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Feairheller, W. R. et al., EPA Contract No. 68-02-1404, Task 12

Monsanto Research Corporation

December 1975

SOURCE TEST OF A LIME PLANT

Standard Lime Company
Div. Martin - Marietta
Woodville , Ohio

$\frac{\text{Stone}}{\text{prod}} = 2.37$

$\frac{\text{feed}}{\text{prod}} = 2.51$ (w/coal)

B-8/A-11

MONSANTO RESEARCH CORPORATION

A SUBSIDIARY OF MONSANTO COMPANY

Monsanto

DAYTON
LABORATORY

DAYTON, OHIO 45407

Source Test of a Lime Plant

Plant Tested

Standard Lime Company
Div. Martin-Marietta
Woodville, Ohio

December 8, 9, and 10, 1975

Prepared for

Environmental Protection Agency
National Air Data Branch
Research Triangle Park
North Carolina 27711

by

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Contract No. 68-02-1404, Task No. 12

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SECTION I

INTRODUCTION

The purpose of the test program was to measure the uncontrolled particulate and nitrogen dioxide emissions, and to obtain particle size data on two of the lime kilns at the Standard Lime Company Plant in Woodville, Ohio. This study was initiated as part of the data acquisition program of the National Air Data Branch of the Environmental Protection Agency.

The sampling program was conducted on the inlet ducts to the baghouse controlling emissions from the No. 4 and No. 6 kilns at the plant. By sampling prior to the control device, data on the emission rate could be obtained and emission factors determined that would represent an uncontrolled facility. During the test period from Dec. 8 to Dec. 10, 1975, kiln No. 6 was producing dead burn dolomitic lime (a more complete conversion to the oxide). Dolomitic limestone, the raw material, is a natural limestone that contains both calcium and magnesium carbonates. As a result, the dolomitic lime contains both calcium and magnesium oxides. Dead burn dolomitic lime or refractory lime is a sintered form of dolomitic lime that is calcined at high temperature with the addition of iron oxide. This material is employed primarily as a refractory for lining steel furnaces.

This report presents particulate mass emission rate as determined by EPA Method 5, the NO_x emission rate as determined by EPA Method 7, and the particle size distribution as determined by Brinks® BMS-11 Cascade Impactor. The emission factors in terms of the feed of dolomitic limestone and the production of dolomitic lime or dead burn lime were calculated for both the particulate and NO_x emissions.

The following sections of this report include: (1) summary of results, (2) process description and operation, (3) details of sampling locations, and (4) sampling and analytical procedures. The field and analytical data is presented in the appendices.

SECTION II

SUMMARY OF RESULTS

Two kilns, numbers 4 and 6, were tested at the Standard Lime Company Plant during the December 8-10, 1975 sampling program. Particulate emissions were determined by EPA Method 5, NO_x emissions by EPA Method 7, and the particle size distribution by the Brinks® cascade impactor.

Particulate Mass Emissions

Kiln No. 4 - Kiln No. 4 was producing dolomitic lime at an average feed rate of 52.3 metric ton/hr (57.6 ton/hr) and an average production rate of 22.6 metric ton/hr (24.7 ton/hr). Sampling was accomplished prior to the baghouse, after multiclone and preheater, so that the uncontrolled emission rate of filterable particulate averaged 923 kg/hr (2035 lb/hr) and total particulate averaged 924 kg/hr (2037 lb/hr). The total particulate data yields an emission factor of 18.0 kg/metric ton (36.0 lb/ton) based on the feed rate and 41.7 kg/metric ton (83.5 lb/ton) based on the product.

The data from the two particulate emission measurements as shown in Table 1 (metric) and Table 2 (English) show considerable variation. Although the volume of gas sampled, the average stack temperature and the volumetric flow rate are very close for the two runs, the mass of material collected

Table 1. SUMMARY OF PARTICULATE EMISSIONS FROM KILNS 4 AND 6 (METRIC)

	Kiln 4[c]			Kiln 6[d]		
Run Number - Kiln Number	1-4	2-4	Average	1-6	2-6	Average
Date	12-9-75	12-9-75		12-10-75	12-10-75	
Volume of Gas Sampled - Nm^3 [a]	1.262	1.269	1.265	0.976	0.746	.851
Percent Moisture by Volume	6.00	2.36	4.18	3.60	3.35	3.48
Average Stack Temperature - °C	198	196	197	274	279	277
Stack Volumetric Flow Rate - Nm^3/min	1666	1649	1658	1511	1113	1312
Percent Isokinetic	91.7	93.1	92.4	98.1	101.8	100.0
Run Time - minutes	60	60	60	72	72	72
Particulates - Front Half						
mg	17751	5624		11964	11278	
g/Nm^3	14.084	4.438	9.261	12.274	15.144	13.709
Kg/hr	1407	439	923	1112	1011	1062
lb/hr	3095.4	965.8		2446.4	2224.2	
Particulates - Total						
mg	17760	5635		11995	11344	
g/Nm^3	14.091	4.447	9.269	12.306	15.233	13.770
Kg/hr	1408	440	924	1115	1017	1066
	3097.6	968.0		2453	2237.4	
Percent Impinger Catch	0.05	0.20	0.125	0.26	0.58	0.420
INORGANIC lb/hr	2.2	2.2		6.6	13.2	
Limestone Feed Rate - metric ton/hr	50.4	54.1	52.3	27.2	27.2	27.2
Production Rate - metric ton/hr	21.8	23.4	22.6	10.4	10.4	10.4
ton/hr	24.0	25.74		11.44	11.44	
Emission Factor (b) - kg/mTon (feed)	27.9	8.1	18.0	41.0	37.4	39.2
kg/mTon (Product)	64.6	18.8	41.7	107.2	97.9	102.5

a) Normal cubic meters at 20°C
b) Front half data only
c) Emission data collected after multiclone and preheater
d) Emission data after low efficiency cyclone

NEAT piece EQUALS UNITS

$1907 \frac{kg}{hr} * \frac{2.2\,lb}{kg} = 3095.4$

$21.8 \frac{m\,ton}{hr} * \frac{2200\,lb}{m\,ton} * \frac{ton}{2000\,lb} = 21.8\,m\,ton/hr * 1.1 \frac{ton}{m\,ton} = 24.0 \frac{ton}{hr}$

Table 2. SUMMARY OF PARTICULATE EMISSIONS FROM KILNS 4 AND 6 (ENGLISH)

	Kiln 4[c]			Kiln 6[d]		
Run Number - Kiln Number	1-4	2-4	Average	1-6	2-6	Average
Date	12-9-75	12-9-75		12-10-75	12-10-75	
Volume of Gas Sampled - DSCF[a]	44.43	44.67	44.55	34.36	26.25	30.31
Percent Moisture by Volume	6.00	2.36	4.18	3.60	3.35	3.48
Average Stack Temperature - °F	388	384	386	526	533	530
Stack Volumetric Flow Rate - DSCFM	58825	58218	58522	53366	39299	46333
Percent Isokinetic	91.7	93.1	92.4	98.1	101.8	100.0
Run Time - minutes	60	60	60	72	72	72
Particulates - Front Half						
mg	17751	5624		11964	11278	
g/DSCF	6.153	1.939	4.046	5.362	6.616	5.989
lb/hr	3102	967	2035	2452	2228	2340
Particulates - Total						
mg	17760	5635		11995	11344	
g/DSCF	6.156	1.943	4.050	5.377	6.655	6.015
lb/hr	3104	969	2037	2459	2241	2350
Percent Impinger Catch	0.05	0.20	0.125	0.26	0.58	0.42
	2.0 lb/hr	2.0 lb/hr		7.0 lb/hr	13 lb/hr	
Limestone Feed Rate - ton/hr	55.6 } 2.32	59.6 } 2.31	57.6	30.0 } 2.61	30.0 } 2.61	30.0
Production Rate - ton/hr	24.0	25.8	24.7	11.5	11.5	11.5
Emission Factor (b) - lb/ton (feed)	55.8	16.2	36.0	82.0	74.7	78.4
lb/ton (Product)	129.3	37.6	83.5	213.8	194.9	204.4

a) Dry standard cubic feet at 68°F, 29.92 in Hg
b) Front half data only
c) Emission data collected after multiclone and preheater
d) Emission data after low efficiency cyclone

and moisture content varied greatly, thus producing a considerable variation in the emission rate.

The plant operation during the first run varied from a feed rate of 54.1 metric ton/hr (59.6 tons/hr) for the first half of the run to 46.8 metric ton/hr (51.6 tons/hr) for the second half of the run. During the second run, the feed rate was 54.1 metric ton/hr (59.6 ton/hr) for the entire run. Filters were changed on run 1 during the port change interval due to the high loading experienced, however, this was not necessary on run 2. There is some indication, based on the filter loadings from run 1, that the lower feed rate during the second half of this run produced a higher emission rate. However, each filter from run 1 collected more material than the filter used for the entire run 2 sampling period. Similarly, the probe washing from run 1 contained over three times the amount of material collected by run 2.

A discussion with plant personnel provided no explanation for the wide variation in results, except the possibility that the feed during run 1 contained considerably more fine material. The difference in moisture content (6.00% for run 1, 2.36% for run 2) is also an indication that the feed material was different for the two runs.

Kiln No. 6 - Kiln No. 6 was producing dead burn dolomite lime at a feed rate of 27.2 metric ton/hr (30.0 tons/hr) and a production rate of 10.4 metric ton/hr (11.5 tons/hr) during both sampling runs. Sampling was accomplished prior to the baghouse, after a low efficiency cyclone so that the measured uncontrolled emission rate of filterable particulates averaged 1062 kg/hr (2340 lb/hr) and total particulate averaged 1066 kg/hr (2350 lb/hr). The total particulate data yields average emission factors of 39.2 kg/metric ton (78.4 lb/ton) based on the feed

rate and 102.5 kg/metric ton (204.4 lb/ton) based on the product. As shown in the test summaries, Table 1 (metric units) and Table 2 (English), the sampling runs at this location are in close agreement.

The production of dead burn lime is a more complete oxide formation than the dolomitic lime and is produced by higher kiln temperatures and slower feed rates. As a result, the higher kiln temperatures would increase emission rates and the lower feed rates would tend to enlarge the emission factors observed for the dead burn material.

NO_x Emissions

The NO_x emission rates and emission factors for both kiln 4 and kiln 6 are summarized in Table 3. Three samples, using the EPA Method 7 procedure were collected at each kiln.

During the sampling period on kiln 4, the feed rate was 54.1 metric ton/hr (59.6 ton/hr) and the production rate of dolomitic lime was 23.4 metric ton/hr (25.8 ton/hr) and the NO_x emission rate, varied from 89.0 to 92.8 lb/hr for an average of 91.1 lb/hr. Based on this data, the emission factors calculate to be 0.764 kg/metric ton of feed (1.53 lb/ton) and 1.77 kg/metric ton of product (3.53 lb/ton).

Kiln 6 was sampled at five minute intervals and at this time the feed rate was 27.2 metric tons/hr (30.0 tons/hr) and the production rate was 10.4 metric ton/hr (11.5 tons/hr). The emission rate as measured by Method 7 varied from 2.58 to 13.1 kg/hr (5.69 to 28.8 lb/hr) for an average value of 7.34 kg/hr (16.2 lb/hr). These values for dead burn lime production are lower and considerably more variable than the values obtained for the NO_x emission rate from dolomitic lime production. The fact that the kiln temperature for the

Table 3. SUMMARY OF NO_x EMISSIONS

	Kiln No. 4				Kiln No. 6			
Run No.	4	5	6	Avg.	4	2	3	Avg.
Date	12/9	12/9	12/9		12/9	12/9	12/9	
Time	1115	1120	1125		1000	1005	1010	
Concentration (ppm)[a]	270.6	282.3	277.9	276.9	13.7	69.2	33.9	38.9
Emission Rate								
g/Nm³	0.513	0.535	0.527	0.525	0.026	0.131	0.064	0.074
lb/dscf x 10^5	3.20	3.34	3.29	3.28	0.162	0.819	0.401	0.461
kg/hr[b]	40.4	42.1	41.5	41.3	2.58	13.1	6.38	7.34
lb/hr[c]	89.0	92.8	91.4	91.1	5.69	28.8	14.1	16.2
Limestone Feed Rate[d]								
metric ton/hr	54.1	54.1	54.1	54.1	27.2	27.2	27.2	27.2
ton/hr	59.6	59.6	59.6	59.6	30.0	30.0	30.0	30.0
Production Rate[d]								
metric ton/hr	23.4	23.4	23.4	23.4	10.4	10.4	10.4	10.4
ton/hr	25.8	25.8	25.8	25.8	11.5	11.5	11.5	11.5
Emission Factor (metric)								
kg/metric ton (feed)	0.747	0.778	0.767	0.764	0.095	0.480	0.234	0.270
kg/metric ton (product)	1.73	1.80	1.77	1.77	0.248	1.25	0.613	0.704
Emission Factor (English)								
lb/ton (feed)	1.49	1.56	1.53	1.53	0.190	0.959	0.469	0.539
lb/ton (product)	3.45	3.60	3.54	3.53	0.495	2.50	1.22	1.41

a. ppm - parts per million by volume

b. Flow rate of 1658 Nm^3/min for kiln No. 4 and 1312 Nm^3/min for kiln No. 6 based on Method 5 runs.

c. Flow rate of 58,522 DSCF/min for kiln No. 4 and 46333 DSCF/min for kiln No. 6 based on Method 5 runs.

d. Feed and Production based on run feed at test time for kiln No. 4 and typical hopper delivery rates for kiln No. 6.

dead burned material is higher than for dolomitic lime, it might be expected that the NO_x emission for kiln 6 would be higher. This was not observed. Plant personnel could offer no explanation for the lower NO_x emission rate for dead burn production or for the wide variation in the results from kiln 6.

There are two fresh air dampers on kiln 6, one at the exit of the kiln, and the other in the straight duct between the multicyclone and the baghouse, just upstream of the sampling port. The latter damper is temperature controlled and the plant personnel indicated that it should not operate until the gas reached a temperature higher than the measured temperature. It is suspected that the fresh air introduced by these dampers reduced the NO_x emission rate and caused the variations in the measured results.

Based on the data obtained, the NO_x emission factors for kiln 6 were 0.270 kg/metric ton of feed (0.539 lb/ton) and 0.704 kg/metric ton of product (1.41 lb/ton).

Particle Size Measurements

Two particle sizing runs, one on each kiln, were performed using a Brink® BMS-11 Cascade Impactor. A description of the device is given in Appendix G and computer printouts of the results are given in Appendix B. Table 4 gives a summary of the particle sizing results. It includes the stage number, 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.

Table 4. BRINK® PARTICLE SIZING

Kiln 4 - 12-9-75

Stage	Weight of Material (mg)	DPC[a]	MG/ACF[b]	Wt. %	Cum. Wt. %
Cyclone	60.600		175.35	60.73	100.00
1	21.100	2.30	61.005	21.14	39.28
2	9.100	1.26	26.33	9.12	18.14
3	2.900	0.79	8.39	2.91	9.02
4	2.800	0.32	8.10	2.81	6.11
5	2.600	0.16	7.52	2.61	3.31
Filter	0.700		2.03	0.70	0.70

Kiln 6 - 12-9-75

Stage	Weight of Material (mg)	DPC[a]	MG/ACF[b]	Wt. %	Cum. Wt. %
Cyclone	88.400		409.67	78.84	100.00
1	7.360	3.09	34.11	6.56	21.16
2	9.220	1.70	42.73	8.22	14.59
3	1.460	1.07	6.77	1.30	6.37
4	1.230	0.45	5.70	1.10	5.07
5	3.650	0.23	16.92	3.26	3.97
Filter	0.800		3.71	0.71	0.71

(a) Characteristic cut point diameter of particles collected (micrometers)

(b) MG/ACF - milligram per actual cubic foot

The results on kiln No. 4 indicate that nearly 61% of the particulate is caught in the probe and cyclone and thus the average particle diameter is larger than 2 micrometer. The rest of the particulate material is spread proportionally across the stages.

The results on kiln No. 6 indicate that almost 79% of the particulate is caught in the probe and cyclone and thus the average particulate diameter is larger than 3 micrometers. The remainder of the particulate is spread across the stages of the impactor with disproportionately large amounts caught on the second and fifth stages.

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

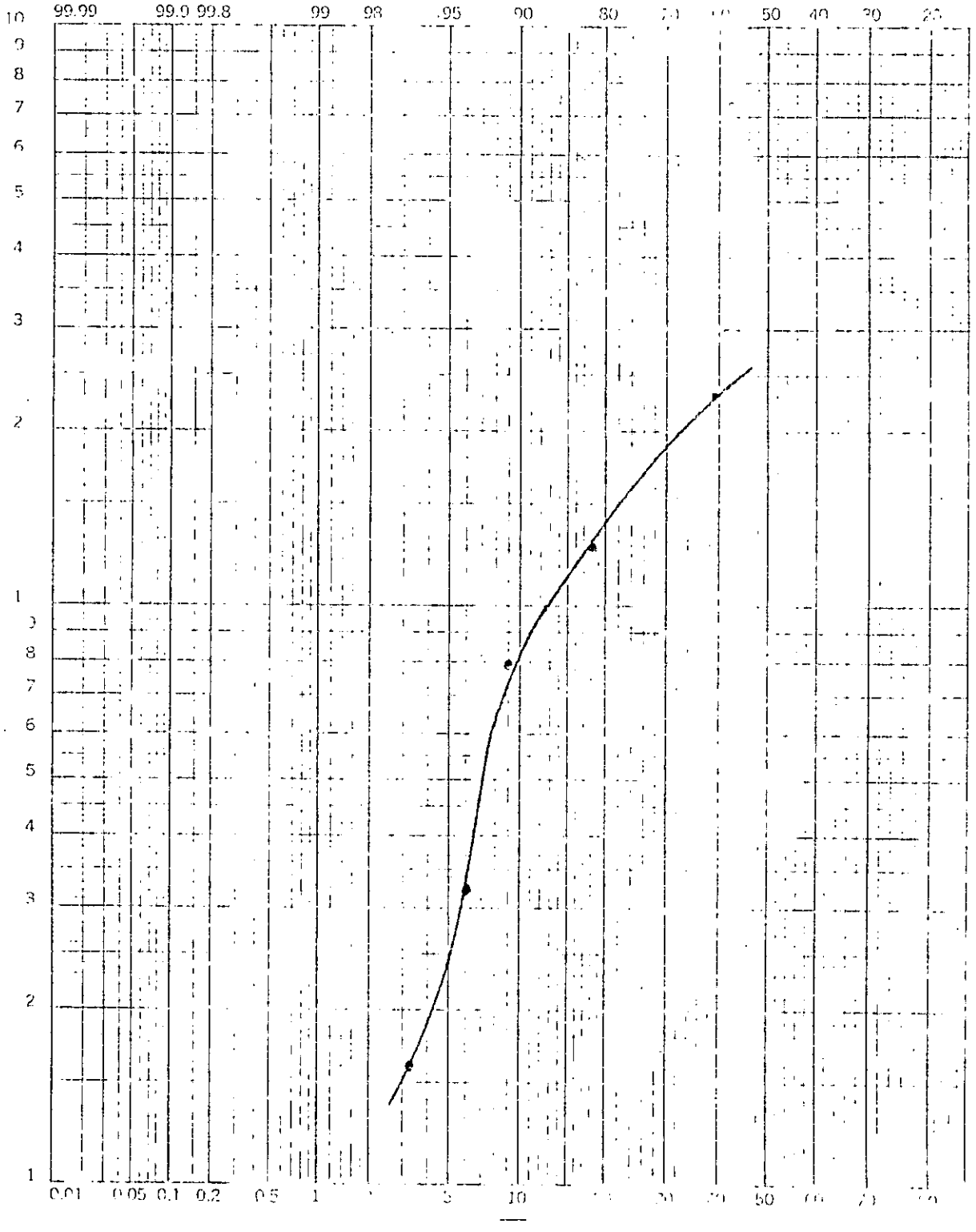


Figure 1. Particle size distribution - kiln 4

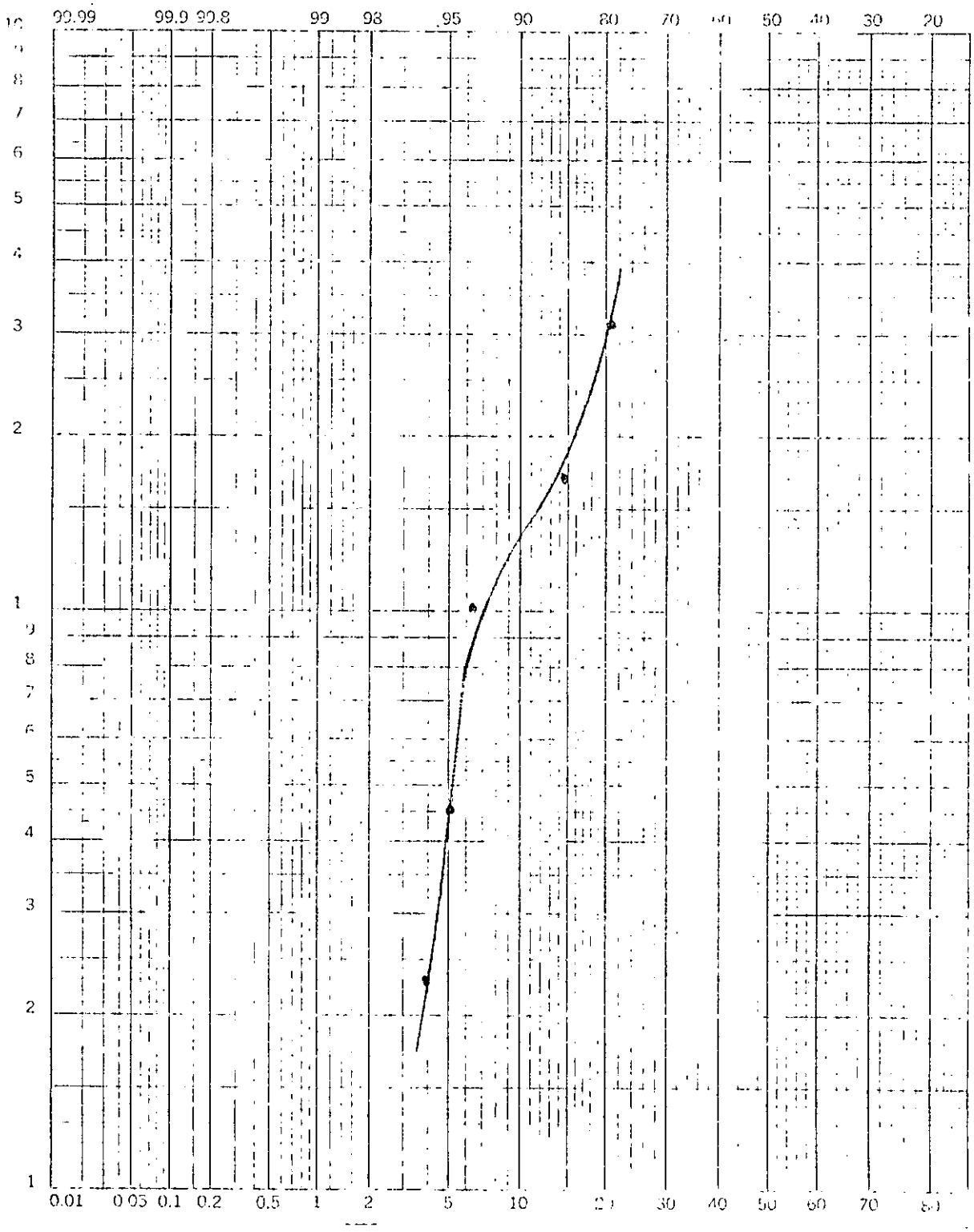


Figure 2. Particle size distribution - kiln 6

SECTION III

PROCESS DESCRIPTION AND OPERATION

The processing at Standard Lime Company involves converting limestone to either dolomitic lime or dead burn dolomite in rotary kilns. The raw material is mainly a combination of calcium and magnesium carbonates and during the process the material is converted to the oxide with loss of carbon dioxide. Dolomitic lime is not a total conversion to the oxide, whereas, the dead burn dolomitic lime is a more complete conversion. In the formation of the dead burn product, iron, in the form of Fe_2O_3, is added to the feed resulting in fuel saving and a hotter kiln temperature. The amount of iron added is regulated in respect to the amount of fines in the feed - the finer the feed the less iron used, and in addition depends somewhat on the condition of the kiln as the fines and iron tend to coat the interior of the kiln.

The kilns are fired by either natural gas, along with pulverized coal, or pulverized coal alone when the natural gas supply is low. Natural gas generally is used during the April to November period and as a result during the December test period the only fuel was coal. The coal typically is obtained in Ohio and as a result has about a 3% sulfur content.

The plant operates on a continuous basis, 7 days a week, 24 hours a day. During the test program, kiln numbers 4 and 6

were sampled and their capabilities and approximate exit temperatures are as follows:

Kiln No.	Capacity (Tons/day)	Exit Temp. (°F)
4	500	450-750
6	300	700-750

The stone feed to the kilns is quarried, pulverized and classified before it is used. These operations are performed at the plant site. The limestone is fed to kiln No. 4 by a hydraulic ram that has the stated capacity of 794 lb. per stroke. The feed rate is varied by the number of strokes per hour. In kiln No. 6 the limestone is fed by a hopper and conveyor. The size of the opening in the hopper and the speed of the conveyor controls the feed rate to this kiln.

The kilns vary in diameter from 10 feet at the feed entrance to eleven feet at their discharge. The initial 320 feet of feed section are ten feet in diameter. An expansion section, a length of eighteen feet, increases the diameter to eleven feet. The final 100 feet is eleven feet in diameter.

Both kilns were equipped with mechanical collectors to separate large particulate from the gas stream after the gas leaves the kiln and prior to its entrance into the baghouse. Kiln 4 was equipped with a high efficiency (estimated at 81%*) multicyclone. However, the collector on kiln 6 was an older, low efficiency (~40%) device.

The kiln exhaust gases run through straight ducts from the outlets of the cyclones to the inlet of a baghouse that controls emissions from kilns 4, 5, and 6. The baghouse has

*Estimate by plant personnel based on 8 ton/hr out of multiclone, 2.3 tons/hr passing through, and 1.5 ton/m residual.

22 compartments and has a total of 15,000 bags, each of which is 6" in diameter by 15 feet long. Each compartment has an exhaust fan leading to a 2' x 2' square stack, four feet high.

The gases are cooled before they enter the baghouse in order to protect the bag material. This is accomplished in several ways. Kiln 4 employs a preheater to heat the feed material and at the same time cool the exhaust gases. Kiln 6 employs dilution air to cool the gas via two dampers, one located at the exit of the kiln and the other, a temperature controlled device, in the duct between the multicyclone collector and the baghouse. In both cases, the duct between the multicyclones and the baghouse were long to provide additional cooling of the gases. On kiln 4, this duct was 186'4" long and 5'6" in diameter. On kiln 6, the duct was approximately 188 feet long and 6'9" I.D. Temperatures of 450-750°F occur in the multicyclones of kiln 4, and 800-900°F for kiln 6. The system is designed to reduce the gas temperature to ~400°F at the baghouse entrance.

All testing was done at the inlet to the baghouse and during this period kiln No. 4 was producing dolomitic lime and kiln No. 6 was producing dead burn dolomitic lime. The raw material feed rates to the kilns, the loss on ignition factor and the calculated production for kilns No. 4 and 6 are shown in Table 5. The loss on ignition factor is based on several months experience on relating measured lime production to the amount of feed. This factor is used on a daily basis to calculate production by dividing the amount of feed by the factor.

Flow diagrams of the operations on kilns 4 and 6 are shown in Figures 3 and 4.

Table 5. PRODUCTION DATA

Kiln #4

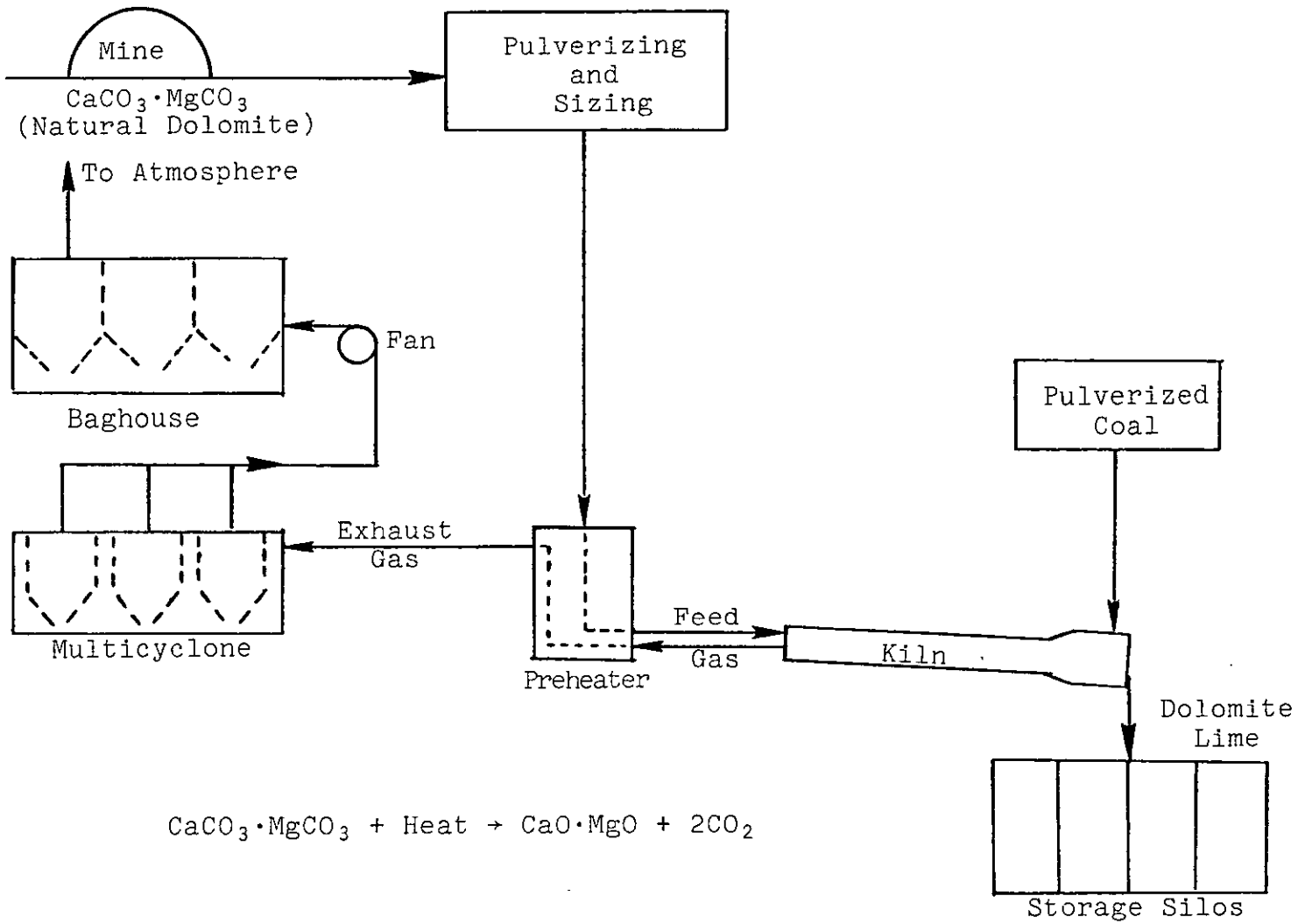
Date	Time	Coal Feed tons/hr	Stone Feed: Ram Strokes per hour	Stone Feed: lb/stroke	Stone Feed: tons/hr	Loss on Ignition Factor	Production Rate tons/hr
12/9/75	600-930	4.3	130	794	51.6	2.315	22.3
	930-1135	4.3	150	794	59.6	2.315	25.8
	1135-1300	4.3	130	794	51.6	2.315	22.3
	1300-1700	4.6	150	794	59.6	2.315	25.8
		4.375					24.05

Kiln #6 (A)

12/10/75	930-1600	4.3	B	B	30.0	2.60	11.5

A. 1.0 ton/hr of iron feed into Kiln 6

B. Stone feed is controlled by hopper opening and conveyor speed.



$$CaCO_3 \cdot MgCO_3 + \text{Heat} \rightarrow CaO \cdot MgO + 2CO_2$$

Figure 3. Kiln no. 4 flow diagram

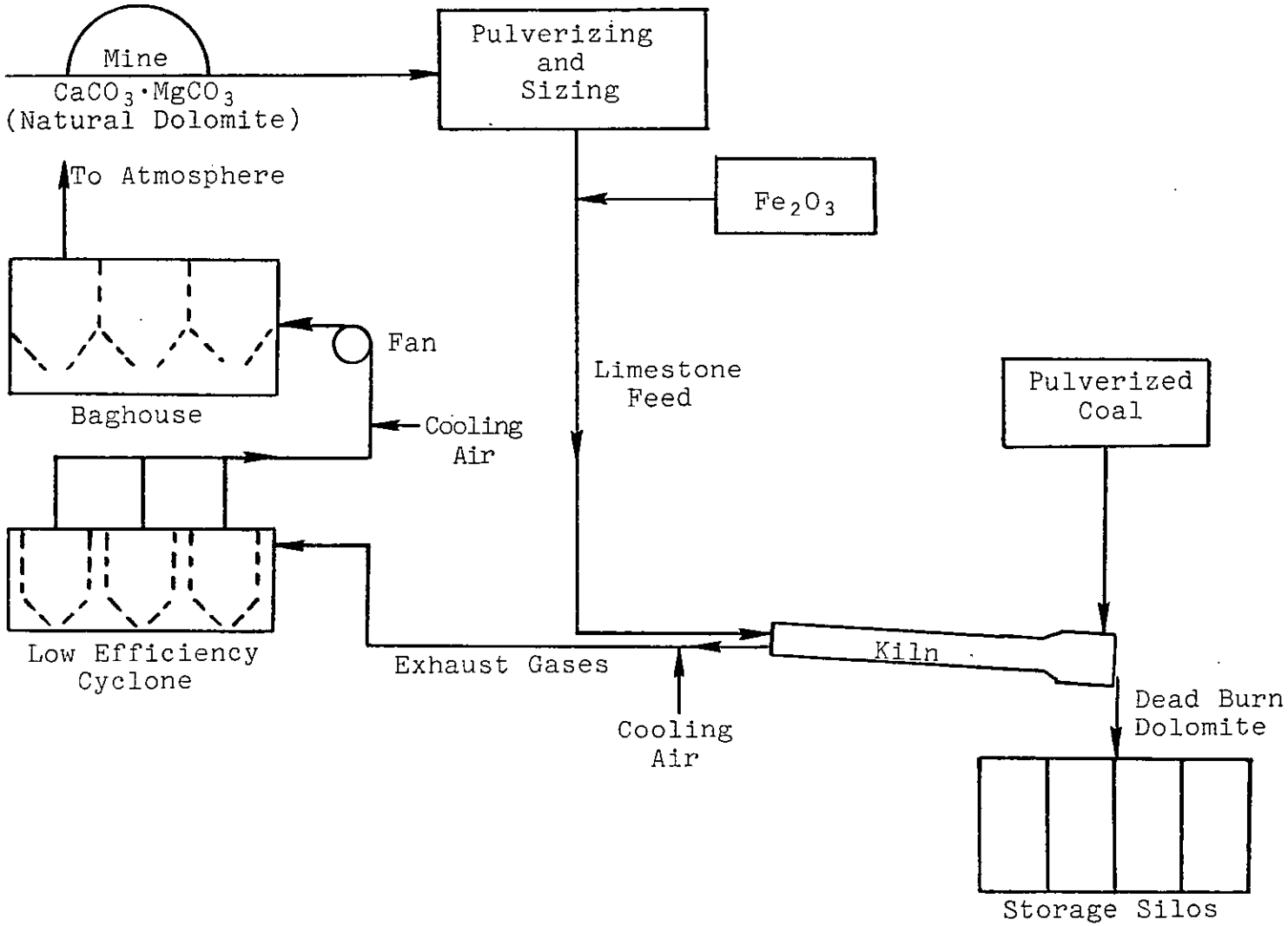


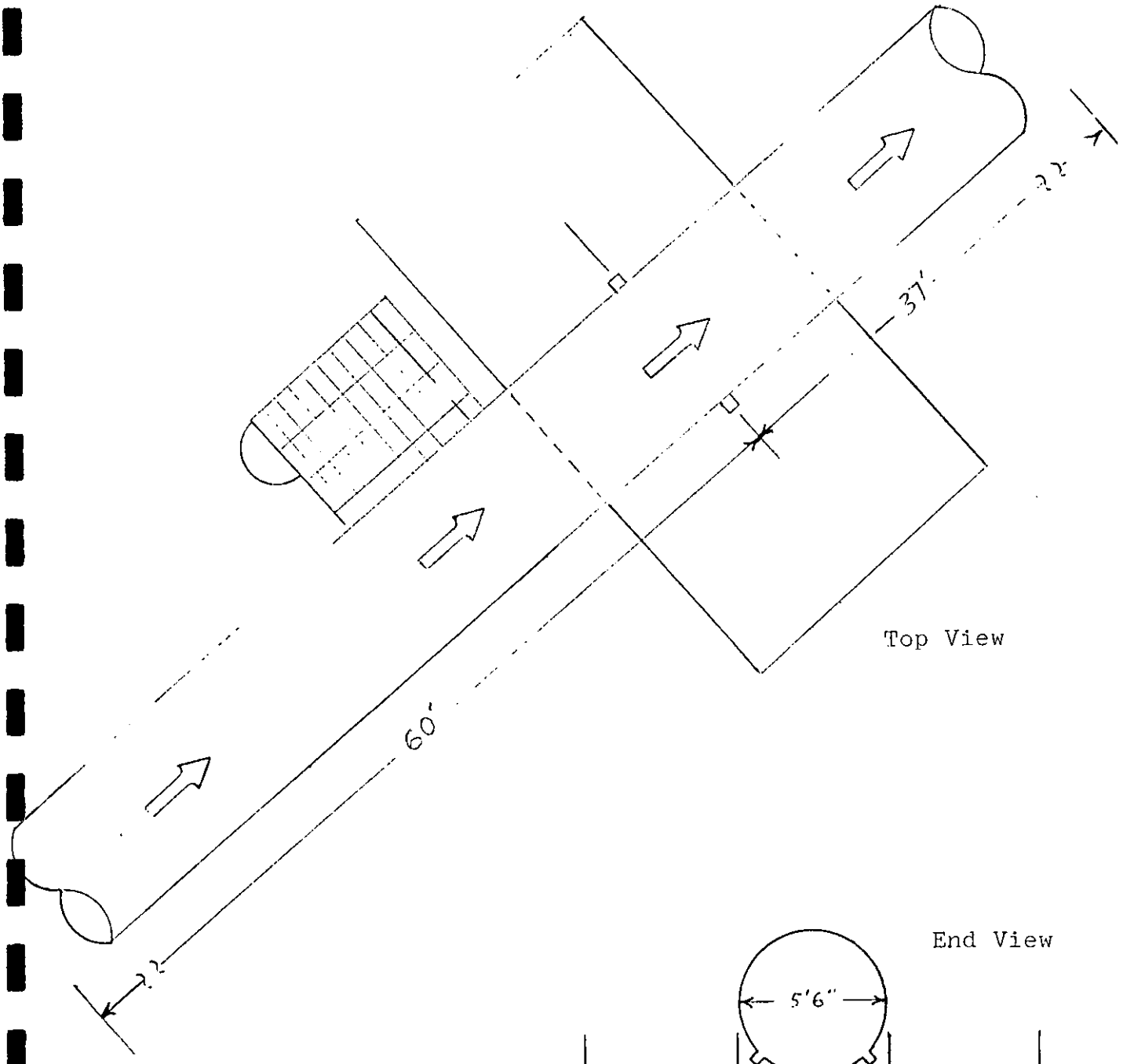
Figure 4. Kiln no. 6 flow diagram

SECTION IV

LOCATION OF SAMPLING POINTS

The exhaust duct on kiln No. 4 and the sampling location are shown on Figure 4. The sampling ports (3" pipe couplings welded to the side of the duct) were located 60 feet (18.29 meters or 10.91 diameters) from the nearest upstream disturbance and 37 feet (11.28 meters or 6.73 diameters) from the nearest downstream disturbance. The ports were installed at a 45 degree angle from horizontal so as to make sampling easier and to eliminate a vertical traverse which may collect dust from the bottom of the duct. The sampling platforms on both sides of the duct were 35 feet above ground level on scaffolding. Since the ports were located over 8 diameters downstream from the nearest disturbance and over 2 diameters upstream from the nearest disturbance, only 12 traverse points (6 along each of the two perpendicular diameters) were required (as specified in the Federal Register, Vol. 36, No. 247, December 23, 1971, Method 1, "Sample and Velocity Traverses for Stationary Sources").

The exhaust duct for kiln No. 6 and the sampling location are shown on Figures 5 and 6. The end view is shown in Figure 5 and the top view in Figure 6. The sampling ports (3" pipe couplings welded to the side of the duct) were located 21'9" (6.64 meters or 3.23 diameters) from the nearest upstream disturbance and 30 feet (9.14 meters or 4.44 diameters)



Top View

End View

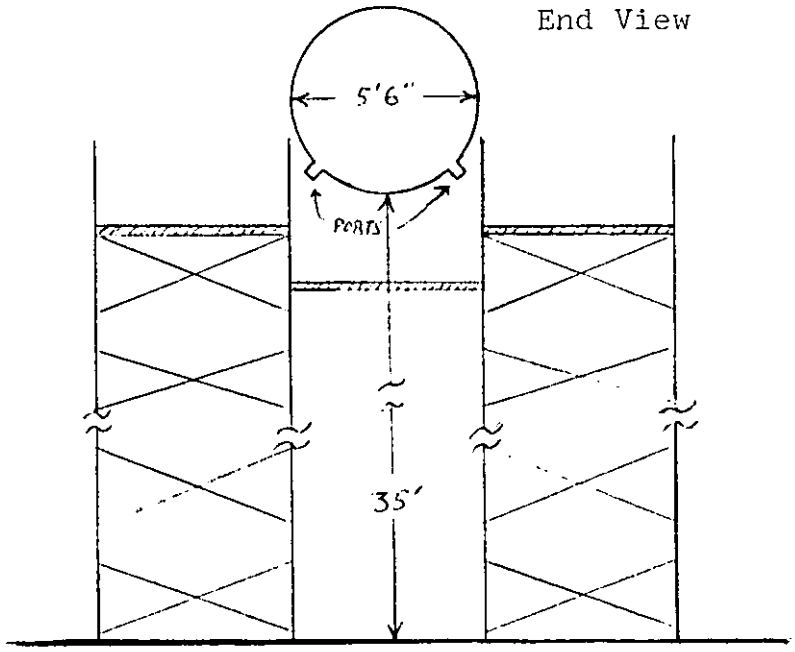


Figure 5. Kiln Stack #4

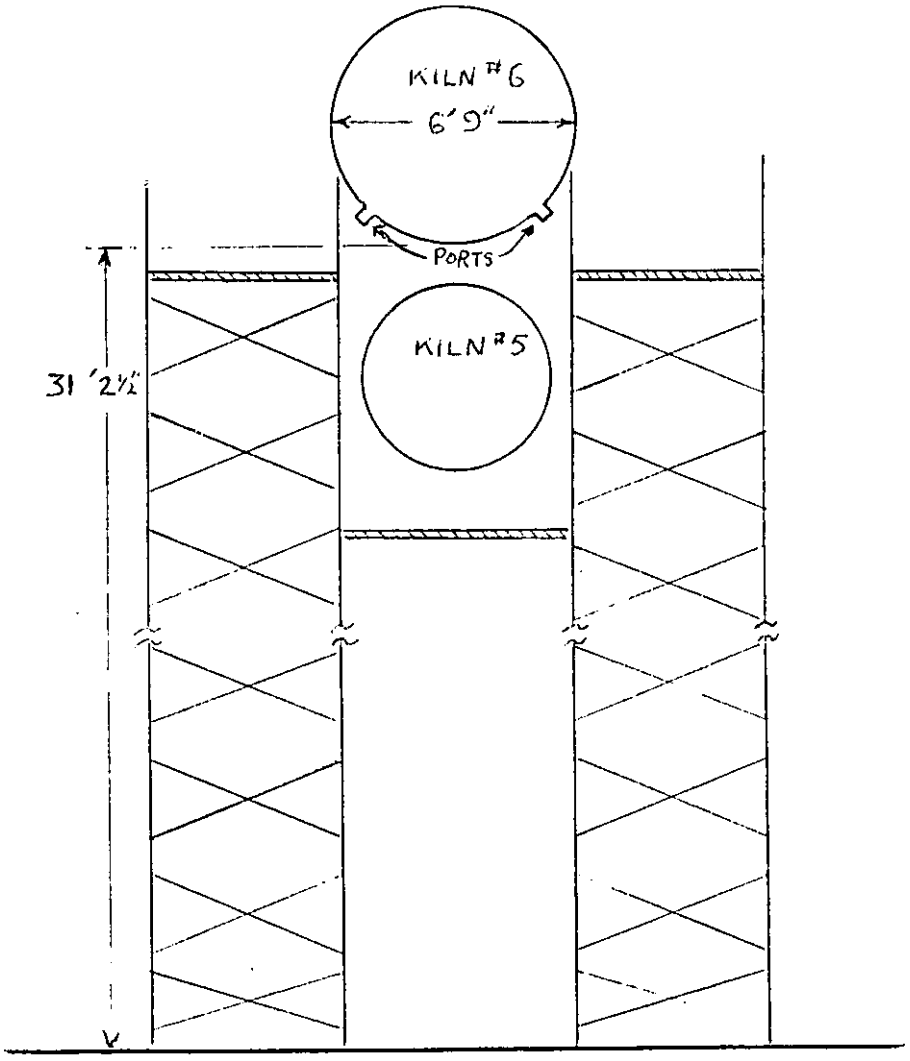


Figure 6. End View of Kiln Stacks 5 and 6

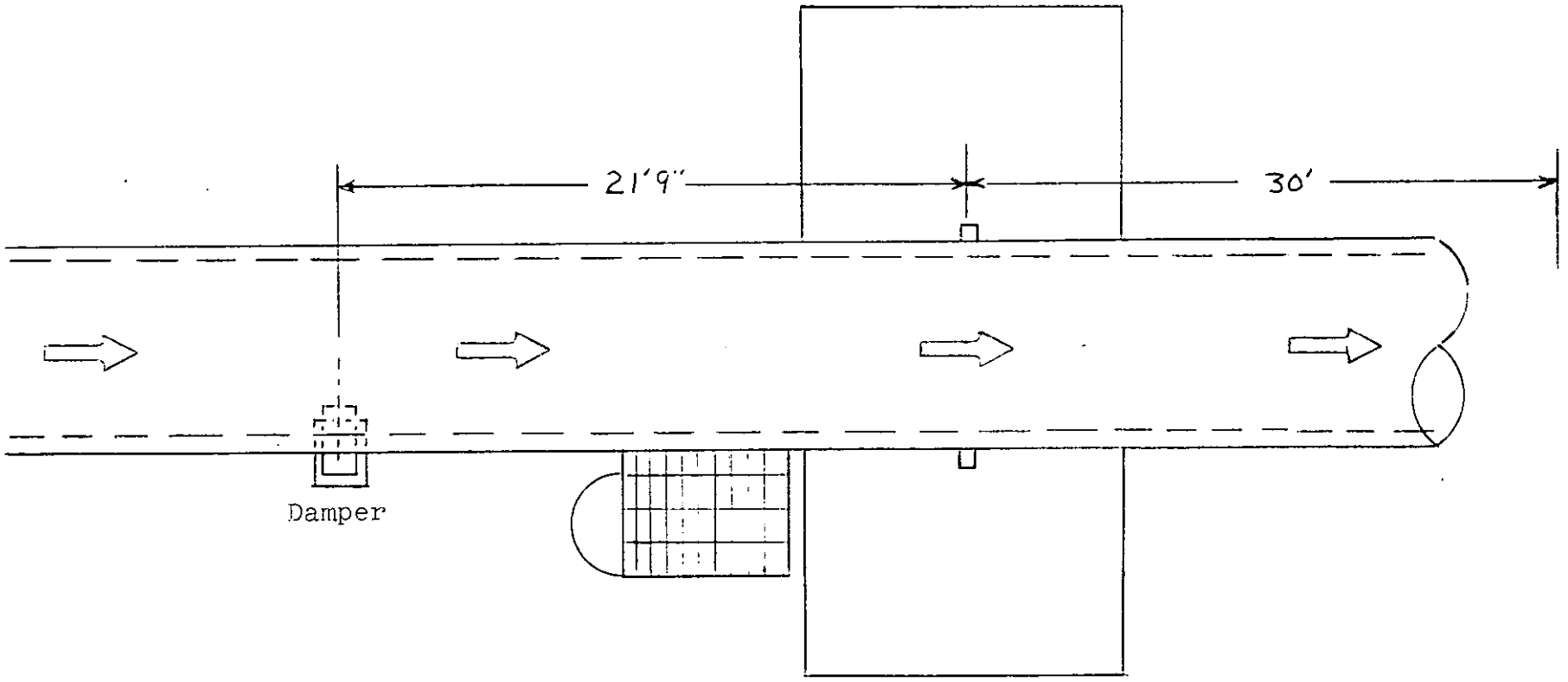


Figure 7. Top View, Kiln Stacks 5 and 6

from the nearest downstream disturbance. The nearest upstream disturbance in this case was a damper mechanism. The ports were installed at a 45 degree angle from the horizontal. The sampling platforms were approximately 30 feet above ground level on scaffolding. Since the ports were located 3.23 diameters downstream from the nearest disturbance, 44 traverse points (22 along each of the two perpendicular diameters) were required (as specified in the above mentioned Federal Register, Method 1). Information obtained on the presurvey indicated that the ports would be closer to the damper (2.5 diameters) and, therefore, a 48 point traverse would be required. The sampling runs were made using the 48 point traverse layout rather than the 44 point layout. The extra 4 sampling points will have no effect on the results. This error occurred due to the fact that the ports were not installed prior to the presurvey and the location suggested by the presurvey team was not followed when the ports were installed.

SECTION V

SAMPLING AND ANALYTICAL PROCEDURES

Sampling Procedures

Gas velocities were measured with a calibrated type S pitot tube and inclined manometer. Velocities were measured at each sampling point across the stack diameter to determine an average value according to procedures described in the Federal Register, Vol. 36, No. 247, December 23, 1971, Method 2. Temperatures were measured with a Type K (Chromel-Alumel) thermocouple connected to a digital thermometer.

An integrated sample of the stack gases was collected during each particulate test by pumping the gas into a Tedlar plastic bag at the rate of approximately 0.033 cfm. This bag sample was then analyzed with an Orsat analyzer for CO_2, O_2, and CO as described in the above mentioned Federal Register, Method 3.

The sampling of particulate emissions from kilns 5 and 6 was done in accordance with Method 5 as given in the above Federal Register, with two exceptions. The procedure given does not provide for the collection of particulate from the "back half" (behind the filter and including the impingers) of the sampling train. The procedure used for the collection of the "back half" samples is given in "Specifications for

Incinerator Testing at Federal Facilities", U. S. Department of Health, Education and Welfare, October 1967.

The second exception to the Federal Register method was to employ a heated teflon-lined flexible connection between the probe and the sample box containing the filter and impinger portions of the train. This flexible connection has ball joints to match the probe and filter holder and was heated to the same temperature as the probe, the temperature being monitored with a type K thermocouple. After the run was completed, the flexible line was cleaned in the same manner as the probe, and the washings were included in the probe wash portion of the samples.

The particle sizing tests were run using a Brink® BMS-11 Sampler. The sampler was operated according to the accompanying manual (Appendix G). The flow rate through the sampler was determined with the use of the preliminary velocity traverses on each kiln 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.

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 procedure was described in Method 7 of the Federal Register. Each flask was evacuated and vacuum tested for one minute, and the initial flask temperature, pressure, and barometric pressure recorded. The sampling probe was inserted into the stack and heated, and the sample flask connected. The 3-way stopcock was turned to the "purge" position and stack gas drawn through the system with a vacuum pump to check for condensation in the probe line. The 3-way stopcock was then

turned to the sample position for 15 to 30 seconds. The flask valve was then closed and disconnected from the probe. The contents were shaken for at least 5 minutes. The flasks were allowed to set for at least 16 hrs. They were then shaken for at least 2 minutes, the final pressure, temperature, and barometric pressure were taken, and the sample was transferred to a storage bottle.

Analytical Procedures

Analytical procedures used on the collected samples generally follow the methods outlined in the Federal Register.

Samples from the Method 5 sampling trains were recovered as outlined in the August 17, 1971 Federal Register. After removal of the filter, all sample exposed surfaces were washed with distilled water or reagent grade acetone as specified. All sample bottles for liquid samples were obtained from Wheaton Scientific, Catalogue No. 219630. Prior to use each of these bottles was acid soaked with 1:1 HNO_3 for one day, rinsed with distilled water and soaked with distilled water for one day.

Analytical procedures for the Method 5 samples follow the Federal Register guidelines, with one exception. Container No. 3 as indicated in the method contains water from the impingers and washing of the glassware of the train. The solution was extracted with chloroform and ether, and then the extracted portion was dried to constant weight, as specified. In addition, the water remaining after extraction was evaporated to dryness at 100°C to constant weight.[1] Both weights

[1]See "Specifications for Incinerator Testing at Federal Facilities", U. S. Department of Health, Education, and Welfare publication, October 1967, page 31.

were included in the total mass of particulate. Sample weights from the Method 5 samplers were reported as "front half" (probe washings and filter collection weights) and "total" (front half plus water, chloroform-ether extract and impinger acetone washing weights).

Nitrogen Oxide samples were analyzed using the Phenoldisulfonic acid, photometric analysis described in the above mentioned December 23, 1971 Federal Register, Method 7.

Clean-up and sample collection from the Brink's® particle sizing runs is achieved by cooling and disassembling the impactor, removing the collection plates or substrates, and placing them in plastic containers for shipment back to the laboratory. The impactor is then cleaned thoroughly with methylene chloride solvent. The final filter is removed and placed in its container for shipment. The nozzle, probe, cyclone, and cyclone catch bottle is washed with methylene chloride and all of the washings were saved for subsequent analysis.

Upon arrival at the laboratory the aluminum collection pans were reweighed to determine the amount of material collected. The final filter was also weighed and its weight gain determined. The methylene chloride washes from the probe and cyclone and subsequent stages were evaporated in a tared container and the weight of residue was determined.

APPENDIX A

COMPLETE PARTICULATE RESULTS

Table A-1. METHOD 5 DATA

14 JAN 1976

STANDARD LIME - DIVISION OF MARTIN MARIETTA
PARTICULATE SAMPLING - 6912-12

ABBR	DESCRIPTION (68 DEG F)	UNITS	1-4	2-4	1-6	2-6
TT	DURATION OF RUN	MINUTES	60.0	60.0	72.0	72.0
PB	BAROMETRIC PRESSURE	IN HG	29.40	29.40	29.48	29.48
DELH	AVG ORIFICE PRESS DROP	IN H2O	2.176	2.002	1.073	0.463
VM	VOL DRY GAS(METER CON)	DCF	43.928	45.011	33.244	25.238
TM	AVG GAS METER TEMP	DEG F	55.9	65.5	44.8	40.8
VMSTD	VOL DRY GAS (STD COND)	DSCF	44.43	44.67	34.36	26.25
VW	TOTAL H2O COLLECTED	ML	59.8	22.8	27.1	19.2
VWG	VOL H2O VAPOR(STD CON)	SCF	2.835	1.081	1.285	0.910
PCNTM	PERCNT MOISTURE BY VOL		6.00	2.36	3.60	3.35
MD	MOLE FRACTION DRY GAS		0.940	0.976	0.964	0.966
CO2	PERCENT CO2		18.2	18.2	16.2	16.2
O2	PERCENT O2		10.8	10.8	10.1	10.1
N2	PERCENT N2		71.0	71.0	73.7	73.7
MWD	MOL WT OF DRY GAS		31.3	31.3	31.0	31.0
MW	MOL WT OF STACK GAS		30.5	31.0	30.5	30.6
DELP	AVG STACK VELOCITY HEAD	IN H2O	1.039	0.958	0.538	0.225
CP	PITOT COEFFICIENT		0.850	0.850	0.855	0.855
TS	STACK TEMPERATURE	DEG F	388.	384.	526.	533.
PM	STACK PRESSURE(STATIC)	IN H2O	-2.90	-2.90	-6.00	-6.00
PS	STACK PRESSURE (ABS)	IN HG	29.19	29.19	29.04	29.04
VS	AVG STACK GAS VELOCITY	FPM	4322.	4099.	2967.	2194.
DS	STACK DIAMETER	INCHES	66.00	66.00	81.00	81.00
AS	STACK AREA	SQ IN	3421.2	3421.2	5153.0	5153.0
QS	STACK FLOW RT(DRY STD)	DSCFM	58825.	58218.	53366.	39299.
QA	STACK FLOW RT(ACTUAL)	ACFM	102665.	97372.	106144.	78516.
DN	PROBE TIP DIAMETER	INCHES	0.245	0.245	0.245	0.245
PCTI	PERCENT ISOKINETIC		91.7	93.1	98.1	101.8
MF	PARTICULATE (FRONT)	MG	17751.10	5623.90	11963.50	11277.80
MT	PARTICULATE (TOTAL)	MG	17760.10	5634.90	11995.30	11344.30
CAN	PARTICULATE (FRONT)	GR/DSCF	6.1532	1.9390	5.3622	6.6161
CAO	PARTICULATE (TOTAL)	GR/DSCF	6.1563	1.9428	5.3765	6.6551
CAT	PARTICULATE (FRONT)	GR/ACF	3.5127	1.1551	2.6861	3.2994
CAU	PARTICULATE (TOTAL)	GR/ACF	3.5145	1.1574	2.6932	3.3188
CAW	PARTICULATE (FRONT)	LB/HR	3101.999	967.439	2452.388	2228.229
CAX	PARTICULATE (TOTAL)	LB/HR	3103.572	969.331	2458.906	2241.367

Table A-2

PARTICULATE CALCULATIONS

Example: Run No. 1-4

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

$$VMSTD = \frac{17.65 \times VM \left(PB + \frac{DELH}{13.6}\right)}{(TM + 460)}$$

$$= \frac{17.65 \times 43.928 \left(29.40 + \frac{2.176}{13.6}\right)}{(55.9 + 460)}$$

$$= 44.43 \text{ dscf}$$

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

$$VWG = 0.0645 \times VW$$

$$= 0.0645 \times 43.928$$

$$= 2.835$$

3. Percent moisture in stack gas

$$PCNTM = \frac{100 \times VWG}{VMSTD + VWG}$$

$$= \frac{100 \times 2.835}{44.43 + 2.835}$$

$$= 6.00$$

Table A-2 (Continued)

PARTICULATE CALCULATIONS

4. Mole fraction of dry gas

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

$$= \frac{100 - 6.00}{100}$$

$$= 0.940$$

5. Molecular weight of dry stack gas

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

$$= (18.2 \times 0.44) + (10.8 \times 0.32) + [(0 + 71.0) \times 0.28]$$

$$= 31.3$$

6. Molecular weight of wet stack gas

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

$$= 31.3 \times 0.94 + 18\ (1 - 0.94)$$

$$= 30.5$$

Table A-2 (Continued)

PARTICULATE CALCULATIONS

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

$$= 4360 \times 29.58 \times \left(\frac{1}{29.19 \times 30.5} \right)^{\frac{1}{2}}$$

$$= 4322 \text{ fpm}$$

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

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

$$= \frac{0.123 \times 4322 \times 3421 \times 0.940 \times 29.19}{388 + 460}$$

$$= 58825 \text{ dscfm}$$

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

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

$$= \frac{0.05645 \times 58825 \times (388 + 460)}{29.19 \times 0.940}$$

$$= 102665 \text{ acfm}$$

Table A-2 (Continued)

PARTICULATE CALCULATIONS

10. Area of nozzle (sq. ft.)

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

$$= 54.54 \times 10^{-4} (0.245)^2$$

$$= 3.27 \times 10^{-4} \text{ sq. ft.}$$

11. Percent Isokinetic

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

$$= \frac{100.0(388 + 460)\left[0.00267(59.8) + \frac{43.928}{(55.9 + 460)}\left(29.40 + \frac{2.176}{13.6}\right)\right]}{(60)(4322)(29.19)(3.27 \times 10^{-4})}$$

$$= 91.7$$

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

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

$$= 0.0154 \times \frac{17751}{44.43}$$

$$= 6.15 \text{ gr/dscf}$$

Table A-2 (Continued)

PARTICULATE CALCULATIONS

13. Particulate - total (gr/dscf)

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

$$= 0.0154 \times \frac{17760}{44.43}$$

$$= 6.156 \text{ gr/dscf}$$

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

$$CAT = \frac{17.65 \times CAN \times PS \times MD}{(TS + 460)}$$

$$= \frac{17.65 \times 6.15 \times 29.19 \times 0.94}{(388 + 460)}$$

$$= 3.5127 \text{ gr/acf}$$

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

$$CAU = \frac{17.65 \times CAO \times PS \times MD}{(TS + 460)}$$

$$= \frac{17.65 \times 6.156 \times 29.19 \times 0.94}{(388 + 460)}$$

$$= 3.5145 \text{ gr/acf}$$

Table A-2 (Continued)

PARTICULATE CALCULATIONS

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

CAW = 0.00857 x CAN x QS

= 0.00857 x 6.1532 x 58825

= 3101.999 lb/hr

17. Particulate - total (lb/hr)

CAX = 0.00857 x CAO x QS

= 0.00857 x 6.1563 x 58825

= 3103.571 lb/hr

[a]Dry standard cubic feet @ 68°F, 29.92 in. Hg

[b]Standard cubic feet @ 68°F, 29.92 in. Hg

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

[d]Dry standard cubic feet per minute @ 68°F, 29.92 in. Hg

[e]Actual cubic feet per minute @ stack conditions

APPENDIX B

PARTICLE SIZE DATA FROM BRINK® BMS-11

Table B-1. PARTICLE SIZE DISTRIBUTION FOR RUN 1-4 (METRIC)

CASCADE IMPACTOR PARTICLE SIZE DISTRIBUTION FOR RUN 1-4

INPUT VARIABLE	UNITS	INPUT DATA
SAMPLING TIME	MIN	5.0
PRESSURE DROP	CM HG	4.57
STATIC PRESSURE	CM H2O	-11.07
PARTICLE DENSITY	G/CC	3.50
BAROMETRIC PRESSURE	CM HG	74.68
GAS MOL WT		30.7
GAS TEMPERATURE	DEG C	53.3
GAS VISCOSITY	POISE	0.00025
GAS DENSITY	G/CC	0.00017

STAGE	WT OF MATERIAL	DPC	MG/ACM	WT PCNT	CUM WT PCNT
CYCLONE	60.600		4.97	60.72	100.00
1	21.100	2.30	1.73	21.14	39.28
2	9.100	1.26	0.75	9.12	18.14
3	2.900	0.79	0.24	2.91	9.02
4	2.800	0.32	0.23	2.81	6.11
5	2.600	0.16	0.21	2.61	3.31
FILTER	0.700		0.06	0.70	0.70

Table B-2. PARTICLE SIZE DISTRIBUTION FOR RUN 1-4 (ENGLISH)

CASCADE IMPACTOR PARTICLE SIZE DISTRIBUTION FOR RUN 1-4

INPUT VARIABLE	UNITS	INPUT DATA
SAMPLING TIME	MIN	5.0
PRESSURE DROP	IN HG	1.80
STATIC PRESSURE	IN H2O	-4.36
PARTICLE DENSITY	G/CC	3.50
BAROMETRIC PRESSURE	IN HG	29.40
GAS MOL WT		30.7
GAS TEMPERATURE	DEG F	128.0
GAS VISCOSITY	POISE	0.00025
GAS DENSITY	G/CC	0.00017

STATE	WT OF MATERIAL	DPC	MG/ACF	WT PCNT	CUM WT PCNT
CYCLONE	60.600		175.35	60.72	100.00
1	21.100	2.30	61.05	21.14	39.28
2	9.100	1.26	26.33	9.12	18.14
3	2.900	0.79	8.39	2.91	9.02
4	2.800	0.32	8.10	2.81	6.11
5	2.600	0.16	7.52	2.61	3.31
FILTER	0.700		2.03	0.70	0.70

Table B-3. PARTICLE SIZE DISTRIBUTION FOR RUN 1-6 (METRIC)

CASCADE IMPACTOR PARTICLE SIZE DISTRIBUTION FOR RUN 1-6

INPUT VARIABLE	UNITS	INPUT DATA
SAMPLING TIME	MIN	5.0
PRESSURE DROP	CM HG	1.40
STATIC PRESSURE	CM H2O	-10.16
PARTICLE DENSITY	G/CC	3.50
BAROMETRIC PRESSURE	CM HG	74.88
GAS MOL WT		30.5
GAS TEMPERATURE	DEG C	92.2
GAS VISCOSITY	POISE	0.00027
GAS DENSITY	G/CC	0.00014

STAGE	WT OF MATERIAL	DPC	MG/ACM	WT PCNT	CUM WT PCNT
CYCLONE	88.400		11.60	78.84	100.00
1	7.360	3.09	0.97	6.56	21.16
2	9.220	1.70	1.21	8.22	14.59
3	1.460	1.07	0.19	1.30	6.37
4	1.230	0.45	0.16	1.10	5.07
5	3.650	0.23	0.48	3.26	3.97
FILTER	0.800		0.10	0.71	0.71

Table B-4. PARTICLE SIZE DISTRIBUTION FOR RUN 1-6 (ENGLISH)

CASCADE IMPACTOR PARTICLE SIZE DISTRIBUTION FOR RUN 1-6

INPUT VARIABLE	UNITS	INPUT DATA
SAMPLING TIME	MIN	5.0
PRESSURE DROP	IN HG	0.55
STATIC PRESSURE	IN H2O	-4.00
PARTICLE DENSITY	G/CC	3.50
BAROMETRIC PRESSURE	IN HG	29.48
GAS MOL WT		30.5
GAS TEMPERATURE	DEG F	198.0
GAS VISCOSITY	POISE	0.00027
GAS DENSITY	G/CC	0.00014

STATE	WT OF MATERIAL	DPC	MG/ACF	WT PCNT	CUM WT PCNT
CYCLONE	88.400		409.67	78.84	100.00
1	7.360	3.09	34.11	6.56	21.16
2	9.220	1.70	42.73	8.22	14.59
3	1.460	1.07	6.77	1.30	6.37
4	1.230	0.45	5.70	1.10	5.07
5	3.650	0.23	16.92	3.26	3.97
FILTER	0.800		3.71	0.71	0.71

APPENDIX C

COMPLETE NO_x RESULTS AND SAMPLE CALCULATION

Table C-1. NO_x RESULTS

NOX CALCULATION (68 DEG F)

STANDARD LIME COMPANY
16 JANUARY 1976

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

VSC	MASS	PPM	LB/DSCF	KG/HR	G/NCM	LB/HR
0.174581E+04	0.456397E+02	0.136986E+02	0.162083E-05	0.258155E+01	0.259603E-01	0.569125E+01
0.174188E+04	0.230191E+03	0.692473E+02	0.819339E-05	0.130499E+02	0.131231E+00	0.287696E+02
0.178052E+04	0.115031E+03	0.338532E+02	0.400553E-05	0.637975E+01	0.641554E-01	0.140647E+02
0.180956E+04	0.934312E+03	0.270552E+03	0.320119E-04	0.403670E+02	0.512724E+00	0.889924E+02
0.160093E+04	0.970096E+03	0.282260E+03	0.333971E-04	0.421138E+02	0.534911E+00	0.928434E+02
0.175603E+04	0.931359E+03	0.277918E+03	0.328835E-04	0.414660E+02	0.526684E+00	0.914154E+02

Table C-2

METHOD 7

NO_X CALCULATIONS

Plant Standard Lime

Date 1-12-76

Test No. Sample Calculation Test #4 Flask #15

Volume of flask and value (ml)	= VF =	2112
Initial absolute pressure of flask (in Hg)	= PI =	2.60
Final absolute pressure of flask (in Hg)	= PF =	28.46
Initial temperature of flask (°F)	= TI =	63
Final temperature of flask (°F)	= TF =	72
Mass of NO_X as NO_2 in gas sample (µg)	= M =	934

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

$$VS = \frac{17.65}{\cancel{17.71}} \times (VF-25)\left(\frac{PF}{TF+460} - \frac{PI}{TI+460}\right)$$

$$VS = \frac{17.65}{\cancel{17.71}} \times (2112 \quad -25)\left(\frac{28.46}{72+460} - \frac{2.60}{63+460}\right) = \underline{\quad 1784 \quad} \text{ ml}$$

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

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

$$C = 6.2 \times 10^{-5} \times \left(\frac{934}{1784}\right) = \underline{\quad 3.246 \times 10^{-5} \quad} \frac{\text{lbs}}{\text{scf}}$$

$$PPM = \frac{24.5}{MW} \times 1.6018 \times 10^7 \times \frac{\#}{scf}$$

$$PPM = \frac{24.5}{46} \times 1.6018 \times 10^7 \times 3.246 \times 10^{-5} = \underline{\quad 277 \quad} \text{ ppm}$$

APPENDIX D

FIELD TEST DATA SHEETS

TRAVERSE POINT LOCATION FOR CIRCULAR DUCTS

PLANT Standard Lime Div. of Martin-Marietta Woodville
DATE 12/8/75
SAMPLING LOCATION #4 Kiln
INSIDE OF FAR WALL TO OUTSIDE OF NIPPLE, (DISTANCE A) 5' 11 1/4"
INSIDE OF NEAR WALL TO OUTSIDE OF NIPPLE, (DISTANCE B) 5 1/4"
STACK I.D., (DISTANCE A - DISTANCE B) 5'6"
NEAREST UPSTREAM DISTURBANCE >12' (20)
NEAREST DOWNSTREAM DISTURBANCE >45' (80)
CALCULATOR Pitot #5A

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	.044	~~66"~~	2 7/8"	5' 7"	8 1/8
2	.147	↓	9 3/4"	↓	15
3	.295		19 1/2		25
4	.705		46 1/2		52
5	.853		56 1/4		61 1/2
6	.956		63 1/8		68 3/8

EPA (Dur) 232
4/72

PRELIMINARY VELOCITY TRAVERSE

PLANT Standard Lime - Woodville
DATE 12-8-75
LOCATION #4 Kiln
STACK I.D. 5' 6"
BAROMETRIC PRESSURE, in. Hg 29.60
STACK GAUGE PRESSURE, in. H_2O -#2.90
OPERATORS Jay - Etter - Hughes

Pitot #5A
C_p = 0.85

SCHEMATIC OF TRAVERSE POINT LAYOUT

Southeast Port

TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
1	1.20	401
2	1.05	411
3	1.10	416
4	1.20	418
5	1.25	395
6	1.00	398
AVERAGE		

Northwest Port

TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
7	0.80	390
8	1.30	404
9	1.30	411
10	1.10	413
11	1.15	415
12	1.10	413
AVERAGE	~~1.06~~ 1.13	407

EPA (Dur) 233
4/72

NOMOGRAPH DATA

PLANT Standard Lime - Woodville

DATE 12/8/75

SAMPLING LOCATION #4 Kiln

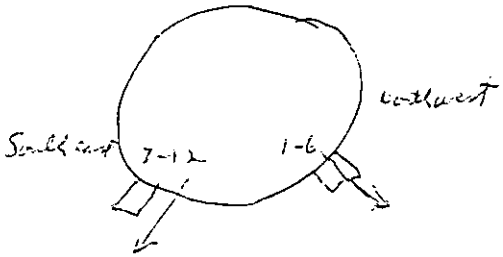
Pitot # 5A : 0.85 = C_p

CALIBRATED PRESSURE DIFFERENTIAL ACROSS ORIFICE, in. H_2O	$\Delta H_@$	1.95
AVERAGE METER TEMPERATURE (AMBIENT + 20 °F), °F	$T_{m_{avg.}}$	50
PERCENT MOISTURE IN GAS STREAM BY VOLUME	B_{wo}	10
BAROMETRIC PRESSURE AT METER, in. Hg	P_m	29.60
STATIC PRESSURE IN STACK, in. Hg ($P_m \pm 0.073$ x STACK GAUGE PRESSURE in in. H_2O)	P_s	29.81
RATIO OF STATIC PRESSURE TO METER PRESSURE	P_s/P_m	1.007
AVERAGE STACK TEMPERATURE, °F	$T_{s_{avg.}}$	407
AVERAGE VELOCITY HEAD, in. H_2O	$\Delta p_{avg.}$	1.13
MAXIMUM VELOCITY HEAD, in. H_2O	$\Delta p_{max.}$	1.30
C FACTOR		0.94
CALCULATED NOZZLE DIAMETER, in.		0.228
ACTUAL NOZZLE DIAMETER, in.		.245 ?
REFERENCE Δp, in. H_2O		0.84

EPA (Dur) 234
4/72

FIELD DATA

PLANT Woodsville – Standard Lime
DATE 12-9-75
SAMPLING LOCATION Kiln #4
SAMPLE TYPE EPA-5
RUN NUMBER 1-4
OPERATOR J. Kaufree & Otter
AMBIENT TEMPERATURE 30°F
BAROMETRIC PRESSURE 29.40
STATIC PRESSURE, (P_s) −2.40" H_2O
FILTER NUMBER (s) 53-6 (1st ½) + 53-7 (2nd ½)



SCHEMATIC OF TRAVERSE POINT LAYOUT

PROBE LENGTH AND TYPE 6' glass
NOZZLE I.D. 0.245"
ASSUMED MOISTURE, % 10
SAMPLE BOX NUMBER 3
METER BOX NUMBER 6
METER $\Delta H_@$ 1.91
~~C FACTOR~~ ΔH Ref 2.38
PROBE HEATER SETTING N.
HEATER BOX SETTING Hi
REFERENCE Δp 1.13

READ AND RECORD ALL DATA EVERY 5 MINUTES LEAK RATE .002 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	PROBE TEMP
			424		DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F				
1	0	1048	575.~~375~~	1.10	2.29	2.29	36.8	57	54	5.5	201	40	115/
2	5	1053	580.155	1.20	2.48	2.48	35.2	57	52	6.3	202	40	131/142
3	10	1058	586.050	1.20	2.48	2.48	39.0	57	52	2.4	206	40	141/145
4	15	1103	591.485	1.25	2.62	2.62	39.1	56	52	9.2	204	41	153/11
5	20	1108	596.620	1.44	1.77	1.77	38.2	56	52	9.6	206	41	165/12
6	25	1113	596.865	0.82	1.72	1.72	36.5	57	52	9.0	205	42	144/12
9	30	1118	600.817										
				.98	2.1	2.1							
7 30	~~25~~	1157	601.103	~~.98~~	~~2.1~~	~~2.1~~	379	57	55	5.5	185	42	155/
8 35	~~30~~	1202	604.819	1.1	2.3	2.3	398	58	54	6.0	183	43	177/
9 40	~~35~~	1207	607.797	1.1	2.3	2.3	403	60	55	6.8	199	45	187/15
10 45	~~40~~	1212	610.592	1.1	2.3	2.3	406	61	55	7.6	210	46	189/1
11 50	~~45~~	1217	615.433	1.0	2.1	2.1	405	60	55	8.7	216	47	177/
12 55	~~50~~	1222	619.156	.68	1.45	1.45	387	61	56	8.0	223	48	174/14
60	~~55~~	1227	622.352										
	~~60~~												

CLEAN-UP DATA

Plant MARTIN MARIETTA Comments:
Date 12/9/75
Sampling Location #4 Kiln
Sample Type EPA-5
Run Number 1-4
Sample Box Number 3
Clean-up Man ETTER & HUGHES

IMPINGERS

	#1	#2	#3	#4	#5
Final Vol.	150 ml	100 ml	0 ml	ml	ml
Initial Vol.	100 ml	100 ml	0 ml	ml	ml
Net Vol.	50 ml	0 ml	0 ml	ml	ml

Total Net Volume in Impingers 50 ml

SILICA GEL

Final Weight	209.8 g	g	g	
Initial Weight	200.0 g	g	g	
Net Weight	9.8 g	g	g	

Total Net Weight in Silica Gel 9.8 g

Total Moisture 59.8 g

Filter Number(s) 53-6
53-7

MRC 7/73

8b'1 ← bbb
b1'c ← 7c'1

DRY MOLECULAR WEIGHT DETERMINATION

PLANT Standard-Lime Woodville
DATE 12/9/75
SAMPLING TIME (24-hr CLOCK) 1300
SAMPLING LOCATION #4 Kiln
SAMPLE TYPE (BAG, INTEGRATED, CONTINUOUS) Integrated
ANALYTICAL METHOD Orsat
AMBIENT TEMPERATURE 72° F
OPERATOR T. Halman

COMMENTS:

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	18.2	18.2	18.2	18.2%				44/100	8.008
O_2 (NET IS ACTUAL O_2 READING MINUS ACTUAL CO_2 READING)	29	10.8%	29	10.8%				32/100	3.456
CO (NET IS ACTUAL CO READING MINUS ACTUAL O_2 READING)	29	0%	29	0%				28/100	
N_2 (NET IS 100 MINUS ACTUAL CO READING)				71%				28/100	19.88
								TOTAL	31.344

EPA (Dur) 230
4/72

ISOKINETIC CALCULATION

Run# 1-4, Date 12-9-75

Location Kiln #4 Stack, Initials [illegible]

MOISTURE

Net volume of liquid collected in impingers and silica gel = V_L = 59.8 ml

Net volume of gas through dry gas meter at meter conditions = V_m = 43.928 cu.ft.

Barometric Pressure - absolute = BP = 29.40 in.Hg

Average absolute meter temperature (°F + 460) = T_m = 516 °R

Percent moisture = M

$$M = \frac{100}{1 + \frac{373.63\ (\ V_m\ )\ (\ BP\ )}{(\ T_m\ )\ (\ V_L\ )}} + 2.5$$

$$= \frac{100}{1 + \frac{373.63\ (43.928)\ (29.40)}{(\ 516\ )\ (\ 59.8\ )}} + 2.5 = 8.51\ \%$$

MOLECULAR WEIGHT

Percent O_2 by volume dry basis = O_2 = ____ %

" CO " " " " = CO = ____ %

" CO_2 " " " " = CO_2 = ____ %

$N_2 = 100 - (O_2 + CO_2 + CO) = 100 - (\ \ +\ \ +\ \ )$

Percent N_2 by volume dry basis = N_2 = ____ %

Dry molecular weight = MD

$MD = 0.44\ (\ CO_2\ ) + 0.32\ (\ O_2\ ) + 0.28\ (\ N_2 + CO\ )$

$MD = 0.44\ (\ \ ) + 0.32\ (\ \ ) + 0.28\ (\ \ +\ \ )$

MD = ~~29~~ 31.344

ISOKINETIC CALCULATION (Cont.d)

Run # 1-4

MOLECULAR WEIGHT (Cont.d)

Stack gas molecular weight = MS

$MS = (MD)[1 - (M \times 10^{-2})] + 18\ (M \times 10^{-2})$

$MS = (\ 30.344)[1 - (0.0851)] + 18\ (0.0851) =$ 30.21

VELOCITY

Static pressure of stack = p = −2.90 H_2O

Pitot tube coefficient, type S = CP = 0.85

Average Absolute Stack Temp. (°F + 460) = T_s = 548 °R

Average of the square root of Δp = $\sqrt{\Delta p}$ = 1.02 $(in.H_2O)^{\frac{1}{2}}$

Absolute pressure of stack $(BP \pm \frac{p}{13.6})$ = P_s = 29.19 in.Hg

Stack gas velocity = V_s

$$V_s = (85.48)(CP)\left[\sqrt{\frac{(T_s)}{(P_s)(MS)}}\right]\left[\sqrt{\Delta p}\right]$$

$$V_s = (85.48)(0.85)\left[\sqrt{\frac{(548)}{(29.19)(30.21)}}\right]\left[1.02\right]$$

= 72.676 FPS

ISOKINETIC PERCENT

Average pressure drop across orifice = ΔH = 2.37 in.H_2O

Total sampling time = T = 60 min.

Diameter of nozzle = d = 0.245 in.

Area of nozzle = A

$A = 54.54 \times 10^{-4}\ (d^2) = 54.54 \times 10^{-4}\ (.245)^2 =$ 0.00033 sq. ft.

I = percent Isokinetic

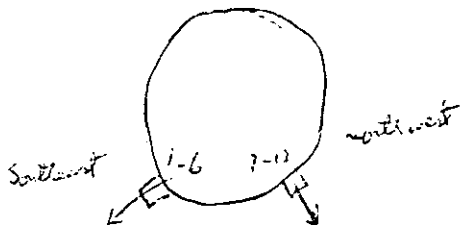
$$I = \frac{(1.667)(T_s)\left[0.00267\ (V_L) + \frac{(V_m)}{(T_m)}\left(PB + \frac{(\Delta H}{13.6}\right)\right]}{(T)(V_s)(P_s)(A)}$$

$$I = \frac{(1.667)(548)\left[0.00267\ (59.8) + \frac{(43.908)}{(516)}\left(29.4 + \frac{(2.37}{13.6}\right)\right]}{(60)(72.676)(29.19)(0.00033)}$$

I = 90.1 %

FIELD DATA

PLANT Standard Lime - Woodville
DATE 12/9/75
SAMPLING LOCATION Kiln #4
SAMPLE TYPE EPA-5
RUN NUMBER 2-4
OPERATOR Thalman-Hughes
AMBIENT TEMPERATURE 35°F
BAROMETRIC PRESSURE 29.40
STATIC PRESSURE, (P_s) -2.9 "H_2O
FILTER NUMBER (s) 52-8



SCHEMATIC OF TRAVERSE POINT LAYOUT

PROBE LENGTH AND TYPE 5 ft
NOZZLE I.D. .245
ASSUMED MOISTURE, % 10
SAMPLE BOX NUMBER IVIR-
METER BOX NUMBER IVIRC
METER $\Delta H_@$ 1.91
C FACTOR
PROBE HEATER SETTING 4.5
HEATER BOX SETTING 4.1
REFERENCE Δp 1.130 ; 2.38 ΔH

READ AND RECORD ALL DATA EVERY 5 MINUTES LEAK RATE .01 CFM @ 23 "Hg

Pitot 5A

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/ Filter
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F				
1	0	1340	~~624.639~~ 55	1.1	2.3	2.3	394	63	61	11.0	221	46	133/142
2	5	1345	627.110	1.2	2.48	2.48	394	63	60	12.0	234	44	144/135
3	10	1350	631,947	.96	2.0	2.0	403	66	61	9.0	248	49	148/140
4	15	1355	635,541	.82	1.75	1.75	403	68	62	8.0	248	50	149/140
5	20	1400	639.251	.92	1.91	1.91	399	64	63	8.0	236	50	134/132
6	25	1405	642.791	.65	1.3	1.38	385	64	64	8.0	236	50	132/135
7	30	1410	646.573	.96	2.0	2.0	363	70	66	6.0	198	42	135/137
8	35	1420	649.925	1.1	2.3	2.3	385	67	66	8.0	230	42	134/142
9	40	1425	653.880	1.2	2.48	2.48	387	67	66	8.0	181	42	117/149
10	45	1430	658.069	1.2	2.48	2.48	384	67	66	9.0	185	43	117/152
11	50	1435	662.947	.75	1.6	1.6	365	67	66	6.0	185	45	123/150
~~12~~ 12	55	1440	665.641	.64	1.35	1.35	350	64	67	6.0	146	41	126/150
	60	1445	668.466										

CLEAN-UP DATA

Plant MARTIN MARIETTA Comments:
Date 12/9/75
Sampling Location #4 KILN
Sample Type EPA 5
Run Number 2-4
Sample Box Number 6
Clean-up Man ETTER & HUGHES

IMPINGERS

	#1	#2	#3	#4	#5
Final Vol.	114 ml	100 ml	0 ml	ml	ml
Initial Vol.	100 ml	100 ml	0 ml	ml	ml
Net Vol.	14 ml	0 ml	0 ml	ml	ml

Total Net Volume in Impingers 14 ml

SILICA GEL

Final Weight	208.8 g	g	g
Initial Weight	200.0 g	g	g
Net Weight	8.8 g	g	g

Total Net Weight in Silica Gel 8.8 g

Total Moisture 22.8 g

Filter Number(s) 53-5

ISOKINETIC CALCULATION

Run# 2-4/ , Date 12-9-75

Location Kl. #4 Std Line , Initials JA

MOISTURE

Net volume of liquid collected in impingers and silica gel = V_L = 22.5 ml

Net volume of gas through dry gas meter at meter conditions = V_m = 45.011 cu.ft.

Barometric Pressure - absolute = BP = 29.40 in.Hg

Average absolute meter temperature (°F + 460) = T_m = 525.5 °R

Percent moisture = M

$$M = \frac{100}{1 + \frac{373.63\ (\ V_m\ )\ (\ BP\ )}{(\ T_m\ )\ (\ V_L\ )}} + 2.5$$

$$= \frac{100}{1 + \frac{373.63\ (\ 45.011\ )\ (\ 29.40\ )}{(\ 525.5\ )\ (\ 22.5\ )}} + 2.5 = 4.87\ \%$$

MOLECULAR WEIGHT

Percent O_2 by volume dry basis = O_2 = ____ %

" CO " " " " = CO = ____ %

" CO_2 " " " " = CO_2 = ____ %

$N_2 = 100 - (O_2 + CO_2 + CO) = 100 - (\ +\ +\ )$

Percent N_2 by volume dry basis = N_2 = ____ %

Dry molecular weight = MD

$MD = 0.44\ (\ CO_2\ ) + 0.32\ (\ O_2\ ) + 0.28\ (\ N_2 + CO\ )$

$MD = 0.44\ (\ \ ) + 0.32\ (\ \ ) + 0.28\ (\ +\ )$

MD = 29 31.344

ISOKINETIC CALCULATION (Cont.d)

Run # 2-4

MOLECULAR WEIGHT (Cont.d)

Stack gas molecular weight = MS

MS = (MD)[1 - (M x 10^{-2})] + 18 (M x 10^{-2})

MS = (31.344)[1 - (0.0487)] + 18 (0.0487) = 30.69

VELOCITY

Static pressure of stack = p = -2.90 H_2O

Pitot tube coefficient, type S = CP = 0.85

Average Absolute Stack Temp. (°F + 460) = T_s = 844 °R

Average of the square root of Δp = $\sqrt{\Delta p}$ = 0.97 $(in.H_2O)^{\frac{1}{2}}$

Absolute pressure of stack $(BP \pm \frac{p}{13.6})$ = P_s = 29.19 in.Hg

Stack gas velocity = V_s

$$V_s = (85.48)\,(\ CP\ )\left[\sqrt{\frac{(\ T_s\ )}{(\ P_s\ )\,(\ MS\ )}}\right]\left[\sqrt{\Delta p}\right]$$

$$V_s = (85.48)\,(0.85)\left[\sqrt{\frac{(\ 844\ )}{(\ 29.19\ )\,(\ 30.69\ )}}\right]\left[0.97\right]$$

= 65.41 FPS

ISOKINETIC PERCENT

Average pressure drop across orifice = ΔH = 2.00 in.H_2O

Total sampling time = T = 60 min.

Diameter of nozzle = d = 0.345 in.

Area of nozzle = A

A = 54.54 x 10^{-4} (d^2) = 54.54 x 10^{-4} ( )^2 = 0.00033 sq. ft.

I = percent Isokinetic

$$I = \frac{(1.667)\,(\ T_s\ )\left[0.00267\,(V_L\ ) + \frac{(\ V_m\ )}{(\ T_m\ )}\left(PB + \frac{(\ \Delta H\ )}{13.6}\right)\right]}{(\ T\ )\,(\ V_s\ )\,(\ P_s\ )\,(\ A\ )}$$

$$I = \frac{(1.667)\,(844)\left[0.00267\,(23.8) + \frac{(45.011)}{(525.5)}\left(29.4 + \frac{(2)}{13.6}\right)\right]}{(60)\,(68.41)\,(29.19)\,(0.00033)}$$

I = 92.2 %

TRAVERSE POINT LOCATION FOR CIRCULAR DUCTS

new location

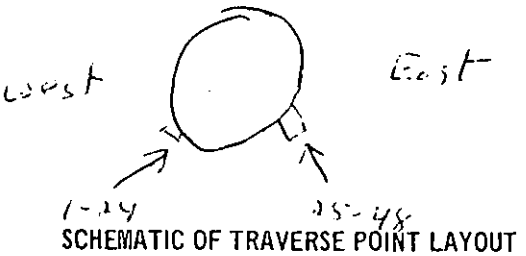
PLANT Standard Lime
DATE 12/10/75
SAMPLING LOCATION #6 Kiln
INSIDE OF FAR WALL TO
OUTSIDE OF NIPPLE, (DISTANCE A) ____
INSIDE OF NEAR WALL TO
OUTSIDE OF NIPPLE, (DISTANCE B) ____
STACK I.D., (DISTANCE A - DISTANCE B) 81"
NEAREST UPSTREAM DISTURBANCE ~~2½ D~~ 5D
NEAREST DOWNSTREAM DISTURBANCE 2½ D
CALCULATOR A. Toy ~~5D~~

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	.011	81"	~~0~~ 1"	5¼ 3	~~6¼~~ 14
2	.032		2½		~~7 3/4~~ 5¼
3	.055		4½		~~9 3/4~~ 7½
4	.079		6 3/8		~~11 5/8~~ 9 3/8
5	.105		8½		~~13 3/4~~ 11½
6	.132		10 3/4		~~16~~ 13 3/4
7	.161		13"		~~18 1/4~~ 16
8	.194		15 3/4		~~21~~ 18 3/4
9	.23		18 5/8		~~23 7/8~~ 21 5/8
10	.272		22		~~27 1/4~~ 25
11	.323		26 1/8		~~31 3/8~~ 29 1/8
12	.398		32 1/4		~~37 1/2~~ 35 1/4
13	.602		48 3/4		~~54~~ 51 3/4
14	.677		54 7/8		~~60 1/8~~ 57 7/8
15	.728		59		~~64 1/4~~ 62
16	.77		62 3/8		~~67 5/8~~ 65 3/8
17	.806		65 1/4		~~70 1/2~~ 68 1/4
18	.839		68		~~73 1/4~~ 71
19	.868		70 1/4		~~75 1/2~~ 73 1/4
20	.895		72 1/2		~~77 3/4~~ 75 1/2
21	.921		74 5/8		~~79 7/8~~ 77 5/8
22	.945		76 1/2		~~81 3/4~~ 79 1/2
23	.968		78 3/8		~~83 7/8~~ 81 3/8
24	.989		80		85 1/4 83

PRELIMINARY VELOCITY TRAVERSE

PLANT Standard Lime - Woodville
DATE 12-10-75
LOCATION Kiln # 6
STACK I.D. 6'9"
BAROMETRIC PRESSURE, in. Hg 29.48
STACK GAUGE PRESSURE, in. H_2O -6.0
OPERATORS McKentree & Etter



SCHEMATIC OF TRAVERSE POINT LAYOUT

Pitot 6A

West

TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
1	0.09	468
2	0.10	514
3	0.11	522
4	0.13	526
5	0.12	524
6	0.125	531
7	0.13	536
8	0.14	539
9	0.165	545
10	0.185	551
11	0.185	553
12	0.185	558
13	0.175	555
14	0.185	554
15	0.19	552
16	0.19	550
17	0.185	547
18	0.18	544
19	0.18	542
20	0.17	534
21	0.17	527
22	0.15	516
23	0.13	524
24	0.14	507
AVERAGE		

East

TRAVERSE POINT NUMBER	VELOCITY HEAD (Δp_s), in. H_2O	STACK TEMPERATURE (T_s), °F
25	0.39	340
26	0.30	375
27	0.21	456
28	0.19	478
29	0.21	502
30	0.22	512
31	0.23	521
32	0.23	530
33	0.25	537
34	0.15	537
35	0.26	543
36	0.25	548
37	0.23	551
38	0.25	551
39	0.23	550
40	0.24	548
41	0.25	550
42	0.23	551
43	0.23	548
44	0.22	545
45	0.20	536
46	0.19	529
47	0.18	523
48	0.17	520
AVERAGE		

EPA (Dur) 233
4/72

NOMOGRAPH DATA

PLANT Standard Lime - Woodville

DATE 12/10/75

SAMPLING LOCATION #6 Kiln

Pitot # 6A = .855 = C_p

CALIBRATED PRESSURE DIFFERENTIAL ACROSS ORIFICE, in. H_2O	$\Delta H_@$	1.98	
AVERAGE METER TEMPERATURE (AMBIENT + 20 °F), °F	$T_{m\,avg.}$	55 ~~40°F~~	~~50°F~~
PERCENT MOISTURE IN GAS STREAM BY VOLUME	B_{wo}	8 ~~5~~	
BAROMETRIC PRESSURE AT METER, in. Hg	P_m	~~29.60~~	29.48
STATIC PRESSURE IN STACK, in. Hg ($P_m \pm 0.073$ x STACK GAUGE PRESSURE in in. H_2O)	P_s	29.04 ~~29.57~~	
RATIO OF STATIC PRESSURE TO METER PRESSURE	P_s/P_m	.985	
AVERAGE STACK TEMPERATURE, °F	$T_{s\,avg.}$	590	
AVERAGE VELOCITY HEAD, in. H_2O	$\Delta p_{avg.}$	.16	
MAXIMUM VELOCITY HEAD, in. H_2O	$\Delta p_{max.}$		
C FACTOR			
CALCULATED NOZZLE DIAMETER, in.			
ACTUAL NOZZLE DIAMETER, in.		.245	
REFERENCE Δp, in. H_2O $\Delta P = 1$		$\Delta H = 1.96$	

EPA (Dur) 234
4/72

FIELD DATA

PLANT Standard Lime - Luzerne Co
DATE 12-10-75
SAMPLING LOCATION Kiln #6
SAMPLE TYPE EPA-5
RUN NUMBER 1 - 6
OPERATOR McKendree & Etter
AMBIENT TEMPERATURE 72
BAROMETRIC PRESSURE 29.48
STATIC PRESSURE, (P_s) -6.0"
FILTER NUMBER (s) 63-4

PROBE LENGTH AND TYPE 7' glass
NOZZLE I.D. .245
ASSUMED MOISTURE, % 8
SAMPLE BOX NUMBER 4
METER BOX NUMBER 3
METER $\Delta H_@$ 1.983
C FACTOR
PROBE HEATER SETTING 4
HEATER BOX SETTING 4
REFERENCE Δp for cpd 1 DH @ 1.96

SCHEMATIC OF TRAVERSE POINT LAYOUT

READ AND RECORD ALL DATA EVERY 1.5 MINUTES LEAK RATE .005 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	Probe Temp / Exit Temp
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F				
1	0	1010	076.804	.11	.23	.23	429	48	46	1.0	176	37	136/14
2	1½	1011.5	77.341	.10	.21	.21	430	47	46	1.0	177	37	136/141
3	3	1013	77.810	.14	.29	.29	429	47	46	1.0	177	36	136/141
4	4.5	1014.5	78.245	.12	.25	.25	459	47	46	1.0	184	35	132/14
5	6	1016	78.561	.15	.315	.315	483	47	46	1.0	184	37	140/14
6	7.5	1017.5	79.341	.17	.36	.36	492	47	46	1.0	184	37	142/14
7	9	1019	79.862	.14	.295	.295	499	47	45	1.0	184	39	142/14
8	10.5	1020.5	80.341	.20	.42	.42	512	46	46	1.0	184	36	144/14
9	12	1022	80.843	.20	.42	.42	524	47	46	1.0	182	36	146/14
10	13½	1023½	81.146	.22	.45	.45	527	46	46	1.0	192	36	153/14
11	15	1025	81.629	.23	.47	.47	543	47	46	1.0	194	36	153/151
12	16.5	1026.5	82.147	.21	.43	.43	546	46	45	1.0	195	36	147/151
13	18	1028	82.677	.39	.78	.78	551	45	45	1.0	195	36	147/14
14	19.5	1029.5	83.344	.49	.98	.98	566	45	45	1.0	195	36	149/151
15	21	1031	84.148	.51	1.02	1.02	566	47	46	1.0	198	36	354/143
16	22½	1032.5	84.910	.46	.93	.93	564	46	45	1.0	206	35	350/145

PLANT Standard Lime DATE 12/10/15 RUN NO. 1-6

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	24	1034	85.846	.31	.75	.75	563	46	45	2.0	207	37	550/15
18	25.5	1035.5	86.541	.37	.75	.75	558	47	46	2.0	208	38	552/15
19	27	1037	87.221	.29	.58	.58	558	46	45	2.0	205	38	557/15
20	28.5	1038.5	87.942	.27	.49	.49	551	47	45	2.0	209	38	557/15
21	30	1040	88.344	.27	.54	.54	541	46	45	2.0	210	36	5.6/15
22	31.5	1041.5	89.010	.21	.43	.43	536	47	46	2.0	210	36	5.0/13
23	33	1043	89.470	.24	.49	.49	528	46	45	2.0	214	39	5.2/15
24	34.5	1044.5	90.510	.19	.395	.395	513	46	46	2.0	214	38	5.0/12
1	36	1110	90.568	.93	1.85	1.85	424	43	43	10.0	214	39	173/
2	37.5	1111.5	91.245	1.5	2.9	2.9	428	44	43	10.0	214	38	152/
3	39	1113	92.677	1.9	3.7	3.7	506	45	44	13.0	212	39	193/
4	40.5	1114.5	94.045	1.9	3.7	3.7	515	44	43	15.0	214	37	191/12
5	42	1116	95.549	1.9	3.7	3.7	524	42	44	15.0	216	38	195/14
6	43.5	1117.5	96.643	1.9	3.7	3.7	539	43	42	16.0	217	38	195/14
7	45	1119	98.142	2.5	4.8	4.8	546	46	42	18.0	233	42	196/14
8	46.5	1120.5	99.671	3.3	6.8	6.8	554	46	42	18.0	240	39	197/14
9	48	1122	101.346	.22	.44	44	550	44	43	18.0	252	39	168/15
10	49.5	1123.5	101.689	.27	.54	.54	560	44	43	2.0	253	39	164/15
11	51	1125	102.347	.26	.53	.53	559	44	43	2.0	244	39	167/12
12	52.5	1126.5	103.750	.26	.53	.53	563	44	43	3.0	246	39	167/12
13	54	1128	103.325	.27	.54	.54	561	45	44	3.0	246	37	187/11
14	55.5	1129.5	104.045	.21	.43	.43	551	44	43	3.0	255	34	289/12
15	57	1131	104.250	.27	.54	.54	559	43	45	3.0	246	39	334/11
16	58.5	1132.5	105.049	.25	.52	.52	559	44	43	3.0	249	38	462/11

PLANT Standard Lime DATE 12/10/75 RUN NO. 1-6

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 DESIRED	ORIFICE PRESSURE DIFFERENTIAL (ΔH), in. H_2O ACTUAL	STACK TEMPERATURE (T_s), °F	DRY GAS METER TEMPERATURE INLET ($T_{m\,in}$), °F	DRY GAS METER TEMPERATURE OUTLET ($T_{m\,out}$), °F	PUMP VACUUM, in. Hg	SAMPLE BOX TEMPERATURE, °F	IMPINGER TEMPERATURE, °F	
17	60	1134	106.141	.25	.52	.52	542	44	43	3.0	255	39	461/12
18	61.5	1135.5	106.344	.27	.54	.54	549	44	43	3.0	255	39	463/12
19	63	1137	106.821	.21	.43	.43	544	44	43	3.0	260	39	474/12
20	64.5	1138.5	107.341	.27	.54	.54	545	44	43	3.0	254	40	548/13
21	66	1140	107.984	.27	.54	.54	531	44	43	3.0	245	35	546/12
22	67.5	1141.5	108.344	.20	.41	.41	535	44	43	3.0	253	38	548/12
23	69	1143	108.944	.27	.54	.54	513	44	43	3.0	257	35	547/12
24	70.5	1144.5	109.554	.23	.47	.47	521	43	43	3.0	253	38	549/12
	72	1146	110.048										
					avg	1.07	avg 526						

CLEAN-UP DATA

Plant STANDARD LIME Comments:
Date 12-10-75
Sampling Location KILN #6
Sample Type EPA 5
Run Number 1-6
Sample Box Number 4
Clean-up Man ETTER, HUGHES, & MCKENDREE

IMPINGERS

	#1	#2	#3	#4	#5
Final Vol.	116 ml	103 ml	1 ml	ml	ml
Initial Vol.	100 ml	100 ml	0 ml	ml	ml
Net Vol.	16 ml	3 ml	1 ml	ml	ml

Total Net Volume in Impingers 20 ml

SILICA GEL

Final Weight	207.1 g	g	g
Initial Weight	200.0 g	g	g
Net Weight	7.1 g	g	g

Total Net Weight in Silica Gel 7.1 g

Total Moisture 27.1 g

Filter Number(s) 63-4

DRY MOLECULAR WEIGHT DETERMINATION

PLANT Standard Lime

DATE 12/10/75

SAMPLING TIME (24-hr CLOCK) 1200 hr - 1215 hr

SAMPLING LOCATION #6 Kiln

SAMPLE TYPE (BAG, INTEGRATED, CONTINUOUS) Bag

ANALYTICAL METHOD Orsat

AMBIENT TEMPERATURE 70°

OPERATOR K. Toy

COMMENTS:

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	16.1	16.1	16.2	16.2			16.2	44/100	7.13
O_2 (NET IS ACTUAL O_2 READING MINUS ACTUAL CO_2 READING)	26.2	10.1	26.3	10.1			10.1	32/100	3.23
CO (NET IS ACTUAL CO READING MINUS ACTUAL O_2 READING)	26.2	0.0	26.3	0.0			0.0	28/100	0.0
N_2 (NET IS 100 MINUS ACTUAL CO READING)		73.8		73.7			73.7	28/100	20.64
								TOTAL	31.00

EPA (Dur) 230
4/72

STANDARD LIME

ISOKINETIC CALCULATION

Run# 1-6, Date 12-10-75

Location KILN #6, Initials R.J.E.

MOISTURE

Net volume of liquid collected in impingers and silica gel = V_L = 274.1 ml

Net volume of gas through dry gas meter at meter conditions = V_m = 33.244 cu.ft.

Barometric Pressure - absolute = BP = 29.48 in.Hg

Average absolute meter temperature (°F + 460) = T_m = 505 °R

Percent moisture = M

$$M = \frac{100}{1 + \frac{373.63\ (\ V_m\ )\ (\ BP\ )}{(\ T_m\ )\ (\ V_L\ )}} + 2.5$$

$$= \frac{100}{1 + \frac{373.63\ (33.244)\ (29.48\ )}{(\ 505\ )\ (\ 27\ )}} + 2.5 = 6.09\ \%$$

MOLECULAR WEIGHT

Percent O_2 by volume dry basis = O_2 = 10.1 %

" CO " " " " = CO = 0.0 %

" CO_2 " " " " = CO_2 = 16.2 %

$N_2 = 100 - (O_2 + CO_2 + CO) = 100 - (\ +\ +\ )$

Percent N_2 by volume dry basis = N_2 = 73.7 %

Dry molecular weight = MD

$MD = 0.44\ (\ CO_2\ ) + 0.32\ (\ O_2\ ) + 0.28\ (\ N_2 + CO\ )$

$MD = 0.44\ (\ 16.2\ ) + 0.32\ (\ 10.1\ ) + 0.28\ (73.7 + 0.0\ )$

MD = 31.00

ISOKINETIC CALCULATION (Cont.d)

Run # 1-6

MOLECULAR WEIGHT (Cont.d)

Stack gas molecular weight = MS

$MS = (MD)[1 - (M \times 10^{-2})] + 18 (M \times 10^{-2})$

$MS = (31.00)[1 - (6.09 \times 10^{-2})] + 18 (6.09 \times 10^{-2}) = 30.21$

VELOCITY

Static pressure of stack = p = -6.0 in. H_2O

Pitot tube coefficient, type S = CP = .855

Average Absolute Stack Temp. (°F + 460) = T_s = 986 °R

Average of the square root of Δp = $\sqrt{\Delta p}$ = .652 $(in.H_2O)^{\frac{1}{2}}$

Absolute pressure of stack $\left(BP \pm \frac{p}{13.6}\right)$ = P_s = ~~29.48~~ 29.04 in.Hg

Stack gas velocity = V_s

$$V_s = (85.48)(CP)\left[\sqrt{\frac{(T_s)}{(P_s)(MS)}}\right]\left[\sqrt{\Delta p}\right]$$

$$V_s = (85.48)(.855)\left[\sqrt{\frac{(986)}{(29.04)(30.21)}}\right][.652]$$

V_s = ~~77.48~~ 50.52 FPS

ISOKINETIC PERCENT

Average pressure drop across orifice = ΔH = 1.07 in.H_2O

Total sampling time = T = 72.0 min.

Diameter of nozzle = d = .245 in.

Area of nozzle = A

$A = 54.54 \times 10^{-4} (d^2) = 54.54 \times 10^{-4} (.245)^2 = 3.274 \times 10^{-4}$ sq. ft.

I = percent Isokinetic

$$I = \frac{(1.667)(T_s)\left[0.00267 (V_L) + \frac{(V_m)}{(T_m)}\left(PB + \left(\frac{\Delta H}{13.6}\right)\right)\right]}{(T)(V_s)(P_s)(A)}$$

$$I = \frac{(1.667)(986)\left[0.00267 (27) + \frac{(33.244)}{(505)}\left(29.48 + \left(\frac{1.07}{13.6}\right)\right)\right]}{(72.0)(\text{~~77.48~~ } 50.52)(29.04)(3.274 \times 10^{-4})}$$

I = 95.91 %

FIELD DATA

PLANT Standard Lime - Woodville
DATE 12/10/75
SAMPLING LOCATION #6 Kiln
SAMPLE TYPE EPA-5
RUN NUMBER 2-6
OPERATOR Tox, Hughes, Etter
AMBIENT TEMPERATURE 35°F
BAROMETRIC PRESSURE 29.48
STATIC PRESSURE, (P_s) −6.0" H_2O
FILTER NUMBER (s) 53-9

PROBE LENGTH AND TYPE Pitot #6 A (6ft. MRC)
NOZZLE I.D. .245
ASSUMED MOISTURE, % 8
SAMPLE BOX NUMBER
METER BOX NUMBER
METER $\Delta H_@$ 1.98
C FACTOR
PROBE HEATER SETTING HE
HEATER BOX SETTING HI
REFERENCE Δp ΔP=1, ΔH=1.96

SCHEMATIC OF TRAVERSE POINT LAYOUT

READ AND RECORD ALL DATA EVERY 1.5 MINUTES LEAK RATE .01 CFM @ ≤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
					DESIRED	ACTUAL		INLET ($T_{m\,in}$), °F	OUTLET ($T_{m\,out}$), °F			
		1385	110.627									
1	0	1335	110.627	~~.30~~.24	.49	.49	~~416~~	43	39	1	153	
2	1.5		111.195	.16	.33	.33	416	43	39	1	16	38
3	3		111.678	.20	.41	.41	495	39	42	1	173	38
4	4.5		112.215	.20	.41	.41	527	39	40	1	171	40
5	6		112.634	.19	.39	.39	532	39	39	.1	176	41
6	7.5		113.115	.24	.49	.49	552	40	41	1		39
7	9		115.664	.23	.47	.47	553	41	40	1		40
8	10.5		114.161	.28	.57	.57	556	40	39	1		39
9	12		114.805	.24	.49	.49	557	40	40			38
10	13.5		115.275	.27	.55	.55	563	40	40			39
11	15		115.836	.28	.57	.57	569	40	39	1.1	211	39
12	16.5		116.437	.27	.55	.55	563	42	39			40
13	18		116.984	.29	.59	.59	567	41	39			39
14	19.5		117.563	.28	.57	.57	555	41	39	1.1		42
15	21		118.161	.23	.47	.47	547	41	40			42
16	22.5		118.691	.27	.55	.55	553	41	39			

Probe tip

771

12

219

PLANT Standard Lime - Woodville DATE 12/10/75 RUN NO. 2-6

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	24		119.271	.25	.51	.51	559	41	40			40
18	25.5		119.818	.28	.57	.57	560	42	40			40
~~19~~ 19	27		120.819	.27	.55	.55	554	41	41			41
20	28.5		121.004	.25	.51	.51	537	41	39			40
21	30		121.559	.26	.53	.53	533	41	40	1.5		40
22	31.5		122.135	.21	.43	.43	520	41	41			42
23	33		122.664	.23	.47	.47	509	41	40			41
24	34.5		123.205	.20	.42	.42	492	41	39			41
1	36	1430	123.737	.19	.40	.40	~~422~~ 492	44	41			
2	37.5		124.289	.15	.31	.31	422	41	39			43
3	39		124.675	.16	.33	.33	487	41	41			47
4	40.5		125.135	.18	.38	.38	521	40	41			45
5	42		125.575	.17	.36	.36	535	41	40			
6	43.5		126.001	.20	.42	.42	537	41	40		255	44
7	45		126.531	.16	.33	.33	536	41	41			
8	46.5		126.978	.19	.40	.40	544	42	41			44
9	48		127.451	.21	.43	.43	547	42	41			
10	49.5		127.948	.19	.40	.40	549	42	41		257	
11	51		128.437	.22	.45	.45	553	42	41			42
12	52.5		128.948	.20	.42	.42	535	43	40	1.9	262	42
13	54		129.444	.17	.36	.36	559	43	40			
14	55.5		130.031	.23	.47	.47	564	42	41	2.0	255	
15	57		130.457	.23	.47	.47	565	42	41			41
16	58.5		130.978	.26	.53	.53	563	42	40			44

10
90
91
92 82
261 9

PLANT Standard Lime-Woodville DATE 12/10/75 RUN NO. 2-6

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	60		131,541	.27	.55	.55	567	42	41				
18	61.5		132.198	.22	.45	.45	557	42	41	2.0	255	42	
19	63		132,657	.25	.51	.51	557	42	40	2.2	254	41	488 9
20	64.5		133,225	.21	.43	.43	552	43	40	2.0	251	45	510 9
21	66		133.748	.24	.50	.50	547	43	41		254	44	525 10
22	67.5		134.299	.23	.48	.48	539	43	41	2.3	252	49	K
23	69		134.865	.22	.45	.45	520	43	42	2.2	251	46	9
24	70,5		135,362	.23	.48	.48	501	43	41		255	44	9
	72		135,865										

CLEAN-UP DATA

Plant Standard Steel Comments:
Date 12/10/75
Sampling Location #6 Kiln
Sample Type EPA-5
Run Number 2-6
Sample Box Number SGB-5
Clean-up Man Toy Etter Hughes

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	207.2 g	g	g
Initial Weight	200 g	g	g
Net Weight	7.2 g	g	g

Total Net Weight in Silica Gel 7.2g g

Total Moisture 19.2 g

292.1
85.5 cm
7.2

Filter Number(s) 53.9

MRC 7/73

SOURCE SAMPLING PROCEDURE – EPA METHOD 7 – NOx

Date 12/9/75

Company Standard Lime-Woodville

Project EPA

Sample Point #6 Kiln (Sample #1, 2 and #3)
#4 Kiln (Sample #4, #5, #6)

Analyst Thalman

Sample			Flask	Initial			Clean Up Analysis		Final			ABS	TOTAL	FLASK	NOx	NOx
Day	Time	No.	No.	Bar. Press. in Hg	Flask Vacuum in Hg	Temp. °F	Day	Time	Bar. Press. in Hg	Flask ~~Vacuum~~ Pressure in ~~in~~ Hg	Temp. °F	@ 420	Dil. ml	Vol.-ABS ml	Conc. lb/scf	Conc. ppm
12/9/75	10:00 A.M.	1	16	29.40	26.8	62	12/11/75	9 15 AM	29.40	-2.4	72°					
12/9/75	10:05 A.M.	2	4	29.40	27.3	62	12/11/75	9 30 AM	29.40	-2.8	72°					
12/9/75	10:10 A.M.	3	8	29.40	27.2	62	12/11/75	9 45 AM	29.40	-4.9	72°					
12/9/75	11:15 A.M.	4	15	29.40	26.8	63	12/11/75	10 15 AM	29.40	-2.4	72°					
12/9/75	11:20 A.M.	5	2	29.40	26.8	63	12/11/75	10 35 AM	29.40	-1.0	72°					
12/9/75	11:25 A.M.	6	11	29.40	26.8	63	12/11/75	10 50 AM	29.40	-1.9	72°					

Brink BMS-11 Data

Run 1-6 12-9-75 5 Minute Sampling Time
2 mm Probe Tip

Started Run 1035 hrs
Finished Run 1040 hrs

Time	ΔP IN. Hg	Inlet Temp. °F	Outlet Temp °F	Static Pressure IN. H_2O
1035	0.55	182	230	4.2
1036	0.55	181	210	3.4
1037	0.55	183	206	4.4
1038	0.55	182	201	4.4
1039	0.55	182	223	3.6
1040	~~Stopped~~			

Brink BMS-11 Data

Run 1-4 12-9-75 5 Minute Sampling Time
1.5 mm Probe Tip

Started Run 1500 hrs
Finished Run 1505 hrs

Time	ΔP IN. Hg	Inlet Temp °F	Outlet Temp °F	Static Pressure IN. H_2O
1500	1.8	83	173	4.6
1501	1.8	82	174	4.0
1502	1.8	81	174	4.6
1503	1.8	81	174	4.2
1504	1.8	83	176	4.4
1505	~~stopped~~			

APPENDIX E

ANALYTICAL DATA SHEETS

ANALYTICAL DATA

PLANT Standard Lime Woodville

DATE 12-9-75

SAMPLING LOCATION Kiln #4

SAMPLE TYPE EPA Method 5

RUN NUMBER 1-4

SAMPLE BOX NUMBER MRC

CLEAN-UP MEN ~~McDonald~~ McKendree & ETTER

ANALYST W. McDonald

COMMENTS:

FRONT HALF

LABORATORY RESULTS

ACETONE WASH OF NOZZLE, PROBE, CYCLONE (BYPASS), FLASK, FRONT HALF OF FILTER HOLDER — CONTAINER 904-3 — 15255.3 mg

53-6 — 1113.5

FILTER NUMBER 53-6 F 1/2 — CONTAINER 53-7 — 1382.3 mg

53-7 2nd 1/2

FRONT HALF SUBTOTAL 17751.1 mg

BACK HALF

IMPINGER CONTENTS AND WATER WASH OF IMPINGERS, CONNECTORS, AND BACK HALF OF FILTER HOLDER — CONTAINER 904-5 — 4.9 mg

ETHER-CHLOROFORM EXTRACTION 904-6 — 0 mg

ACETONE WASH OF IMPINGERS, CONNECTORS, AND BACK HALF OF FILTER HOLDER — CONTAINER 904-4 — 4.1 mg

BACK HALF SUBTOTAL 9.0 mg

TOTAL WEIGHT 17760.1 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 Standard Lime

DATE 12-9-75

SAMPLING LOCATION #4 Kiln

SAMPLE TYPE EPA 5

RUN NUMBER 2-4

SAMPLE BOX NUMBER 6

CLEAN-UP MEN Etter & Hughes

ANALYST W. McDonald

COMMENTS:

FRONT HALF

LABORATORY RESULTS

ACETONE WASH OF NOZZLE, PROBE, CYCLONE (BYPASS), FLASK, FRONT HALF OF FILTER HOLDER — CONTAINER 904-7 — 4683.0 mg

FILTER NUMBER 53-8 — CONTAINER 53-8 — 940.9 mg

FRONT HALF SUBTOTAL 5623.9 mg

BACK HALF

IMPINGER CONTENTS AND WATER WASH OF IMPINGERS, CONNECTORS, AND BACK HALF OF FILTER HOLDER — CONTAINER 904-9 — 0.8 mg

ETHER-CHLOROFORM EXTRACTION 904-10 — 1.3 mg

ACETONE WASH OF IMPINGERS, CONNECTORS, AND BACK HALF OF FILTER HOLDER — CONTAINER 904-8 — 8.5 mg

BACK HALF SUBTOTAL 10.6 mg

TOTAL WEIGHT 5634.5 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 Standard Lime

DATE 12-10-75

SAMPLING LOCATION Kiln #6

SAMPLE TYPE EPA 5

RUN NUMBER 1-6

SAMPLE BOX NUMBER MRC 4

CLEAN-UP MEN Etter, Hughes McKendree

ANALYST W. McDonald

COMMENTS:

FRONT HALF

LABORATORY RESULTS

ACETONE WASH OF NOZZLE, PROBE, CYCLONE (BYPASS), FLASK, FRONT HALF OF FILTER HOLDER — CONTAINER 904-11 — 11305.1 mg

FILTER NUMBER 63-4 — CONTAINER 63-4 — 658.4 mg

FRONT HALF SUBTOTAL 11963.5 mg

BACK HALF

IMPINGER CONTENTS AND WATER WASH OF IMPINGERS, CONNECTORS, AND BACK HALF OF FILTER HOLDER — CONTAINER 904-13 — 23.1 mg

ETHER-CHLOROFORM EXTRACTION 904-14 — 5.7 mg

ACETONE WASH OF IMPINGERS, CONNECTORS, AND BACK HALF OF FILTER HOLDER — CONTAINER 904-12 — 3.0 mg

BACK HALF SUBTOTAL 31.8 mg

TOTAL WEIGHT 11995.3 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 Standard Lime

DATE 12-10-75

SAMPLING LOCATION #6 Kiln

SAMPLE TYPE EPA 5

RUN NUMBER 2-6

SAMPLE BOX NUMBER SGB-5

CLEAN-UP MAN H. Toy & Etter & Hughes
W. McDonald

COMMENTS:

FRONT HALF

LABORATORY RESULTS

ACETONE WASH OF NOZZLE, PROBE, CYCLONE (BYPASS), FLASK, FRONT HALF OF FILTER HOLDER — CONTAINER 904-15 — 10420.0 mg

FILTER NUMBER 53-9 — CONTAINER 53-9 — 857.8 mg

FRONT HALF SUBTOTAL 11277.8 mg

BACK HALF

IMPINGER CONTENTS AND WATER WASH OF IMPINGERS, CONNECTORS, AND BACK HALF OF FILTER HOLDER — CONTAINER 904-17 — 57.4 mg

ETHER-CHLOROFORM EXTRACTION 904-18 — 6.7 mg

ACETONE WASH OF IMPINGERS, CONNECTORS, AND BACK HALF OF FILTER HOLDER — CONTAINER 904-16 — 2.4 mg

BACK HALF SUBTOTAL 66.5 mg

TOTAL WEIGHT 11344.3 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

Standard Lime Brinks @ Liquid

ANALYSIS REPORT	PROJECT NUMBER 6912-12
TO	FROM
DATE	CC

4 Kiln

	mg. Samples
Probe	18.9
Cyclone	11.7
Stage 1	4.8
" 2	2.0
" 3	1.7
" 4	2.1
" 5	2.4

TOTAL mg. 73.6

6 Kiln

Probe	80.0
Cyclone	8.4
Stage 1	2.5
" 2	1.4
" 3	1.3
" 4	1.1
" 5	3.6

TOTAL mg 98.3

Glass Filters Brinks

ANALYSIS REPORT	PROJECT NUMBER
TO	FROM
DATE	CC

#6 KILN

65-1 4.86 mg

65-2 7.82 mg

65-3 0.156 mg

65-4 0.129 mg

65-5 0.045 mg

TOTAL 13.01 mg

#4 KILN

65-6 = 16.3 mg

65-7 7.1 mg

65-8 1.2 mg

65-9 0.7 mg

65-10 0.2 mg

TOTAL 25.5 mg

#4 thimble #102 wgt = 0.7 mg

#6 " #108 wgt = 0.8 mg

APPENDIX F

SAMPLING AND ANALYTICAL PROCEDURES

Method 5 MRC Clean Up Procedure

1. Transportation to Clean Up Area

After the run is finished the train can be removed to the clean up area. This can be done with the probe in place or it can be removed from the train and sealed at both ends. If the probe is removed, the cyclone entrance must be sealed to avoid any loss of contamination of its contents. Caution must be exercised when sealing the system for transportation so that cooling of the front half of the train will not cause water to be pulled into it from the back half.

2. Probe Clean Up

Remove any material from the outside of the probe and nozzle that may contaminate the sample by falling or being washed into the sample bottle. Remove the nozzle and rinse the inside with acetone into the front 1/2 acetone sample bottle. Brush the inside with a clean test tube brush while flushing with acetone into the sample bottle. Wash the brush with acetone into the bottle. Rinse the inside of the nozzle a final time with acetone.

Elevate one end (the nozzle end) of the probe and rinse through with acetone into the front 1/2 sample bottle while slowly rotating through 720°. Run a clean probe brush through the probe while flushing with acetone and slowly rotating the brush. When the brush is exposed on the down stream end of the probe, rinse it into the sample bottle with acetone. Do not pull the brush back through the probe. Repeat the brushing step. Rinse the probe a final time by flushing with acetone while rotating it 360°. Wash the funnel into the sample bottle. Observe the probe inside and repeat the clean up procedure if sample particles are obvious.

3. Cyclone and Filter Clean Up

Remove the cyclone and connecting glassware. Rinse the cyclone with acetone into the collection flask and pour into the front 1/2 sample bottle. Repeat until all loose material is collected. If sample material adheres to the inside surfaces, a small test tube brush can be used to free it, and it should be rinsed into the sample bottle. If a brush or spatula is used to clean the cyclone and catch bottle, it must be cleaned into the sample bottle. All connecting glassware between the cyclone system and filter must be treated in the same manner i.e., flushing and or brushing the sample exposed surfaces into the sample container with acetone until no sample material is visible.

The filter assemble must be disassembled in a dust free area. The filter membrane should be loosened from the silicon rubber gasket by running a knife blade or spatula between them being careful not to scrape or loosen particles of glass from the glass frit. Lift the filter, using a spatula, and place into its storage container. Carefully scrape all particles of filter material from both mating surfaces (i.e.: the silicon rubber gasket and the front-half glass holder) and place them in the storage container. Rinse and brush the front-half glass holder's sample exposed surfaces into the sample bottle with acetone. Do not wash or rinse the frit. Wash brushes, spatulas and funnels into the sample and store.

4. Back 1/2 Clean Up

Rinse the back half filter holder, connecting glass to the first impinger, and impinger "U" bends with distilled water into the back half water wash sample bottle by filling or flushing twice. Remove each of the first three impingers and pour the content into a graduated cylinder for measurement. Transfer these contents into the sample bottle. Wash each of the three impingers two times by squirting about 100 ml of distilled water into each, covering the inlet and outlet openings with clean caps or clean fingers, and shaking to cause the wash water to contact all of the inside surfaces. Pour this wash water into the sample bottle and rinse the graduated cylinder and funnel into sample bottle with distilled water. Seal the bottle and store.

Rinse the back half filter holder, the filter to impinger connectors, and the impinger "U" bends with acetone into the back half acetone wash sample bottle by filling or flushing two times. Wash each of the three impingers two times by adding about 100 ml of acetone and shaking as with the water wash. Transfer these washings to the sample bottle. Rinse the graduated cylinder used to measure the water and the funnel with acetone into the sample bottle. Cap the bottle and store.

The sampling and analysis procedures used on Methods 3 and 7 were from the Federal Register, Vol. 36, No. 247, December 23, 1971 were followed during sampling at Standard Lime Company.

APPENDIX G

BRINK® BMS-11 SAMPLER MANUAL

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.

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

Impactor and Auxiliary Apparatus

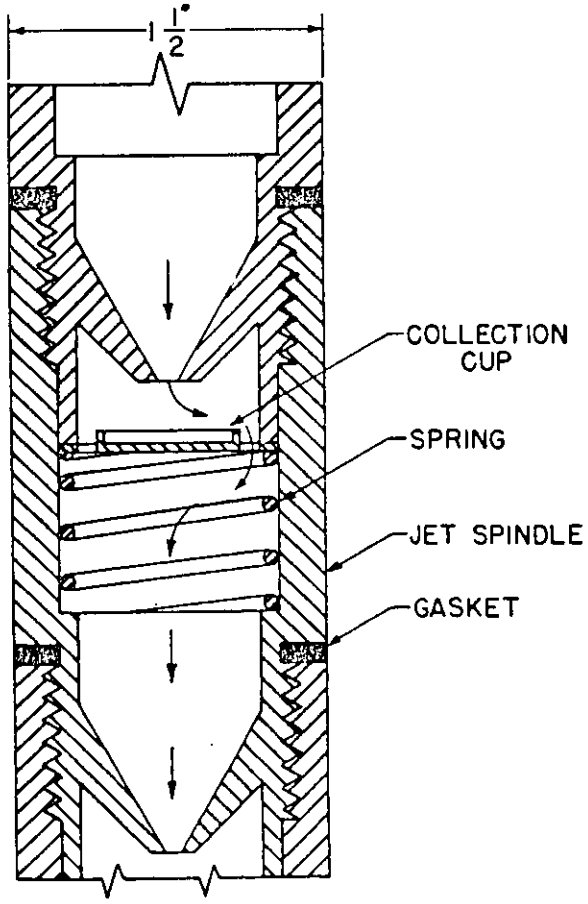
The cascade impactor has five in-line stages, each of which has a jet that utilizes a collection cup as an impaction plate. A spring holds each collection cup in place. The particles suspended in the gases pass through a jet, particles with sufficient inertia impact against a cup, and the remainder pass 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 15½ 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. 2½ L-R Manufacturing Co. blower, inside the box, is driven by a 8000 r.p.m. Fairchild Industries (Model

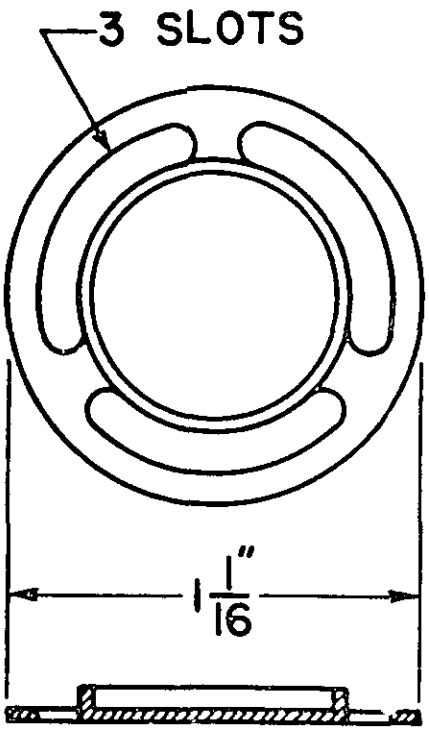
Table I. Dimensions of Cascade Impactor Jets

Jet No.	Dimensions, Cm. 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



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.

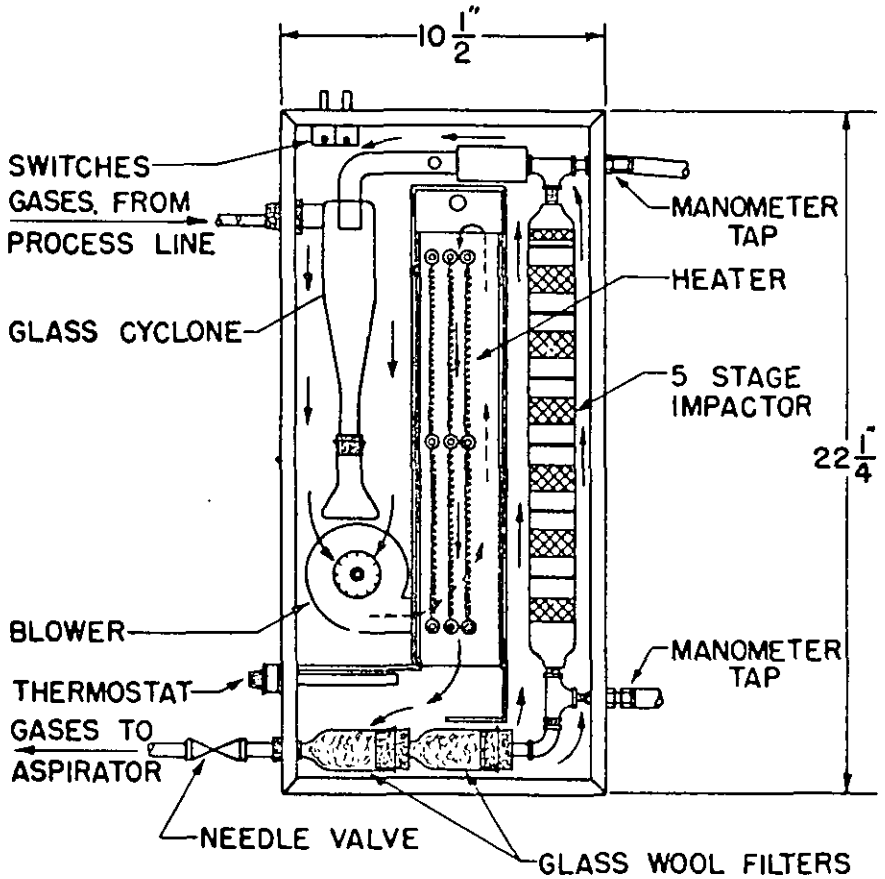
A sample line, heated with flexible tape heaters (electromagnetic heating tape, Howe and French), is controlled with a Variac. Sample probes and lines are sized for isokinetic sampling.

Experimental Procedure

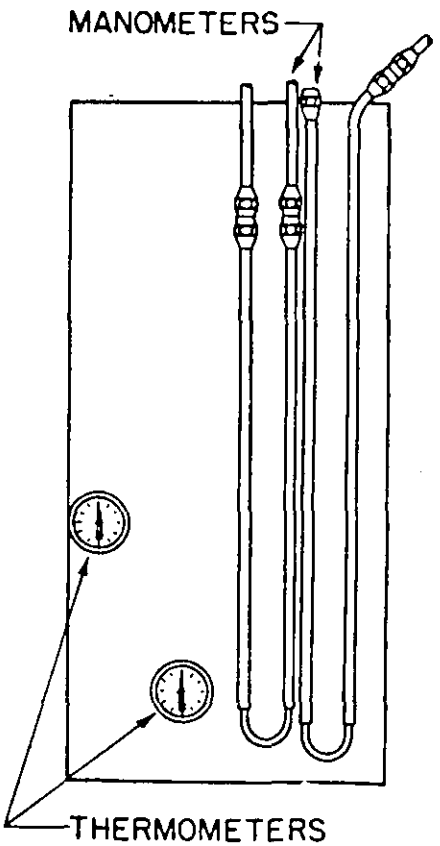
Prior to each test, the impactor and auxiliary apparatus were tested for leaks under 8-inch mercury vacuum. Then the sample line and the impactor box were heated to the temperature of the process stream. The sample probe was inserted in the process stream and gas flow through the impactor was started 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:

$$V_0 = 24.5\ (\Delta P)^{0.490} \qquad (1)$$

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:

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

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

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

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

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

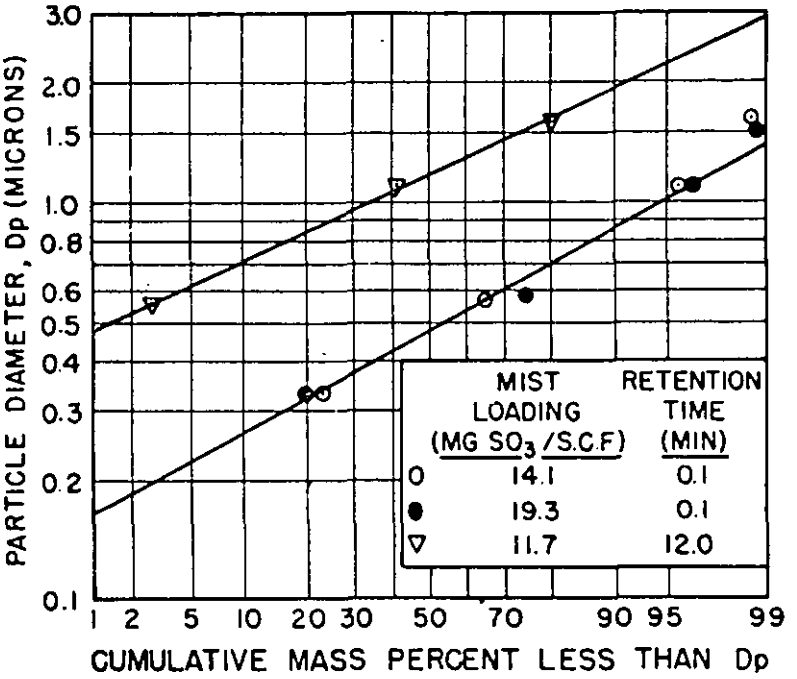


Figure 1. Cumulative particle size distribution of sulfuric acid mist generated in the laboratory is a function of mist loading and retention time

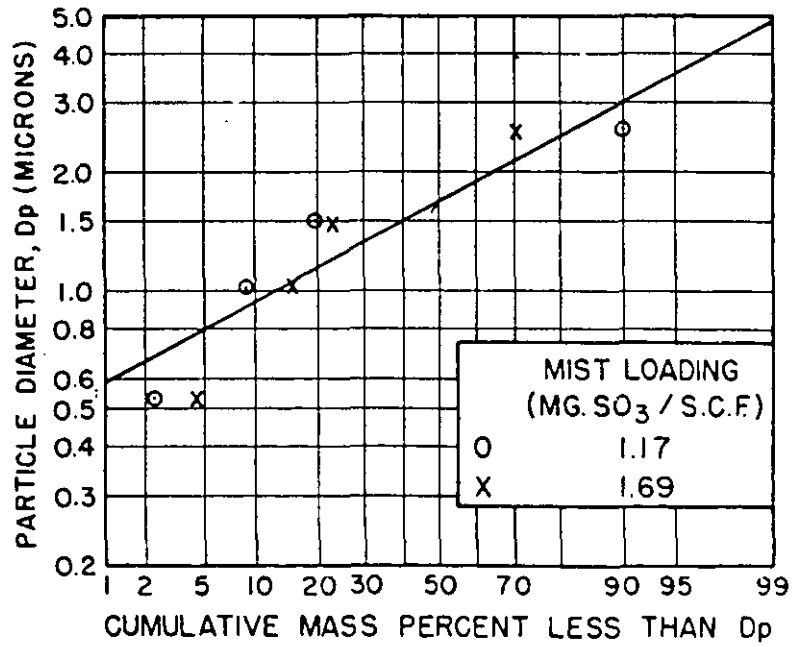


Figure 2. Cumulative particle size distribution of sulfuric acid plant aerosols

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 $\bar{v} = (10)^3 \sqrt{\frac{8 g_c P_2 (1.013)}{\pi \rho}}$

ψ = dimensionless inertial parameter, $= C\rho_p v_2 D_p^2/18\,\mu D_c$ (10)^3

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.)

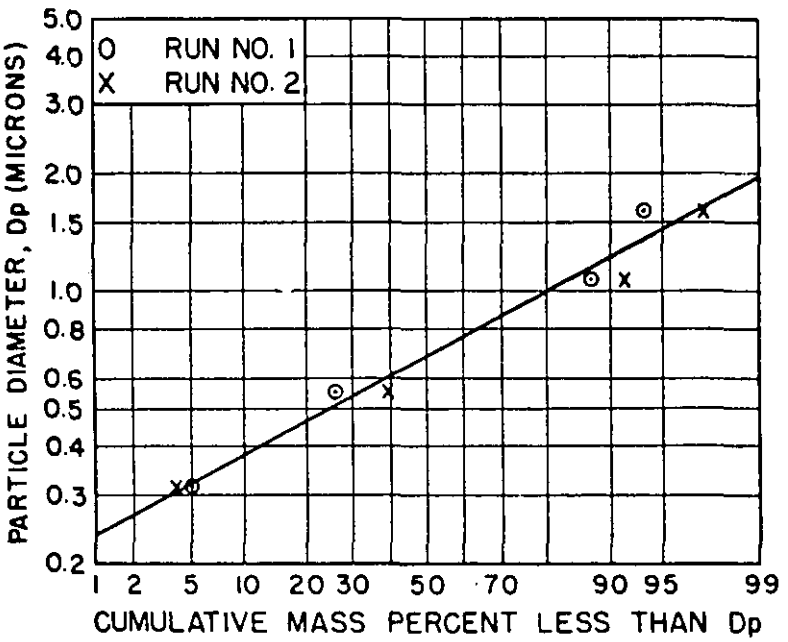


Figure 3. Distribution of phosphoric acid mist leaving typical plant can be used to control process. Analysis of aerosols under varying plant conditions aids in the selection of new equipment

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ACCEPTED August 14, 1957

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

APPENDIX H

PROJECT PARTICIPANTS

Project Participants

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Office of Air Quality Planning and Standards
Emission Standards and Engineering Division

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Patrick Hughes	Technician (Field Sampling)
Roger Etter	Technician (Field Sampling)
Francine A. Kulik	Research Chemist (Analysis)
Windle H. McDonald	Technician (Analysis)
Joan T. Hecathorn	Secretary