S00024

Title: —

Plant and Location: Inland Steel, East Chicago, IN

AP-42 Section 12.2
Reference
Report Sect. 4
Reference 122

SCC: 30300303

Test Date: 6/76

By Whom: —

(I think pages of text out of order – mJZ)

Encoded By:

Date Encoded:

Completed By:

Form No.:

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

April 14, 1977

OFFICE OF ENFORCEMENT

MEMORANDUM

Subject: Report entitled "Determination of Atmospheric Emissions During Coke Oven Pushing for Inland Steel Coke Plant 2, Battery 9, Calderon Experiment, Coke Quench in the Guide"

From: Bernard Bloom, Environmental Engineer BB
Technical Support Branch, DSSE (EN-341)

To: See Distribution

Please find the subject report attached for your information.

If you have any questions, please do not hesitate to contact me.

Attachment

Distribution:

Ken Eng - Region II
Tom Maslany - Region III
Bruce Miller - Region IV
Drew Trenholm - RTP

Inland Steel Company
Research Laboratories
3001 East Columbus Drive
East Chicago, Indiana 46312

Inland Steel

March 29, 1977

Mr. Bernie Bloom
EN-341
U.S. EPA
401 M Street, N.W.
Washington, D.C. 20460

Dear Bernie:

At your request, I am enclosing a copy of the report by Robert B. Jacko entitled "Determination of Atmospheric Emissions During Coke Oven Pushing for Inland Steel Coke Plant 2, Battery 9, Calderon Experiment, Coke Quench in the Guide." As I expressed to you at our meeting on March 17, 1977, we have many reservations concerning the data in this report, particularly with the representativeness of the emission rate and particle size distribution of the samples collected and with the statistical analysis. Therefore, we would not wish to be in the position of having to vouch for or defend the report. Nevertheless, as you know, some of this information has been used in evaluating the Calderon car. We would be very interested in any help you can give us in obtaining data from other sources, especially pushing (e.g., Donner Hanna) and quench tower (e.g., Lorain) emission data collected recently by the EPA. We would appreciate your letting us know when that information is available, and how we might obtain it.

We appreciated the opportunity of discussing the Calderon car with you and Larry, and are hopeful that we can find some way of proceeding with its development.

Very truly yours,

Norman A. Robins
Director
Process Research Division

NAR/kaw

cc: J.R. Brough
L.F. Kertcher (incl. att.)
R.G. Phelps

Plant No. 2 - Coke Plants
Calderon Experiment
Coke Quench in the Guide
P. O. KX 44723

TABLE of CONTENTS

Plant No. 2 - Coke Plants
Calderon Experiment
Coke Quench in the Guide
P. O. KX 44723

List of Figures

Page

List of Tables

Plant No. 2 - Coke Plants
Calderon Experiment
Coke Quench in the Guide
P.O. KX 44723

INTRODUCTION

Tests have been carried out at Inland Steel Coke Plant 2, Battery 9 for the determination of atmospheric emissions of gases and particulates during the coke oven pushing operation. This report covers pushes during which a "Calderon Quench in the Coke Guide" experiment was being conducted. In addition, 5 additional conventional pushes were sampled subsequent to the Calderon experiments on the same battery.

OBJECTIVE

The objective of these tests is to determine the atmospheric emissions of particulates, adsorbed hydrocarbons, gaseous hydrocarbons, sulfur oxides and CO, during coke oven pushing for "Calderon Quenches in the Guide" and conventional pushes.

FACILITY DESCRIPTION

These tests were performed at Inland Steel in East Chicago, Indiana on Coke Plant 2, Battery 9. The ovens are approximately 20 to 25 years old, manufactured by Koppers and accept a nominal 30,000 lb coal charge. The ovens are approximately 12 m long x 3.6 m high x 0.45 m wide and are arranged in a battery of approximately 100 parallel ovens.

During the Calderon experiment, oven numbers 93 and 95 were sampled during 5 pushes. Ovens 86, 88, 91, 93 and 95 were sampled during the conventional push portion of the test.

Typical coking time ranged from 16 hrs., 10 min. to 24 hrs., 39 min. for all 10 pushes. For subsequent calculations to determine the particulate mass emission factors (i.e., lb.-particulates/ton-coke-produced), a yield factor of 0.7 lb.-coke/lb.-coal charged was assumed for all 10 pushes.

SAMPLING METHODOLOGY

Since the pushing emissions are fugitive emissions, the problem of measuring the atmospheric emission rate is more complex than measurement of emissions in a confined stream such as a stack. The approach of the coke oven sampling was, nevertheless, analogous to the normal stack sampling approach. A representative sample of the particulate plume was taken for the duration of the push, while measurements of plume rise velocity and cross-sectional area were made. The data thus obtained were used to determine suspended particulate concentration and emission rate in much the same way as an EPA Method 5 stack sample.

Measurement of the suspended particulate concentration required that an isokinetic sample of the particulate be obtained, along with measurements of the gas flow rate through the sampler. Since it is useful to know the particulate concentration both at standard conditions and at the conditions in the plume, the temperature of the gas flowing through the sampler was measured in the plume and at the point of gas flow measurement.

A high volumetric sampling rate (≈ 35 CFM) was made necessary by the short sampling time available, relative to the several hours used in obtaining a standard stack sample.

The equipment used to obtain the measurements is shown schematically in Figures 1 and 2. Figure 1 shows a cross section through a typical by-product coke oven with the quench car and mobile sampling vehicle in position. The sampling head is positioned approximately 30 ft above grade slightly above the top of the coke guide. Depending on the existing wind direction and velocity, the sampling vehicle is located up to 3 or 4 ovens downwind of the one being pushed so that the sample nozzle is in the plume. Figure 2 shows the details of the sampling head, temperature and velocity sensors and instrumentation.

Samples were extracted by pulling push plume gas through a stainless steel sampling head, containing a 20 cm x 25 cm glass fiber filter. Each sampling nozzle is 5.1 cm in diameter.

The nozzle extends several cm into the filter housing in order to prevent fallout of any particulate which settles inside the housing. Flow through the sampling heads was monitored by measuring the pressure drop across a calibrated orifice in the blower outlet. The orifice temperature was monitored by a thermistor in the blower exhaust. Plume temperature was measured by two thermocouples located outside the sampling heads. The anemometer was chosen because

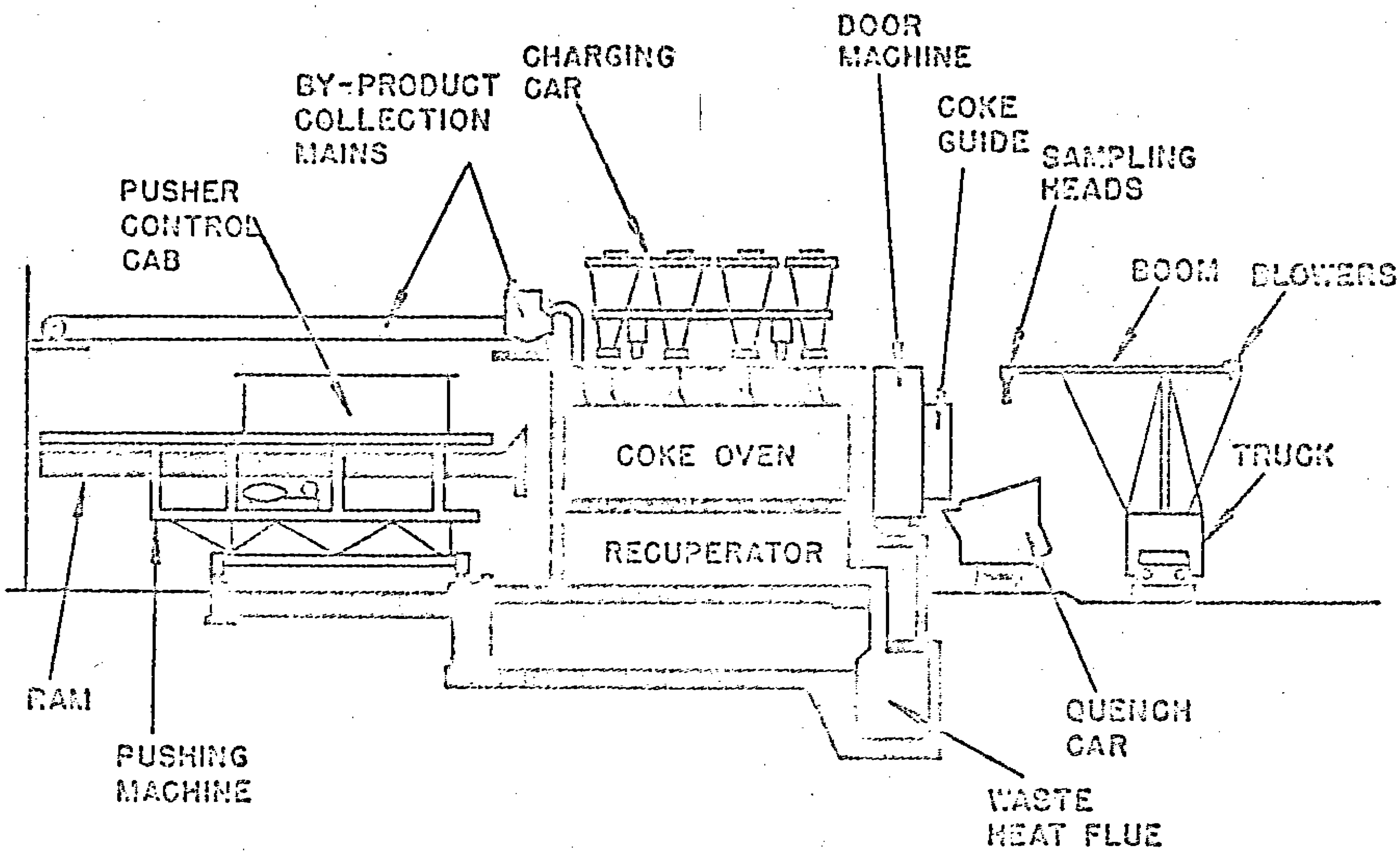

Figure 1 Cross section of coke oven battery, including sampling vehicle

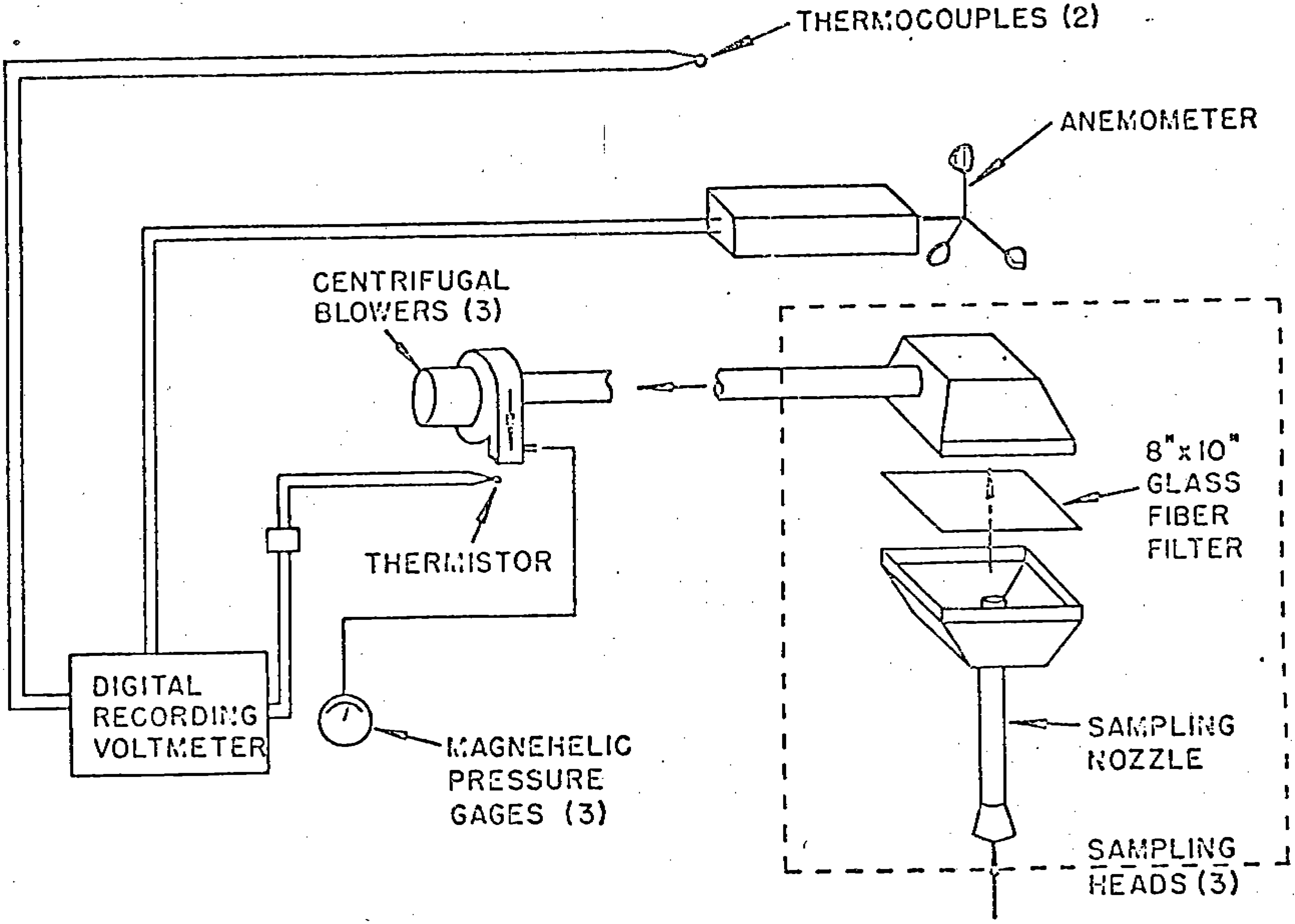

Figure 2 Schematic diagram of sampling heads and instruments used on coke oven sampling boom

the plume velocity is typically below the range for which pitot tubes are useful. Temperature and velocity signals were recorded continuously by an Esterline-Angus ® Model D-2020 multi-channel digital recording voltmeter.

Not shown in Figure 3 is the Andersen cascade impactor for determining particle size distribution in the push plume. The Andersen head was mounted in an insulated, heated oven adjacent to the 8" x 10" glass fiber filter sampling head. The Andersen head must be preheated to prevent moisture condensation during sample extraction.

In addition, three, 500 milli-liter glass gas sampling flasks were mounted downstream of the 8"x10" fiber filter for extraction of gas samples. The inlet to each of the stop-cocked flasks was fitted with a critical flow orifice sized such that when a vacuum of 26 in-Hg was pulled on the flask a gas sample would be drawn into the flask over the total push time. Also, each flask inlet was connected to a normally-closed solenoid actuated valve. At onset of sample extraction, the valves were energized allowing the gas sample to flow into the initially evacuated glass flasks. When the push was complete, the solenoid was de-energized thus sealing the sample within each flask. The flasks were then taken to the laboratory for subsequent gas analysis.

Thus during a push, five simultaneous samples were extracted.

1. Total particulate at a sampling rate of approximately 35 CFM on 8" x 10" glass fiber filter

2. Andersen sample for particle size distribution.

3. 500 ml gas sample for SO_x

4. 500 ml gas sample for CO, O_2, N_2, CO_2

5. 500 ml gas sample for total hydrocarbons as methane

The sampling hardware and instrumentation mentioned above were inserted in the plume by means of the boom and tower arrangement shown in Figure 3. The tower was raised from the horizontal by a winch and A-frame assmebly. The boom, which is hinged at the point of attachment to the tower, was then swung into position and held stationary by control cables.

PUSH PLUME CHARACTERIZATION

The plume cross-sectional area was obtained by measuring the plume diameter on 16 mm motion picture films taken during the sampling. For the present set of samples a circular plume cross-section was assumed for both Calderon and conventional pushes.

The 16 mm motion picture films were analyzed using a stop-action projector. The actual sampling time was determined by timing the sample with stop watches, excluding the time periods when the nozzle was not in the plume.

To account for differences between projector elapsed time when viewing the film and real time, the following equation was used.

$$t_r = t_{p,e} (r_p/r_c)$$

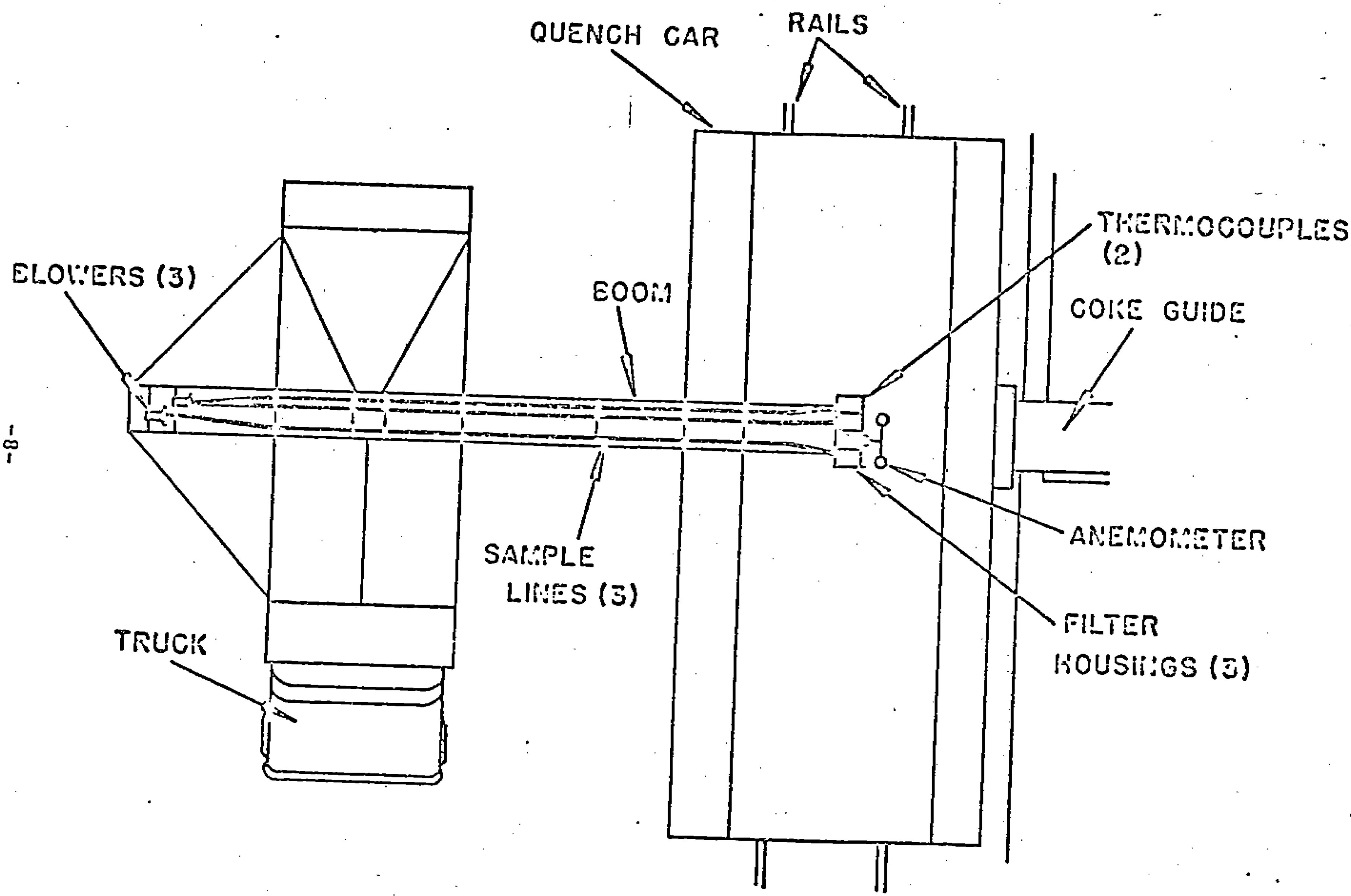

Figure 3 Top view of sampling vehicle and coke quench car

where t_r = real time for push duration (sec)

$t_{p,e}$ = projector elapsed time (sec)

r_p = projector frame rate (frames/sec) measured with frame counter on projector & stopwatch during projection of film

r_c = camera frame rate (frames/sec), calibrated to real time prior to using in field

Note that push time for the Calderon runs was the time the quench H_2O was flowing, not the time estimate from film analysis. (The H_2O flow time is less than film push time.)

The plume cross-sectional area (assumed circular) was averaged for the duration of each push by measuring the plume diameter every 8 frames (every 0.5 sec at 16 frames/sec). The linear measurements of the plume were calibrated for each push by measuring a known dimension on the sampling boom.

SAMPLE HANDLING AND ANALYSIS

At the completion of a push, the tower is lowered to the vicinity of the top of the sampling truck where the samples are retrieved.

Total Particulates

The stainless steel sampling head with nozzle and 8 x 10" glass fiber filter is removed as a unit to the laboratory environment inside the sampling vehicle. The predesiccated/ weighed filter is folded in half along its 8" diamension and placed in a paper envelope for subsequent post desiccation and weighing. A soxhlet benzene extraction was performed on aliquots of the filters for determination of adsorbed hydrocarbons.

Particulates remaining in the nozzle and transition were retrieved dry when possible and saved for subsequent soxhlet benzene extraction. To ensure retrieval of all particulates, the nozzle and transition were then backwashed with acetone and saved for subsequent gravimetric analysis.

Andersen Head

The particle size distribution sample is placed in a desiccator for subsequent gravimetric analysis

Gas Samples

Each 500 ml glass flask is retrieved for subsequent analysis. One of the three flasks was used with a length of stain detector tube to bracket gas concentrations. Both CO and SO_2 detector tubes were used. Where they were used is so indicated on the data tables.

Another flask was used for gas chromatography analysis for CO, CO_2, N_2 and O_2.

The third flask was used for total hydrocarbon analysis on a Beckman total carbon analyzer and wet chemical determination for SO_x.

RESULTS

Table 1 contains the results of both Calderon and conventional pushing plume particulate concentration. Note that the average particulate concentration for the five Calderon runs was 0.092 grains/SCF. The conventional push concentration was 0.538 grains/SCF which is greater than the Calderon push.

Plant No. 2 - Coke Plants
Calderon Experiment
Coke Quench in the Guide

P. O. KX 44723

TP PM 10 SO2 CO HC

Table 1. Calderon and Raw Push Particulate Concentrations

Sample No.	Date 1976	Inland Oven No.	8x10 filter wt. gain grams	Nozzle Backwash grams	Total Partic. Catch grams	Sample Volume Flow Rate, SCFM	Sample Time Min. Calderon (H_2O only)	Particulate Concentra. grains/SCF (grains/ACF)
				CALDERON PUSHES				
67	6/7	93	0.2115	0.3016	0.5131	30.0	2.52	0.105 (0.083)
68	6/8	95	0.0863	0.1401	0.2264	39.1	2.87	0.031 (0.026)
69	6/8	93	0.0840	0.8408	0.9248	28.9	1.92	0.257 (0.205)
70	6/9	95	0.0775	0.1324	0.2099	31.3	2.95	0.035 (0.028)
71	6/9	93	0.0531	0.0947	0.1478	31.9	2.23	0.032 (0.026)
						s = 0.097	cv=105%	Avg. 0.092, (0.074)
				CONVENTIONAL PUSHES			from films	
72[a]	6/10	95	0.0595	0.3430	0.4025	47.5	0.42	0.311 (0.274)
73[a]	6/10	86	0.1586	0.3232	0.4818	49.9	0.47	0.317 (0.277)
74[a]	6/10	93	0.1478	0.3065	0.4543	47.8	0.41	0.358 (0.303)
75[b]	6/10	88	0.1040	0.1140	0.2180	52.3	0.43	0.150 (0.134)
76[c]	6/11	91	0.3381	1.0537	1.3918	40.7	0.34	1.552 (1.357)
								Avg. 0.538 (0.469)
							s =	0.57
							cv =	106%

[a] clean; [b] clean/green; [c] green

s sample standard deviation

cv is coefficient of variation, s/avg.

DETERMINATION OF ATMOSPHERIC EMISSIONS DURING COKE OVEN PUSHING

for

INLAND STEEL COKE PLANT 2, BATTERY 9

CALDERON EXPERIMENT

COKE QUENCH IN THE GUIDE

by

Robert B. Jacko, Ph.D., P.E.
Environmental Engineering Consultant
W. Lafayette, Indiana 47906

Test Dates
June 8 through 11, 1976

Report Date
July 22, 1976

The total particulate mass emission rate (mer) is also of interest and these values are given in Table 2. Note that the conventional push tests had an average mer of 0.642 lb/sec as compared to the Calderon test average of 0.079 lb/sec. The mer of total particulates for the Calderon pushes is approximately 1/8 that of the conventional pushes. However, the particulate concentration and emission rate are not necessarily the most meaningful parameters for determining if there indeed is a difference between these two types of pushes. Table 3 contains a parameter called an emission factor and indicates the total particulate released to the atmosphere per ton of coke produced. Refer to last column in Table 3. Using this emission factor, therefore, takes into account other factors such as push time and coke produced. For example, even though the particulate concentration and rate of particulate emission of the Calderon pushes is much lower than a conventional push, the pushing time of the Calderon quench is on the average 5 times longer than a conventional push. Referring to Table 3, it is seen that the Calderon average emission factor is 0.91 lb-part./ton-coke and compares to the conventional push emission factor of 1.60 lb-part/ton-coke. Apparently, the Calderon push results in less total particulates released to the atmosphere. However, note the relatively large coefficient of variation (cv) of the Calderon pushes. The cv is a measure of the scatter of the sample distribution and numerically is the standard deviation divided by the mean ($s/\bar{x}$).

Plant No. 2 - Coke Plants
Calderon Experiment
Coke Quench in the Guide
P.O. KX 44723

Table 2. Calderon and Raw Push Particulate Mass Emission Rates

Sample No.	Date (1976)	Inland Oven No.	Coking Time hrs:min	Plume Temp. F	Plume Velocity ft/sec	Cross-sectional Area (ft^2)	Push Time (sec) H_2O Only	Particulate Mass Emiss Rate lb/sec
				CALDERON PUSHES				
67	6/7	93	17:10	207	14.8	556	151	0.098
68	6/8	95	16:42	167	10.0	495	172	0.018
69	6/8	93	23:25	203	19.9	380	115	0.221
70	6/9	95	22:11	195	15.6	363	177	0.023
71	6/9	93	23:23	181	16.1	573	134	0.034
							Avg.	0.079
				CONVENTIONAL PUSHES				
							from films	
72	6/10	95	24:39	141	22.8	661	30.3	0.590
73	6/10	86	19:30	146*	11.9**	735	31.1	0.346
74	6/10	93	24:06	165	18.8	819	31.8	0.666
75	6/10	88	16:30	132	21.7	1232	29.7	0.512
76	6/11	91	20:15	146*	15.0**	377	23.7	1.096
							Avg.	0.642

* avg. of samples 72, 74, 75
** from film analysis not anemometer

Plant No. 2 - Coke Plants
Calderon Experiment
Coke Quench in the Guide
P. O. KX 44723

Table 3. Calderon and Raw Push Emission Factors

Sample No.	Date 1976	Inland Oven No.	Coal Charge lbs.	Coke[1] Produced tons	Total Particulate Mass into Atmos., lbs		Emission Factor lb.-part./ton-coke
			CALDERON PUSHES				
67	6/7	93	32,500	11.38	14.80		1.30
68	6/8	95	32,500	11.38	3.10		0.27
69	6/8	93	32,500	11.38	25.42		2.23
70	6/9	95	32,500	11.38	4.07		0.36
71	6/9	93	32,500	11.38	4.56		0.40
						Avg.	0.91, s = 0.85, cv = 93%
			CONVENTIONAL PUSHES				
72	6/10	95	32,500	11.38	17.88		1.57
73	6/10	86	32,500	11.38	10.76		0.95
74	6/10	93	32,500	11.38	21.18		1.86
75	6/10	88	32,500	11.38	15.21		1.34
76	6/11	91	32,400	11.34	25.96		2.29
						Avg.	1.60 s = 0.51, cv = 32%

[1] assumes 1.0 lb-coal yields 0.7 lb coke

s sample standard deviation

cv is coefficient of variation, s/avg.

Therefore, a conclusion as to which type of push results in less particulate released to the atmosphere cannot be made only by observation of these two mean values. A series of statistical tests should be applied.

Calderon vs. Conventional Push Statistical Tests

The test to be applied to the sample population of both the Calderon pushes and the conventional pushes involves a test to determine if the difference between each respective sample mean is significant or whether it may be attributed to chance. The test is called the "paired sample t test" and assumes all samples came from a normal population and that the sample variances are equal. Before proceeding with the "t" test it is desireable to determine if the sample variances are equal using an "F" test. The following text covers these tests.[1]

A Calderon Push Emission Factors	Difference	B Conventional Push Emission Factors
1.30	+0.27	1.57
0.27	+0.68	0.95
2.23	-0.37	1.86
0.36	+0.98	1.34
0.40	+1.89	2.29
$\bar{x}_A = 0.910$	$\Delta\bar{x} = 0.838$	$\bar{x}_B = 1.60$
$s = 0.850$		$s = 0.510$
$s_A^2 = 0.717$		$s_B^2 = 0.260$

$$F = \frac{s_A^2}{s_B^2} = \frac{0.717}{0.260} = 2.76$$

Null Hypothesis $\sigma_A^2 = \sigma_B^2$

Alt. Hypothesis $\sigma_A^2 \neq \sigma_B^2$

$$F_{.01}\ (4,4) = 16$$

since 2.76 << 16, null hypotheses accepted, and the variances are equal. Therefore, it is now acceptable to use Paired Sample t test

$$t = \frac{\Delta\bar{x} \quad \text{(i.e., mean of difference)}}{s/\sqrt{n}}$$

Null Hypothesis $\mu_A - \mu_B = 0$

Alt. Hypothesis $\mu_A - \mu_B \neq 0$

$\Delta\bar{x} = 0.838$

$s = 0.651$

$n = 5$

ν (degress of freedom) = n-1 = 4

Substituting: $t = \dfrac{0.838}{0.651/\sqrt{5}} = 2.88$

From Area Table, two tailed test ($\nu = 4$)

@ $t_{.05/2}$ $> +2.776$
< -2.776

Therefore, t statistic large enough at 2.88 to reject null hypothesis. Therefore, there appears to be a statistically significant difference between Calderon and Conventional tests.

If one throws out the high Calderon Value:

1.30
0.27
~~2.23~~
0.36
0.40

Plant No. 2 - Coke Plants
Calderon Experiment
Coke Quench in the Guide
P.O. KX 44723

$\bar{x} = 0.583, \; s = 0.48 \; s_A^2 = 0.232$

Since n is now different use Smith Satterthwaite Test:

$$t = \frac{\bar{x}_A - \bar{x}_B}{\sqrt{\frac{S_A^2}{n_1} + \frac{S_B^2}{n_2}}}$$

$$t = \frac{(1.602 - 0.583)}{\sqrt{\frac{0.232}{4} + \frac{0.390}{5}}} = 2.762$$

Null Hyp, H_o : $\mu_A - \mu_B = 0$

Alt. Hyp, H_1 $\mu_A - \mu_B \neq 0$

From area table, two tailed test with ν =

$$= \frac{\left(\frac{s_A^2}{n_A} + \frac{s_B^2}{n_B}\right)^2}{\frac{(s_A^2/n_A)^2}{n_A - 1} + \frac{(s_B^2/n_B)^2}{n_B - 1}} = \frac{\left(\frac{.232}{4} + \frac{.390}{5}\right)^2}{\frac{\left(\frac{.232}{4}\right)^2}{3} + \frac{\left(\frac{.390}{5}\right)^2}{4}}$$

$$\nu = \frac{0.0185}{0.00112 + 0.00152} = \frac{0.0185}{0.00264} = 7$$

$$t_{.05/2} \; (\nu = 7) \; \begin{matrix} > 2.365 \\ < 2.365 \end{matrix}$$

Therefore, t statistic is large enough to reject null hypothesis and Calderon test is significantly different from Conventional Pushes.

Battery 6 Measurements

Extensive tests have been performed previously on the coke ovens in Battery 6, of Coke Plant 2, Jacko[2]. The fifteen conventional pushes reported in reference 2 result in the following:

	lb-part/ton-coke
Clean pushes	1.2
Green push	3.3
Overall	2.1
AP - 42	0.9

AP-42 is an EPA document listing factors as best known some years ago and is shown here as a comparison only.

The overall value of 2.1 compares to 1.6 lb-part/ton-coke from the 5 conventional pushes being reported here and is within reasonably close agreement. The 1.6 value certainly falls within the clean and green push averages shown above. Therefore, it can be said that a relatively high degree of confidence can be placed on the emission factors for the 5 conventional pushes reported in Table 3 of this report.

Particle Size Distribution

Figure 4 contains the aerodynamic particle size distribution data from the 5 Calderon pushes. The cumulative frequency distribution is not a lognormal function as would have been indicated by a straight line fit to the data.

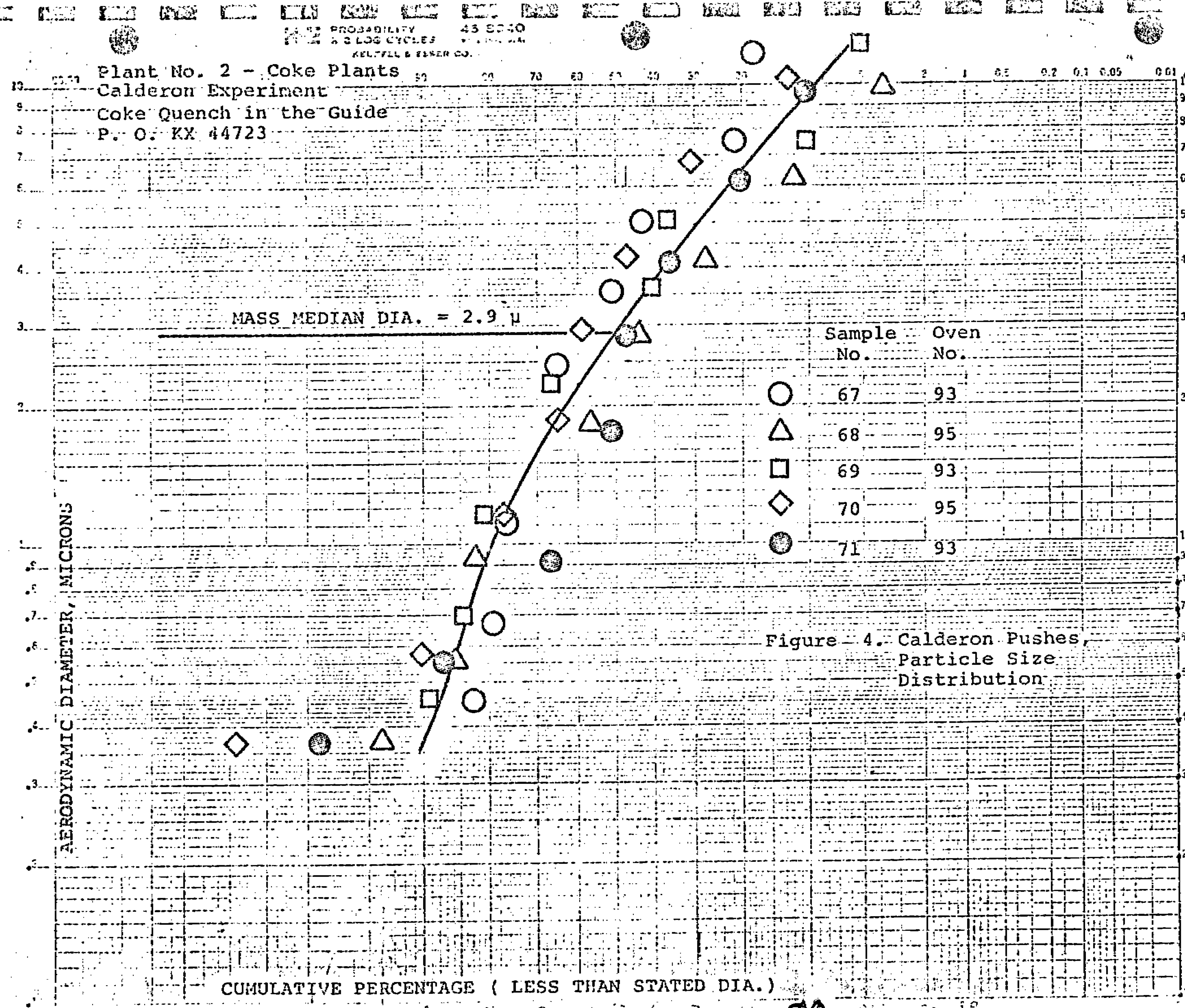

Figure 4. Calderon Pushes, Particle Size Distribution

90

However, the more important point to be made regarding the distribution is that the mass median diameter is 2.9 microns. Figure 5 contains the aerodynamic size distribution from three of the five conventional pushes (only 3 measurements were made). Note the mass median diameter is 3.1 microns and when compared to the Calderon push size distribution is not significantly different. Both Caleron and conventional pushes appear to release particles to the atmosphere which are not markedly different in aerodynamic size as far as the suspended particulate matter is concerned.

Gas Measurements

Table 4 contains the results of the gas analysis for N_2, O_2, CO, SO_x and total hydrocarbons as CO_2 + CH_4. Note that the CO and SO_x (SO_2 & SO_3) are relatively insignificant for both the Calderon and the conventional pushes. Difficulty with the gas chromatographic analysis for CO_2 resulted in not being able to separate out the CO_2 from the total hydrocarbons expressed as CH_4. Therefore, total hydrocarbons are expressed as CO_2 + HC as CH_4. There is not a great deal of difference between the Calderon and conventional pushes as far as CO_2 + HC is concerned. The higher CO_2 + HC concentration for the Calderon push may be due to a water gas reaction.

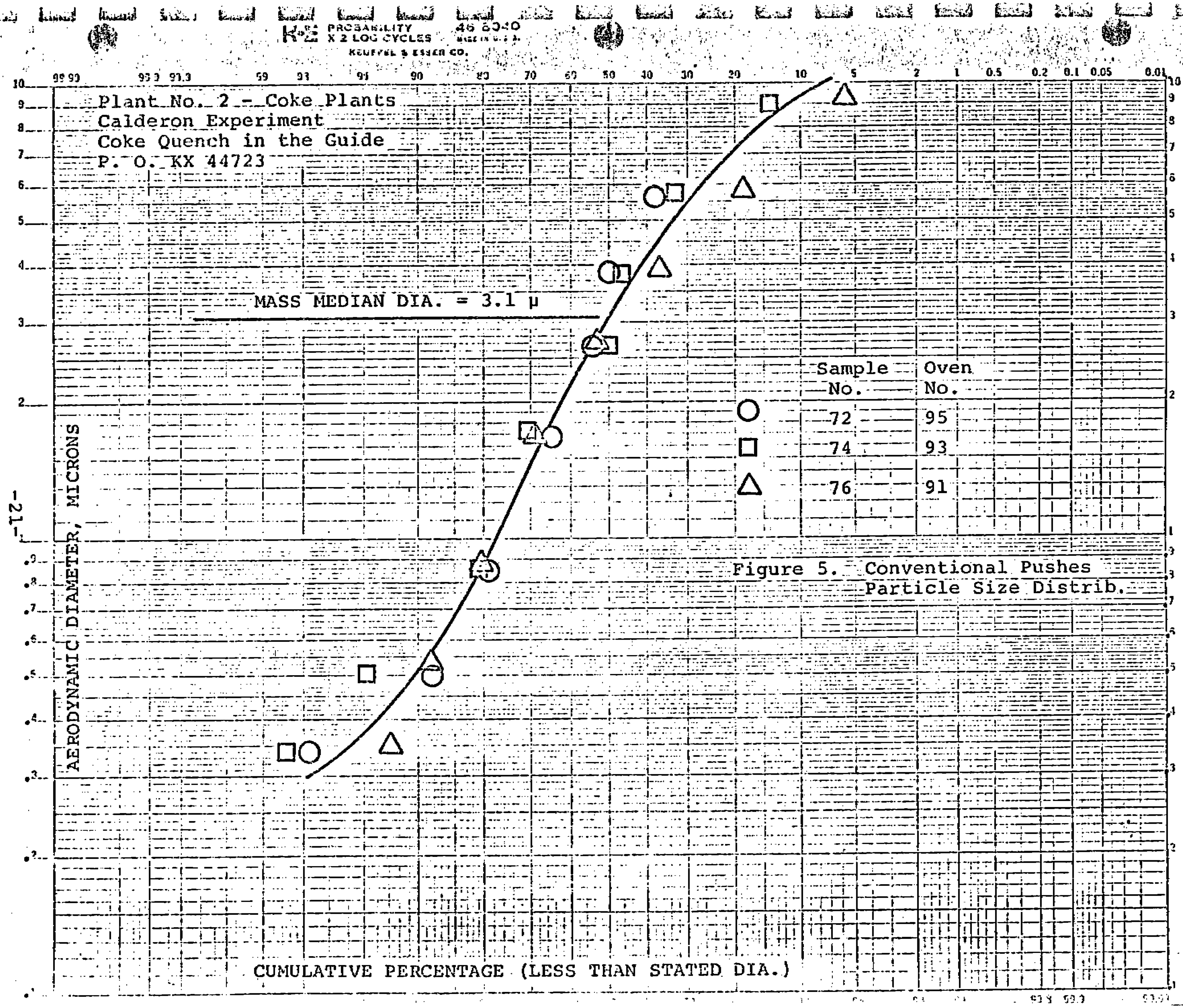

Figure 5. Conventional Pushes Particle Size Distrib.

Table 4. Calderon and Raw Push Gas Analysis

Sample No.	Date 1976	Inland Oven No.	N_2 (1) %	O_2 (1) %	CO (2) (1) PPM	SO_x (3) SO_2+SO_3 PPM	Total (4) Carbon PPM (as CH_4) CO_2 (1) +CO+HC	CO_2+HC (as CH_4) PPM
				CALDERON PUSHES				
67	6/7	93	78.5	21.3	25	27	500	475
68	6/8	95	77.9	21.8	100	381	350	250
69	6/8	93	81.2	18.5	15	25	530	515
70	6/9	95	79.2	20.5	<25	N.D.	760	735
71	6/9	93	78.9	20.8	<25	27	660	635
				AVG.	38	115	560	522
				CONVENTIONAL PUSHES				
72	6/10	95	79.0	20.8	25	27	400	375
73	6/10	86	-	-	-	-	-	-
74	6/10	93	78.1	21.6	<25	27	270	245
75	6/10	88	-	-	-	-	-	-
76	6/11	91	78.9	20.9	<25	27	630	605
				AVG.	25	27	433	408

(1) Analysis by Gas Chromotography

(2) Analysis by length of stain detector tube

(3) Analysis by wet chemical method (similar to EPA method 6)

(4) Analysis by total carbon analyzer

Soxhlet Benzene Extractions

Table 5 contains the results of a benzene soxhlet extraction performed on the dry portion of the backwash particulate and an aliquot of the 8 x 10'' glass fiber filter. Note that the total organic fraction for the Calderon pushes was 6% as compared to 2.1% for the conventional pushes. However, a direct comparison of these two figures would again be misleading and the emission factor is the number which should be compared. The last column in Table 5 indicates an average organic emission factor of 0.038 lb-organics/lb-coke for the Calderon pushes as compared to 0.031 lb-organics/lb-coke for the conventional pushes. The numbers appear to be approximately the same since the difference between them is well within experimental error. Therefore, the Calderon and conventional push plumes do not appear to be different in terms of adsorbed organic emissions.

SUMMARY

Throughout this report a comparison has been made between the Calderon quench push and conventional byproduct coke oven pushing emissions. It must be kept in mind that the conventional push discussed in this report is not the total emission to the atmosphere when one considers the transport time and the emissions of the quench tower. In other words, for a fair comparison of the Calderon air pollution emissions, the emissions from transporting the coke after a conventional push to the quench tower and the quench tower emissions should be added to the conventional push plume emissions reported in

Plant No. 2 - Coke Plants
Calderon Experiment
Coke Quench in the Guide
P. O. KX 44723

Table 5. Particulate Adsorbed Hydrocarbons

Sample No.	Date 1976	Oven No.	Total Particulate Catch (grams)	Total* Organic Wt. (grams)	Total Organic Fraction (%)	Organic Emission Factor lb. organics/lb-coke
			CALDERON PUSHES			
67	6/7	93	0.5131	0.0288	5.61	0.073
68	6/8	95	0.2264	0.0152	6.71	0.018
69	6/8	93	0.9248	0.0148	1.60	0.036
70	6/9	95	0.2099	0.0106	5.05	0.018
71	6/9	93	0.1478	0.0161	10.89	0.043
				AVG.	6.0	AVG. 0.038
			CONVENTIONAL PUSHES			
72	6/10	95	0.4025	0.0074	1.84	0.029
73	6/10	86	0.4818	0.0068	1.41	0.013
74	6/10	93	0.4543	0.0082	1.80	0.033
75	6/10	88	0.2180	0.0111	5.09	0.068
76	6/11	91	1.3918	0.0087	0.62	0.014
				AVG.	2.1	AVG. 0.031

*backwash and filter

this report. The Calderon by its very nature includes the quench emissions and of course has no transport time emissions to a quench tower.

No copious data exists for conventional push emissions during transport to the quench tower or for the quench tower emissions. Kaiser Engineers have performed emission tests on quench towers and once these tests have been surveyed to see if they are comparable to the emissions which could be expected from the Inland towers, then that value should be added to the conventional push emissions reported here.

This report has shown that although particulate concentration and mass emission rate for Calderon pushes are substantially lower than conventional pushes, the important perameter to consider is the emission factor. Applying statistical tests to the emission factors and examining the mean of the difference between the Calderon and conventional push has resulted in the determination that the Calderon push has a statistically significant lower emission factor. Moreover, if the push time of the Calderon unit could be reduced with no loss in scrubbing efficiency then this technique appears to be even more viable than reported here.

REFERENCES

1. Miller, I. and Freund, J. "Probability and Statistics for Engineers", Prentice Hall, 1965.

2. Jacko, R.B. et.al, "The By-Product Coke Oven Pushing Operation: Total and Trace Metal Particulate Emissions", Presented at the 69th Annual Meeting of the Air Pollution Control Assn., Portland, Ore., June 27-July 1, 1976.

APPENDIX

ORIGINAL DATA

Plant No. 2
Calderon Experiment
Coke Quench in the [illegible]
P.O. KY44723

Particle Size Data from Andersen Sampler

Sample #67 flow = 0.81 ACFM

Stage	wt. gain grams	wt. %	Cum. %	ECD (microns)
0	0.0055	18.27	81.73	11.80
1	.0010	3.32	78.41	7.45
2	.0066	21.93	56.48	5.0
3	.0022	7.31	49.17	3.55
4	.0044	14.62	34.55	2.44
5	.0033	10.96	23.59	1.11
6	.0010	3.32	20.27	0.675
7	.0009	2.99	17.23	0.455
Back up filter	.0052	17.28		
total	0.0301			

Sample #68 flow = 1.10 ACFM

stage				
0	.0010	3.77	96.23	9.95
1	.0021	7.92	88.31	6.21
2	.0042	15.85	72.46	4.17
3	.0044	16.60	55.86	2.89
4	.0033	12.45	43.41	1.82
5	.0066	24.91	18.50	0.94
6	.0011	4.15	14.35	0.56
7	.0022	8.30	6.05	0.37
Back up filter	.0016	6.04		
total	0.0265			

Sample #69 flow = 0.77 ACFM

0	.0011	5.19	94.81	12.1
1	.0011	5.19	89.62	7.59
2	.0055	25.94	63.68	5.06
3	.0010	4.72	58.96	3.63
4	.0054	25.47	33.49	2.26
5	.0031	14.62	18.87	1.16
6	.0007	3.50	15.57	0.70
7	.0010	4.72	10.85	0.46
BACK UP FILTER	.0023	10.85		
total	0.0212			

Plant No. 2
Calderon Experiment
Coke Quench in the Guide
P.O. XX 44723

Particle Size Data from Andersen Sampler

(2)

Sample #70 flow = 1.05 ACFM

Stage	wt. gain grams	wt. %	Cum.%	ECD (micron)
0	.0044	12.46	87.54	10.20
1	.0066	18.70	68.84	6.43
2	.0055	15.58	53.26	4.27
3	.0044	12.46	40.80	2.94
4	.0021	5.95	34.85	1.86
5	.0044	12.46	22.39	1.14
6	.0044	12.46	9.93	0.58
7	.0033	9.35	0.58	0.38
Back up filter	.0002	0.57		
total	0.0353			

Sample #71 flow = 1.14 ACFM

Stage	wt. gain grams	wt. %	Cum.%	ECD (micron)
0	.0022	10.28	89.72	9.72
1	.0022	10.28	79.44	6.16
2	.0033	15.42	64.02	4.10
3	.0022	10.28	53.74	2.81
4	.0011	5.14	48.60	1.77
5	.0033	15.42	33.18	0.92
6	.0044	20.56	12.62	0.55
7	.0022	10.28	2.34	0.37
Back up FILTER	.0005	2.34		
total	0.0214			

Sample #72 flow = 1.25 ACFM

Stage	wt. gain grams	wt. %	Cum.%	ECD (micron)
0	.0033	14.29	85.71	9.03
1	.0055	23.81	61.90	5.07
2	.0027	11.69	50.21	3.83
3	.0010	4.33	45.88	2.63
4	.0024	10.39	35.49	1.66
5	.0033	14.29	21.20	0.85
6	.0022	9.52	11.68	0.50
7	.0022	9.52	2.16	0.34
Back up filter	.0005	2.16		
total	0.0231			