1 percent. At 10 μm the CPLT ranged from 37.50 percent to 25.09 percent.

Comparing all three tests, no apparent trends are present in relation to sample point locations (upper or lower). For example, the following table shows the CPLT 10 μm for each run:

CPLT 10 μm - Multiclone Inlet

Run Number	Test 1	Test 2	Test 3
P3/P1	17.30	40.85	37.50
P3/P2	16.78	24.21	30.45
P5/P1	16.18	20.46	29.74
P5/P2	31.18	22.17	25.09

P3 - Port 3 upper location
P5 - Port 5 lower location

The differences between the upper and lower point runs may be due to the poor inlet sampling location. Both upstream and downstream disturbances were less than 1.0 equivalent duct diameter.

TABLE 2-12

COMPARATIVE CPLT* DATA FOR TEST 3
PARTICLE SIZE DISTRIBUTION TESTS
AP GREEN REFRACTORIES COMPANY
ROTARY CALCINER
INLET TO MULTICLONE
MEXICO, MISSOURI
OCTOBER 21, 1983

Interpolated Diameter (μm)[1]	20.00	15.00	10.00	6.00	2.50	1.25	1.00
Run Number	Cumulative Percent Less Than Interpolated Diameter						
P3/P1	64.52	53.55	37.50	17.61	3.41	0.44	0.34
P3/P2	57.92	46.20	30.45	12.03	1.71	0.59	0.34
P5/P1	56.25	44.65	29.74	12.86	3.08	1.19	0.82
P5/P2	50.79	38.90	25.09	10.73	2.23	1.03	0.67
Minimum	50.79	38.90	25.09	10.73	1.71	0.44	0.34
Maximum	64.52	53.55	37.50	17.61	3.41	1.19	0.82
Average	57.37	45.83	30.70	13.31	2.61	0.81	0.54
Standard Deviation	5.65	6.03	5.12	3.00	0.78	0.36	0.25
Relative Standard Deviation (%)	9.85	13.16	16.68	22.54	29.89	44.44	46.30

* Cumulative Percent Less Than
[1] Microns

Note: Particle size distributions are based upon an assumed particulate density of 1 gram/cc; actual particulate density is 2.65 to 3.00 grams/cc.

2.4.2 Rotary Calciner - Venturi Scrubber Outlet

For the outlet location one run was performed per test. Comparative data analyses were not performed for the outlet tests because of PADRE's data comparison routine. As stated before, this routine permits comparison of data for two or more runs of a specified test - each outlet test had one run.

Table 2-9 presents the summary of the CPLT data.

2.5 Averaged Distributions for Tests 1, 2, and 3

A comparison (inlet to outlet) on a test basis was performed using the average interpolated CPLT data from individual test runs. The averages yield a single particle size distribution for each test. Average interpolated CPLT data was performed on the inlet test runs only.

Tables 2-13, 2-14, and 2-15 present the averaged interpolated diameter data for Tests 1, 2, and 3, respectively. Figures 2-1, 2-2, and 2-3 show the inlet and outlet particle size distributions based upon interpolated diameters for Tests 1, 2, and 3, respectively.

All outlet test distributions appear to be bi- or tri-modal. Test 1 on the inlet appears to be bi-modal. However, Tests 2 and 3 inlet definitely appear to be single mode log-normal.

Tables 2-13, 2-14, and 2-15 also show the fractional efficiency of each interpolated diameter. The efficiencies reveal typical venturi scrubber performance (i.e., very high efficiency above 1 micron, with a rapidly decreasing efficiency below 1 micron).

2.6 Comparison of Cumulative Percent Less Than 10 um

During the course of the calciner/dryer NSPS development, EPA is planning to collect data on the particulate emission fraction with an equivalent

TABLE 2-13

COMPARATIVE CPLT* DATA FOR TEST 1
PARTICLE SIZE DISTRIBUTION TESTS
AP GREEN REFRACTORIES COMPANY
ROTARY CALCINER
INLET TO MULTICLONE AND OUTLET FROM VENTURI SCRUBBER
MEXICO, MISSOURI
OCTOBER 18, 1983

Interpolated Diameter (μm)[1]		20.00	15.00	10.00	6.00	2.50	1.25	1.00
Run Number	Location	Cumulative Percent Less Than Interpolated Diameter						
P3/P1		40.36	28.22	17.30	8.92	4.76	3.42	3.15
P3/P2	Inlet	40.80	28.43	16.78	7.45	2.25	1.28	0.74
P5/P1		40.98	28.41	16.18	5.88	1.34	1.07	0.59
P5/P2		59.74	47.89	31.18	10.90	1.71	0.50	0.18
Average		45.47	33.24	20.36	8.29	2.51	1.57	1.17
1	Outlet	78.2	63.6	60.5	58.6	58.6	56.2	45.8
Efficiency		99.894	99.909	99.975	99.983	99.974	99.925	98.628

* Cumulative Percent Less Than
1 Microns

Note: Particle size distributions are based upon an assumed particulate density of 1 gram/cc; actual particulate density is 2.65 to 3.00 grams/cc.

TABLE 2-14

COMPARATIVE CPLT* DATA FOR TEST 2
PARTICLE SIZE DISTRIBUTION TESTS
AP GREEN REFRACTORIES COMPANY
ROTARY CALCINER
INLET TO MULTICLONE AND OUTLET FROM VENTURI SCRUBBER
MEXICO, MISSOURI
OCTOBER 20, 1983

Interpolated Diameter (μm)[1]		20.00	15.00	10.00	6.00	2.50	1.25	1.00
Run Number	Location	Cumulative Percent Less Than Interpolated Diameter						
P3/P1		67.98	57.31	40.85	19.82	4.82	1.27	0.61
P3/P2		45.32	33.15	20.46	8.74	3.52	1.89	1.31
P5/P1	Inlet	48.24	36.01	22.17	8.16	1.14	0.20	0.06
P5/P2		50.16	38.14	24.21	9.78	1.85	0.46	0.26
Average		52.92	41.15	26.92	11.63	2.83	0.96	0.56
1	Outlet	99.0	88.6	66.0	44.9	34.9	31.9	21.8
Efficiency		99.998	99.951	99.732	99.626	99.128	98.629	97.855

* Cumulative Percent Less Than
[1] Microns

Note: Particle size distributions are based upon an assumed particulate density of 1 gram/cc; actual particulate density is 2.65 to 3.00 grams/cc.

TABLE 2-15

COMPARATIVE CPLT* DATA FOR TEST 3
PARTICLE SIZE DISTRIBUTION TESTS
AP GREEN REFRACTORIES COMPANY
ROTARY CALCINER
INLET TO MULTICLONE AND OUTLET FROM VENTURI SCRUBBER
MEXICO, MISSOURI
OCTOBER 21, 1983

Interpolated Diameter (μm)[1]		20.00	15.00	10.00	6.00	2.50	1.25	1.00
Run Number	Location	Cumulative Percent Less Than Interpolated Diameter						
P3/P1	Inlet	64.52	53.55	37.50	17.61	3.41	0.44	0.34
P3/P2	Inlet	57.92	46.20	30.45	12.03	1.71	0.59	0.34
P5/P1	Inlet	56.25	44.65	29.74	12.86	3.08	1.19	0.82
P5/P2	Inlet	50.79	38.90	25.09	10.73	2.23	1.03	0.67
Average	Inlet	57.37	45.83	30.70	13.31	2.61	0.81	0.54
1	Outlet	96.1	89.9	81.9	62.1	43.8	39.6	24.3
Efficiency		99.974	99.970	99.963	99.960	99.335	98.863	98.548

* Cumulative Percent Less Than
[1] Microns

Note: Particle size distributions are based upon an assumed particulate density of 1 gram/cc; actual particulate density is 2.65 to 3.00 grams/cc.

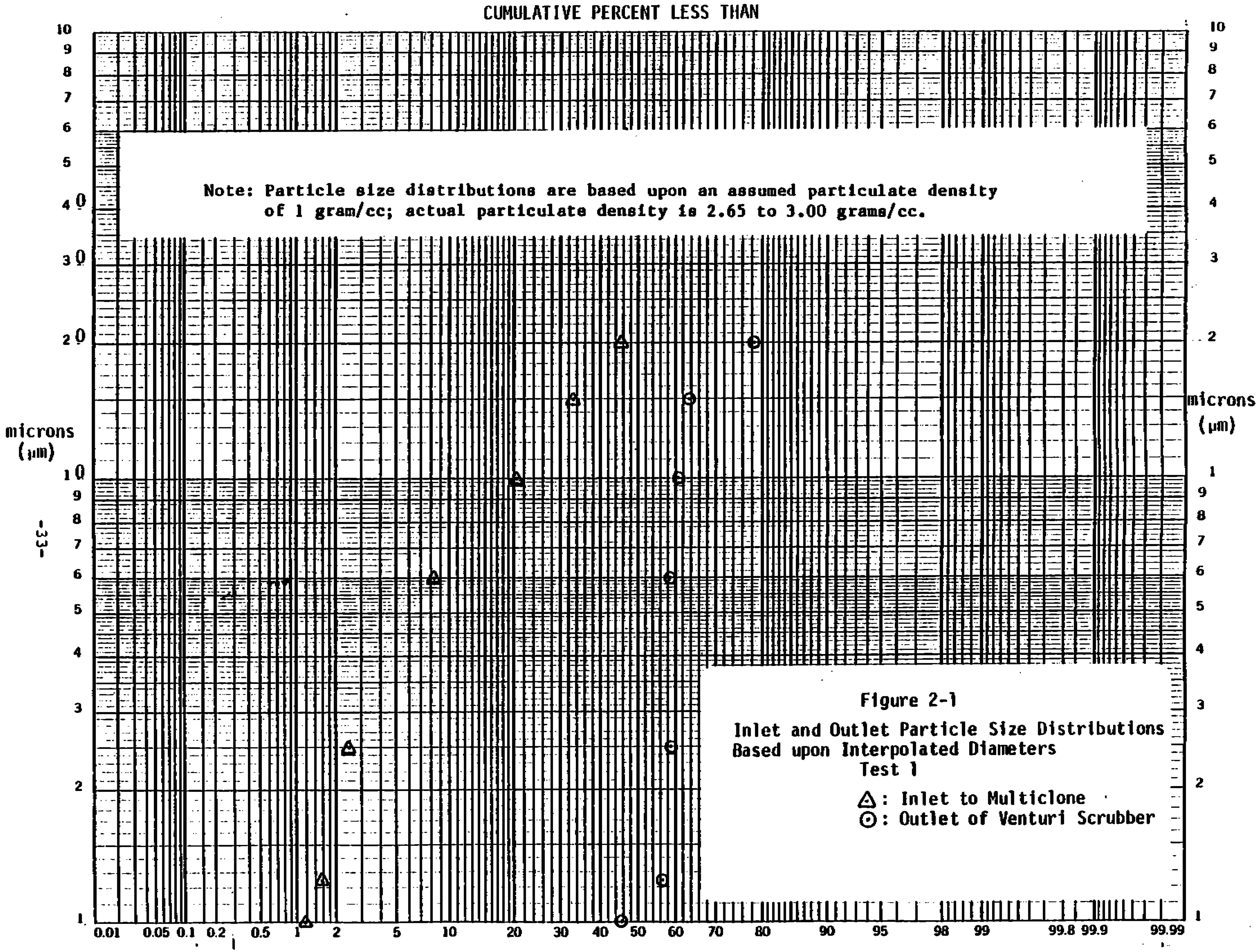


Figure 2-1

Inlet and Outlet Particle Size Distributions Based upon Interpolated Diameters

Test 1

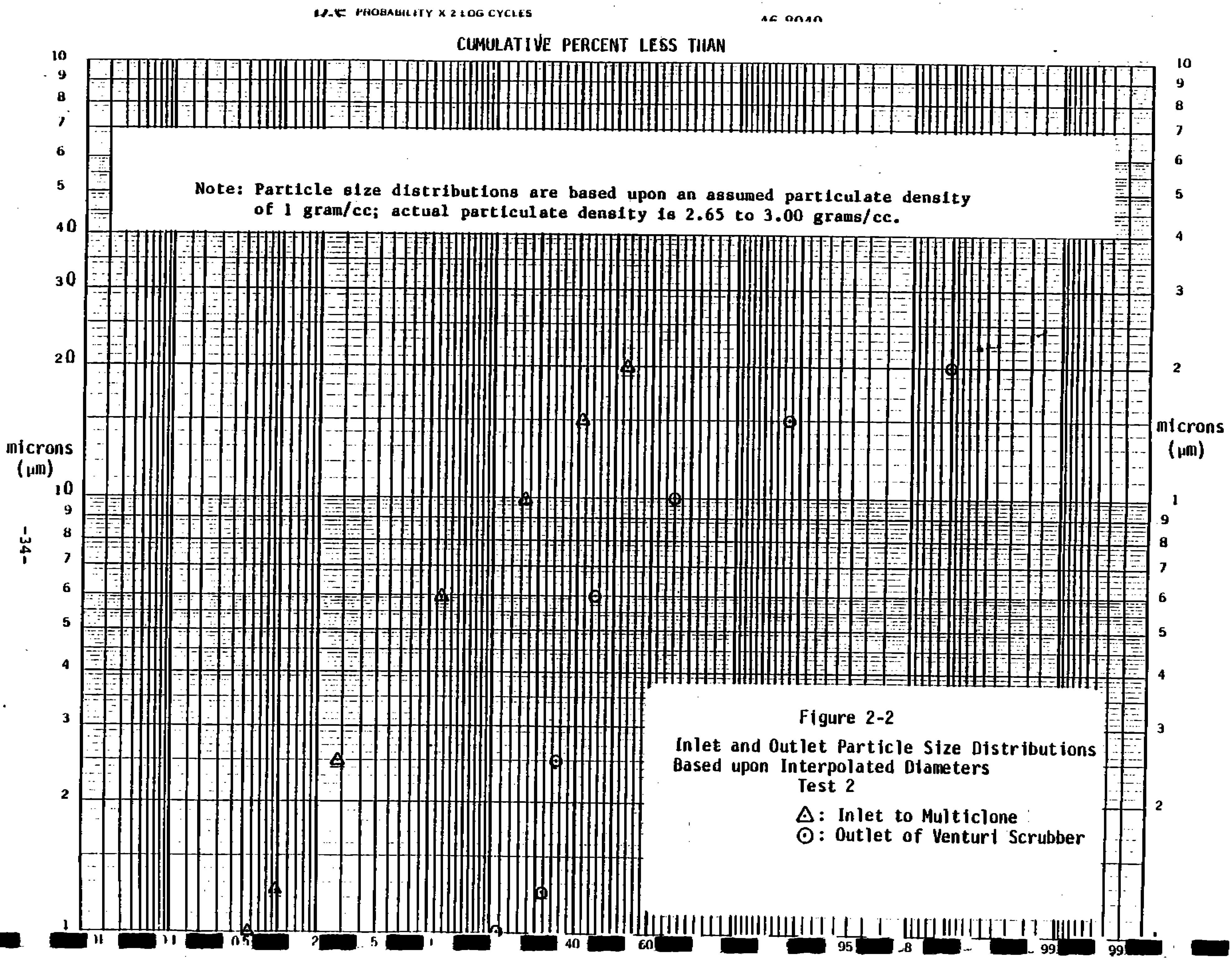


Figure 2-2

Inlet and Outlet Particle Size Distributions Based upon Interpolated Diameters

Test 2

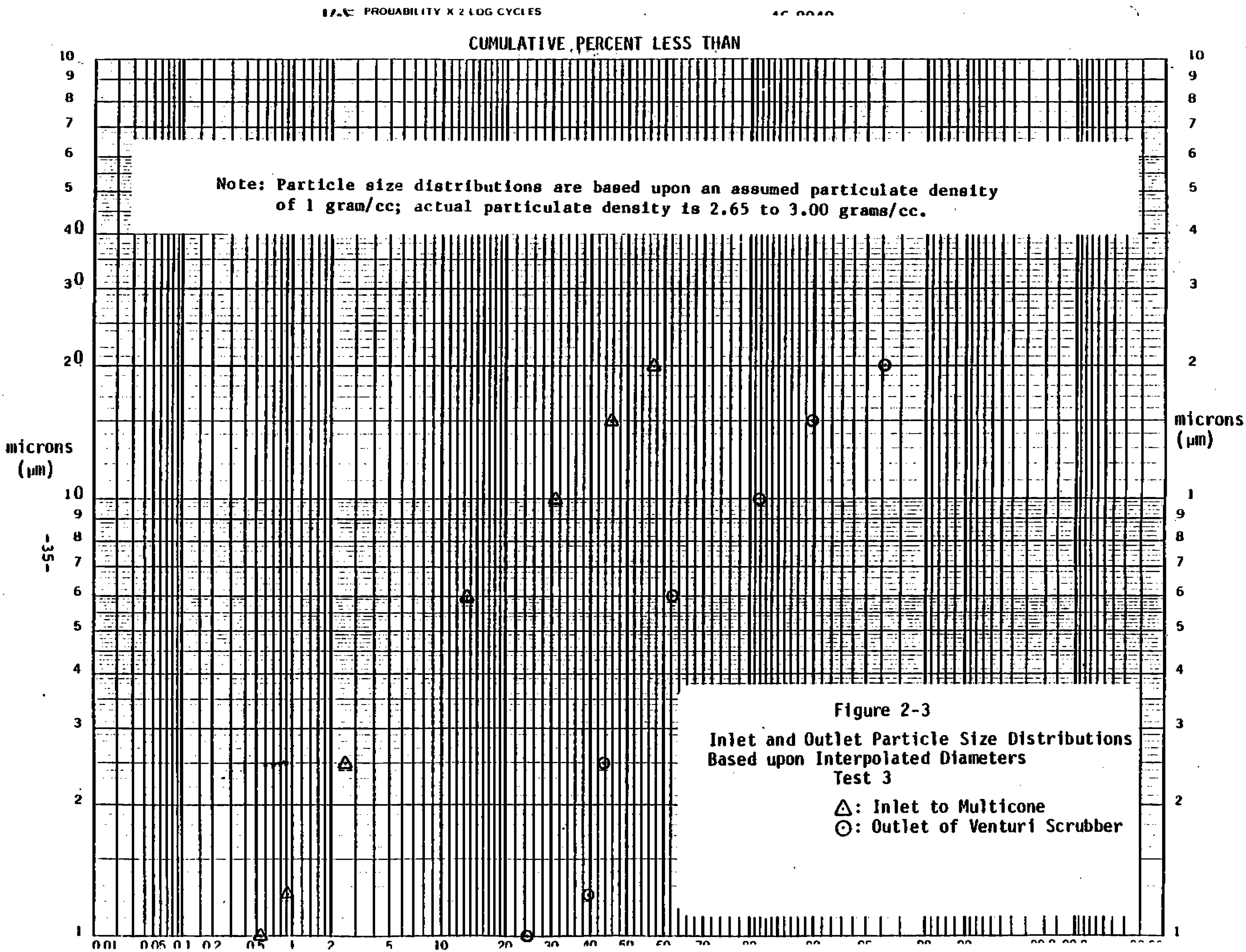


Figure 2-3

Inlet and Outlet Particle Size Distributions
Based upon Interpolated Diameters
Test 3

aerodynamic diameter equal to, or less than, 10 um because of the current emphasis upon limiting ambient air concentrations of inhalable particulates. It was of particular interest during this test program to determine whether consistent results could be obtained at particle diameters of 10 um or smaller. Table 2-16 presents a comparative summary of the cumulative percent mass less than 10 um for the three tests (inlet and outlet). Comparison of the inlet and outlet locations at CPLT 10 um shows a wide range.

The relative standard deviations for the inlet and outlet tests were 20.1 and 16.0 percent, respectively.

2.7 Visible Emissions

The opacity of the venturi scrubber outlet was monitored during the emission testing program by a certified visible emission observer. All observation locations conformed to the guidelines of EPA Method 9. The outlet plume was monitored during two of the three emission tests. Observations were not performed during the third test due to the poor visibility caused by inclement weather. All opacities were zero, and these data are shown in Table 2-17.

2.8 Fugitive Emissions

Fugitive emission (FE) observations were monitored during the emission testing program by an FE observer. All observation locations conformed to the guidelines of EPA Method 22. The rotary calciner hopper inlet was monitored during two of the three emission tests. Observations were not performed during the third test due to the rainy weather. The inclement weather caused the feed material to become almost a "muddy" substance. All observations were zero, and these data are shown in Table 2-18.

TABLE 2-16

COMPARISON OF CUMULATIVE PERCENT LESS THAN 10 μm
PARTICLE SIZE DISTRIBUTION TESTS
AP GREEN REFRACTORIES COMPANY
ROTARY CALCINER
INLET TO MULTICLONE AND OUTLET FROM VENTURI SCRUBBER
MEXICO, MISSOURI

Test No.	Inlet CPLT 10 μm	Outlet CPLT 10μm
1	20.36	60.5
2	26.92	66.0
3	30.70	81.9

Note: Particle size distributions are based upon an assumed particulate density of 1 gram/cc; actual particulate density is 2.65 to 3.00 grams/cc.

TABLE 2-17

VISIBLE EMISSIONS OBSERVATIONS AT THE ROTARY CALCINER - VENTURI SCRUBBER OUTLET, AP GREEN REFRACTORIES COMPANY, MEXICO, MISSOURI

Date	Test Number	Six-Minute Time Period	Average Opacity (Percent)	Observer Location
18 Oct 83	1	1048 - 1053	0	1000 Ft. NE of Outlet
		1054 - 1059	0	
		1100 - 1105	0	
		1106 - 1111	0	
		1112 - 1117	0	
		1118 - 1123	0	
		1124 - 1129	0	
		1130 - 1135	0	
		1136 - 1141	0	
		1136 - 1141	0	
		1142 - 1147	0	
		1148 - 1153	0	
		1154 - 1159	0	
		1200 - 1205	0	
		1206 - 1211	0	
		1212 - 1217	0	
		1218 - 1223	0	
		1224 - 1229	0	
		1230 - 1235	0	
		1236 - 1241	0	
		1242 - 1247	0	
		1248 - 1253	0	
		1254 - 1259	0	
		1300 - 1305	0	
		1306 - 1311	0	
		1312 - 1317	0	
		1318 - 1323	0	
		1324 - 1329	0	
		1330 - 1335	0	
		1336 - 1341	0	
		1342 - 1343*	0	
		1448 - 1453	0	
		1454 - 1459	0	
		1500 - 1505	0	
		1506 - 1511	0	
		1512 - 1517	0	
		1518 - 1523	0	
		AVERAGE	0	

*Method 5 test stopped to maintain simultaneous sampling with the inlet tests.

TABLE 2-17 (continued)

VISIBLE EMISSIONS OBSERVATIONS AT THE ROTARY CALCINER - VENTURI SCRUBBER OUTLET, AP GREEN REFRACTORIES COMPANY, MEXICO, MISSOURI

Date	Test Number	Six-Minute Time Period	Average Opacity (Percent)	Observer Location
20 Oct 83	2	1014 - 1019	0	600 Ft. NE of Outlet
		1020 - 1025	0	
		1026 - 1031	0	
		1032 - 1037	0	
		1038 - 1043	0	
		1044 - 1049	0	
		1050 - 1055	0	
		1056 - 1101	0	
		1102 - 1107	0	
		1108 - 1113	0	
		1114 - 1119	0	
		1120 - 1125	0	
		1126 - 1131	0	
		1132 - 1137	0	
		1138 - 1143	0	
		1144 - 1145*	0	
		1315 - 1320	0	
		1321 - 1326	0	
		1327 - 1332	0	
		1333 - 1338	0	
		1339 - 1344	0	
		1345 - 1350	0	
		1351 - 1356	0	
		1357 - 1402	0	
		1403 - 1408	0	
		1409 - 1414	0	
		1415 - 1420	0	
		1421 - 1426	0	
		1427 - 1432	0	
		1433 - 1438	0	
		1439 - 1444	0	
		1445 - 1450	0	
		1451 -	0	
		AVERAGE	0	

*Method 5 test stopped to maintain simultaneous sampling with the inlet tests.

TABLE 2-18

FUGITIVE EMISSIONS OBSERVATIONS AT THE ROTARY CALCINER - HOPPER INLET, AP GREEN REFRACTORIES COMPANY, MEXICO, MISSOURI

Date	Run Number	Twenty-Minute Time Period	Accumulated Emission Time (Min:Sec)	Observer Location
18 Oct 83	1	1045 - 1105	0:0	Natural light behind observer. Observer in doorway of conveyor belt shed.
		1115 - 1135	0:0	
		1145 - 1205	0:0	
		1215 - 1235	0:0	
		1245 - 1305	0:0	
		1315 - 1335	0:0	
		Total	0:0	
20 Oct 83	2	1010 - 1030	0:0	Natural light behind observer. Observer in doorway of conveyor belt shed.
		1040 - 1100	0:0	
		1110 - 1130	0:0	
		1140 - 1200	0:0	
		1210 - 1230	0:0	
		1240 - 1300	0:0	
		1310 - 1330	0:0	
		1340 - 1400	0:0	
		1410 - 1430	0:0	
		Total	0:0	

2.9 Sieve and Moisture Analysis - Feed and Product Materials

Samples of the feed (raw material clay) and product materials were collected during each emission test. Samples from each location were then composited. Sieving and moisture content analyses were performed on the composite samples in accordance with ANSI/ASTM Standard C92-76: Standard Test Methods for Sieve Analysis and Water Content of Refractory Materials.

2.9.1 Feed Material

The sieve analysis and moisture content data are shown in Table 2-19. The average moisture content was 9.1 percent. The sieve analysis showed, for all three tests, that at least 82 percent of the material was larger than 1 millimeter.

2.9.2 Product Material

The sieve analysis and moisture content data are shown in Table 2-20. The average moisture content was zero percent. The sieve analysis showed, for all three tests, that at least 90 percent of the material was larger than 1 millimeter.

2.9.3 Trace Metals Analysis

For one run at each location, the Method 5 particulate catch and the distilled water reagent from the impingers were analyzed for trace metals by using atomic absorption or inductively coupled argon plasma spectrometry. Table 2-21 presents the results of the trace metals analysis.

TABLE 2-19

FEED MATERIAL SAMPLES
SIEVE ANALYSIS/MOISTURE CONTENT
AP GREEN REFRACTORIES COMPANY
MEXICO, MISSOURI

Sieve Size	Total Percent Retained On Sieve, Test 1	Test 2	Test 3
8 mm[a]	26.1	45.2	56.5
4 mm	24.7	22.1	14.1
2 mm	20.2	11.0*	9.0
1 mm	11.2	8.6	7.0
850 µm[b]	1.8	1.6	1.4
710 µm	1.6	1.4	1.2
300 µm	4.3	1.2	2.6
250 µm	4.4	4.4	4.0
125 µm	3.6	2.9	2.7
63 µm	1.7	1.4	1.3
Bottom Pan	0.2	0.2	0.2
Percent Moisture	9.1	8.8	9.5

[a] millimeter
[b] micron
* some sample loss occurred

TABLE 2-20

PRODUCT MATERIAL SAMPLES
SIEVE ANALYSIS/MOISTURE CONTENT
AP GREEN REFRACTORIES COMPANY
MEXICO, MISSOURI

Sieve Size	Total Percent Retained On Sieve		
	Test		
	1	2	3
8 mm[a]	38.6	52.1	71.2
4 mm	24.9	27.9	20.4
2 mm	18.2	13.3	6.5
1 mm	9.4*	4.3	1.3
850 µm[b]	1.2	0.5	0.1
710 µm	1.0	0.3	0.1
300 µm	1.7	0.3	0.1
250 µm	2.6	0.8	0.1
125 µm	1.8	0.3	0.1
63 µm	0.5	0.1	0.1
Bottom Pan	0	0	0
Percent Moisture	0	0	0

[a] millimeter
[b] micron
* some sample loss occurred

TABLE 2-21

TRACE METALS ANALYTICAL RESULTS
IMPINGER REAGENTS AND METHOD 5 FILTERS

Element	Inlet Imp. 1 micg.	Outlet Imp. 2 micg.	Outlet Imp. 2 micg.
Beryllium (Be)	< 1	< 1	< 1
Calcium (Ca)	276	1,144	1,600
Chromium (Cr)	< 20	148	306
Iron (Fe)	23.2	560	1,125
Manganese (Mn)	< 10	< 10	< 10
Nickel (Ni)	< 10	23.4	58.2
Silicon (Si)	156	1,700	2,750
Titanium (Ti)	< 10	< 10	< 10
Vanadium (V)	< 10	< 10	< 10
Zinc (Zn)	< 5	13.0	47.3
Aluminum (Al)	720	< 20	62.0
Magnesium (Mg)	6.0	1,014	14.6
Lead (Pb)	0.72	1.96	2.50
Mercury (Hg)	***	0.35	0.23
Fluorine (F)	< 50	260	473

* Analysis of filters only

*** Not enough sample remaining to complete analysis.

3.0 PROCESS DESCRIPTION

3.1 General

AP Green provides a complete line of refractory products and services. The products include firebrick of all qualities—low, medium, high, and super duty; 50 percent to 99 percent alumina; mullite; silicon carbide; and zircon. AP Green also produces a full line of basic brick including chrome, chrome-magnesite, magnesite-chrome, magnesite, and metal encased. AP Green manufactures insulating firebrick, ceramic fibers, industrial insulations, and all types of mortars, plastics, castables, ramming mixes, gunning materials, and special refractory mixes.

3.2 Calcining Process

3.2.1 Raw Material

Fire clay is a generic commodity term which encompasses many different types of clay (including Missouri flint clays and plastic clays) used in manufacturing refractory products. There are significant variations in the chemical composition, in the contained impurities (e.g., sulfur), and in the particle size characteristics of these different clays. For Missouri flint clays, about 75 percent of the particles are less than 1.0 um and 96 percent are less than 10 um. For Missouri plastic clays, 93 percent of the particles are less than 10 um, and 47 percent are less than 1.0 um. The bulk of the raw material requirements for this plant is provided by mining of Missouri clay deposits. Additional raw materials are shipped from other states or are imported (e.g., calcined bauxite from China). At this plant, about 15 different grades of clay are fed to the dryer, and the rotary kiln system is used to calcine about 35 different clay materials.

3.2.2 Rotary Calciner

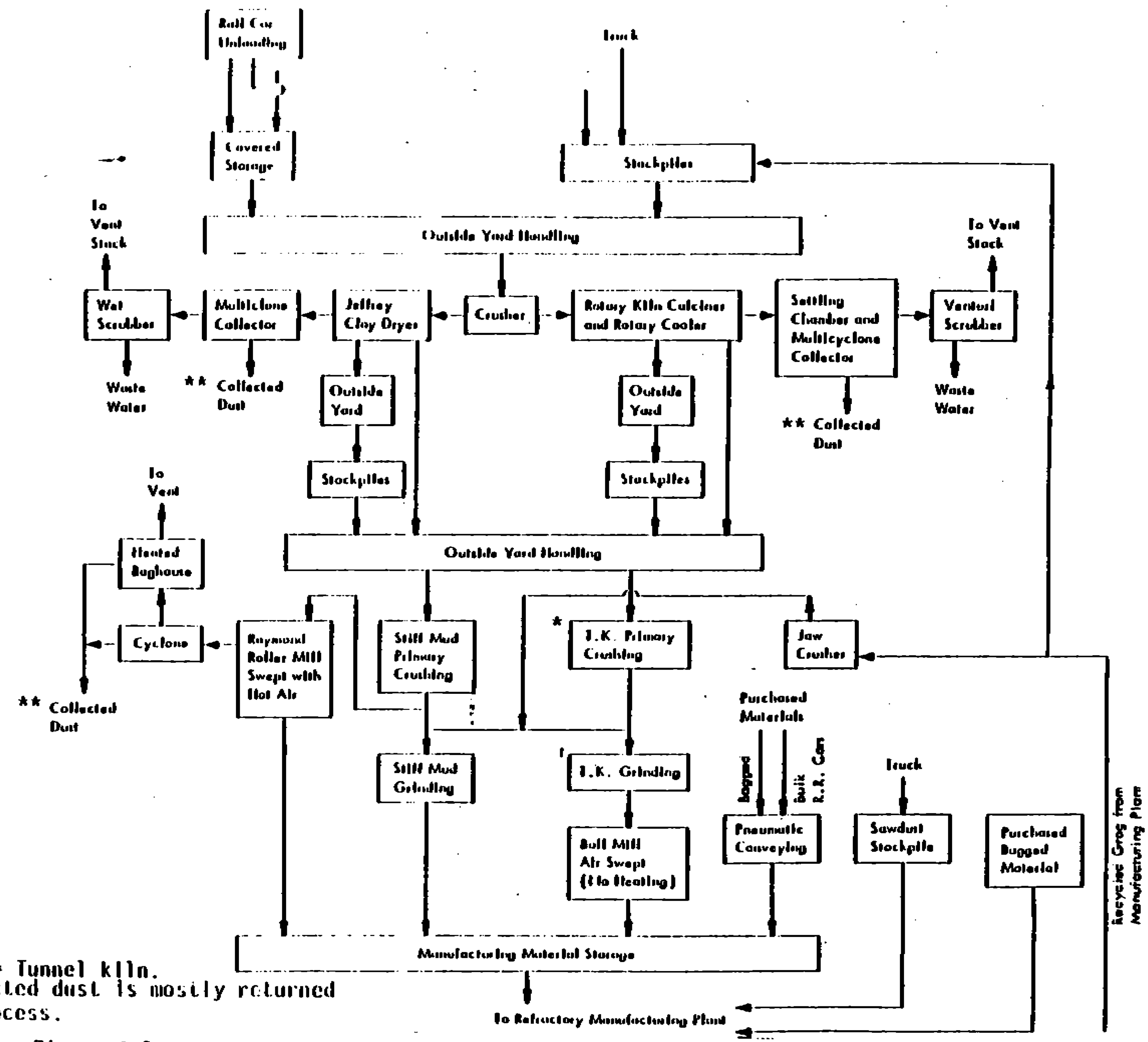
A partial process flow diagram of the AP Green facility is shown in Figure 3-1. The process unit tested is a rotary calciner which was manufactured by Vulcan Iron Works and was installed in 1947. The rotary calciner is operated continuously 24 hours per day, 7 days per week as required to meet product demand. This kiln, which is 2.4m (8 feet) in diameter and 36.6m (120 feet) long, is direct-fired (using natural gas or No. 2 fuel oil) with the combustion gases entering at the discharge end (counterflow).

3.2.3 Calciner Design Capacity

The design production rate and the actual production rate are both 7.2 Mg/h (8 tph). The maximum gas temperature is 1316°C (2400°F), and the retention time is approximately 60 minutes. The fuel-to-product ratio is 4,885 MJ/Mg (4.2 million Btu/ton) of product. The design exhaust gas flow rate is 708 to 991 m^3/min (25,000 to 35,000 ft^3/min) at a temperature of 370° to 430°C (700° to 800°F). Data for the the calciner are shown in Table 3-1.

3.2.4 Calciner Exhaust Gases

The exhaust gas stream from the rotary kiln is passed through a settling chamber, a multiclone collector, and a venturi scrubber to a vent stack. Some of the collected dust is reused in plant processes. Data for the



*T.K. = Tunnel kiln.
**Collected dust is mostly returned to process.

Figure 3-1. Partial flow diagram for fire clay plant of A. P. Green Refractories Company of Mexico, Missouri, (handling and processing of raw materials prior to use in refractory manufacturing plant).

TABLE 3-1. DATA FOR THE CLAY CALCINER AT A. P. GREEN REFRACTORIES COMPANY PLANT AT MEXICO, MISSOURI[a,b]

Type of equipment	Rotary kiln calciner and rotary cooler
Manufacturer	Vulcan Iron Works
Date of installation	1947
Equipment dimensions:	
Inside diameter and length (ft)	8 x 120 (calciner only)
Type of operation	Continuous
Design production rate (tph)	8
Design evaporation rate, lb water/h	N/A[c]
Actual production rate, (tph)	8
Method of determining actual	Scale
Hours of operation, daily average	24
Hours of operation, weekly average	Variable
Retention time (minutes)	60 to 90
Maximum temperature (gas) (°F)	2400
Heat application method	Counterflow
Fuel used	Natural gas or No. 2 fuel oil
Fuel to product ratio (million Btu/ton)	4.2
Exhaust gas flow:	
Design (ft^3/min)	25,000-35,000
Actual (ft^3/min)	N/A
Feed moisture content (%) (Normal)	10-15
Final moisture content (%)	0
Product exit temperature (°F)	900-1000

[a,b]Data Source: Research Triangle Institute plant trip report to EPA dated February 4, 1982. MRI plant trip report to EPA dated October 21, 1983.
[c]N/A = Not available.

emission control equipment are shown in Table 3-2. The venturi scrubber was manufactured by American Air Filter Company (Size 28 Kinpactor). The design gas flow rate is 708 to 991 m^3/min (25,000 to 35,000 acfm). The operating temperature is 49° to 71°C (120° to 160°F). The gas pressure drop across the throat or scrubber body is normally 6 to 6.7 kPa (24 to 27 in. w.c.).

3.2.5 Storage

At the discharge end of the rotary calciner, the hot clay passes over a grizzly to remove small amounts of sinter (large lumps) formed by incipient fusion. These lumps are discharged onto a reject pile. Material passing through the grizzly is fed into a rotary cooler (1.5m [5 ft] diameter by 18.3m [60 ft] long and lined with refractory). Ambient air drawn through the cooler from its discharge end cools the clay and then passes through the rotary calciner. The cooled calcine is discharged from the rotary cooler into a collection pit. From this pit, the calcined clay is retrieved and used in various refractory manufacturing processes.

3.3 Process Conditions During Testing

3.3.1 Monitoring Procedures

All processes were operated normally during the emission testing. The rotary calciner was fired with natural gas and Missouri flint clay was calcined during all three runs. This clay had been selected for calcining because it was considered by plant personnel to be the most difficult to control with respect to particulate emissions. Operation of the rotary

TABLE 3-2. DATA FOR EMISSION CONTROL EQUIPMENT FOR THE CALCINER/COOLER AT A. P. GREEN REFRACTORIES COMPANY AT MEXICO, MISSOURI[a,b]

Types of control devices	Rotary calciner/cooler
Primary/secondary	Settling chamber, multi-cyclone collector/ Venturi scrubber
Data for primary control device (multiclone):	
Manufacturer	Zurn Industries--for multiclone
Height of multiclone collector, ft	15.9
Height of bottom cone, ft	8.9
Inlet dimensions, in.	54 by 120
Outlet dimensions, in.	36 by 120
Gas pressure drop across multiclone, in. w.c.	2.5
Data for secondary control devices:	
Manufacturer	American Air Filter Co.
Model number	Size 28 Kinpactor
Design gas flow rate, acfm	25,000-35,000
Actual gas flow rate, acfm	N/A[c]
Operating temperature, °F	120°-160°
Design inlet concentration, gr/dscf	4.0-14.0
Scrubbing liquid	Water
Scrubbing liquid inlet pressure, psig	70-80
Liquid flow rate, gpm	280-350
Gas pressure drop across throat or scrubber body, in. w.c.	24-27
Gas pressure drop across entire system, in. w.c. (primary plus secondary control)	30-33
Maintenance operations:	
Lubrication for scrubber pumps when operating	Daily
Other maintenance and repairs	Performed as required or during downtimes

[a,b]Data Source: Research Triangle Institute plant trip report to EPA dated February 4, 1982. MRI plant trip report to EPA dated October 21, 1983.
[c]N/A = Not available.

calciner is determined by the type of clay processed and the temperature within the kiln necessary to achieve calcination without fusing the clay into lumps. The amount of clay fed to the calciner by the conveyor belt (which is equipped with a scale) was measured in the control booth by a totalizer. The calcined clay production rate during the three runs ranged from 7.5 Mg/h (8.3 tph) to 8.6 Mg/h (9.5 tph). This production level was slightly greater than the design production rate. However, the quality of the calcined product did not decline at the higher rate, therefore, personnel did not decrease the rate of clay fed to the calciner. The calciner firing temperature was adjusted manually by raising or lowering the fuel gas pressure. The firing temperature during testing ranged from 1191°C (2175°F) to 1282°C (2340°F) with an associated fuel gas pressure of 124 to 131+ kPa (18 to 19+ psi). In addition to those parameters mentioned above, the calciner feed-end temperature, gas temperature at the venturi inlet, demister temperature, and the water flow rate to the venturi were also monitored; the recorded data are shown in Tables 3-3, 3-4, and 3-5.

3.3.2 Production Rates

American Air Filter specifies that, for the venturi scrubber, a 1,060 to 1,325 pm (280 to 350 gpm) water flow rate be maintained for gas flows ranging from 708 to 991 m^3/min (25,000 to 35,000 acfm). These operating conditions produce a design liquid-to-gas ratio of 1.3 to 1.5 /m^3 (10 to 11 gal/1,000 ft^3). During all the tests, the water flow rate remained relatively constant with a range of 791 to 810 lpm (208 to 212 gpm) for a gas flow of 491 m^3/min (17,000 acfm). Thus, the liquid-to-gas ratio during the test is 1.4 l/m^3 (12 gal/1,000 ft^3). The pressure drop across the venturi

TABLE 3-3. OPERATING CONDITIONS--RUN NO. 1--OCTOBER 18, 1983

Time	Calciner firing temp., °F	Calciner feed-end temp., °F	Venturi inlet temp., °F	Demister temp., °F	Water flow rate to venturi, gpm	Firebox gas pressure, psi	Total tons of clay fed to calciner	Rate of clay fed to calciner, tph	Pressure differential across venturi throat, in. w.c.
0800	2175	800	850	118	210	17	02396.35		26.1
0830	2175	820	740	120	210	17	02400.74	8.76	26.1
0900	2175	840	770	120	210	17+	02405.12	8.77	26.2
0930	2175	840	645	120	210	18	02409.50	8.70	26.2
1000	2175	820	740	120	210	18	02413.87	8.75	26.2
1030	2175	840	745	120	210	18	02418.28	8.86	26.2
1100	2175	840	750	120	209	19+	02422.70	8.83	26.2
1130	2175	840	750	120	210	19	02427.14	8.78	26.2
1200	2175	840	750	120	209	19+	02431.57	8.87	26.2
1230	--[a]	820	740	120	209	18+	02435.92	8.67	26.2
1300	--[a]	820	720	120	208	18+	02440.27	8.70	26.2
1330	--[a]	820	740	120	208	19	02444.59	8.85	26.2
1400	--[a]	820	740	120	208	18+	02448.91	8.64	26.2
1430	--[a]	820	740	120	210	19	02453.44	8.84	26.2
1500	2200	820	740	120 ?	210	19	02457.97	9.06	26.3
1530	2200	820	740	120	210	18+	02462.28		26.3
1600	2225	820	720	120	210	19	02466.60	8.63	26.2

[a] Electrical short in gauge.

TABLE 3-4. OPERATING CONDITIONS--RUN NO. 2--OCTOBER 20, 1983

Time	Calciner firing temp., °F	Calciner feed-end temp., °F	Venturi inlet temp., °F	Demister temp., °F	Water flow rate to venturi, gpm	Firebox gas pressure, psi	Total tons of clay fed to calciner	Rate of clay fed to calciner, tph	Pressure differential across venturi throat, in. w.c.
0700	--[b]						02807.00		
0800	2250	820	--[a]	110	210	18	02815.73	8.60	26.1
0830	--[b]					18	02820.12	8.81	26.1
0900	2250	820	--[a]	110	210	18+	02824.52	8.79	26.1
0930	2250	820	--[a]	112	210	19	02828.93	8.82	26.1
1000	2250	820	--[a]	112	210	19	02833.34	8.82	26.1
1030	2250	820	--[a]	114	210	18+	02837.75	8.83	26.0
1100	2250	820	--[a]	114	210	19	02842.16	8.82	26.0
1130	2250	820	--[a]	112	210	18+	02846.58	8.84	26.1
1200	2250	820	--[a]	112	210	19	02851.00	8.84	26.1
1230	2300	820	710	114	210	18+	02855.42	8.84	26.1
1300	2300	820	710	114	210	18+	02859.84	8.84	26.1
1330	2325	820	710	114	210	18+	02864.26	8.90	26.1
1400	2325	820	710	114	210	18+	02868.67	8.83	26.1
1430	2325	820	710	114	210	18+	02873.16	8.71	26.1
1500	2325	820	710	114	210	19	02877.64	8.97	26.1
1530	2325	820	710	114	210	18+	02881.07		26.1
1600	--					18+	02886.50	8.46	26.1

[a]Electrical short in gauge.
[b]No reading taken.

TABLE 3-5. OPERATING CONDITIONS--RUN NO. 3--OCTOBER 21, 1983

Time	Calciner firing temp., °F	Calciner feed-end temp., °F	Venturi inlet temp., °F	Demister temp., °F	Water flow rate to venturi, gpm	Firebox gas pressure, psi	Total tons of clay fed to calciner	Rate of clay fed to calciner, tph	Pressure differential across venturi throat, in. w.c.
0700							03019.20		
0800	2325	840	740	115	221	19+	03028.74	9.54	26.1
0830	2325	840	730	112	215	19+	03032.88	8.68	26.0
0900	2325	840	740	112	209	19+	03037.03	8.29	26.0
0930	2325	840	737	112	200	19+	03041.56	8.86	26.0
1000	2325	840	740	110	212	19+	03046.08	9.05	26.0
1030	2325	840	740	112	211	19+	03050.42	8.72	26.0
1100	2325	840	740	110	212	19+	03054.76	8.68	26.0
1130	2325	840	730	110	212	19	03059.14	8.81	26.0
1200	2340	840	740	110	214	18	03063.53	8.77	26.0
1230	2340	840	735	110	214	18+	03067.95	8.83	26.0
1300	2325	840	730	110	214	18	03072.37	8.84	26.0
1330	2325	840	725	110	214	18	03076.78	--	26.0
1400	2325	840	720	110	214	18	03081.19	8.82	26.0
1430	2325	840	730	110	214	18			26.0

also remained constant with an average value of 6.5 kPa (26 in. w.c.). Due to the consistency of the parameters monitored, for both process and control equipment, during testing it is believed the process was operating normally.

Both fugitive and visible emission observations were made during testing by the EMB contractor. During testing there were no observations greater than 0 percent.

4.0 SCOPE OF THE SAMPLING PROGRAM BY SITE

The primary objectives of this emission measurement program was to obtain the following data from the inlet and outlet sampling locations of the rotary calciner/cooler pollution control devices:

1. Particulate matter concentrations
2. Particulate matter mass emission rates
3. Particle size distributions of the particulate matter

In addition, visible emissions observations were made at the exhaust stack and fugitive emissions observations were performed at the inlet transfer point of the rotary calciner. Grab samples of the raw material and product were collected for sieve analysis and moisture content.

An overhead view of the process is shown in Figure 4-1.

4.1 Multiclone Inlet - Particulate Matter Tests

Sampling was performed in the 34-inch by 57-inch rectangular horizontal duct which connects the settling chamber to the multiclone. Seven sampling ports were located 22 inches (0.4 equivalent duct diameters) upstream from the settling chamber exhaust and 11 inches (0.2 equivalent duct diameters) downstream from a 90^{o} bend into the multiclone. The inlet location is shown schematically in Figure 4-2. According to EPA Method 1 a total of 49 sampling points were used (7 sampling points per traverse). For Tests 2, 3, and 4 twenty-eight sampling points were used (see Section 2.1).

4.2 Multiclone Inlet - Particle Sizing Tests

The particle sizing tests were performed at the same location as the particulate tests. Presently there are seven sampling ports, two were

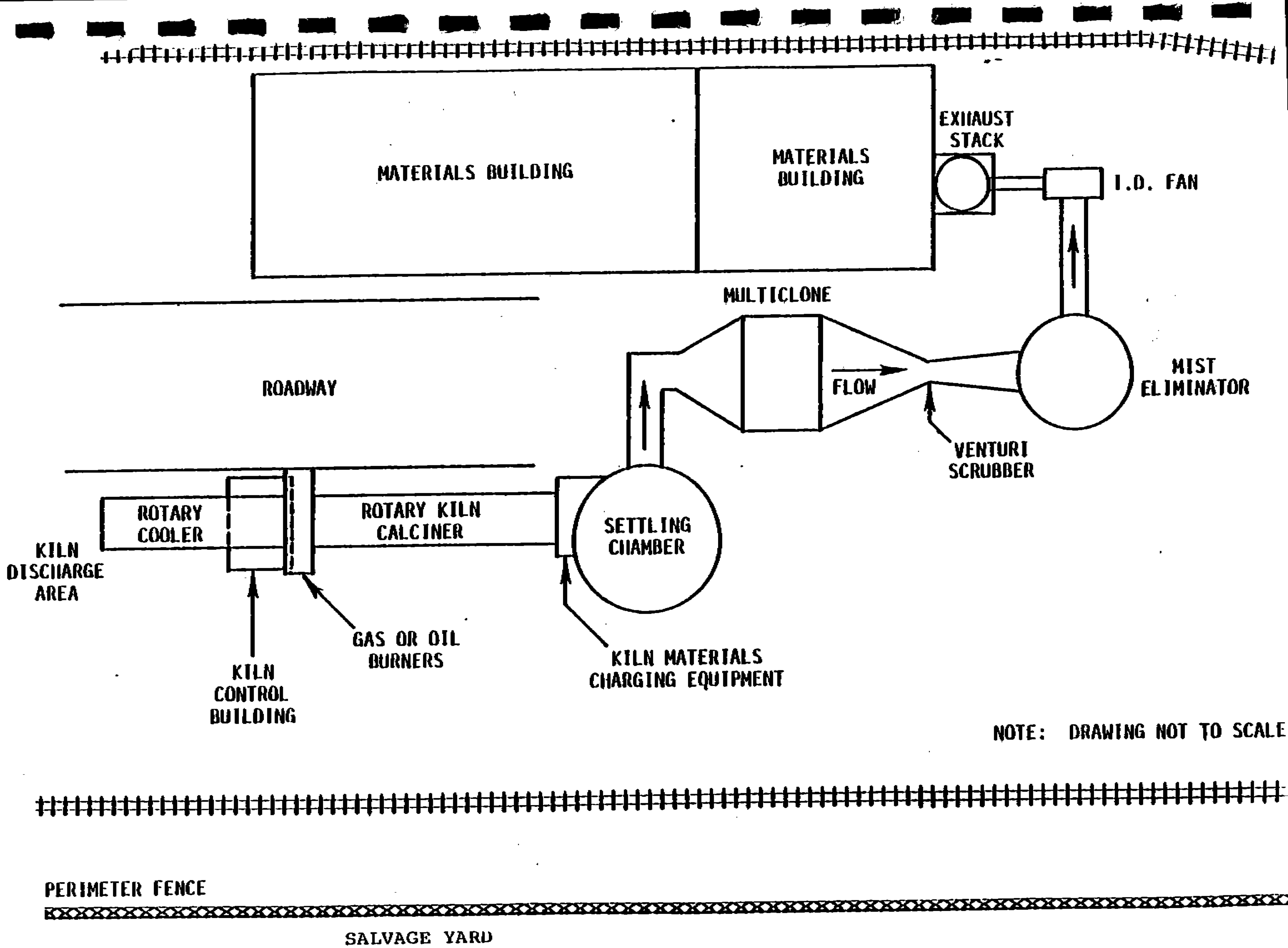


Figure 4-1
Overhead View-Rotary Kiln/Cooler
AP Green Refractories
[illegible]

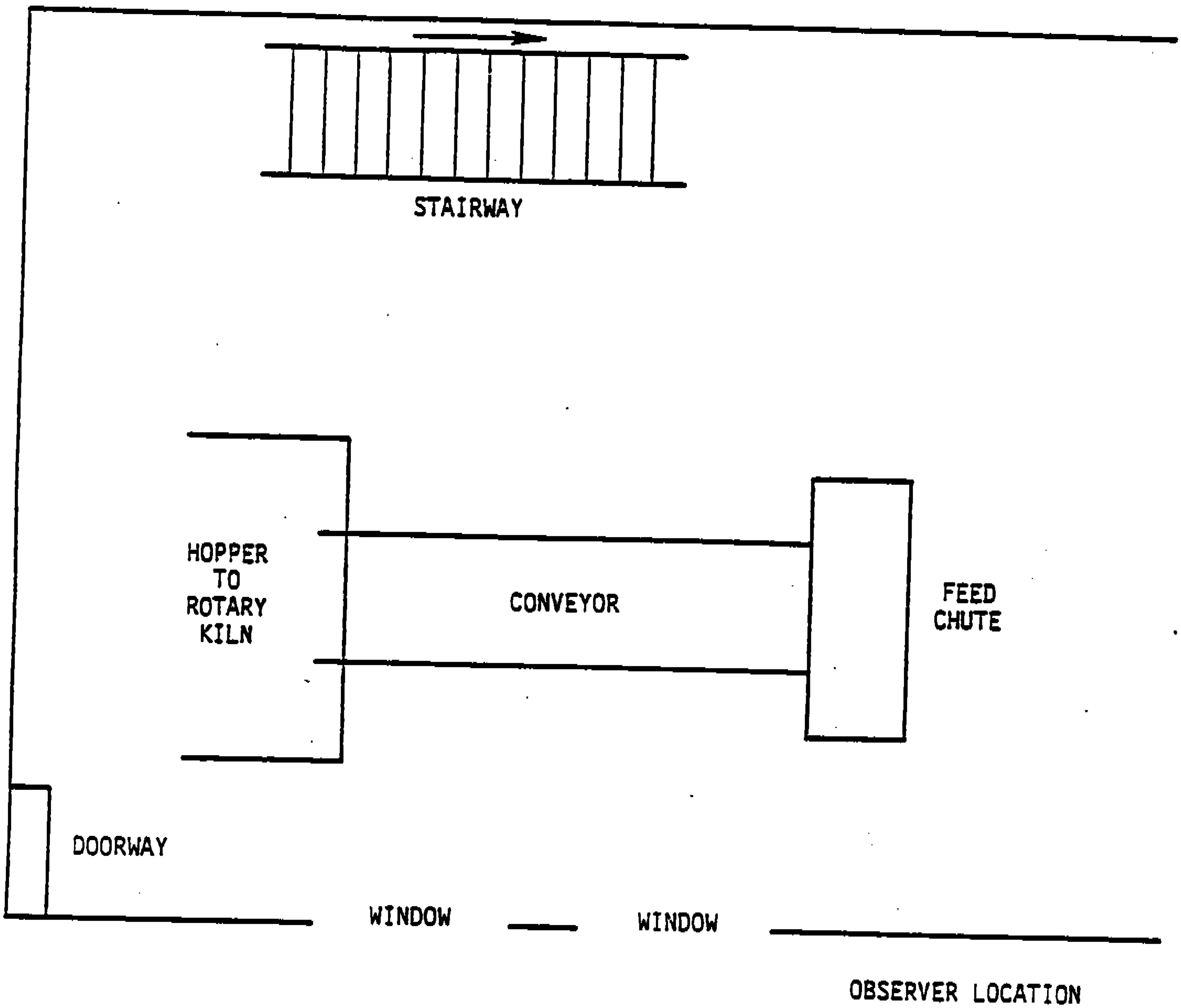


Figure 4-8
Overhead View-Indoor
Inlet Raw Material Transfer Point
Fugitive Emissions Inspection
AP Green Refractories
Mexico, Missouri

5.0 SAMPLING AND ANALYTICAL METHODS

This section presents descriptions of the sampling and analysis procedures used during the sampling program performed at AP Green Refractories Company Rotary Calciner/Cooler, in Mexico, Missouri during the week of October 17-21, 1983.

This sampling program required that both the inlet and outlet sampling locations be run simultaneously during the particulate matter and particle size tests (four sampling trains running simultaneously).

Andersen right-angle inlet pre-separators and Mark III cascade impactors were used in general accordance with manufacturer recommended operating procedures and the draft IERL guidelines.

5.1 Preliminary Measurements

Prior to the start of the sampling program preliminary measurements, of various sampling parameters, were made at both the inlet and outlet sampling locations. This preliminary work was performed by a three-member crew one day before the start of the sampling program. Parameters monitored were as follows:

1. Full velocity and temperature traverse
2. Moisture content
3. CO_2 and O_2 concentration
4. Particulate loadings

The preliminary data provided information for setting up the sampling nomograph and chosing the proper nozzle size to ensure that the flowrate through the impactor would be less than 0.75 actual cubic feet per minute (acfm). The particulate loadings were determined by using EPA Method 17.

The brushings and loose particulate from the nozzle, pre-separator, interconnecting coupling, and impactor inlet throat was deposited into a tared aluminum foil square which was placed in a petri dish for handling and desiccation.

A Staticmaster® non-static brush and small camel hair artist's brushes were used for the recovery of any loose particulate.

Individual collection substrates were recovered using tweezers only. Any loose particulate on the collection substrate support plate, associated cross-bar and gasket, and the bottom of the preceding support plate was placed into tared aluminum foil squares along with the collection substrate.

5.4.2 Sample Drying and Weighing

Desiccation and weighing of the collected samples was performed near the site in an air-conditioned motel room. The motel room made for a practical weighing area. A relatively low and constant humidity could be easily maintained and traffic into and out of the room was easily controlled and kept to a minimum.

A Mettler Model H18 analytical balance capable of weighing to the nearest 0.1 milligram (mg) was used. All substrates, aluminum foil squares, and pre-separator sample weighing pans were desiccated and weighed to a constant weight at the weighing area. Substrates were weighed in sets and uniquely identified.

The recovered samples were placed in a tightly sealed desiccator where they remained for at least 12 hours. After desiccation, the recovered samples were weighed. Tared aluminum foil squares and the pre-separator sample weighing pans were handled only with tweezers. Only one post-test weighing was performed. Reported final weights were not checked to a constant final weight. The substrates and loose particulate matter was placed back into their respective petri dishes after weighing. The petri dishes were sealed with Parafilm® for transporting and storage. Appendix D contains the filter weight data performed in the field.

5.4.3 Data Reduction

Data reduction was performed back at TRC using the Particle Data Reduction System (PADRE). The PADRE user's guide accompanies this report in Appendix J.

Final data reduction and analysis was performed return from the field. Appendix B contains the PADRE data summaries used for each test.

5.5 Plume Opacity - Venturi Scrubber Outlet

A certified observer monitored the stack plume opacity in accordance with EPA Reference Method No. 9. Visible emissions observations were made during the first two particulate tests. Due to adverse weather conditions VE observations could not be made during the third test. Field data sheets are presented in Appendix C.

5.6 Fugitive Emisions - Rotary Calciner Inlet

Fugitive emissions observations were made during the first two particulate test at the rotary calciner inlet transfer point. Again due to the high amount of rainfall observations were not made, on the saturated clay, during the third test. Observations conformed to the guidelines as specified in EPA Method 22. Field data sheets are presented in Appendix C.

5.7 Feed and Product Material - Grab Samples

A composite sample of approximately 8 pounds was collected at the inlet to the rotary calciner and outlet from the rotary cooler during the course of each particulate matter/particle size test. The samples were stored and shipped in watertight containers.

Back at the TRC laboratory each sample was analyzed for moisture content and sieve analysis according to ANSI/ASTM C 92-76: Standard Test Methods For Sieve Analysis And Water Content Of Refractory Materials. A copy of the method and laboratory data is included in Appendix F.

6.0 QUALITY ASSURANCE

6.1 Introduction

TRC's emission measurement quality assurance program is designed to ensure that sampling and analysis work is performed by qualified people using the proper equipment in accordance with written procedures in order to provide accurate and representative emission data. The program is based upon EPA's Quality Assurance Handbook for Air Pollution Measurement Systems, Volume III (EPA-600/4-7-027b). Additionally, quality assurance procedures recommended in the draft IERL guidelines for particle size distribution measurements were incorporated in this program.

6.2 Sampling Train Components

TRC's sampling equipment, including nozzles, pitot tubes, dry gas meters, orifices, and thermocouples, were uniquely identified and calibrated in accordance with documented procedures and acceptance criteria prior to and after the field test program. Calibration data for the sampling equipment are contained in Appendix E.

6.3 Pre-Separators and Cascade Impactors - Particle Size Tests

All nozzles, pre-separators, interconnecting couplings, impactor bodies, plates, gaskets, and cross-bars were cleaned in an ultrasonic bath and then visually checked for cleanliness prior to shipment to the field. Additionally, ten randomly selected holes on each plate were measured to the nearest 0.0001 inch diameter for comparison with design specifications. The acceptance criteria was that the average measured hole diameter had to be within 0.001 inch of the design specifications. The Andersen hole diameter specifications were as follows:

Plate	Hole Diameter - inches
0	0.0636
1	0.0465
2	0.0360
3	0.0280
4	0.0210
5	0.0136
6	0.0100
7	0.0100

Hole diameter inspection data are contained in Appendix E.

Prior to shipment to the field, and prior to and after each test, each component was sealed with Parafilm® to prevent contamination and sample loss. After each sample recovery the pre-separator, impactor body, and plates were brushed and visually inspected for cleanliness.

6.4 Sample Collection Substrates - Particle Size Tests

Reeve Angel 934AH glass fiber sample collection substrates were used. TRC did not perform the acid wash preconditioning procedure described in the draft IERL guidelines. The substrates were supplied by Andersen, who assured TRC that the substrates would not require preconditioning.

During impactor assembly, sample recovery, and weighing, the substrates were handled with laboratory tweezers. Finger contact with the substrates was kept to an absolute minimum.

6.5 Substrate Weighing - Particle Size Tests

A Mettler H18 analytical balance capable of weighing to the nearest 0.1 milligram (mg) was used. Before shipment to the field, the balance was inspected by a Mettler representative.

Each morning, while in the field, the balance was checked using Class S weights traceable through the State of Connecticut quality control standard to the National Bureau of Standards (NBS). Three weights - 0.100 gram, 1.000 gram, and 10.00 grams - were used along with a zero check. The balance zero was also checked after every fifth substrate weighing to ensure representative measurements. Daily balance quality assurance data are presented in Appendix D.

6.6 Blank Sample - Particle Size Test

A blank control sample was run to determine if any collection substrate or pre-separator sample weight change occurred as a consequence of impactor preparation, transportation, sample recovery, or weighing operations.

For the blank run, a pre-separator/impactor assembly was prepared in an identical manner to those used for the actual particle size distribution measurement runs. The assembly was transported to the sample site (inlet) where it remained until the completion of the normal particle size test. The assembly was then transported back to the motel room were it was then subjected to the normal sample recovery procedures. Collection substrate and pre-separator recovery weighings indicated no weight gain. Therefore, no sample weight bias was introduced by the preparation, transportation, recovery, or weighing procedures. Further documentation can be found in Appendix G.

6.7 Sample Recovery

All sample recoveries were performed by one member of the field crew whose sole task was sample recovery. Sample recovery was performed in a motel room especially set up for filter recovery.

6.8 EPA Method 3

All Method 3 analyses were performed in triplicate, with three passes being performed through each absorbing bubbler to ensure complete absorption. Each analyzer was leak-checked according to the method prior to any analysis. Samples were analyzed immediately upon completion of the sampling.

APPENDIX A

PARTICULATE DATA SUMMARIES

Includes:

A.1 Multiclone Inlet
A.2 Venturi Scrubber Outlet

APPENDIX A.1

Multiclone Inlet

PARTICULATE TEST DATA

TEST	1	TIME	10:53-15:28
LOCATION	INLET	DATE	18 Oct 83
FIRM	A P GREEN REFRACTORIES	PROJECT NO.	2177-E84

Input A

P bar	Barometric Pressure - in. Hg	29.42
As	Stack Area - Ft^2	13.5
Dn	Nozzle Diameter - in.	0.191
Time	Total Sampling Time - min.	98
Y	Calibration Factor	1.01
Cp	Pitot Coefficient	0.84
$(\Delta P)^{1/2}$	Average Square Root of Velocity Head (in. H_2O)	0.5377
ΔH	Average Orifice Pressure Drop - in. H_2O	0.157
Tm	Average Meter Temperature °F	58
Pstk	Average Stack Pressure - in. H_2O	-0.69
Tstk	Average Stack Temperature °F	853
Vm	Meter Volume at Meter Conditions - Ft^3	21.80
Vl	Total Water Vapor Collected - ml	106.4
CO_2	% CO_2 in Stack Gas (Dry)	5.8
O_2	% O_2 in Stack Gas (Dry)	11.2
CO	% CO in Stack Gas (Dry)	0

Input B

Mn	Total Particulate Catch - Mg	11269.44

Input C'

	F-factor - DSCF/MMBTU	

Input C

% H	% Hydrogen in Fuel	
% C	% Carbon in Fuel	
% S	% Sulfur in Fuel	
% N	% Nitrogen in Fuel	
% O	% Oxygen in Fuel	
GCV	Gross Califoric Volume of Fuel - BTU/lb	

Calculated

Vm (std)	Meter Volume at Standard Conditions (Dry)-Ft^3	22.08
% H_2O	% H_2O Vapor in Stack Gas	18.5
Mws	Molecular Weight of Stack Gas (Wet)	27.27
Vs	Average Velocity of Stack Gas - FPM	3000
Qs	Actual Stack Gas Flowrate - ACFM	40000
Qs (std)	Stack Gas Flowrate (0.0% H_2O; STP) - DSCFM	17700
% I	% Isokinetic (Avg. Nozzle Vel/Avg. Stk Vel)	118.7
Cs	Particulate Concentration-lb/DSCF	1.125×10^{-3}, 7.875 gr/DSCF
Er	Particulate Emission Rate-lb/hour	869.7
F	F Factor - DSCF/MM BTU	
E	Particulate Emissions - lbs/MM BTU	

Rev. 2 6/17/81

PARTICULATE TEST DATA

TEST 2 TIME 10:25 - 14:15

LOCATION INLET DATE 20 OCT 83

FIRM AP GREEN REFRACTORIES PROJECT NO. 2177 - E84

Input A

P bar	Barometric Pressure - in. Hg	29.32
As	Stack Area - Ft^2	13.5
Dn	Nozzle Diameter - in.	0.260
Time	Total Sampling Time - min.	112
Y	Calibration Factor	1.01
Cp	Pitot Coefficient	0.84
$(\Delta P)^{1/2}$	Average Square Root of Velocity Head (in. H_2O)	0.5464
ΔH	Average Orifice Pressure Drop - in. H_2O	0.435
Tm	Average Meter Temperature °F	52
Pstk	Average Stack Pressure - in. H_2O	-0.60
Tstk	Average Stack Temperature °F	842
Vm	Meter Volume at Meter Conditions - Ft^3	40.69
Vl	Total Water Vapor Collected - ml	236.0
CO_2	% CO_2 in Stack Gas (Dry)	5.5
O_2	% O_2 in Stack Gas (Dry)	11.3
CO	% CO in Stack Gas (Dry)	0

Input B

Mn	Total Particulate Catch - Mg	23280.88

Input C'

	F-Factor - DSCF/MMBTU	

Input C

% H	% Hydrogen in Fuel	
% C	% Carbon in Fuel	
% S	% Sulfur in Fuel	
% N	% Nitrogen in Fuel	
% O	% Oxygen in Fuel	
GCV	Gross Califoric Volume of Fuel - BTU/lb	

Calculated

Vm (std)	Meter Volume at Standard Conditions (Dry)-Ft^3	41.58
% H_2O	% H_2O Vapor in Stack Gas	21.1
Mwg	Molecular Weight of Stack Gas (Wet)	26.94
Vs	Average Velocity of Stack Gas - FPM	3000
Qs	Actual Stack Gas Flowrate - ACFM	41000
Qs (std)	Stack Gas Flowrate (0.0% H_2O; STP) - DSCFM	13000
% I	% Isokinetic (Avg. Nozzle Vel/Avg. Stk Vel)	106.4
Cs	Particulate Concentration-lb/DSCF	1.50×10^{-3}
Er	Particulate Emission Rate-lb/hour	1150.2
F	F Factor - DSCF/MM BTU	
E	Particulate Emissions - lbs/MM BTU	

PARTICULATE TEST DATA

TEST 3 TIME 0915 - 1120

LOCATION Multiclone Inlet DATE 10/21/83

FIRM AP Green PROJECT NO. 2177-E34

Input A

P bar	Barometric Pressure - in. Hg	29.18
As	Stack Area - Ft^2	13.5
Dn	Nozzle Diameter - in.	0.260
Time	Total Sampling Time - min.	112
Y	Calibration Factor	1.01
Cp	Pitot Coefficient	0.84
$(\Delta P)^{1/2}$	Average Square Root of Velocity Head (in. H_2O)	0.5423
ΔH	Average Orifice Pressure Drop - in. H_2O	0.429
Tm	Average Meter Temperature °F	50
Pstk	Average Stack Pressure - in. H_2O	-0.65
Tstk	Average Stack Temperature °F	851
Vm	Meter Volume at Meter Conditions - Ft^3	39.99
Vl	Total Water Vapor Collected - ml	242.1
CO_2	% CO_2 in Stack Gas (Dry)	6.0
O_2	% O_2 in Stack Gas (Dry)	10.4
CO	% CO in Stack Gas (Dry)	0

Input B

Mn	Total Particulate Catch - Mg	23800.54

Input C' F-factor - DSCF/MMBTU

Input C

% H	% Hydrogen in Fuel	
% C	% Carbon in Fuel	
% S	% Sulfur in Fuel	
% N	% Nitrogen in Fuel	
% O	% Oxygen in Fuel	
GCV	Gross Califoric Volume of Fuel - BTU/lb	

Calculated

Vm (std)	Meter Volume at Standard Conditions (Dry)-Ft^3	40.83
% H_2O	% H_2O Vapor in Stack Gas	21.8
Mws	Molecular Weight of Stack Gas (Wet)	26.89
Vs	Average Velocity of Stack Gas - FPM	2000
Qs	Actual Stack Gas Flowrate - ACFM	41,000
Qs (std)	Stack Gas Flowrate (0.0% H_2O; STP) - DSCFM	13000
% I	% Isokinetic (Avg. Nozzle Vel/Avg. Stk Vel)	106.8
Cs	Particulate Concentration-lb/DSCF	1.29×10^{-3}
Er	Particulate Emission Rate-lb/hour	964.4
F	F Factor - DSCF/MM BTU	
E	Particulate Emissions - lbs/MM BTU	

Rev. 2 6/17/81

PARTICULATE TEST DATA

TEST: 4 — TIME: 1205 - 1426

LOCATION: Multiclone Inlet — DATE: 10/21/83

FIRM: AP Green — PROJECT NO.: 2177-E84

Input A

P bar	Barometric Pressure - in. Hg	29.16
As	Stack Area - Ft^2	13.5
Dn	Nozzle Diameter - in.	0.260
Time	Total Sampling Time - min.	112
Y	Calibration Factor	1.00
Cp	Pitot Coefficient	0.84
$(\Delta P)^{1/2}$	Average Square Root of Velocity Head (in. H_2O)	0.5608
ΔH	Average Orifice Pressure Drop - in. H_2O	0.457
Tm	Average Meter Temperature °F	54
Pstk	Average Stack Pressure - in. H_2O	-0.65
Tstk	Average Stack Temperature °F	837
Vm	Meter Volume at Meter Conditions - Ft^3	40.94
Vl	Total Water Vapor Collected - ml	226.2
CO_2	% CO_2 in Stack Gas (Dry)	5.2
O_2	% O_2 in Stack Gas (Dry)	11.5
CO	% CO in Stack Gas (Dry)	0

Input B

Mn	Total Particulate Catch - Mg	20584.52

Input C'

	F-factor - DSCF/MMBTU	

Input C

% H	% Hydrogen in Fuel	
% C	% Carbon in Fuel	
% S	% Sulfur in Fuel	
% N	% Nitrogen in Fuel	
% O	% Oxygen in Fuel	
GCV	Gross Califeric Volume of Fuel - BTU/lb	

Calculated

Vm (std)	Meter Volume at Standard Conditions (Dry)-Ft^3	41.04
% H_2O	% H_2O Vapor in Stack Gas	20.6
Mws	Molecular Weight of Stack Gas (Wet)	26.96
Vs	Average Velocity of Stack Gas - FPM	3130
Qs	Actual Stack Gas Flowrate - ACFM	42300
Qs (std)	Stack Gas Flowrate (0.0% H_2O; STP) - DSCFM	13000
% I	% Isokinetic (Avg. Nozzle Vel/Avg. Stk Vel)	121.3
Cs	Particulate Concentration-lb/DSCF	1.11×10^{-3}
Er	Particulate Emission Rate-lb/hour	874.8
F	F Factor - DSCF/MM BTU	
E	Particulate Emissions - lbs/MM BTU	

Rev. 2 6/17/81

APPENDIX A.2

Venturi Scrubber Outlet

PARTICULATE TEST DATA

TEST 1 TIME 10:48 – 15:14

LOCATION OUTLET DATE 18 OCT 83

FIRM A P GREEN REFRACTORIES PROJECT NO. 2177 – E84

Input A		
P bar	Barometric Pressure - in. Hg	29.42
As	Stack Area - Ft²	7.9
Dn	Nozzle Diameter - in.	0.255
Time	Total Sampling Time - min.	192
Y	Calibration Factor	1.00
Cp	Pitot Coefficient	0.84
(ΔP) 1/2	Average Square Root of Velocity Head (in. H_2O)	0.5836
ΔH	Average Orifice Pressure Drop - in. H_2O	1.08
Tm	Average Meter Temperature °F	62
Pstk	Average Stack Pressure - in. H_2O	-0.17
Tstk	Average Stack Temperature °F	143
Vm	Meter Volume at Meter Conditions - Ft³	110.62
Vl	Total Water Vapor Collected - ml	594.7
CO_2	% CO_2 in Stack Gas (Dry)	4.8
O_2	% O_2 in Stack Gas (Dry)	12.2
CO	% CO in Stack Gas (Dry)	0
Input B		
Mn	Total Particulate Catch - Mg	86.18
Input C'	F-Factor - DSCF/MMBTU	
Input C		
% H	% Hydrogen in Fuel	
% C	% Carbon in Fuel	
% S	% Sulfur in Fuel	
% N	% Nitrogen in Fuel	
% O	% Oxygen in Fuel	
GCV	Gross Califoric Volume of Fuel - BTU/lb	
Calculated		
Vm (std)	Meter Volume at Standard Conditions (Dry)-Ft³	110.34
% H_2O	% H_2O Vapor in Stack Gas	20.2
Mws	Molecular Weight of Stack Gas (Wet)	26.98
Vs	Average Velocity of Stack Gas - FPM	26.98
Qs	Actual Stack Gas Flowrate - ACFM	2200
Qs (std)	Stack Gas Flowrate (0.0% H_2O; STP) - DSCFM	17000
% I	% Isokinetic (Avg. Nozzle Vel/Avg. Stk Vel)	12000
Cs	Particulate Concentration-lb/DSCF	107.7
Er	Particulate Emission Rate-lb/hour	1.72×10^{-6}
F	F Factor - DSCF/MM BTU	1.23
E	Particulate Emissions - lbs/MM BTU	

Rev. 2 6/17/81

PARTICULATE TEST DATA

TEST 2 TIME 09:55 - 14:50

LOCATION OUTLET - Venturi DATE 20 Oct 83

FIRM A P Green Refractories PROJECT NO. 2177 - E84

Input A

P bar	Barometric Pressure - in. Hg	29.23
As	Stack Area - Ft^2	7.9
Dn	Nozzle Diameter - in.	0.255
Time	Total Sampling Time - min.	192
Y	Calibration Factor	1.00
Cp	Pitot Coefficient	0.84
$(\Delta P)^{1/2}$	Average Square Root of Velocity Head (in. H_2O)	0.5774
ΔH	Average Orifice Pressure Drop - in. H_2O	0.971
Tm	Average Meter Temperature °F	61
Pstk	Average Stack Pressure - in. H_2O	-0.19
Tstk	Average Stack Temperature °F	144
Vm	Meter Volume at Meter Conditions - Ft^3	105.30
Vl	Total Water Vapor Collected - ml	535.80
CO_2	% CO_2 in Stack Gas (Dry)	4.4
O_2	% O_2 in Stack Gas (Dry)	13.0
CO	% CO in Stack Gas (Dry)	0

Input B

Mn	Total Particulate Catch - Mg	37.84

Input C' F-factor - DSCF/MMBTU

Input C

% H	% Hydrogen in Fuel	
% C	% Carbon in Fuel	
% S	% Sulfur in Fuel	
% N	% Nitrogen in Fuel	
% O	% Oxygen in Fuel	
GCV	Gross Califoric Volume of Fuel - BTU/lb	

Calculated

Vm (std)	Meter Volume at Standard Conditions (Dry)-Ft^3	104.53
% H_2O	% H_2O Vapor in Stack Gas	19.4
Mws	Molecular Weight of Stack Gas (Wet)	27.04
Vs	Average Velocity of Stack Gas - FPM	2200
Qs	Actual Stack Gas Flowrate - ACFM	17000
Qs (std)	Stack Gas Flowrate (0.0% H_2O; STP) - DSCFM	12000
% I	% Isokinetic (Avg. Nozzle Vel/Avg. Stk Vel)	102.3
Cs	Particulate Concentration-lb/DSCF	7.98×10^{-7}
Er	Particulate Emission Rate-lb/hour	0.567
F	F Factor - DSCF/MM BTU	
E	Particulate Emissions - lbs/MM BTU	

PARTICULATE TEST DATA

TEST 3 — TIME 0908 - 1236

LOCATION Venturi Outlet — DATE 10/21/83

FIRM AP Green — PROJECT NO. 2177-E84

Input A

P bar	Barometric Pressure - in. Hg	29.12
As	Stack Area - Ft^2	7.9
Dn	Nozzle Diameter - in.	0.255
Time	Total Sampling Time - min.	204
Y	Calibration Factor	1.00
Cp	Pitot Coefficient	0.84
$(\Delta P)^{1/2}$	Average Square Root of Velocity Head (in. H_2O)	0.6128
ΔH	Average Orifice Pressure Drop - in. H_2O	1.068
Tm	Average Meter Temperature °F	60
Pstk	Average Stack Pressure - in. H_2O	-0.22
Tstk	Average Stack Temperature °F	145
Vm	Meter Volume at Meter Conditions - Ft^3	117.47
Vl	Total Water Vapor Collected - ml	608.4
CO_2	% CO_2 in Stack Gas (Dry)	4.6
O_2	% O_2 in Stack Gas (Dry)	12.7
CO	% CO in Stack Gas (Dry)	0

Input B

Mn	Total Particulate Catch - Mg	40.53

Input C'

	F-factor - DSCF/MMBTU	

Input C

% H	% Hydrogen in Fuel	
% C	% Carbon in Fuel	
% S	% Sulfur in Fuel	
% N	% Nitrogen in Fuel	
% O	% Oxygen in Fuel	
GCV	Gross Califoric Volume of Fuel - BTU/lb	

Calculated

Vm (std)	Meter Volume at Standard Conditions (Dry)-Ft^3	116.42
% H_2O	% H_2O Vapor in Stack Gas	19.8
Mws	Molecular Weight of Stack Gas (Wet)	27.0
Vs	Average Velocity of Stack Gas - FPM	2300
Qs	Actual Stack Gas Flowrate - ACFM	12000
Qs (std)	Stack Gas Flowrate (0.0% H_2O; STP) - DSCFM	12000
% I	% Isokinetic (Avg. Nozzle Vel/Avg. Stk Vel)	100.1
Cs	Particulate Concentration-lb/DSCF	7.68×10^{-7}
Er	Particulate Emission Rate-lb/hour	0.574
F	F Factor - DSCF/MM BTU	
E	Particulate Emissions - lbs/MM BTU	

Rev. 2 6/17/81

Test #1 - Outlet Particulate Test

EMISSION CALCULATION SYMBOLS

La - Allowable leak rate, cfm

Vm_{total} - Total meter sample volume, ft^3

T_{total} - Total sampling time, min

L_p - Final leak rate of sampling train, cfm

Vmc_{total} - Total volume sampled corrected for excessive leakage, ft^3

Y - Dry gas meter calibration factor, dimensionless

T_{std} - Standard temperature, ^oF

$Tm_{avg.}$ - Average dry gas meter temperature, ^oF

P_{bar} - Barometric pressure, "Hg

$\Delta H_{avg.}$ - Average orifice pressure drop, "H_2O

P_{std} - Standard pressure, "Hg

V_I - Volume of liquid collected in impingers, ml

V_{SG} - Volume of liquid collected in silica gel, grams

M_s - Molecular weight of stack gas, lb/lb-mole

$\%CO_2$ - Percent CO_2 by volume (dry basis), %

%CO - Percent CO by volume (dry basis), %

$\%N_2$ - Percent N_2 by volume (dry basis), %

$\%O_2$ - Percent O_2 by volume (dry basis), %

D_{st} - Average duct gas density, lbs/ft^3

Ps_{avg} - Average duct static pressure, "H_2O

Ts_{avg} - Average duct temperature, ^oF

EA - Excess air, %

V_s - Average duct velocity, ft/min

C_p - Pitot tube coefficient, dimensionless

$(\sqrt{\Delta P})avg$ - Average square root of velocity head, $\sqrt{"H_2O}$

A_s - Cross-sectional area of duct, ft^2

Q - Duct volumetric flow rate, acfm

Q_{std} - Duct volumetric flow rate, corrected to dry standard conditions, dscfm

D_n - Nozzle diameter, inches

F - F factor, DSCF/MM BTU

%H - Percent by weight of hydrogen in fuel

%C - Percent by weight of carbon in fuel

%S - Percent by weight of sulfur in fuel

%N - Percent by weight of nitrogen in fuel

%O - Percent by weight of oxygen in fuel

GCV - Gross calorific value of fuel, BTU/lb.

C - Actual particulate concentration, grains/acf

C_s - Particulate concentration, grains/dscf

ER - Particulate emission rate, lbs/hr

E - Particulate emissions, lbs/MM BTU

C_s @ 12% CO_2 - Particulate concentration, grains/dscf @ 12% CO_2

C_s @ 50% EA - Particulate concentration, grains/dscf @ 50% EA

C_{Lb} - Particulate concentration, lbs/1000 duct gas

C_{Lb} @ 12% CO_2 - Particulate concentration, lbs/1000 lbs @ 12% CO_2

C_{Lb} @ 50% EA - Particulate concentration, lbs/1000 lbs @ 50% EA

M_n - Total particulate collected, mg

Test # 1 - Outlet Particulate Test

1. Allowable Leak Rate

$$La = 0.02 \text{ cfm or } 0.04 \frac{V_m \text{ total}}{T \text{ total}} \quad \text{which ever is less.}$$

$$\frac{0.04\ V_m \text{ total}}{T_{\text{total}}} = 0.04 \times \underline{\qquad}$$

La = cfm

2. Correction for Excessive Leak Rate

Lp = cfm

if Lp > La use V_{mc} total in place of V_m total in all subsequent equations.

$$V_{mc \text{ total}} = V_{m \text{ total}} - (Lp - La)\ T_{\text{total}}$$

$$V_{mc \text{ total}} = \quad -(\quad - \quad) \quad = \quad ft^3$$

3. Volume of Sample Measured by Dry Gas Meter, Corrected to Standard Conditions

$$V_{m} \text{ total (std)} = V_m \text{ total} \quad Y \left(\frac{T_{std} + 460}{T_{m\ avg} + 460}\right) \left[\frac{P_{bar} + \frac{\Delta H\ avg}{13.6}}{P_{std}}\right]$$

$$V_m \text{ total (std)} = (110.62) \times 1.00 \left(\frac{68 + 460}{62 + 460}\right) \left[\frac{29.42 + \frac{1.08}{13.6}}{29.92}\right]$$

V_m total (std) = 110.32 dscf

4. Moisture Content of Duct Gas

$$\%\ H_2O = \frac{0.04707\ (V_I + V_{SG})}{V_m \text{ total (std)} + 0.04707\ (V_I + V_{SG})} \times 100$$

$$\%\ H_2O = \frac{0.04707\ (594.7)}{(110.32) + 0.04707\ (594.7)} \times 100$$

% H_2O = 20.2 %

5. Molecular Weight of Stack Gas

$$M_s = \left[(0.44 \times \%\,CO_2)+(0.28 \times \%\,CO)+(0.28 \times \%\,N_2)+(0.32 \times \%\,O_2)\right]\left(1 - \frac{\%\,H_2O}{100}\right) + 0.18\,(\%\,H_2O)$$

$$M_s = \left[(0.44 \times 4.8)+(0.28 \times 0)+(0.28 \times 83.0)+(0.32 \times 12.2)\right]\left(1 - \frac{20.2}{100}\right) + 0.18\,(20.2)$$

$$M_s = 26.98 \text{ lb/lb-mole}$$

6. Average Duct Gas Density

$$D_{st} = 0.0458 \times M_s \left(\frac{P_{bar} + \frac{P_{s\,avg}}{13.6}}{T_{s\,avg} + 460}\right)$$

$$D_{st} = 0.0458 \times 26.98 \left(\frac{29.42 + \frac{-0.17}{13.6}}{143 + 460}\right)$$

$$D_{st} = 0.0603 \text{ lbs/ft}^3$$

7. Excess Air

$$EA = 100 \left[\frac{\%\,O_2 - 0.5\,\%\,CO}{0.264\,\%\,N_2 - (\%\,O_2 - 0.5\%\,CO)}\right]$$

$$EA = 100 \left[\frac{12.2 - 0.5 \times (0)}{0.264 \times 84 - (12.2 - 0.5 \times 0)}\right]$$

$$EA = 122\ \%$$

8. Average Duct Velocity

$$V_s = 5129.4\ C_p\ (\sqrt{\Delta P})_{avg} \sqrt{\frac{T_{s\,avg} + 460}{\left(P_{bar} + \frac{P_{s\,avg}}{13.6}\right) M_s}}$$

$$V_s = 5129.4 \times 0.84 \times 0.5836 \sqrt{\frac{143 + 460}{\left(29.42 + \frac{-0.17}{13.6}\right) 26.98}}$$

$$V_s = 2192 \text{ ft/min}$$

(2200)

9. Duct Volumetric Flow Rate

$$Q = V_s \times A_s$$

$$Q = 2192 \times 7.9$$

Q = 17317 acfm

(17000)

10. Duct Volumetric Flow Rate, Corrected to Dry Standard Conditions

$$Q_{std} = Q \left(1 - \frac{\% H_2O}{100}\right) \left(\frac{T_{std} + 460}{T_{s\ avg} + 460}\right) \left(\frac{P_{bar} + \frac{P_{s\ avg}}{13.6}}{P_{std}}\right)$$

$$Q_{std} = 17317 \left(1 - \frac{20.2}{100}\right) \left(\frac{68 + 460}{143 + 460}\right) \left(\frac{29.42 + \frac{-0.17}{13.6}}{29.92}\right)$$

Q_{std} = 11893 dscfm

(12000)

11. Isokinetic Factor

$$I = \frac{5.67\ (T_{s\ ave} + 460)(V_{m\ std})}{\left(P_{bar} + \frac{P_{s\ avg}}{13.6}\right) V_s \times T_{total} \left(1 - \frac{\%\ H_2O}{100}\right)\left(\frac{(Dn)^2 \times 0.7854}{144}\right)}$$

$$I = \frac{5.67\ (143 + 460)(110.32)}{\left(29.42 + \frac{-0.17}{13.6}\right) 2192 \times 192 \left(1 - \frac{20.2}{100}\right)\left(\frac{(.255)^2 \times 0.7854}{144}\right)}$$

I = 107.7 %

12. F - Factor

$$F = \frac{10^6(3.64\%\ H + 1.53\%\ C + 0.57\%\ S + 0.14\%\ N - 0.46\%\ O)}{GCV}$$

$$F = \frac{10^6(3.64 \times \quad + 1.53 \times \quad + 0.57 \times \quad + 0.14 \times \quad - 0.46 \times \quad)}{}$$

F = NA DSCF/MM BTU

13. Actual Particulate Concentration

$$C = \frac{0.01543 \times Mn}{Vm_{std}} \frac{(T_{std} + 460)}{T_{s\,avg} + 460} \frac{\left(P_{bar} + \frac{P_{s\,avg}}{13.6}\right)}{P_{std}} \left(1 - \frac{\%H_2O}{100}\right)$$

$$C = \frac{0.01543 \times 86.18 (68 + 460) \left(29.42 + \frac{-0.17}{13.6}\right) \left(1 - \frac{20.2}{100}\right)}{110.32 (143 + 460) (29.92)}$$

$C = 8.28 \times 10^{-3}$ grains/acf

14. Particulate Concentration, Corrected to Dry Standard Conditions

$$C_s = 0.01543 \times \frac{Mn}{V_{m\,std}}$$

$$C_s = 0.01543 \times \frac{86.18}{110.32}$$

$C_s = 0.012$ grains/dscf

15. Particulate Emission Rate

$ER = 0.008571 \times C_s \times Q_{std}$

$ER = 0.008571 \times 0.012 \times 11893$

$ER = 1.23$ lbs/hr.

16. Particulate Emission

$$E = 0.0001429\ C_s \times F \left(\frac{20.9}{20.9 - \%O_2}\right)$$

$$E = 0.0001429 \times \quad \times \left(\frac{20.9}{20.9 - \quad}\right)$$

E = NA lbs/MM BTU

17. Particulate Concentration Corrected to Dry Standard Conditions and 12% CO_2

$$C_s\ @\ 12\%\ CO_2 = \frac{12}{\%\ CO_2} \times C_s$$

$$C_s\ @\ 12\%\ CO_2 = \frac{12}{\quad} \times$$

C_s @ 12% CO_2 = NA grains/dscf @ 12% CO_2

APPENDIX B

PADRE DATA SUMMARIES

Includes:

B.1 Multiclone Inlet
B.2 Venturi Scrubber Outlet

APPENDIX B.1

Multiclone Inlet

TRC

PADRE Data Entry Form: RUN Data

Contractor ID, CNRTR: TRC Site ID, SITE: APG Test date, IDATE: 101883

Test comments, TCOMM Multiclone Inlet #1

Assumed particle density, RHO 1.00 (gm/ml) → gm/cc is units printed

Run index, IRUN (assigned)	1	2	3	4
Run comments, RCOMM	Port 3	Port 3	Port 5	Port 5
	Point 1	Point 2	Point 1	Point 2
	502	501	504	505
Run date, JDATE	101883	101883	101883	101883
Start time, ISTART	1145	1240	1505	1538
Duration, DUR (min)	0.25	1	2	2
RUN type, RTYPE	I	I	I	I
% H_2O in stack gas	18.5	18.5	18.5	19.5
Composition of dry stack gas				
% CO_2	5.8	5.8	5.8	5.8
% CO	0	0	0	0
% N_2	83.1	83.1	83.1	83.1
% O_2	11.2	11.2	11.2	11.2
Ambient pressure, PAMBNT (in. Hg)	29.42	29.42	29.42	29.42
Stack P wrt ambnt, DPSTK (in. H_2O)	-0.69	-0.69	-0.69	-0.69
Stack temperature, TSTACK (°F)	860	872	830	830
Stack gas velocity, VSTACK (ft/s)	50.0	50.0	50.0	50.0
Impactor temperature, TIMP (°F)	860	872	830	830
Flow rate determination method				
if EPA method 5, <u>then</u>				
initial gas vol., GMVOLI (ACF)	140.365	141.592	143.065	144.658
final gas vol., GMVOLF (ACF)	140.414	141.778	143.448	145.050
volume of water collected, VOLH_2O (ml)	0.24	0.91	1.87	1.91
temp. of meter, TMETER (°F)	60	65	67	67
meter calibration factor, CMETER	1.01	1.01	1.01	1.01
orifice ΔP, DPMTR (in. H_2O)	0.13	0.13	0.13	0.13
<u>else</u>				
impactor flow rate, FLOW (ACFM)				
Max. particle dia., DMAX (microns)	100	100	100	100
3 Cyclone cut point, CYCL (microns)	10	10	10	10
1 Nozzle diameter, DNOZZ (in.)	0.1891	0.1892	0.1891	0.1891
2 Nozzle cut point, CUTNOZ (microns)	10	10	10	10
4 Nozzle/cyclone mass, CMASS (mg)	34.9	74.4	269.4	120.5
Was backup filter used? BF	Y	Y	Y	Y
Large particles on back-up filter? FLARGE	N	N	N	N
Impactor type, IMPNAM	Andersen	Andersen	Andersen	Andersen
Impactor model, IMPMOD	Mark III	Mark III	Mark III	Mark III
Impactor plate set ID, IPLATE	Generic	Generic	Generic	Generic
Number of stages used, NS (Do not count cyclone or backup filter)	8	8	8	8
Substrate ID, IDSUBS (assigned)	434	435	13[illegible]	1

TRC

PADRE Data Entry Form: RUN Data

Contractor ID, CNRTR: TRC Site ID, SITE: ARG Test date, IDATE: 102083

Test comments, TCOMM: Multiclone Inlet #2

Assumed particle density, RHO: 1.00 gm/ml

Run index, IRUN (assigned)	1	2	3	4
Run comments, RCOMM	Port 3	Port 5	Port 5	Port 3
	Point 1	Point 1	Point 2	Point 2
Run date, JDATE	507	508	509	510
Start time, ISTART	102083	102083	102083	102083
Duration, DUR (min)	1015	1105	1312	1426
RUN type, RTYPE	2	2	2	2
% H_2O in stack gas	I	I	I	I
Composition of dry stack gas	21.1	21.1	21.1	21.1
% CO_2				
% CO	5.5	5.5	5.5	5.5
% N_2	0	0	0	0
% O_2	83.2	83.2	83.2	83.2
Ambient pressure, PAMBNT (in. Hg)	11.3	11.3	11.3	11.3
Stack P wrt ambnt, DPSTK (in. H_2O)	29.32	29.32	29.32	29.32
Stack temperature, TSTACK (°F)	-0.60	-0.60	-0.60	-0.60
Stack gas velocity, VSTACK (ft/s)	855	850	830	840
Impactor temperature, TIMP (°F)	50.0	50.0	53.0	56.0
Flow rate determination method	855	849	827	837
if EPA method 5, then	Y	Y	Y	Y
initial gas vol., GMVOLI (ACF)	145.164	146.591	149.071	150.84
final gas vol., GMVOLF (ACF)	145.575	146.966	149.464	151.246
volume of water collected, VOLH2O (ml)	2.38	2.18	2.28	2.31
temp. of meter, TMETER (°F)	63	61	61	60
meter calibration factor, CMETER	1.01	1.01	1.01	1.01
orifice ΔP, DPMTR (in. H_2O)	0.135	0.135	0.135	0.135
else				
impactor flow rate, FLOW (ACFM)				
Max. particle dia., DMAX (microns)	100	100	100	100
Cyclone cut point, CYCL (microns)	10	10	10	10
Nozzle diameter, DNOZZ (in.)	0.1891	0.1892	0.1891	0.1892
Nozzle cut point, CUTNOZ (microns)	10	10	10	10
Nozzle/cyclone mass, CMASS (mg)	74.0	263.6	199.8	103.3
Was backup filter used? BF	Y	Y	Y	Y
Large particles on back-up filter? FLARGE	N	N	N	N
Impactor type, IMPNAM	Andersen	Andersen	Andersen	Andersen
Impactor model, IMPMOD	Mark III	Mark III	Mark III	Mark III
Impactor plate set ID, IPLATE	Generic	Generic	Generic	Generic
Number of stages used, NS (Do not count cyclone or backup filter)	8	8	8	8
Substrate ID, IDSUBS (assigned)	775	159	332	504

TRC

PADRE Data Entry Form: RUN Data

Contractor ID, CNRTR: TRC Site ID, SITE: APG Test date, IDATE: 102183

Test comments, TCOMM Multiclone Inlet #3

Assumed particle density, RHO 1.00 gm/ml

Run index, IRUN (assigned)	1	2	3	4
Run comments, RCOMM	Port 3 Point 1 512	Port 3 Point 2 513	Port 5 Point 1 514	Port 5 Point 2 515
Run date, JDATE	102183	102183	102183	102183
Start time, ISTART	0935	1030	1122	1235
Duration, DUR (min)	2	2	2	2
RUN type, RTYPE	I	I	I	I
% H_2O in stack gas	21.8	21.8	21.8	20.6
Composition of dry stack gas				
% CO_2	6.0	6.0	6.0	5.2
% CO	0	0	0	0
% N_2	83.6	83.6	83.6	83.3
% O_2	10.4	10.4	10.4	11.5
Ambient pressure, PAMBNT (in. Hg)	29.18	29.18	29.18	29.18
Stack P wrt ambnt, DPSTK (in. H_2O)	-0.65	-0.65	-0.65	-0.65
Stack temperature, TSTACK (°F)	867	856	843	840
Stack gas velocity, VSTACK (ft/s)	50.0	50.0	50.0	51.7
Impactor temperature, TIMP (°F)	865	855	843	846
Flow rate determination method				
if EPA method 5, then				
initial gas vol., GMVOLI (ACF)	157.150	158.728	160.277	161.798
final gas vol., GMVOLF (ACF)	157.544	159.151	160.685	162.215
volume of water collected, $VOLH_2O$ (ml)	2.39	2.56	2.47	2.30
temp. of meter, TMETER (°F)	56	58	59	59
meter calibration factor, CMETER	1.01	1.01	1.01	1.01
orifice ΔP, DPMTR (in. H_2O)	0.14	0.14	0.14	0.14
else				
impactor flow rate, FLOW (ACFM)				
Max. particle dia., DMAX (microns)	100	100	100	100
Cyclone cut point, CYCL (microns)	10	10	10	10
Nozzle diameter, DNOZZ (in.)	0.1891	0.1891	0.1891	0.1891
Nozzle cut point, CUTNOZ (microns)	10	10	10	10
Nozzle/cyclone mass, CMASS (mg)	62.5	210.6	140.8	199.7
Was backup filter used? BF	Y	Y	Y	Y
Large particles on back-up filter? FLARGE	N	N	N	N
Impactor type, IMPNAM	Andersen	Andersen	Andersen	Andersen
Impactor model, IMPMOD	Mark III	Mark III	Mark III	Mark III
Impactor plate set ID, IPLATE	Generic	Generic	Generic	Generic
Number of stages used, NS (Do not count cyclone or backup filter)	8	8	8	8
Substrate ID, IDSUBS (assigned)	16	270	351	134

TRC

PADRE Data Entry Form: WEIGHT Data

Substrates ID (assigned)			434	435	130	102
Description			Set 502	Set 501	Set 504	Set 505
No. of weights			1	1	1	1

Units of all weights should be milligrams. Order should be from largest particles to smaller particles; cyclone (if used), first, impactor stages, and backup filter (if used) last.

Stage			Set 502	Set 501	Set 504	Set 505
Pre	1.	Pre-weight	1398.1	1394.3	1463.2	1400.2
		Post-weight	1433.0	1460.7	1672.6	1520.7
0	2.	Pre-weight	405.3	390.9	365.8	385.4
		Post-weight	405.8	395.0	379.2	395.6
1	3.	Pre-weight	374.9	374.8	380.1	398.5
		Post-weight	375.5	376.6	389.4	408.9
2	4.	Pre-weight	453.4	404.5	382.1	405.8
		Post-weight	454.9	407.2	390.7	422.5
3	5.	Pre-weight	416.6	386.3	380.7	376.2
		Post-weight	417.5	387.5	389.0	384.3
4	6.	Pre-weight	461.0	421.0	397.0	386.3
		Post-weight	462.0	424.0	405.1	391.5
5	7.	Pre-weight	425.1	383.9	395.0	399.7
		Post-weight	425.9	384.6	395.0 *	402.3
6	8.	Pre-weight	429.3	398.2	445.3	410.5
		Post-weight	429.7	399.1	448.0	411.7
7	9.	Pre-weight	398.5	387.2	382.0	358.6
		Post-weight	398.8	387.6	382.5	358.6
BUF	10.	Pre-weight	476.7	474.6	491.6	454.5
		Post-weight	478.0	474.8	492.7	454.7

* see filter weight sheet

TRC

PADRE Data Entry Form: WEIGHT Data

Substrates ID (assigned)			495	159	332	504
Description			set 507	Set 508	Set 509	set 510
No. of weights			1			

Units of all weights should be milligrams. Order should be from largest particles to smaller particles; cyclone (if used), first, impactor stages, and backup filter (if used) last.

Stage						
Pre	1.	Pre-weight	1404.0	1402.5	1399.9	1405.7
		Post-weight	1478.0	1666.1	1599.7	1569.0
0	2.	Pre-weight	422.5	435.2	369.6	406.0
		Post-weight	429.8	450.0	385.2	411.1
1	3.	Pre-weight	392.9	407.1	393.1	390.5
		Post-weight	403.7	415.3	400.6	398.6
2	4.	Pre-weight	484.6	404.6	415.3	341.3
		Post-weight	497.0	418.5	430.5	347.5
3	5.	Pre-weight	436.4	392.6	444.8	378.0
		Post-weight	436.5	401.8	453.0	384.4
4	6.	Pre-weight	422.7	403.3	459.0	436.0
		Post-weight	430.0	409.8	465.4	440.0
5	7.	Pre-weight	402.5	354.8	433.4	412.2
		Post-weight	407.5	360.3	436.5	414.5
6	8.	Pre-weight	413.6	363.5	437.3	440.7
		Post-weight	415.3	367.3	438.1	441.3
7	9.	Pre-weight	379.0	358.0	408.7	363.2
		Post-weight	379.1	358.7	408.7	363.2
BUF	10.	Pre-weight	468.6	414.6	471.3	471.0
		Post-weight	469.0	417.8	471.4	471.3

TRC

PADRE Data Entry Form: WEIGHT Data

Substrates ID (assigned)			16	270	351	131
Description			Set 512	Set 513	Set 514	Set 515
No. of weights						

Units of all weights should be milligrams. Order should be from largest particles to smaller particles; cyclone (if used), first, impactor stages, and backup filter (if used) last.

Stage						
Pre	1.	Pre-weight	1400.5	1406.4	1408.3	1407.5
		Post-weight	1463.0	1625.0	1549.1	1607.2
0	2.	Pre-weight	453.0	439.9	437.8	395.2
		Post-weight	457.2	470.7	448.7	407.3
1	3.	Pre-weight	395.6	401.6	424.5	421.5
		Post-weight	401.4	422.6	437.0	436.3
2	4.	Pre-weight	442.8 *	444.1	418.7	415.9
		Post-weight	442.8	465.6	434.2	432.0
3	5.	Pre-weight	433.0	392.8	394.1	422.4
		Post-weight	453.3	401.9	401.7	431.3
4	6.	Pre-weight	438.4	429.4	421.1	442.5
		Post-weight	444.3	436.5	427.1	450.5
5	7.	Pre-weight	388.7	433.7	409.8	457.1
		Post-weight	392.6	437.6	414.0	460.8
6	8.	Pre-weight	393.7	417.8	428.6	438.1
		Post-weight	393.9	419.4	430.1	440.0
7	9.	Pre-weight	370.1	423.2	418.0	462.4
		Post-weight	370.1	423.4	418.0	462.8
BUF	10.	Pre-weight	438.8	500.5	457.1	505.6
		Post-weight	439.1	501.0	458.5	506.6

APPENDIX B.2

Venturi Scrubber Outlet

TRC

PADRE Data Entry Form: RUN Data

Contractor ID, CNRTR: TRC Site ID, SITE: APG Test date, IDATE: 101883

Test comments, TCOMM Venturi Scrubber outlet #1

Assumed particle density, RHO 1.00 gm/ml

Run index, IRUN (assigned).	5			
Run comments, RCOMM	Set			
	503			
Run date, JDATE	101883			
Start time, ISTART	1045			
Duration, DUR (min)	240			
RUN type, RTYPE	0			
% H_2O in stack gas	20.2			
Composition of dry stack gas				
% CO_2	4.8			
% CO	0			
% N_2	83.0			
% O_2	12.2			
Ambient pressure, PAMBNT (in. Hg)	29.39			
Stack P wrt ambnt, DPSTK (in. H_2O)	-0.17			
Stack temperature, TSTACK (°F)	134			
Stack gas velocity, VSTACK (ft/s)	36.7			
Impactor temperature, TIMP (°F)	134			
Flow rate determination method				
if EPA method 5, then				
initial gas vol., GMVOLI (ACF)	961.56			
final gas vol., GMVOLF (ACF)	1047.99			
volume of water collected, VOLH2O (ml)	464.7			
temp. of meter, TMETER (°F)	64			
meter calibration factor, CMETER	1.01			
orifice ΔP, DPMTR (in. H_2O)	0.44			
else				
impactor flow rate, FLOW (ACFM)				
Max. particle dia., DMAX (microns)	100			
Cyclone cut point, CYCL (microns)	10			
Nozzle diameter, DNOZZ (in.)	0.1891			
Nozzle cut point, CUTNOZ (microns)	10			
Nozzle/cyclone mass, CMASS (mg)	81.6			
Was backup filter used? BF	Y			
Large particles on back-up filter? FLARGE	N			
Impactor type, IMPNAM	Andersen			
Impactor model, IMPMOD	Mark III			
Impactor plate set ID, IPLATE	Generic			
Number of stages used, NS (Do not count cyclone or backup filter)	8			
Substrate ID, IDSUBS (assigned)	406			

TRC

PADRE Data Entry Form: RUN Data

Contractor ID, CNRTR: TRC   Site ID, SITE: APG   Test date, IDATE: 102083

Test comments, TCOMM: Venturi scrubber outlet #2

Assumed particle density, RHO 1.00 gm/ml

Field	Value
Run index, IRUN (assigned)	5
Run comments, RCOMM	Set 506
Run date, JDATE	102083
Start time, ISTART	0955
Duration, DUR (min)	240
RUN type, RTYPE	0
% H_2O in stack gas	19.4
Composition of dry stack gas	
% CO_2	4.4
% CO	0
% N_2	82.6
% O_2	13.0
Ambient pressure, PAMBNT (in. Hg)	29.23
Stack P wrt ambnt, DPSTK (in. H_2O)	-0.19
Stack temperature, TSTACK (°F)	136
Stack gas velocity, VSTACK (ft/s)	36.7
Impactor temperature, TIMP (°F)	136
Flow rate determination method	
if EPA method 5, then	
initial gas vol., GMVOLI (ACF)	56.50
final gas vol., GMVOLF (ACF)	187.22
volume of water collected, VOLH2O (ml)	665.1
temp. of meter, TMETER (°F)	60
meter calibration factor, CMETER	1.01
orifice ΔP, DPMTR (in. H_2O)	0.99
else	
impactor flow rate, FLOW (ACFM)	
Max. particle dia., DMAX (microns)	100
Cyclone cut point, CYCL (microns)	10
Nozzle diameter, DNOZZ (in.)	0.250
Nozzle cut point, CUTNOZ (microns)	10
Nozzle/cyclone mass, CMASS (mg)	16.0
Was backup filter used? BF	Y
Large particles on back-up filter? FLARGE	N
Impactor type, IMPNAM	Andersen
Impactor model, IMPMOD	Mark III
Impactor plate set ID, IPLATE	Generic
Number of stages used, NS (Do not count cyclone or backup filter)	8
Substrate ID, IDSUBS (assigned)	333

TRC

PADRE Data Entry Form: RUN Data

Contractor ID, CNRTR: TRC Site ID, SITE: APG Test date, IDATE: 102/83

Test comments, TCOMM: Venturi Scrubber Outlet #3

Assumed particle density, RHO: 1.00 gm/ml

Field	Value
Run index, IRUN (assigned)	5
Run comments, RCOMM	1 set
	511
Run date, JDATE	102183
Start time, ISTART	0910
Duration, DUR (min)	240
RUN type, RTYPE	0
% H_2O in stack gas	19.8
Composition of dry stack gas	
% CO_2	4.6
% CO	0
% N_2	82.7
% O_2	12.7
Ambient pressure, PAMBNT (in. Hg)	29.12
Stack P wrt ambnt, DPSTK (in. H_2O)	-0.22
Stack temperature, TSTACK (°F)	135
Stack gas velocity, VSTACK (ft/s)	38.3
Impactor temperature, TIMP (°F)	134
Flow rate determination method	
if EPA method 5, then	
initial gas vol., GMVOLI (ACF)	197.90
final gas vol., GMVOLF (ACF)	329.24
volume of water collected, VOLH_2O (ml)	680.2
temp. of meter, TMETER (°F)	58
meter calibration factor, CMETER	1.01
orifice ΔP, DPMTR (in. H_2O)	0.99
else	
impactor flow rate, FLOW (ACFM)	
Max. particle dia., DMAX (microns)	100
Cyclone cut point, CYCL (microns)	10
Nozzle diameter, DNOZZ (in.)	0.250
Nozzle cut point, CUTNOZ (microns)	10
Nozzle/cyclone mass, CMASS (mg)	12.3
Was backup filter used? BF	Y
Large particles on back-up filter? FLARGE	N
Impactor type, IMPNAM	Andersen
Impactor model, IMPMOD	Mark III
Impactor plate set ID, IPLATE	Generic
Number of stages used, NS (Do not count cyclone or backup filter)	8
Substrate ID, IDSUBS (assigned)	476

TRC

PADRE Data Entry Form: WEIGHT Data

Substrates ID (assigned)		406	333	476	
Description		Set 503	Set 506	Set 511	
No. of weights					

Units of all weights should be milligrams. Order should be from largest particles to smaller particles; cyclone (if used), first, impactor stages, and backup filter (if used) last.

Stage						
Pre	1.	Pre-weight	1402.2	1463.8	1400.4	
		Post-weight	1483.8	1419.8	1412.7	
0	2.	Pre-weight	424.2	401.5	413.4	
		Post-weight	424.8	418.7	414.6	
1	3.	Pre-weight	411.3	384.5	367.7	
		Post-weight	411.6	397.7	368.5	
2	4.	Pre-weight	430.1	417.2	374.3	
		Post-weight	430.7	431.1	378.6	
3	5.	Pre-weight	444.3	417.5	374.2	
		Post-weight	445.1	427.2	399.1	
4	6.	Pre-weight	468.5	435.9	420.7	
		Post-weight	468.8	448.2	430.3	
5	7.	Pre-weight	433.0	436.6	387.0	
		Post-weight	433.0	450.0	395.3	
6	8.	Pre-weight	433.5	437.2	373.9	
		Post-weight	438.0	453.0	382.6	
7	9.	Pre-weight	388.7	436.1	409.2	
		Post-weight	395.0	451.4	417.3	
BUF	10.	Pre-weight	455.4	500.0	471.1	
		Post-weight	477.7	514.6	476.5	

Particle Size

~~PARTICULATE~~ TEST DATA

TEST 1 - PARTICLE SIZE TIME 10:45 - 15:00

LOCATION OUTLET DATE 18 OCT 83

FIRM A P GREEN REFRACTORIES PROJECT NO. 2177-E84

Input A

P bar	Barometric Pressure - in. Hg	29.39
As	Stack Area - Ft^2	7.9
Dn	Nozzle Diameter - in.	0.189
Time	Total Sampling Time - min.	240
Y	Calibration Factor	1.01
Cp	Pitot Coefficient	0.84
$(\Delta P)^{1/2}$	Average Square Root of Velocity Head (in. H_2O)	0.6325
ΔH	Average Orifice Pressure Drop - in. H_2O	0.44
Tm	Average Meter Temperature °F	64
Pstk	Average Stack Pressure - in. H_2O	-0.17
Tstk	Average Stack Temperature °F	134
Vm	Meter Volume at Meter Conditions - Ft^3	86.43
Vl	Total Water Vapor Collected - ml	464.7
CO_2	% CO_2 in Stack Gas (Dry)	4.8
O_2	% O_2 in Stack Gas (Dry)	12.2
CO	% CO in Stack Gas (Dry)	0

Input B

Mn	Total Particulate Catch - Mg	

Input C'

	F-factor - DSCF/MMBTU	

Input C

% H	% Hydrogen in Fuel	
% C	% Carbon in Fuel	
% S	% Sulfur in Fuel	
% N	% Nitrogen in Fuel	
% O	% Oxygen in Fuel	
GCV	Gross Califoric Volume of Fuel - BTU/lb	

Calculated

Vm (std)	Meter Volume at Standard Conditions (Dry)-Ft^3	
% H_2O	% H_2O Vapor in Stack Gas	
Mws	Molecular Weight of Stack Gas (Wet)	
Vs	Average Velocity of Stack Gas - FPM	
Qs	Actual Stack Gas Flowrate - ACFM	
Qs (std)	Stack Gas Flowrate (0.0% H_2O; STP) -- DSCFM	
% I	% Isokinetic (Avg. Nozzle Vel/Avg. Stk Vel)	
Cs	Particulate Concentration-lb/DSCF	
Er	Particulate Emission Rate-lb/hour	
F	F Factor - DSCF/MM BTU	
E	Particulate Emissions - lbs/MM BTU	

Particle size

PARTICULATE TEST DATA

TEST	2	TIME	09:55 - 14:35
LOCATION	OUTLET - PARTICLE SIZING	DATE	20 OCT 83
FIRM	A P GREEN REFRACTORIES	PROJECT NO.	2177-E84

Input A

P bar	Barometric Pressure - in. Hg	29.23
As	Stack Area - Ft^2	7.9
Dn	Nozzle Diameter - in.	0.250
Time	Total Sampling Time - min.	240
Y	Calibration Factor	1.01
Cp	Pitot Coefficient	0.84
$(\Delta P)^{1/2}$	Average Square Root of Velocity Head (in. H_2O)	0.5831
ΔH	Average Orifice Pressure Drop - in. H_2O	0.97
Tm	Average Meter Temperature °F	60
Pstk	Average Stack Pressure - in. H_2O	-0.19
Tstk	Average Stack Temperature °F	136
Vm	Meter Volume at Meter Conditions - Ft^3	130.72
Vl	Total Water Vapor Collected - ml	665.1
CO_2	% CO_2 in Stack Gas (Dry)	4.4
O_2	% O_2 in Stack Gas (Dry)	13.0
CO	% CO in Stack Gas (Dry)	0

Input B

Mn	Total Particulate Catch - Mg	

Input C' F-factor - DSCF/MMBTU

Input C

% H	% Hydrogen in Fuel	
% C	% Carbon in Fuel	
% S	% Sulfur in Fuel	
% N	% Nitrogen in Fuel	
% O	% Oxygen in Fuel	
GCV	Gross Califoric Volume of Fuel - BTU/lb	

Calculated

Vm (std)	Meter Volume at Standard Conditions (Dry)-Ft^3	
% H_2O	% H_2O Vapor in Stack Gas	
Mws	Molecular Weight of Stack Gas (Wet)	
Vs	Average Velocity of Stack Gas - FPM	
Qs	Actual Stack Gas Flowrate - ACFM	
Qs (std)	Stack Gas Flowrate (0.0% H_2O; STP) - DSCFM	
% I	% Isokinetic (Avg. Nozzle Vel/Avg. Stk Vel)	
Cs	Particulate Concentration-lb/DSCF	
Er	Particulate Emission Rate-lb/hour	
F	F Factor - DSCF/MM BTU	
E	Particulate Emissions - lbs/MM BTU	

Rev. 2 6/17/81

Particle Size

~~PARTICULATE~~ TEST DATA

TEST 3 - PS TIME 0910 - 1316

LOCATION Venturi Outlet DATE 10/21/93

FIRM AP Green PROJECT NO. 2177-ES4

Input A		
P bar	Barometric Pressure - in. Hg	29.12
As	Stack Area - Ft^2	7.9
Dn	Nozzle Diameter - in.	0.250
Time	Total Sampling Time - min.	240
Y	Calibration Factor	1.01
Cp	Pitot Coefficient	0.84
$(\Delta P)^{1/2}$	Average Square Root of Velocity Head (in. H_2O)	0.5831
ΔH	Average Orifice Pressure Drop - in. H_2O	0.99
Tm	Average Meter Temperature °F	58
Pstk	Average Stack Pressure - in. H_2O	-0.02
Tstk	Average Stack Temperature °F	135
Vm	Meter Volume at Meter Conditions - Ft^3	131.34
Vl	Total Water Vapor Collected - ml	680.2
CO_2	% CO_2 in Stack Gas (Dry)	4.6
O_2	% O_2 in Stack Gas (Dry)	12.7
CO	% CO in Stack Gas (Dry)	0
Input B		
Mn	Total Particulate Catch - Mg	
Input C'	F-factor - DSCF/MMBTU	
Input C		
% H	% Hydrogen in Fuel	
% C	% Carbon in Fuel	
% S	% Sulfur in Fuel	
% N	% Nitrogen in Fuel	
% O	% Oxygen in Fuel	
GCV	Gross Califoric Volume of Fuel - BTU/lb	
Calculated		
Vm (std)	Meter Volume at Standard Conditions (Dry)-Ft^3	
% H_2O	% H_2O Vapor in Stack Gas	
Mws	Molecular Weight of Stack Gas (Wet)	
Vs	Average Velocity of Stack Gas - FPM	
Qs	Actual Stack Gas Flowrate - ACFM	
Qs (std)	Stack Gas Flowrate (0.0% H_2O; STP) - DSCFM	
% I	% Isokinetic (Avg. Nozzle Vel/Avg. Stk Vel)	
Cs	Particulate Concentration-lb/DSCF	
Er	Particulate Emission Rate-lb/hour	
F	F Factor - DSCF/MM BTU	
E	Particulate Emissions - lbs/MM BTU	

Rev. 2 6/17/81