PARTICULATE, SULFUR DIOXIDE, NITROGEN OXIDES, AND CARBON MONOXIDE EMISSION MEASUREMENTS FROM LIME KILNS

Plant Tested

Virginia Lime Company
Ripplemead, Virginia

April 29 and 30, May 1, 2 and 3, 1975

Prepared for

Environmental Protection Agency
Office of Air Quality Planning and Standards
Emission Measurement Branch
Research Triangle Park,
North Carolina 27711

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Contract No. 68-02-1404 Task No. 11

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I. INTRODUCTION

Monsanto Research Corporation (MRC) was contracted under the Environmental Protection Agency's "Field Sampling of Atmospheric Emissions" program to provide emission data from a lime kiln at Virginia Lime Company, Ripplemead, Virginia, a division of Rangaire Corporation.

The field test work was directed by Thomas F. Lahre, Technical Development Section. The sampling was performed by MRC with Thomas L. Peltier as Team Leader.

This report tabulates the data collected from the exhaust of the No. 2 lime kiln of the Virginia Lime Company during the sampling program on April 30 and 31 and May 1, 2 and 3, 1975. The coal-fired kiln was not equipped with a pollution control device when the sampling was performed. However, wet scrubbers are currently being installed to meet the Virginia air pollution regulations. The kiln produces 350 tons per day of product (pebble lime) which varies in size from one inch to two and one-half inches. To produce 350 tons of product, 700 tons of feed and approximately 120 tons of coal are required.

The exhaust gas from the kiln was sampled to determine particulate concentrations according to the procedures described in the Federal Register, Vol. 36, No. 247, December 23, 1971, Method 5, "Determination Particulate Emissions from Stationary Sources." Method 1, "Sample and Velocity Traverses for Stationary Sources"; Method 2, "Determination of Stack Gas

Velocity and Volumetric Flow Rate (Type S Pitot tube)"; Method 3, "Gas Analysis for Carbon Dioxide, Excess Air, and Dry Molecular Weight"; and Method 4, "Determination of Moisture in Stack Gases" are other procedures that were required for the Method 5 tests.

Method 6, "Determination of Sulfur Dioxide Emissions from Stationary Sources" and Method 7, "Determination of Nitrogen Oxide Emissions from Stationary Sources" were also performed on the exhaust gases. Method 10, "Determination of Carbon Monoxide Emissions from Stationary Sources," from Federal Register, Vol. 39, No. 47, March 8, 1974 was utilized during the sampling program. Brink® particle sizing was performed on the particulate in the exhaust gases to obtain the size of the particles being emitted.

Samples of the feed material, product, and coal were collected during the sampling runs, with the feed and product analyzed for sulfur content, while the coal samples were analyzed for heating value and proximate analysis.

The following sections of this report include a summary of results, description of process, sampling location and sampling and analytical procedures. Appendices include all field and analytical data from this sampling project.

II. SUMMARY OF RESULTS

Data on particulate emissions and the limestone feed rates from the No. 2 lime kiln are summarized in Table 1. Emission data are divided into two parts, the front half and total catch. The front half includes the filter, the probe, probe tip, cyclone, filter holder, and associated glassware washings. The total catch includes the front half plus the material collected in the water impingers, the impinger washing, with both acetone and water, and the ether-chloroform extract of the water from the impinger.

Runs 3, 4 and 5 are complete sampling runs and the data from these runs is most representative of the particulate emissions from this source. Runs 1 and 2 were incomplete sampling runs, each collecting samples from one half of the total number of traverse points.

The data for runs 3, 4, and 5 was obtained by sampling at each traverse point for one minute for a total of 48 minutes of run time. Between 23.7 and 26.7 dry standard cubic feet of gas were sampled during the three runs to provide the front half and total catch results, which are given in Table 1 and also in Appendix A. Due to the high particulate loading, the sampling train filters were changed at the end of each traverse. The space on the platforms was limited and it was necessary to disconnect the twelve foot probe from the sample box in order to move the sampling system to the second port to complete the second

Table 1

SUMMARY OF PARTICULATE RESULTS

	4/30/75		5/01/75		5/02/75		5/03/75		5/03/75	
Run Number	1		2		3		4		5	
Vol. of gas sampled (DSCF-Nm³)a	11.30	.334	19.59	.555	26.01	.736	23.71	.671	26.72	.757
% Moisture by volume	6.60	6.60	2.73	2.73	3.75	3.75	4.74	4.74	4.76	4.76
Average stack temp. (°F-°C)	403	206	392	200	388	198	394	201	395	202
Stack Volumetric Flow Rate (DSCFM-Nm³/sec)b	45515	21.5	61090	28.8	59260	28.0	53432	25.2	55795	26.3
Stack Volumetric Flow Rate (ACFM-m³/sec)c	84753	40.0	107751	50.9	105183	49.6	96796	45.7	101189	47.8
% Isokinetic	98.8	98.8	90.5	90.5	92.9	92.9	94.0	94.0	101.4	101.4
Duration of run-minutes	26.7	26.7	36	36	48	48	48	48	48	48
Limestone Feed Rate (Ton/hr-metric ton/hr)	23	20.9	28	25.4	29	26.3	27	24.5	29	26.3
Particulates-probe, cyclone and filter catch										
mg	8944.1	8944.1	11072.5	11072.5	19586.7	19586.7	13125.0	13125.0	15864.7	15864.7
(grain/DSCF-gm/Nm³)d	11.6765	26.72	8.7061	19.92	11.5965	26.54	8.5239	19.51	9.1422	20.92
(lb/hr-kg/hr)	4554.6	2065.9	4558.0	2067.5	5889.4	2671.4	3903.2	1770.5	4371.4	1982.8
Particulates-total catch										
mg					19727.1	19727.1	13180.5	13180.5	15938.2	15938.2
(grains/DSCF-gm/Nm³)					11.6797	26.73	8.5599	19.59	9.1845	21.02
(lb/hr-kg/hr)					5931.5	2690.5	3919.7	1777.9	4391.19	1992.0
Percent impinger catch					0.7	0.7	0.4	0.4	0.5	0.5
Emission Factor										
lb/Ton-kg/mTon (Product)	396	197.6	325.6	162.8	409.1	204.6	290.3	145.2	302.8	151.4
lb/Ton-kg/mTon (Feed)	198	98.3	163	81.4	205	102.3	145	72.6	151	75.7

a - Dry standard cubic feet @ 70°F, 29.92 in Hg - normal cubic meters at 21.1°C, 760 mm Hg

b - Dry standard cubic feet per minute - normal cubic meters per second

c - Actual cubic feet per min., stack conditions - actual cubic meters per second

d - Grains per dry standard cubic feet - mg per normal cubic meters half of the sampling run. During this transfer, care was taken to prevent loss of particulate that had settled out on the walls of the probe liner.

The data for Run No. 1 was obtained from the port adjacent to the ladder, and consists of all 24 points of the traverse for this port. During the transfer to the second port, the probe liner was broken. The run was terminated at this time and the sampling system cleaned up. Run No. 2, was begun from the other port, i.e., 90° away from the port closest to the ladder. Halfway through the run, after completion of the first 24 traverse points from one port, a rainstorm prevented further sampling. Rather than to continue this run over a two day period, the run was terminated at the point and the sampling system cleaned up. As runs 1 and 2 were not complete runs, only the front half samples were analyzed in the laboratory. These results are given in Table 1, along with the complete data of runs 3, 4 and 5.

The cleanup of all sampling trains was done at the site. All filters, impinger liquid and washings were transported to the Dayton Laboratory. The analysis of the front half of sampling train followed the procedures given in Method 5 of the December 23, 1971 Federal Register. The back half analysis was completed as outlined in "Specifications for Incinerator Testing at Federal Facilities", U. S. Department of Health, Education and Welfare, October 1967.

The results of the sulfur dioxide testing are given in Table 2. Runs Nos. 1 and 2 were performed on April 30, 1975, before and after Particulate Run No. 1. The emission rate that is given in the table is based on the velocity determined during the preliminary velocity traverse performed on April 29, 1975. The sulfur dioxide Run No. 3 was performed on May 2, 1975

Table 2

SUMMARY OF SO_2 RESULTS

Date	4/30	4/30	5/2
Run	1	2	3
Volume of gas sampled			
DSCF	1.026	0.939	0.786
Nm^3	.0291	0.0266	.0223
SO_2 Concentration			
ppm	127	230	160
lb/DSCF x 10^{-5}	2.0686	3.7502	2.6034
g/Nm^3	.331	.601	.417
SO_2 Emission Rate			
lb/hr	71[a]	128.7[a]	92[b]
kg/hr	32.2	58.4	41.7
Feed Rate[c]			
Ton/hr-mTon/hr	27 24.5	27 24.5	29 26.3
Emission Factor			
lb/Ton-kg/mTon (Product)	5.3 2.6	9.5 4.8	6.3 3.2
lb/Ton-kg/mTon (Feed)	2.6 1.3	4.8 2.4	3.2 1.6

a - based on velocity from preliminary traverse 5/29/75

b - based on velocity from Method 5 - Run #3

c - average for 8-hour shift

and the emission rate results are based on the velocity determined from the Method 5 run performed on that day.

The sulfur content of the coal used as fuel on the days of the test are given in Table 3. This table also gives the proximate analysis of the coal including the moisture, volatiles, ash, fixed carbon and BTU content. The analytical procedures were performed according to ASTM-D271-70. The total sulfur contents of the feed limestone and product lime (Table 4) were determined by two different methods, the Bromine method, at MRC and the Leco Method at Bowser-Morner Testing Laboratory in Dayton, Ohio. Both methods are given in the ASTM C25-72 procedure for lime and limestone analysis. The sulfur contents of the limestone and lime as determined by the two methods were considerably different as evidenced by the data in Appendix G. The precision of the results by each method separately was quite good. In addition, standard samples were prepared for the Bromine method by adding known amounts of sodium sulfate to calcium carbonate and determining the recovery. The results indicated 99.8 and 100% recovery of the sulfur in samples throughout the analytical procedure. Check samples were resubmitted for analysis by the Leco Method. One possible explanation in the difference between methods is that the Leco Method provides direct sulfur readings from zero to 1 1/2% sulfur from the burette. As the reported sulfur content range from .02 to .035 only a small portion of the range is used. This does not explain why on samples the first day the Leco Method gave results about one half of the bromine sulfur values.

Table 5 contains the data required for a total sulfur balance around the No. 2 kiln. Included in the table are the total input sulfur from the coal and limestone feed and the total output sulfur from the sulfur dioxide, the calcined lime

Table 3

COAL ANALYSIS*

Date	Run No.	Total Percent Moisture	Percent Moisture	Percent Volatile	Percent Ash	Fixed Carbon	Btu/lb	Sulfur Percent
4-30-75	1	7.84	1.27	38.2	11.53	49.00	12183	0.95
5-2-75	3	3.97	0.89	29.6	12.49	57.02	12620	0.85
5-3-75	4	5.08	1.28	37.7	2.76	58.28	13698	0.74

*Values are as-fired basis

Table 4

TOTAL SULFUR CONTENT OF FEED AND PRODUCT

Date	Material	% Sulfur[a]	% Sulfur[b]
4-30-75	Feed	.072	.042
	Product	.065	.022
5-2-75	Feed	.042	.020
	Product	.023	.029
5-3-75	Feed	.025	.023
	Product	.029	.031

[a] ASTM C25-72, Standard Bromine Method (See Appendix G)

[b] ASTM C25-72, Leco Method (See Appendix G)

Table 5. TOTAL SULFUR BALANCE

Source	Date and Quantity					
	4/30 (Run 1)		4/30 (Run 2)		5/2 (Run 3)	
	Leco (A)	Bromine (B)	Leco (A)	Bromine (B)	Leco (A)	Bromine (B)
1. Limestone Feed						
Feed Rate (ton/hr)	27		27		29	
Sulfur Content (%)	.042	.072	.042	.072	.023	.042
Sulfur Input (lb/hr)	22.7	38.9	22.7	38.9	13.3	24.4
2. Coal Feed						
Feed Rate (ton/hr)	4.5		4.5		4.8	
Sulfur Content (%)(C)	0.95		0.95		0.85	
Sulfur Input (lb/hr)	85.5		85.5		81.6	
3. Total Sulfur Input (lb/hr)	108.2	124.4	108.2	124.4	94.9	106.0
4. Product Yield*						
Rate (ton/hr)	13.5		13.5		14.5	
Sulfur Content (%)	.022	.065	.022	.065	.031	.023
Sulfur Content (lb/hr)	5.9	17.6	5.9	17.6	9.0	6.7
5. Gaseous Emissions						
SO_2 Emissions (lb/hr)	71		128.7		92	
Sulfur Emissions (lb/hr)	35.5		64.4		46	
6. Sulfur in Particulate Emissions (D)						
Sulfur Content (%)	0.17		0.17		0.165	
Sulfur Emissions (lb/hr)	7.7		7.7		9.8	
7. Total Sulfur Output (lb/hr)	49.1	60.8	78.0	89.7	64.8	62.5
8. Difference Input-Output (lb/hr)	59.1	63.6	30.2	34.7	30.1	43.5
9. % Input Unaccounted For $\left(\frac{\text{No. 8}}{\text{No. 3}}\right)$	54.6	51.1	27.9	27.9	31.7	41.0
10. % Conversion of Total Input S to Gaseous S = $\frac{\text{Gaseous S}}{\text{Total Input S}} \times 100$	32.8	28.5	59.5	51.8	48.5	43.4

A Leco refers to the results by the Leco Method for sulfur

B Bromine refers to the results by the Bromine Method for sulfur

C Sulfur content in coal determined by ASTM-D271-70

D Bromine refers to the results by the Bromine Method for sulfur

* Plant Yield

product and the particulate emissions. The sulfur content of the particulate collected on the filter and the probe and cyclone washings was determined by using the Bromine method. Completing the balance using the limestone feed and coal as sources of sulfur and using the SO_2, product, and particulate emissions as sulfur outlets results in a considerably smaller amount of sulfur out than into the system. The unaccountable sulfur is given in No. 8 and No. 9 on Table 5. Also given in Table 5 is the percent conversion of input sulfur to gaseous sulfur.

$$\%\ \text{Conversion} = \frac{\text{Gaseous sulfur}}{\text{Sulfur in from limestone feed and coal}} \times 100$$

In all three sulfur balances from the No. 2 kiln, the amount of sulfur out through the product and emissions is approximately 50% or less than the amount in through the limestone and coal feed. A possible explanation for this is that there is an indication that EPA Method 6 for gaseous SO_2 does not give the correct results on emission sources that contain lime due to adsorption of SO_2.

The Method 7 NO_x results are summarized in Table 6. The four samples were withdrawn from the source over a fifteen minute period at three different times. The results of the individual samples and the average for each fifteen minute period is given in the table. The concentration and the emission rate is based on the preliminary velocity traverse performed on April 29, 1975. A sample calculation and a computerized printout of the results are given in Appendix B.

Two particle sizing runs using a Brink® BMS-11 Cascade impactor were performed on the exhaust of the No. 2 kiln. A description of the device is given in Appendix D along with a computer printout of the results of the testing program. Table 7 gives a summary of the particle sizing data. It includes the stage number,

Table 6

SUMMARY OF NO_x RESULTS

Date	Time	ppm[a]	lb/DSCF x 10^{-5}	grams/Nm³	lb/hr[b]	Kg/hr[b]	Feed Ton/hr	Rate[c] mTon/hr	Emission Factor Product lb/Ton	Emission Factor Product kg/mTon	Emission Factor Feed lb/Ton	Emission Factor Feed kg/mTon
4-30-75	1515	124	1.47	.235	47.7	21.6						
4-30-75	1520	155	1.84	.295	59.7	27.1						
4-30-75	1525	134	1.59	.255	51.5	23.4						
4-30-75	1530	121	1.43	.229	46.4	21.0						
Ave.		133.5	1.58	.254	51.3	23.3	27	24.5	3.80	1.90	1.90	0.95
5-1-75	1105	45	0.54	.087	17.5	7.9						
5-1-75	1110	140	1.66	.266	53.8	24.4						
5-1-75	1115	138	1.62	.260	52.5	23.8						
5-1-75	1120	69	0.82	.131	26.6	12.1						
Ave.		98	1.16	.186	37.6	17.1	29	26.3	2.60	1.30	1.30	0.65
5-1-75	1305	139	1.63	.261	52.8	24.0						
5-1-75	1310	102	1.22	.195	39.6	17.9						
5-1-75	1315	72	0.85	.136	27.6	12.5						
5-1-75	1320	63	0.80	.128	25.9	11.8						
Ave.		95	1.13	.180	36.5	16.6	29	26.3	2.52	1.26	1.25	0.63

[a] Parts per million by volume

[b] Based on volumetric flow rate from preliminary traverse 4/29/75 (dscfm)

[c] Average for 9-hour shift

TABLE 7

Brink® Particle Sizing

Run #1 - 5/02/75

Stage	Weight of Material	DPC	mg/ACF	Weight PCNT	Cumulative Weight PCNT
Cyclone	67.300		91.88	96.46	100.00
1	0.45	2.77	.62	.65	3.55
2	0.46	1.62	.63	.66	2.90
3	0.10	1.10	.14	.15	2.24
4	0.12	0.56	.17	.18	2.10
5	0.14	0.34	.20	.21	1.93
Filter	1.20		1.64	1.72	1.72

Run #2 - 5/03/75

Stage	Weight of Material	DPC	mg/ACF	Weight PCNT	Cumulative Weight PCNT
Cyclone	66.70		121.96	97.09	100.00
1	.59	1.96	1.08	.86	2.92
2	.14	1.13	.26	.21	2.06
3	.21	.75	.39	.31	1.85
4	.10	.36	.19	.15	1.55
5	.06	.18	.11	.09	1.40
Filter	.90		1.65	1.32	1.32

the weight of material collected on the stage, the diameter of the particles in microns on the stage, the concentration of the particles, the weight percent, and the cumulative weight percent.

The first run with the Brinks unit was to establish run conditions, and during this run the flow rate through the sampler as measured by the ΔP across the impactor was lower than isokinetic. Based on the stack conditions and use of a 3 mm nozzle, the ΔP should be 4.5" of mercury. The first run indicated the sampling time should be about 5 minutes. Run 2 was run under these conditions, and thus should be representative of isokinetic sampling.

The results, as shown by both runs indicate that about 97% of the particulate is caught in the probe and cyclone and thus is larger than 2 micrometer in diameter. Only 3% of the total mass collected was distributed through the stages of the impactor.

The results of the particle sizing are plotted on probability log paper in Figures 1 & 2.

The Method 10 testing with the Beckman Model 864 Infrared Analyzer was performed each day on the Orsat grab sample. Trouble with the analyzer led to no results for April 30 and inconclusive results on May 1. On the third day of testing, the meter on the analyzer became pegged and the sampling team assumed that there were operational difficulties since full scale was 3000 ppm carbon monoxide. An Orsat was performed and it was discovered that the CO content of the exhaust gas was between 0.3 and 0.4%. The people at the plant had no idea what the CO concentration was in the exhaust gases. The same results were obtained during particulate Runs No. 4 and 5.

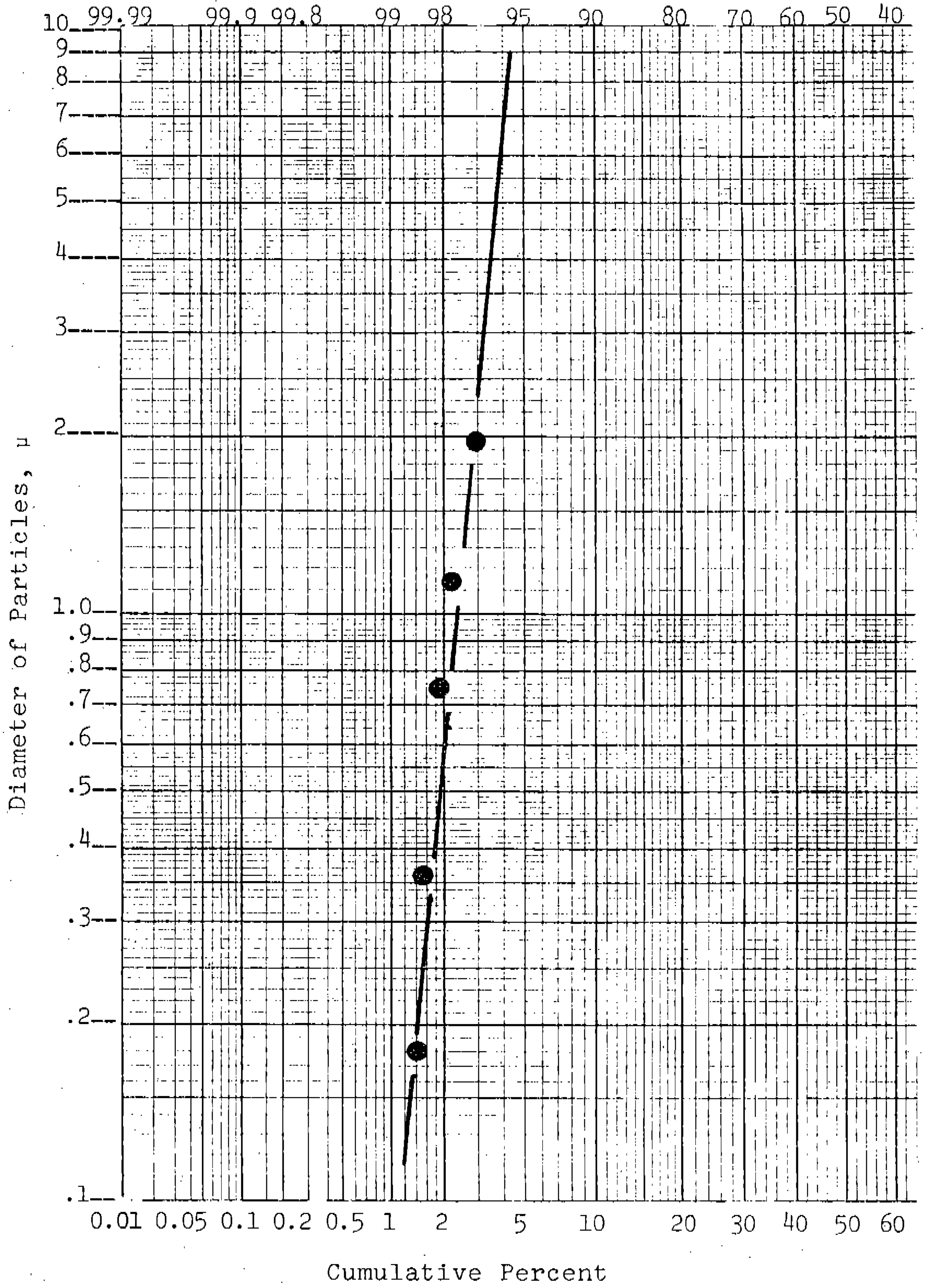


Figure 1. Cumulative Particle Size Data, Run No. 1

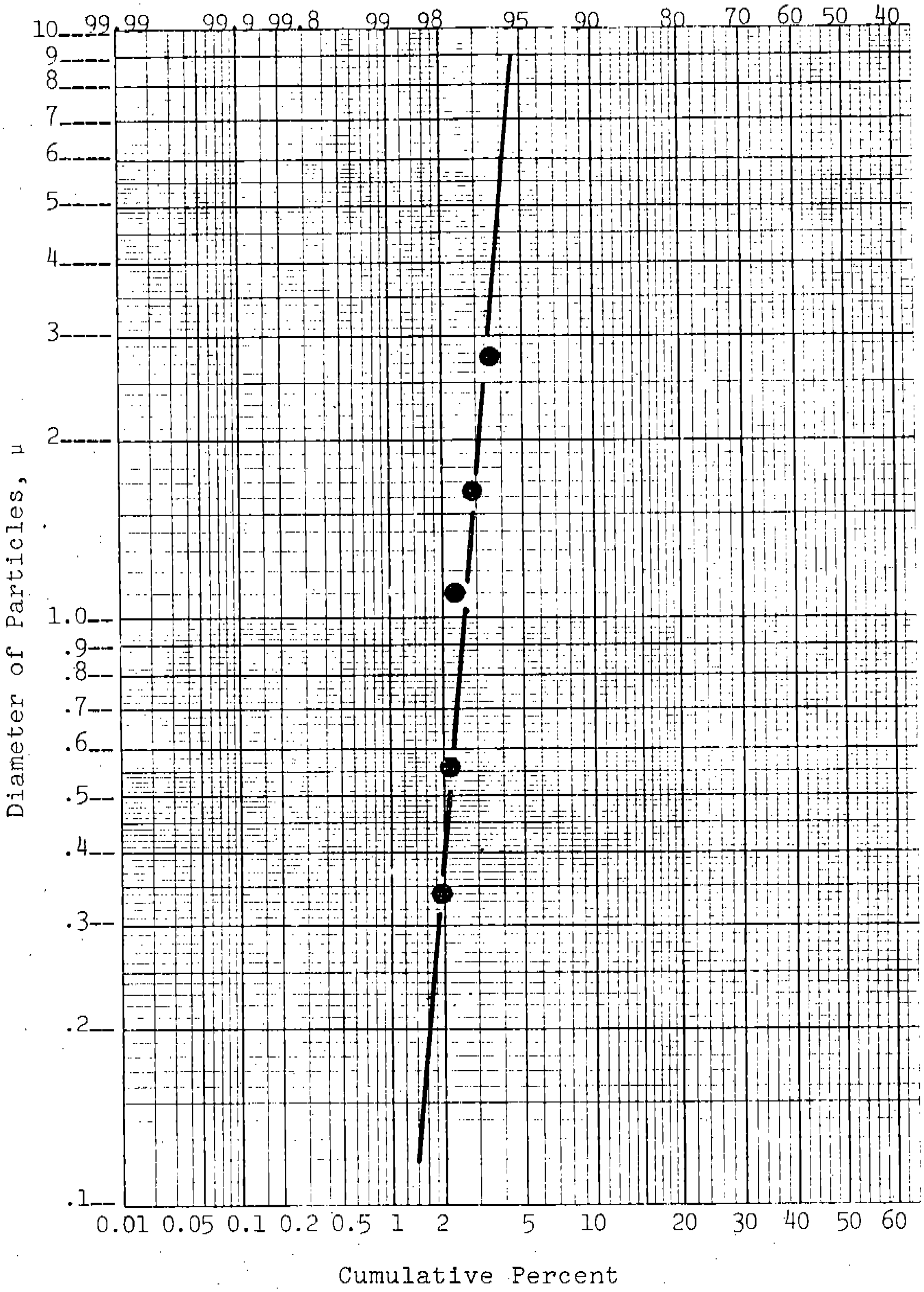


Figure 2. Cumulative Particle Size Data, Run No. 2

The calibration gases for the CO analyzer were 300, 600, and 900 ppm since lower levels of CO were expected. Therefore, the CO analyzer gave an indication that the concentration was greater than approximately 3000 ppm with the Orsat values confirming this concentration. Table 8 gives a summary of the carbon monoxide emissions.

Table 9 gives an average emission factor for each of the pollutants that were sampled at Virginia Lime. The factors are an average of all runs performed.

Table 8

CARBON MONOXIDE RESULTS

Date	5-2		5-3		5-3	
Run No.	3		4		5	
Analyzer Reading - ppm	>3000		>3000		>3000	
Orsat Reading %	0.3		—		0.3	
Flow Rate - DSCFM	59260		53432		55795	
Emissions[a] - lb/hr	761		686		716	
kg/hr	345		311		325	
Limestone Feed Rate						
Ton/hr - mTon/hr	29	26.3	27	24.5	29	26.3
Emission Factor						
lb/Ton - kg/mTon (Feed)	26.2	13.1	25.4	12.7	24.7	12.4
lb/Ton - kg/mTon (Product)	52.5	26.2	50.8	25.4	49.4	24.7

[a] Using 3000 ppm as CO content

Table 9

EMISSION FACTORS

Type of Run	lb/Ton - kg/mTon (Feed)			lb/Ton - kg/mTon (Product)		
Method 5 - particulate	0.89 167 ~~172~~	0.45 84 ~~86~~	CONDENSIBLE TOTAL	1.78 334 ~~344~~	0.89 167 ~~172~~	CONDENSIBLE TOTAL
Method 6 - SO_2	3.5	1.8		7.0	3.5	
Method 7 - NO_x	1.5	0.75		3.0	1.50	
~~Method 10 - CO~~	~~25.4~~	~~12.7~~		~~50.8~~	~~25.4~~	(Operational Problems possible. [CO] > 3000 ppm, but not exactly known.)

(First 2 of 5 runs not included due to sampling difficulties)

III. PROCESS DESCRIPTION AND OPERATION

Virginia Lime Company in Ripplemead, Virginia has three rotary lime kilns which produce calcined lime. The limestone which is fed into the kilns is mined, crushed, and sized on site. The product, calcined lime or pebble lime, is cooled and stored in silos before being sold to customers. The pulverized coal that is used to heat the limestone and convert it to calcined lime has a typical heat content of 12,830 Btu/lb, 8.9% ash, and 0.8% sulfur. The kilns are operated continuously, 24 hours a day, seven days a week. The capacity of kilns No. 1, 2, and 3, is 150, 350, and 350 tons of product/day respectively. A flow diagram of the lime plant is shown in Figure 3.

The limestone feed is mined from a nearby mountain and trucked to the plant site where it is crushed and sized. The feed to the kiln varies from one to two and a half inches at its largest dimension. The stone is conveyed to a storage bin directly above the kiln from where it falls into the rotating kiln and gradually tumbles toward the opposite end of the kiln. Pulverized coal is blown into the kiln at the product end and the combustion gases are pulled through the kiln by a fan on the outlet. The heat of the burning coal causes the limestone feed ($CaCO_3$, calcium carbonate) to give off carbon dioxide (CO_2) and form calcium oxide (CaO). The stone fed into the kiln has a four hour residence time before it is emitted as product. As the product leaves the kiln, it falls into satellite

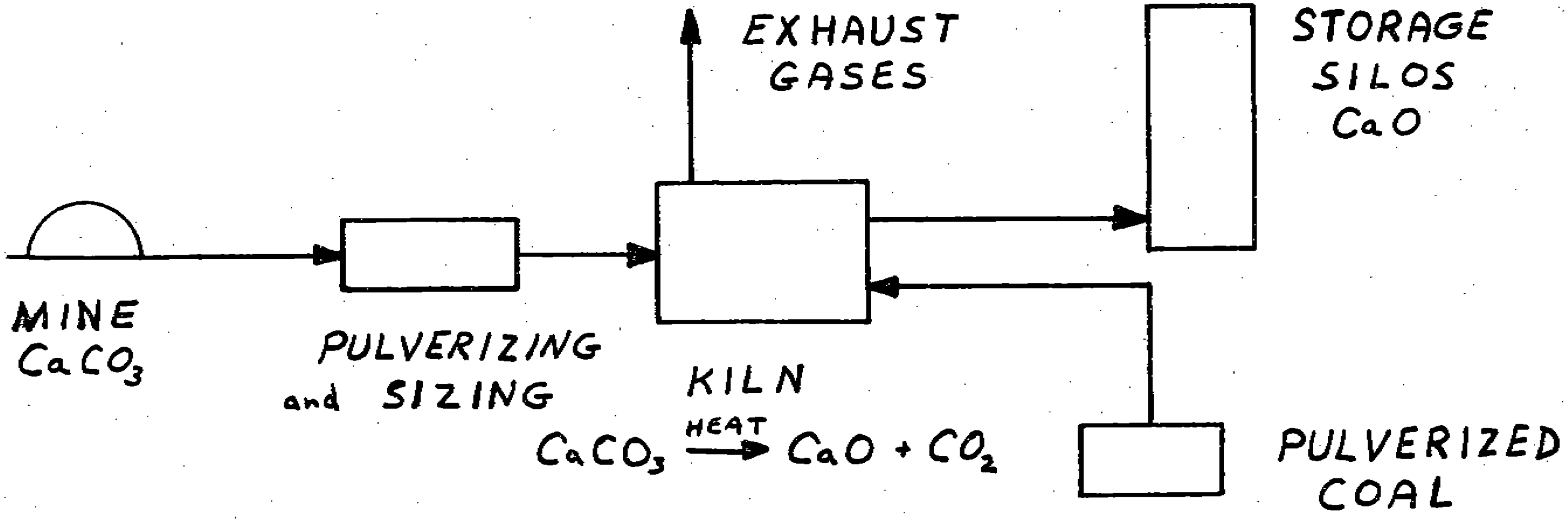


Figure 3. Flow Diagram of Lime Plant

coolers that are mounted on the shell of the kiln. Air entering the kiln goes through the coolers where it is heated and the product is cooled. The product falls from the coolers and is then conveyed to storage silos until it can be shipped to customers. Nos. 1 and 2 kilns have the satellite coolers, while No. 3 kiln is equipped with a contact grate cooler. Heat is transferred from the product by the grates and by air which passes over the grates.

The pulverized coal burns as it passes through the kiln and the resulting fly ash plus small particles of both limestone and product are exhausted out the stack. At the time of the sampling, Kiln No. 2 was not equipped with pollution control equipment. The gases and particulates went from the kiln through a fan to the exhaust stack. Ducon wet scrubbers are currently being inatalled on all three kilns.

The feed rate of limestone to the kiln is weighed and is recorded as the average tons/hour. The size of the feed is also recorded. At this plant there is no provision for determining the amount of coal burned or the amount of product produced. The plant personnel indicated that based on historical information, six tons of limestone feed yields three tons of product and requires one ton of coal for heat. These relationships were used in the calculations of coal usage and product yield in the sulfur material balance. Appendix F contains the plant production data.

A summary of the feed data, coal usage and product yield is given in Table 10.

Table 10

SUMMARY OF FEED, PRODUCT, AND COAL RATES

	Feed (T/hr)*	Product (T/hr)*	Coal** (T/hr)*
4-30-75	27	13.5	4.5
5-1-75	27	13.5	4.5
5-2-75	29	14.5	4.8
5-3-75	29	14.5	4.8
		ave: 14.0	

*9-hr average of 1st shift production

**Based on plant records indicating 1 Ton of coal/3 Ton of product

IV. SAMPLING LOCATION

The exhaust stack on Kiln No. 2 and the sampling location is shown in Figure 4. Figure 5 is a top view diagram of the stack indicating the location of the sampling platform and the boards used with the sampling train. The sampling ports (holes cut into the 1/4" steel stack) were located 21 feet (6.4 meters or 2.2 diameters) from the nearest downstream disturbance, an inlet from the I.D. fan. The ports were 32 feet (9.75 meters and 3.3 diameters) from the top of the stack. The stack was listed as being 10 feet (3.05 meters) in diameter, but after a measurement, the diameter proved to be 9 feet 8 inches (2.95 meters). The total stack height was approximately 80 feet (24.4 meters) with the ports being 45 feet (13.7 meters) above the ground.

The sampling platform extended only 90° around the stack. The platform was reached by climbing up the inlet duct and then up a 15 foot ladder onto the platform. The small platform presented a difficult situation for sampling with a twelve foot probe.

The ports were only 2 diameters from the inlet, requiring 48 traverse points (24 along each of the two perpendicular diameters) as specified in the <u>Federal Register</u>, Method 1. A 12' probe and pitot tube were used on the sampling train which was rested on two sampling boards which were provided by Virginia Lime. The consoles for the particulate trains were operated from the ground. Methods 6 and 7 samples were

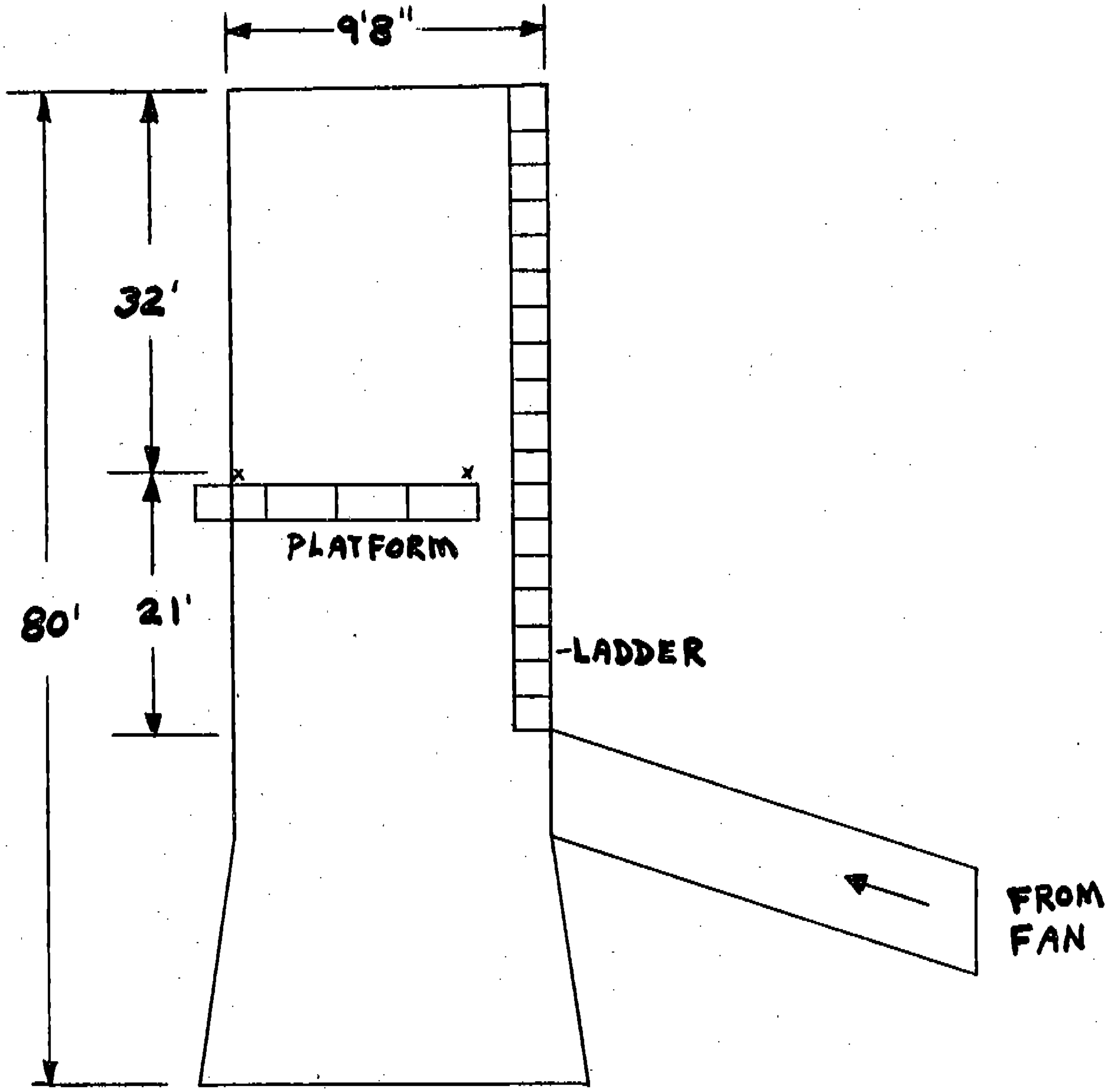


Figure 4. Side View of #2 Kiln Stack

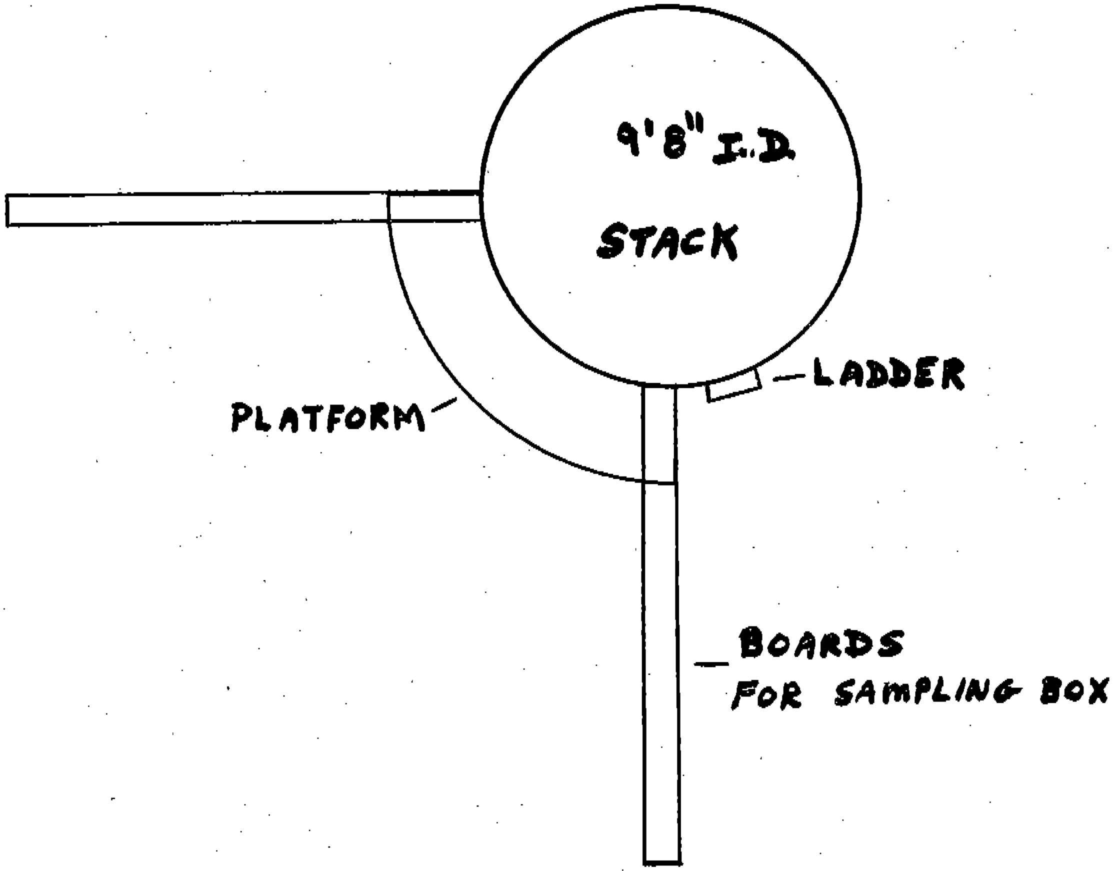


Figure 5. Top View of #2 Kiln Stack

both collected from the sampling platform. Samples for carbon monoxide analysis by Method 10 were collected in Tedlar bags at the stack, and the gas in these bags were analyzed with a Beckman NDIR set up in a nearby shed. The monitor was calibrated as specified on site.

V. SAMPLING AND ANALYTICAL PROCEDURES

The outlet gases from the rotary kiln at the Virginia Lime Company were sampled for particulate emissions, particle size, sulfur dioxide, nitrogen oxides, and carbon monoxide. Sampling procedures were designated by the EPA. Analyses of the collected samples were performed by Monsanto Research Corporation. Appendix H presents detailed sampling and analytical procedures.

Velocity and Gas Temperature

Gas velocities were measured with a calibrated type S pitot tube and inclined draft gauge. Velocities were measured at each sampling point across the stack diameter to determine an average value according to procedures described in the Federal Register, Methods 1 and 2. Temperatures were measured with the use of a thermocouple and digital thermometer that was calibrated in Dayton prior to the test.

Molecular Weight

A one-hour integrated sample of the stack gases was collected during each particulate test by pumping the gas into a Tedlar bag at the rate of approximately 1 cfh. The sampling train was assembled as shown in Figure 6. The bag sample was analyzed with an Orsat analyzer for CO_2, O_2, and CO as described in the Federal Register, Method 3. The CO content of the exhaust gas was also measured by using a Beckman Model

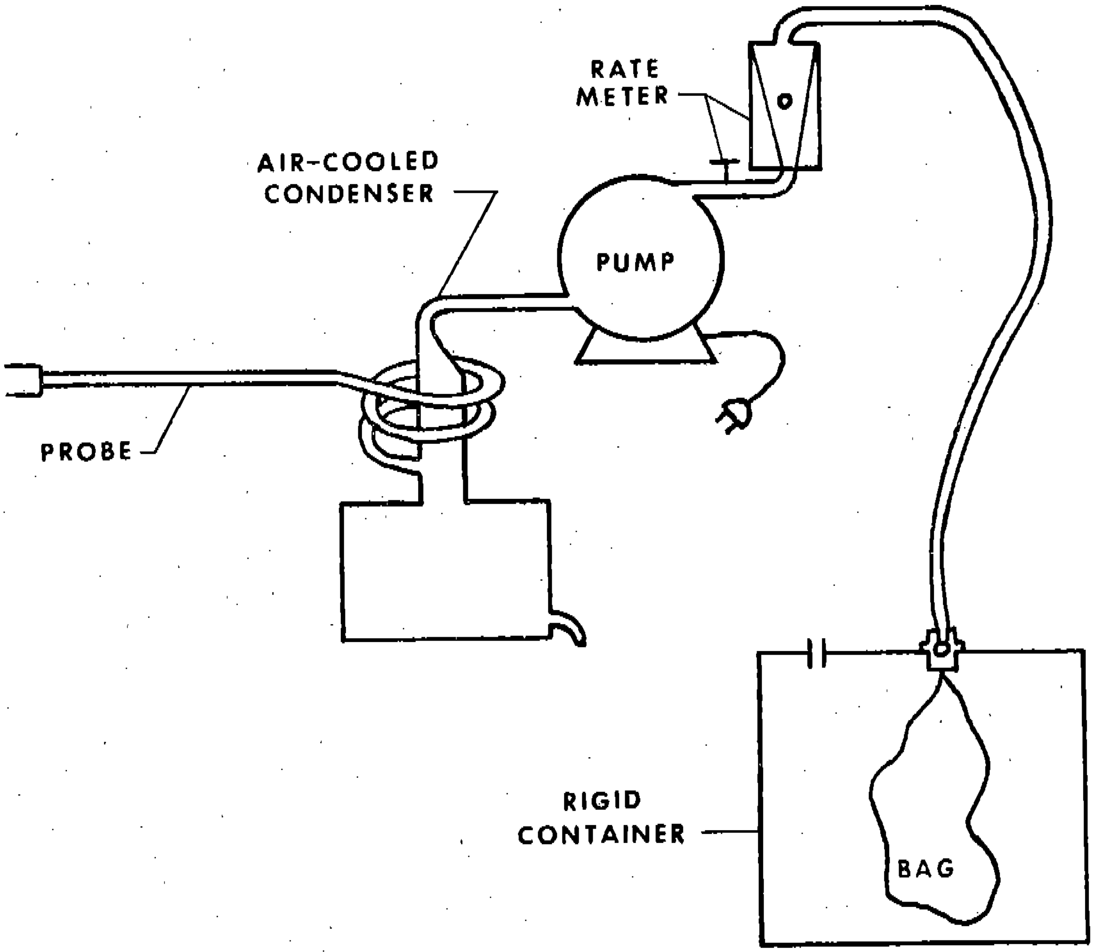


Figure 6. Integrated gas sampling train

864 Infrared Analyzer. The procedures of the Federal Register, Method 10 were followed during the testing program. Calibration gases included 302, 610, and 913 ppm of CO in nitrogen and a zero gas with less than 1 ppm CO.

Particulates

Concentrations of particulate matter in the exhaust gases were measured by Method 5 of the Federal Register. The sampling train consisting of a heated glass-lined probe, a 3-inch diameter glass-fiber filter, and a series of Greenburg-Smith impingers was used for particulate sampling, as shown in Figure 7.

Sampling was conducted under isokinetic conditions by monitoring stack gas velocity with a pitot tube and adjusting the sampling rate accordingly. The five particulate runs were performed during a four day period, with Runs Nos. 4 and 5 being performed on May 3. Run No. 1, a 26.7 minute run on a 24-point traverse, ended when the probe was broken moving from one port to the next. Run No. 2 was a 36 minute run on a 24-point traverse in the port that was not sampled in Run No. 1. This run was ended when a sudden electrical storm prevented further sampling for the day. Runs Nos. 3, 4, and 5 were all two 24-point traverse runs that lasted for 48 minutes. A 0.364 inch diameter probe tip was used in all five runs.

The filter had to be changed at the end of each traverse because of the high grain loading in the exhaust gases. If this had not been done, it would have been impossible to maintain the required ΔH across the orifice. Extreme care had to be taken when handling and cleaning the probe because of the amount of particulate that accumulated during the run.

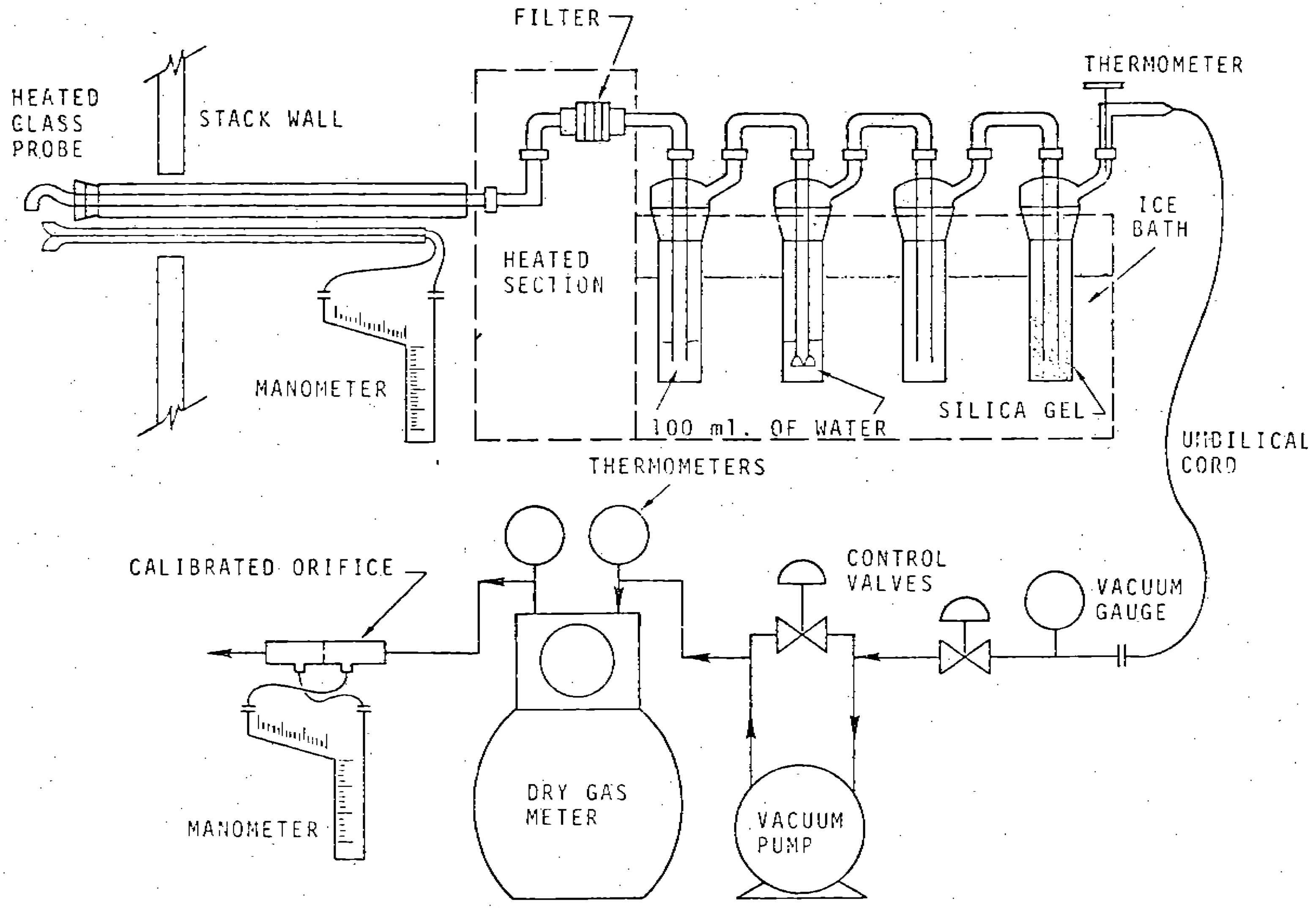


Figure 7. Particulate sample train

The various pieces of glassware and the probe were cleaned according to Method 5 procedures. The acetone and water washes and the impinger water was placed in Wheaton bottles and shipped to the Dayton Laboratory for analysis. After analysis at the lab, the probe washings and filter collection weights are referred to as the "front half" and the "total", with the "total" being the front half plus weights from the impinger water and water wash, the acetone wash, and the extraction of the water.

Nitrogen Oxides

Nitrogen oxides were collected in evacuated 2-liter flasks containing 25 ml of a dilute sulfuric acid/hydrogen peroxide absorbing solution. The sampling and analytical procedures were performed according to Method 7 of the Federal Register, Vol. 36, No. 247, December 23, 1971. The sampling train is illustrated in Figure 8. The volume of all flasks was determined in the laboratory prior to sampling.

Sulfur Dioxide

Sulfur dioxide concentration was measured according to the procedures set forth in Method 6 of the Fereral Register.

Carbon Monoxide

An attempt was made to determine the carbon monoxide levels in the exhaust gases with the use of a Beckman Model 864 Infrared Analyzer. Sampling was done according to Method 10 of the Federal Register, Vol. 39, No. 47, March 8, 1974. Calibration gases of 302, 610, and 913 ppm were used to calibrate the infrared analyzer. The 1 hour integrated gas samples used for Method 3 were also used for Method 10 analysis.

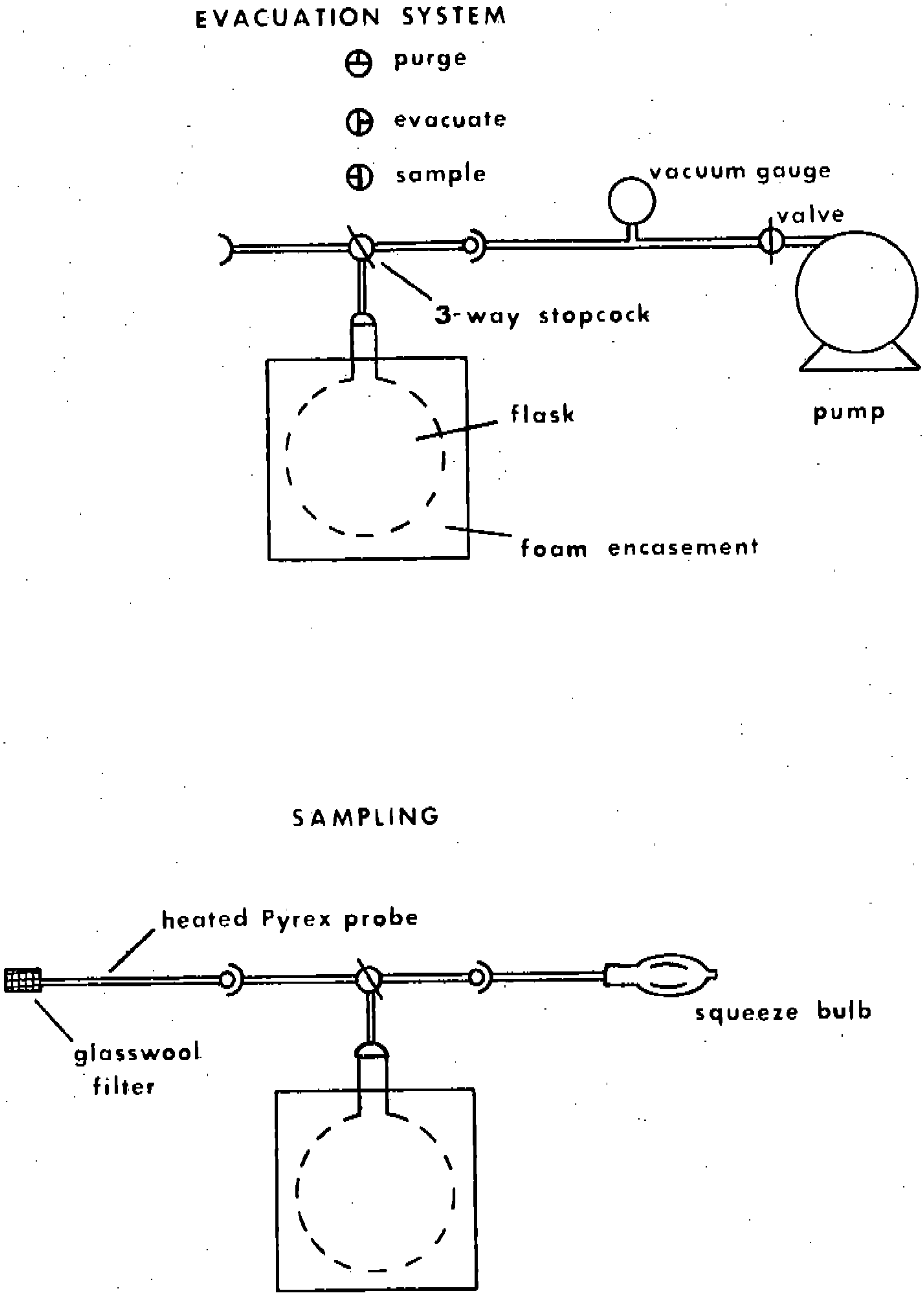


Figure 8. Nitrogen oxide sampling equipment

The CO levels proved to be too high to determine with the infrared analyzer since its upper limit was 3000 ppm. The method as written requires an instrument for the 0-1000 ppm range. The values indicated for CO percent in this report are the result of an Orsat analysis on the integrated sample.

Total Sulfur Analysis

The samples of the limestone feed and the pebble lime product that were collected during the Method 5 runs were analyzed for total sulfur content. Two methods were used to determine the amount of sulfur present, the Standard Bromine Method and the Leco Method with both being included in ASTM C25-72, Chemical Analysis of Limestone. The Bromine Method involves determining the sulfur present by weighing an amount of limestone, reacting it to form $BaSO_4$, and weighing the $BaSO_4$ to determine the amount of sulfur present. The Leco Method involves the use of a Leco automatic titrator to neutralize the sulfur dioxide formed when the limestone is burnt.

Coal Analysis-Proximate

A proximate analysis of the coal was performed according to ASTM D271-70. The moisture, volatile, ash, fixed carbon, sulfur, and Btu contents were determined. The coal samples were collected from the storage silo at a location near the pulverizer that was used to grind the coal to a fine powder which was then fed directly into the kiln.

Particle Sizing

Two particle sizing runs were performed on the exhaust gases from the kiln. A Brink® BMS-11 Sampler was used to obtain the size distribution. The sampler was operated according to the accompanying manual (Appendix D). The flow rate through the sampler was determined with the use of a preliminary velocity traverse on the stack and the various calibration curves provided with the instrument. A predetermined pressure drop across the particle sizer resulted in a calculated velocity and therefore a desired particle size distribution.

APPENDIX A

COMPLETE PARTICULATE RESULTS AND SAMPLE CALCULATIONS

TABLE A-1

Method 5 Data

ABBR	DESCRIPTION	UNITS	1	2	3	4	5
TT	DURATION OF RUN	MINUTES	26.7	36.0	48.0	48.0	48.0
PB	BAROMETRIC PRESSURE	IN HG	28.01	28.03	28.02	27.95	27.95
DELH	AVG ORIFICE PRESS DROP	IN H2O	0.535	0.920	0.850	0.696	1.153
VM	VOL DRY GAS(METER CON)	DCF	12.515	21.414	28.146	25.405	28.442
TM	AVG GAS METER TEMP	DEG F	66.7	83.7	77.9	71.0	68.1
VMSTD	VOL DRY GAS (STD COND)	DSCF	11.80	19.59	26.01	23.71	26.72
VW	TOTAL H2O COLLECTED	ML	17.6	11.6	21.4	24.9	28.2
VWG	VOL H2O VAPOR(STD CON)	SCF	0.834	0.550	1.014	1.180	1.337
PCNTM	PERCNT MOISTURE BY VOL		6.60	2.73	3.75	4.74	4.76
MD	MOLE FRACTION DRY GAS		0.934	0.973	0.962	0.953	0.952
CO2	PERCENT CO2		6.1	9.7	10.7	11.0	8.8
O2	PERCENT O2		12.6	14.3	12.4	14.0	15.5
N2	PERCENT N2		81.3	76.0	76.6	75.0	75.7
MWD	MOL WT OF DRY GAS		29.5	30.1	30.2	30.3	30.0
MW	MOL WT OF STACK GAS		28.7	29.8	29.7	29.7	29.5
DELP	AVG STACK VELOCITY HEAD	IN H2O	0.067	0.114	0.109	0.092	0.099
TS	STACK TEMPERATURE	DEG F	403.	392.	388.	394.	395.
PM	STACK PRESSURE(STATIC)	IN H2O	-0.14	-0.14	-0.14	-0.14	-0.14
PS	STACK PRESSURE (ABS)	IN HG	28.00	28.02	28.01	27.94	27.94
VS	AVG STACK GAS VELOCITY	FPM	1155.	1468.	1433.	1319.	1379.
DS	STACK DIAMETER	INCHES	116.00	116.00	116.00	116.00	116.00
AS	STACK AREA	SQ IN	10568.3	10568.3	10568.3	10568.3	10568.3
QS	STACK FLOW RT(DRY STD)	DSCFM	45515.	61090.	59260.	53432.	55795.
QA	STACK FLOW RT(ACTUAL)	ACFM	84753.	107751.	105183.	96796.	101189.
DN	PROBE TIP DIAMETER	INCHES	0.364	0.364	0.364	0.364	0.364
PCTI	PERCENT ISOKINETIC		98.8	90.5	92.9	94.0	101.4
MF	PARTICULATE (FRONT)	MG	8944.10	11072.50	19586.70	13125.00	15864.70
MT	PARTICULATE (TOTAL)	MG	0.00	0.00	19727.10	13180.50	15938.20
CAN	PARTICULATE (FRONT)	GR/DSCF	11.6765	8.7061	11.5965	8.5239	9.1422
CAO	PARTICULATE (TOTAL)	GR/DSCF	0.0000	0.0000	11.6797	8.5599	9.1845
CAT	PARTICULATE (FRONT)	GR/ACF	6.2654	4.9319	6.5280	4.7013	5.0367
CAU	PARTICULATE (TOTAL)	GR/ACF	0.0000	0.0000	6.5748	4.7211	5.0600
CAW	PARTICULATE (FRONT)	LB/HR	4554.571	4558.029	5889.376	3903.168	4371.432
CAX	PARTICULATE (TOTAL)	LB/HR	0.000	0.000	5931.591	3919.673	4391.685

Table A-2

PARTICULATE CALCULATIONS

Example: Run No. 3

1. Volume of dry gas sampled at standard conditions (dscf[a])

$$\text{VMSTD} = \frac{17.7 \times \text{VM}\left(\text{PB} + \frac{\text{DELH}}{13.6}\right)}{(\text{TM} + 460)}$$

$$= \frac{17.7 \times 28.146 \times \left(28.02 + \frac{.85}{13.6}\right)}{77.9 + 460}$$

$$= 26.009 \text{ dscf}$$

2. Volume of water vapor at standard conditions (scf[b])

$$\text{VWG} = 0.0474 \times \text{VW}$$

$$= 0.0474 \times 21.4$$

$$= 1.014$$

3. Percent moisture in stack gas

$$\text{PCNTM} = \frac{100 \times 1.014}{26.009 + 1.014}$$

$$= 3.75$$

PARTICULATE CALCULATIONS

4. Mole fraction of dry gas

$$MD = \frac{100 - PCNTM}{100}$$

$$= \frac{100 - 3.75}{100}$$

$$= .963$$

5. Molecular weight of dry stack gas

$$MWD = (\%CO_2 \times 0.44) + (\%O_2 \times 0.32) + [(\%C + \%N_2) \times 0.28]$$

$$= (10.7 \times 0.44) + (12.4 \times 0.32) + [(.3 + 76.6) \times 0.28]$$

$$= 30.2$$

6. Molecular weight of wet stack gas

$$MW = MWD \times MD + 18\ (1 - MD)$$

$$= 30.2 \times 0.963 + 18\ (1 - .963)$$

$$= 27.7$$

7. Stack gas velocity at stack conditions (fpm^c)

$$VS = 4360 \times \left[\frac{\sum_{i=1}^{i=n} \sqrt{DELP \times (TS + 460)}}{n}\right] \times \left[\frac{1}{PS \times MW}\right]^{\frac{1}{2}}$$

where n = the number of data points

$$= 4360 \times 9.16 \times \left(\frac{1}{28.02 \times 27.7}\right)^{\frac{1}{2}}$$

$$= 1433 \text{ fpm}$$

Table A-2 (Continued)

PARTICULATE CALCULATIONS

8. Stack gas volumetric flow rate at standard conditions (dscfm[d])

$$QS = \frac{0.123 \times VS \times AS \times MD \times PS}{TS + 460}$$

$$= \frac{0.123 \times 1433 \times 10568.3 \times 0.963 \times 28.02}{388 + 460}$$

$$= 59260 \text{ dscfm}$$

9. Stack gas volumetric flow rate at stack conditions (acfm[e])

$$QA = \frac{0.05645 \times QS\ (TS + 460)}{PS \times MD}$$

$$= \frac{0.05645 \times 59260 \times (388 + 460)}{28.02 \times 0.963}$$

$$= 105{,}183 \text{ acfm}$$

10. Area of nozzle (sq ft)

$$AN = 54.54 \times 10^{-4}(DN)^2$$

$$= 54.54 \times 10^{-4}(0.364)^2$$

$$= 7.23 \times 10^{-4} \text{ sq ft}$$

11. Percent Isokinetic

$$PCTI = \frac{100.0(TS + 460)\left[0.00267(VW) + \frac{VM}{(TM + 460)}\left(PB + \frac{DELH}{13.6}\right)\right]}{(TT)\ (VS)\ (PS)\ (AN)}$$

$$= \frac{100.0(388+460)\left[0.00267(21.4)+\frac{28.146}{(77.9+460)}\left(28.02+\frac{.85}{13.6}\right)\right]}{48 \times 23.88 \times 28.01 \times (7.23 \times 10^{-4})}$$

$$= 92.9$$

Table A-2 (Continued)

PARTICULATE CALCULATIONS

12. Particulate-probe, cyclone, and filter (gr/dscf)

$$CAN = 0.0154 \times \frac{MF}{VMSTD}$$

$$= 0.0154 \times \frac{19586.7}{26.01}$$

$$= 11.5965 \text{ gr/dscf}$$

13. Particulate-total (gr/dscf)

$$CAO = 0.0154 \times \frac{MT}{VMSTD}$$

$$= 0.0154 \times \frac{19727.1}{26.01}$$

$$= 11.6797$$

14. Particulate-probe, cyclone, and filter at stack conditions (gr/acf)

$$CAT = \frac{17.7 \times CAN \times PS \times MD}{(TS + 460)}$$

$$= \frac{17.7 \times 11.5965 \times 28.02 \times 0.963}{(388 + 460)}$$

$$= 6.5280 \text{ gr/acf}$$

Table A-2 (Continued)

PARTICULATE CALCULATIONS

15. Particulate-total at stack conditions (gr/acf)

$$CAU = \frac{17.7 \times CAO \times PS \times MD}{(TS + 460)}$$

$$= \frac{17.7 \times 11.6797 \times 28.02 \times 0.963}{(388 + 460)}$$

$$= 6.5748 \text{ gr/acf}$$

16. Particulate-probe, cyclone and filter (lb/hr)

$$CAW = 0.00857 \times CAN \times QS$$

$$= 0.00857 \times 11.5965 \times 59260$$

$$= 5889.376 \text{ lb/hr}$$

17. Particulate-total (lb/hr)

$$CAX = 0.00857 \times CAO \times QS$$

$$= 0.00857 \times 11.6797 \times 59260$$

$$= 5931.591 \text{ lb/hr}$$

---

[a] Dry standard cubic feet @ 70°F, 29.92 in. Hg

[b] Standard cubic feet @ 70°F, 29.92 in. Hg

[c] Feet per minute @ stack conditions; n = number of data points

[d] Dry standard cubic feet per minute @ 70°F, 29.92 in. Hg

[e] Actual cubic feet per minute @ stack conditions

APPENDIX B

COMPLETE NO_x RESULTS AND SAMPLE CALCULATIONS

TABLE B-1

NO_x RESULTS

```
NOX CALCULATION
VSC-SAMPLE VOLUME AT STANDARD CONDITIONS(DRY BASIS),ML.
MASS-MASS OF NO2 IN GAS SAMPLE,UG.
PPM-PPM,NOX AS NO2
LB/SCF-CONCENTRATION OF NOX AS NO2(DRY BASIS),LB/SCF


    VSC                MASS                PPM                LB/SCF

0.159819E+04       0.377809E+03        0.123872E+03        0.146566E-04
0.182587E+04       0.540489E+03        0.155113E+03        0.183531E-04
0.185328E+04       0.473971E+03        0.134012E+03        0.158564E-04
0.166384E+04       0.383593E+03        0.120806E+03        0.142939E-04
0.184574E+04       0.159455E+03        0.452689E+02        0.535624E-05
0.903652E+03       0.241880E+03        0.140259E+03        0.165955E-04
0.924039E+03       0.242603E+03        0.137574E+03        0.162779E-04
0.162061E+04       0.213682E+03        0.690908E+02        0.817487E-05
0.159304E+04       0.419744E+03        0.138067E+03        0.163362E-04
0.190149E+04       0.372747E+03        0.102719E+03        0.121538E-04
0.160496E+04       0.220912E+03        0.721251E+02        0.853389E-05
0.170335E+04       0.220912E+03        0.679589E+02        0.804094E-05
```

SOURCE SAMPLING PROCEDURE – EPA METHOD 7 – NOx

Date 1/30/75

Company Va Lime

Project 6912-11

Sample Point #2 kiln outlet

Analyst Peltier + McDonald

Sample			Flask	Initial			Clean Up Analysis		Final			ABS	TOTAL	FLASK	NOx	NOx
Day	Time	No.	No.	Bar. Press. in Hg	Flask Vacuum ~~in~~ Hg cm	Temp. °F	Day	Time	Bar. Press. in Hg	Flask Vacuum in Hg	Temp. °F	@ 420	Dil. ml	Vol.-ABS ml	Conc. lb/scf	Conc. ppm
4/30	3:15	1	17	27.98	23.98 60.9	67	5/1/75	9 30 Am	28.02	-.63 -1.6	61					
4/30	3:20	2	11	27.98	26.89 68.3	67	5/1/75	9 35 Am	28.02	-.55 -1.4	61					
4/30	3:25	3	15	27.98	27.17 69.0	67	5/1/75	9 40 Am	28.02	-1.42 -3.6	61					
4/30	3:30	4	14	27.98	27.13 68.9	67	5/1/75	9 55 Am	28.02	-3.07 -7.8	61					
5/1/75	11:05	5	2	28.02	27.56 70.0	61	5/1/75	9 45 Am	28.10	1.22 -3.1	62 ✓					
5/1/75	11:10	6	3	28.02	27.09 68.9	61	5/2	9 00 am	28.10	14.45 -36.7	62 ✓					
5/1/75	11:15	7	50	28.02	27.48 69.8	61	5/2	9 05 am	28.10	14.17 -36.0	62 ✓					
5/1/75	11:20	8	10	28.02	27.24 69.2	61	5/2	9 15 am	28.10	3.98 -10.8	62 ✓					
5/1/75	1:05	9	7	28.03	27.17 69.0	71	5/2	9 20 am	28.10	4.33 -11.0	62 ✓					
5/1/75	1:10	10	8	28.03	27.05 68.7	71	5/2	9 25 am	28.10	.79 -2.0	62 ✓					
5/1/75	1:15	11	42/4	28.03	27.44 69.7	71	5/2	9 30 am	28.10	3.94 -10.0	62 ✓					
5/1/75	1:20	12	12	28.03	27.20 69.1	71	5/2	9 35 am	28.10	2.72 -7.0	62 ✓					

METHOD 7

NO_x CALCULATIONS

Plant Virginia Lime Company

Date 7/23/75

Test No. Sample Calculation Test #3 Flask #15

Volume of flask and value (ml) = VF = 2112

Initial absolute pressure of flask (in Hg) = PI = 0.81

Final absolute pressure of flask (in Hg) = PF = 26.60

Initial temperature of flask (°F) = TI = 67

Final temperature of flask (°F) = TF = 61

Mass of NO_x as NO_2 in gas sample (μg) = M = 474

Volume of sample at standard conditions, dry basis(ml) = VS

$$VS = 17.71 \text{ x } (VF-25)\left(\frac{PF}{TF+460} - \frac{PI}{TI+460}\right)$$

$$VS = 17.71 \text{ x } (2132 - 25)\left(\frac{26.60}{61+460} - \frac{0.81}{67+460}\right) = 1852 \text{ ml}$$

Concentration of NO_x as NO_2 (dry basis) (lbs/scf) = C

$$C = 6.2 \text{ x } 10^{-5} \text{ x}\left(\frac{M}{VS}\right)$$

$$C = 6.2 \text{ x } 10^{-5} \text{ x } \left(\frac{474}{1852}\right) = 1.587 \times 10^{-5} \frac{\text{lbs}}{\text{scf}}$$

$$ppm = \frac{24.5}{MW} \times 1.6018 \times 10^{7} \times \frac{\#}{SCF}$$

$$ppm = \frac{24.5}{46} \times 1.6018 \times 10^{+7} \times 1.587 \times 10^{-5} = 135 \text{ ppm}$$

APPENDIX C

COMPLETE SO_2 RESULTS AND SAMPLE CALCULATIONS

METHOD 6

SO_2 CALCULATION

Plant Virginia Lime Date 4/30/75

Location Run# 1

Barometric Pressure Absolute (in Hg) BP = 28.01

Average Meter Temperature (°R)

Absolute (°F + 460) T_m = 532

Volume Through Dry Gas Meter (CF) V_m = 1.100

Volume of $Ba(ClO_4)_2$ to Titrate Sample (ml) V_t = 2.73

Volume of $Ba(ClO_4)_2$ to Titrate Blank (ml) V_b = 0.50

Normality of $Ba(ClO_4)_2$ Solution (g-eq/l) N = 0.0108

Total Volume of Solution (ml) V_s = 250

Volume of Aliquot (ml) V_a = 20

Volume of Gas at Standard Conditions (SCF) = V_g

$$V_g = 17.71\frac{(V_m)(BP)}{(T_m)} = 17.71\frac{(1.100)(28.01)}{(532)} = 1.026$$

Concentration of SO_2 (lbs/SCF) dry basis = C

$$C = 7.05 \times 10^{-5}\frac{(V_t-V_b)(N)(V_s)}{(V_g)(V_a)} = 7.05 \times 10^{-5}\frac{(2.23)(0.0108)(250)}{(1.026)(20)}$$

C = 2.0686×10^{-5} lbs/SCF

Velocity of Stack Gas (Actual)(FPS) V = 24.2 *

% Moisture in Stack Gas M = 6.6

Area of Stack (ft^2) A = 73.39

Absolute Stack Temperature (°R) T_s = 863

Absolute Stack Pressure (in Hg) P_s = 28.00

SO_2 Flow Rate (lbs/hr) = S

$$S = \frac{6.377 \times 10^{+4}(1-(M\times10^{-2}))(V)(A)(P_s)(C)}{(T_s)}$$

$$S = \frac{6.377 \times 10^{4}(.934)(24.2)(7339)(28.00)(2.0686 \times 10^{-5})}{(863)}$$

S = 71.0 (lbs/hr)

ppm = 127

* Correlate to preliminary traverse data on 4/29/75

METHOD 6

SO_2 CALCULATION

Plant Virginia Lime Date 4/30/75
Location Run# 2

Barometric Pressure Absolute (in Hg) BP = 28.01
Average Meter Temperature (°R)
Absolute (°F + 460) T_m = 538
Volume Through Dry Gas Meter (CF) V_m = 1.018
Volume of $Ba(ClO_4)_2$ to Titrate Sample (ml) V_t = 4.20
Volume of $Ba(ClO_4)_2$ to Titrate Blank (ml) V_b = 0.50
Normality of $Ba(ClO_4)_2$ Solution (g-eq/l) N = 0.0108
Total Volume of Solution (ml) V_s = 250
Volume of Aliquot (ml) V_a = 20
Volume of Gas at Standard Conditions (SCF) = V_g

$$V_g = 17.71 \frac{(V_m)(BP)}{(T_m)} = 17.71 \frac{(1.018)(28.01)}{(538)} = 0.939$$

Concentration of SO_2 (lbs/SCF) dry basis = C

$$C = 7.05 \times 10^{-5} \frac{(V_t - V_b)(N)(V_s)}{(V_g)(V_a)} = 7.05 \times 10^{-5} \frac{(3.7)(0.0108)(250)}{(.939)(20)}$$

C = 3.7502×10^{-5} lbs/SCF

Velocity of Stack Gas (Actual)(FPS) V = 24.2 *
% Moisture in Stack Gas M = 6.6
Area of Stack (ft^2) A = 73.39
Absolute Stack Temperature (°R) T_s = 863
Absolute Stack Pressure (in Hg) P_s = 28.00

SO_2 Flow Rate (lbs/hr) = S

$$S = \frac{6.377 \times 10^{+4}(1-(M \times 10^{-2}))(V)(A)(P_s)(C)}{(T_s)}$$

$$S = \frac{6.377 \times 10^4 (24.2)(.934)(73.39)(28.00)(3.7502 \times 10^{-5})}{(863)}$$

S = 128.7 (lbs/hr)

ppm = 230

* Correlate to preliminary traverse data on 4/29/75

METHOD 6

SO_2 CALCULATION

Plant Virginia Lime Date 5/7/75
Location Run# 3

Barometric Pressure Absolute (in Hg) BP = 28.02
Average Meter Temperature (°R)
Absolute (°F + 460) T_m = 547.5
Volume Through Dry Gas Meter (CF) V_m = 0.867
Volume of $Ba(ClO_4)_2$ to Titrate Sample (ml) V_t = 2.65
Volume of $Ba(ClO_4)_2$ to Titrate Blank (ml) V_b = 0.50
Normality of $Ba(ClO_4)_2$ Solution (g-eq/l) N = 0.0108
Total Volume of Solution (ml) V_s = 250
Volume of Aliquot (ml) V_a = 50
Volume of Gas at Standard Conditions (SCF) = V_g

$$V_g = 17.71 \frac{(V_m)(BP)}{(T_m)} = 17.71 \frac{(.867)(28.02)}{(547.5)} = .786$$

Concentration of SO_2 (lbs/SCF) dry basis = C

$$C = 7.05 \times 10^{-5} \frac{(V_t - V_b)(N)(V_s)}{(V_g)(V_a)} = 7.05 \times 10^{-5} \frac{(2.15)(0.0108)(250)}{(.786)(20)}$$

C = 2.6034×10^{-5} lbs/SCF

Velocity of Stack Gas (Actual)(FPS) V = 23.88 *
% Moisture in Stack Gas M = 3.75
Area of Stack (ft^2) A = 73.39
Absolute Stack Temperature (°R) T_s = 848
Absolute Stack Pressure (in Hg) P_s = 28.01

SO_2 Flow Rate (lbs/hr) = S

$$S = \frac{6.377 \times 10^{+4}(1-(M \times 10^{-2}))(V)(A)(P_s)(C)}{(T_s)}$$

$$S = \frac{6.377 \times 10^{4} (.9625)(23.88)(73.39)(28.01)(2.6034 \times 10^{-5})}{(848)}$$

S = 92.5 (lbs/hr)

Ppm = 160

* Correlate with Run #3 - Method 5

APPENDIX D

PARTICLE SIZE DATA FROM BRINK® BMS-11

TABLE D-1

RUN #1, PARTICLE SIZING

```
          CASCADE IMPACTOR PARTICLE SIZE DISTRIBUTION FOR RUN 1

          INPUT VARIABLE           UNITS       INPUT DATA
          --------------           -----       ----------

          SAMPLING TIME           MIN              13.0
          PRESSURE DROP           IN HG             1.00
          STATIC PRESSURE         IN H2O           -0.14
          PARTICLE DENSITY        G/CC              3.00
          BAROMETRIC PRESSURE     IN HG            28.02
          GAS MOL WT                               29.7
          GAS TEMPERATURE         DEG F           160.0
          GAS VISCOSITY           POISE          0.00021
          GAS DENSITY             G/CC           0.00099

 STAGE    WT OF MATERIAL     DPC       MG/ACF     WT PCNT     CUM WT PCNT
 -----    --------------     ---       ------     -------     -----------

 CYCLONE       67.300                   91.88      96.46          3.55

   1            0.450        2.77        0.62       0.65          2.90

   2            0.460        1.62        0.63       0.66          2.24

   3            0.100        1.10        0.14       0.15          2.10

   4            0.120        0.56        0.17       0.18          1.93

   5            0.140        0.34        0.20       0.21          1.72

 FILTER         1.200                    1.64       1.72          0.00
```

TABLE D-2

RUN #2, PARTICLE SIZING

```
CASCADE IMPACTOR PARTICLE SIZE DISTRIBUTION FOR RUN 2

INPUT VARIABLE          UNITS      INPUT DATA
--------------          -----      ----------

SAMPLING TIME           MIN             5.0
PRESSURE DROP           IN HG           4.50
STATIC PRESSURE         IN H2O         -0.14
PARTICLE DENSITY        G/CC            3.00
BAROMETRIC PRESSURE     IN HG          27.95
GAS MOL WT                             29.7
GAS TEMPERATURE         DEG F         160.0
GAS VISCOSITY           POISE        0.00021
GAS DENSITY             G/CC         0.00099

STAGE    WT OF MATERIAL    DPC     MG/ACF     WT PCNT     CUM WT PCNT
-----    --------------    ---     ------     -------     -----------

CYCLONE      66.700               121.96       97.09          2.92

  1           0.590       1.96      1.08        0.86          2.06

  2           0.140       1.13      0.26        0.21          1.85

  3           0.210       0.75      0.39        0.31          1.55

  4           0.100       0.36      0.19        0.15          1.40

  5           0.060       0.18      0.11        0.09          1.32

FILTER        0.900                 1.65        1.32          0.01
```

Brink data

Run #1 -5:00pm 5/2 - 3 mm probe tip

1" Hg ΔP (.05 CFM)

13 minute sampling time

Exit temp = 160° F

Run# 2 5/3/75 3 mm probe tip

4.5" Hg ΔP (.10 CFM)

5 minute run

Exit temp - 160° F

A reprint from I&EC
Industrial & Engineering Chemistry
Vol. 50, No. 4, April 1958, Pages 645-648

Cascade Impactor for Adiabatic Measurements

J. A. BRINK, Jr.[1] Monsanto Chemical Co., Everett, Mass.

Data on development, design, and use of a practical instrument in the field make it possible to build a convenient tested device for special purposes. Particle-size measurements make possible determination of acceptable stack discharges of aerosols, evaluation of installed collection equipment, rational selection and design of equipment, and recognition of potential problems early in the development of new processes.

IMPINGEMENT DEVICES have been used for years for sampling gas-borne particles (*4-6*). Owens (*9*) and Ferry, Farr, and Hartmann (*1*) used a single jet and a dry glass slide to collect samples of gas particulates suspended in a gaseous medium, and measured the sizes of impacted particles with a microscope by laborious particle counts. In May's cascade system of impactor stages (*8*) particles were separated into five fractions ranging in particle size from 1 to 50 microns. Laskin (7) used May's impactor on heavy aerosol particles of micron and submicron sizes. A modified cascade impactor extended measurements into the submicron range (*13*).

Extensive theoretical and experimental work with cascade impactors has been done by Ranz and Wong (*11*, *12*), Gillespie and Johnstone (*2*, *3*), and others at the University of Illinois. Pilcher, Mitchell, and Thomas (*10*) and Wilcox (*14*, *15*) investigated the characteristics of impactors and made significant improvements in design.

In many industrial plants aerosols are found in high concentrations in gases saturated with vapor at 30° to 200° C. For measuring particle-size distributions of aerosols in such gases, special equipment is required. An "in-line" cascade impactor and accessory equipment for adiabatic measurements on industrial processes were developed at Monsanto in 1954. They are small, light, and compact, and can be carried in a suitcase for tests at plants throughout the country.

Impactor and Auxiliary Apparatus

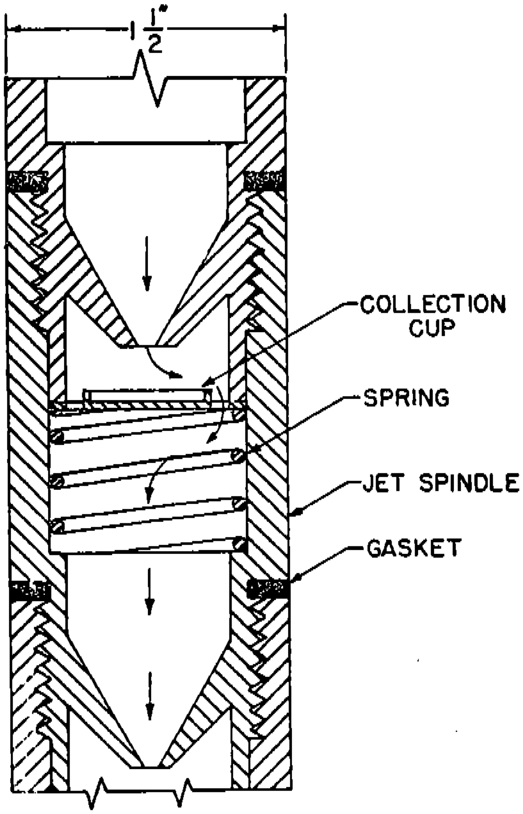
The cascade impactor has five in-line stages, each of which has a jet that utilizes a collection cup as an impaction plate. A spring holds each collection cup in place. The particles suspended in the gases pass through a jet, particles with sufficient inertia impact against a cup, and the remainder pass through annular slots located around the cup. Each collection cup has annular slots with a total cross-sectional area 30 times the area of the largest jet; turbulent effects at the slots were negligible with this design. The dimensions of the impactor jets (Table I) were selected as described by Ranz and Wong (*11*). The impactor is $15^1/_2$ inches long and was machined from 316 stainless steel. Particles in the 0.3- to 3.0-micron range are collected.

A glass cyclone, with the same dimensions as that described by Gillespie (*2*, *3*), is used upstream from the impactor. Two filters, consisting of Corning No. 9480 filter tubes packed tightly with No. 800 Pyrex glass wool, collect particles less than 0.3 micron in diameter. The cyclone, impactor, and filters are mounted in a box with a removable side. A No. $2^1/_2$ L-R Manufacturing Co. blower, inside the box, is driven by a 8000 r.p.m. Fairchild Industries (Model

Table I. Dimensions of Cascade Impactor Jets

	Dimensions, Cm.	
Jet No.	Jet diam.	Spacing of jet opening[a]
1	0.249	0.747
2	0.1775	0.533
3	0.1396	0.419
4	0.0946	0.282
5	0.0731	0.220

[a] From collection cup surface.



The in-line impactor has five stages. Particles in the range of 0.3 to 3.0 microns are collected by successive impingement

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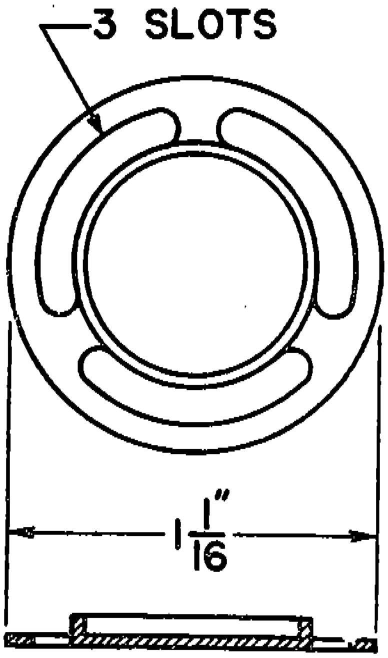
[1] Present address, Research Department, Monsanto Chemical Co., St. Louis, Mo.



Collection cups are positioned so that the distance from the jet decreases as the jet diameter becomes smaller. Annular slots around cup minimize turbulence

1401) motor on the back side of the box. A heater, consisting of three 12-inch sections of Nichrome resistance wire (Catalog No. 416, Size 1, coiled type, Eagle Electric Mfg. Co.), is mounted in the box. The three sections of the heater are connected in series and operated on 110 volts. The air temperature is controlled with a 100° to 400° F. thermostat (Fenwall, Inc., Catalog No. 1731-0). The box was designed so that air could be circulated at a high velocity past the cyclone, impactor, and filters. The blower discharges air through a duct below the heater and then over the heater, impactor, and cyclone back to the blower inlet. Thermometers, mounted on the removable side of the box, indicate the temperature of the air entering the blower and leaving the heater. Two manometers, mounted on the removable side of the box and connected to the impactor, measure the static pressure at the inlet and the pressure drop across the impactor.

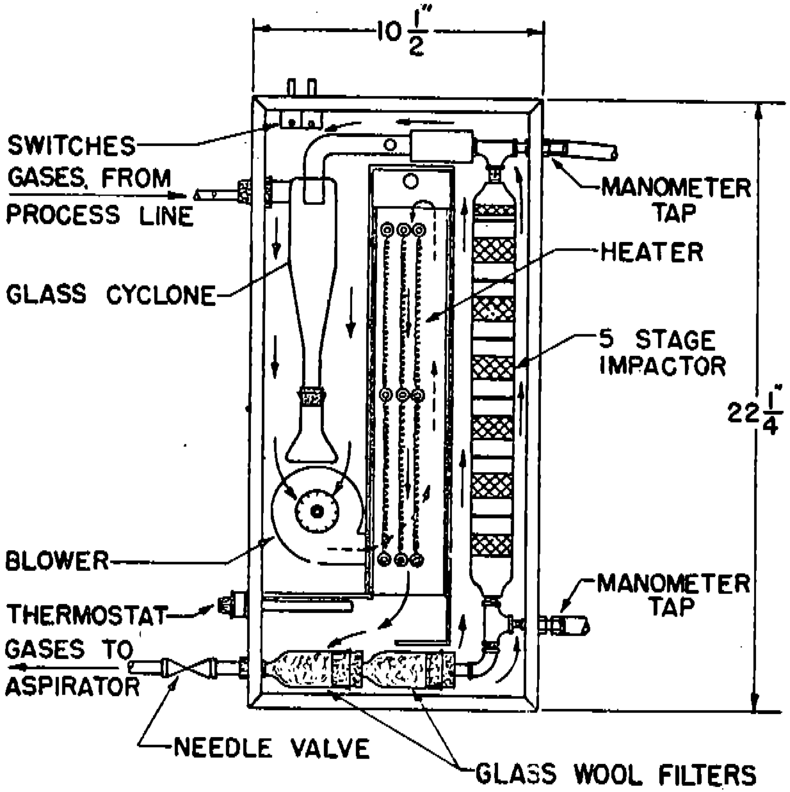
A sample line, heated with flexible tape heaters (electromagnetic heating tape, Howe and French), is controlled with a Variac. Sample probes and lines are sized for isokinetic sampling.

Experimental Procedure

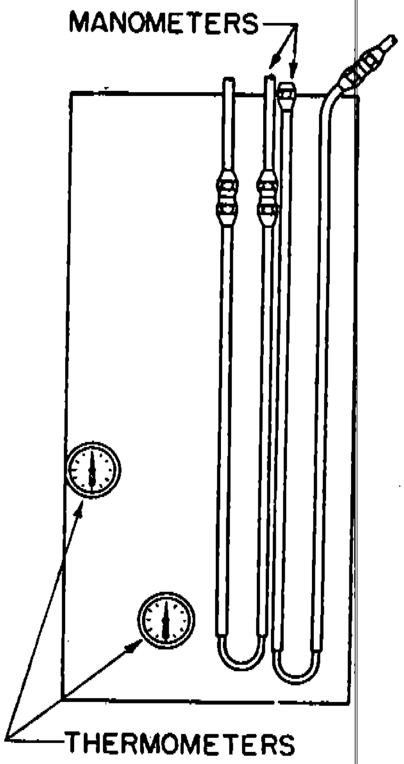
Prior to each test, the impactor and auxiliary apparatus were tested for leaks under 8-inch mercury vacuum. Then the sample line and the impactor box were heated to the temperature of the process stream. The sample probe was inserted in the process stream and gas flow through the impactor was started and held constant until the end of the test. A vacuum of 4 to 8 inches of mercury was usually required, giving flow rates of 2700 to 3700 cc. per minute.

Usually, 40 to 80% of the aerosol was collected on one cup or stage of the impactor. The sample time was limited by re-entrainment from this cup; a 25- to 50-mg. sample could be collected on one cup without re-entrainment. The maximum sample time was used, so that reasonable quantities were collected on other cups. With one trial run, the flow rate for subsequent runs was set at a level that would give maximum collection on the third or middle stage of the impactor, and the sample time was set at the maximum time feasible without re-entrainment.

After each test the sample cups were removed from the impactor with tweezers. The quantity collected on each cup was determined by weighing and/or chemical analyses. The glass cyclone was washed with water and the solution analyzed. The glass wool filters were leached with water and the resulting solution was analyzed; or the glass wool was removed, the filter holder was rinsed, and the glass wool and solution were analyzed either volumetrically or gravimetrically, depending on the type of aerosol. Both weighing and chemical analyses were used when condensation or evaporation was a potential source of



Compact make-up of impactor and its auxiliary equipment make it suitable for tests throughout the plant



Temperature and pressure during sampling period are controlled by observing and adjusting instruments. Interpretation of data aids in identifying aerosols collected error; double analyses showed that errors due to condensation or evaporation were negligible and sampling was adiabatic.

Calibration of Impactor

The in-line impactor was designed with the internal dimensions used by Ranz and Wong (*11*), except that the gases leaving any stage passed through annular slots around the collection cups rather than out the side. As the velocities through the slots were $^1/_{30}$ to $^1/_{350}$ the jet velocities, the in-line impactor was expected to perform in the same way as impactors used by Ranz and Wong.

Sulfuric acid mists were generated in the laboratory and passed through different retention chambers in the manner described by Gillespie (*2, 3*). Particle-size determinations were made on these mists with the in-line impactor (Figure 1). These data are in good agreement with data reported by Gillespie, who used impactors calibrated by Ranz and Wong (*11*). This work showed that the in-line impactor should have the same calibration as determined by them.

With a gas meter, the in-line impactor was calibrated as a flowmeter. The relationship between gas flow through the impactor and pressure drop across the impactor, for air at 25° C. and 14.7 p.s.i.a., was determined to be:

$$V_0 = 24.5\ (\Delta P)^{0.440} \qquad (1)$$

The gas flow, V_0, for process gases at different temperatures and pressures, was calculated from this equation, using suitable corrections for differences in gas density.

Particle-Size Distribution Calculations

Calculation of particle-size distributions was based on the generalized calibration curve determined by Ranz and Wong (*11*). The characteristic diameter, D_{pc}, for each stage of the impactor may be calculated from

$$D_{pc} = \left(\frac{18\,\mu D_c}{C\,\rho_p\,v_2}\right)^{1/2} (\psi_{50})^{1/2}\,(10)^4 \qquad (2)$$

where $(\psi_{50})^{1/2} = 0.38$ for round jets (*11*). However, as the C factor is a function of D_p, calculation of D_{pc} is not as straightforward as indicated by Equation 2. C is defined in general as:

$$C = 1 + \left(\frac{2L}{D_p}\right)[1.23 + 0.41e^{-0.44D_p\,(10)^{-4}/L}]\,(10)^4 \qquad (3)$$

for $\quad 0.1 < [2L(10)^4/D_p] < 134$

When

$$\left(\frac{D_p(10)^{-4}}{L}\right) > 2.7,$$

the exponential term in Equation 3 may be neglected and

$$C = 1 + (2.46)(10)^4\,(L/D_p) \qquad (4)$$

This condition existed in most applications of the impactor. For air at normal room temperature and pressures, Equation 4 becomes

$$C = 1 + 0.165/D_p \qquad (5)$$

When gases are expanded through a jet, the temperature change can be estimated on the basis of frictionless adiabatic flow for a perfect gas (*3*). However, in most cases this temperature change is negligible and the velocity of the gases at the jet throat, v_2, can be estimated as follows:

$$v_2 = \frac{4\,V_0}{\pi(D_c)^2}\,\frac{(P_0)}{(P_2)} \qquad (6)$$

When D_p is taken equal to D_{pc}, Equations 2, 4, and 6 can be combined to give

$$D_{pc} = \frac{-15.3\,\mu}{\sqrt{g_c\rho P_2}} + \sqrt{\frac{234\,\mu^2}{g_c\rho P_2} + \frac{(2.05)(10)^8\mu D_c^3 P_2}{\rho_p V_0 P_0}} \qquad (7)$$

The characteristic diameters for each stage of the impactor can be calculated directly from Equation 7. When $D_p/L \times (10)^{-4} < 2.7$, Equations 2, 3, and 6 must be solved by approximation. For any test, after *Dpc* was calculated for

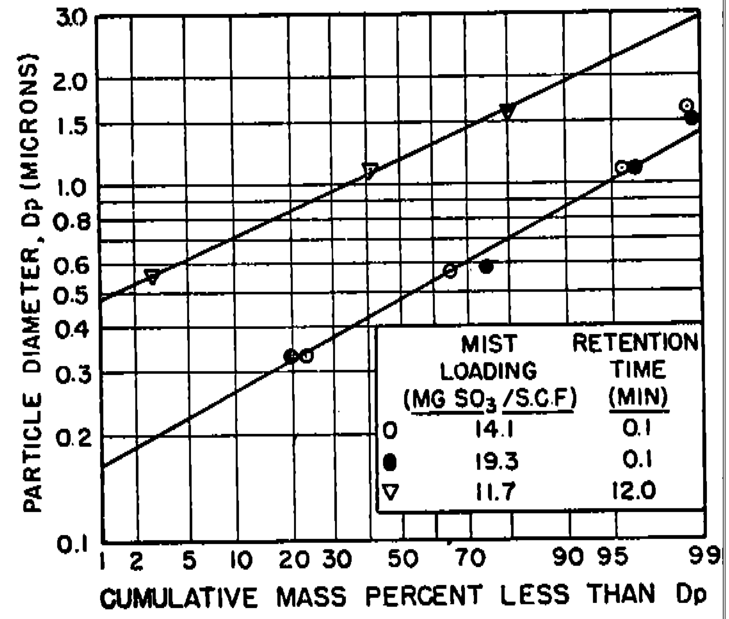


Figure 1. Cumulative particle size distribution of sulfuric acid mist generated in the laboratory is a function of mist loading and retention time

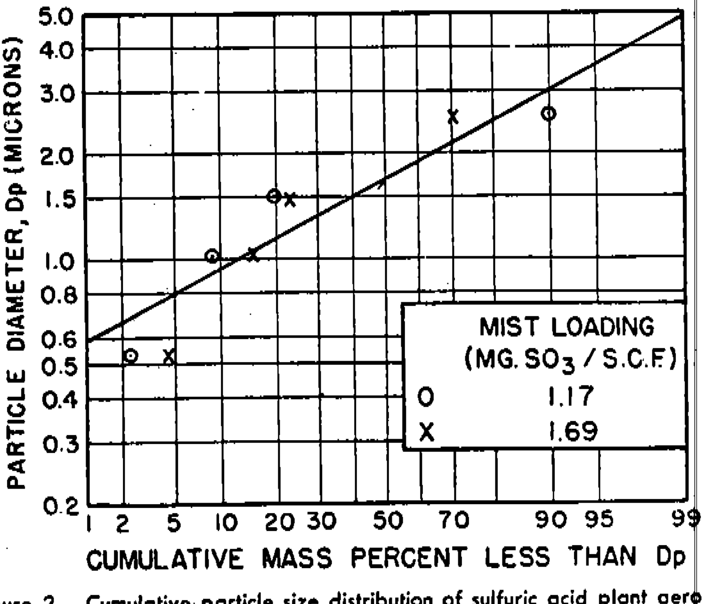


Figure 2. Cumulative particle size distribution of sulfuric acid plant aerosols

Table II. Particle-Size Distribution Curve Calculation

Jet No.	D_{pc}	% Collected	Cumulative % $<D_{pc}$
1	3.14	0.39	99.61
2	1.63	0.68	98.93
3	1.10	2.74	96.19
4	0.57	21.60	74.59
5	0.33	54.73	19.86
Glass filter			
1	...	19.86	
2	...	0	

each stage, cumulative distributions as shown in Figures 1 to 3 were calculated. For example, consider the curve given for a mist loading of 19.3 mg. of sulfur trioxide per standard cubic foot and a retention time of 0.1 minute in Figure 1. The data for this test are given in Table II. As 19.86% of the mist was not collected by the last stage, this percentage of the mist has diameters smaller than 0.33 micron, the D_{pc} for the last stage. The cumulative per cent not collected by stage 4 was 19.86% + 54.73% = 74.59%. This calculation was continued as shown in Table II and then the curve was plotted as shown in Figure 1.

Field Measurements

The impactor and auxiliary apparatus have been used extensively at plants throughout the country. Measurements of particle-size distributions of aerosols within and leaving eight different acid plants have been measured, and collection efficiencies of different types of full-scale dust and mist collectors for different particle sizes have shown that the impactor is a valuable and practical instrument for field use.

The particle-size distribution and loading of the mist leaving a new contact sulfuric acid plant are shown in Figure 2. This plant is of the Leonard-Monsanto design, a single unit with a rated capacity of 400 tons per day on a 100% sulfuric acid basis. Process gases in phosphoric acid plants are usually saturated with 5 to 40% water vapor, depending on the process design and operation, and adiabatic measurements are required. A typical particle-size distribution for the acid mist leaving a phosphoric acid plant is given in Figure 3.

Particle-size determinations by chemical company personnel make possible determination of acceptable stack discharges of aerosols, evaluation of installed collection equipment, rational selection and design of equipment, and recognition of potential problems early in the development of new processes.

Acknowledgment

The many helpful suggestions made by H. F. Johnstone, W. E. Ranz, Herbert Kraemer, J. B. Wong, and G. R. Gillespie on the design and operation of cascade impactors are gratefully acknowledged.

H. P. Willett and other engineers at the Chemical Construction Corp. assisted in the design of the in-line impactor.

D. A. Moore assisted in the experimental aspects of the work and in the preparation of a company report on which this discussion is based. W. M. Davis made several helpful suggestions.

Nomenclature

C = empirical correction factor for resistance of gas to movement of small particles as defined in Equation 3, 4, or 5
D_c = diameter of impactor jet, cm.
D_p = diameter of aerosol particle, microns
D_{pc} = characteristic diameter of aerosol particle for impactor stage, microns
g_c = 1 (g.)/(atm.)(cm.)(sec.)^2
L = mean free path for gas molecules, cm. $L = 2\mu/\rho\bar{v}$
P_0 = absolute pressure at inlet to impactor, atm.
P_2 = pressure after jet, atm.
ΔP = pressure drop across impactor, inches Hg
T_2 = temperature after jet, °K.
V_0 = gas flow at inlet to impactor, cc./second. $V_0 = 24.5\,(\Delta P)^{0.440}$ for air at 25° C. and 14.7 p.s.i.a.
v_2 = average linear velocity of gas through jet, at P_2 and T_2, cm. per second
$\bar{v}$ = average molecular velocity of gas, cm. per second $\bar{v} = (10)^4 \sqrt{\frac{8g_c\,P_2(1.013)}{\pi\rho}}$
ψ = dimensionless inertial parameter, $= C\rho_p v_2 D_p^2/18\,\mu D_c\,(10)^8$
ψ_{50} = inertial parameter for impactor efficiency of 50%
ρ = gas density after jet at T_2 and P_2, gram per cc.
ρ_p = density of aerosol particle, gram per cc.
μ = viscosity of gas after jet at T_2 and P_2, g./(cm.)(sec.)

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RECEIVED for review March 21, 1957
ACCEPTED August 14, 1957

Annual Meeting; AIChE, Boston, Mass., December 1956.

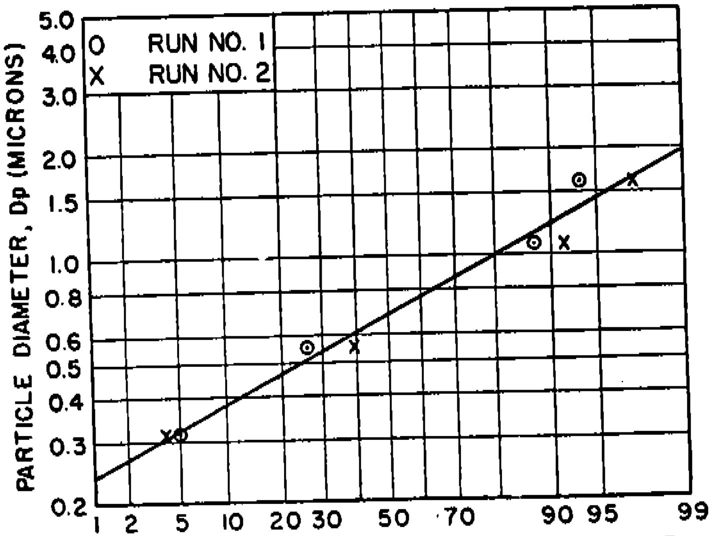


Figure 3. Distribution of phosphoric acid mist leaving typical plant can be used to control process. Analysis of aerosols under varying plant conditions aids in the selection of new equipment

APPENDIX E

CARBON MONOXIDE DATA

FIELD DATA SHEET - METHOD 10

LOCATION Virginia Lime

TEST CO

DATE 4/30/75

OPERATOR T. Lewis

TUNE METER READING

CALIB. METER READING

GAIN TURNS NUMBER

COMMENTS:

% CO_2 By FYRITE = 8.5
" " ORSAT = 8.5

CLOCK TIME	ROTAMETER SETTING (Cubic ft/min, cubic ft/hr)	CO ANALYZER Meter Reading	RUN NUMBER
7:35	0	0	1
7:40	1	Run abort	
7:53	1		2

FIELD DATA SHEET - METHOD 10

LOCATION Virginia Lime

TEST CO

DATE 5/1/75

OPERATOR J. Lewis

TUNE METER READING 35

CALIB. METER READING 82.5

GAIN TURNS NUMBER 2.73

COMMENTS:

1) Recorder pen plugged up, And only meter reading available.

2) Run 1-2 was made with glass wool in probe TIP.

3) No Ice bath was used

4) Run 1-3 was made without glass wool

CLOCK TIME	ROTAMETER SETTING (Cubic ft/min, cubic ft/hr)	Range 3 CO ANALYZER Meter Reading	RUN NUMBER
2:17	3.0	0	1-1
2:22	2.8	.78	1-1
3:10	3.0	0	1-2
3:15	2.8	53 ✓	1-2
~~3:29~~	~~3.0~~	~~0~~	~~1-3~~
3:34	3.0	0	1-3
3:39	2.8	64.5	1-3
3:42	3.0	0	1-4
3:47	2.8	62.5	1-4
3:50	3.0	0	1-5
3:55	2.9	58.0	1-5
4:00	3.0	0	1-6
4:05	2.8	55.0	1-6

FIELD DATA SHEET - METHOD 10

LOCATION Virginia Lime

TEST CO

DATE 5/3/75

OPERATOR T. Lewis

TUNE METER READING 35

CALIB. METER READING —

GAIN TURNS NUMBER 2.77

COMMENTS:

1) Run 1-1 conducted w/Ice bath & glass wool in probe.

CLOCK TIME	ROTAMETER SETTING (Cubic ft/min, cubic ft/hr)	CO ANALYZER Meter Reading	RUN NUMBER
~~10:22~~	~~1.5~~	~~Valve Closed~~	~~1-1~~
~~10:27~~	~~1.5~~	~~ON Tedlar bag~~	
10:25	1.5	0	1-1
10:30	1.5	>100 Range 1	1-1
10:35	2.0	0	1-2
10:40	2.0	>100 Range 1	1-2

TRAVERSE POINT LOCATION FOR CIRCULAR DUCTS

PLANT Va Lime
DATE 4/29/75
SAMPLING LOCATION #2 Kiln out
INSIDE OF FAR WALL TO
OUTSIDE OF NIPPLE, (DISTANCE A) [illegible]
INSIDE OF NEAR WALL TO
OUTSIDE OF NIPPLE, (DISTANCE B)
STACK I.D., (DISTANCE A - DISTANCE B) 10'
NEAREST UPSTREAM DISTURBANCE 21' [illegible] diameters
NEAREST DOWNSTREAM DISTURBANCE > 2' diameter
CALCULATOR Peltier

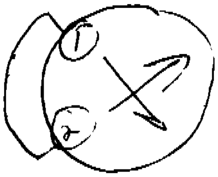
SCHEMATIC OF SAMPLING LOCATION

TRAVERSE POINT NUMBER	% ~~FRACTION~~ OF STACK I.D.	STACK I.D.	PRODUCT OF COLUMNS 2 AND 3 (TO NEAREST 1/8 INCH)	DISTANCE B	TRAVERSE POINT LOCATION FROM OUTSIDE OF NIPPLE (SUM OF COLUMNS 4 & 5)
1	1.1	10'			1 3/8
2	3.2	↓			3 7/8
3	5.5				6 5/8
4	7.9				9 1/2
5	10.5				12 5/8
6	13.2				15 7/8
7	16.1				19 3/8
8	19.4				23 1/4
9	23.0				27 5/8
10	27.2				32 5/8
11	32.3				38 3/4
12	39.8				47 3/4
13	60.2				72 1/4
14	67.7				81 1/4
15	72.8				87 3/8
16	77.0				92 3/8
17	80.6				96 3/4
18	83.9				100 5/8
19	86.8				104 1/8
20	89.5				107 3/8
21	92.1				110 1/2
22	94.5				113 3/8
23	96.8				116 1/8
24	98.9				118 5/8

EPA (Dur) 232
4/72

PRELIMINARY VELOCITY TRAVERSE

PLANT Va Lime
DATE 4/29/75
LOCATION #2 kiln outlet
STACK I.D. 10' – 4"
BAROMETRIC PRESSURE, in. Hg —
STACK GAUGE PRESSURE, in. H_2O –.14
OPERATORS Peltier & Lucas



SCHEMATIC OF TRAVERSE POINT LAYOUT

①

TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
1	.1	375
2	.11	385
3	.13	403
4	.14	406
5	.14	413
6	.15	422
7	.15	420
8	.13	424
9	.14	421
10	.1	425
11	.08	432
12	.12	427
13	.08	425
14	.05	420
15	.05	420
16	.07	424
17	.05	420
18	.08	420
19	.06	420
20	.07	414
21	.07	419
22	.08	419
23	.06	412
24	.06	413
AVERAGE		415.8

②

TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
1	.1	340
2	.07	330
3	.11	385
4	.08	399
5	.11	406
6	.11	414
7	.1	414
8	.12	418
9	.09	425
10	.09	431
11	.1	431
12	.08	429
13	.1	431
14	.11	429
15	.09	428
16	.1	424
17	.09	427
18	.09	428
19	.1	432
20	.09	426
21	.08	423
22	.07	419
23	.05	406
24	.06	420
AVERAGE		413.5

EPA (Dur) 233
4/72

– .14 323 .315 — 414.7

MOISTURE IN STACK GAS DETERMINATION

METHOD 4

Plant Va Lime Date 4/29/75

Run # 1 Location Sampled #2 Kiln outlet

Volume of gas at meter conditions (CF) = VM = 801.654 - 802.754 ~~801.610~~ = 1.1

Average meter temperature (°F) = TM = 93

Barometric pressure absolute (in Hg) = PB = 27.36

VMS = Volume of gas sampled at standard conditions (SCF)

$$VMS = \frac{(17.71)(VM)(PB)}{(TM + 460)} = \frac{17.71\ (1.1)(\quad)}{(93 + 460)} =$$ ~~1.04~~ .96

Volume of water final ______ Wt. of silica gel final ______

Volume of water initial ______ Wt. of silica gel initial ______

Volume collected V_1 = ______ Wt. of water V_2 = ______ gm

Total volume of water collected (ml) = $V_1 + V_2$ = VL = 1.9

Volume of water vapor at standard conditions (CF) = VW

VW = (.0474)(VL) = .0474(1.9) = .0901

Mole fraction of water vapor = M

$$M = \frac{VW}{VMS + VW} = \frac{(.0901)}{(1.04) + (.0901)} = M =$$ 8.5

Percent moisture = (100)(M) = 100 (   ) = %M 8.0

NOMOGRAPH DATA

PLANT Va Lime

DATE 4/30/75

SAMPLING LOCATION #2 Kiln outlet

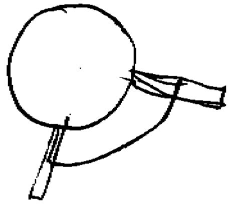
CALIBRATED PRESSURE DIFFERENTIAL ACROSS ORIFICE, in. H_2O	$\Delta H_@$	
AVERAGE METER TEMPERATURE (AMBIENT + 20°F), °F	$T_{m\,avg.}$	90
PERCENT MOISTURE IN GAS STREAM BY VOLUME	B_{wo}	8.5
BAROMETRIC PRESSURE AT METER, in. Hg	P_m	
STATIC PRESSURE IN STACK, in. Hg ($P_m \pm 0.073$ x STACK GAUGE PRESSURE in in. H_2O)	P_s	
RATIO OF STATIC PRESSURE TO METER PRESSURE	P_s/P_m	1.0
AVERAGE STACK TEMPERATURE, °F	$T_{s\,avg.}$	415
AVERAGE VELOCITY HEAD, in. H_2O	$\Delta p_{avg.}$	.1
MAXIMUM VELOCITY HEAD, in. H_2O	$\Delta p_{max.}$	.14
C FACTOR	.96	
CALCULATED NOZZLE DIAMETER, in.	.42	
ACTUAL NOZZLE DIAMETER, in.	.375	
REFERENCE Δp, in. H_2O	.15	

EPA (Dur) 234
4/72

.224
.256

FIELD DATA

PLANT Virginia Lime
DATE 4/30/75
SAMPLING LOCATION #2 Kiln
SAMPLE TYPE EPA-5
RUN NUMBER 1
OPERATOR H. Toy W. MacDonald
AMBIENT TEMPERATURE 60°F
BAROMETRIC PRESSURE 28.05
STATIC PRESSURE, (P_s)
FILTER NUMBER (s) 32-3



PROBE LENGTH AND TYPE
NOZZLE I.D. .364
ASSUMED MOISTURE, % 8%
SAMPLE BOX NUMBER SGB
METER BOX NUMBER MRC #4
METER $\Delta H_@$ 1.346
C FACTOR .70
PROBE HEATER SETTING High
HEATER BOX SETTING High
REFERENCE Δp .23

SCHEMATIC OF TRAVERSE POINT LAYOUT

READ AND RECORD ALL DATA EVERY 1.5 MINUTES LEAK RATE .009 CFM @15 "Hg (without probe)

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F	Probe
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F		TC not working		
	0	[illegible]	85.248										
1	0	1510	85.248	.09	.72	.72	409	65	64	3.0		59	140
2	1.5	1511.5	85.919	.085	.67	.67	410	66	64	2.9		58	151
3	3	1513	86.727	.08	.65	.65	412	66	64	3.0		58	158
4	4.5	1514.5	87.522	.075	.60	.60	415	66	64	2.9		58	163
5	6	1516	88.284	.075	.60	.60	408	67	64	2.9		58	166
6	7.5	1517.5	89.037	.09	.72	.72	407	67	64	3.2		58	168
7	9	1519	89.835	.085	.67	.67	409	68	65	3.2		58	170
8	10.5	1520.5	90.639	.08	.65	.65	408	68	65	3.5		58	170
9	12	1522	91.433	.08	.65	.65	404	69	65	3.6		58	170
10	13.5	1523.5	92.218	.07	.56	.56	401	69	65	3.5		58	172
11	15	1525	92.954	.075	.60	.60	404	69	65	3.8		58	173
12	16.5	1526.5	93.708	.06	.47	.47	402	70	65	3.6		58	175
13	18	1528	94.400	.07	.56	.56	403	70	66	3.9		58	175
14	19.5	1529.5	95.127	.06	.47	.47	401	70	65	3.8		58	178
15	21	1531	95.812	.05	.39	.39	398	71	66	3.6		59	181
16	22.5	1532.5	96.445	.03	.23	.23	387	71	66	3.0		59	183

PLANT Virginia Lime DATE 4/30/75 RUN NO. 1

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, K °F	IMPINGER TEMPERATURE, °F	Probe
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F		not working		
		1532.5	/										
17	24	1534	97.001	.025	.19	.19	386	71	66	2.8		59	183
18	25.5	1535.5	97.437	.03	.23	.23	383	70	66			59	181
~~19~~	27		Hit other side										
20	28.5	→	26.67 exact time stopped										
21	30												
22	31.5												
23	33												
24	34.5												
	36												
1	27		97.763										
2	28.5												
3	30												
4	31.5												
5	33												
6	34.5												
7	36												
8	37.5												
9	39												
10	40.5												
11	42												
12	43.5												
13	45												
14	46.5												
15	48												
16	49.5												

CLEAN-UP DATA

Plant Virginia Lime

Comments:

Date 4/30/75

Sampling Location #2 Kiln

Sample Type EPA -5

Run Number 1

Sample Box Number

Clean-up Man H. Toy W. MacDonald.

IMPINGERS

	#1	#2	#3	#4	#5
Final Vol.	108 ml	102 ml	2 ml	ml	ml
Initial Vol.	100 ml	100 ml	0 ml	ml	ml
Net Vol.	8 ml	2 ml	2 ml	ml	ml

Total Net Volume in Impingers 12 ml

SILICA GEL

Final Weight	205.6 g	g	g
Initial Weight	200 g	g	g
Net Weight	~~5~~ 5.6 g	g	g

stem of silica gel impinger broken inside top.

Total Net Weight in Silica Gel 5.6 g

Total Moisture 17.6 g

Filter Number(s) 32-3

MRC 7/73

DRY MOLECULAR WEIGHT DETERMINATION

PLANT Virginia Lime
DATE 5/1/75 -
SAMPLING TIME (24-hr CLOCK) 1200 hrs
SAMPLING LOCATION #2 Kiln
SAMPLE TYPE (BAG, INTEGRATED, CONTINUOUS) Bag
ANALYTICAL METHOD Orsat
AMBIENT TEMPERATURE 70°
OPERATOR W MacDonald

COMMENTS: Run #1

RUN / GAS	1		2		3		AVERAGE NET VOLUME	MULTIPLIER	MOLECULAR WEIGHT OF STACK GAS (DRY BASIS) M_d, lb/lb-mole
	ACTUAL READING	NET	ACTUAL READING	NET	ACTUAL READING	NET			
CO_2	6.0	6.0	6.2	6.2	6.2	6.2	6.1	44/100	2.684
O_2 (NET IS ACTUAL O_2 READING MINUS ACTUAL CO_2 READING)	18.8	12.8	18.4	12.2	18.8	12.6	12.6	32/100	4.032
CO (NET IS ACTUAL CO READING MINUS ACTUAL O_2 READING)								28/100	
N_2 (NET IS 100 MINUS ACTUAL CO READING)							81.3	28/100	22.764
								TOTAL	29.48

EPA (Dur) 230
4/72

FIELD DATA

PLANT Virginia Lime
DATE 5/1/75
SAMPLING LOCATION #2 Kiln
SAMPLE TYPE EPA-5
RUN NUMBER 2
OPERATOR H. Toy W. MacDonald
AMBIENT TEMPERATURE 61°F
BAROMETRIC PRESSURE 28.03
STATIC PRESSURE, (P_s)
FILTER NUMBER (s) 33-21

TC for stack not working hooked to probe TC for stack temp. Checked probe temp periodically

PROBE LENGTH AND TYPE 12'
NOZZLE I.D. .364
ASSUMED MOISTURE, % 8%
SAMPLE BOX NUMBER SGB-5
METER BOX NUMBER MRC-4
METER $\Delta H_@$ 1.346
C FACTOR .70
PROBE HEATER SETTING High
HEATER BOX SETTING High
REFERENCE Δp .230

SCHEMATIC OF TRAVERSE POINT LAYOUT

READ AND RECORD ALL DATA EVERY 1.5 MINUTES LEAK RATE .014 CFM @15"Hg

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft³	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F	Probe
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F				
	0	1440	101.793										
1	0	1440	101.793	.08	.65	.65	383	79	78	3.9		74	120
2	1.5	1441.5	102.429	.10	.80	.80	385	80	78	4.1		69	
3	3	1443	103.298	.10	.80	.80	383	81	78	4.2		68	155
4	4.5	1444.5	104.170	.09	.72	.72	388	82	78	4.1		66	
5	6	1446	105.008	.09	.72	.72	393	83	79	4.2		65	
6	7.5	1447.5	105.829	.095	.76	.76	390	84	79	4.6		65	
7	9	1449	106.668	.08	.65	.65	392	84	79	4.5		65	186
8	10.5	1450.5	107.471	.08	.65	.65	388	85	79	4.5		65	
9	12	1452	108.251	.07	.56	.56	391	85	80	4.4		65	
10	13.5	1453.5	109.000	.065	.52	.52	387	86	80	4.4		65	
11	15	1455	109.705	.08	.65	.65	393	86	80	5.1		66	
12	16.5	1456.5	110.455	.09	.72	.72	398	87	80	5.8		66	
13	18	1458	111.259	.08	.65	.65	390	87	81	5.8		66	
14	19.5	1459.5	112.055	.11	.88	.88	400	88	81	7.2		65	
15	21	1501	112.910	.14	1.15	1.15	396	89	81	9.1		65	
16	22.5	1502.5	113.666	.14	1.15	1.15	401	90	81	10.0		65	

PLANT Virginia Lime DATE 5/1/75 RUN NO. 2

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
					DESIRED	ACTUAL		INLET $(T_{m\ in})$, °F	OUTLET $(T_{m\ out})$, °F			
	22.5	1502.5										
17	24	1504	114.879	.17	1.4	1.4	400	91	82	12.4		65
18	25.5	1565.5	115.961	.17	1.4	1.4	392	91	82	13.7		65
19	27	1507	117.063	.13	1.05	1.05	392	91	82	13.4		66
20	28.5	1508.5	118.117	.15	1.2	1.2	388	91	83	14.0		66
21	30	1510	119.161	.16	1.3	1.3	390	91	83	15.0		66
22	31.5	1511.5	120.198	.155	1.25	1.26	397	91	83	15.6		67
23	33	1513	121.244	.155	1.25	1.25	392	92	84	17.0		67
24	34.5	1514.5	122.285	.15	1.2	1.2	389	91	84	17.8		68
[illegible]	36	1516	123.207									
[illegible]												
1	36		123.207									
2	37.5											
3	39											
4	40.5											
5	42											
6	43.5											
7	45											
8	46.5											
9	48											
10	49.5											
11	51											
12	52.5											
13	54											
14	55.5											
15	57											

Probe

217

PLANT Virginia Lime DATE 5/1/75 RUN NO. 2

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F			
	57											
16	58.5											
17	60											
18	61.5											
19	63											
20	64.5											
21	66											
22	67.5											
23	69											
24	70.5											
	72											

CLEAN-UP DATA

Plant Va Lime

Comments:

Date 5/1/75
Sampling Location #2 kiln outlet
Sample Type Method 5
Run Number #2
Sample Box Number 5
Clean-up Man W.D, JP, HT

IMPINGERS

	#1	#2	#3	#4	#5
Final Vol.	2 ml	ml	ml	ml	ml
Initial Vol.	ml	ml	ml	ml	ml
Net Vol.	ml	ml	ml	ml	ml

Total Net Volume in Impingers [illegible] 10 ml

SILICA GEL

Final Weight	g	g	g
Initial Weight	g	g	g
Net Weight	g	g	g

Total Net Weight in Silica Gel 1.6 g

Total Moisture 11.6 g

Filter Number(s) 33 - 21

MRC 7/73

DRY MOLECULAR WEIGHT DETERMINATION

PLANT Virginia Lime
DATE 5/1/78
SAMPLING TIME (24-hr CLOCK) 1200 hrs
SAMPLING LOCATION #2 Kiln Run #2
SAMPLE TYPE (BAG, INTEGRATED, CONTINUOUS) Bag
ANALYTICAL METHOD Fyrite
AMBIENT TEMPERATURE 70°F
OPERATOR T. Lewis

COMMENTS:
this used
for ISOKINETICS

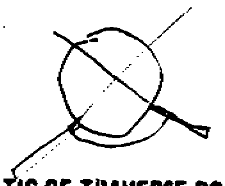
RUN / GAS	1 ACTUAL READING	1 NET	2 ACTUAL READING	2 NET	3 ACTUAL READING	3 NET	AVERAGE NET VOLUME	MULTIPLIER	MOLECULAR WEIGHT OF STACK GAS (DRY BASIS) M_d, lb/lb-mole
CO_2	9.8		9.5		9.8		9.7	44/100	4.268
O_2 (NET IS ACTUAL O_2 READING MINUS ACTUAL CO_2 READING)	14.3		14.3		[illegible]		14.3	32/100	4.576
CO (NET IS ACTUAL CO READING MINUS ACTUAL O_2 READING)							0	28/100	
N_2 (NET IS 100 MINUS ACTUAL CO READING)							76	28/100	21.28
								TOTAL	30.124

EPA (Dur) 230
4/72

FIELD DATA

PLANT Virginia Lime
DATE 5/2/75
SAMPLING LOCATION #2 Kiln
SAMPLE TYPE EPA-5
RUN NUMBER 3
OPERATOR H. Toy W. MacDonald T. Peltier
AMBIENT TEMPERATURE 72°F
BAROMETRIC PRESSURE 28.02
STATIC PRESSURE, (P_s)
FILTER NUMBER (s) 33-23, 32-13

PROBE LENGTH AND TYPE 12'
NOZZLE I.D. .364
ASSUMED MOISTURE, % 6%
SAMPLE BOX NUMBER 3GB-5
METER BOX NUMBER 4 MRC
METER $\Delta H_@$ 1.346
C FACTOR .74
PROBE HEATER SETTING High
HEATER BOX SETTING High
REFERENCE Δp .24



SCHEMATIC OF TRAVERSE POINT LAYOUT

READ AND RECORD ALL DATA EVERY 1 MINUTES LEAK RATE .014 CFM @ 15"Hg

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft³	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F TC not working	IMPINGER TEMPERATURE, °F
					DESIRED	ACTUAL		INLET $(T_{m\,in})$, °F	OUTLET $(T_{m\,out})$, °F			
	0		123.524									
1	0	1325	123.524	.09	.68	.68	393	72	72	5.9		66
2	1	1326	123.987	.095	.72	.72	396	73	72	5.8		63
3	2	1327	124.556	.10	.75	.75	392	73	72	5.9		62
4	3	1328	125.132	.085	.64	.64	395	73	72	5.4		63
5	4	1329	125.685	.08	.61	.61	393	74	72	5.2		62
6	5	1330	126.341	.075	.57	.57	398	74	72	5.1		61
7	6	1331	126.845	.065	.48	.48	397	74	72	4.5		61
8	7	1332	127.317	.06	.45	.45	394	75	72	4.4		62
9	8	1333	127.765	.06	.45	.45	392	75	73	4.5		62
10	9	1334	128.210	.065	.48	.48	394	76	73	4.6		63
11	10	1335	128.661	.075	.57	.57	395	76	73	5.2		62
12	11	1336	129.142	.10	.75	.75	397	77	74	6.5		61
13	12	1337	129.675	.14	1.08	1.08	391	77	73	8.7		61
14	13	1338	130.398	.13	1.0	1.0	396	78	76	9.3		61
15	14	1339	130.956	.14	1.08	1.08	401	78	73	9.7		61
16	15	1340	131.622	.15	1.15	1.15	398	78	73	10.3		61

Probe

deck stuck started again

4.859

PLANT Virginia Lime DATE 5/2/~~6~~75 RUN NO. 3

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
		1340			DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F			
17	16	1341	132.304	.14	1.08	1.08	403	79	73	10.6		62
18	17	1342	132.984	.14	1.08	1.08	398	79	74	10.6		62
19	18	1343	133.657	.16	1.22	1.22	396	79	74	11.4		63
20	19	1344	134.343	.17	1.31	1.31	399	79	74	12.6		63
21	20	1345	135.054	.17	1.31	1.31	400	80	74	13.4		64
22	21	1346	135.775	.17	1.31	1.31	405	80	74	14.2		64
23	22	1347	136.515	.155	1.19	1.19	396	80	74	14.2		65
24	23	1348	137.245	.175	1.35	1.35	355	80	74	15.3		65
	24	1349	137.891				396					
			Change filter to 32 -13									
1	24	1434	137.891	.06	.45	.45	367	80	79	3.9		72
2	25		138.265	.07	.53	.53	367	79	79	4.2		68
3	26		138.729	.065	.48	.48	374	79	78	4.1		67
4	27		139.191	.075	.57	.57	375	80	79	4.6		64
5	28		139.671	.08	.61	.61	375	80	79	4.8		64
6	29		140.174	.105	.79	.79	381	80	78	5.9		63
7	30		140.719	.11	.84	.84	381	81	79	6.1		61
8	31		141.301	.10	.76	.76	378	81	79	6.2		61
9	32		141.886	.09	.69	.69	378	82	79	6.0		60
10	33		142.445	.10	.76	.76	379	82	79	6.1		61
11	34		142.011	.10	.76	.76	383	83	79	6.4		60
12	35		143.577	.095	.72	.72	381	83	79	6.5		60
13	36		144.139	.095	.72	.72	382	83	79	6.9		60
14	37		144.701	.10	.85	.85	380	84	79	7.5		60 ← Change ref ΔP to .22 for 380°
15	38		145.295	.11	.93	.93	385	84	79	8.8		59

Probe

171

*at 37 min changed ref. ΔP to .22 (avg stack temp 380°)

12.546

PLANT Virginia Lime DATE 5/2/75 RUN NO. 3

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
					DESIRED	ACTUAL		INLET $(T_{m\,in})$, °F	OUTLET $(T_{m\,out})$, °F			
16	39		145.885	.12	1.02	1.02	383	85	79	9.5		60
17	40		146.521	.11	.93	.93	383	85	79	9.9		61
18	41		147.155	.12	1.02	1.02	383	85	79	10.3		61
19	42		147.801	.125	1.07	1.07	379	86	79	11.2		60
20	43		148.451	.125	1.07	1.07	378	85	79	11.8		60
21	44		149.115	.115	.97	.97	382	85	75	11.8		60
22	45		149.761	.12	1.02	1.02	384	85	79	12.2		60
23	46		150.418	.12	1.02	1.02	377	85	80	12.8		60
24	47		151.074	.11	.93	.93	378	85	79	12.8		61
	48		151.670									

Probe

194

CLEAN-UP DATA

Plant Virginia Lime

Date 5/2/75

Sampling Location #2 Kiln

Sample Type EPA - 5

Run Number 3

Sample Box Number SGB 5

Clean-up Man A. Toy

Comments: Broke end of wash bottle into 2ND impinger

IMPINGERS

	#1	#2	#3	#4	#5
Final Vol.	111 ml	101 ml	ml	ml	ml
Initial Vol.	100 ml	100 ml	ml	ml	ml
Net Vol.	11 ml	1 ml	ml	ml	ml

Total Net Volume in Impingers 12 ml

SILICA GEL

Final Weight	209.4 g	g	g
Initial Weight	200.0 g	g	g
Net Weight	9.4 g	g	g

Total Net Weight in Silica Gel 9.4 g

Total Moisture 21.4 g

Filter Number(s) 32-13

33-23

320.5
111.1
209.4

MRC 7/73

DRY MOLECULAR WEIGHT DETERMINATION

PLANT Virginia Lime
DATE 5/2/75
SAMPLING TIME (24-hr CLOCK)
SAMPLING LOCATION #2 Kiln
SAMPLE TYPE (BAG, INTEGRATED, CONTINUOUS) Bag
ANALYTICAL METHOD Orsat
AMBIENT TEMPERATURE
OPERATOR Tony Lewis

COMMENTS: Run #3

RUN / GAS	1		2		3		AVERAGE NET VOLUME	MULTIPLIER	MOLECULAR WEIGHT OF STACK GAS (DRY BASIS) M_d, lb/lb-mole
	ACTUAL READING	NET	ACTUAL READING	NET	ACTUAL READING	NET			
CO_2	10.8	10.8	10.8	10.8	10.6	10.6	10.7	44/100	
O_2 (NET IS ACTUAL O_2 READING MINUS ACTUAL CO_2 READING)	22.4	11.6	23.2	12.4	23.8	13.2	12.4	32/100	
CO (NET IS ACTUAL CO READING MINUS ACTUAL O_2 READING)	22.8	0.4	23.4	0.2	24.2	0.4	.3	28/100	
N_2 (NET IS 100 MINUS ACTUAL CO READING)								28/100	
								TOTAL	30.21

EPA (Dur) 230
4/72

FIELD DATA

PLANT Virginia Lime
DATE 5/3/78
SAMPLING LOCATION #2 Kiln
SAMPLE TYPE EPA-5
RUN NUMBER 4
OPERATOR H. Toy W. MacDonald
AMBIENT TEMPERATURE 62°F
BAROMETRIC PRESSURE 27.95
STATIC PRESSURE, (P_s)
FILTER NUMBER (s) 38-13, 33-22

PROBE LENGTH AND TYPE 12'
NOZZLE I.D. .364
ASSUMED MOISTURE, % 4%
SAMPLE BOX NUMBER SGB-5
METER BOX NUMBER MRC-4
METER $\Delta H_@$ 1.346
C FACTOR .76
PROBE HEATER SETTING High
HEATER BOX SETTING High
REFFERENCE Δp .20

SCHEMATIC OF TRAVERSE POINT LAYOUT

READ AND RECORD ALL DATA EVERY 1 MINUTES LEAK RATE .018 CFM @ 15.5" Hg

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F TC not working correctly Probe
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F			
	0	1017	152.837									
1	0	1017	152.837	.075	.49	.49	376	66	64	3.9		71
2	1	1018	153.292	.08	.53	.53	380	66	64	3.8		68
3	2	1019	153.777	.09	.59	.59	381	67	64	4.0		66
4	3	1020	154.273	.09	.59	.59	382	68	64	4.0		65
5	4	1021	154.773	.07	.46	.46	384	68	64	3.5		
6	5	1022	155.235	.065	.42	.42	384	69	64	3.4		65
7	6	1023	155.658	.06	.39	.39	385	69	64	3.4		
8	7	1024	156.061	.045	.29	.29	390	70	65	2.9		
9	8	1025	156.437	.05	.32	.32	391	70	65	3.1		
10	9	1026	156.798	.05	.32	.32	392	71	65	3.1		
11	10	1027	157.168	.05	.32	.32	392	71	65	3.1		
12	11	1028	157.535	.06	.39	.39	395	72	65	3.7		64
13	12	1029	157.927	.09	.59	.59	397	72	66	4.8		
14	13	1030	158.493	.10	.65	.65	398	73	66	5.3		
15	14	1031	158.912	.11	.72	.72	397	73	66	5.8		
16	15	1032	159.452	.14	.93	.93	400	74	66	7.1		

PLANT Virginia Lime DATE 5/3/75 RUN NO. 4

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F			
17	16	1033	160.049	.125	.83	.83	401	74	66	7.0		
18	17	1034	160.654	.16	1.07	1.07	403	75	66	8.0		
19	18	1035	161.283	.14	.93	.93	400	75	66	8.0		
20	19	1036	161.922	.14	.93	.93	400	76	66	8.0		
21	20	1037	162.551	.145	.96	.96	399	76	67	8.3		60
22	21	1038	163.185	.15	1.0	1.0	399	76	67	8.8		
23	22	1039	163.834	.13	.87	.87	400	77	67	8.4		
24	23	1040	164.453	.13	.87	.87	398	77	67	8.3		
	24	1041	164.976									
				Change filter to 33-22					Changed ref ΔP to .21			
1	24	1110	164.976	.045	.39	.39	384	72	71	3.0		66
2	25		165.358	.05	.43	.43	386	72	71	3.1		63
3	26		165.792	.055	.47	.47	389	72	70	3.2		61
4	27		166.241	.065	.56	.56	390	72	70	3.8		60
5	28		166.725	.055	.47	.47	389	72	70	3.3		59
6	29		167.189	.075	.66	.66	394	73	70	4.2		59
7	30		167.695	.065	.56	.56	394	73	70	4.0		59
8	31		168.182	.07	.62	.62	393	74	70	4.2		59
9	32		168.692	.09	.79	.79	395	74	70	5.1		59
10	33		169.247	.085	.74	.74	392	75	70	5.1		59
11	34		169.811	.09	.79	.79	395	75	70	5.4		59
12	35		170.391	.085	.74	.74	403	76	71	5.4		59
13	36		170.964	.09	.79	.79	399	76	71	5.7		58
14	37		171.543	.08	.71	.71	401	77	71	5.4		58
15	38		172.100	.10	.88	.88	397	78	71	6.3		58
16	39		172.698	.08	.71	.71	398	78	71	5.8		58

Probe

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PLANT Virginia Lime DATE 5/3/75 RUN NO. 4

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F	Probe
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F				
17	40		173.264	.10	.88	.88	403	78	71	6.8		58	
18	41		173.861	.10	.88	.88	399	78	71	6.9		59	
19	42		174.471	.10	.88	.88	400	79	71	7.0		58	
20	43		175.085	.11	.96	.96	395	79	72	7.6		58	
21	44		175.721	.11	.96	.96	399	79	72	8.0		58	
22	45		176.357	.11	.96	.96	399	79	72	8.2		58	
23	46		176.999	.12	1.07	1.07	399	80	72	8.8		58	
24	47		177.665	.12	1.07	1.07	401	80	72	9.0		58	
	48		178.242										190

CLEAN-UP DATA

Plant Virginia Lime

Comments:

Date 5/3/75

Sampling Location #2 Kiln

Sample Type EPA-5

Run Number 4

Sample Box Number SCB-5

Clean-up Man H. Toy W. MacDonald

IMPINGERS

	#1	#2	#3	#4	#5
Final Vol.	113 ml	104 ml	ml	ml	ml
Initial Vol.	100 ml	100 ml	ml	ml	ml
Net Vol.	13 ml	4 ml	ml	ml	ml

Total Net Volume in Impingers 17 ml

SILICA GEL

Final Weight	207.9 g	g	g
Initial Weight	200 g	g	g
Net Weight	7.9 g	g	g

Total Net Weight in Silica Gel 7.9 g

Total Moisture 24.9 g

Filter Number(s) 335-22
58-15

DRY MOLECULAR WEIGHT DETERMINATION

PLANT Virginia Lime
DATE 5/3/75
SAMPLING TIME (24-hr CLOCK) 1000 hrs – 1130 hrs
SAMPLING LOCATION #2 Kiln
SAMPLE TYPE (BAG, INTEGRATED, CONTINUOUS) Bag
ANALYTICAL METHOD Fyrite
AMBIENT TEMPERATURE
OPERATOR T. Lewis

COMMENTS:
Run # 4

GAS \ RUN	1		2		3		AVERAGE NET VOLUME	MULTIPLIER	MOLECULAR WEIGHT OF STACK GAS (DRY BASIS) M_d, lb/lb-mole
	ACTUAL READING	NET	ACTUAL READING	NET	ACTUAL READING	NET			
CO_2		11.0		11.0			11.0	44/100	4.84
O_2 (NET IS ACTUAL O_2 READING MINUS ACTUAL CO_2 READING)		14.1		13.9		13.9	14.0	32/100	4.48
CO (NET IS ACTUAL CO READING MINUS ACTUAL O_2 READING)								28/100	
N_2 (NET IS 100 MINUS ACTUAL CO READING)							75	28/100	21.0
								TOTAL	30.32

FIELD DATA

PLANT Virginia Lime
DATE 5/3/78
SAMPLING LOCATION #2 Kiln
SAMPLE TYPE EPA - 5
RUN NUMBER 5
OPERATOR A. Toy W. MacDonald T. Peltier
AMBIENT TEMPERATURE 60°F
BAROMETRIC PRESSURE 27.98
STATIC PRESSURE, (P_s)
FILTER NUMBER (s) 33-16, 38-15

PROBE LENGTH AND TYPE 12'
NOZZLE I.D. .364
ASSUMED MOISTURE, % 4%
SAMPLE BOX NUMBER SGB-5
METER BOX NUMBER MRC-5
METER $\Delta H_@$ 1.741
C FACTOR 1.0
PROBE HEATER SETTING High
HEATER BOX SETTING High
REFERENCE Δp .16

SCHEMATIC OF TRAVERSE POINT LAYOUT

READ AND RECORD ALL DATA EVERY 1 MINUTES LEAK RATE .018 CFM @ 15"Hg

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
					DESIRED	ACTUAL		INLET $(T_{m\,in})$, °F	OUTLET $(T_{m\,out})$, °F			
	C	1535	947.222									
1	0	1535	947.222	.05	.57	.57	377	68	67	2.5		58
2	1	1536	947.628	.045	.51	.51	377	67	67	2.5		58
3	2	1537	948.065	.05	.57	.57	380	68	67	2.5		57
4	3	1538	948.500	.06	.68	.68	382	68	67	2.9		56
5	4	1539	948.971	.055	.63	.63	385	68	67	2.8		55
6	5	1540	949.438	.06	.68	.68	387	68	67	3.0		55
7	6	1541	949.905	.07	.82	.82	388	68	67	3.0		54
8	7	1542	950.406	.07	.82	.82	392	69	67	3.0		54
9	8	1543	950.928	.065	.74	.74	394	69	67	3.0		53
10	9	1544	951.433	.08	.93	.93	393	69	67	4.0		53
11	10	1545	951.971	.10	1.15	1.15	393	70	67	4.6		53
12	11	1546	952.545	.09	1.05	1.05	392	70	67	4.7		53
13	12	1547	953.129	.10	1.15	1.15	394	70	67	4.8		53
14	13	1548	953.714	.11	1.28	1.28	396	70	67	5.6		52
15	14	1549	954.333	.09	1.05	1.05	397	71	67	5.3		52
16	15	1550	954.931	.085	.98	.98	395	71	67	5.1		52

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FIELD DATA

PLANT ____________
DATE ____________
SAMPLING LOCATION ____________
SAMPLE TYPE ____________
RUN NUMBER ____________
OPERATOR ____________
AMBIENT TEMPERATURE ____________
BAROMETRIC PRESSURE ____________
STATIC PRESSURE, (P_s) ____________
FILTER NUMBER (s) ____________

Run # 5

PROBE LENGTH AND TYPE ____________
NOZZLE I.D. ____________
ASSUMED MOISTURE, % ____________
SAMPLE BOX NUMBER ____________
METER BOX NUMBER ____________
METER $\Delta H_@$ ____________
C FACTOR ____________
PROBE HEATER SETTING ____________
HEATER BOX SETTING ____________
REFERENCE Δp ____________

SCHEMATIC OF TRAVERSE POINT LAYOUT

READ AND RECORD ALL DATA EVERY ______ MINUTES LEAK RATE ______ CFM @ ____ "Hg

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F			
17	16	1551	955.505	.09	1.05	1.05	395	72	67	5.2		53
18	17	1552	956.089	.10	1.15	1.15	391	72	67	5.4		53
19	18	1553	956.685	.10	1.15	1.15	396	72	67	5.7		53
20	19	1554	957.274	.10	1.15	1.15	395	72	67	5.8		53
21	20	1555	957.869	.11	1.28	1.28	394	72	67	5.9		52
22	21	1556	958.485	.10	1.15	1.15	392	73	67	5.9		52
23	22	1557	959.102	.11	1.28	1.28	390	73	67	6.8		52
24	23	1558	969.728	.12	1.41	1.41	394	73	67	7.1		52
	24	1559	960.311									
				Change filter			38-15					
1	24	1624	960.311	.10	1.15	1.15	389	66	65	3.8		57
2	25	1625	960.851	.09	1.05	1.05	391	66	65	3.9		55
3	26	1626	961.452	.095	1.1	1.1	392	66	65	4.0		54
4	27	1627	962.046	.095	1.1	1.1	396	66	65	4.0		54
5	28	1628	962.635	.09	1.05	1.05	396	66	65	4.0		54

Probe 164

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FIELD DATA

Run # 5

PLANT ________
DATE ________
SAMPLING LOCATION ________
SAMPLE TYPE ________
RUN NUMBER ________
OPERATOR ________
AMBIENT TEMPERATURE ________
BAROMETRIC PRESSURE ________
STATIC PRESSURE, (P_s) ________
FILTER NUMBER (s) ________

PROBE LENGTH AND TYPE ________
NOZZLE I.D. ________
ASSUMED MOISTURE, % ________
SAMPLE BOX NUMBER ________
METER BOX NUMBER ________
METER $\Delta H_@$ ________
C FACTOR ________
PROBE HEATER SETTING ________
HEATER BOX SETTING ________
REFERENCE Δp ________

SCHEMATIC OF TRAVERSE POINT LAYOUT

READ AND RECORD ALL DATA EVERY ______ MINUTES LEAK RATE _____ CFM @ ____ "Hg

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24 hr CLOCK)	GAS METER READING (V_m), ft³	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F			
6	29	1629	963.231	.085	.98	.98	358	67	65	4.0	R	53
7	30	1630	963.808	.075	.87	.87	399	67	65	3.8		54
8	31	1631	964.356	.075	.87	.87	398	67	65	3.8		54
9	32	1632	964.901	.07	.82	.82	399	68	65	3.6		54
10	33	1633	965.426	.065	.74	.74	399	68	65	3.4		54
11	34	1634	965.933	.075	.87	.87	399	69	65	3.7		54
12	35	1635	966.453	.07	.82	.82	399	70	65	3.7		54
13	36	1636	966.988	.095	1.1	1.1	402	70	65	4.3		53
14	37	1637	967.552	.14	1.65	1.65	404	71	66	6.0		53
15	38	1638	968.208	.13	1.55	1.55	409	71	66	6.0		53
16	39	1639	968.915	.14	1.65	1.65	407	72	66	6.9		53
17	40	1640	969.635	.15	1.78	1.78	402	72	66	7.1		53
18	41	1641	970.375	.15	1.78	1.78	401	73	66	7.5		52
19	42	1642	971.135	.155	1.82	1.82	403	73	66	8.2		52
20	43	1643	971.897	.155	1.82	1.82	400	73	66	8.4		52
21	44	1644	972.661	.16	1.89	1.89	401	74	66	8.4		53

Pg4

FIELD DATA

Run #5

PLANT ____
DATE ____
SAMPLING LOCATION ____
SAMPLE TYPE ____
RUN NUMBER ____
OPERATOR ____
AMBIENT TEMPERATURE ____
BAROMETRIC PRESSURE ____
STATIC PRESSURE, (P_s) ____
FILTER NUMBER (s) ____

PROBE LENGTH AND TYPE ____
NOZZLE I.D. ____
ASSUMED MOISTURE, % ____
SAMPLE BOX NUMBER ____
METER BOX NUMBER ____
METER $\Delta H_@$ ____
C FACTOR ____
PROBE HEATER SETTING ____
HEATER BOX SETTING ____
REFERENCE Δp ____

SCHEMATIC OF TRAVERSE POINT LAYOUT

READ AND RECORD ALL DATA EVERY ____ MINUTES LEAK RATE ____ CFM @ ____ "Hg

TRAVERSE POINT NUMBER	SAMPLING TIME, min	CLOCK TIME (24-hr CLOCK)	GAS METER READING (V_m), ft^3	VELOCITY HEAD (Δp_s), in. H_2O	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O		STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE		PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F			
22	45	1645	973.433	.14	1.68	1.68	399	74	66	8.6		53
23	46	1646	974.191	.16	1.88	1.88	397	74	66	9.0		53
24	47	1647	974.961	.18	2.1	2.1	403	74	66	10.3		53
	48	1648	975.664									

Probe

184

CLEAN-UP DATA

Plant Virginia Lime
Comments:

Date 5/30/75
Sampling Location #2 Kiln
Sample Type EPA-5
Run Number 5
Sample Box Number SGB-5
Clean-up Man H. Toy

IMPINGERS

	#1	#2	#3	#4	#5
Final Vol.	116 ml	104 ml	ml	ml	ml
Initial Vol.	100 ml	100 ml	ml	ml	ml
Net Vol.	16 ml	4 ml	ml	ml	ml

Total Net Volume in Impingers 20 ml

SILICA GEL

Final Weight	208.2 g	g	g
Initial Weight	200 g	g	g
Net Weight	g	g	g

Total Net Weight in Silica Gel 8.2 g

Total Moisture 28.2 g

Filter Number(s) 33-16
38-15

MRC 7/73

DRY MOLECULAR WEIGHT DETERMINATION

PLANT Virginia Lime

DATE 5/3/75

SAMPLING TIME (24-hr CLOCK) 1300/pm

SAMPLING LOCATION

SAMPLE TYPE (BAG, INTEGRATED, CONTINUOUS) Fyrite BAG -

ANALYTICAL METHOD Fyrite

AMBIENT TEMPERATURE 60

OPERATOR W. McDonald

COMMENTS: Run #5

RUN / GAS	1		2		3		AVERAGE NET VOLUME	MULTIPLIER	MOLECULAR WEIGHT OF STACK GAS (DRY BASIS) M_d, lb/lb-mole
	ACTUAL READING	NET	ACTUAL READING	NET	ACTUAL READING	NET			
CO_2	9.0	9.0	8.5	8.5	9.0	9.0	8.8	44/100	3.872
O_2 (NET IS ACTUAL O_2 READING MINUS ACTUAL CO_2 READING)	15.5	15.5	15.5	15.5	15.5	15.5	15.5	32/100	4.96
CO (NET IS ACTUAL CO READING MINUS ACTUAL O_2 READING)	.2	.2	.4	.4	.2	.2	.3	28/100	.08
N_2 (NET IS 100 MINUS ACTUAL CO READING)							75.4	28/100	21.116
								TOTAL	30.028

KILN OPERATION LOG

4-29-75

coal
1 ton / 3 ton product

	FEED DATA				
	HOUR	SIZE FEED	AVG. TONS/ HOUR	TIME OF FEED CHANGE	COAL METER READING
FIRST SHIFT	7	2	29	7:30	
	8	4	26		
	9	4	12		
	10	4			
	11	2	3	11^00	
	12	1	16	11:30	
	1	1	30		
	2	2	23	1^30	
	3	4	27	2^00	
TONS OF FEED BURNED 137 ✓					
SECOND SHIFT	3	4	27		
	4	4	27		
	5	4	29		
	6	4	28		
	7	4	30		
	8	4	28		
	9	4	29		
	10	4	28		
	11	4	28		
TONS OF FEED BURNED 227 ✓					
THIRD SHIFT	11	4	28		
	12	3	14	11:15	
	1	3	24		
	2	3	29		
	3	2	22	3:00	
	4	2	27		
	5	2	27		
	6	2	29		
	7	2	27		
TONS OF FEED BURNED 201 ✓					

KILN OPERATION LOG

4-30-75

	HOUR	FEED DATA			COAL METER READING
		SIZE FEED	AVG. TONS/ HOUR	TIME OF FEED CHANGE	
FIRST SHIFT	7	2	29	730	
	8	1	27		
	9	1	30		
	10	1	31		
	11	1	28		
	12	1	30		
	1	1	24		
	2	1	19		
	3	1	23		

TONS OF FEED BURNED 212 ✓

SECOND SHIFT	3	1	27		
	4	1	21		
	5	1	27		
	6	1	30		
	7	1	28		
	8	1	29		
	9	1	27		
	10	1	29		
	11	1	27		

TONS OF FEED BURNED 218 ✓

THIRD SHIFT	11	1	27	12:00	
	12	2	28	12:50	
	1	3	29		
	2	3	28		
	3	3	28		
	4	3	29		
	5	3	28		
	6	3	30		
	7	3	28		

TONS OF FEED BURNED 228 ✓

KILN OPERATION LOG

5-1-75

	FEED DATA				
	HOUR	SIZE FEED	AVG. TONS/ HOUR	TIME OF FEED CHANGE	COAL METER READING
FIRST SHIFT	7	2	25		
	8	2	27		
	9	2	32		
	10	2	25	104	
	11	2	30		
	12	1	26		
	1	1	31		
	2	1	27		
	3	1	30		

TONS OF FEED BURNED 215

SECOND SHIFT	3	1	30		
	4	1	29		
	5	1	29		
	6	1	29		
	7	1	29		
	8	1	10		
	9	1	27		
	10	1	29		
	11	1	27		

TONS OF FEED BURNED 209

THIRD SHIFT	11	2	27	11:15	
	12	2	27		
	1	2	30		
	2	2	29		
	3	2	29		
	4	2	29		
	5	4	29	5:15	
	6	4	27		
	7	4	27		

TONS OF FEED BURNED 22[illegible]

KILN OPERATION LOG

5-2-75

	HOUR	FEED DATA			CO. MET READ
		SIZE FEED	AVG. TONS/ HOUR	TIME OF FEED CHANGE	
FIRST SHIFT	7	4	27		
	8	4	30		
	9	2	28	900	
	10	2	29	930	
	11	4	30	1100	
	12	4	29		
	1	4	28		
	2	4	29		
	3	4	29		

TONS OF FEED BURNED 231 ✓

SECOND SHIFT	3	4	29		
	4	4	29		
	5	4	30		
	6	4	29		
	7	4	29		
	8	2	17	8:00	
	9	2	29		
	10	2	26	10:05	
	11	1	29		

TONS OF FEED BURNED 218 ✓

THIRD SHIFT	11	1	29		
	12	1	29		
	1	1	28		
	2	1	28		
	3	1	29		
	4	1	27		
	5	1	26		
	6	1	30		
	7	1	29		

TONS OF FEED BURNED 226 ✓

KILN OPERATION LOG

5-3-75

	HOUR	FEED DATA			COAL METER READING
		SIZE FEED	AVG. TONS/ HOUR	TIME OF FEED CHANGE	
FIRST SHIFT	7	1	29		
	8	1	8		
	9	1	29		
	10	1	28		
	11	2	25	11:15	
	12	4	30	12:30	
	1	4	30		
	2	4	24		
	3	4	29		

TONS OF FEED BURNED 203 ✓

SECOND SHIFT	3	4	29		
	4	4	29		
	5	4	29		
	6	4	29		
	7	2	29	7:00	
	8	2	29		
	9	2	28		
	10	2	28		
	11	2	29		

TONS OF FEED BURNED 230 ✓

THIRD SHIFT	11	2	29		
	12	2	29		
	1	2	27		
	2	2	28		
	3	2	29		
	4	2	29		
	5	2	28		
	6	4	29	6:00	
	7	4	27		

KILN OPERATION LOG

5-4-75

		FEED DATA			
	HOUR	SIZE FEED	AVG. TONS/ HOUR	TIME OF FEED CHANGE	COAL METER READING
FIRST SHIFT	7	2	27	7:30	
	8	1	25	8:00	
	9	1	29		
	10	1	29		
	11	1	29		
	12	1	29		
	1	1	29		
	2	1	25		
	3	1	28		

TONS OF FEED BURNED 223 ✓

SECOND SHIFT	3	1	28		
	4	1	31		
	5	1	28		
	6	1	29		
	7	1	26		
	8	1	29		
	9	1	26	9:00	
	10	2	28	10:00	
	11	4	27		

TONS OF FEED BURNED 224 ✓

THIRD SHIFT	11	4	27		
	12	4	28		
	1	4	27		
	2	4	24		
	3	4	25		
	4	4	30		
	5	[illegible]	27	5:30	
	6	[illegible]	28		

APPENDIX G

ANALYTICAL DATA SHEETS

ANALYTICAL DATA

PLANT Virginia Lime

DATE 4/30/75

SAMPLING LOCATION #2 Kiln

SAMPLE TYPE EPA-5

RUN NUMBER 1

SAMPLE BOX NUMBER MRC #4 + SGB

CLEAN-UP MAN H. Toy

COMMENTS:

FRONT HALF

		LABORATORY RESULTS
ACETONE WASH OF NOZZLE, PROBE, CYCLONE (BYPASS), FLASK, FRONT HALF OF FILTER HOLDER	CONTAINER 4A	7683.5 mg
FILTER NUMBER 1.6883 ______ 0.4277 ______ 1.2606 ______	CONTAINER 32-3	1260.6 mg

FRONT HALF SUBTOTAL 8944.1 mg

BACK HALF

IMPINGER CONTENTS AND WATER WASH OF IMPINGERS, CONNECTORS, AND BACK HALF OF FILTER HOLDER	CONTAINER ______	______ mg
	ETHER-CHLOROFORM EXTRACTION	______ mg
ACETONE WASH OF IMPINGERS, CONNECTORS, AND BACK HALF OF FILTER HOLDER	CONTAINER ______	______ mg

BACK HALF SUBTOTAL ______ mg

TOTAL WEIGHT 8944.1 mg

MOISTURE

IMPINGERS

FINAL VOLUME ______ ml

INITIAL VOLUME ______ ml

NET VOLUME ______ ml

SILICA GEL

FINAL WEIGHT	______ g	______ g	______ g
INITIAL WEIGHT	______ g	______ g	______ g
NET WEIGHT	______ g	______ g	______ g

TOTAL MOISTURE ______ g

EPA (Dur) 231
4/72

ANALYTICAL DATA

PLANT Virginia Lime

DATE 5/1/75

SAMPLING LOCATION #2 Kiln

SAMPLE TYPE EPA-5

RUN NUMBER 2

SAMPLE BOX NUMBER MRC #4 SGB

CLEAN-UP MEN W. McDONALD

ANALYST

COMMENTS:

FRONT HALF

		LABORATORY RESULTS
ACETONE WASH OF NOZZLE, PROBE, CYCLONE (BYPASS), FLASK, FRONT HALF OF FILTER HOLDER	CONTAINER 5A	8526.5 mg
FILTER NUMBER 2978.1 mg 432.1 2546.0	CONTAINER 33-21	2546.0 mg

FRONT HALF SUBTOTAL 11072.5 mg

BACK HALF

IMPINGER CONTENTS AND WATER WASH OF IMPINGERS, CONNECTORS, AND BACK HALF OF FILTER HOLDER	CONTAINER	mg
	ETHER-CHLOROFORM EXTRACTION	mg
ACETONE WASH OF IMPINGERS, CONNECTORS, AND BACK HALF OF FILTER HOLDER	CONTAINER	mg

BACK HALF SUBTOTAL mg

TOTAL WEIGHT 11072.5 mg

MOISTURE

IMPINGERS

FINAL VOLUME ml

INITIAL VOLUME ml

NET VOLUME ml

SILICA GEL

FINAL WEIGHT	g	g	g
INITIAL WEIGHT	g	g	g
NET WEIGHT	g	g	g

TOTAL MOISTURE g

EPA (Dur) 231
4/72

ANALYTICAL DATA

PLANT Virginia Lime
DATE 5/2/75
SAMPLING LOCATION #2 Kiln
SAMPLE TYPE EPA 5
RUN NUMBER 3
SAMPLE BOX NUMBER S.GB-5
CLEAN-UP MEN H. Toy
ANALYST

COMMENTS:

FRONT HALF

LABORATORY RESULTS

ACETONE WASH OF NOZZLE, PROBE, CYCLONE (BYPASS), FLASK, FRONT HALF OF FILTER HOLDER	CONTAINER 6A	15871.8 mg
FILTER NUMBER 2145.2 2427.0 428.6 428.7 1716.6 1998.3	CONTAINER 33-23 32-13	1716.6 mg 1998.3

FRONT HALF SUBTOTAL 19586.7 mg

BACK HALF

IMPINGER CONTENTS AND WATER WASH OF IMPINGERS, CONNECTORS, AND BACK HALF OF FILTER HOLDER	CONTAINER B-10	9.60 mg	INORG.
	ETHER-CHLOROFORM EXTRACTION	78.2 mg	ORG
ACETONE WASH OF IMPINGERS, CONNECTORS, AND BACK HALF OF FILTER HOLDER	CONTAINER 7A	52.6 mg	INORG.

BACK HALF SUBTOTAL 140.4 mg

TOTAL WEIGHT 19727.1 mg

MOISTURE

IMPINGERS
FINAL VOLUME ______ ml
INITIAL VOLUME ______ ml
NET VOLUME ______ ml

SILICA GEL

FINAL WEIGHT	g	g	g
INITIAL WEIGHT	g	g	g
NET WEIGHT	g	g	g

TOTAL MOISTURE 21.4 g

EPA (Dur) 231
4/72

ANALYTICAL DATA

PLANT Virginia Lime

DATE 5/3/75

SAMPLING LOCATION #2 Kiln

SAMPLE TYPE E.PA - 5

RUN NUMBER 4

SAMPLE BOX NUMBER S.GB - 5

CLEAN-UP MAN H. Toy + W. McDonald

COMMENTS:

FRONT HALF

LABORATORY RESULTS

ACETONE WASH OF NOZZLE, PROBE, CYCLONE (BYPASS), FLASK, FRONT HALF OF FILTER HOLDER	CONTAINER 8A	10923.2 mg
FILTER NUMBER 1541.6 1523.0 432.2 430.6 1109.4 1092.4	CONTAINER 38-13 33-22	1092.4 mg 1109.4

FRONT HALF SUBTOTAL 13125.0 mg

BACK HALF

IMPINGER CONTENTS AND WATER WASH OF IMPINGERS, CONNECTORS, AND BACK HALF OF FILTER HOLDER	CONTAINER B-9	34.1 mg
	ETHER-CHLOROFORM EXTRACTION B-4	7.2 mg
ACETONE WASH OF IMPINGERS, CONNECTORS, AND BACK HALF OF FILTER HOLDER	CONTAINER 9A	14.2 mg

BACK HALF SUBTOTAL 55.5 mg

TOTAL WEIGHT 13180.5 mg

MOISTURE

IMPINGERS

FINAL VOLUME ______ ml

INITIAL VOLUME ______ ml

NET VOLUME ______ ml

SILICA GEL

FINAL WEIGHT	______ g	______ g	______ g
INITIAL WEIGHT	______ g	______ g	______ g
NET WEIGHT	______ g	______ g	______ g

TOTAL MOISTURE 24.9 g

EPA (Dur) 231
4/72

ANALYTICAL DATA

PLANT Virginia Lime

DATE 5/3/75

SAMPLING LOCATION #2 Kiln

SAMPLE TYPE EPA #5

RUN NUMBER 5

SAMPLE BOX NUMBER SGB-5

CLEAN-UP MAN H. Toy & W. McDonald

COMMENTS:

FRONT HALF

			LABORATORY RESULTS
ACETONE WASH OF NOZZLE, PROBE, CYCLONE (BYPASS), FLASK, FRONT HALF OF FILTER HOLDER		CONTAINER 10 A	13824.3 mg
FILTER NUMBER	1531.2 1379.3	CONTAINER 33-16	1095.9 mg
	435.3 434.8	38-15	944.5
	1095.9 944.5		
		FRONT HALF SUBTOTAL	15864.7 mg

BACK HALF

IMPINGER CONTENTS AND WATER WASH OF IMPINGERS, CONNECTORS, AND BACK HALF OF FILTER HOLDER	CONTAINER B-8	31.0 mg
	ETHER-CHLOROFORM EXTRACTION	23.7 mg
ACETONE WASH OF IMPINGERS, CONNECTORS, AND BACK HALF OF FILTER HOLDER	CONTAINER 11A	18.8 mg
	BACK HALF SUBTOTAL	73.5 mg
	TOTAL WEIGHT	15938.2 mg

MOISTURE

IMPINGERS

FINAL VOLUME ________ ml

INITIAL VOLUME ________ ml

NET VOLUME ________ ml

SILICA GEL

FINAL WEIGHT ________ g ________ g ________ g

INITIAL WEIGHT ________ g ________ g ________ g

NET WEIGHT ________ g ________ g ________ g

TOTAL MOISTURE 28.2 g

EPA (Dur) 231
4/72

1

HEAT OF COMBUSTION DATA SHEET

Virginia Lime - Coal

Sample No. 4/30/75 4:00pm Date 5/19/75 Observer F. A. Kulik

Sample + Capsule 10.8836

Tare Wt. Capsule 9.9080

Net Wt. Sample 0.9756

Average Room Temp. 23.5 °C

OBSERVATIONS

Time Min.	Time Sec.	Temperature °C
5		21.736
10		21.750 ←
11	00	23.03
11	15	23.50
11	30	23.78
11	45	23.97
16		24.662
17		24.670
18		24.671 ←
19		24.670
20		24.667
21		24.663
22		24.660
23		24.657
24		
25		
26		

Corrected Temperature Rise:

Final Temp. 24.671

Scale Corr. .005

True Final = 24.676

R_2(c-b) = .020

Corrected Final = 24.696

Initial Temp. 21.750

Scale Corr. .001

True Initial = 21.751

r_1(b-a) = .004

Corrected Initial = 21.755

Net Temp. Rise = 2.941

1.8 x 2417.6 (Water Equiv.) x 2.941 (Net Temp. Rise) = 12798.3 ✓ Total BTU

Interpolation to Find "Six-Tenths Point:"

0.6R = .6(24.671 (Final Temp.) - 21.750 (Initial Temp.)) = 1.753 °C

Temp. at .6R = 21.750 (Init. Temp.) + 1.753 (0.6R) = 23.503 °C

Time (b) at .6R = 11:15 (Prior Time) + 0 (Time Gain) = 11:15 Min. + Sec.

(b-a) = 11:15 (Time (b)) - 10:00 (Time Fired) = 1:15 (Min. + Sec.) = 1.25 Min. + 100 Ths.

(c-b) = 18:00 (Final Time) - 11:15 (Time (b)) = 6:45 (Min. + Sec.) = 6.75 Min. + 100 Ths.

Radiation Rates:

Initial Rate (r_1) = .014 (Prelim. Rise) ÷ 5 (Minutes) = .003 °C per Min.

Final Rate (r_2) = .014 (Final Fall) ÷ 5 (Minutes) = .003 °C per Min.

Corrections for Total BTU:

Fuse Wire = 4.14 x 6.6 = 27.32 BTU

Sulfur = 23 x 0.9756 (Wt. Sample) x 0.95 (% S) = 21.3 BTU

Acid Titration = 14.60 ml x 0.1000 N x 24.8 = 36.21 BTU

Total Correction = 84.8 ~~[illegible]~~ BTU

Net Heat Liberated 12713.5 BTU

Heat of Combustion = 12713.5 (Net Heat Liberated) ÷ 0.9756 (Wt. Sample) = 13031.5 BTU/lb

Air dry

130315 ÷ (1-.0127 ~~[illegible]~~) = 13199 ~~[illegible]~~ BTU/lb-Oven Dry

~~[illegible]~~ 13199 × (1-.0784) = 12164 ~~[illegible]~~ BTU/lb As Rec'd

HEAT OF COMBUSTION DATA SHEET

③

Virginia Lime - Coal

Sample No. 4/30/75 4:00pm Date 5/19/75 Observer F. A. Kulek

Sample + Capsule 10.8724

Tare Wt. Capsule 9.9071

Net Wt. Sample 0.9653

Average Room Temp. 23 °C

OBSERVATIONS

Time Min.	Time Sec.	Temperature °C
5		20.239
10		20.273
11	00	21.53
11	15	21.90
11	30	22.20
11	45	22.44
16		23.188
17		23.195
18		23.206
19		23.208
20		23.208
21		23.207
22		23.205
23		23.203
24		23.207
25		
26		

Corrected Temperature Rise:

Final Temp. 23.208

Scale Corr. .002

True Final = 23.210

R_2(c-b) = .000

Corrected Final = 23.210

Initial Temp. 20.273

Scale Corr. .009

True Initial = 20.282

r_1(b-a) = .010

Corrected Initial = 20.292

Net Temp. Rise = 2.918

1.8 x 2417.6 (Water Equiv.) x 2.918 ~~2.930~~ (Net Temp. Rise) = 12698.2 ~~12706.9~~ Total BTU

Interpolation to Find "Six-Tenths Point:"

0.6R = .6(23.208 (Final Temp.) - 20.273 (Initial Temp.)) = 1.761 °C

Temp. at .6R = 20.273 (Init.Temp.) + 1.761 (0.6R) = 22.034 °C

Time (b) at .6R = 11:15 (Prior Time) + :07 (Time Gain) = 11:22 Min. + Sec.

(b-a) = 11:22 (Time (b)) - 10:00 (Time Fired) = 1:22 (Min. + Sec.) = 1.37 Min. + 100 Ths.

(c-b) = 19:00 (Final Time) - 11:22 (Time (b)) = 7:38 (Min. + Sec.) = 7.63 Min. + 100 Ths.

Radiation Rates:

Initial Rate (r_1) = .034 (Prelim. Rise) ÷ 5 (Minutes) = .007 °C per Min.

Final Rate (r_2) = .001 (Final Fall) ÷ 5 (Minutes) = 0 ~~.0002~~ °C per Min.

Corrections for Total BTU:

Fuse Wire = 4.14 x 5.6 = 23.18 BTU

Sulfur = 23 x 0.9653 (Wt. Sample) x .95 (% S) = 21.1 BTU

Acid Titration = 14.85 ml x .1000 N x 24.8 = 36.8 BTU

Total Correction = 81.1 BTU

Net Heat Liberated = 12617.1 BTU

Heat of Combustion = 12617.1 (Net Heat Liberated) ÷ 0.9653 (Wt. Sample) = 13070.7 BTU/lb

13070.7 ÷ (1 - .0127) = 13238.8 ~~13904.0~~

13238.8 ~~[illegible]~~ x (1 - .0784) = 12200 ~~12843~~

HEAT OF COMBUSTION DATA SHEET

Sample No. Virginia time - Coal 5/3/75 11:35 Date 5/19/75 Observer J. A. Kulick ③

Sample + Capsule ~~9.9~~ 10.8757

Tare Wt. Capsule 9.9053

Net Wt. Sample 0.9704

Average Room Temp. 22 1 °C

OBSERVATIONS

Time Min.	Time Sec.	Temperature °C
5		20.986
10		21.009 ←
11	00	22.24
11	15	22.73
11	30	23.07
11	45	23.34
16		24.188
17		24.195
18		24.197 ←
19		24.197
20		24.194
21		24.190
22		24.190
23		24.187
24		
25		
26		

Corrected Temperature Rise:

Final Temp. 24.197

Scale Corr. .005

True Final = 24.202

R_2(c-b) = .013

Corrected Final = 24.215

Initial Temp. 21.009

Scale Corr. .005

True Initial = 21.014

r_1(b-a) = .007

Corrected Initial = 21.021

Net Temp. Rise = 3.194

1.8 x 2417.6 (Water Equiv.) x 3.194 (Net Temp. Rise) = 13899.3 Total BTU

Interpolation to Find "Six-Tenths Point:"

0.6R = .6(24.197 (Final Temp.) - 21.009 (Initial Temp.)) = 1.913 °C

Temp. at .6R = 21.009 (Init.Temp.) + 1.913 (0.6R) = 22.922 °C

Time (b) at .6R = 11'15 (Prior Time) + '08 (Time Gain) = ~~11:24~~ 11:23 Min. + Sec.

(b-a) = 11:23 (Time (b)) - 10:00 (Time Fired) = 1:23 (Min. + Sec.) = ~~1.40~~ 1.38 Min. + 100 Ths.

(c-b) = 18:00 (Final Time) - 11:23 (Time (b)) = ~~6:36~~ 6:37 (Min. + Sec.) = ~~6.36~~ 6.62 Min. + 100 Ths.

Radiation Rates:

Initial Rate (r_1) = .023 (Prelim. Rise) ÷ 5 (Minutes) = .005 °C per Min.

Final Rate (r_2) = 0.010 (Final Fall) ÷ 5 (Minutes) = .002 °C per Min.

Corrections for Total BTU:

Fuse Wire = 4.14 x 6.8 = 28.2 BTU

Sulfur = 23 x 0.9704 (Wt. Sample) x 0.74 (% S) = 16.5 BTU

Acid Titration = 16.40 ml x .1000 N x 24.8 = 40.7 BTU

Total Correction = 85.4 BTU

Net Heat Liberated = 13813.9 BTU

Heat of Combustion = 13813.9 (Net Heat Liberated) ÷ 0.9704 (Wt. Sample) = 14235.3 BTU/lb

14235.3 ÷ (1 − .0128) = 14419.9

14419.9 x (1 − .0508) = 13687

HEAT OF COMBUSTION DATA SHEET

Virginia Lime - Coal

Sample No. 5/3/75 11:35

Date 5/19/75 Observer F. A. Kulik

Sample + Capsule 10.9006

Tare Wt. Capsule 9.9049

Net Wt. Sample 0.9957

Average Room Temp. 23 °C

OBSERVATIONS

Time Min.	Time Sec.	Temperature °C
5		20.968
10		20.990 ←
11	00	22.29
11	15	22.77
11	30	23.15
11	45	23.44
16		24.255
17		24.261
18		24.263 ←
19		24.263
20		24.262
21		24.260
22		24.258
23		24.255
24		
25		
26		

Corrected Temperature Rise:

Final Temp. 24.263

Scale Corr. .006

True Final = 24.269

R_2(c-b) = .013

Corrected Final = 24.282

Initial Temp. 20.990

Scale Corr. ~~.009~~ .005

True Initial = 20.995

r_1(b-a) = .005

Corrected Initial = 21.000

Net Temp. Rise = 3.282

1.8 x 2417.6 (Water Equiv.) x 3.282 (Net Temp. Rise) = 14282.2 Total BTU

Interpolation to Find "Six-Tenths Point:"

0.6R = .6(24.263 (Final Temp.) - 20.990 (Initial Temp.)) = 1.964 °C

Temp. at .6R = 20.990 (Init. Temp.) + 1.964 (0.6R) = 22.954 °C

Time (b) at .6R = 11:15 (Prior Time) + :07 (Time Gain) = 11:22 Min. + Sec.

(b-a) = 11:22 (Time (b)) - 10:00 (Time Fired) = 1:22 (Min. + Sec.) = 1.37 Min. + 100 Ths.

(c-b) = 18:00 (Final Time) - 11:22 (Time (b)) = 6:38 (Min. + Sec.) = 6.63 Min. + 100 Ths.

Radiation Rates:

Initial Rate (r_1) = .022 (Prelim. Rise) ÷ 5 (Minutes) = .004 °C per Min.

Final Rate (r_2) = .008 (Final Fall) ÷ 5 (Minutes) = .002 °C per Min.

Corrections for Total BTU:

Fuse Wire = 4.14 x 7.3 = 30.2~~2~~ BTU

Sulfur = 23 x 0.9957 (Wt. Sample) x 0.73 (% S) = 16.7 BTU

Acid Titration = 5.90 ml x N/1000 N x 24.8 = 39.4~~6~~ BTU

Total Correction = 86.3 BTU

Net Heat Liberated = 14195.9 BTU

Heat of Combustion = 14195.9 (Net Heat Liberated) ÷ 0.9957 (Wt. Sample) = ~~14137.1~~ BTU/lb 14257.2

14257.2 ÷ (1 - .~~[illegible]~~ .0128) = 14442.1

14442.1 x (1 - .~~[illegible]~~ .0508) = 13708

⑤

HEAT OF COMBUSTION DATA SHEET

Sample No. Virginia Lime - Coal Run #3

Date 5/20/75

Observer L. A. Kulik

Sample + Capsule 10.8944

Tare Wt. Capsule 9.9049

Net Wt. Sample 0.9895

Average Room Temp. 23° °C

OBSERVATIONS

Time Min.	Time Sec.	Temperature °C
5		20.726
10		20.750 ←
11	00	22.04
11	15	22.41
11	30	22.79
11	45	23.05
16		23.709
17		23.718
18		23.720 ←
19		23.720
20		
21		
22		23.715
23		23.713
24		
25		
26		

Corrected Temperature Rise:

Final Temp. 23.720

Scale Corr. .003

True Final = 23.723

R_2(c-b) = .007

Corrected Final = 23.730

Initial Temp. 20.750

Scale Corr. .007

True Initial = 207.57

r_1(b-a) = .007

Corrected Initial = 20.764

Net Temp. Rise = 2.966

1.8 x 2417.6 (Water Equiv.) x 2.966 (Net Temp. Rise) = 12907.1 Total BTU

Interpolation to Find "Six-Tenths Point:"

0.6R = .6(23.720 (Final Temp.) - 20.750 (Initial Temp.)) = 1.782 °C

Temp. at .6R = 20.750 (Init.Temp.) + 1.782 (0.6R) = 22.532 °C

Time (b) at .6R = 11:15 (Prior Time) + :05 (Time Gain) = 11:20 Min. + Sec.

(b-a) = 11:20 (Time (b)) - 10:00 (Time Fired) = 1:20 (Min. + Sec.) = 1.33 Min. + 100 Ths.

(c-b) = 18.00 (Final Time) - 11:20 (Time (b)) = 6:40 (Min. + Sec.) = 6.67 Min. + 100 Ths.

Radiation Rates:

Initial Rate (r_1) = 0.024 (Prelim. Rise) ÷ 5 (Minutes) = .005 °C per Min.

Final Rate (r_2) = .007 (Final Fall) ÷ 5 (Minutes) = ~~.0014~~ .001 °C per Min.

Corrections for Total BTU:

Fuse Wire = 4.14 x 8.4 = 34.8 BTU

Sulfur = 23 x 0.9895 (Wt. Sample) x .9 (% S) = 20.5 BTU

Acid Titration = 15.15 ml x 0.1000 N x 24.8 = 37.6 BTU

Total Correction = 92.9 BTU

Net Heat Liberated = 12814.2 BTU

Heat of Combustion = 12814.2 (Net Heat Liberated) ÷ 0.9895 (Wt. Sample) = 13044.1 BTU/lb

13044.1 ÷ (1 - .0089) = 13161.2

13161.2 X (1 - .0397) = 12639

⑥

HEAT OF COMBUSTION DATA SHEET

Sample No. Virginia Lime - Coal Run #3

Date 5/20/75 Observer F. A. Kulik

Sample + Capsule 10.9059

Tare Wt. Capsule 9.9049

Net Wt. Sample 1.0010

Average Room Temp. 23 °C

OBSERVATIONS

Time Min.	Time Sec.	Temperature °C
5		20.703
10		20.728
11	00	21.84
11	15	22.30
11	30	22.64
11	45	22.89
16		23.729
17		23.734
18		23.738 ←
19		23.736
20		23.736
21		23.734
22		
23		23.730
24		
25		
26		

Corrected Temperature Rise:

Final Temp. 23.738

Scale Corr. .003

True Final = 23.741

R_2(c-b) = .013

Corrected Final = 23.754

Initial Temp. 20.728

Scale Corr. .007

True Initial = 20.735

r_1(b-a) = .007

Corrected Initial = 20.742

Net Temp. Rise = 3.012

1.8 x 2417.6 (Water Equiv.) x 3.012 (Net Temp. Rise) = 13107.3 Total BTU

Interpolation to Find "Six-Tenths Point:"

0.6R = .6(23738 (Final Temp.) - 20.728 (Initial Temp.)) = 1.806 °C

Temp. at .6R = 20.728 (Init.Temp.) + 1.806 (0.6R) = 22.534 °C

Time (b) at .6R = 11:15 (Prior Time) + :10 (Time Gain) = 11:25 Min. + Sec.

(b-a) = 11:25 (Time (b)) - 10:00 (Time Fired) = 1.25 (Min. + Sec.) = 1.42 (Min. + 100 Ths.)

(c-b) = 18:00 (Final Time) - 11:25 (Time (b)) = 6:35 (Min. + Sec.) = 6.58 (Min. + 100 Ths.)

Radiation Rates:

Initial Rate (r_1) = .025 (Prelim. Rise) ÷ 5 (Minutes) = .005 °C per Min.

Final Rate (r_2) = .008 (Final Fall) ÷ 5 (Minutes) = .002 °C per Min.

Corrections for Total BTU:

Fuse Wire = 4.14 x 8.3 = 34.4 BTU

Sulfur = 23 x 1.001 (Wt. Sample) x 0.79 (% S) = 18.2 BTU

Acid Titration = 14.40 ml x ______ N x 24.8 = 35.7 BTU

Total Correction = 88.3 BTU

Net Heat Liberated = 13019.0 BTU

Heat of Combustion = 13019.0 (Net Heat Liberated) ÷ 1.0010 (Wt. Sample) = 13006.0 BTU/lb

13006.0 ÷ (1 − .0089) = 13122.8

13122.8 × (1 − .0397) = 12602

⑦

HEAT OF COMBUSTION DATA SHEET

Sample No. Benzoic Acid

Date 5/20/75 Observer F. A. [illegible]

Sample + Capsule 10.9060

Tare Wt. Capsule 9.9051

Net Wt. Sample 1.0009

Average Room Temp. 23 °C

OBSERVATIONS

Time Min.	Time Sec.	Temperature °C
5		21.160
10		21.178
11	00	22.12
11	15	22.57
11	30	22.85
11	45	23.04
16		23.785
17		23.791
18		23.792 ←
19		23.791
20		23.790
21		
22		
23		23.784
24		
25		
26		

Corrected Temperature Rise:

Final Temp. 23.792

Scale Corr. .004

True Final = 23.796

R_2(c-b) = .013

Corrected Final = 23.809

Initial Temp. 21.178

Scale Corr. .003

True Initial = 21.181

r_1(b-a) = .006

Corrected Initial = 21.187

Net Temp. Rise = 2.622

1.8 x 2417.6 (Water Equiv.) x 2.622 (Net Temp. Rise) = 11410.1 Total BTU

Interpolation to Find "Six-Tenths Point:"

0.6R = .6(23.792 (Final Temp.) - 21.178 (Initial Temp.)) = 1.568 °C

Temp. at .6R = 21.178 (Init.Temp.) + 1.568 (0.6R) = 22.746 °C

Time (b) at .6R = 11:15 (Prior Time) + 9 (Time Gain) = 11:24 Min. + Sec.

(b-a) = 11:24 (Time (b)) - 10:00 (Time Fired) = 1:24 (Min. + Sec.) = 1.40 Min. + 100 Ths.

(c-b) = 18:00 (Final Time) - 11:24 (Time (b)) = 6:36 (Min. + Sec.) = 6.60 Min. + 100 Ths.

Radiation Rates:

Initial Rate (r_1) = .018 (Prelim. Rise) ÷ 5 (Minutes) = .004 °C per Min.

Final Rate (r_2) = .008 (Final Fall) ÷ 5 (Minutes) = .002 °C per Min.

Corrections for Total BTU:

Fuse Wire = 4.14 x 7.0 = 29.0 BTU

Sulfur = 23 x ____ (Wt. Sample) x ____ (% S) = ____ BTU

Acid Titration = 5.5 ml x .1000 N x 24.8 = 13.6 BTU

Total Correction = 42.6 BTU

Net Heat Liberated = 11410.1 BTU

Heat of Combustion = 11367.5 (Net Heat Liberated) ÷ 1.0009 (Wt. Sample) = 11357.3 BTU/lb

11373 BTU/lb

0.14% error

BOWSER-MORNER Testing Laboratories, Inc.

420 Davis Ave. • P.O. Box 51 • Dayton, Ohio 45401 • 513/253-8805
5247 Secor Road • P.O. Box 5847 • Toledo, Ohio 43613 • 419/473-2566

LABORATORY REPORT

May 12, 1975

Report to: Monsanto Research Corporation
Dayton Laboratory
Dayton, Ohio 45407

Laboratory No. 050617-26
Authorization: D-79750

Report on: Ten (10) Samples Submitted for Sulfur Content

Sample Identification:			Sulfur (as received basis)
#1	Product	Run #1	.027 - .025
#2	Feed	Run #1	.035 - .032
#3	Product	Run #2	.023 - .023
#4	Feed	Run #2	.031 - .033
#5	Product	Run #3	.029 - .029
#6	Feed	Run #3	.019 - .021
#7	Product	Run #4	.027 - .027
#8	Feed	Run #4	.027 - .025
#9	Product	Run #5	.022 - .024
#10	Feed	Run #5	.019 - .017

Respectfully submitted,

BOWSER-MORNER Testing Laboratories, Inc.

Samuel Lucas, Jr.
Manager, Analytical Chemistry Lab.

3- Client
2- File
SL/jp

BOWSER-MORNER Testing Laboratories, Inc.
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KENTUCKY DISTRICT • Route 8 West • P.O. Box 636 • Maysville, Kentucky 41056 • 606/564-5508

LABORATORY REPORT

September 29, 1975

Report to: Monsanto Research Corporation
1515 Nicholas Road
Dayton, Ohio 45418
Attn: Francine Kulak

Laboratory No. 092433
Authorization:

Report on: Four (4) Samples of Limestone Submitted for Sulfur Content in Percent by Weight

Sample Identification:	Sulfur
#1 Feed Limestone 4-30-75	.050
#2 Product 4-30-75 4:00 PM	.018
#3 Feed Limestone 5-2-75 3:25 PM	.026
#6 Product 5-2-75 3:35 PM Run #3	.032

Respectfully submitted,

BOWSER-MORNER Testing Laboratories, Inc.
Samuel Lucas Jr.
Samuel Lucas, Jr.
Manager, Analytical Chemistry Lab.

3- Client
2- File
SL/jp

Sulfates on Virginia Lime

7EP

%Sulfur

feed on 4/30 = 0.0715 % #2

product 4/30 0.0650 % #1

feed on 5/2 0.0420 % #6

product 5/2 ~~[illegible]~~ % 0.023 % #5

feed on 5/3 0.025 % #8

product on 5/3 0.029 #7

ANALYSIS REPORT	**PROJECT NUMBER** 13-080-7601-6912-11
TO Tom Peltier	**FROM** S. Kulik
DATE 11/25/75	**CC**

Method: ASTM C25-73 - Standard Bromine Method for Total Sulfur

% Sulfur on particulate of front half acetone wash from Method 5 train.

Sample		g sample	g $BaSO_4$	% S
4A	Run #1	1.0110	0.0125	0.17
4A		1.0033	0.0124	0.17
6A	Run #3	0.9988	0.0126	0.17
6A		1.0057	0.0120	0.16

Calculation: $$\frac{\text{wt } \overset{BaSO_4}{\cancel{\text{sample}}}\ (g) \times 13.734}{\text{wt sample g}} = \% S$$

APPENDIX H

SAMPLING AND ANALYTICAL PROCEDURES

SAMPLING AND ANALYTICAL METHODS

1. Methods 1 through 7 from the Federal Register, Vol. 36, No. 247, December 23, 1971 were followed during the sampling at Virginia Lime Company.

2. Method 10 from the Federal Register, Vol. 39, No. 47, March 8, 1974 was followed during the carbon monoxide sampling at Virginia Lime Company.

3. Total sulfur content of the feed and product materials was determined according to ASTM C25-72, Chemical Analysis of Limestone.

4. Proximate coal analysis was performed according to ASTM D271-70. The moisture, volatiles, ash, fixed carbon, sulfur, and Btu contents were determined.

Designation: C 25 - 72

American National Standard K67 3
American National Standards Institute

Standard Methods of
CHEMICAL ANALYSIS OF LIMESTONE, QUICKLIME, AND HYDRATED LIME[1]

This Standard is issued under the fixed designation C 25; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

23. Total Sulfur

23.1 *Standard Bromine Method*—Weigh 1 g of the prepared sample. Add approximately 0.5 g of Na_2CO_3. Mix thoroughly in a porcelain crucible (Note 27) and heat gently until sintered. Then ignite for 15 min at a temperature of approximately 1000 C, taking care to allow access of air to the contents of the crucible. Cool and place the crucible in a 250-ml beaker and cover with hot water. Add 10 ml of bromine water, then 30 ml HCl (1+1) and boil until solution is complete and all bromine has been expelled. Remove the crucible, washing it with water. Add a few drops of methyl red and render the solution alkaline with NH_4OH (1+1). Boil the solution for 1 or 2 min, filter, and wash with hot water. To the filtrate add 5 ml of HCl (1+1), adjust the volume to about 200 ml, bring the solution to boiling, and while boiling add 10 ml of hot $BaCl_2$ (10 percent). Allow to stand overnight. Filter, wash with hot water, ignite, and weigh as $BaSO_4$.

NOTE 27—It is usually desirable to make a fusion in a platinum crucible. However, it has been found that with limestones very high in impurities, when the fusion is made in a muffle, the damage to platinum ware is considerable. It has been proved that the use of porcelain crucibles introduces no appreciable error.

23.2 *Alternative Leco Method:*

23.2.1 *Description*—The total sulfur in various types of materials can be determined accurately by the Leco automatic titrator and high frequency induction furnace. The sulfur in the sample burns to SO_2 in the furnace and is carried to the titrator by the oxygen stream. The gas enters a titration vessel containing HCl, KI, starch, and just enough KIO_3 to release some free iodine to turn the starch blue. The SO_2 bleaches the blue color and KIO_3 solution is added automatically to maintain the blue color. When all the SO_2 has been released, the blue color no longer fades and the amount of KIO_3 solution used is read on a buret directly as percent sulfur.

NOTE 28—The Leco instrument should be standardized by using a calcium oxide of known sulfur content as determined by the bromine method in 21.1.

23.2.2 *Apparatus:*

23.2.2.1 *Induction Furnace*, "S" modification, Leco Model No. 521.

23.2.2.2 *Automatic Titrator*, Leco Model No. 532.

23.2.2.3 *Oxygen Tank and Regulators.*

23.2.2.4 *Purifying Train*, Leco Model No. 516.

23.2.2.5 *Combustion Crucibles*, Leco Model No. 528-120.

23.2.2.6 *Crucible Covers*, Leco Model No. 528-41.

23.2.2.7 *Glass Accelerator Scoop*, Leco Model No. 503-32.

23.2.2.8 *Starch Dispenser.*

23.2.2.9 *Timer*, Leco Model No. 593-100.

23.2.2.10 *Loading Funnel*, Leco Model No. 503-31.

23.2.3 *Reagents:*

23.2.3.1 *Copper Ring Accelerator*, Leco Catalog No. 550-184.

23.2.3.2 *Hydrochloric Acid* (HCl) 35 percent, Baker Catalog No. 9535.

23.2.3.3 *Low-Sulfur Powdered Iron*, Leco Catalog No. 501-78.

23.2.3.4 *Phenylmercuric Acetate*, MC&B Catalog No. P 5027.

23.2.3.5 *Potassium Iodate* (KIO_3) crystal, Baker Catalog No. 3156.

23.2.3.6 *Potassium Iodide* (KI) crystal, Baker Catalog No. 3162.

23.2.3.7 *Starch*, water-soluble, Baker Catalog No. 4006.

23.2.3.8 *Tin Metal Accelerator*, Leco Catalog No. 501-76.

23.2.4 *Solutions:*

23.2.4.1 *Hydrochloric Acid*—Dilute 15 ml of hydrochloric acid to 1 liter with water.

23.2.4.2 *Starch*—Weigh 9.0 g of starch into a small beaker. Add 5 to 10 ml of water and stir into a smooth paste. Add starch slowly while stirring into 500 ml of boiling water. Cool and add 15 g of KI. Transfer the solution to a 1-liter volumetric flask, shake well, and dilute to volume. Discard any starch solution that imparts a red tinge to the blue color when titrating. To help preserve the starch solution, add 0.01 g of phenylmercuric acetate.

23.2.4.3 *Potassium Iodate, Standard Solution*—Accurately weigh 0.22269 g of KIO_3. Correct this mass for purity. Transfer carefully into a 1-liter volumetric flask and dilute to volume with water. The solution is stable for at least 3 months. For a 0.500-g sample mass, the buret reads directly in percent sulfur.

23.2.5 *Procedure:*

23.2.5.1 Allow 15 min for the electronics in the furnace and titrator to warm up.

23.2.5.2 Weigh 0.500 + 1.0 mg of prepared sample and brush carefully into the crucible using the loading funnel.

23.2.5.3 Add accelerators to the crucible using level scoops in the following order: (*1*) 1 scoop of tin metal, (*2*) 1 scoop of iron powder, and (*3*) 1 copper ring.

23.2.5.4 Cover the crucible with a crucible cover. Do not reuse crucibles or covers.

23.2.5.5 Run a blank determination for each series of determination, that is, all accelerators and no sample.

23.2.5.6 Place the sample on the pedestal and lift into position in the combustion tube.

23.2.5.7 With the oxygen flow set at 1.0 liter/min, add the HCl to the middle of the bell-shaped portion of the titration vessel. Always fill to the same point.

23.2.5.8 Add one measure of starch solution to the titration vessel.

23.2.5.9 Turn the double throw switch to the END POINT position (down). Allow the instrument to set the end point. After the indicator light (for solenoid valve) has stopped blinking, place the switch in the NEUTRAL position and fill the KIO_3 buret. Turn the switch to the TITRATE position.

23.2.5.10 Set the GRID CURRENT TAP Switch to "Low," "Medium," or "High" position. Determine the position on a test run, with the sample and accelerators that will give a complete burn-off above 350 mA as indicated on the PLATE CURRENT AMMETER.

23.2.5.11 Set the automatic timer to the time required to combust the sample completely as follows:

Sample	Time, min
Quicklime	8
Hydrated lime	10
Limestone	12

23.2.5.12 After the furnace has shut off, read directly in percent sulfur.

23.2.5.13 Report the analysis as percent total sulfur.

APPENDIX I

PROJECT PARTICIPANTS

PROJECT PARTICIPANTS

Environmental Protection Agency
Office of Air Quality Planning and Standards

Thomas F. Lahre	Engineer, Technical Development Section

Monsanto Research Corporation

William R. Feairheller, Jr.	Research Group Leader
Thomas L. Peltier	Research Engineer
Harlan D. Toy	Research Engineer
Woodrow Lewis, Jr.	Research Engineer
Francine A. Kulik	Research Chemist
Windle H. McDonald	Technician (Field Sampling)
Lloyd A. Cox	Technician (Analysis)
Flo Ella Phillips	Technician (Analysis)
Norma Jean Baker	Secretary