EPA-340/1-77-014a
August 1977

Stationary Source Enforcement Series

SOURCE TESTING OF A STATIONARY COKE-SIDE ENCLOSURE

GREAT LAKES CARBON CORPORATION ST. LOUIS, MISSOURI PLANT

VOLUME I

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Enforcement
Office of General Enforcement
Washington, D.C. 20460

STUDY OF COKE-SIDE COKE-OVEN EMISSIONS

(Volume 1 of 3)

Great Lakes Carbon Corporation
St. Louis, Missouri

Contract No. 68-02-4108
Task No. 14

Prepared for:

Technical Support Branch
Division of Stationary Source Enforcement
U.S. Environmental Protection Agency
Washington, D.C. 20460

Prepared by:

Clayton Environmental Consultants, Inc.
25711 Southfield Road
Southfield, Michigan 48075

August 31, 1977

DISCLAIMER

This report was furnished to the Environmental Protection Agency by Clayton Environmental Consultants, Inc. in fulfillment of Contract No. 68-02-1408, Task Order No. 14. The contents of this report are reproduced herein as received from the contractor. The opinions, findings, and conclusions expressed are those of the authors and not necessarily those of the Environmental Protection Agency.

ACKNOWLEDGEMENTS

This report was prepared under the direction of Mr. John Mutchler with the assistance of principal authors Thomas Loch, Fred Cooper, and Janet Vecchio of Clayton Environmental Consultants, Inc. The Project Officer for the U.S. Environmental Protection Agency was Mr. Kirk Foster. The authors are grateful to Mr. Foster for his recommendations, comments, and review throughout the execution and report-development phases of the study. The authors also appreciate the valuable contributions of Bernard Bloom and Louis Paley of EPA to this project. Finally, the assistance of individuals from the following offices at the field-study site is very gratefully acknowledged: the management of Great Lakes Carbon Corporation, St. Louis, Missouri; the City of St. Louis Division of Air Pollution Control; and the Region VII Enforcement Division (Kansas City, Missouri), the Region V Surveillance and Analysis Division (Chicago, Illinois), and the National Environmental Investigation Center (Denver, Colorado) of the Environmental Protection Agency.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY OF TERMS

1. Atypical operating conditions

   Extremely infrequent major process change (or upset).

2. Average rate of coke-side particulate emissions

   The sum of the particulate emissions captured by the shed and the emissions which are fugitive from the shed.

3. Coke side

   That side of a coke-oven battery from which the ovens are emptied of coke.

4. Degree of greenness of a coke oven push

   A subjective, visual estimate of the quantity of particulate matter released during a single coke oven push by estimation of the apparent visibility of the plum immediately above the quench car.

5. Door leakage

   Any visible emissions observed emanating from coke-side oven doors, push-side oven doors, or push-side chuck doors.

6. Filterable particulate

   Material captured on or before the front filter of a particulate sampling train.

7. Fugitive particulate emissions

   Particulate emissions which escape capture from the shed and pass unrestrained into the atmosphere.

8. Green coke

   Coke which, when pushed from an oven, produces copious quantities of visible emissions, particulate matter, and/or flame on the coke side of the battery.

9. Net coking time

   The elapsed time in minutes between the charging of a coke oven with coal and the pushing of that same oven.

10. Non-pushing cycle

That portion of the repetitive coke pushing operation outside the pushing cycle. This period includes the time during which no push has occurred beneath the shed (A Battery) for 30 minutes. (During this period coke ovens on the C Battery were normally being pushed.)

11. Precision of a test result

The statistical confidence interval associated with the mean value of a series of replicate measurements at a risk level of five percent.

12. Pushing cycle

That portion of the coke pushing operation during which ovens beneath the shed (A Battery) were being pushed at a regular interval of approximately one oven every 23 minutes up to 30 minutes beyond the time of the most recent push.

13. Settleable particulate

That material collected in a cylinder whose height is two to three times its diameter and which passes through a No. 18 (1 mm) sieve, ASTM Method 1739-70.

14. Total particulate

Filterable particulate plus that material captured in impingers containing distilled water immediately following the filter in the sampling train.

15. Transmissometer

A device, utilizing a light source and a light detection circuit, which provides a measurement of the transmittance of stack gas passing between the light source and the detector.

16. Typical operating conditions

Any process operating conditions which are not atypical.

1.0 INTRODUCTION

1.1 Background

The Division of Stationary Source Enforcement, United States Environmental Protection Agency (EPA) retained Clayton Environmental Consultants, Inc. to conduct a study of coke-side emissions at coke-oven batteries producing foundry coke at Great Lakes Carbon Corporation (GLC) in St. Louis, Missouri. One of three batteries of GLC was equipped with a shed-type enclosure designed to contain particulate and gaseous emissions produced on the coke side of the battery during coking and coke pushing. An induced draft fan exhausts the shed enclosure through ductwork to the quench tower for discharge to the atmosphere. At the time of the study, no control device other than improvised spray headers in the ductwork and quench tower was included in the control system. to abate emissions in the shed exhaust gas.

Foundry coke is produced by three batteries of ovens at the GLC plant. The south battery ("A") is equipped with the coke-side shed. The center battery ("B") and north battery ("C") were not equipped with a functional shed at the time of the study. During this study, B Battery was being rebuilt; only the 40-oven A Battery and 35-oven C Battery operated during the testing program. All three coke batteries at GLC are similar in construction, capacity, and operation. Furthermore, all three are served by a single work crew using a single set of charging equipment and a single quench car.

At the time of the study, construction of a shed over the B and C Batteries was in progress. Nevertheless, coke-side emissions from C-Battery ovens escaped directly to the atmosphere and

were not captured by the shed, nor did they affect results of the sampling in the exit gases of the A-Battery shed.

Exhaust gas sampling was conducted primarily in the A-Battery shed exhaust duct using EPA standard source testing methods, or similar methods modified to suit this particular source, to measure particulate and gaseous emissions during the test program. Additionally, the particulate emissions from the coke side of the coke-oven battery which escaped capture by the shed were measured. Process operating conditions were monitored to assure the collection of representative samples with respect to "typical" operating conditions. The source testing results were correlated with process data and other, secondary observational data auxiliary to the emission measurements. The results of the field study and analysis of the data are presented in Volume 1, while all raw data and background data are provided in Volumes 2 and 3.

The field study was conducted during the week of April 21, 1975 by the staff of Clayton Environmental Consultants. Messrs. Kirk Foster, Louis Paley, and Bernard Bloom of the Division of Stationary Source Enforcement, U.S. EPA, and Messrs. Edward Roe and George Shell of Great Lakes Carbon Corporation provided coordination with the plant operation. A listing of project participants and their respective roles in the study is included in Appendix A (Volume 2).

1.2 Purpose and Scope

The purpose of this study was to provide basic engineering data concerning the quantities and characteristics of air-contaminants emitted from the coke side of the A-Battery coke ovens,

and further, to evaluate the performance of the shed in capturing coke-side emissions.

The scope of the study included the measurement of emissions from the A-Battery shed and the monitoring of process parameters which may affect or be related to emission rates. In addition to the emission tests, dustfall measurements were collected beneath the shed and in similar locations near the ovens of the nearby unshedded C-Battery. Additional emission parameters were monitored by EPA personnel, including the "degree-of-greenness" of each push beneath the shed during sampling, visual opacity of the quench tower exit gases (the ultimate point of discharge to the atmosphere from the coke-side shed), and optical density, measured with a transmissometer installed temporarily on the exhaust gas duct and located between the shed and the quench tower.

The EPA emission testing program focused primarily on the measurement of gaseous and particulate emission rates, and characterization of the chemical species and size distribution of particulate contaminants in the duct exhausting the emissions from the shed capture system. Measured contaminants included:

1. Particulate during the coke pushing cycle;
2. Particulate during the non-pushing cycle;
3. Particle size distribution during the pushing cycle;
4. Sulfur dioxide;
5. Sulfur trioxide;
6. Polynuclear aromatic hydrocarbons;
7. Carbon monoxide;
8. Gaseous hydrocarbons; and
9. Phenolics.

1.3 Limitations

This comprehensive emission study was neither intented nor designed to include an evaluation of the effect of the coke-side shed on the occupational environment. With the exception of the dustfall measurements collected beneath the shed, the study effort dealt mainly with the quantity and characteristics of contaminator present in the shed exhaust. Thus, any definitive evaluation of related occupational exposure within this or any coke-side shed would be supplementary to the study reported herein.

2.0 SUMMARY AND CONCLUSIONS

To fulfill the purpose of this study, and therefore provide basic engineering data concerning process emissions, fugitive emissions from the shed, and capture efficiency of the shed, the measured findings in the study and the field data have been analyzed with respect to emission factors and emission rates attributable to: pushing and non-pushing cycles, fugitive particulate emissions, door leaks, and the overall pushing operation. Determination of these emission data required estimation and calculation of the shed's capture efficiency for filterable particulate emissions. Additionally, other basic engineering data necessary for the specification of (future) retrofitted collectors installed on the shed exhaust were collected and included the measurement of particulate emissions composition, particle size distribution, and the determination of exhaust stream composition as affected by other species of contaminants detected in the shed exhaust. Finally, in an attempt to relate these measurements to process conditions and thereby enable cautious application of these results to other coke-oven batteries, correlations were attempted between various process parameters and the computed emission factors.

2.1 Particulate Emission Factors and Rates

2.1.1 In-Duct Emissions During Pushing Cycle

Filterable particulate emission measurements made in the duct evacuating the shed during the time when ovens were pushed beneath the shed indicated that the average emission factor is 0.38 pound per ton of dry coal charged to the ovens pushed (±0.24 pound per ton).* The corresponding average emission rate during the time when pushing of ovens was occurring beneath the shed indicated that an average of 16.7 pounds per hour (±8.8 pounds per hour) of filterable particulate were emitted. These estimates inherently exclude fugitive emissions due to shed leakage and inherently include door leakage emissions.

2.1.2 In-Duct Emissions During Non-Pushing Cycle

Particulate emission measurements made when no ovens were being pushed beneath the shed indicated an average emission factor due to door leaks of 0.36 pound per ton of dry coal charged to all ovens beneath the shed (±0.40 pound per ton). The corresponding emission rate occurring during the time when no ovens were being pushed beneath the shed averaged 6.9 pounds per hour of filterable particulate (±7.6 pounds per hour). These estimates inherently exclude fugitive emissions due to shed leakage and inherently include only door leak emissions.

---

* The notation (±0.24 pound per ton) is an estimate of the statistical precision of the average value based upon a 95-percent level of confidence. Although the precision is ±0.24, the confidence interval for a concentration, emission rate, or emission factor is always bounded by a minimum value of zero. Likewise, the corresponding confidence interval for a percentage is always bounded by a maximum value of 100 percent. (See Section 5.11)

2.1.3 Overall Emissions Due to Pushing Operation Only

The push-only emission factor for filterable particulate emissions, including estimated fugitive emissions but excluding door leaks, averaged 0.25 pound of filterable particulate per ton of dry coal fed to the ovens pushed (±0.35 pound per ton). The corresponding overall emission rate of filterable particulate due to the pushing operation (including fugitive emissions) averaged 10.7 pounds of filterable particulate per hour (±14.5 pounds per hour).

2.1.4 Overall Emissions Due to Door Leaks Only

Because the shed capture efficiency was estimated to be 100 percent for door leak emissions, the overall emission factors (i.e., including fugitive emissions) and emission rates for door leak emissions are identical to those presented in Section 2.1.2 where in-duct measured emissions during the non-pushing cycle are documented. (See Section 2.2 for shed capture efficiencies.) No fugitive emission measurements were conducted during non-pushing periods; rather, the estimated non-pushing capture efficiency is based upon visual determination.

2.2 Particulate Capture Efficiency of the Shed

The efficiency of the shed in capturing and exhausting coke-side emissions from pushing ranged from 81 to 98 percent, and averaged 91 percent (±12 percent). Fugitive emissions during periods when ovens were not being pushed were not measured, but were estimated visually to be minimal. Assuming that no fugitive particulate

escapes the shed during the non-pushing cycle, the overall efficiency of the shed in capturing particulate ranged from 92 to 99 percent, and averaged 96 percent (±5 percent).

Wind speed and direction affected the location and extent of end leaks (smoke emissions that escape from under the shed) from the Great Lakes Carbon coke-side shed. Particulate emissions from the pushing of coke ovens are less likely to be collected by the shed capture system if the oven being pushed is located on the downwind end of the shedded coke battery. End-leak measurement estimates of particulate materials escaping the collection system from the north end of the shed on April 23, 1975, ranged from 2 to 19 percent of the overall (duct plus fugitive) particulate emissions during pushing, and averaged 9 percent (±12 percent).

2.3 Composition of Particulate Emissions

Eighty-seven percent (±9 percent) of the total particulate was captured as filterable particulate, the remaining 13 percent (±9 percent) was captured in the impinger (back-half) portion of the sampling train. Cyanide, chloride, and sulfate accounted for minor portions of filterable and total particulate during both pushing-cycle and non-pushing cycle particulate tests. For both the pushing and non-pushing-cycle particulate tests, 87 percent (±7 percent) of the filterable particulate was inorganic, that is, insoluble in cyclohexane or acetone. However, only 22 percent (±16 percent) of the impinger catch material was inorganic. Although carbonaceous material apparently constituted the majority of filterable particulate, x-ray fluorescence indicated that chlorine, sulfur, silicon, and aluminum were also present in the filterable particulate.

2.4 Particle Size Distribution

Variation in particle size distribution measured during each of several tests correlated poorly with net coking time, possibly due to multiple pushes being captured in each particle size test. A statistically significant correlation was found, however, between oven temperature and the percentage of particles less than five microns in diameter. Size distributions measured by the Brink and Andersen impactor methods indicated that 10 percent (±3 percent) and 13 percent (±4 percent), respectively, of the particulate was submicron in diameter as emitted during pushing-cycle tests.

2.5 Emission Rates of Other Materials

Coke-side emission rates of gaseous substances and other contaminants from this source were minor. Polynuclear aromatic compounds and those with similar structures (such as pyrene) were not found in detectable quantities. Sulfur dioxide plus sulfur trioxide emission rates ranged from 1.7 to 4.2, and averaged 2.8 pounds per hour (±3.2 pounds per hour). The emission rate of carbon monoxide at the peak during the push ranged from 8 to 24, and averaged 14 pounds per hour (±21 pounds per hour). Total light hydrocarbon emissions during peak emissions averaged seven pounds per hour (±6 pounds per hour).

2.6 Dustfall Measurements

For two of the three locations considered, dustfall (settleable particulate) rates beneath the shed were statistically greater than those at corresponding locations in the unshedded C Battery. As expected, greater dustfall rates were experienced at the A Battery

near the shed wall than at locations nearer the bench. In contrast, greater dustfall rates at the C Battery areas were found at the bench location than at the site equivalent to the wall location on A Battery.

2.7 Indices of Visible Emissions

Statistical analyses indicate that pushing-cycle filterable particulate emission factors were statistically significantly correlated with the average "degree-of-greenness" rating for pushes observed during the pushing-cycle particulate tests. No statistically significant linear correlation could be established, however, between quench tower plume opacity (the discharge stack for the shed exhaust) and pushing-cycle filterable particulate emission factors. This lack of correlation may have been due to the small number of particulate tests available as well as the limitations involved with reading the plume opacity in the presence of the steam plume from the quenching operation.

One index used to characterize the optical density of the shed exhaust in the duct as it varied during the course of the push was the average of the maximum attenuation coefficients of the pushes included in the multi-push particulate test. No statistically significant linear correlation was apparent between this index and the pushing-cycle filterable particulate emission factor, likely due to the limited number of particulate tests available. The attenuation coefficient integrated over time, however, was found to be significantly correlated with the pushing-cycle filterable particulate emission factor. It is therefore concluded that increased optical density (manifest by integrated attenuation coefficient or the degree-of-greenness rating) accompanied elevated filterable particulate emission factors measured during the four pushing-cycle particulate tests in this study.

Correlations were also examined among the four indices of visible emissions monitored independently in the project: degree-of-greenness, maximum attenuation coefficient, integrated attenuation coefficient, and quench tower opacity. Statistical analyses between various combinations of these variables suggest that all combinations are highly interrelated. These results indicate that, for example, the integrated attenuation coefficient is statistically significantly correlated to the quench tower opacity, the degree-of-greeness rating is statistically significantly correlated to the quench tower opacity, and the maximum attenuation coefficient is statistically significantly correlated to degree-of-greenness.

2.8 Process and Emissions Correlations

Observations of coke-side door leaks indicated that door leaks more likely occurred during the initial coking period, after oven charging, than in the later hours of the coking period.

Pushing-cycle filterable particulate emission factors were found to be significantly correlated with average net coking time but were not significantly correlated with average oven temperature.

Temperatures of ovens pushed during particle sizing tests were found to be significantly correlated with the percentage of particles less than five microns in diameter but not with the percentage of submicron particulate. No correlation could be found between the particle size distribution and the net coking time of ovens pushed during particle sizing tests.

3.0 PROCESS AND OPERATIONS DESCRIPTION

3.1 Description of the Coking Process

Coking is a process by which coal is destructively distilled in an atmosphere of low oxygen content to produce volatile gases and a residue of relatively non-volatile coke. In the byproduct coke production process (constituting more than 90 percent of the coke produced in the United States), the gases and volatile matter distilled from the charged coal are recovered throughout the coking cycle, processed, and partially recycled to the ovens for use as fuel.

A contiguous series of rectangular chambers, coke ovens, separated by heating flues placed between the ovens, constitutes a coke "battery." Based upon production requirements and hardware available at a given battery, ovens are charged, coked, and pushed according to a relatively fixed schedule. Coking times for the production of foundry coke can range from 25 to 32 hours, with the ovens being maintained at a temperature between 1800 and 2400°F throughout the period.

During the coking cycle, volatiles are driven from the charged coal beginning at the oven walls and proceeding toward the center of the charge. When the charge is "fully coked out," a ram operating from the "push side" of the oven forces the coke through the oven and out the "coke side" of the oven where the incandescent coke passes through a temporarily-aligned coke guide and falls into a quench car. The incandescent coke is subsequently quenched using water sprays in a quench tower generally positioned at or near the end of the battery.

Great Lakes Carbon Corporation, a producer of foundry coke, is located on the south side of St. Louis, Missouri, adjacent to the Mississippi River and River DesPeres. Figure 3.1 shows the location of the plant relative to its immediate surroundings. The GLC plant produces coke from coal which is unloaded from river barges or from railroad cars. The coke product is transported from the GLC plant by rail.

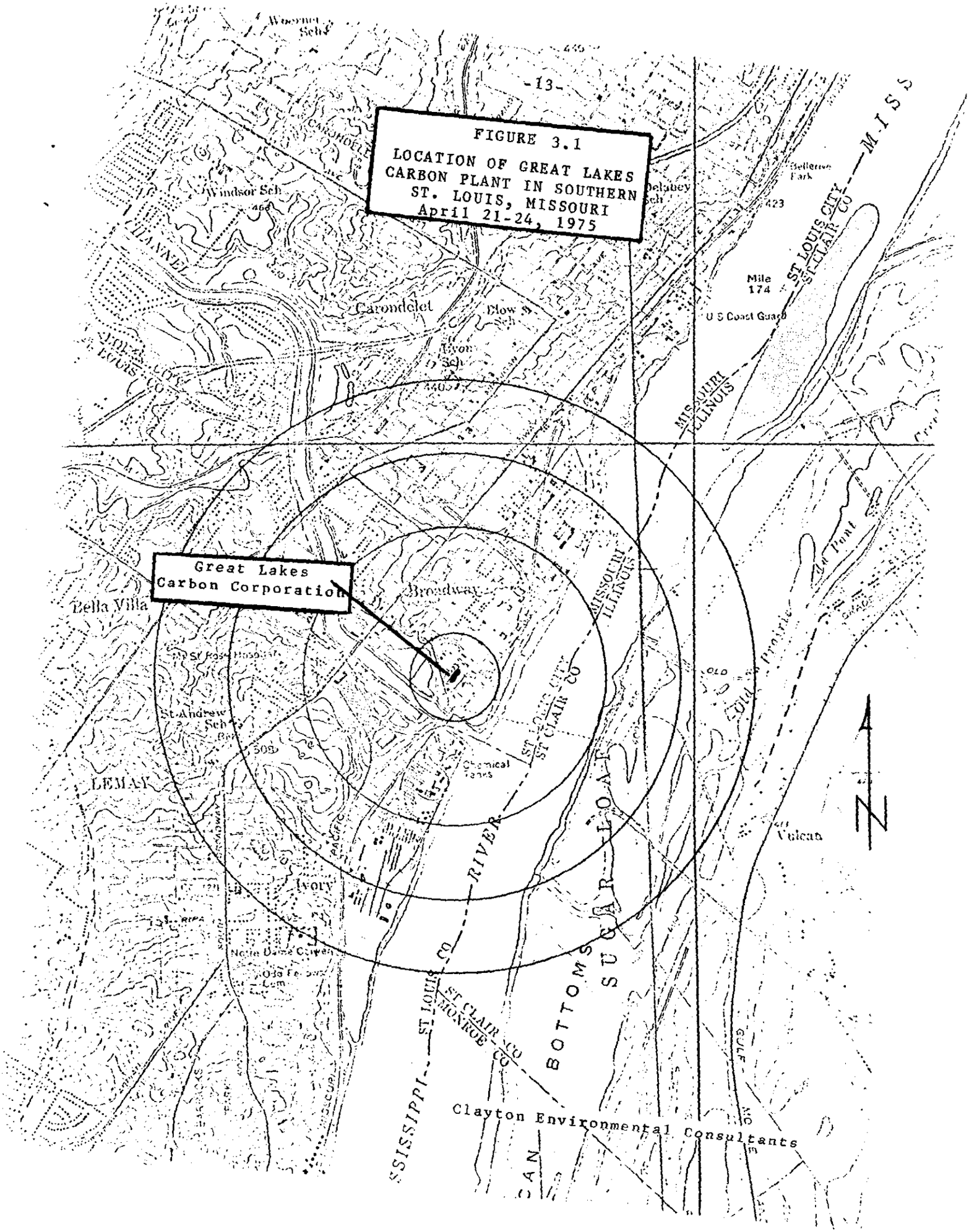
The ovens in the three batteries are serviced by one larry car, two pushing machines, two door machines on the push side, two door machines with coke guides on the coke side, and one quench car. Again, "B" Battery was inoperative during the study because it was being rebuilt. Therefore, the availability of charging and pushing machines to the other two batteries was somewhat more optimal than normal operations.

At GLC, the charge car is filled with approximately 13.7 tons of dry coal per charge. During the testing program, charging of an oven normally occurred 15 to 20 minutes after that oven had been pushed and the doors replaced. Net coking times averaged approximately 28 hours. Thus, the 75 operating ovens were pushed at an average interval of about 23 minutes.

The normal sequence of oven pushing usually resulted in five or six ovens being pushed beneath the shed (Ovens 1 through 55), followed by five ovens being pushed north of the production office in the unshedded C-Battery area. A typical sequence of oven pushing was: 2, 12, 22, 32, 42, 52 (A Battery); 92, 102, 112, 122, 132 (C Battery); 4, 14 ...

Sources of emissions which contribute to the materials captured by and exhausted from the shed include:

FIGURE 3.1
LOCATION OF GREAT LAKES CARBON PLANT IN SOUTHERN ST. LOUIS, MISSOURI
April 21-24, 1975



1. Pushing Operations:

   a. Emissions from the coke side of an oven whose door has been removed, before and after pushing;

   b. Emissions from and during pushing of the hot coke thrcugh the coke guide into the quench car;

   c. Emissions from the newly-filled quench car immediately following pushing and before the car leaves the shed as it travels to the quench tower;

2. Door Leaks:

   Emissions from leaking coke-oven doors after the oven has been charged with coal and placed under positive pressure during the conversion of the coal to coke.

The A Battery at the GLC plant contains 40 Simon-Carves ovens south of the control room (Ovens 1 through 55), and the C Battery contains an additional 35 Wilputte ovens north of the office (Ovens 83 through 132). As indicated, ovens 56 to 82 (B Battery) were undergoing repair and were not coking at the time of the study (coke-oven numbering system at GLC excludes 8's, 9's, and 0's in the last digit).

Plant personnel at GLC indicated that during this study, coke batteries A and C operated at typical conditions. Clean, as well as green, pushes were experienced during the sampling phase of the study.

3.2 Description of the Shed Capture System

The shed capture system on Battery A is constructed of corrugated metal on a steel frame. It covers the coke-side bench and

part of the quench car tracks and extends from approximately 25 feet beyond Oven 1 to approximately 15 feet beyond Oven 55. The shed does not extend to the ground or bench level on the side or at the ends because the coke guide car and the quench car must move in and out of the structure during the production cycle. The side of the shed extends vertically down to approximately 10 to 11 feet above grade, slightly below the top of the outer wall of the quench car. A sketch of the north face of the shed, which must allow clearance for the coke guide car and quench car, is shown in Figure 3.2-1. A detailed drawing of the side view of the shed is shown in Figure 3.2-2 to give an overall perspective of the general appearance of the structure.

Exhaust gases are evacuated from the shed through a variable cross-section, rectangular duct that extends the entire length of the shed immediately beneath the shed's peak (Figure 3.2-3). Air scoops are located along the sides and bottom of this duct in such a way as to allow the duct to capture the exhaust gases along its entire length inside the shed. A vane-axial fan draws the exhaust gas from the shed through a rectangular duct with a slight downslope to the front face of the quench tower. The ultimate point of exit to the atmosphere of the shed exhaust gas is from the top of the quench tower. During normal operations, water is sprayed from nozzles placed along the length of this rectangular duct downstream of the fan (additional water is sprayed from the top of the quench tower). Emission samples were collected in this rectangular duct during the test program. Therefore, to allow better measurement of the coke-side emissions as captured by the shed, the water to

FIGURE 3.2-1

CONFIGURATION OF NORTH END OF SHED

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

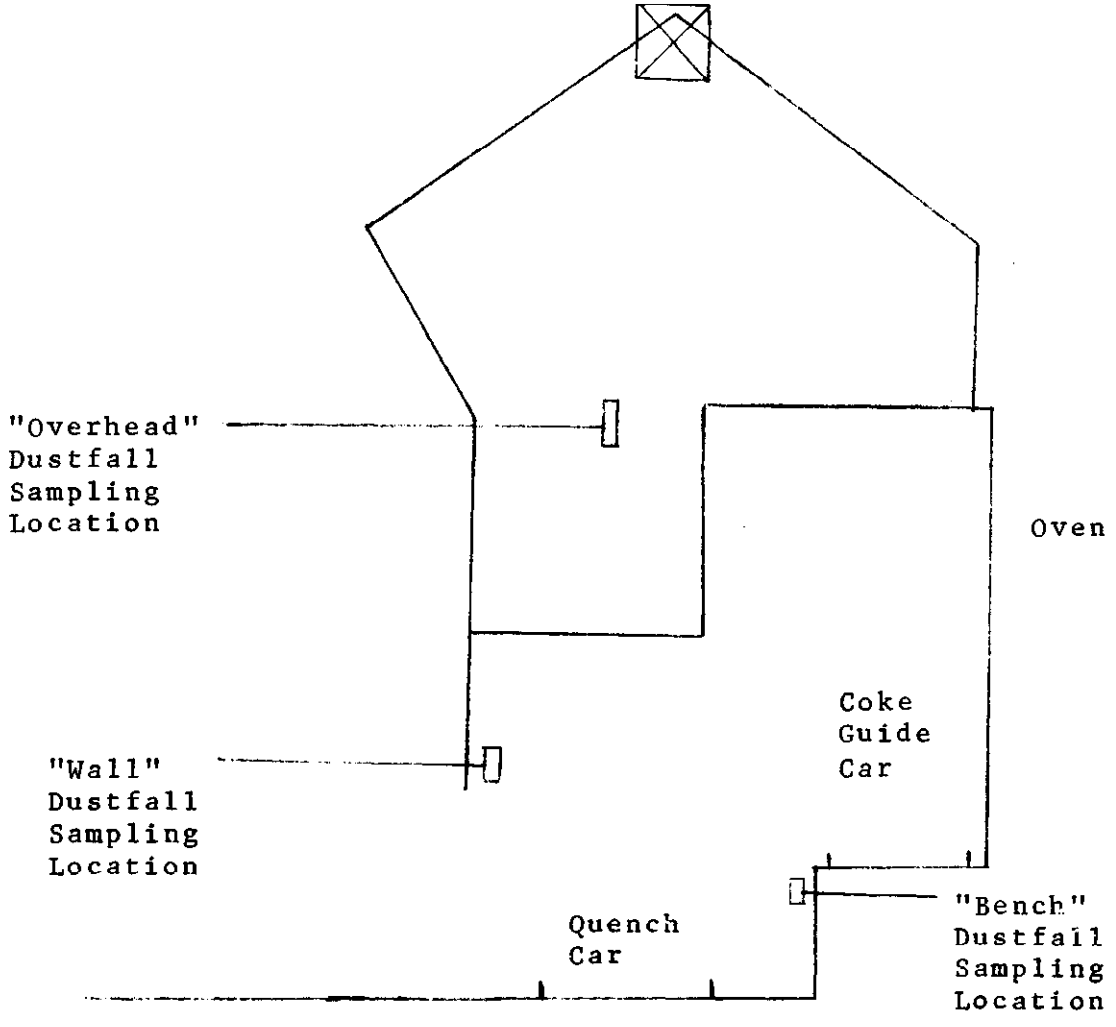
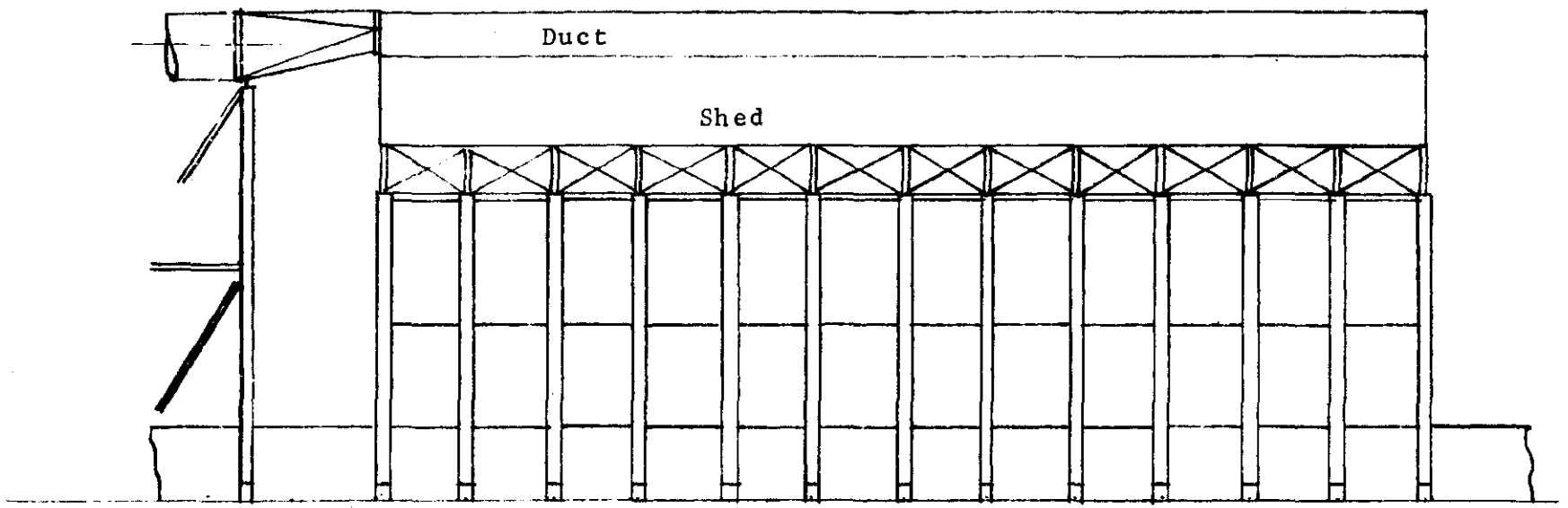


FIGURE 3.2-2

DIAGRAM OF SIDE VIEW OF SHED

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975



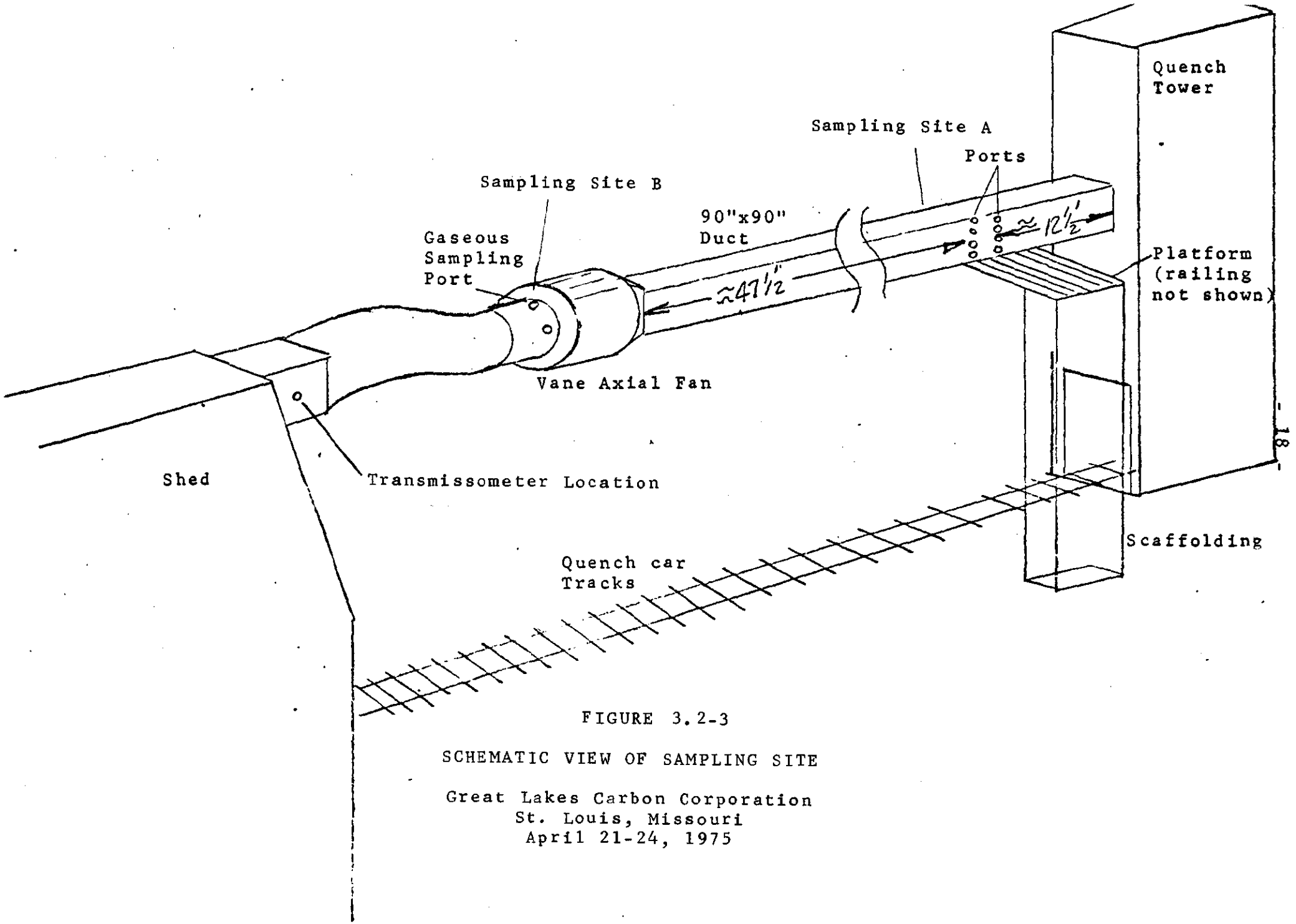


FIGURE 3.2-3

SCHEMATIC VIEW OF SAMPLING SITE

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

the spray nozzles in the rectangular duct was turned off during the sampling period.

Because the ends and the sides of the hood are not completely enclosed, so as to permit the door machine and quench car to enter and exit, the capture efficiency of the hood is less than 100 percent. During the pushing of an oven, a black plume was seen to rise to the upper portions of the shed and some of the particulate emission was seen to escape from the side and the ends of the shed. Wind speed and direction obviously affected the rate of emissions escaping from the shed system. A southerly wind likely results in particulate emissions from the north end of the shed, especially when the oven being pushed is near the north end. Similarly, northerly winds enhance particulate escape at the south end of the shed.

4.0 SAMPLING AND ANALYTICAL METHODS

4.1 Location of Sampling Points

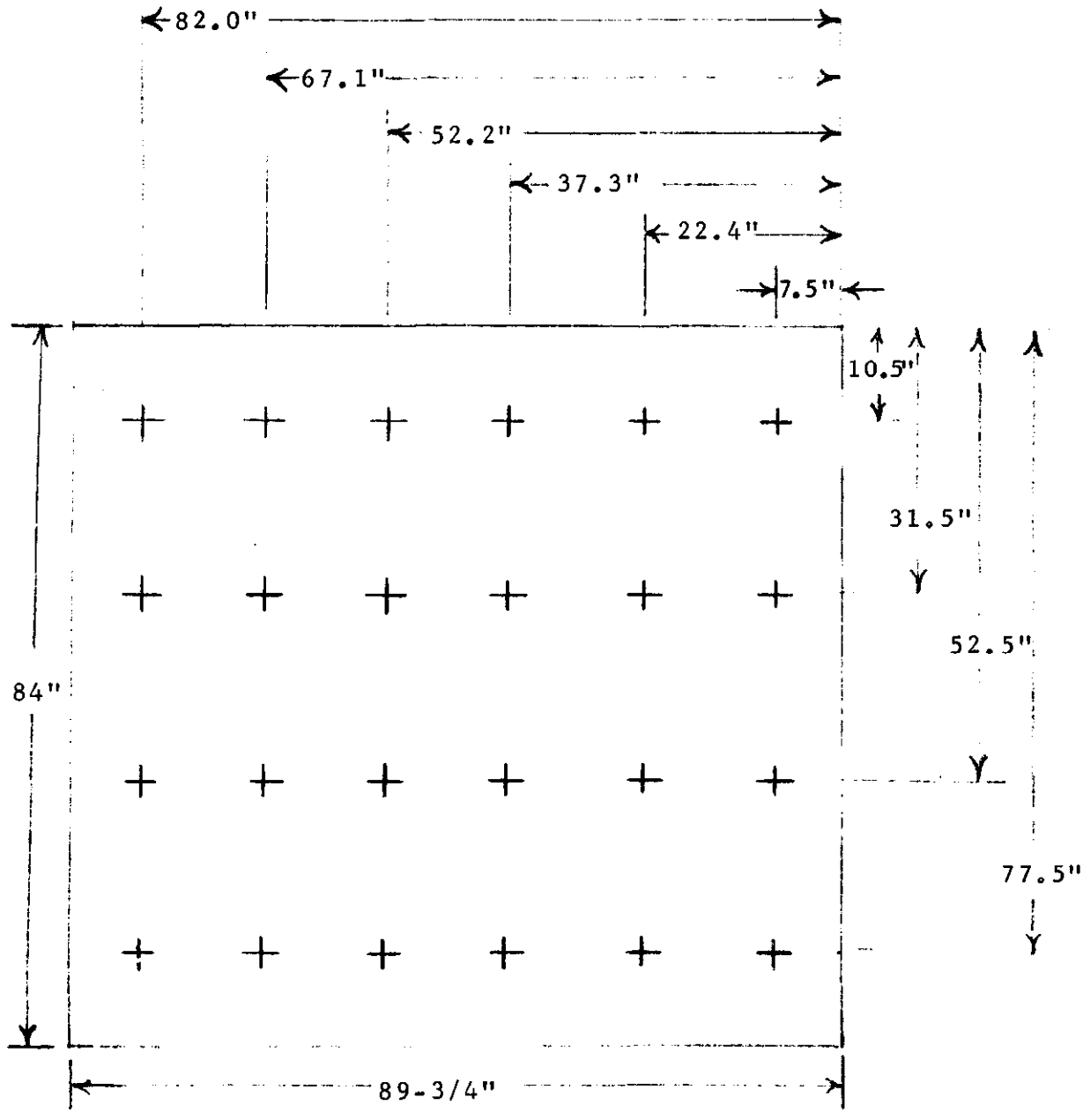
Sampling of particulate, particle sizing, and measurement of exhaust gas velocity and flowrate were conducted at the uniform airflow profile located at cross section A shown in Figure 3.2-3. Sampling for substances other than particulate, such as sulfur oxides, polynuclear aromatics, etc., was conducted in the more turbulent airflow stream located at cross section B (Figure 3.2-3). near the inlet of the vane-axial fan. The dimensions of the duct at location A were 89-3/4" by 84" with an equivalent duct diameter of 8.16 feet. This location is therefore six equivalent diameters downstream of any bend or obstruction and 1.5 equivalent diameters upstream of the quench tower. An independent velocity traverse at this location indicated no spiraling airflow patterns in the rectangular cross section at location A as might result from the nearby vane-axial fan. Figure 4.1 indicates the location of sampling points in the duct cross section. These points were accessible through two sets of four ports located on the west side of the duct, one set of ports for each of the two particulate test modes (pushing and non-pushing).

Velocity pressure measurements taken at sampling cross section A were made using a standard S-type Pitot tube. Temperature measurements were made using an iron-constantan thermocouple attached to a calibrated Mini-mite potentiometer. All calibrations are included in Appendices J through O (Volume 3) and discussed further in Section 4.9.

FIGURE 4.1

LOCATION OF SAMPLING POINTS
COKE-SIDE SHED EXHAUST DUCT

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975



4.2 In-Duct Particulate Emissions

Particulate sampling methods follow the guidelines outlined in EPA Methods 1 through 5.[1] Deviations from these procedures included the following:

1. An abbreviated number of sampling points was chosen in order to complete one particulate test per day for each of the two modes (pushing-cycle and non-pushing-cycle).

2. An integrated sample of the stack gas was not analyzed for each particulate test by the standard Orsat procedure. Before the testing began, however, an Orsat analysis of stack gas collected during a coke oven push indicated that the composition of the stack gas was essentially that of air.

3. Collected particulate samples were not simply weighed but were analyzed as well for other components as outlined in the particulate analysis flowcharts (Figure 4.2). Particulate captured by the impingers was included in "total particulate," whereas "filterable particulate" only included the probe and cyclone washes plus the filter catch.

4. Filter and probe temperatures were not maintained at 250°F. Temperatures were adjusted to slightly above stack temperatures to assure that no moisture condensation occurred in the train upstream of the filter.

The "pushing-cycle" particulate tests refer to samples acquired during those times when the ovens beneath the shed capture

FIGURE 4.2

PARTICULATE ANALYSIS FLOWCHART

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Pushing-Cycle Particulate Test 1 &
Non-pushing-Cycle Particulate Test 1

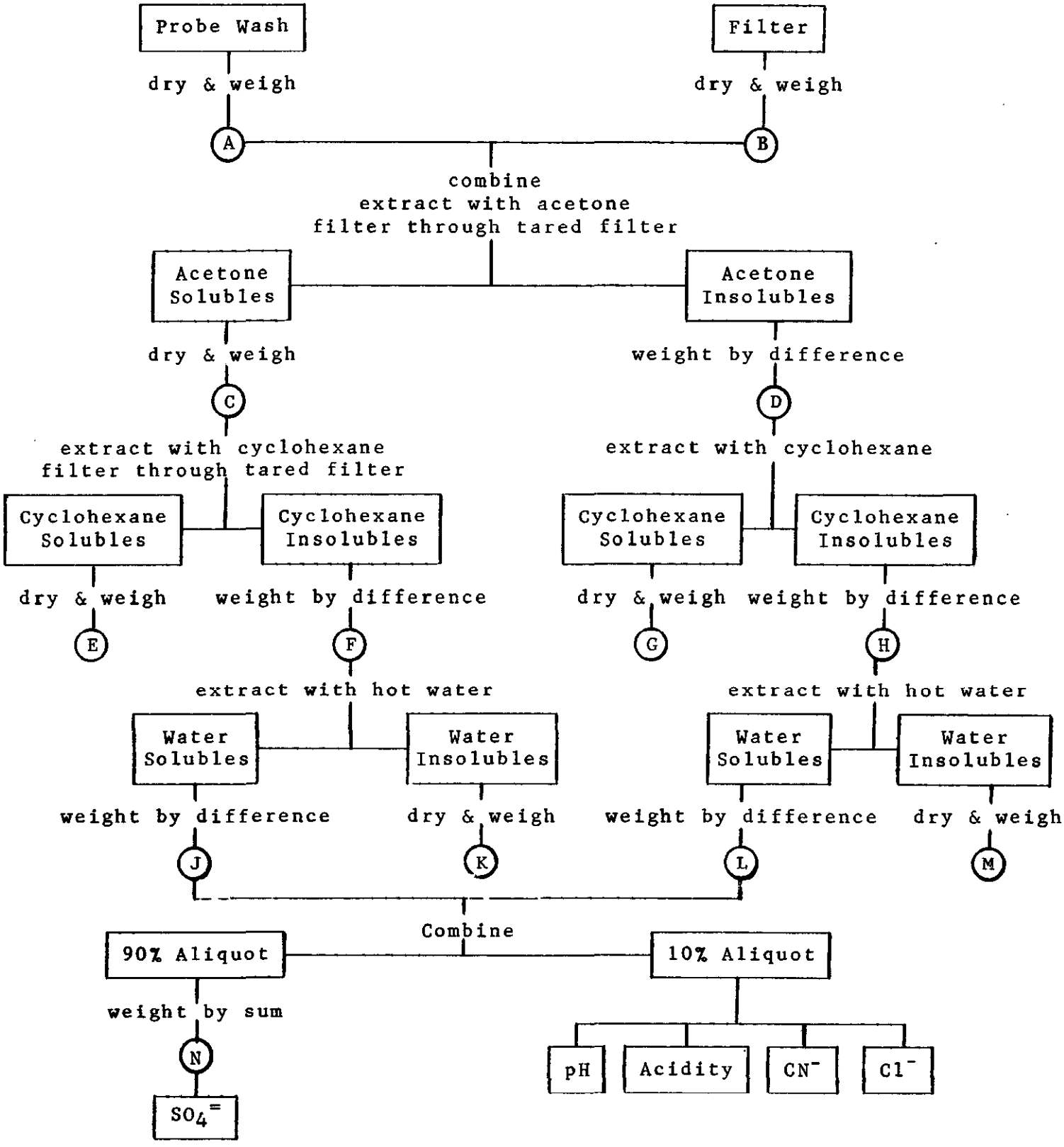


FIGURE 4.2 (continued)

PARTICULATE ANALYSIS FLOWCHART

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Pushing-Cycle Particulate Tests 2, 3, and 4 &
Non-pushing-Cycle Particulate Tests 2 and 3

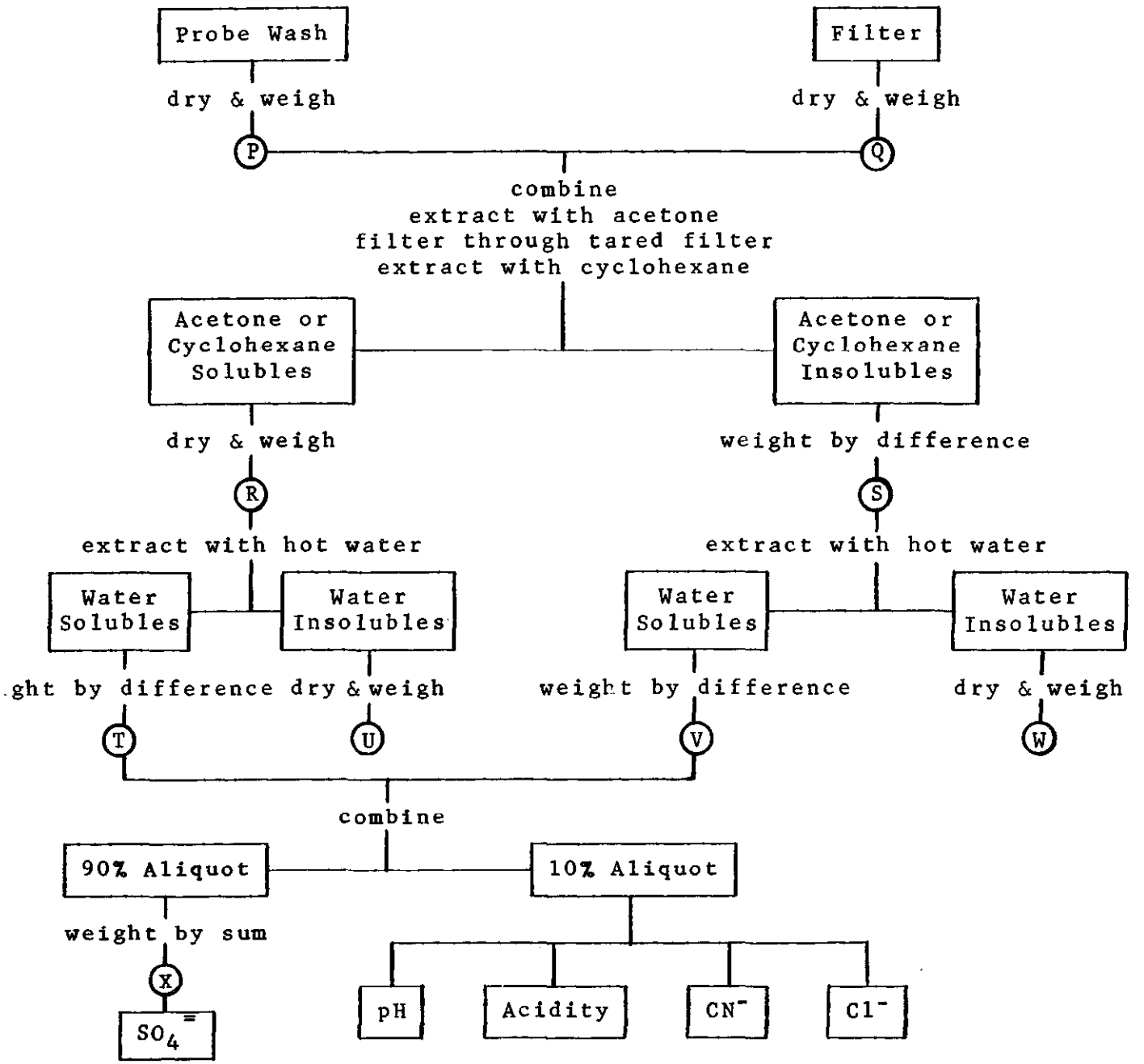
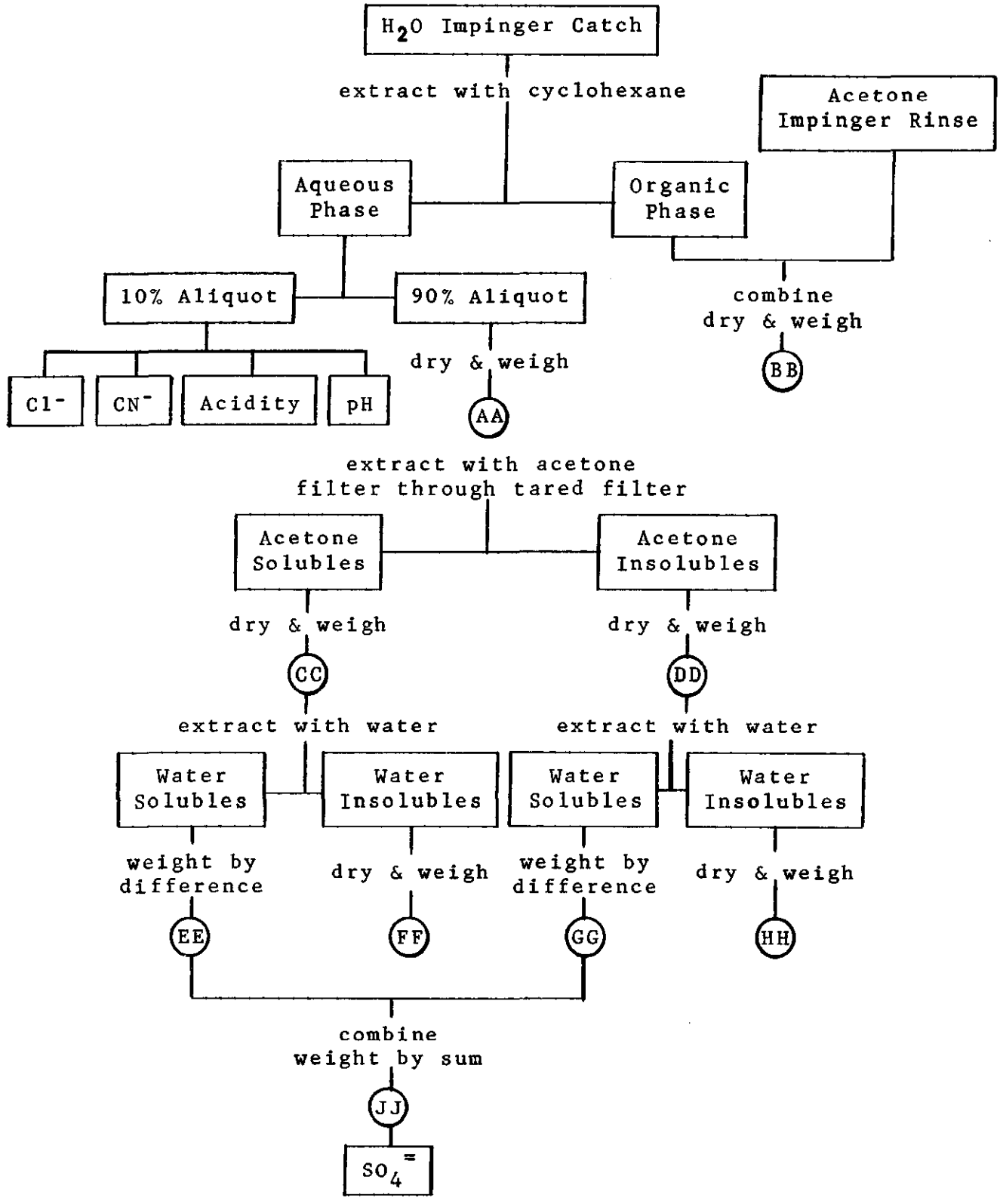


FIGURE 4.2 (continued)

PARTICULATE ANALYSIS FLOWCHART

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

All Particulate Tests



system were being pushed sequentially. During the normal pushing cycle, five or six ovens beneath the shed would be pushed at approximately 20- to 30-minute intervals (e.g., ovens 3, 13, 23, 33, 43, and 53). Pushing-cycle particulate tests commenced as a push beneath the shed began, and the test terminated no more than 30 minutes after the most recent push occurred beneath the shed. By following this timing procedure, the approximate average pushing rate beneath the shed was reflected in the particulate samples.

"Non-pushing-cycle" particulate tests were conducted only when the pushing-cycle particulate samples were not being collected (i.e., when oven pushing was occurring on the C Battery, which is not under the shed). Therefore, these tests measured the particulate generated from door leaks only. To further insure that pushing emissions were not captured during the non-pushing-cycle test, that test was discontinued temporarily for one-minute intervals each time the quench car, filled with hot coke from the C Battery, traveled beneath the shed on its journey to the quench tower. Also, the non-pushing-cycle particulate tests were discontinued as an oven beneath the shed was prepared for pushing. Field data sheets for pushing and non-pushing-cycle particulate tests are included in Appendix P (Volume 3). Summaries of calculated sampling volumes, etc., are included in Appendix F (Volume 2).

4.3 Fugitive Emissions

End leaks of emissions resultant from coke oven pushes at the north end of the shed were estimated and later compared with emissions exhausted through the shed capture system. A series of four filterable particulate measurements was conducted on April

23, 1975, to measure end leaks from the 12' x 15' rectangular area over the bench on the north end of the shed (Figure 3.2-1). The test used a 47-mm diameter glass-fiber filter, a probe, and a dry-gas test-meter assembly similar to that used for filterable particulate emissions from the shed capture system. A vane anemometer measured exhaust gas velocities as the instrument was passed slowly over representative portions of the rectangular cross section from which particulate emissions were observed to escape from the shed. The probe-filter assembly was swept over this area during each of four tests.

4.4 Particle Size Distribution

Particle size Tests 1 through 9 were collected with a Brink impactor which included the use of five separation stages plus a cyclone pre-separator and a 47-mm type A back-up filter, following the procedure outlined in the instructions.[2] The entire unit was placed in the stack and samples were drawn isokinetically through an appropriately sized nozzle preceding the cyclone. After sufficient pushes (one to eight pushes) were sampled to collect a weighable portion of material on each stage, the collection plates and cyclone collector were rinsed with acetone and the sample transferred to glass sample containers. In the laboratory, the acetone from the sample was evaporated and the samples weighed on a laboratory balance capable of resolving 0.1 milligram.

Particle size sampling with an Andersen impactor was conducted similarly, following the procedure outlined in the instructions.[3] No filter paper was used in the collection plates and the cyclone pre-separator was not used during this evaluation.

4.5 Emissions of Other Materials

4.5.1 Sulfur Dioxide and Sulfur Trioxide

Sulfur dioxide and sulfur trioxide samples were collected by the Shell method. Filtered, sampled gas was passed through isopropyl alcohol to collect the sulfur trioxide and then through 3-percent hydrogen peroxide to collect sulfur dioxide in Greenburg-Smith impingers. Each sample was collected from the shed exhaust gas during at least one coke oven push. A description of the sampling and analytical procedure is included in Appendix Q (Volume 3).

4.5.2 Gaseous Contaminants by Charcoal Tube Collection

Emissions of benzene, the homologues of benzene, and pyridine were measured by adsorption of these gases from the stack gas on activated charcoal. Later the charcoal was desorbed with an appropriate eluant which was then analyzed by gas chromatographic techniques.

A description of the sampling method used for these measurements is indicated in Appendix R (Volume 3).

4.5.3 Polynuclear Aromatic Compounds

Polynuclear aromatics, including benzo(a+e)pyrene, chrysene, fluoranthene, and pyrene were measured with a sampling train consisting of a probe, a filter, and impingers containing cyclohexane. Filterable emissions included the probe wash and filter catch, whereas total emissions also included the impinger catch. Analysis of each fraction was performed independently.

Sampling for these contaminants was conducted over a minimum of one hour and included sampling during at least one coke oven push to assure that collected emissions represented both door leaks and coke oven pushes beneath the shed. A detailed description of the sampling method is found in Appendix S (Volume 3).

4.5.4 Gaseous Contaminants by Collection in Gas Burette

Emission concentrations of carbon monoxide, total light hydrocarbons, methane and homologues, ethene and homologues, and acetylene were measured by collection in gas burettes. This "grab sample" was analyzed in the laboratory by extraction of a small sample from the burette with a hypodermic needle and syringe followed by injection into a gas chromatograph. A detailed description of the sampling method is indicated in Appendix T (Volume 3).

4.5.5 Gaseous Contaminants by Collection in Aqueous Sodium Hydroxide

Cyanide, chloride, nitrogen oxides, sulfite, sulfate, and phenolic materials were collected in impingers containing a 0.1 N solution of sodium hydroxide after the exhaust gas materials had previously been passed through a filter. Cyanide and chloride ion concentrations were measured with ion selective electrodes. Sulfite and sulfate were measured turbidimetrically. Oxides of nitrogen were measured by the phenoldisulfonic acid spectrophotometric method. Phenolic materials were measured by distillation followed by gas chromatography. A detailed description of the sampling and analytical procedures is indicated in Appendix U (Volume 3).

4.6 Dustfall Measurements

Settleable particulate was measured at various locations beneath the shed and in geometrically similar locations near the unshedded C Battery. Settleable particulate was measured by placing dustfall buckets (with 6-inch diameter openings) at various locations and transferring these samples at approximately 12-hour intervals. Approximately one inch of distilled water was placed at the bottom of the dustfall bucket at the beginning of the sampling period. The location of the dustfall bucket was indicated by the oven nearest the dustfall sampling location and by the terms "bench," "wall," "overhead," or "coke guide car." For example, the "No. 12 Bench" site indicates that the dustfall bucket was nearest oven No. 12 and was located along the coke-side bench.

Locating the dustfall buckets was difficult because the buckets had to be placed at a point where the coke guide car and the quench car would not interfere with the bucket. Buckets at the "bench" site were located approximately five feet above the ground level and approximately one foot away from the bench wall (Figure 3.2-1). At this location, coke passing through the coke guide passed directly over the dustfall buckets en route to the quench car when nearby ovens were being pushed.

Dustfall buckets at the "wall" site were located inside the shed wall approximately one foot above the bottom of the wall and approximately one foot inward from the wall. At this location, the quench car passed not beneath but approximately one foot to the side of the bucket en route to the quench tower.

Dustfall buckets were placed on the No. 1 car (operating beneath the shed) and the No. 2 car (operating at the north end of the battery outside the shed) approximately 15 feet north of the coke guide at an elevation approximately three feet higher than the bottom of the coke guide. Both buckets were located north of the coke guide. Dustfall buckets at the "overhead" location were suspended from the supporting steel work at the upper portion of the shed. The buckets were located immediately above the quench car at an elevation slightly above the top of the oven.

In the laboratory, the material captured in each bucket was passed through a No. 18 sieve (1-mm square holes) and the weight captured on the sieve was determined first by drying the collected material and then weighing the material on an analytical balance capable of resolving 0.1 milligram. The material passing through the sieve was further filtered to separate the water-soluble from the water-insoluble dustfall portions. Materials captured on the filter were dried and weighed on an analytical balance and the water-soluble materials passing through the filter were placed in a beaker in an oven operated at 105°C where the water was evaporated from the sample. The dry residue was then weighed on an analytical balance. Dustfall materials were then divided into three categories:

1. That composed of particles which were collected on the No. 18 sieve;
2. Materials passing through the No. 18 sieve which were not water soluble; and
3. Materials passing through the No. 18 sieve which were water soluble.

Settleable particulate was calculated from the second and third categories above.

The materials captured in category No. 2 (water-insoluble smaller particles) were further characterized by acetone solubility, cyclohexane solubility, and pH for six of the samples. The samples were divided into three weighed portions. Acetone was added to the first portion and the resulting slurry was passed through a filter after which the acetone solution was evaporated to produce a residue of constant weight. This indicated the percent of acetone solubles. Similarly, the second weighed portion was treated with cyclohexane to indicate the percent of cyclohexane solubles. Water was added to the third portion and the pH of the resulting slurry was measured with a pH meter.

4.7 X-ray Fluorescence and Microscopic Analysis

Samples of filterable particulate were captured over brief sampling periods during coke-oven pushing on a cellulose acetate filter for subsequent X-ray analysis. The description of the procedure and the computer results of the evaluation are indicated in Appendix G (Volume 2).

The same filter samples were also examined using light microscopy and scanning electron microscopy techniques to determine particle morphology, size, and physical characteristics. The analysis technique and results are presented in Appendix H (Volume 2).

4.8 Visible Emissions Monitoring

4.8.1 Degree-of-Greenness Ratings

During the testing program each individual coke-oven push was observed visually and rated according to the opacity of the plume immediately above the quench car. Observations

were made and recorded by EPA-certified visible emissions observers in all cases (Appendix V, Volume 3). The results of this subjective, opacity-type rating technique were labeled "degree-of-greenness." A high rating indicates an opaque plume resulting from the pushing of "green" (insufficiently carburized) coke. Each push was divided into three approximately equal parts and each third of the push was classified according to greenness by giving it a separate rating number. Faint or light plumes were given a "1" rating, and opaque plumes usually accompanied by flames in the plume were classified as "4." Ratings of "2" or "3" were subjective interpolations between the number "1" and number "4" conditions.

A plume whose three-part rating was, for example, "1-2-4" indicated that the first third of the push was fairly clean, the middle segment of the push resulted in a moderately clean plume, and the last third of the push was extremely dirty. The sum of the three digits (7 in this example) is an indication of the overall greenness as a function of the plume appearance. The duration, in seconds, of each push varied somewhat; therefore, the time-weighted product of the duration (D) and the sum of degree-of-greenness ratings (S) yielded a parameter which characterized each push in terms of a plume appearance above the quench car. The degree-of-greenness rating accounts for the emissions generated during the falling of coke into the quench car as well as those arising from the coke in the quench car. Emissions data presented in Section 5.0 are accompanied by these degree-of-

greenness records for the pushes which occurred during emission measurements.

4.8.2 Stack Opacity Rating

During the source testing program, the opacity of the plume emitted from the shed capture system, which entered the atmosphere above the quench tower, was observed and recorded by EPA Method 9 (40CFR60) at 15-second intervals (Appendix W, Volume 3). (Minor portions of the plume were sometimes observed to exit to the atmosphere through the quench car door of the quench tower.) Between the pushes occurring under the shed, this source produced a plume of zero- or five-percent opacity. As a direct result of pushing under the shed, however, the opacity above the quench tower would increase to 25 to 30 percent. Immediately following the elevated plume opacity readings, the steam plume from the quenching operation masked the plume from the shed capture system; thus, the duration of elevated stack opacity could not be determined by visual methods. Observations of quench tower plume opacity, including average and maximum percent opacity of the quench tower emissions during each push for the particulate emission and particle sizing tests, are presented in Section 5.0.

4.8.3 Transmissometer Data

During the test program, a transmissometer was installed in the shed exhaust duct at the rectangular section immediately downstream of the shed and upstream of the exhaust

fan. The transmissometer continuously monitored the opacity levels of the exhaust air discharged from the shed capture system by transmitting a beam of light across the duct and measuring the amount of attenuation. A description of the transmissometer system, and its operation, including an analysis of the opacity (optical density) measurement data obtained during the test period is set forth in the report prepared by EPA shown in Appendix I (Volume 2).

The transmissometer strip chart records show that during the period when no pushing was occurring under the shed, the optical density of the stack exhaust gas was only very slightly above the background opacity line of the strip chart recording due to door leaks under the shed. The instrument was zeroed during this time when the shed appeared to be relatively "clean"; therefore, an absolute zero opacity base line was not established. During a push, the opacity density of the stack would increase, reach a maximum, and then decrease gradually until the shed was evacuated of the plume produced by that oven-pushing operation. Normally, the optical density would return to near the zero base line within two minutes after the push had begun, thus providing a measure of the pushing emissions clearing time.

The optical density of the exhaust gas sometimes increased beyond the zero base line at times other than during pushing. A noticeable increase was evident when excessive door leaking occurred or when the quench car, returning from the quench tower, passed beneath the shed,

resulting in a steam plume which was detected by the transmissometer.

Two characteristic parameters were determined for each coke-oven push from the transmissometer data: maximum or peak optical density during the push and total optical density. The second parameter is a relative measure of the total area beneath the optical-density-versus-time curve produced by the strip chart recording.

For the purposes of comparing the opacity levels measured by transmissometer with opacity readings made by trained observers at the GLC plant and other coke plants and for developing correlations with mass emissions measurements and process variables, the maximum optical density and optical-density-time values were converted to equivalent values of attenuation coefficients by the formula:

$$\sum = \frac{\text{optical density}}{\text{path length}} = \frac{\ln(1/T)}{\text{path length}}$$

where: $\sum$ = attenuation coefficient; and

$$T = \text{transmittance} = 1 - \left(\frac{\text{opacity}}{100}\right)$$

Correlations between the particulate emission factors and various indices of visible emissions, including maximum and total optical density as measured and calculated from the transmissometer strip chart recordings for each push occurring during the particulate and particle sizing tests, are presented in Section 5.0. Reproductions of the strip charts themselves are contained in Appendix X (Volume 3).

4.8.4 Door Leak Inspection Data

During the sampling study, door leaks were observed and recorded as they occurred around the oven doors on the push and coke sides of the battery. If it was visually apparent that a door beneath the coke shed was leaking, the oven number of that door was noted at the time of the door leakage survey. Sometimes an oven could not be observed because it was obscured by the coke guide car; this was so noted on the field data sheets that are presented in Appendix Y (Volume 3).

4.9 Calibration of Sampling Equipment and Example Calculations

Before and after the field study was conducted, several key pieces of the sampling equipment were calibrated, including Pitot tubes, dry-gas meters, orifice meters, sampling nozzles, and thermocouple potentiometers. Where correction factors are applicable, the average of pre- and post-study calibration correction factors was applied.

The S-type Pitot tube used to measure stack gas velocities was calibrated over a range of velocity pressures and compared with velocity pressures measured with a standard-type Pitot tube. Appendix J (Volume 3) contains a description of the procedure used for Pitot tube calibration; Appendix K (Volume 3) contains the Pitot tube calibration data used for this study.

The dry-gas test meters and orifice meters used to measure sample volume were calibrated against a wet-test meter according to the procedure found in Appendix L (Volume 3). Pre- and post-study calibration data are presented in Appendix M (Volume 3).

Thermocouple potentiometers were calibrated according to the procedure outlined in Appendix N (Volume 3), and accuracy to within five degrees Fahrenheit was assured over a wide range of stack gas temperatures.

Sampling nozzle diameters were measured with a micrometer before and after the study, This calibration procedure is described in Appendix O (Volume 3).

Appendix Z (Volume 3) contains sample calculations for particulate emissions, gaseous emissions, particle size distribution, and dustfall.

4.10 Quality Assurance and Chain of Custody

To insure the integrity of all samples, the chain of custody procedure (Appendix AA, Volume 3) was followed conscientiously. At all times, either one member of the Clayton test team was with the samples or the samples were locked securely in storage.

5.0 PRESENTATION AND DISCUSSION OF RESULTS

5.1 Comparison of Pushing-Cycle and Non-Pushing-Cycle Particulate Tests

In this test program, particulate samples were collected during each of two cycles of the coke-pushing operation at the Great Lakes Carbon plant. Samples collected during the "pushing cycle" were collected continuously during the time that the production schedule called for the pushing of ovens beneath the shed. When the schedule called for the pushing of ovens at the C Battery (those ovens not beneath the shed), no pushing was occurring beneath the shed. Therefore, particulate emissions captured during this time were labeled "non-pushing-cycle" particulate tests. Sampling during each of these two different types of operational cycles was an attempt to quantify the relative contribution of door leaks and oven pushes to the particulate emissions.

Table 5.1-1 summarizes the particulate emissions occurring during the pushing cycle (oven pushes plus door leaks - Appendix B, Volume 2) and the non-pushing cycle (door leaks only - Appendix C, Volume 2). The difference in the particulate emissions during the two cycles is an indication of the relative contribution of coke-oven pushing to the total particulate emissions from the coke side. This calculation inherently assumes that the average door leak rate during non-pushing-cycle tests is the same as that during pushing-cycle particulate tests. From Table 5.1-1 it is evident that the pushing of coke ovens accounts for an average of 56 percent of the filterable particulate emissions captured by the shed during

TABLE 5.1-1

SUMMARY OF PARTICULATE EMISSIONS

Coke Shed
Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test Condition	Test No.	Stack Gas Conditions		Particulate Concentration (gr/DSCF)			Particulate Emission Rate (lbs/hr)		
		Temp (°F)	Flowrate (DSCFM)	Filterable	Back half	Total	Filterable	Back half	Total
Pushing Cycle	1	75	129,000	0.019	0.001	0.020	20.6	1.1	21.7
	2	85	119,000	0.013	0.002	0.016	13.7	2.5	16.2
	3	74	123,000	0.015	0.003	0.018	15.7	3.4	19.1
	4	88	121,000	0.028	0.003	0.031	29.0	3.2	32.2
	Avg(1-3)	78	124,000	0.016	0.002	0.018	16.7	2.3	19.0
	Avg(1-4)	80	123,000	0.019	0.002	0.021	19.8	2.6	22.3
Non-Pushing Cycle	1	69	128,000	0.006	0.0003	0.007	6.9	0.37	7.2
	2	85	125,000	0.009	0.001	0.010	10.0	1.1	11.1
	3	70	132,000	0.003	0.001	0.005	3.9	1.4	5.3
	Avg	75	128,000	0.006	0.0008	0.007	6.9	0.96	7.9
Push-Only (Pushing Cycle-Non-Pushing Cycle)	1	--	----	0.013	0.0007	0.013	13.7	0.7	14.5
	2	--	----	0.004	0.001	0.006	3.7	1.4	5.1
	3	--	----	0.012	0.002	0.013	11.8	2.0	13.8
	Avg	--	----	0.010	0.001	0.011	9.7	1.4	11.1

the pushing cycle. This conclusion is dependent upon the characteristics of the pushes occurring beneath the shed during the pushing-cycle particulate tests. Table 5.1-2 displays the data necessary to characterize these pushes.

To determine the relative contribution of oven pushing to the filterable particulate emissions during the entire cycle, the relative duration of each of the two cycles in the overall production schedule must be established. Because 40 ovens are beneath the shed and 35 are outside of the shed, the pushing operation is in the pushing-cycle mode approximately 12.8 hours per day (40/75 times 24 hours per day). Similarly, the non-pushing cycle is in operation 11.2 hours per day (35/75 * 24 hours per day). The contribution of oven pushing to the overall filterable particulate emissions from the overall operation is 43 percent, as shown in the following time-weighted average calculation:

$$\frac{9.7 \text{ lbs/hr} * 12.8 \text{ hrs/day}}{16.7 \text{ lbs/hr} * 12.8 \text{ hrs/day} + 6.9 \text{ lbs/hr} * 11.2 \text{ hrs/day}} = 42.7\%$$

This indicates that the continuous leaking of smaller amounts of particulate matter from coke-oven doors accounts for a greater portion of the filterable particulate emitted by the shed capture system (57 percent) than the infrequent but more concentrated emissions resultant from the pushing of coke ovens at GLC's A Battery. A similar time-weighted calculation, using the back-half emissions listed in Table 5.1-1, indicates that 60 percent of the back-half emissions at GLC's A Battery may be attributed to door leaks.

TABLE 5.1-2

PUSH CHARACTERISTICS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test Pushing-Cycle Particulate 1 Date 4/21/75 & 4/22/75

Time	Oven Pushed	Net Coking Time	Degree of Greenness				Quench Tower Opacity		Plume Attenuation Coefficient (sec.-meters^{-1})	Maximum Attenuation Coefficient (meters^{-1})
			Rating	Sum (S)	Duration (D)	S*D	Average Percent	Maximum Percent		
10:40	7	26:10	232	7	28	196	18.0	30	29.92	0.885
10:52	17	26:02	332	8	29	232	16.0	25	32.52	0.976
12:30	27	26:56	322	7	34	238	9.0	15	5.88	0.156
12:46	37	27:15	212	5	38	190	4.0	5	5.00	0.137
13:04	47	27:19	311	5	34	170	7.5	15	9.51	0.286
16:30	2	28:07	221	5	29	145	8.0	15	3.25	0.091
16:40	12	28:04	444	12	26	312	42.5	80	54.64	1.626
16:47	22	27:56	331	7	28	196	9.0	10	9.11	0.260
17:00	32	27:48	442	10	29	290	16.7	30	32.52	0.976
17:10	42	27:35	432	9	27	243	--	--	4.55	0.117
17:30	52	27:44	111	3	28	84	--	--	4.55	0.117
09:50	5	27:50	131	5	32	160	17.0	30	6.50	0.195
10:04	15	27:46	221	5	29	145	7.5	15	2.60	0.104
10:46	45	27:35	212	5	38	190	14.6	25	8.46	0.247
11:25	55	26:45	221	5	38	190	--	--	5.85	0.163
AVERAGE		27:23	--	7	31	199	14.2	25	14.32	0.422

TABLE 5.1-2 (continued)
PUSH CHARACTERISTICS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test Pushing-Cycle Particulate 2 Date 4/22/75

Time	Oven Pushed	Net Coking Time	Degree of Greenness				Quench Tower Opacity		Plume Attenuation Coefficient (sec.-meters^{-1})	Maximum Attenuation Coefficient (meters^{-1})
			Rating	Sum (S)	Duration (D)	S*D	Average Percent	Maximum Percent		
14:08	7	27:12	232	7	32	224	15.0	30	17.85	0.650
14:21	17	26:01	432	9	35	315	26.7	50	25.50	0.703
14:32	27	25:40	221	5	33	165	8.0	10	7.99	0.217
15:20	37	26:05	111	3	31	93	5.6	10	4.55	0.130
15:35	47	26:06	211	4	26	104	8.3	15	9.76	0.286
16:15	14	48:30	221	5	26	130	5.6	15	3.50	0.072
16:25	34	48:20	211	4	35	140	8.6	20	4.55	0.124
18:15	2	25:32	221	5	32	160	5.0	10	3.25	0.078
18:22	12	25:27	444	12	34	408	52.5	80	32.52	0.976
18:32	22	25:25	211	4	31	124	6.3	10	6.50	0.195
14:45	32	25:20	432	9	36	324	40.0	60	29.92	0.885
AVERAGE		29:58	--	6	32	199	16.5	30	13.26	0.392

TABLE 5.1-2 (continued)

PUSH CHARACTERISTICS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test Pushing-Cycle Particulate 3 Date 4/23/75

Time	Oven Pushed	Net Coking Time	Degree of Greenness				Quench Tower Opacity		Plume Attenuation Coefficient (sec.-meters^{-1})	Maximum Attenuation Coefficient (meters^{-1})
			Rating	Sum (S)	Duration (D)	S*D	Average Percent	Maximum Percent		
08:45	23	26:02	221	5	34	170	5.0	10	5.20	0.137
08:59	33	26:04	321	6	35	210	6.0	10	4.55	0.130
09:14	43	26:02	432	9	38	342	15.8	25	19.52	0.585
10:08	53	26:38	211	4	38	152	11.7	25	6.50	0.174
13:12	5	27:01	222	6	37	222	11.7	25	18.21	0.546
13:27	15	27:02	211	4	35	140	5.8	10	5.20	0.150
13:42	25	26:52	322	7	35	245	14.0	25	22.77	0.664
14:00	35	42:33	212	5	40	200	4.2	10	3.25	0.098
14:14	45	27:02	211	4	38	152	5.8	10	7.16	0.208
14:31	55	27:17	121	4	40	160	2.7	5	4.55	0.130
AVERAGE		28:15	--	5	37	199	8.3	15	9.69	0.282

TABLE 5.1-2 (continued)

PUSH CHARACTERISTICS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test Pushing-Cycle Particulate 4 Date 4/24/75

Time	Oven Pushed	Net Coking Time	Degree of Greenness				Quench Tower Opacity		Plume Attenuation Coefficient (sec.-meters^{-1})	Maximum Attenuation Coefficient (meters^{-1})
			Rating	Sum (S)	Duration (D)	S*D	Average Percent	Maximum Percent		
10:45	13	25:56	432	9	38	342	--	--	24.04	0.533
11:12	23	26:06	312	6	34	204	--	--	6.30	0.141
11:35	33	26:10	212	5	40	200	--	--	8.25	0.195
12:45	43	26:31	421	7	36	252	--	--	34.02	1.067
13:12	53	26:43	344	11	45	495	--	--	95.36	2.602
AVERAGE		26:17	--	8	39	299	--	--	33.59	0.908

5.2 Calculation of Emission Factors

5.2.1 Emission Factor for Coke-Oven Pushing

Because oven pushing accounted for a majority of the particulate captured during pushing-cycle particulate tests, the process weight rates, used in the calculation of emission factors during these tests (Appendix B, Volume 2), were based on the weight of dry coal fed to those ovens pushed and the weight of coke produced during the given test. For example, Table 5.1-2 indicates that 15 ovens were pushed during Pushing-Cycle Particulate Test No. 1. Assuming that each oven was charged with 13.7 tons of dry coal and that 10.5 tons of coke were produced during each push, the process weight represented in this test was 205.5 tons of dry coal or 157.5 tons of coke. Appendix F (Volume 2) indicates that the net test duration was 288 minutes. Therefore, the feed rate was calculated to be 42.8 tons of dry coal per hour, or 32.8 tons of coke per hour.

Using these feed rates and the emission rates from Table 5.1-1, the emission factors for the pushing-cycle and push-only emissions are calculated in Table 5.2.1. By including the contribution of fugitive emissions (see Section 5.3 for documentation of fugitive emissions), the push-only emissions measured by the shed capture system are increased by 10 percent and included in Table 5.2.1.

5.2.2 Emission Factor for Door Leaks

Process weight rates for the non-pushing-cycle particulate tests, which measure door leak emissions, could not be

TABLE 5.2.1

SUMMARY OF PARTICULATE EMISSION FACTORS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test Condition	Test No.	Particulate Emission Rate (lbs/hr)		Process Weight Rate		Particulate Emission Factor			
						Filterable		Total	
		Filterable	Total	tons dry coal/hr	tons coke/hr	lbs/ton dry coal	lbs/ton coke	lbs/ton dry coal	lbs/ton coke
Pushing Cycle	1	20.6	21.7	42.8	32.8	0.48	0.63	0.51	0.66
	2	13.7	16.2	47.1	36.1	0.29	0.38	0.34	0.45
	3	15.7	19.1	41.7	32.0	0.38	0.49	0.46	0.60
	4	29.0	32.2	32.9	25.2	0.88	1.2	0.98	1.3
	Average (1-3)	16.7	19.0	43.9	33.6	0.38	0.50	0.44	0.57
	Average (1-4)	19.8	22.3	41.1	31.5	0.51	0.68	0.57	0.75
Non-Pushing Cycle	1	6.9	7.2	19.1	14.6	0.36	0.47	0.38	0.49
	2	10.0	11.1	19.3	14.8	0.52	0.68	0.58	0.75
	3	3.9	5.3	20.0	15.4	0.20	0.25	0.26	0.34
	Average	6.9	7.9	19.5	14.9	0.36	0.47	0.41	0.53
Push-Only*	1	13.7	14.5	42.8	32.8	0.32	0.42	0.34	0.44
	2	3.7	5.1	47.1	36.1	0.079	0.10	0.11	0.14
	3	11.8	13.8	41.7	32.0	0.28	0.37	0.33	0.43
	Average	9.7	11.1	43.9	33.6	0.23	0.30	0.26	0.34
Push-Only Including Fugitives	1	15.1	16.0	42.8	32.8	0.35	0.46	0.37	0.49
	2	4.1	5.6	47.1	36.1	0.087	0.11	0.12	0.16
	3	13.0	15.2	41.7	32.0	0.31	0.41	0.36	0.48
	Average	10.7	12.3	43.9	33.6	0.25	0.33	0.28	0.38

* Emission factors for push-only emissions (i.e., no door leaks included) are computed by subtracting emission rates and subsequently dividing by the "process weight." Due to the use of two different process weights for pushing and non-pushing cycles, emission factors cannot be subtracted directly.

calculated from pushing data because these test periods inherently excluded coke pushing. Process weights were established by dividing the total weight of dry coal fed to all of the ovens beneath the shed by the average coking time for those ovens containing the coal charge associated with the emissions occurring during that non-pushing-cycle particulate test (Appendix C, Volume 2).

Door leak emission factors, shown in Table 5.2.1, averaged 0.36 pound of filterable particulate per ton of dry coal fed to all ovens producing door leak emissions, or 0.47 pound per ton of coke produced.

5.2.3 Overall Emission Factor

The average overall emission factor for filterable particulate emissions from the coke side of the A Battery is the sum of the emission factor for particulate originating from door leaks and that from coke-oven pushing. Therefore, 0.61 (0.25 + 0.36) pound of filterable particulate per ton of dry coal fed or 0.80 (0.33 + 0.47) pound per ton of coke produced, was emitted from the coke side of the battery. Although the process weights used in computing the two components of the summed emission factor are different (i.e., coal fed to pushed ovens for pushing emissions and coal fed to all ovens for door leaks), the sum is a meaningful indicator of coke-side overall emissions because all leaking ovens are pushed eventually. Thus, the emission factor depends upon the characteristics of the pushes occurring during the testing as well as the degree of door maintenance practiced at the time of field measurements.

5.3 Significance of Fugitive Leaks

Table 5.3-1 summarizes the measurement of particulate emissions escaping from the north end of the shed. During these four tests on April 23, 1975, fugitive particulate emissions from this source ranged from 0.0081 to 0.090 pound per ton of dry coal fed to the coke ovens, or 0.011 to 0.12 pound per ton of coke produced. When these emission factors are compared to the emission factor for filterable particulate measured during Pushing-Cycle Particulate Test 3 on April 23, 1975 (0.38 pound of particulate per ton of dry coal fed), the end leakage ranges from 2 to 19, and averages 9 percent of the emissions from coke-oven pushing. Thus, the average capture efficiency of the shed during pushing was 91 percent, as shown in Table 5.3-2. Then, the total emissions from pushing only were about $\left(\frac{1.00}{0.91}\right)$ or 110 percent of the emissions captured by the shed and measured in the shed exhaust.

The sum of the degree-of-greenness ratings for the five pushes represented in the four fugitive emission estimation tests averaged 5.8. The 10 pushes constituting Pushing-Cycle Particulate Test 3 had an average degree-of-greenness sum of 5.4 (Table 5.1-2). These results indicate that the five pushes represented in the fugitive emission estimation were of the same approximate degree-of-greenness rating as those measured in the particulate test.

Subjectively, there was no visible evidence that door leaks contributed to fugitive emissions; therefore, the total non-pushing-cycle emissions were emitted through the shed capture system. Considering both the pushing and non-pushing cycles, the overall average percent capture efficiency of the shed thus appears to be about 96 percent, as shown in Table 5.3-2.

TABLE 5.3-1

SUMMARY OF FUGITIVE EMISSION ESTIMATION
NORTH END OF SHED

Great Lakes Carbon Corporation
St. Louis, Missouri
April 23, 1975

Fugitive Particulate Test Number	Time	Oven(s) Pushed	Flowrate (SCFM)	Particulate Concentration (gr/SCF)	Particulate Emission Rate (lbs/hr)	Particulate Emission Factor	
						lb/ton dry coal	lb/ton coke
1	14:14 - 14:56	45,55	39,960	0.0103	3.53	0.090	0.12
2	17:10 - 17:14	27	39,960	0.0048	1.66	0.0081	0.011
3	17:18 - 17:23	37	39,960	0.0143	4.91	0.030	0.039
4	17:26 - 17:32	47	39,960	0.0091	3.10	0.023	0.030
A V E R A G E			(39,960)	0.0096	3.30	0.038	0.050

TABLE 5.3-2

SHED PARTICULATE CAPTURE EFFICIENCIES

Great Lakes Carbon Corporation
St. Louis, Missouri
April 23, 1975

Fugitive Particulate Test Number	Particulate Capture Efficiency of the Shed During Coke Oven Pushing (Percent)	Overall Particulate Capture Efficiency of the Shed* (Percent)
1	81	92
2	98	99
3	93	97
4	94	97
Average	91	96

*Overall Efficiency = $\left(\frac{\text{Efficiency during pushing}}{100}\right) * 0.43 + 0.57 \left(\frac{100}{100}\right)$

where the factors, 0.43 and 0.57, represent the fractions of time corresponding to pushing and non-pushing operational modes, respectively, occurring under the shed, and the capture efficiency during non-pushing is estimated to be 100 percent.

Table 5.3-1 indicates that greater emission factors were calculated for emissions leaking from the north end of the shed when ovens at the north end of the shedded A Battery were being pushed. Fugitive Particulate Test 1 (which resulted in a higher emission factor of leaks at the north end of the shed) represented the pushes of ovens 45 and 55, located at the north end of the shed. The smallest fugitive emission factor was estimated during Test No. 2 when Oven No. 27 (center of shed) was pushed.

Although the end leak measurements made on April 23 only included the pushing of five ovens, it was noted that the characteristics of these pushes were similar to those observed during the tests which measured particulate exhausted through the shed capture system. The wind blew from the southeast quadrant during the measurement of fugitive emissions, a direction which is expected to result in maximum emissions from the north end. Wind speeds were approximately 10 miles per hour (Appendix BB, Volume 3), which is somewhat above the annual average wind speed (Appendix CC, Volume 3).

In summary, from these data we conclude that, based on visual evaluation, the shed is less than 100 percent efficient in capturing coke-pushing emissions. An increased leakage rate is observed as a result of higher wind speeds, as a result of pushing occurring near the end of the shed, especially the downwind end, and as a result of pushes with a high degree of greenness. During conditions which were relatively conducive to leakage, average emissions escaping the shed ranged from 0.0081 to 0.090 pound per ton with an average of 0.038 pound per ton of dry coal fed, or 0.050 pound per ton of coke produced.

5.4 Chemical and Physical Characteristics of Particulate Emissions

Tables 5.4-1 and 5.4-2 indicate that the distribution of total particulate catch, for both pushing-cycle and non-pushing-cycle particulate tests, averages 87 percent as filterable particulate and 13 percent as materials captured in the impingers following the filter in the front half of the sampling train.

Cyanide, chloride, and sulfate accounted for minor portions of filterable particulate during both pushing- and non-pushing-cycle particulate tests. Table 5.4-3 indicates that 87 percent of the filterable particulate matter is neither soluble in acetone nor cyclohexane, indicating that a minor portion of the filterable particulate is organic in composition (Figure 4.2). On the other hand, only 22 percent of the particulate captured in the impingers is composed of materials insoluble in cyclohexane, indicating that a majority of this particulate material is of organic composition for both the pushing- and non-pushing-cycle particulate tests. Table 5.4-4 indicates that nearly all particulate fractions were slightly acidic.

X-ray fluorescence analysis of filterable particulate emissions produced during the pushing of a coke oven indicated that the non-carbon portion of the collected particulate contained the elements chlorine, sulfur, silicon, and aluminum with minor amounts of calcium and iron (Appendix G, Volume 2).

Microscopic examination of filterable particulate emissions produced during the pushing of coke revealed a variety of particles which, for the purpose of the analysis, were classified into 8 different categories based on particle morphology, color, birefringence,

TABLE 5.4-1

EMISSION OF PARTICULATE CONTAMINANTS (LBS/HR)
PUSHING CYCLE

Coke Shed
Great Lakes Carbon Corporation
St. Louis, Missouri
April 23, 1975

Test No.		Particulate Fraction					
		Particulate	Cyanide	Chloride	Sulfate	Organics	Inorganics
1	Filterable	20.6	<0.87	0.04	0.25	1.9	18.7
	Back-half	1.1	<1.2	0.45	1.2	0.60	0.51
	Total	21.7	<2.1	0.49	1.4	2.5	19.2
2	Filterable	13.7	<0.72	0.10	0.07	0.43	13.2
	Back-half	2.5	<0.91	0.62	0.37	1.9	0.59
	Total	16.2	<1.6	0.72	0.44	2.4	13.8
3	Filterable	15.7	<0.69	0.12	0.17	3.2	12.5
	Back-half	3.4	<1.3	0.62	0.64	3.1	0.27
	Total	19.1	<2.0	0.74	0.81	6.3	12.8
4	Filterable	29.0	<1.0	0.21	0.15	5.1	23.9
	Back-half	3.2	<2.0	0.74	0.78	2.4	0.78
	Total	32.2	<3.0	0.94	0.93	7.5	24.7
Average (1-3)	Filterable	16.7	<0.76	0.09	0.16	1.8	14.8
	Back-half	2.3	<1.1	0.56	0.74	1.9	0.46
	Total	19.0	<1.9	0.65	0.88	3.7	15.3

TABLE 5.4-2

EMISSION OF PARTICULATE CONTAMINANTS (LBS/HR)
NON-PUSHING CYCLE

Coke Shed
Great Lakes Carbon Corporation
St. Louis, Missouri
April 23, 1975

Test No.		Particulate Fraction					
		Particulate	Cyanide	Chloride	Sulfate	Organics	Inorganics
1	Filterable	6.9	<1.3	0.11	<0.06	0.80	6.1
	Back-half	0.37	<1.0	0.33	0.12	0.37	<0.06
	Total	7.2	<2.3	0.44	0.12	1.2	6.1
2	Filterable	10.0	<0.95	0.19	0.15	1.5	8.5
	Back-half	1.1	<0.86	0.24	0.41	0.50	0.63
	Total	11.1	<1.8	0.43	0.56	2.0	9.1
3	Filterable	3.9	<0.76	0.07	<0.03	0.61	3.3
	Back-half	1.4	<0.95	0.36	<0.04	1.1	0.32
	Total	5.3	<1.7	0.43	<0.07	1.7	3.6
Average	Filterable	6.9	<1.0	0.12	0.05-0.08	0.97	6.0
	Back-half	0.96	<0.94	0.31	0.18-0.19	0.66	0.32-0.34
	Total	7.9	<1.9	0.43	0.23-0.25	1.6	6.3

TABLE 5.4-3

CHARACTERIZATION OF PARTICULATE WEIGHT

(Referenced to Flow Diagram in Figure 4.2)

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test	Particulate fraction, weight in grams												
	A	B	C	D*	E	F*	G	H*	J*	K	L*	M	N$^{\Delta}$
Non-pushing 1	0.0546	0.00113	0.0052	0.0505	0.0033	0.0019	0.0013	0.0492	0.0009	0.0010	0.0059	0.0433	0.0068
Pushing 1	0.2602	0.02482	0.0160	0.2690	0.0122	0.0038	0.0104	0.2586	0.0019	0.0019	0.0349	0.2237	0.0368

* By Difference

$^{\Delta}$ By Sum

TABLE 5.4-3 (continued)

CHARACTERIZATION OF PARTICULATE WEIGHT

(Referenced to Flow Diagram in Figure 4.2)

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test	Particulate fraction, weight in grams								
	P	Q	R	S*	T*	U	V*	W	X△
Non-pushing 2	0.0416	0.05236	0.0139	0.0801	0.0069	0.0070	0.0487	0.0314	0.0556
Non-pushing 3	0.0124	0.02474	0.0058	0.0313	0.0016	0.0042	0.0077	0.0236	0.0093
Pushing 2	0.1099	0.01965	0.0041	0.1254	0.0029	0.0012	0.0761	0.0493	0.0790
Pushing 3	0.1361	0.01311	0.0307	0.1185	0.0072	0.0235	0.0067	0.1118	0.0139
Pushing 4	0.1440	0.03058	0.0305	0.1441	0.0073	0.0232	0.1309	0.0132	0.1382

* By Difference

△ By Sum

TABLE 5.4-3 (continued)
CHARACTERIZATION OF PARTICULATE WEIGHT
(Referenced to Flow Diagram in Figure 4.2)

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test	Particulate fraction, weight in grams								
	AA	BB	CC	DD*	EE*	FF	GG*	HH	JJ$^{\Delta}$
Non-pushing 1	<0.0005	0.0030	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Non-pushing 2	0.0059	0.0047	0.0008	0.0051	0.0008	<0.0005	0.0045	0.0006	0.0053
Non-pushing 3	0.0030	0.0102	<0.0005	0.0030	<0.0005	<0.0005	0.0027	0.0003	0.0027
Pushing 1	0.0071	0.0083	0.0030	0.0041	0.0030	<0.0005	0.0039	0.0002	0.0069
Pushing 2	0.0056	0.0183	0.0012	0.0044	0.0012	<0.0005	0.0039	0.0005	0.0051
Pushing 3	0.0026	0.0292	<0.0005	0.0026	<0.0005	<0.0005	0.0023	0.0003	0.0023
Pushing 4	0.0047	0.0144	0.0009	0.0038	0.0009	<0.0005	0.0037	0.0001	0.0046

* By Difference

$^{\Delta}$ By Sum

TABLE 5.4-4

SUMMARY OF WATER SOLUBLE pH
AND ACIDITY/ALKALINITY ON PARTICULATE SAMPLES

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Sampling Conditions	Test Number	Portion of Sampling Train	pH	Acidity (meq/gm)
Non-pushing Cycle	1	Front Back	6.8 5.0	<0.0001 <0.007
	2	Front Back	6.5 3.7	<0.00003 0.01
	3	Front Back	7.5 5.8	<0.00005 <0.001
Pushing Cycle	1	Front Back	5.0 4.0	0.00006 0.008
	2	Front Back	6.2 3.8	<0.00002 0.004
	3	Front Back	6.2 4.3	<0.00001 0.002
	4	Front Back	6.8 4.0	<0.00001 0.002

and surface characteristics. The bulk of the particles were naturally coke and partially-coked coal. Significant amounts of coal and mineral particles were also present. The size of the particles ranged from sub-micron to about 100 microns depending on the type of particle, with a typical size mode of about three microns. Green pushes seemed to generate a greater amount of submicron particles (0.5 - 1 micron) than clean pushes, although it was difficult to draw conclusions on the difference between normal pushes and green pushes when so few samples were available for examination. Particle characterizations for each of the five filter samples analyzed are summarized in the letter report prepared by the IIT Research Institute, Chicago, Illinois, shown in Appendix H (Volume 2).

5.5 Particle Size Analysis

The size distributions of particulate, as measured by the Brink and Andersen impactor methods (Appendix D, Volume 2), are presented graphically in Figures 5.5-1 and 5.5-2, respectively. A statistical comparison (chi-square test for independence) of the percentage of particulate less than one micron and the percentage less than five microns shows no significant differences among the 14 particle size distributions. The average of the nine Brink-method tests indicates 10 percent of the particulate to be less than one micron, whereas the average of the five Andersen-method samples shows 13 percent of the particulate to be submicron. Thus, overall, an average of 12 percent of the particulate was submicron.

Table 5.5-1 displays the characteristics of the pushes occurring beneath the shed during the particle size tests.

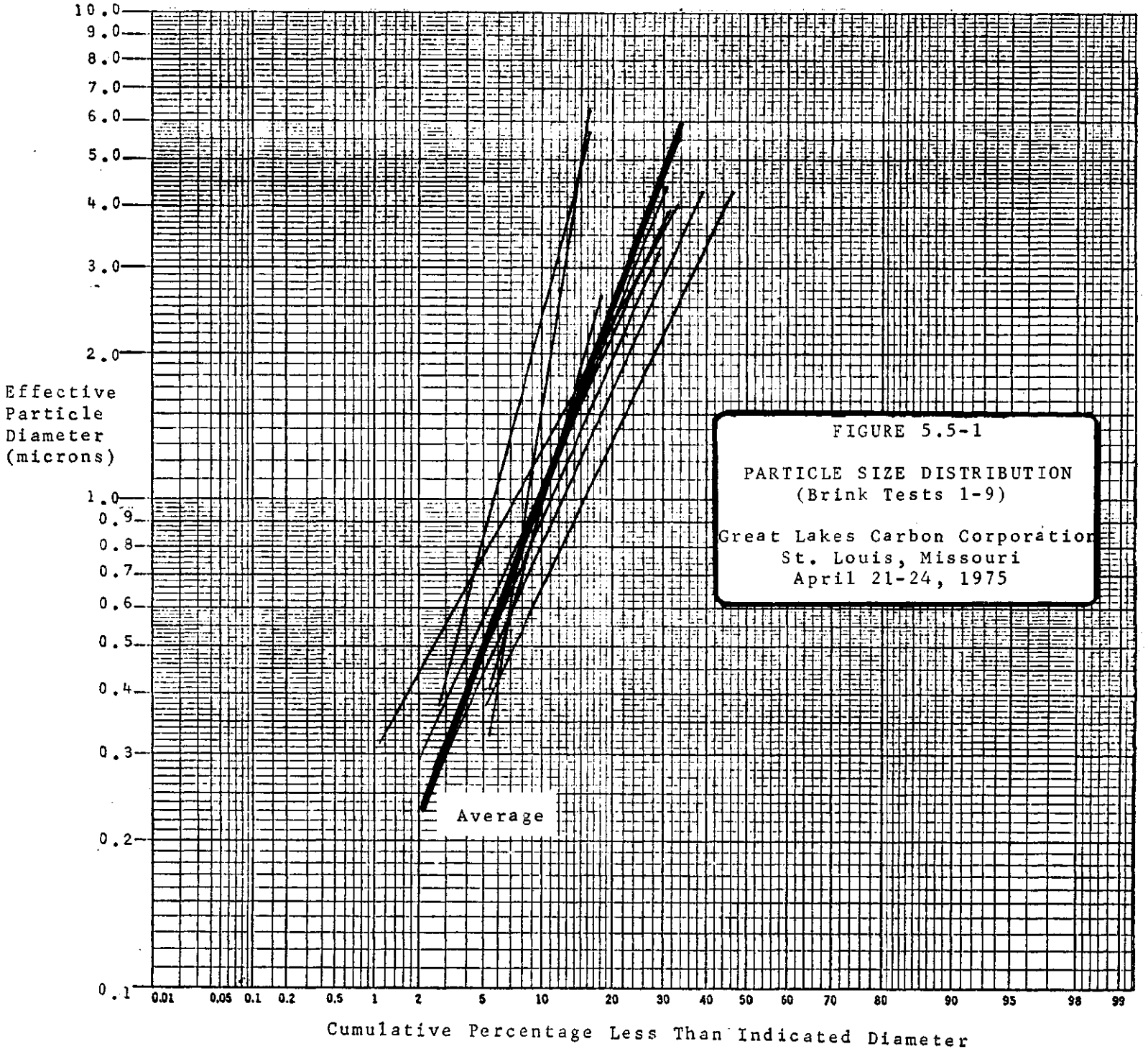


FIGURE 5.5-1

PARTICLE SIZE DISTRIBUTION
(Brink Tests 1-9)

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

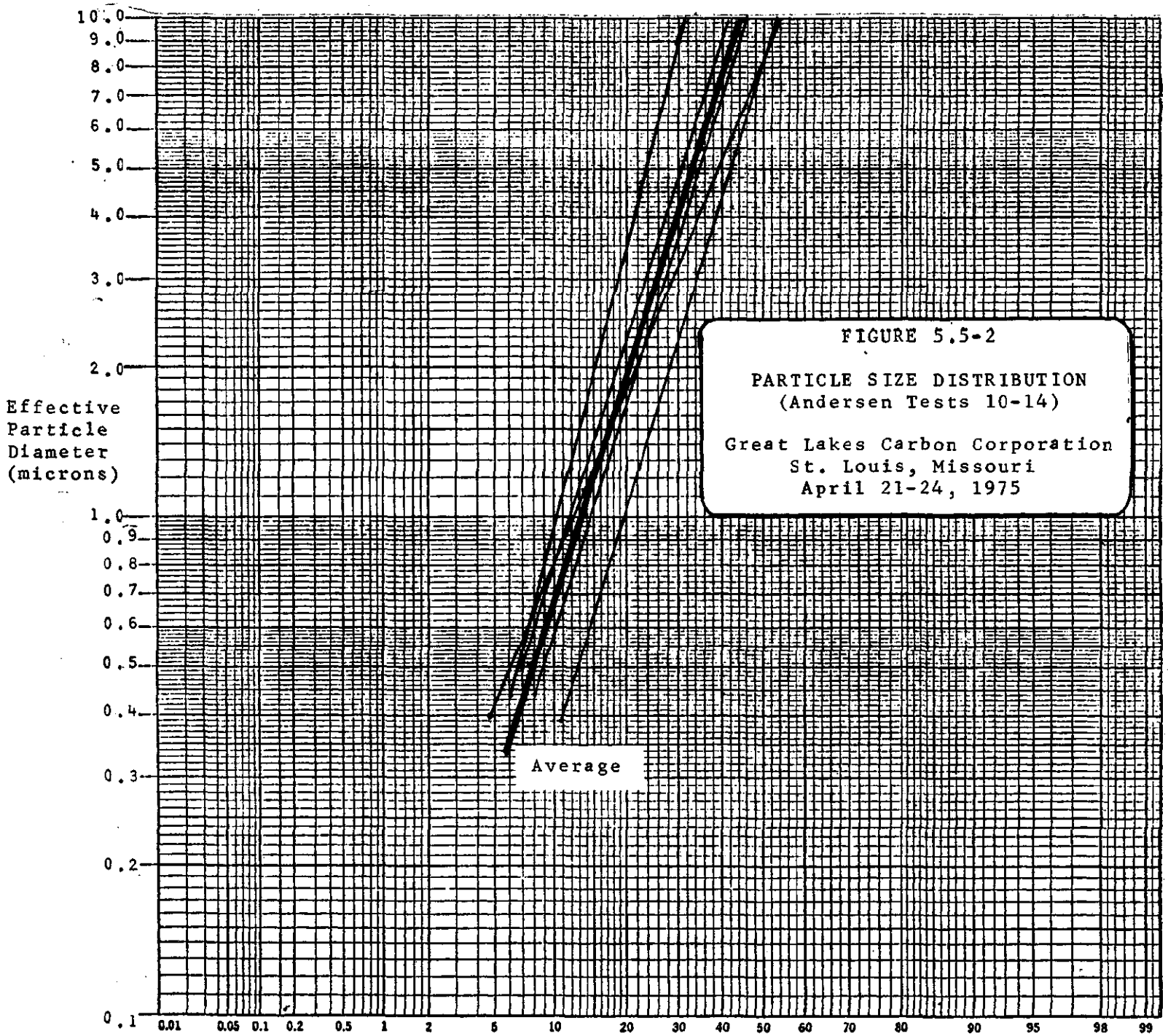


FIGURE 5.5-2

PARTICLE SIZE DISTRIBUTION
(Andersen Tests 10-14)

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

TABLE 5.5-1

PUSH CHARACTERISTICS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test Pushing-Cycle Particle Size 1 Date 4/22/75

Time	Oven Pushed	Net Coking Time	Degree of Greenness				Quench Tower Opacity		Plume Attenuation Coefficient (sec.-meters^{-1})	Maximum Attenuation Coefficient (meters^{-1})
			Rating	Sum (S)	Duration (D)	S*D	Average Percent	Maximum Percent		
09:50	5	27:50	131	5	32	160	17.0	30	6.50	0.195
10:04	15	27:46	221	5	29	145	7.5	15	2.60	0.104
10:21	25	27:45	332	8	33	264	33.0	60	29.92	0.885
AVERAGE		27:47	--	6	31	190	19.2	35	13.01	0.395

TABLE 5.5-1 (Continued)
PUSH CHARACTERISTICS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test Pushing-Cycle Particle Size 2 & 3 Date 4/22/75

Time	Oven Pushed	Net Coking Time	Degree of Greenness				Quench Tower Opacity		Plume Attenuation Coefficient (sec.-meters^{-1})	Maximum Attenuation Coefficient (meters^{-1})
			Rating	Sum (S)	Duration (D)	S*D	Average Percent	Maximum Percent		
14:08	7	27:12	232	7	32	224	15.0	30	17.85	0.650
14:21	17	26:01	432	9	35	315	26.7	50	25.50	0.703
14:32	27	25:40	221	5	33	165	8.0	10	7.99	0.217
15:20	37	26:05	111	3	31	93	5.6	10	4.55	0.130
15:35	47	26:06	211	4	26	104	8.3	15	9.76	0.286
16:15	14	48:30	221	5	26	130	5.6	15	3.50	0.072
16:25	34	48:20	211	4	35	140	8.6	20	4.55	0.124
AVERAGE		32:33	--	5	31	167	11.1	20	10.53	0.312

TABLE 5.5-1 (Continued)

PUSH CHARACTERISTICS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test Pushing-Cycle Particle Size 4 & 5 Date 4/22/75

Time	Oven Pushed	Net Coking Time	Degree of Greenness				Quench Tower Opacity		Plume Attenuation Coefficient (sec.-meters^{-1})	Maximum Attenuation Coefficient (meters^{-1})
			Rating	Sum (S)	Duration (D)	S*D	Average Percent	Maximum Percent		
18:15	2	25:32	221	5	32	160	5.0	10	3.25	0.078
18:22	12	25:27	444	12	34	408	52.5	80	32.52	0.976
18:32	22	25:25	211	4	31	124	6.3	10	6.50	0.195
18:45	32	25:20	432	9	36	324	40.0	60	29.92	0.885
AVERAGE		25:26	--	8	33	254	26.0	40	18.05	0.534

TABLE 5.5-1 (Continued)

PUSH CHARACTERISTICS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test Pushing-Cycle Particle Size 6 & 7 Date 4/23/75

Time	Oven Pushed	Net Coking Time	Degree of Greenness				Quench Tower Opacity		Plume Attenuation Coefficient (sec.-meters^{-1})	Maximum Attenuation Coefficient (meters^{-1})
			Rating	Sum (S)	Duration (D)	S*D	Average Percent	Maximum Percent		
09:14	43	26:02	432	9	38	342	15.8	25	19.52	0.585
10:08	53	26:38	211	4	38	152	11.7	25	6.50	0.174
13:12	5	27:01	222	6	37	222	11.7	25	18.21	0.546
13:27	15	27:02	211	4	35	140	5.8	10	5.20	0.150
13:42	25	26:52	322	7	35	245	14.0	25	22.77	0.664
14:00	35	42:33	212	5	40	200	4.2	10	3.25	0.098
14:14	45	27:02	211	4	38	152	5.8	10	7.16	0.208
14:31	55	27:17	121	4	40	160	2.7	5	4.55	0.130
AVERAGE		28:48	--	5	38	202	9.0	15	10.90	0.319

TABLE 5.5-1 (Continued)

PUSH CHARACTERISTICS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test Pushing-Cycle Particle Size 8 & 9 Date 4/23/75

Time	Oven Pushed	Net Coking Time	Degree of Greenness				Quench Tower Opacity		Plume Attenuation Coefficient (sec.-meters^{-1})	Maximum Attenuation Coefficient (meters^{-1})
			Rating	Sum (S)	Duration (D)	S*D	Average Percent	Maximum Percent		
16:50	7	26:25	214	7	31	217	20.8	45	33.76	1.236
16:55	17	26:19	342	9	30	270	8.3	20	14.27	0.390
17:10	27	25:40	342	9	30	270	15.8	35	75.07	1.952
17:20	37	25:25	221	5	30	150	9.0	20	15.35	0.585
17:27	47	25:22	421	7	29	230	6.7	15	14.49	0.546
AVERAGE		25:50	--	7	30	227	12.1	25	30.59	0.942

TABLE 5.5-1 (Continued)
PUSH CHARACTERISTICS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test Pushing-Cycle Particle Size 10 Date 4/23/75

Time	Oven Pushed	Net Coking Time	Degree of Greenness				Quench Tower Opacity		Plume Attenuation Coefficient (sec.-meters^{-1})	Maximum Attenuation Coefficient (meters^{-1})
			Rating	Sum (S)	Duration (D)	S*D	Average Percent	Maximum Percent		
13:12	5	27:01	222	6	37	222	11.7	25	18.21	0.546
13:27	15	27:02	211	4	35	140	5.8	10	5.20	0.150
13:42	25	26:52	322	7	35	245	14.0	25	22.77	0.664
14:00	35	42:33	212	5	40	200	4.2	10	3.25	0.098
14:14	45	27:02	211	4	38	152	5.8	10	7.16	0.208
AVERAGE		30:18	--	5	37	192	8.3	15	11.32	0.333

TABLE 5.5-1 (Continued)
PUSH CHARACTERISTICS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test Pushing-Cycle Particle Size 11 Date 4/23/75

Time	Oven Pushed	Net Coking Time	Degree of Greenness				Quench Tower Opacity		Plume Attenuation Coefficient (sec.-meters^{-1})	Maximum Attenuation Coefficient (meters^{-1})
			Rating	Sum (S)	Duration (D)	S*D	Average Percent	Maximum Percent		
17:10	27	25:40	342	9	30	270	15.8	35	75.07	1.952
17:20	37	25:25	221	5	30	150	9.0	20	15.35	0.585
17:27	47	25:22	421	7	29	203	6.7	15	14.49	0.546
AVERAGE		25:29	--	7	30	208	10.5	25	34.97	1.028

TABLE 5.5-1 (Continued)

PUSH CHARACTERISTICS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test Pushing-Cycle Particle Size 12 Date 4/24/75

Time	Oven Pushed	Net Coking Time	Degree of Greenness				Quench Tower Opacity		Plume Attenuation Coefficient (sec.-meters^{-1})	Maximum Attenuation Coefficient (meters^{-1})
			Rating	Sum (S)	Duration (D)	S*D	Average Percent	Maximum Percent		
08:25	51	26:50	--	--	--	--	--	--	--	--
AVERAGE		26:50	--	--	--	--	--	--	--	--

TABLE 5.5-1 (Continued)

PUSH CHARACTERISTICS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test Pushing-Cycle Particle Size 13 Date 4/24/75

Time	Oven Pushed	Net Coking Time	Degree of Greenness				Quench Tower Opacity		Plume Attenuation Coefficient (sec.-meters^{-1})	Maximum Attenuation Coefficient (meters^{-1})
			Rating	Sum (S)	Duration (D)	S*D	Average Percent	Maximum Percent		
10:45	13	25:56	432	9	38	342	--	--	24.04	0.533
11:12	23	26:06	312	6	34	204	--		6.30	0.141
AVERAGE		26:01	--	8	36	273	--	--	15.17	0.337

TABLE 5.5-1 (Continued)

PUSH CHARACTERISTICS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test Pushing-Cycle Particle Size 14 Date 4/24/75

Time	Oven Pushed	Net Coking Time	Degree of Greenness				Quench Tower Opacity		Plume Attenuation Coefficient (sec.-meters^{-1})	Maximum Attenuation Coefficient (meters^{-1})
			Rating	Sum (S)	Duration (D)	S*D	Average Percent	Maximum Percent		
12:45	43	26:31	421	7	36	252	--	--	34.02	1.067
13:12	53	26:43	344	11	45	495	--	--	95.36	2.602
AVERAGE		26:37	--	9	40	374	--	--	64.69	1.834

No correlation could be found between variations in size distribution (fractions less than one and five microns) measured during each of the individual tests and average net coking time for ovens pushed during each test (Table 5.5-1). Oven temperatures, however, were found to be statistically significantly correlated with the percentage of particles less than five microns in diameter, but not with the percentage less than one micron in diameter. (Oven temperature data were considered proprietary information and are not included in this report.)

The percentage of organic material (i.e., soluble in acetone and cyclohexane) present in particle size samples was determined by extracting the residue collected in the cyclone or the zero stage and on a combination of two or more lower stages (see Appendix D, Volume 2). For the Brink samples, the mean organic content of the particulate matter caught in the cyclone or zero stage, 12.1 percent, was found to be significantly less than the mean organic content for the combination of all other stages, 44.6 percent. The average cyclone or zero stage cut-off was 6.6 microns for these tests. A similar result was obtained for the Andersen samples. The organic content of the combined residue for the fourth stage through the final filter was found to be significantly greater than that of the combined residues from stages 0 and 1 and the combined residues from stages 2 and 3. The cut-off for this final portion of the sample averaged 3.6 microns and the mean organic content was 36.9 percent.

The concentration of filterable particulate matter has also been calculated for each of the particle sizing samples. The results,

displayed in Table 5.5-2, indicate a range from 0.007 to 0.089 gr/DSCF. In consideration of the relatively short sampling period used for these tests, the results, on a whole, compare favorably with those obtained during the pushing-cycle particulate tests.

5.6 Door Leak Rates

The leaking of coke-side oven doors is more apparent immediately after the charging of an oven than late in the coking period. Figure 5.6 shows the frequency of oven leaks at various times after oven charging. These data were accumulated from those found in Appendix Y (Volume 3) and proprietary production data. Appendix Y indicates which ovens were observed to be leaking at various observation times during the study. The 75 leaking-door observations indicated in Figure 5.6 show a gradual decay of frequency of door leaks as a function of the residence time of the coal in the charged oven. These data suggest that volatile materials from the coked coal are emitted at greater rates at the beginning of the coking period than later in the coking period.

5.7 Emission-Related Correlations

5.7.1 Correlations Between Pushing-Cycle Filberable Particulate Emission Factors and Operating Data

The source testing in this project yielded four pushing-cycle particulate tests for which emission factors have been computed in terms of pounds per ton of dry coal fed and pounds per ton of coke produced. One of the objectives of the project was to identify the operational variables which may affect the level of the emission factor, such as net coking time and average oven temperature. Another was to identify optical

TABLE 5.5-2

CONCENTRATION OF PARTICULATE MATTER
CALCULATED FROM PARTICLE SIZING SAMPLES

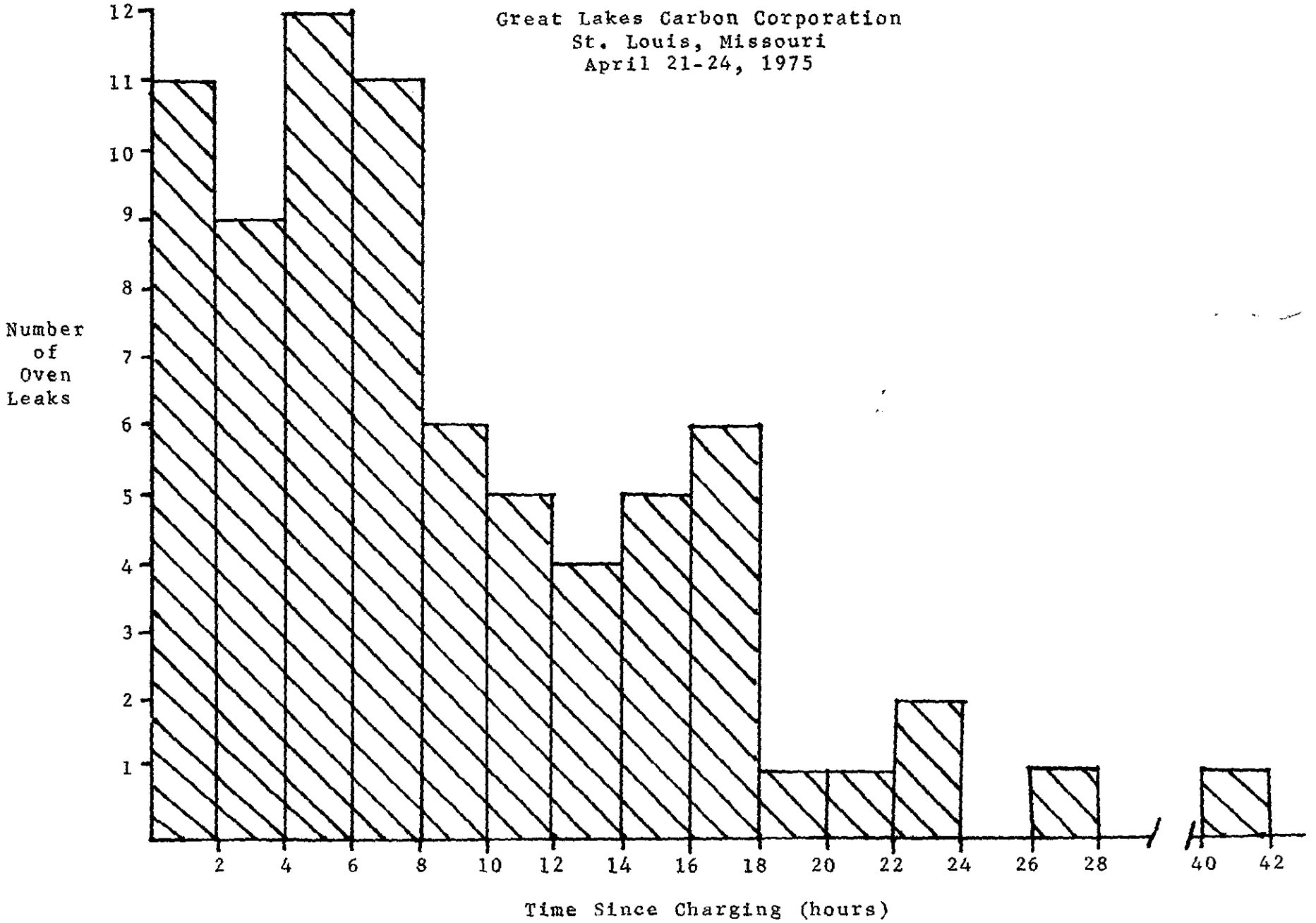
Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Test No.	1975 Date	Sampling Period		Sampled Volume (DSCF)	Sample Weight (mg)	Particulate Concentration (gr/DSCF)
		Start	Stop			
Brink-1	4-22	09:43	10:33	4.32	7.6	0.027
Brink-2	4-22	14:05	16:28	10.8	13.7	0.020
Brink-3	4-22	14:05	16:28	11.1	10.0	0.014
Brink-4	4-22	18:09	18:59	4.27	6.9	0.025
Brink-5	4-22	18:09	18:59	3.89	7.3	0.029
Brink-6	4-23	09:16	15:00	16.9	10.9	0.010
Brink-7	4-23	09:16	15:00	15.2	7.2	0.007
Brink-8	4-23	16:40	17:35	4.31	7.3	0.026
Brink-9	4-23	16:40	17:35	4.31	9.5	0.034
Andersen-10	4-23	13:02	14:22	69.0	94.3	0.021
Andersen-11	4-23	17:12	17:24	9.33	32.0	0.053
Andersen-12	4-24	08:28	08:41	10.4	18.7	0.028
Andersen-13	4-24	10:34	11:24	41.9	40.4	0.015
Andersen-14	4-24	12:46	13:26	35.0	202.3	0.089

FIGURE 5.6

COKE-SIDE DOOR LEAKS AFTER OVEN CHARGING

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975



emission characteristics which correlate with the emission factors. Because of the very limited data set, it is difficult to examine the effect of several variables acting simultaneously. Therefore, the relationships between the particulate emission factors, operating parameters, and optical plume characteristics are examined by consideration of only one "independent" variable at a time.

The emission factors, in terms of pounds of filterable particulate per ton of dry feed, were plotted as a function of the average net coking time for each of the four pushing-cycle particulate tests (Figure 5.7.1-1). As expected, the more fully-coked product (longer net coking time) results in reduced filterable particulate emission factors. A log-log relationship was found to yield a superior statistically significant relationship for the four sets of data available from this study.

Figure 5.7.1-2 displays the filterable particulate emission factors as a function of average oven temperature. (Again, oven temperature data were considered proprietary and not included in this report.) Based upon the limited data acquired, the correlation is not significant. This may be due to the fact that oven temperatures are recorded only once per shift by plant personnel; thus, the single reading may not represent the actual range of temperatures for those ovens pushed during a particulate test. Additionally, only three particulate samples are available during which oven temperatures were recorded.

FIGURE 5.7.1-1

EFFECTS OF COKING TIME ON PARTICULATE EMISSIONS
COKING TIME VERSUS FILTERABLE PARTICULATE EMISSIONS
PUSHING-CYCLE PARTICULATE TESTS 1-4

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

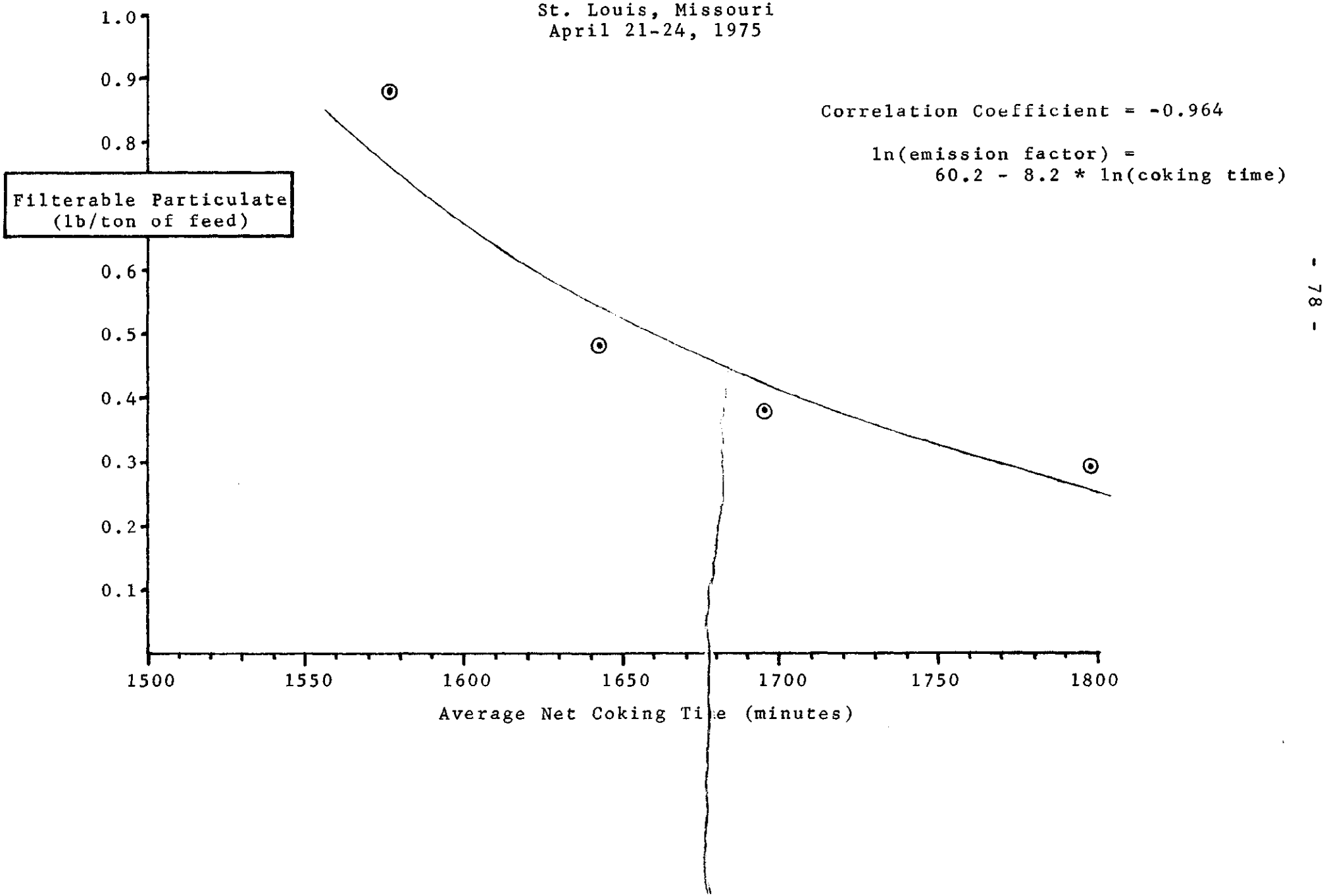
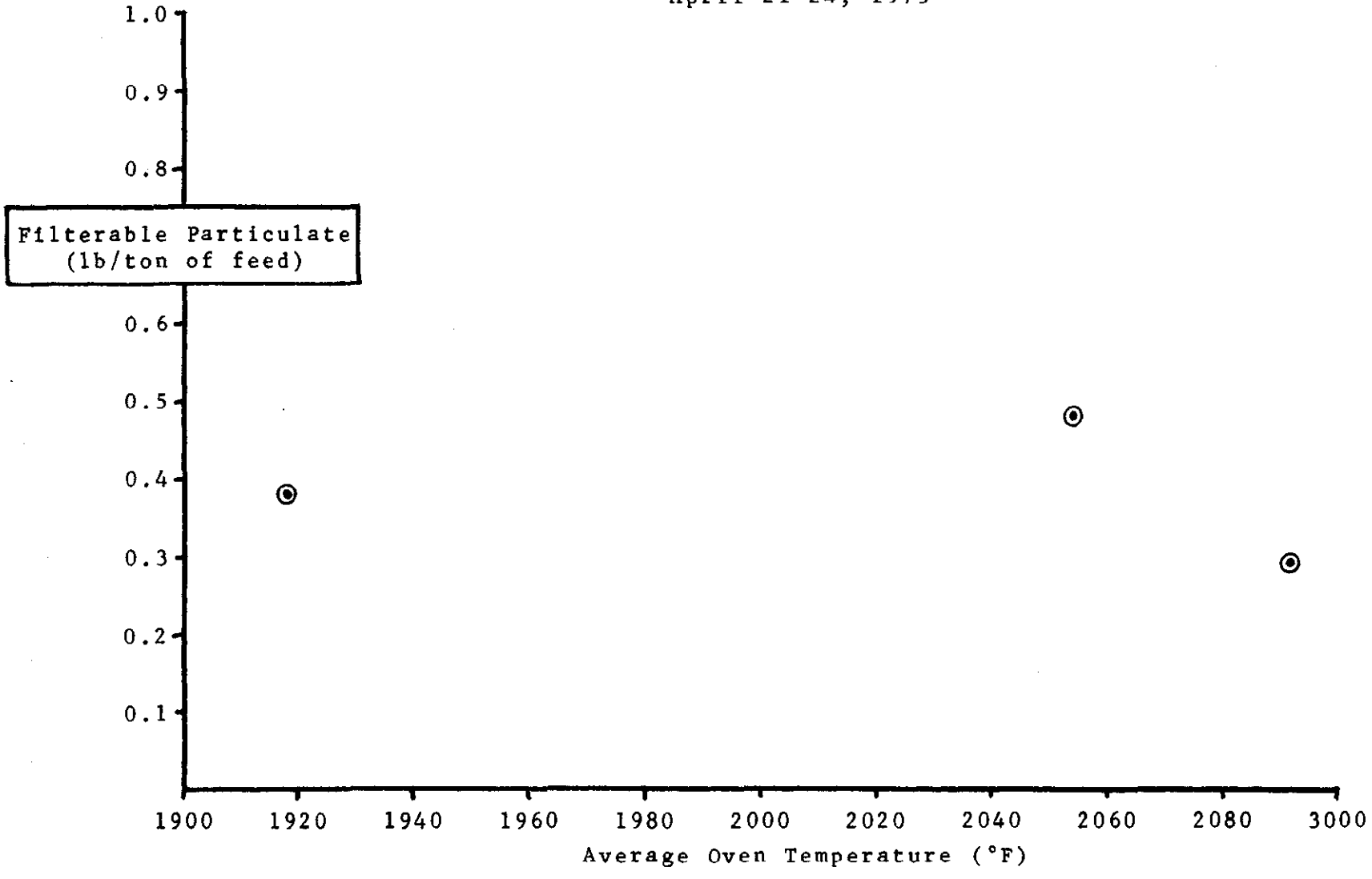


FIGURE 5.7.1-2

AVERAGE OVEN TEMPERATURE VERSUS FILTERABLE PARTICULATE EMISSIONS
PUSHING-CYCLE PARTICULATE TESTS 1-3

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975



5.7.2 Correlations Between Pushing-Cycle Filterable Particulate Emission Factors and Indices of Visible Emissions

Filterable particulate emission factors exhibited a statistically significant correlation with the average degree-of-greenness ratings for the tests (Figure 5.7.2-1). Unfortunately, as shown in Table 5.1-2, Pushing-Cycle Particulate Tests 1, 2, and 3 resulted in identical average degree-of-greenness ratings, an occurrence which limits the usefulness of correlation analysis when so few data are available; nevertheless, the empirical correlation is dramatic in this case.

The two parameters of optical density measured with the transmissometer were each plotted against the filterable particulate emission factor, pounds per ton of dry feed, for the four pushing-cycle particulate tests. Figure 5.7.2.-2 shows the filterable particulate emission factor as a function of the average maximum attenuation coefficients for the pushes included in a particulate test. Although the linear relationship between these two variables appears to be reasonable, a statistically significant correlation was not found, due to the limited amount of data. Figure 5.7.2-3 presents emission factors as a function of the plume attenuation coefficient integrated over time. The correlation in this case was found to be statistically significant. Both plots indicate that Test 2 resulted in a somewhat lower particulate emission than would be expected from the results of the other three tests, based on transmissometer data. Nevertheless, increased optical density obviously accompanied elevated filterable particulate emission factors during the four pushing-cycle particulate tests.

FIGURE 5.7.2-1

DEGREE OF GREENNESS VERSUS FILTERABLE PARTICULATE EMISSIONS
PUSHING-CYCLE PARTICULATE TESTS 1-4

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

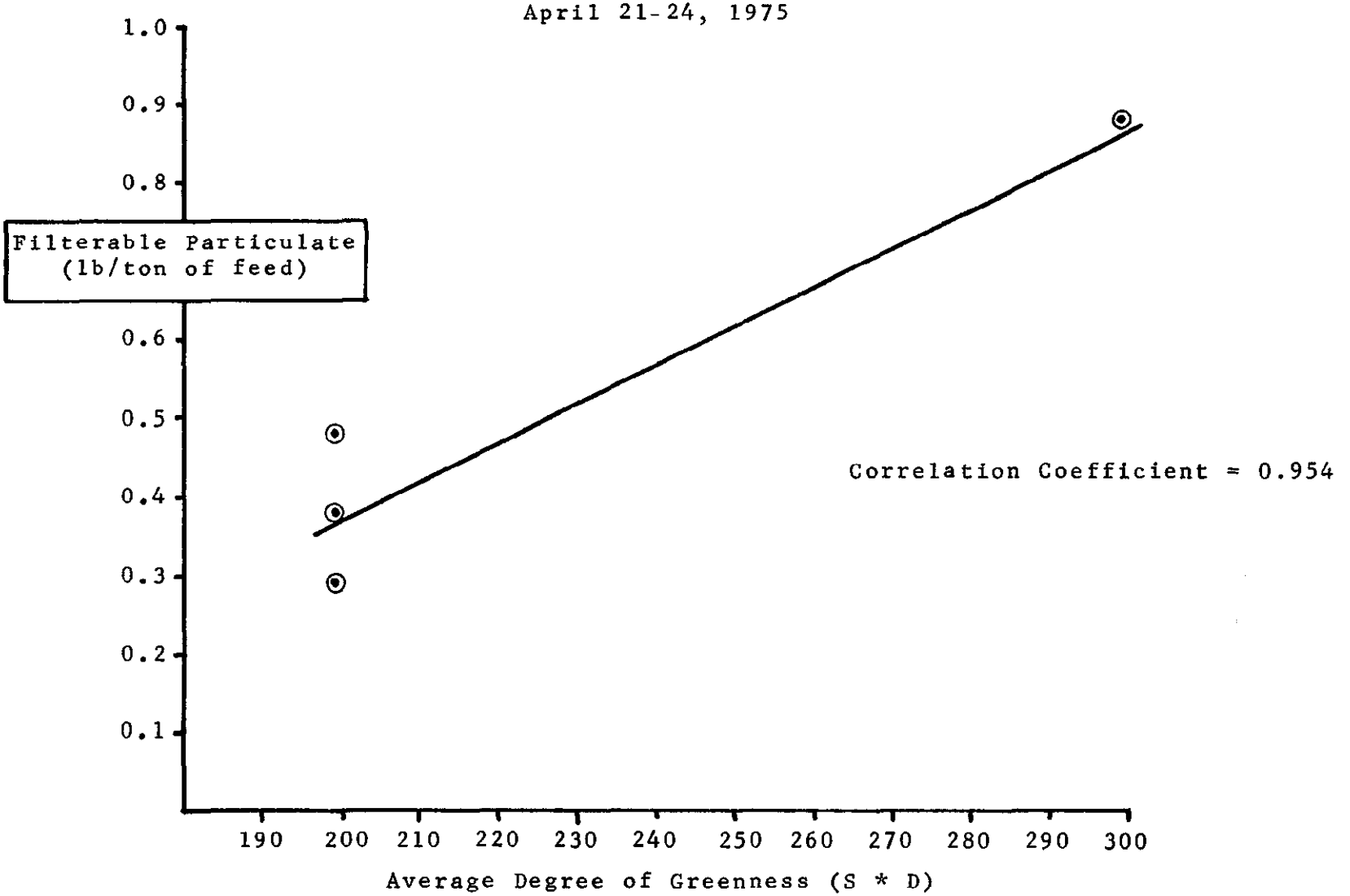


FIGURE 5.7.2-2

MAXIMUM ATTENUATION COEFFICIENT VERSUS FILTERABLE PARTICULATE EMISSIONS
PUSHING-CYCLE PARTICULATE TESTS 1-4

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

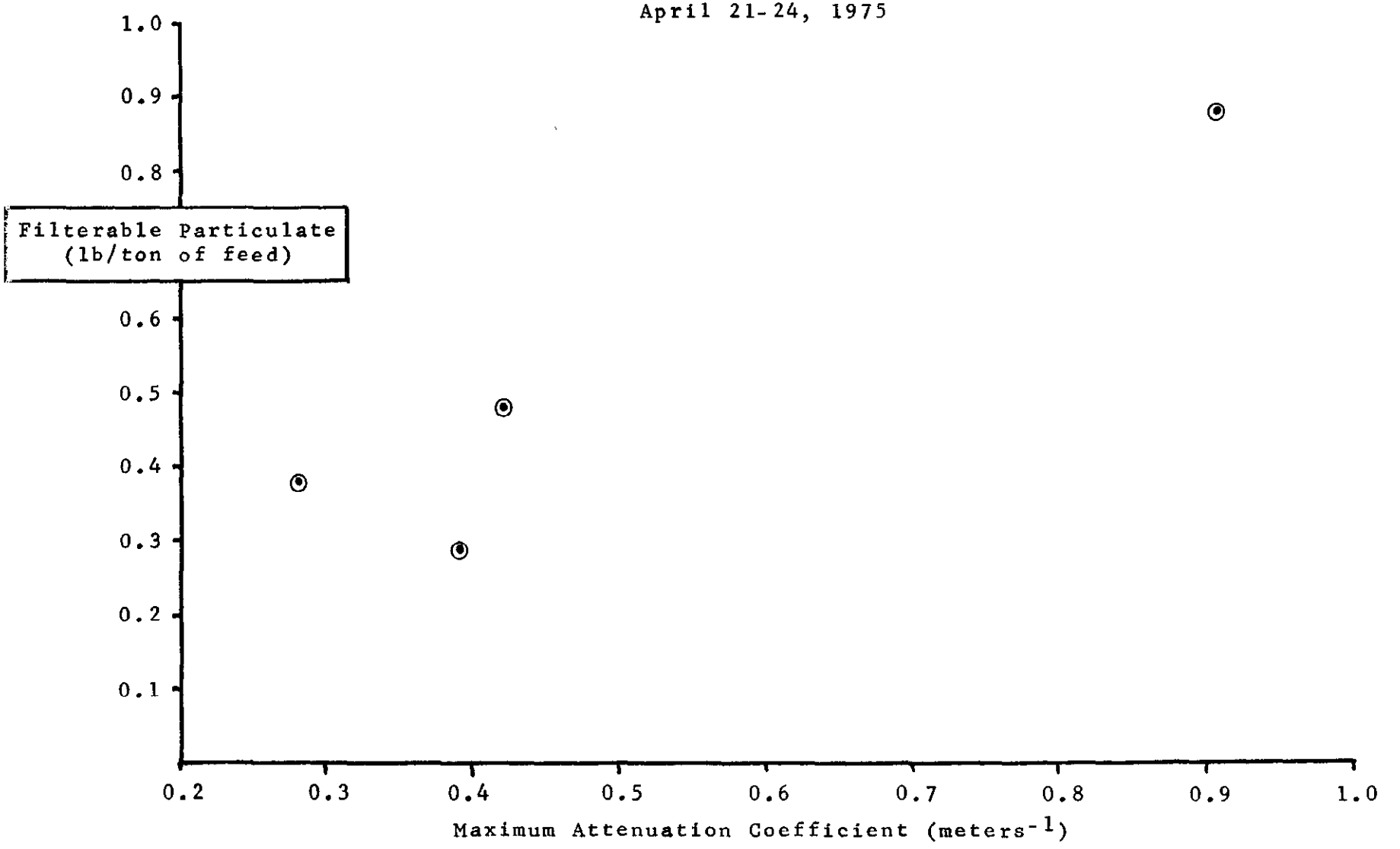
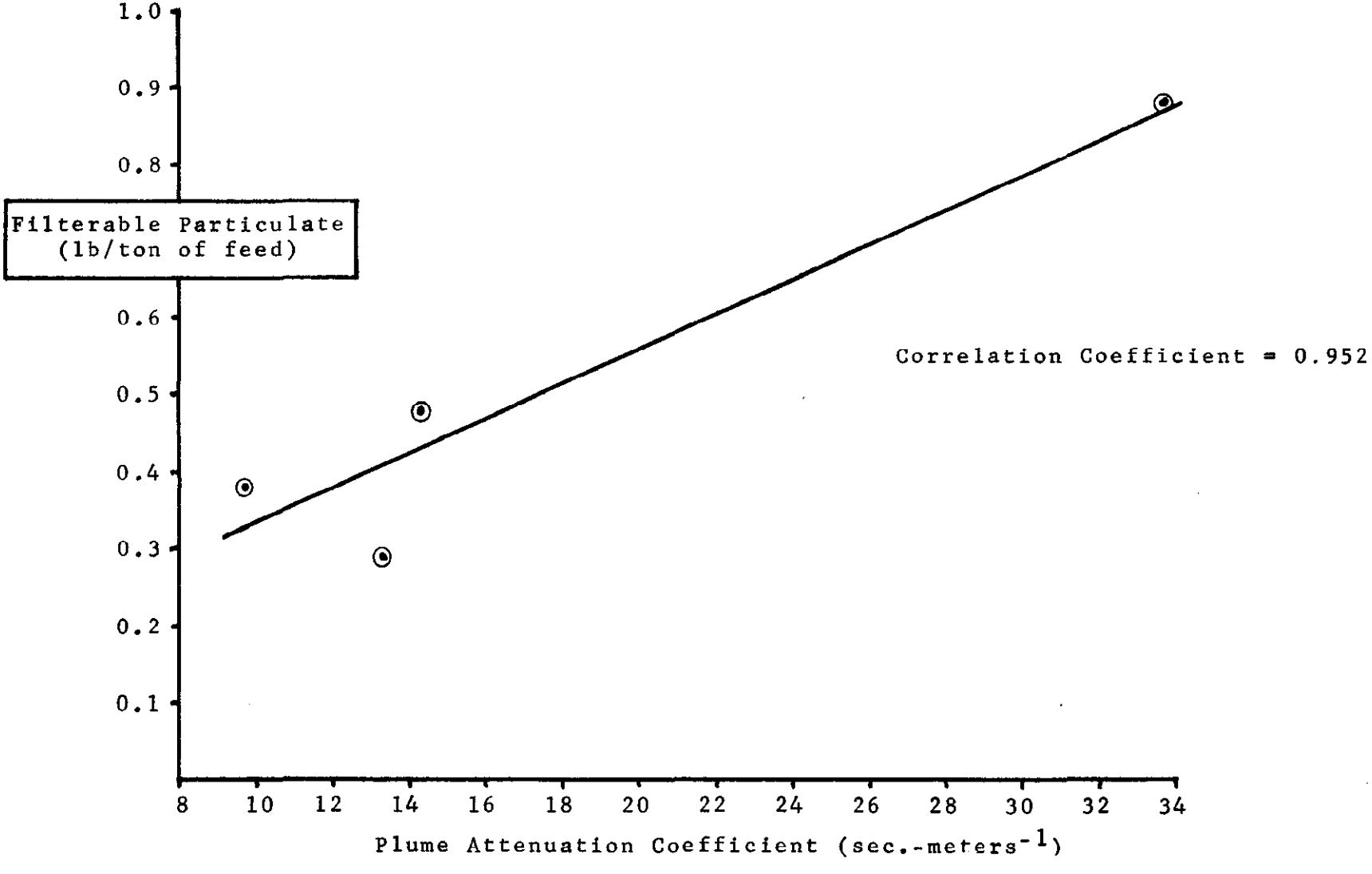


FIGURE 5.7.2-3

PLUME ATTENUATION COEFFICIENT VERSUS FILTERABLE PARTICULATE EMISSIONS
PUSHING-CYCLE PARTICULATE TESTS 1-4

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975



Quench tower opacity data were not found to be statistically significantly correlated with filterable particulate emission factors for pushing-cycle tests. This lack of correlation may be attributable to the small amount of data and the limitation of reading opacities in the presence of the steam plume from the quenching operation. Figure 5.7.2-4 displays a graph of quench tower opacity as a function of filterable particulate emission factor.

5.7.3 Correlations Among Visible Emissions Parameters

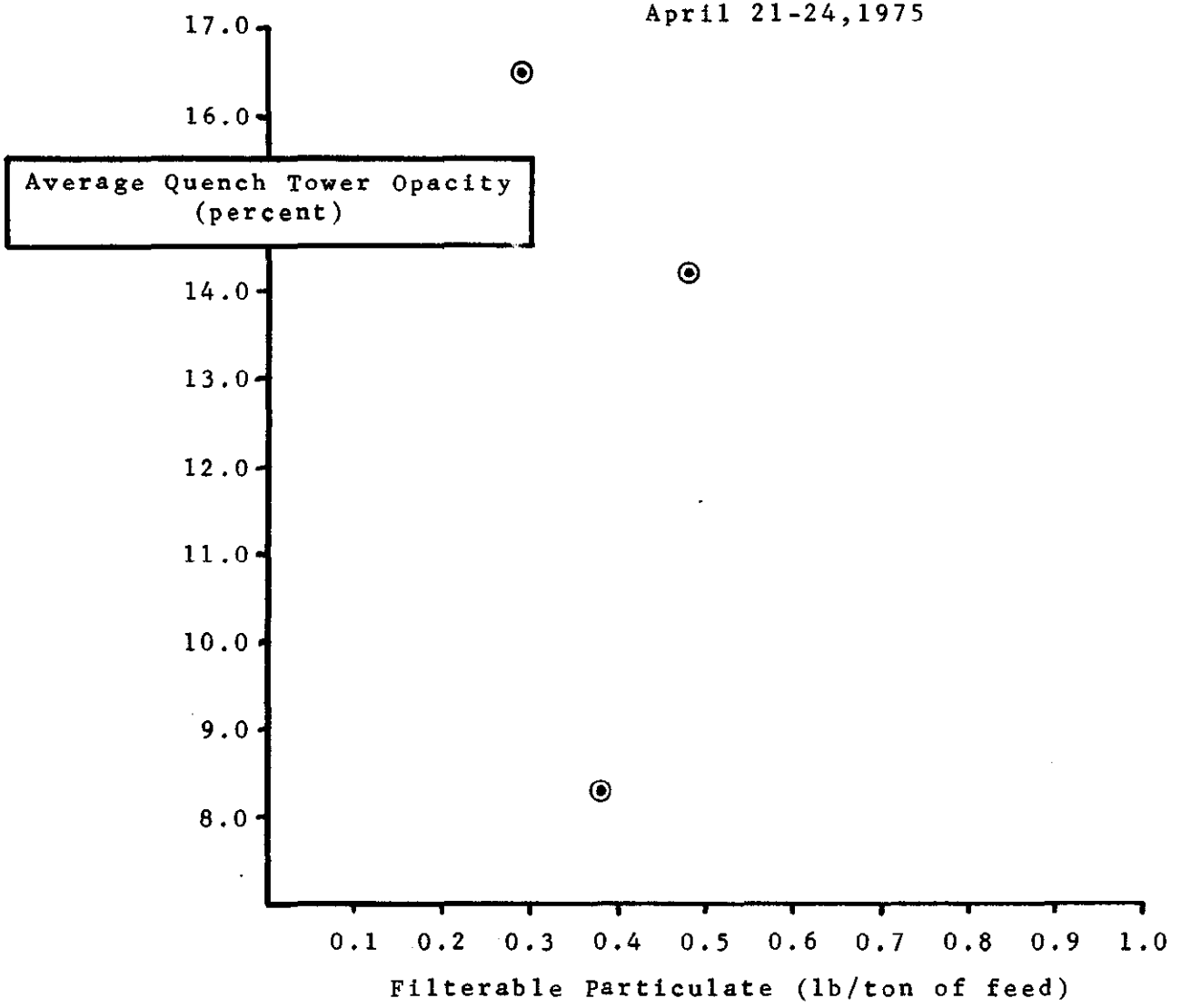
Four optical emission characteristics were monitored independently in the project: degree-of-greenness (DOG), maximum attenuation coefficient (MAC), integrated attenuation coefficient (IAC), and quench tower opacity (QTO). These four variables can be paired such that six two-variable combinations can be examined. Statistical analysis shows clearly that all combinations are highly interrelated, as shown below in order of decreasing linear correlation coefficients:

Combination	Number of Observations	Correlation Coefficient
MAC and IAC	41	0.996
IAC and QTO	33	0.818
MAC and QTO	33	0.814
DOG and QTO	33	0.810
DOG and IAC	41	0.809
MAC and DOG	41	0.797

FIGURE 5.7.2-4

FILTERABLE PARTICULATE EMISSIONS VERSUS AVERAGE QUENCH TOWER OPACITY
PUSHING-CYCLE PARTICULATE TESTS 1-3

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975



Individual degree-of-greenness ratings for the ovens observed during the four particulate tests were plotted against the maximum optical density measured by the transmissometer for each push (Figure 5.7.3). As expected, high degree-of-greenness ratings resulted in generally higher optical densities. The scattering of data points observed is likely due to the subjectivity of the degree-of-greenness rating as well as the dispersion of the coke-pushing plume beneath the shed following the degree-of-greenness observation but prior to the plume passing the transmissometer beam.

5.8 Significance of Emissions of Other Contaminants

Emission testing for gases and other contaminants during this sampling program indicated that minor quantities of all gaseous constituents were found for all tests (Table 5.8 and Appendix E, Volume 2). The polynuclear aromatic compounds and those with similar structures (pyridine, phenolic compounds, benzo(a+e)pyrene, chrysene, fluoranthene, and pyrene) were not found in detectable quantities. The average emission rates of benzene and benzene and its homologues were less than one pound per hour, while sulfur dioxide plus sulfur trioxide emissions averaged less than three pounds per hour.

The emission rate of carbon monoxide, resultant from the incomplete conbustion of the freshly-pushed coke, averaged 14 pounds per hour. It should be noted that this emission rate and those of the light hydrocarbon compounds were instantaneous rates measured during a push, which is likely the peak emission period in the overall cycle. Total light hydrocarbon emissions averaged only seven pounds per hour.

FIGURE 5.7.3

DEGREE OF GREENNESS VERSUS MAXIMUM ATTENUATION COEFFICIENT
PUSHING-CYCLE PARTICULATE TESTS 1-4

Great Lakes Carbon Corporation
St. Louis, Missouri
April, 21-24, 1975

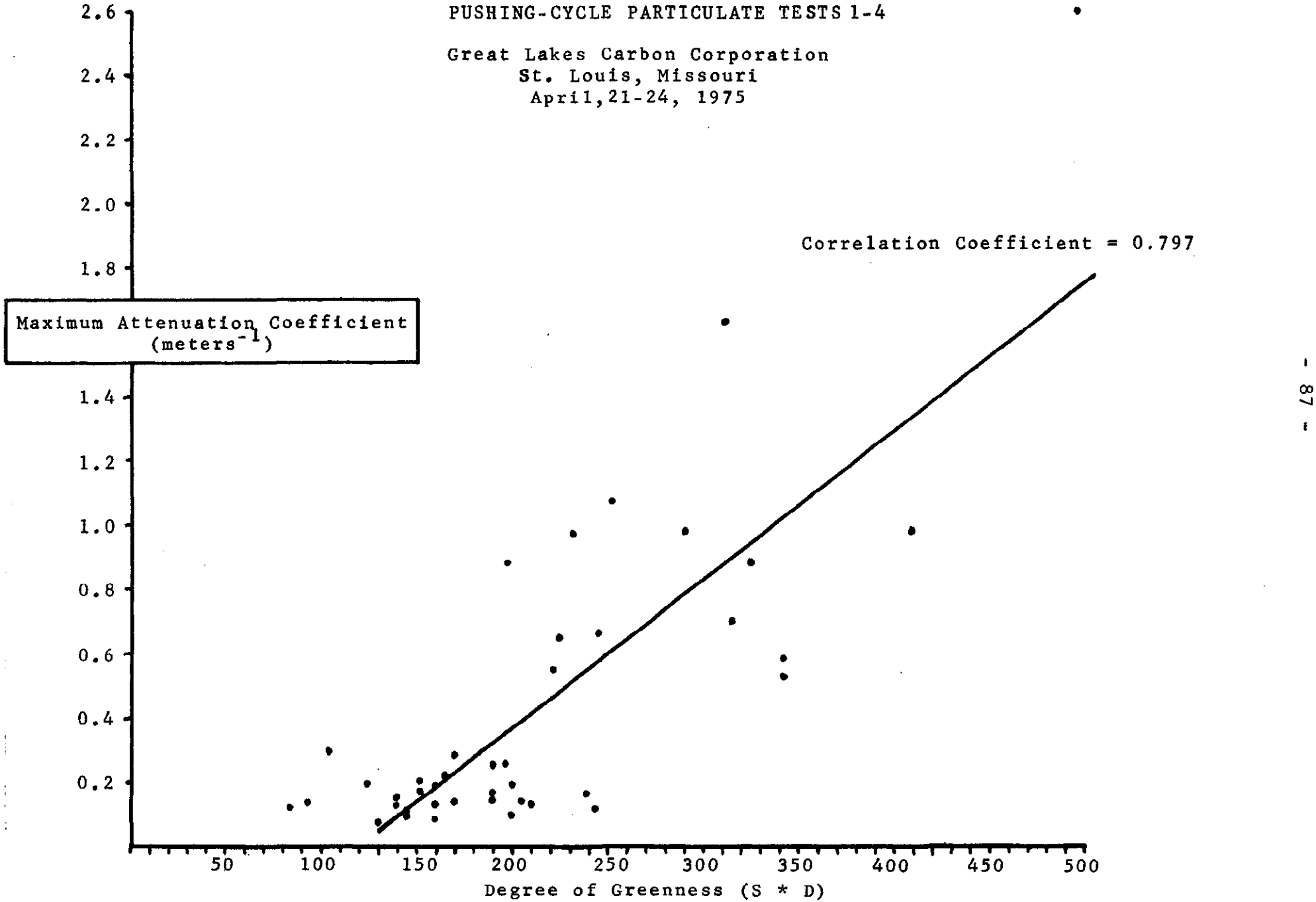


TABLE 5.8

SUMMARY OF CONTAMINANT EMISSION RATES (LBS/HOUR)

Coke Shed
Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Contaminant	Test No.			Average
	1	2	3	
Acetylene*	0.48	0.10	0.25	0.28
Benzene	0.35	0.57	1.0	0.64
Benzene & Homologues	0.48	0.73	1.3	0.84
Filterable Benzo(a)pyrene	<0.11	<0.08	<0.10	<0.10
Total Benzo(a)pyrene	<0.16	<0.13	<0.15	<0.15
Carbon Monoxide*	24.2	10.7	8.1	14.3
Gaseous Chloride	0.63	0.43	0.40	0.49
Filterable Chrysene	<0.06	<0.05	<0.06	<0.06
Total Chrysene	<0.09	<0.07	<0.09	<0.08
Gaseous Cyanide	0.002	0.008	0.002	0.004
Filterable Cyclohexane Solubles	<15.4	12.1	14.3	8.8-13.9
Total Cyclohexane Solubles	15.4	18.1	[illegible]	30.3
Filterable Cyclohexane Insolubles	<9.3	206	28.7	78.2-81.3
Total Cyclohexane Insolubles	<10.8	206	28.7	78.2-81.8
Ethene & Homologues*	2.4	1.2	1.1	1.6
Filterable Fluoranthene	<0.05	0.05	<0.05	0.02-0.05
Total Fluoranthene	<0.08	<0.07	<0.07	<0.07
Total Light Hydrocarbons (as CH_4)*	7.9	9.1	4.7	7.2
Methane & Homologues*	6.7	8.0	4.2	6.3
Gaseous Nitrogen Oxides (as NO_2)	0.09	0.06	0.05	0.07
Gaseous Phenolics	<0.54	<0.43	<0.34	<0.44
Filterable Pyrene	<0.05	<0.07	<0.06	<0.06
Total Pyrene	<0.07	<0.08	<0.08	<0.08
Pyridine	<0.03	<0.03	<0.03	<0.03
Gaseous Sulfate	3.5	0.51	1.2	1.7
Gaseous Sulfite	<0.08	1.1	0.11	0.40-0.43
Sulfur Dioxide	0.42	1.1	0.84	0.79
Sulfur Trioxide	3.8	1.3	0.84	2.0

*Emission rates are maximum (short-term) rates measured during oven pushing.

Results of the caustic solution absorption tests indicated that cyanide was emitted at an average of 0.004 pound per hour. Fluoride, nitrogen oxide compounds, and sulfate and sulfite compounds were also present in minor amounts.

5.9 Assessment of the Shed's Impact Upon Dustfall in the Work Environment

Table 5.9-1 presents the dustfall data collected at the various sites within the shed and in similar locations in the unshedded C Battery. Chemical characteristics of selected dustfall samples are presented in Table 5.9-2.

In order to identify how the shed affects measurable dustfall rates, other potentially-influential factors were first evaluated. These other variables were: a) greenness of the pushes, b) pushing rate, and c) location of the dustfall bucket. The data used for the analyses are summarized in Table 5.9-3. All statistical analyses were performed using the logarithms of the dustfall rates since dustfall rates are known to be log-normally distributed.(4)

As shown in Table 5.9-3, nine pairs of simultaneous samples were collected. An initial test for statistical outliers was performed using these paired data. To determine the precision of each pair of samples, the difference in the logarithms of the paired values was divided by the geometric mean of the pair. These nine precision values, expressed as percentages, were then evaluated to determine if any pair could be considered an outlier. The pair of samples taken on the No. 12 Bench on April 23 was classified as an outlier in this manner and was not used in further analyses. The precision value for this pair was 26.0 percent, while those for the other eight pairs ranged from 0.1 to 2.6 percent.

TABLE 5.9-1

SUMMARY OF DUSTFALL MEASUREMENTS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Site	Sampling Period				Settleable Particulate		Weight Collected On No. 18 Sieve		Water Soluble Dustfall Percent of Settleable Particulate
	Start		Stop						
	1975 Date	Time	1975 Date	Time	$gm/m^2/wk$	$tons/mi^2/mo$	Weight (gm)	Percent of Total	
No. 12 Bench	4/21	15:20	4/22	08:20	8470	104,000	4.9669	24.1	0.6
No. 12 Bench	4/21*	17:55	4/22	08:20	8550	105,000	2.8720	17.7	0.7
No. 12 Bench	4/22	09:30	4/22	18:02	1570	19,200	0.1624	10.1	0.5
No. 12 Bench	4/22*	09:30	4/22	18:02	1120	13,700	0.3010	22.4	0.6
No. 12 Bench	4/22	18:25	4/23	08:15	1250	15,200	0.8763	31.9	7.1
No. 12 Bench	4/22*	18:25	4/23	08:15	Void	Void	Void	Void	Void
No. 12 Bench	4/23	09:48	4/23	17:45	21,000	257,000	10.1142	35.8	0.7
No. 12 Bench	4/23*	09:48	4/23	17:45	2120	25,900	1.4853	44.8	1.3
No. 12 Bench	4/23	18:25	4/24	08:50	5880	71,900	6.5937	41.7	0.2
No. 12 Bench	4/23*	18:25	4/24	08:50	5280	64,600	7.0882	46.2	0.2
No. 31 Bench	4/21	15:30	4/22	09:30	4220	51,600	4.5982	35.8	0.5
No. 31 Bench	4/22	09:45	4/22	18:02	1200	14,700	0.1959	15.3	0.4
No. 31 Bench	4/22	18:25	4/23	08:15	Void	Void	Void	Void	Void
No. 31 Bench	4/23	09:48	4/23	17:46	2100	25,700	0.9013	33.1	0.5

*Duplicate Sample

TABLE 5.9-1 (continued)

SUMMARY OF DUSTFALL MEASUREMENTS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Site	Sampling Period				Settleable Particulate		Weight Collected On No. 18 Sieve		Water Soluble Dustfall Percent of Settleable Particulate
	Start		Stop						
	1975 Date	Time	1975 Date	Time	$gm/m^2/wk$	$tons/mi^2/mo$	Weight (gm)	Percent of Total	
No. 31 Bench	4/23	18:29	Void	Void	Void	Void	Void	Void	Void
No. 37 Bench	4/21	15:32	4/22	09:45	1540	18,800	3.3320	52.3	0.9
No. 37 Bench	4/22	10:00	4/22	18:02	1080	13,200	2.7908	74.7	2.3
No. 37 Bench	4/22	18:25	4/23	08:15	4260	52,100	6.9827	52.2	0.9
No. 37 Bench	4/23	09:48	4/23	17:48	2570	31,500	2.0489	47.9	0.8
No. 37 Bench	4/23	18:29	4/24	08:48	Void	Void	Void	Void	Void
No. 46 Bench	4/21	15:35	4/22	10:01	1580	19,400	2.6439	45.5	0.9
No. 46 Bench	4/22	10:08	4/22	18:02	1490	18,200	2.4716	65.9	0.8
No. 85 Bench	4/22	10:39	4/22	18:18	498	6090	0.6736	61.9	3.8
No. 85 Bench	4/22	18:48	4/23	08:20	3100	37,900	12.4319	73.2	3.3
No. 85 Bench	4/23	09:20	4/23	18:50	1960	24,000	0.5892	22.6	0.6
No. 85 Bench	4/23	18:50	4/24	08:44	5720	69,900	36.5175	80.9	1.2
No. 94 Bench	4/21	15:44	4/22	10:12	495	6060	0.7866	44.2	0.9
No. 94 Bench	4/22	10:20	4/22	18:18	695	8500	0.7572	55.8	3.2

*Duplicate Sample

TABLE 5.9-1 (continued)

SUMMARY OF DUSTFALL MEASUREMENTS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Site	Sampling Period				Settleable Particulate		Weight Collected On No. 18 Sieve		Water Soluble Dustfall Percent of Settleable Particulate
	Start		Stop						
	1975 Date	Time	1975 Date	Time	$gm/m^2/wk$	$tons/mi^2/mo$	Weight (gm)	Percent of Total	
No. 94 Bench	4/22	18:48	4/23	08:20	2390	29,200	1.6997	32.7	1.2
No. 94 Bench	4/23	09:20	4/23	18:50	1770	21,600	0.6911	27.5	1.4
No. 94 Bench	4/23	18:53	4/24	08:42	1830	22,400	1.0243	27.1	0.7
No.106 Bench	4/21	15:45	4/22	10:20	1480	18,100	7.6222	71.9	1.1
No.106 Bench	4/22	10:25	4/22	18:18	936	11,400	0.2083	20.6	2.9
No.106 Bench	4/22	18:48	4/23	08:20	2280	27,900	1.8557	35.7	2.2
No.106 Bench	4/23	09:20	4/23	18:50	1590	19,400	0.6449	28.2	1.0
No.106 Bench	4/23	18:58	4/24	08:40	1440	17,600	2.3869	52.8	1.3
No.117 Bench	4/21	15:57	4/22	10:27	1650	20,200	4.9051	59.7	2.6
No.117 Bench	4/22	10:35	4/22	18:18	1240	15,100	0.6003	36.7	1.4
No. 2 Wall	4/21	16:17	4/22	11:40	8560	105,000	0.8860	4.7	0.1
No. 2 Wall	4/22	11:50	4/22	18:04	14,900	182,000	0.3769	3.6	0.2
No. 2 Wall	4/23	10:06	4/23	18:53	3020	36,900	0.1629	5.4	0.3
No. 2 Wall	4/23	18:34	4/24	08:55	8190	100,000	1.3156	9.3	0.2

*Duplicate Sample

TABLE 5.9-1 (continued)

SUMMARY OF DUSTFALL MEASUREMENTS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Site	Sampling Period				Settleable Particulate		Weight Collected On No. 18 Sieve		Water Soluble Dustfall Percent of Settleable Particulate
	Start		Stop						
	1975 Date	Time	1975 Date	Time	$gm/m^2/wk$	$tons/mi^2/mo$	Weight (gm)	Percent of Total	
No. 25 Wall	4/21	17:38	4/22	12:15	10,700	131,000	0.6533	2.9	0.1
No. 25 Wall	4/22	12:20	4/22	18:06	21,200	260,000	0.0121	0.1	0.01
No. 25 Wall	4/22	19:18	4/23	08:40	11,400	139,000	1.0135	5.8	0.2
No. 25 Wall	4/23	10:06	4/23	18:55	11,000	135,000	0.7194	6.4	0.2
No. 25 Wall	4/23	18:32	4/24	09:00	9120	112,000	1.9715	12.1	0.2
No. 36 Wall	4/21	17:44	4/22	11:25	14,600	178,000	0.0523	0.2	0.2
No. 36 Wall	4/22	11:35	4/22	18:08	9480	116,000	0.4321	6.0	0.2
No. 36 Wall	4/22	19:16	4/23	08:45	9980	122,000	1.0076	6.5	0.2
No. 36 Wall	4/23	10:12	4/23	18:57	12,300	151,000	1.3069	10.0	0.2
No. 36 Wall	4/23	18:36	4/24	09:04	12,700	155,000	4.0224	16.8	0.1
No. 46 Wall	4/21	18:03	4/22	11:05	6720	82,200	0.5757	4.4	0.2
No. 46 Wall	4/21*	18:03	4/22	11:05	8510	104,000	0.6036	3.7	0.2
No. 46 Wall	4/22	11:20	4/22	18:10	6720	82,200	0.3075	5.8	0.5
No. 46 Wall	4/22*	11:20	4/22	18:10	6980	85,400	0.1829	3.4	0.3

*Duplicate Sample

TABLE 5.9-1 (continued)

SUMMARY OF DUSTFALL MEASUREMENTS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Site	Sampling Period				Settleable Particulate		Weight Collected On No. 18 Sieve		Water Soluble Dustfall Percent of Settleable Particulate
	Start		Stop						
	1975 Date	Time	1975 Date	Time	$gm/m^2/wk$	$tons/mi^2/mo$	Weight (gm)	Percent of Total	
No. 46 Wall	4/22	19:14	4/23	08:45	8000	97,800	0.7842	6.3	0.2
No. 46 Wall	4/22*	19:14	4/23	08:50	9260	113,000	0.6834	4.8	0.2
No. 46 Wall	4/23	10:12	4/23	18:58	6130	75,000	0.1806	3.0	0.3
No. 46 Wall	4/23*	10:12	4/23	18:58	5940	72,700	0.3742	6.2	0.2
No. 46 Wall	4/23	18:45	4/24	09:06	4530	55,400	0.9768	12.2	0.4
No. 46 Wall	4/23*	18:45	4/24	09:06	4380	53,600	0.9736	12.5	0.4
No. 85 Wall	4/21	17:08	4/22	13:15	78.4	958	0.0086	4.8	1.8
No. 85 Wall	4/22	13:20	4/22	18:54	106	1290	1.1405	94.7	38.0
No. 85 Wall	4/22	19:05	4/23	18:50	104	1280	0.0163	5.7	6.2
No. 85 Wall	4/23	19:20	4/24	08:33	378	4630	0.0184	3.3	<0.02
No. 106 Wall	4/21	17:09	4/22	13:13	606	7410	0.2106	13.8	0.3
No. 106 Wall	4/22	13:17	4/22	18:52	502	6140	0.0052	1.7	0.9
No. 106 Wall	4/22	19:05	4/23	18:50	553	6760	0.0541	3.7	0.4
No. 106 Wall	4/23	19:25	4/24	08:31	841	10,300	0.0712	5.6	0.1

*Duplicate Sample

TABLE 5.9-1 (continued)

SUMMARY OF DUSTFALL MEASUREMENTS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Site	Sampling Period				Settleable Particulate		Weight Collected On No. 18 Sieve		Water Soluble Dustfall Percent of Settleable Particulate
	Start		Stop						
	1975 Date	Time	1975 Date	Time	$gm/m^2/wk$	$tons/mi^2/mo$	Weight (gm)	Percent of Total	
No. 117 Wall	4/21	17:11	4/22	13:08	841	10,300	0.1430	7.3	0.2
No. 117 Wall	4/22	13:14	4/22	18:50	587	7180	0.1996	35.9	1.0
No. 117 Wall	4/22	19:05	4/23	18:50	1010	12,300	0.1766	6.4	0.4
No. 117 Wall	4/23	19:30	4/24	08:30	458	5600	0.0254	3.8	<0.02
Car No. 1 (South)	4/21	16:52	4/22	13:30	3190	39,000	0.3565	4.8	0.2
Car No. 1 (South)	4/22	13:35	4/22	18:45	1920	23,500	0.1091	9.2	0.5
Car No. 1 (South)	4/22	19:12	4/23	08:35	4720	57,700	0.4887	6.7	0.4
Car No. 1 (South)	4/23	09:43	4/23	19:00	3750	45,800	0.6354	14.4	0.2
Car No. 1 (South)	4/23	19:10	4/24	08:45	2490	30,500	0.2818	7.1	0.3
Car No. 2 (North)	4/21	15:59	4/22	10:42	1340	16,400	1.1897	30.4	0.3
Car No. 2 (North)	4/22	10:50	4/22	19:05	1310	16,000	0.1511	11.4	0.3
Car No. 2 (North)	4/22	19:15	4/23	08:40	3120	38,100	0.4066	8.2	0.5
Car No. 2 (North)	4/23	09:22	4/23	19:00	2240	27,400	0.2495	9.6	0.3
Car No. 2 (North)	4/23	19:15	4/24	08:47	810	9900	0.1435	10.8	<0.008

*Duplicate Sample

TABLE 5.9-1 (continued)

SUMMARY OF DUSTFALL MEASUREMENTS

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Site	Sampling Period				Settleable Particulate		Weight Collected On No. 18 Sieve		Water Soluble Dustfall Percent of Settleable Particulate
	Start		Stop						
	1975 Date	Time	1975 Date	Time	$gm/m^2/wk$	$tons/mi^2/mo$	Weight (gm)	Percent of Total	
No.14 Overhead	4/22	19:35	4/23	09:00	3750	45,800	0.3123	5.4	0.4
No.14 Overhead	4/23	09:32	4/23	19:00	4280	52,400	0.2719	5.8	0.3
No.14 Overhead	4/23	19:00	4/24	08:48	5800	71,000	0.4548	5.0	0.1
No.26 Overhead	4/22	19:30	4/23	09:00	2760	33,800	0.2131	5.0	0.7
No.26 Overhead	4/23	09:32	4/23	19:00	2930	35,800	0.2184	6.8	0.3
No.26 Overhead	4/23	19:00	4/24	08:48	5000	61,200	0.7365	8.9	0.2

*Duplicate Sample

TABLE 5.9-2

CHEMICAL CHARACTERIZATION OF DUSTFALL*

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Sampling Site	Sampling Period				Acetone Solubles		Cyclohexane Solubles		pH
	Start		Stop		Weight (gm)	Percent of Total	Weight (gm)	Percent of Total	
	Date	Time	Date	Time					
No. 12 Bench	4/23	09:48	4/23	17:45	0.0176	1.0	0.0007	0.04	5.70
No. 31 Bench	4/22	09:45	4/22	18:02	0.0014	0.1	<0.0006	<0.06	5.80
No. 46 Bench	4/21	15:35	4/22	10:01	0.0127	0.4	0.0010	0.03	6.48
No. 85 Bench	4/23	09:20	4/23	18:50	0.0142	0.7	<0.0006	0.03	4.88
No. 94 Bench	4/23	18:53	4/24	08:42	0.0389	1.4	0.0029	0.1	4.92
No. 46 Wall	4/22	19:14	4/23	08:45	0.0038	0.03	0.0013	0.01	6.80

* These data represent the portion of each dustfall sample which passed through the No. 18 sieve.

TABLE 5.9-3

DUSTFALL SUMMARY ($gm/m^2/wk$)

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Sampling Location	1975 Sampling Period					Geometric Mean
	4/21-22	4/22	4/22-23	4/23	4/23-24	
No. 12 Bench	8,470	1,570	1,250	21,000**	5,880	--
No. 12 Bench*	8,550	1,120	VOID	2,120**	5,280	--
No. 12 Bench Geometric Mean	8,510	1,330	1,250	--	5,570	2,980
No. 31 Bench	4,220	1,200	VOID	2,100	VOID	2,200
No. 37 Bench	1,540	1,080	4,260	2,570	VOID	2,070
No. 46 Bench	1,580	1,490	--	--	--	1,530
Shedded Bench Geometric Mean	3,060	1,270	2,310	2,320	5,570	2,420
No. 85 Bench	--	498	3,100	1,960	5,720	1,450
No. 94 Bench	495	695	2,390	1,770	1,830	1,220
No. 106 Bench	1,480	936	2,280	1,590	1,440	1,490
No. 117 Bench	1,650	1,240	--	--	--	1,430
Unshedded Bench Geometric Mean	1,070	796	2,570	1,770	1,620	1,380
No. 2 Wall	8,560	14,900	--	3,020	8,190	7,490
No. 25 Wall	10,700	21,200	11,400	11,000	9,120	10,500
No. 36 Wall	14,600	9,480	9,980	12,300	12,700	11,700
No. 46 Wall	6,720	6,720	8,000	6,130	4,530	--
No. 46 Wall*	8,510	6,980	9,260	5,940	4,380	--
No. 46 Wall Geometric Mean	7,560	6,850	8,610	6,030	4,450	6,540
Shedded Wall Geometric Mean	10,000	9,890	9,930	7,050	8,060	8,800
No. 85 Wall	78.4	106	104	--	378	134
No. 106 Wall	606	502	553	--	841	613
No. 117 Wall	841	587	1,010	--	458	691
Unshedded Wall Geometric Mean	342	315	387	--	526	385
South Car (Shedded)	3,190	1,920	4,720	3,750	2,490	3,060
North Car (Unshedded)	1,340	1,310	3,120	2,240	810	1,580
No. 14 Overhead	--	--	3,750	4,280	5,800	4,530
No. 26 Overhead	--	--	2,760	2,930	5,000	3,430
Shedded Overhead Geometric Mean	--	--	3,220	3,540	5,390	3,940

* Duplicate Sample.
**Statistical tests indicate that these values are suspect. They were not used in further statistical analyses.

In all additional evaluations, the geometric mean dustfall rate was then used for the remaining paired samples.

An average greenness for ovens pushed during each daytime dustfall sample was determined by averaging the value of S*D for the pushes that occurred during the sampling period. For dustfall samples taken within the shed, pushes at Ovens 1 through 55 were used; for unshedded samples, pushes at Ovens 83 through 132 were used. These average greenness values were then arranged in ascending order to determine a median value, 160. All greenness values below 160 were labeled "low" and all above 160 were labeled "high." It is interesting to note that none of the values for unshedded samples were associated with a "high" average greenness. Also, only six of the 43 shedded samples for which greenness data were available had average greenness values considered to be "low."

A pushing rate for each dustfall sample was determined and normalized by counting the number of either shedded or unshedded ovens, as applicable, that were pushed during a sample, dividing by the time duration of the sample, and then dividing by the number of ovens in the shedded or unshedded area. Again, the values were arranged in ascending order and the median was found to be 0.037 push per hour per oven. All pushing rates below this value were considered "low" and all rates equal to or above this value were considered "high."

The dustfall data were then arranged into several cells in order to best eliminate any confounding effect of the multiple variables. These cells, shown in Table 5.9-4, were defined by first dividing the data into that applicable to shedded and unshedded

TABLE 5.9-4

FORMAT USED FOR ANALYSES OF DUSTFALL DATA ($gm/m^2/wk$)

Great Lakes Carbon Corporation
St. Louis, Missouri
April 21-24, 1975

Battery		Shedded				Unshedded			
Greenness		Low		High		Low		High	
Pushing Rate		Low	High	Low	High	Low	High	Low	High
LOCATION	Bench			1250 1200 1080 4260* 1490	8510 1330 4220 2100 1540 2570 1580	695 936	498 1960 495 1770 1480 1590 1650 1240		
	Wall	11,400 9980 8610		14,900 3020 10,700 21,200 11,000 9480 12,300 6850 6030	8560 14,600 7560	106 502 587	78.4 104 606 553 841 1010		
	Car	4720		3190 3750	1920	1310	1340 2240		
	Overhead	3750 2760		4280 2930					

* Within this combination of variables, this value was judged to be an outlier and was not included in further analyses.

areas. Each area was subdivided into one of four locations: "bench," "wall," "car," or "overhead." The next two subdivisions were those of "low" and "high" pushing rates and "low" and "high" greennesses. A single cell now contained the most homogeneous subset of data available. Tests for statistical outliers were then conducted within each cell using the logarithms of the dustfall rates. Only a single value, as indicated in Table 5.9-4, was found to be an outlier at this stage and was not used in subsequent analyses.

In order to determine whether greenness and dustfall rate were correlated, the number of subdivisions was reduced by one so that greenness was no longer used as a basis of subdivision. In each of the remaining 16 cells, the logarithm of dustfall rate for each sample was paired with its average greenness value. The linear correlation coefficient for the pairs in each cell was then determined. Since none of the correlation coefficients was found to be significant at the five-percent level, it was concluded that greenness and dustfall rate were not correlated for this set of data.

Since greenness and dustfall rate were not found to be correlated, those dustfall rates which did not have a greenness rating associated with them could now be included in further analyses. Thus, these values were added to their respective cells determined in the previous analysis, and the tests for outliers were repeated. No additional suspect values were found.

The correlation between pushing rate and dustfall rate was evaluated next. The number of subdivisions was reduced by one by eliminating pushing rate as a basis of division. In each of the eight remaining cells, the logarithm of dustfall rate was then

paired with its associated pushing rate. The linear correlation coefficient was determined for each cell, and only two of the values were found to be significant at the five-percent level. These were the 10 data pairs for shedded and unshedded car locations. On the basis of the fact that five of the seven correlation coefficients were not significant, it was concluded that pushing rate and dustfall rate were not significantly related for the overall data set.

Two factors remained to be considered — the location of the dustfall bucket and the shed effect, i.e., shedded versus unshedded areas. To determine whether location was a significant variable, two separate one-way analyses of variance were performed. The wall-bench-car-overhead location samples were compared to one another for the shedded area and for the unshedded area. For the samples taken under the shed, the geometric mean of the wall samples was found to be significantly higher than the geometric means of the bench, car, and overhead samples. In addition, the geometric mean of the overhead samples was found to be significantly greater than that of the bench samples. For the samples taken in the unshedded area, the geometric mean of the wall samples was found to be significantly lower than the geometric means of the bench samples and the car samples. In both areas the geometric mean dustfall rates for the bench and car samples were essentially the same.

Since location of the dustfall bucket appeared to be a significant factor, a one-way analysis of variance was done for each of the three locations common to both areas to determine whether the shed was a significant factor. At two of the three locations — the wall and the car — the geometric mean dustfall rates under the

shed were found to be significantly higher than those samples taken outside the shed. For the bench location, however, the geometric mean dustfall rate under the shed was not statistically different from that found at the corresponding unshedded location. It can thus be concluded that both the presence of the shed and the location of the dustfall container have a significant influence upon measured dustfall rate in this study.

5.10 Impact of the Shed Upon Airborne Agents Within

A semi-enclosed shed adjacent to a coke-oven battery could have a significant effect upon the quality of the work environment within the shed. The shed enclosure tends to confine the coke-oven emissions both during and between coke-pushing operations, and, by restricting the dispersion and dilution that would occur by direct discharge to the atmosphere, elevates the magnitude and duration of concentrations of suspended dust and the myriad of chemical substances present in the coking emissions. During non-push conditions, however, it is possible that the steady flow of ventilation air into the shed hooding might act to reduce concentrations.

This evaluation of coke-side emissions, however, was intended neither to document nor interpret the exposures of coke-oven operators to coke-side emissions within the shed. Two studies by the National Institute for Occupational Safety and Health (NIOSH), however, did address this issue.[5,6]

5.11 Precision of Test Results

Although the terms "precision" and "accuracy" are often regarded as synonymous, each has a specific technical meaning. The accuracy

of a measurement signifies the closeness with which the measurement approaches the true value. Precision, on the other hand, characterizes the repeatability of the measurements. Thus, the precision of a measurement denotes the closeness with which a given measurement approaches the average of a series of measurements taken under similar conditions. Clearly, if the bias is large, a measurement may be very precise but very inaccurate.

Many techniques exist to evaluate the precision of a result. Ideally, simultaneous replicate samples are taken and the coefficient of variation, the standard deviation expressed as a percentage of the mean, is used as a measure of precision. In this study, a replicate sampling technique was used only for nine pairs of dustfall samples. The precision of these paired samples is discussed in Section 5.9.

When the sample at hand is the only measure of the variability of data at given conditions, a confidence interval can be used to bracket the true mean of the population. This interval may be regarded as a first estimate of the precision of the results. In this study, such confidence intervals were constructed (using the t-statistic and assuming normality) at the 95-percent level, implying a five-percent risk of not bracketing the true mean value of a series of test measurements. This confidence interval is expressed in the Summary and Conclusions (Section 2.0) as m ($\pm$ r), where m is the arithmetic mean and 2r is the confidence interval. This technique was used in the evaluation of particulate emission rates, shed capture efficiencies, composition of particulate matter, particle sizing data, and emission rates of gases. Although the statistical precision is expressed as ($\pm$ r) with a confidence interval of 2r, any confidence interval for the mean of a percentage

is necessarily bounded by a maximum value of 100. Likewise, the confidence interval for a concentration, emission rate, or emission factor is limited by a minimum value of zero.

This report prepared by:

Fred I. Cooper

Thomas A. Loch, Ph.D., P.E.

Janet L. Vecchio

John E. Mutchler, P.E.

REFERENCES

1. "Standards of Performance for New Stationary Sources," Federal Register, 40CFR60, June 14, 1974.

2. "BMS-11 Sampler — Sampling Instructions," Monsanto Enviro-Chem Systems, Inc.

3. "Operating Instructions for Andersen Stack Sampling Equipment," Andersen 2000, Inc.

4. TR-2 Air Pollution Measurement Committee, "Recommended Standard Method for Continuing Dustfall Survey (APM-1, Revision 1)," Journal of Air Pollution Control Association, 16:7, pp 372-377, 1966.

5. National Institute for Occupational Safety and Health, Division of Technical Services, Industrial Hygiene Services Branch, "An Industrial Hygiene Survey of the Bethlehem Steel Corporation (Burns Harbor Facility) Coke Side Emission Collecting Shed," Project No. 75-32, April 28, 1975.

6. National Institute for Occupational Safety and Health, Division of Technical Services, Industrial Hygiene Services Branch, "An Industrial Hygiene Survey of the Great Lakes Carbon Corporation (Missouri Coke & Chemical Division) Coke Side Emission Collecting Shed," Project No. 75-31, April 28, 1975.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA/1-77-014a		

4. TITLE AND SUBTITLE	5. REPORT DATE
Study of Coke-Side Coke-Oven Emissions Volume I	August 31, 1977 6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
John E. Mutchler, Thomas A. Loch, Fred I. Cooper, Janet L. Vecchio	

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Clayton Environmental Consultants, Inc. 25711 Southfield Road Southfield, Michigan 48075	11. CONTRACT/GRANT NO. 68-02-1408; Task 14

12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Division of Stationary Source Enforcement U.S. ENVIRONMENTAL PROTECTION AGENCY 401 M Street, S.W. Washington, D.C. 20460	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
Volumes II and III of this report are appendices that supplement Volume I.

16. ABSTRACT
This report summarizes a study of coke-side emissions at three coke-oven batteries producing foundry coke at Great Lakes Carbon Corporation (GLC) in St. Louis, Missouri. Of the three bateries, the south battery "A" is equipped with the coke-side shed. The center battery "B" and the north battery "C" were not equipped with a functional shed at the time of the study. Objectives of this study were to develop:

1) Basic engineering data concerning process eimssions, fugitive emissions from the shed, capture efficiency of the shed, and quantity and characteristics of contaminants present in the shed exhaust.

2) Other basic engineering data for specification of future retrofitted control devices for removal of air contaminants in the shed exhaust.

3) Correlations to relate these measurements to process conditions.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Coking Air pollution Opacity Visual inspection Particles Particle size distribution	New Source Performance Standards Emission Testing Performance Tests	 13B 14D

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Unlimited	Unclassified	117
	20. SECURITY CLASS (This page)	22. PRICE
	Unclassified	

EPA Form 2220-1 (9-73)