8.6

MIDWEST RESEARCH INSTITUTE

EPA/600/X-85/343a

REPORT

CHARACTERIZATION OF INHALABLE PARTICULATE MATTER EMISSIONS FROM A WET PROCESS CEMENT PLANT

DRAFT REPORT

August 1983

Volume I

EPA Contract No. 68-02-3158, Technical Directive No. 10
MRI Project No. 4892-L(04)

For

Industrial Environmental Research Laboratory
Environmental Protection Agency
5555 Ridge Avenue
Cincinnati, Ohio 45268

Attn: Charles H. Darvin

MIDWEST RESEARCH INSTITUTE 425 VOLKER BOULEVARD, KANSAS CITY, MISSOURI 64110 • 816 753-7600

MRI WASHINGTON, D.C. 20006 – Suite 250, 1750 K Street, N.W. • 202 293-3800

CHARACTERIZATION OF INHALABLE PARTICULATE MATTER EMISSIONS FROM A WET PROCESS CEMENT PLANT

by

Mark D. Hansen
John S. Kinsey
Fred J. Bergman

DRAFT REPORT

August 1983

Volume I

EPA Contract No. 68-02-3158, Technical Directive No. 10
MRI Project No. 4892-L(04)

For

Industrial Environmental Research Laboratory
Environmental Protection Agency
5555 Ridge Avenue
Cincinnati, Ohio 45268

Attn: Charles H. Darvin

MIDWEST RESEARCH INSTITUTE 425 VOLKER BOULEVARD, KANSAS CITY, MISSOURI 64110 • 816 753-7600

PREFACE

This report was prepared for the Environmental Protection Agency (EPA), Industrial Environmental Research Laboratory, under Conract No. 68-02-3158, Technical Directive No. 10. It describes the results of emission testing conducted by Midwest Research Institute (MRI) for the study, "Characterization of Inhalable Particulate Matter Emissions from the Cement Industry." The field testing was conducted at the Ideal Basic Industries, Inc., cement plant, Ada, Oklahoma, during the period April 30 through May 6, 1981.

The work was conducted by the Field Programs Section of the Environmental Systems Department under the general supervision of Ken Wilcox, Head, Field Programs Section. Mark D. Hansen was the project leader and also served as field team leader. He was assisted in the field by George Cobb, Marilyn Gabriel, Ed Whited, Kent Hall, Cecily Beall, and Ed Olson. John Kinsey was responsible for the evaluation of the production process. Fred Bergman assisted in preparation of the report.

We would like to express our appreciation to personnel of the Ideal Basic Industries, Inc., plant, who gave their assistance and cooperation. We especially want to thank Harry Javernick, Plant Manager, Mr. Bob Reese, Project Engineer, and Tom Quaid, Technical Supervisor, for the excellent support given to the project.

Approved for:

MIDWEST RESEARCH INSTITUTE

Andrew Trenholm

for M. P. Schrag, Director
Environmental Systems Department

August 1983

ABSTRACT

This report presents data for the characterization of inhalable particulate emissions performed by Midwest Research Institute (MRI) at a wet process cement plant. The plant selected for this study was the Ideal Basic Industries, Inc., cement plant located at Ada, Oklahoma. This plant is typical of wet process operations within the cement industry.

Emission testing for both total mass and particle size was conducted by MRI on the plant's No. 2 kiln. Emissions from the kiln are controlled by an electrostatic precipitator (ESP). A baseline assessment of the ESP was conducted by PEDCo Environmental, Inc.

Inhalable particulate emission factors have been calculated for the selected particle diameters of 2.5, 10.0, and 15.0 μm. The calculated emission factors for each testing location are based on the total mass emission rate and the particle size data from that source.

CONTENTS

FIGURES

FIGURES (continued)

TABLES

TABLES (concluded)

SECTION 1.0

PROCESS DESCRIPTION AND OPERATION

1.1 INTRODUCTION

This report presents the results of testing by Midwest Research Institute (MRI) for inhalable particulates at the Ideal Basic Industries, Inc., cement plant located in Ada, Oklahoma. Testing was conducted at this plant during the period April 30 to May 6, 1981.

Testing was conducted on both the controlled and uncontrolled emissions from the No. 2 kiln and for fugitive dust. The tests are described in detail in Sections 2.0 and 3.0. A baseline assessment of the electrostatic precipitator was conducted by PEDCo Environmental, Inc. (PEDCo). The results of that assessment are provided in Appendix A.

1.2 PROCESS SPECIFICATIONS AND NORMAL OPERATION

The facility tested is a wet process portland cement plant with a total production capacity of 1,800 tons of cement per day. The plant operates two identical rotary kilns for the production of clinker. Each kiln is 12 ft in diameter and 450 ft in length with a production capacity of 40 tons of clinker per hour. The No. 2 kiln, originally installed in 1958, was selected for testing. The kiln contains chain in the feed end from the 306-ft position to the 432-ft position in four sections. The total chain weight is 106.6 tons with a chain density of 15.3 lb/ft^3. The kiln is refractory lined up to the 364-ft position for shell protection and insulation. The internal diameter of the kiln in the refractory section is 11 ft 4 in.

From feed tanks, the slurry is fed into the kiln by a rotating bucket feeder resembling a ferris wheel. The slurry typically contains 30% moisture, 77% carbonate material (mostly calcium), and 2% alkali material (mostly potassium).

The kiln is fired with pulverized coal that is locally mined and washed. Secondary air is obtained from the clinker cooler heat exchanger to provide preheated air for coal drying and combustion through the firing hood. Typical coal firing rates are between 5.0 and 6.5 tons/hr at a raw meal dry solids feed rate of 60 tons/hr (insufflation not included in weight). The thermal heat requirements are in the range of 2.1 to 2.5 x 10^6 Btu/ton of slurry feed (3.2 to 3.8 x 10^6 Btu/ton of clinker) at a typical coal heat value of 12,750 Btu/lb (dry basis).

Insufflation dust is collected from the first two fields of the electrostatic precipitator (ESP), combined with unit No. 1's insufflation material, and returned to the burner end of the kiln.

Kiln process operating parameters are recorded on a daily operating log sheet once an hour by plant personnel. Key parameters recorded include coal firing rate, slurry feed rate, insufflation rate, kiln rotation rate, exit gas temperature, flue gas oxygen, and other important parameters related to kiln operation. Formulas used to calculate the dry slurry feed rate and insufflation rate from operating data are provided in Appendix A.

1.3 ESP SPECIFICATIONS AND NORMAL OPERATION

Particulate emissions from kiln No. 2 are controlled by an ESP manufactured by Wheelabrator-Frye, Inc. The unit was installed in 1975 as a replacement for the original control device. The ESP has three electrical fields in the direction of flow, each section energized by separate but identical transformer-rectifier (T-R) sets. The unit has three pyramid-shaped hoppers from which dust is continuously removed through rotary air locks and into screw conveyors. Collected dust from the first two hoppers is insufflated back to the kiln for reprocessing. Dust from the last hopper is penumatically conveyed to a storage tank for removal by truck.

Design specifications for the tested ESP are presented in Table 1-1. The design factors are organized into three categories: hardware, electrical, and application. Hardware specifications identify the significant mechanical and dimensional characteristics of the unit. Electrical specifications describe the rated power, voltage, and current levels of the T-R sets along with other electrical qualifiers. The application category includes the important gas and particulate design parameters of the ESP.

TABLE 1-1. ESP DESIGN SPECIFICATIONS

Hardware specifications	
Manufacturer	Wheelabrator-Frye, Inc.
Manufacturer contract number	06-1326
Year installed	1975
Collection plate area (total)	92,252 ft^2
Number of chambers	1
Number of fields	3
Plate spacing	12 in.
Plate height	30.8 ft
Plate width	12.5 ft
Number of gas passages	40
Cross-sectional area	1,232 ft^2
Linear feet of discharge wire	86,400 ft
Rapper type (plate)	Hammers
Rapper type (wires)	Hammers
Electrical specifications	
Number of transformer-rectifier (T-R) sets	3
Rating(s) of T-R set	78.5 kVA
Maximum primary voltage	440 V
Maximum primary current	178 A
Maximum secondary voltage	55 kV
Maximum secondary current	1,000 mA
Maximum current density/plate area	0.0325 mA/ft^2
Maximum current density/electrode length	0.035 mA/ft
Application specifications	
Gas flow rate, total	240,000 acfm
Gas temperature, inlet	600°F
Gas composition	30% H_2O by volume
Gas velocity, superficial	3.25 ft/s
Specific collection area	384 ft^2/acfm
Collection efficiency	99.93%
Particulate concentration, inlet	15.0 gr/acf
Particulate concentration, outlet	0.01 gr/acf

SECTION 2.0

SAMPLING LOCATIONS, EQUIPMENT, PROCEDURES, AND SAMPLING

This section describes the sampling locations, equipment, and procedures used for sampling both ducted and unducted emission sources at Ideal Basic Industries, Inc. In general, sampling locations were in five primary areas: inlet and outlet ducts to kiln No. 2 electrostatic precipitator (ESP) unit; raw product ducts; insufflation hoppers; and paved roads.

Figure 2-1 presents a general overview of the plant facilities and sampling locations.

2.1 SAMPLING LOCATIONS

The plant operates two rotary kilns for the production of cement product. Emissions from each kiln are controlled by a separate ESP unit. Gases exiting two ESP units are exhausted to the atmosphere through a common stack. Both kilns and both ESP units are essentially identical. Kiln No. 2 and its corresponding (north) ESP unit were selected for testing because of the presence of scaffolding and ports. Figure 2-2 presents a general overview of the twin ESP units and common outlet stack. Figure 2-3 presents a schematic of kiln No. 2 and its ESP unit with the inlet sample port locations indicated.

2.1.1 Inlet to Kiln No. 2 ESP Unit

Inhalable particulate matter emission tests were conducted on kiln No. 2 emissions before they entered the ESP control device.

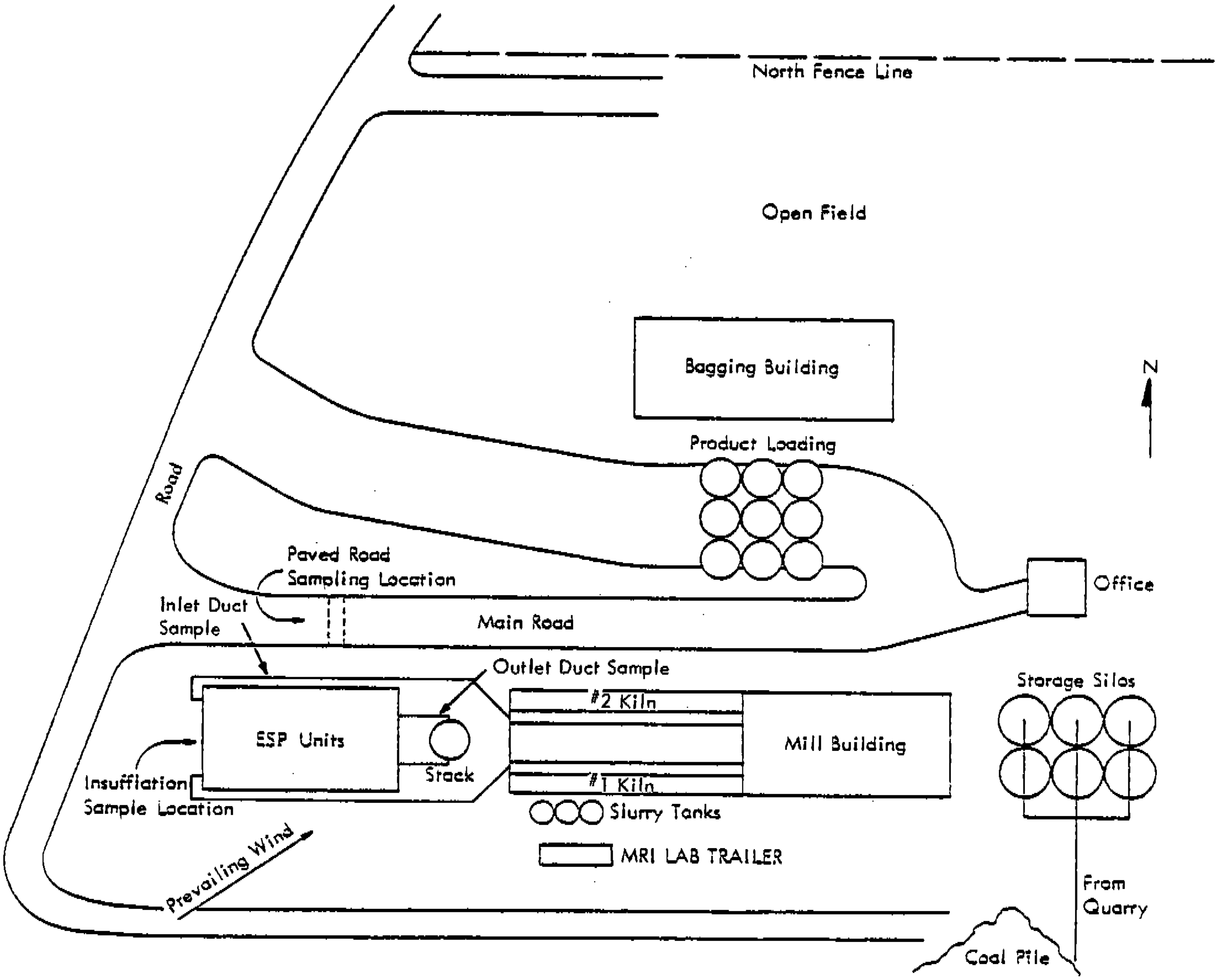


Figure 2-1. General overview of Ideal Basic Industries, Inc., cement plant, Ada, Oklahoma.

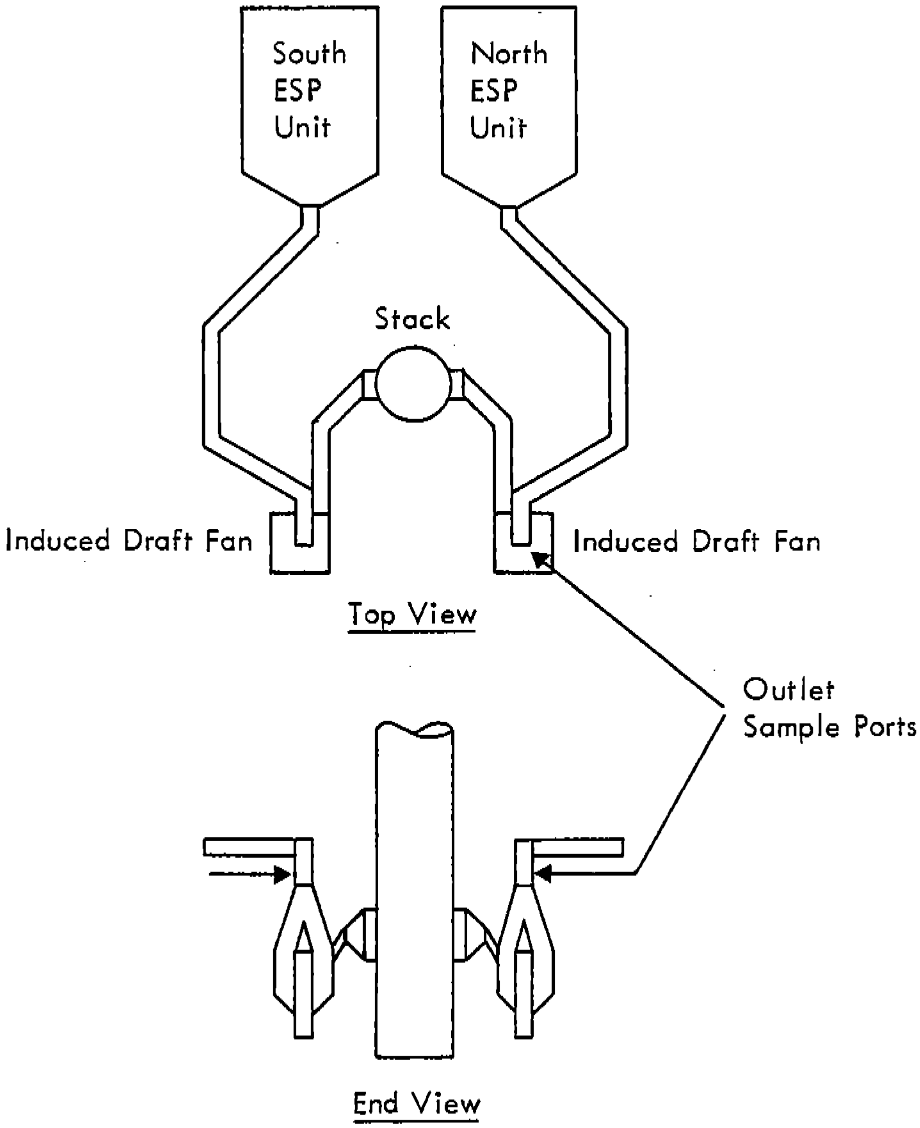


Figure 2-2. General overview of the twin electrostatic precipitator units and common outlet stack at Ideal Basic Industries, Inc.

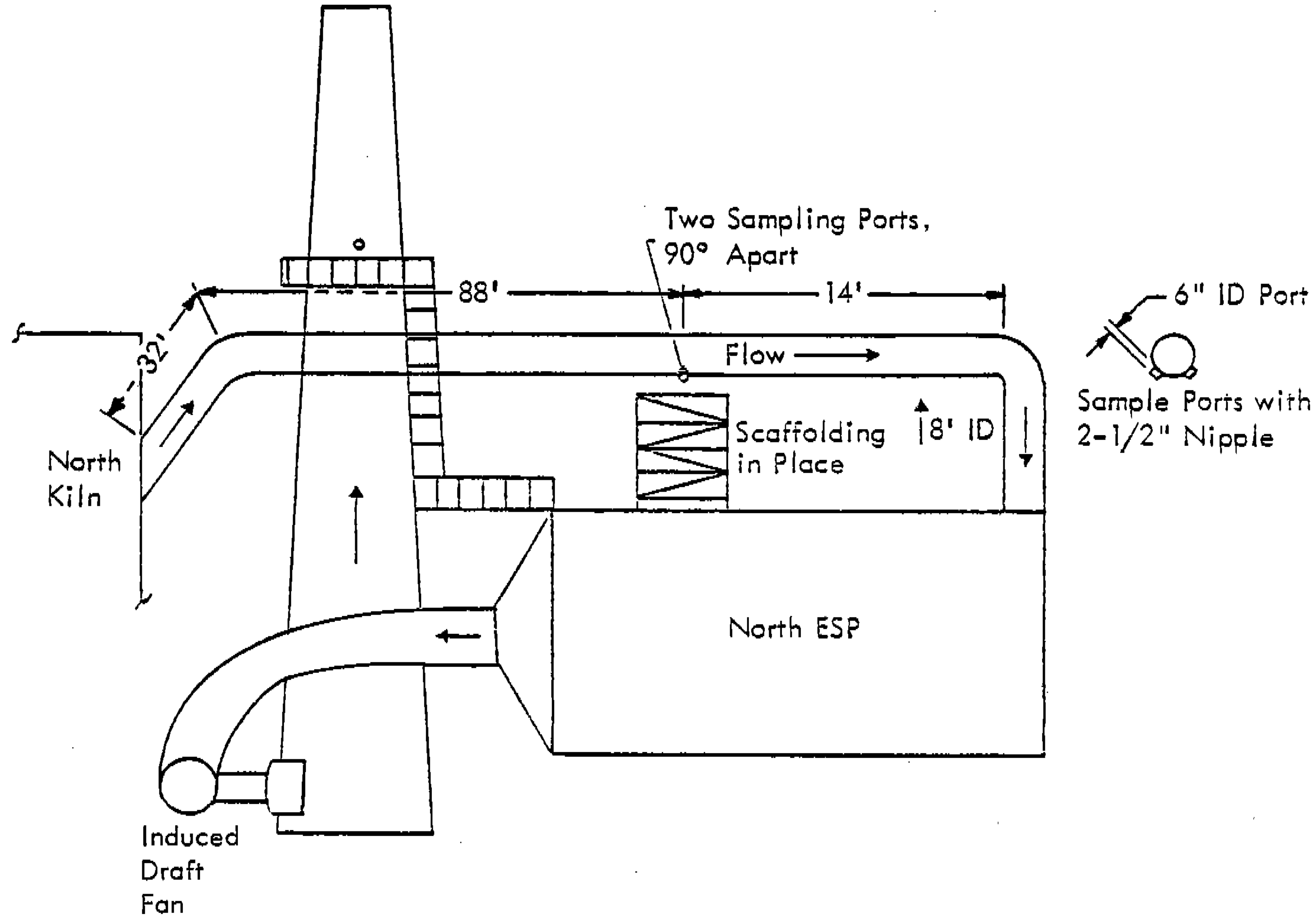


Figure 2-3. Schematic of Ideal Basic Industries, Inc., kiln No. 2 (north kiln) and electrostatic precipitator unit showing inlet sample port locations.

Testing was accomplished using two 6-in. ID sample ports, 90° apart on the bottom of the 8-ft ID circular duct connecting the kiln and the ESP unit. Figure 2-4 is a schematic of the sample ports, sample quadrants, and sample point locations.

An accumulation of material in the bottom of the inlet duct to the ESP unit was discovered during EPA Method 2 determinations. The depth of the material was determined and calculations were made to adjust the total unobstructed area of the duct in order to be able to establish the four sample quadrants and sampling points. Additional discussion of the rationale of this adjustment is presented in Section 2.4, "Sampling." The calculation procedure used to correct for the obstructed area is presented in Appendix B.

2.1.2 Outlet from Kiln No. 2 ESP Unit

Inhalable particulate matter was characterized on kiln No. 2 emissions in the exit duct of the ESP control device. The sampling ports were located in a vertical section of duct below a 90° bend from a horizontal section of duct from the ESP unit and above the induced draft fan. Testing was accomplished using four 6-in. ID sample ports an equal distance apart on the side of the 9 ft 7/8 in. x 8 ft 11-7/8 in. rectangular vertical section of duct. A schematic of the sample port locations at the outlet duct from the ESP unit on kiln No. 2 is presented in Figure 2-5. Figure 2-6 presents a schematic of the sample ports, sample quadrants, and sample point locations.

2.1.3 Raw Product Samples

Grab samples of raw product feed were collected for chemical analysis. These grab samples were collected by plant personnel from the kiln No. 2 feed tank.

2.1.4 Insufflation Dust Samples

The Ideal Basic Industries, Inc., cement plant utilizes a single insufflation dust system for the two ESP units controlling kiln emissions.

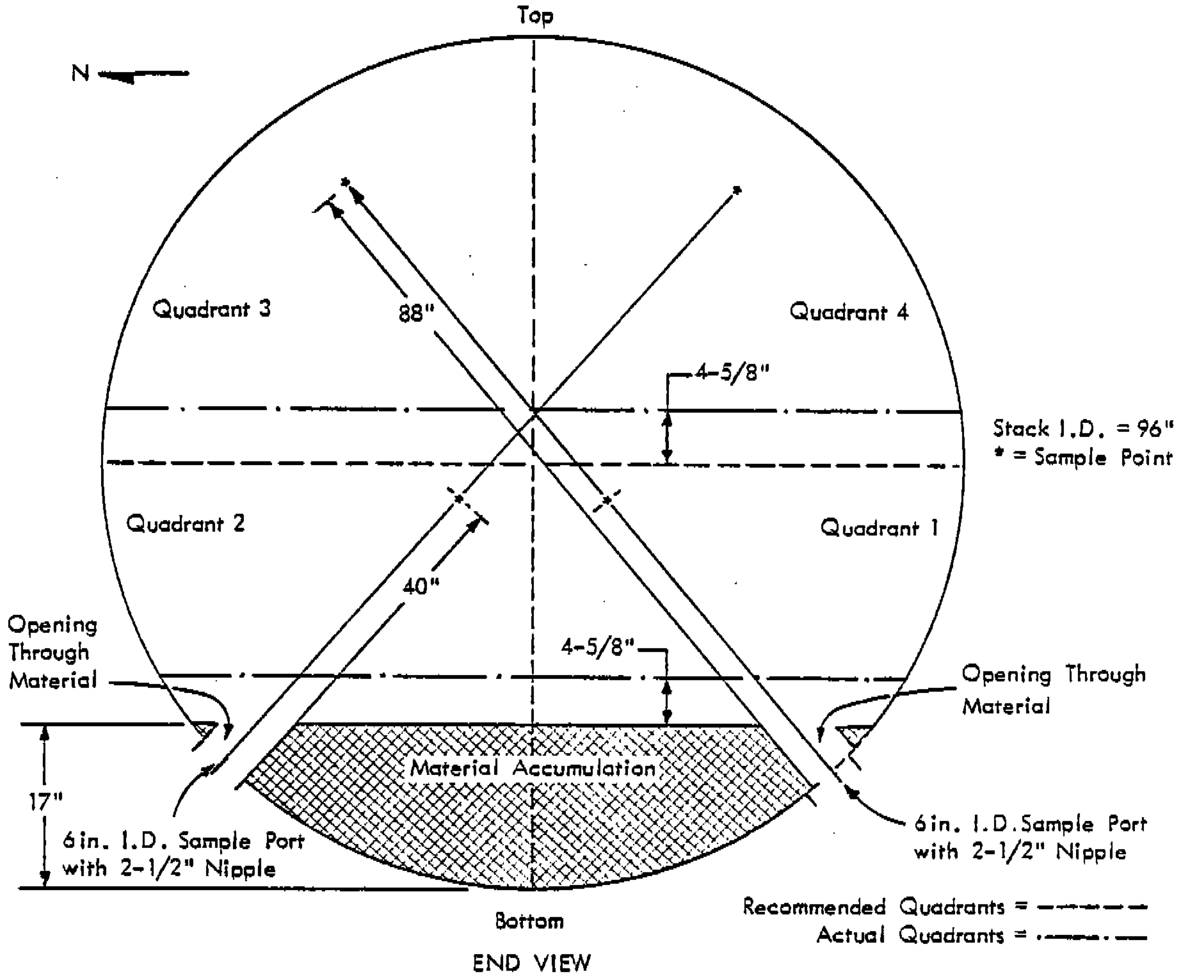


Figure 2-4. Schematic of sample ports, sample quadrants, and sample point locations at the inlet duct to the Ideal Basic Industries, Inc., kiln No. 2 electrostatic precipitator unit.

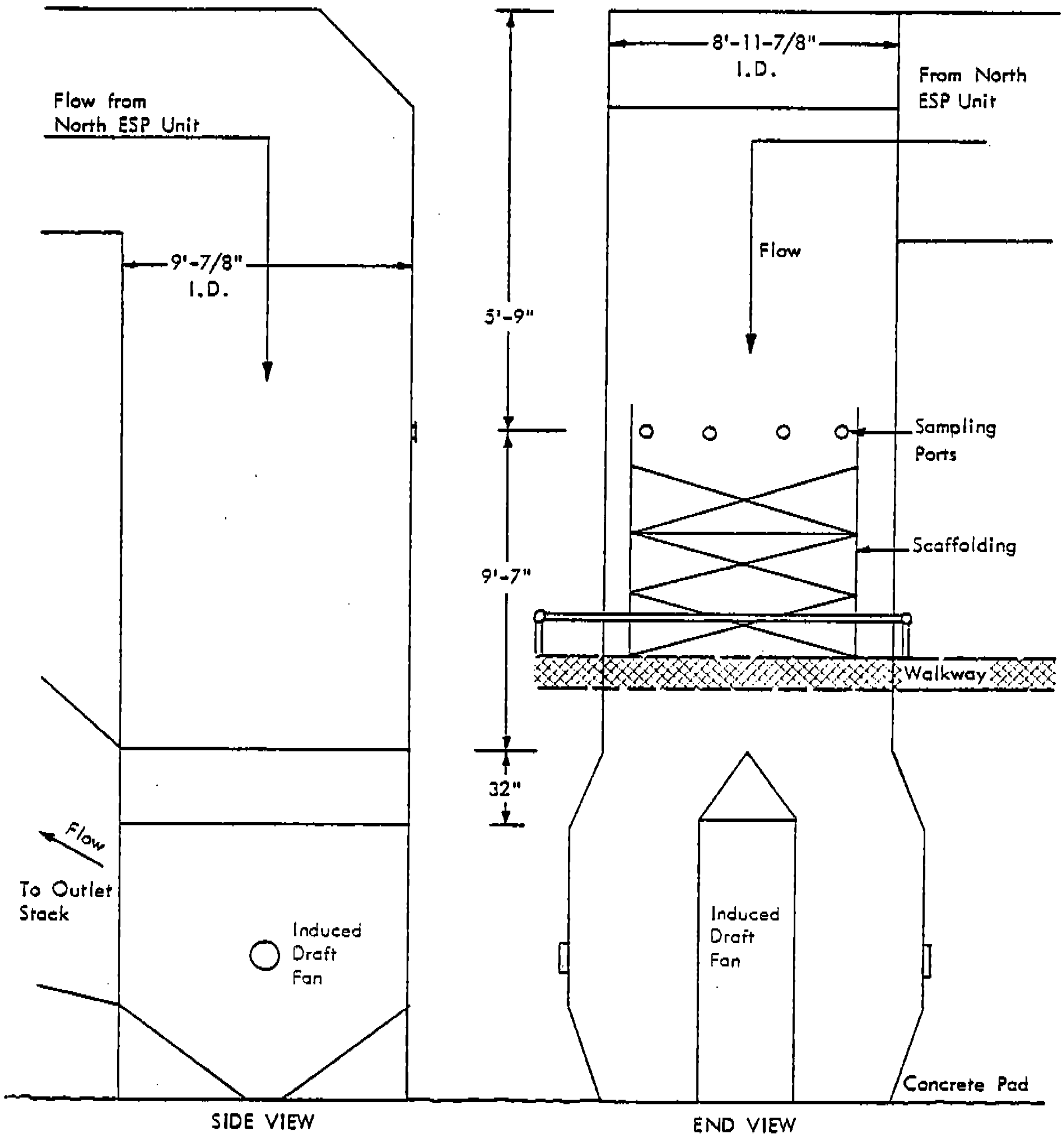


Figure 2-5. Schematic of outlet duct sample port locations at the Ideal Basic Industries, Inc., kiln No. 2 electrostatic precipitator unit.

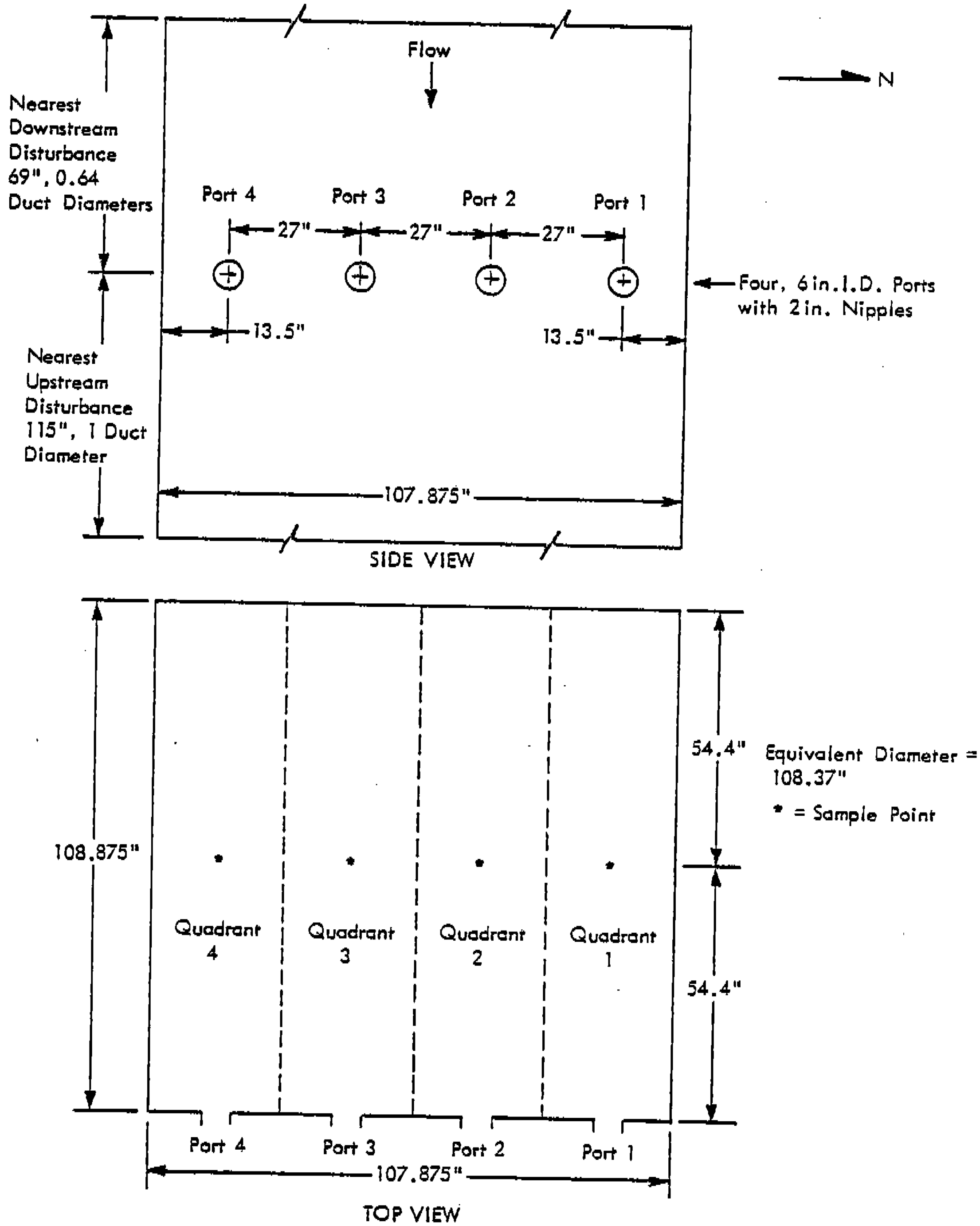


Figure 2-6. Schematic of sample ports, sample quadrants, and sample point locations at the outlet duct from Ideal Basic Industries, Inc., kiln No. 2 electrostatic precipitator unit.

Grab samples of insufflation dust were collected. To obtain samples, a 4-in. diameter pneumatic tap located near ground level was opened. The tap is located between the two ESP units on the west side of the structures. The general location of the tap was indicated in Figure 2-1.

2.1.5 Paved Road Fugitive Emissions

Emissions from roads were sampled for characterization of fugitive emissions generated by in-plant vehicular traffic. A cross-section of concrete surfaced road located on the main plant entrance road was selected for sampling. The section of road is located north of the ESP units and was indicated on Figure 2-1. Large haul trucks enter the plant property via this main road on their way to the loading area. After being loaded, they exit the plant using a different road.

2.2 SAMPLING EQUIPMENT

2.2.1 Particulate Mass

2.2.1.1 EPA Method 5 Train--

The EPA Method 5 train was used for mass sampling at the inlet to the ESP. The sampling train consisted of a Research Appliance Company (RAC) console and sample box. The probe nozzle and liner were made of 316 stainless steel, and the remainder of the train was made of borosilicate glass. Particulate matter was collected on 4-in. diameter, preweighed glass fiber filters.

2.2.1.2 EPA Method 17 Train--

The EPA Method 17 train was used for mass sampling at the outlet from the ESP. The in-stack filtration sampling system used was in accordance with the configuration presented in the Federal Register, Vol. 43, No. 37, Thursday, February 23, 1978.

The metering and flow control system for this train consisted of a RAC console. The filtration system consisted of an in-stack filter holder

(Sierra Instruments, Inc., Model 273) coupled to a 5/8-in. OD pipe. The nozzle and filter holder were made of 316 stainless steel. Particulate matter was collected on 47-mm diameter, preweighed, glass fiber filters. A condenser-ice bath cooling system with silica gel trap was used for determining moisture content of the stack gas.

2.2.2 Particle Size

2.2.2.1 Andersen High Capacity Stack Sampler (HCSS)--

An Andersen high capacity stack sampler (HCSS) cascade impactor (Andersen 2000) with 15-μm preseparator (Sierra Instruments, Inc.) was used for particle size distribution measurements of emissions at the inlet to the ESP.

The Andersen HCSS cascade impactor consists of two single jet impaction chambers followed by a third stage cyclone and a backup thimble filter. A RAC console was used for control and metering of flows. A condenser-ice bath cooling system with silica gel trap was used for determining moisture content. Particulate matter was collected inside the Stage 1 and Stage 2 impactor chambers and the Stage 3 cyclone. All particles remaining in the gas stream downstream of the Stage 3 cyclone were collected in a preweighed, high efficiency glass fiber thimble filter.

2.2.2.2 Andersen Mark III--

An Andersen Mark III cascade impactor (Andersen 2000) with 15-μm preseparator (Sierra Instruments, Inc.) was used for particle size distribution measurements of emissions at the outlet of the ESP.

The Andersen Mark III is a multistage, multijet cascade impactor. A RAC console was used for control and metering of flows. A condenser-ice bath cooling system with silica gel trap was used for determining moisture content. Particulate matter was collected on 2.5-in. diameter preweighed glass fiber filters (manufactured by Andersen 2000).

2.2.3 Paved Road Fugitive Emissions

Paved road fugitive dust samples were collected by portable electric vacuum cleaner with preweighed, disposable, paper vacuum cleaner bags.

2.2.4 Equipment Calibration

All ducted emission sampling equipment calibration was performed according to EPA requirements as stated in the Federal Register, Vol. 42, No. 160, August 18, 1977. Appendix C contains the calibration data for the equipment used during this field test.

2.3 SAMPLING PROCEDURES

2.3.1 Pretest Preparations

2.3.1.1 Particulate mass--

2.3.1.1.1 EPA Method 5 train--Four-inch diameter type A/E (Gelman Sciences, Inc.) glass fiber filters were used for particulate collection substrates in the EPA Method 5 train at the inlet to the ESP unit. The filters were placed in numbered 4-3/4 in. diameter by 3/16 in. deep aluminum weighing pans. The filters and weighing pans were desiccated for 24 hr. Each filter and its corresponding numbered weighing pan were then weighed on a Mettler Model AK 160 electronic balance. Weighings were recorded to the nearest 0.1 mg. The filters and weighing pans were again desiccated for 6 hr and weighed. The 6-hr desiccation was repeated until two consecutive weighings agreed within 1.0 mg (0.001 g). Laboratory weighing data are presented in Appendix D. Plastic petri dishes were used as shipping containers.

Glass beakers (250 ml) were used for recovery of mass train samples. The beakers were first washed in Alconox and rinsed with tap water. The beakers were numbered by using a lead pencil on the etched surface of the beaker. The beakers were then rinsed with distilled water and heated in an oven to 500°F for 1 hr. The beakers were transferred using beaker tongs to a desiccation chamber and dessicated for 24 hr. The beakers were then weighed on a Mettler Model AK 160 electronic balance to the nearest 0.1 mg. The beakers were redessicated and reweighed at 6-hr intervals until two consecutive weighings agreed within 1.0 mg (0.001 g). After completion of weighing, the beakers were placed in plastic Whirl-Pak containers and placed in their original boxes for shipping.

2.3.1.1.2 EPA Method 17 Train--Gelman type A/E 47-mm diameter glass fiber filters were used for particulate collection substrates in the EPA Method 17 train at the ESP outlet location. The filters were placed in numbered 57-mm diameter aluminum weighing pans. The desiccation and weighing procedures followed for these filters were identical to the procedures used for the EPA Method 5 filters. Plastic petri dishes were also used as shipping containers.

Glass beakers (150 ml) were used for recovery of EPA Method 17 samples. The beakers were cleaned, desiccated, and weighed according to the procedures described for the EPA Method 5 sample beakers. These beakers were also transported in plastic Whirl-Pak containers.

2.3.1.2 Particle size--

2.3.1.2.1 Andersen high capacity stack sampler with 15-μm preseparator--The entire Andersen HCSS impactor and 15-μm preseparator system and nozzles were washed in detergent and rinsed with distilled water and acetone. The acceleration and vent tubes were cleaned with a high pressure air stream.

A 1.5-in. diameter by 4.75-in. long aluminum tube was used as a container for each glass fiber thimble filter. The aluminum tube also served as a weighing container. The thimble filter and aluminum tube were prepared for field use as follows:

- The aluminum tubes were numbered with an engraver and the aluminum tubes and lids washed in alconox, rinsed with tap water, and deionized, distilled water.

- The tubes and lids were then heated in an oven to 500°F for 1 hr. After heating, the tubes were handled only with beaker tongs.

- After cooling, a thimble filter was placed in each container, which was then placed in a desiccator for 24 hr at ambient conditions. The tubes and thimbles were weighed to the nearest 0.1 mg on a Mettler Model AK 160 electronic balance. The tubes and thimbles were desiccated and weighed at 6-hr intervals until two consecutive weighings agreed within 1.0 mg (0.001 g). The lids were placed on the aluminum tubes and the assembly wrapped in aluminum foil for shipment.

Aluminum weighing pans 57 mm in diameter and 20 mm deep were used in recovering samples from the first four impactor stages. Each weighing pan was numbered with a metal engraver. The aluminum weighing pans were then desiccated and weighed following the procedures used for the aluminum tubes and thimbles. The aluminum weighing pans were placed in 100-mm diameter by 20-mm deep plastic petri dishes used as shipping containers.

2.3.1.2.2 Andersen Mark III impactor with 15-µm preseparator--Ten 3-in. x 3-in. pieces of aluminum foil were cut to serve as holders for each filter set. The aluminum foil squares were folded in half and labeled, and the appropriate glass fiber filter substrate (Andersen 2000) was placed inside. The filter sets were conditioned by vacuum desiccation for a period of 1 hr. Each filter, including its aluminum foil square, was weighed on a Cahn Instruments Model 27 electrobalance to the nearest 0.01 mg. The vacuum desiccation and weighing procedures were repeated at 15-min intervals until two consecutive weighings agreed within 0.05 mg. Each complete filter set was then placed in a glassine envelope for shipping.

2.3.1.2.3 Paved road fugitive emissions--Paper vacuum cleaner bags were preweighed on a triple beam, Ohaus balance to the nearest 0.1 g and then placed in individual shipping envelopes.

2.4 SAMPLING

The sampling criteria for both the particle sizing and mass tests were obtained from the "Procedures Manual for Inhalable Particulate Sampler Operation," prepared by Southern Research Institute, November 30, 1979, for EPA. The manual specifies four individual sampling points with a ± 20% isokinetic sampling rate.

2.4.1 Kiln No. 2 ESP Outlet Test Location

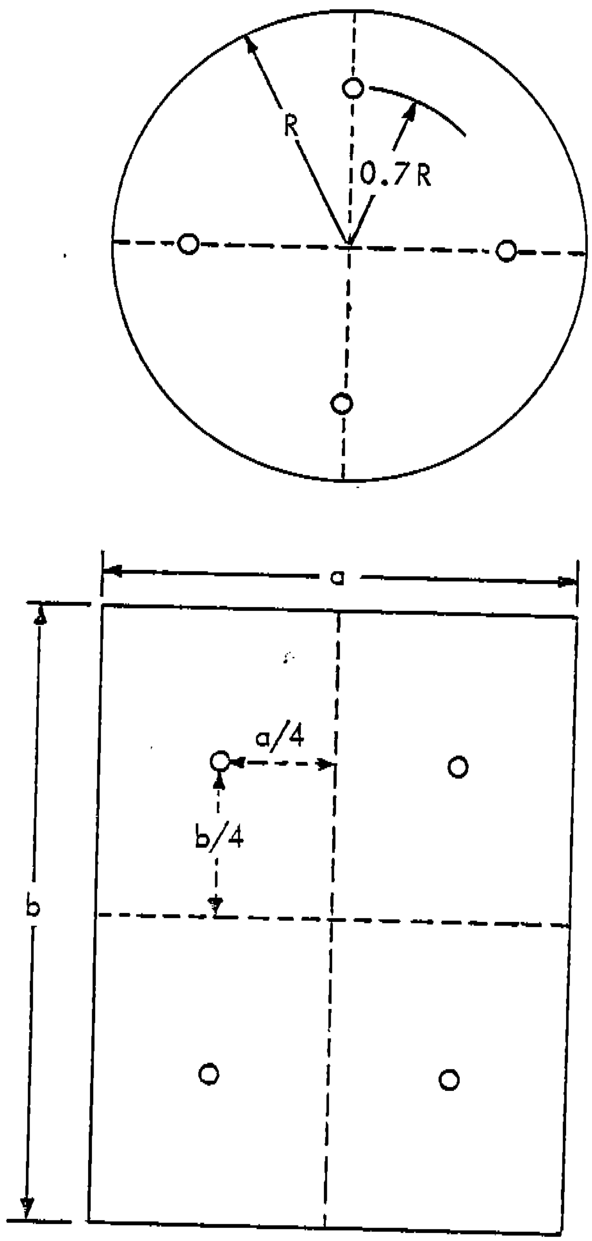
According to the manual, the recommended sampling points for circular and square or rectangular ducts can be determined by using the calculations shown on Figure 2-7. A preliminary survey of the Ideal Basic Industries, Inc., plant facilities did not locate any sampling ports near the outlet duct that meet either the EPA Method 1 criterion of eight downstream and two upstream duct diameter or the minimum criterion of two downstream and 0.5 upstream duct diameter. So, at a meeting held at EPA offices in Research Triangle Park on January 22, 1981, EPA recommended that MRI use an alternate sampling position, shown in Figure 2-8.

The sample ports for this alternate position were located one duct diameter downstream from a 90° bend, an equal distance apart on a single axis. The duct was traversed in a plane expected to contain the greatest variation in concentration.

2.4.2 ESP Inlet Test Location

The testing strategy used to sample the horizontal, circular duct at the inlet sampling location varied from the recommended sampling point array, because of the accumulation of material in the bottom of the duct.

The accumulated material presented two problems for testing at this location. First, the unobstructed area of the duct had to be determined and calculations made to adjust the location of the four sampling points.



O = Sampling Location

Figure 2-7. Recommended sampling points for circular and square or rectangular ducts.

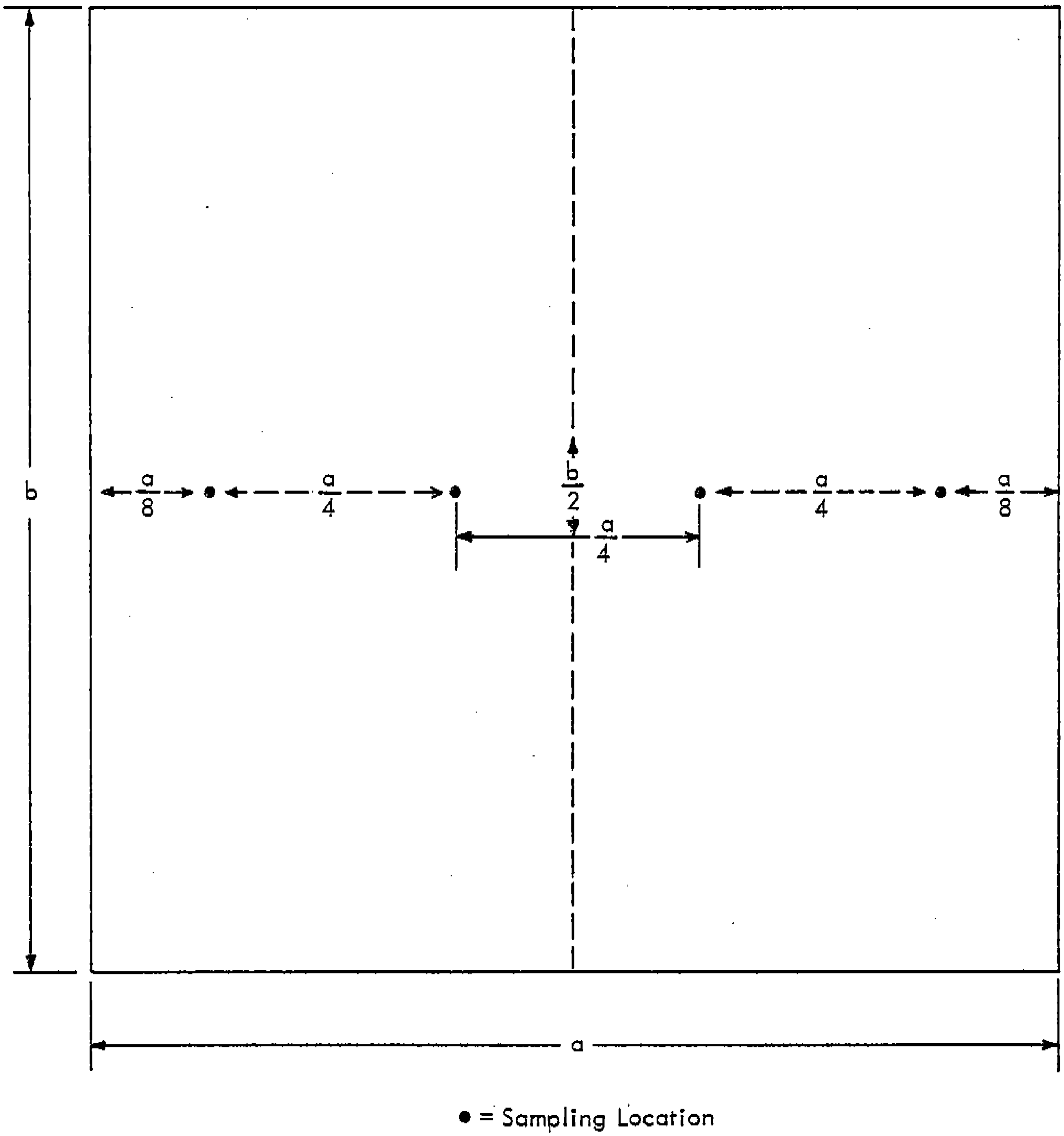


Figure 2-8. Alternate recommended sampling points for square or rectangular ducts.

The total inside area of the duct, including the obstructed region, was 50.3 ft^2. The obstructed portion amounted to 6.0 ft^2 or about 12% of the total duct area, leaving an unobstructed area of 44.3 ft^2. Appendix B contains the formula and calculations used to determine the unobstructed area of the duct. All computerized results used the unobstructed (corrected) duct area of 44.3 ft^2 for determination of emission parameters. For sampling purposes, the calculations used for determination of the unobstructed area of the duct shifted the four sampling quadrants and sampling points upward towards the top of the duct. The recommended sampling quadrants and actual sampling quadrants were shown in Figure 2-4.

The second problem associated with the accumulated material involved the two sampling ports which were located 90° apart in the bottom of the circular duct (see Figure 2-4). Prior to EPA Method 2 measurements, a hole was opened through the material. The duct pressure was negative, so this hole generally remained open, because of the frequent opening of the port covers. However, during EPA Method 2 measurements, the accumulated material continuously plugged the pitot lines at the two traverse points located nearest the port openings. Several velocity traverses were attempted with the same result. No reliable velocity data were obtained for these traverse points. Results are presented in Appendix E.

The difficulty in obtaining reliable velocity data near the port openings during EPA Method 2 measurements resulted in an additional shift upward of the two bottom quadrant sampling points. The calculated sampling point locations, without any duct obstruction, would have been 14.4 in. and 81.6 in. into the duct from each port. After correcting the stack area to accommodate the obstructed region, the four sampling points were shifted upward 4.6 in., to 19.0 in. and 86.2 in., respectively. Several attempts were made with the "S" pitot at 19 in. into the duct to determine if velocity data could be obtained during actual sampling. These attempts were unsuccessful, as were others at various distances up to 30.0 in. into the duct. A decision was made to shift the two lower quadrant sampling points to a distance of 40.0 in. into the duct in order to obtain the necessary stack velocity readings during testing. Prior to the initiation of sampling, a circular metal insert was placed inside the port opening. This insert helped to prevent material from accumulating directly at the port opening, enabling the sampling probes to be inserted or withdrawn through the insert without becoming either plugged or contaminated by the accumulated material. The four sampling points used at this test location were shown on Figure 2-4.

2.4.3 ESP Outlet Mass Method

An EPA Method 17 sampling train (in-stack filtration system) was used for total particulate mass sampling at the outlet duct from the ESP unit. Method 17 was used on the outlet instead of Method 5 in an effort to eliminate collecting condensible alkali oxides during the mass determinations. This decision was based upon the lower gas temperatures at this location, approximately 50°F, and the longer time the kiln exhaust gases had to travel before arriving at the test location.

2.4.4 ESP Inlet Particle Sizing Method

An Andersen HCSS with 15-μm preseparator was used for particle sizing at the inlet duct to the ESP unit. This impactor was chosen because it is designed for the heavy grain loading situations in which standard impactors cannot be used.

An Andersen Mark III impactor with 15-μm preseparator was used for particle sizing at the outlet duct from kiln No. 2 ESP unit. This impactor was chosen for use at this location because it is designed for moderate grain loading situations.

2.4.5 Sample Blanks

2.4.5.1 Particulate Mass--

Three filters of each type used for sampling were selected and weighed as blanks each day that sample filters were final weighed. One blank filter of each type was weighed before any samples were weighed. The second blank filter was weighed during sample weighing. The third blank filter was weighed at the completion of sample weighing. The three weights of each filter type were averaged at the end of each day. The difference between the average tare and average final weight of each filter type was then applied as a correction factor to samples weighed on that day. The blank filter weight analyses are presented in Appendix D.

Acetone blanks were determined in triplicate. The acetone blank analyses are also presented in Appendix D.

Field blanks were collected and analyzed but were not used as a correction factor.

2.4.5.2 Particle Sizing--

A particle sizing blank filter set consisted of one slotted impaction substrate with aluminum foil holder and one 2.5-in. diameter unslotted final filter with aluminum foil holder. The blank sets were desiccated, weighed, and handled in the same manner as actual sets used for testing. Three blank sets were selected and weighed in the field on the day that samples were weighed. One blank set was weighed prior to sample weighings, one set during weighing, and one set after samples had been weighed. The average final weight of each substrate type was used as a correction factor. Separate correction factors were determined for the slotted impactor substrates and the unslotted final filters.

Three thimble filters were used as blanks for the Andersen HCSS impactor. The three blank thimble filters were weighed in the field at the end of each day. The average weight gain or loss compared to the average tare weight of the three blank thimbles was used as a correction factor for that day.

2.4.6 Raw Product Samples

Grab samples of raw product feed were collected from the No. 2 feed tank by Ideal Basic Industries, Inc., plant personnel. One grab sample was collected during each 8-hr plant shift, for a total of three raw product feed samples each 24 hr. The samples were labeled as to the date and the shift during which they were collected. Samples were stored in plastic bags for subsequent analysis.

2.4.7 Insufflation Dust Samples

Grab samples of insufflation dust were collected with a fine mesh nylon bag from a 4-in. diameter pneumatic tap. One sample was collected each testing day by MRI personnel. The samples were labeled and stored in plastic bags for subsequent analysis.

2.4.8 Paved Road Fugitive Emissions

Sampling and analysis was accomplished according to the document, "Manual for Characterization of Industrial Roads," Draft Report, November 7, 1980, prepared by Midwest Research Institute for Industrial Environmental Research Laboratory, EPA, Research Triangle Park, North Carolina 27711.

Road samples were taken across a 20-ft wide cross-section of the road with a power vacuum and captured in tared vacuum bags. Four samples were collected. The vacuum bags were returned to MRI and reweighed to determine the sample mass. The surface loading was then calculated given a known mass on a specific area. The bags were then cut open to recover the sample. Each sample was dry sieved to determine its silt content.

2.4.9 Test Identification System

A system of identification was developed for the tests at the Ideal Basic Industries, Inc., cement plant. A typical test number, ESP-0-2-1(B), was derived as follows:

- The first designation indicates the sampling location: e.g., ESP.

- The next designation indicates either the outlet (0) or inlet (I) location of the control device being tested.

- The first number is the number of the quadrant being tested: e.g., number "2" above.

- The second number, e.g., number "1" in the above example, is the run number (one run in each of four quadrants.)

- The letter designation shown in parentheses indicates a repeat of the run in that particular quadrant. In the above example, the "B" indicates that this is the second run of Run 1 in quadrant 2, because the first run did not meet established test criteria. The first run that did not meet the test criteria was then labeled "A." If a run met all criteria the first time, a letter "A" was not designated. Only in the case of a repeated run was a letter designated. If a run was repeated the third time, then the letter "C" was designated; and so on.

SECTION 3.0

RESULTS

The results obtained from this test are summarized for ducted sources in Section 3.1 and for nonducted sources in Section 3.5. The data are presented in both graphical and tabular forms. The computer printouts of the mass and particle size runs from which the results have been summarized are presented in Appendices F and G, respectively. The sampling log is presented in Appendix H and the raw field data for ducted sources are presented in Appendix I.

Two types of cement were produced by the plant during the testing. The results are presented as Type I, Type II, and combined. Emission factors are presented for both types of cement, as well as combined.

3.1 DUCTED SOURCES

3.1.1 Acceptance Criteria

Only data that have met specific acceptance criteria are summarized in this section. These criteria, as obtained from "Procedures Manual for Inhalable Particulate Sampler Operation" (SoRI-EAS-79-761, 4181-37), November 30, 1979, prepared by Southern Research Institute for EPA, are:

1. Each total mass and particle size run must be within ± 20% of isokinetic.

2. The particulate grain loading from the total mass train and the IP train must be within ± 50%.

Two total mass and four particle sizing tests consisting of four runs per test (one run per quadrant) were conducted at the ESP inlet test site. Two total mass and two particle sizing tests consisting of four runs per test (one run per quadrant) were conducted at the ESP outlet test site. The average particulate grain loading for each set of four runs was determined, as well as the average for the number of tests conducted. Any measurement of the total mass which differed from the mean by more than 50% was considered suspect. The suspect value was compared with that found by the particle size train used at the same point. If these values disagreed by less than 50%, it was assumed that the deviations probably were due to stratification of the particulate and all of the data were retained.

Table 3-1 summarizes the data used for the acceptance criteria for the ESP inlet and outlet test locations. For the test to meet acceptance criteria, the values in the column labeled (% from $\bar{X}$) must be less than 50. The % from $\bar{X}$ is calculated as follows:

$$\frac{\bar{X}\text{ for all tests} - \bar{X}\text{ for individual test of 4 runs}}{\bar{X}\text{ for all tests}} \times 100$$

For the first test shown in Table 3-1, this was calculated as follows:

$$\frac{78.2 - 67.4}{78.2} \times 100 = 14$$

The data from runs that were suspect or did not meet the acceptance criteria are presented in Appendix J. Duplicate runs that were not used in the final calculations are presented in Appendix K.

3.1.2 Emission Factor Calculations

The emission factors for the inlet and outlet of the ESP were calculated for 2.5, 10.0, and 15.0 μm as follows:

TABLE 3-1. SUMMARY OF KILN NO. 2 ELECTROSTATIC PRECIPITATOR INLET AND OUTLET TEST ACCEPTANCE CRITERIA--COMBINED PRODUCT TEST RESULTS

Test No.	Quadrant No.	Run No.	Test date	% Isokinetic	Particulate loading (gr/dscf)[a]	$\bar{X}$[b]	% from $\bar{X}$
Inlet mass train (EPA Method 5)							
1	1	1	5-2-81	105.4	98.2		
	2	1	5-4-81	114.5	106.7		
	3	1	5-1-81	116.5	29.9	67.4	14
	4	1	5-2-81	92.8	34.8		
2	1	2	5-4-81	109.6	174.9		
	2	2	5-5-81	98.1	69.7		
	3	2	5-5-81	101.6	39.3	89.1	14
	4	2	5-6-81	102.4	72.6		
					$\bar{X}$ = 78.2		
Outlet mass train (EPA Method 17)							
1	1	1(C)	5-6-81	103.5	0.0075		
	2	1	5-1-81	108.8	0.0060		
	3	1	5-2-81	111.2	0.0099	0.0073	27
	4	1	5-2-81[c]	102.5	0.0058		
2	1	2	5-4-81	96.5	0.019		
	2	2(B)	5-6-81	112.1	0.024		
	3	2	5-5-81	99.8	0.0051	0.013	30
	4	2	5-5-81	94.7	0.0028		
					$\bar{X}$ = 0.01		

Test No.	Quadrant No.	Run No.	Test date	% Isokinetic	Particulate loading (gr/dscf)	$\bar{X}$	% from $\bar{X}$
Inlet IP train (Andersen High Capacity Stack Sampler with 15 μm preseparator)							
1	1	1	5-2-81	84.1	78.6		
	2	1	5-4-81	98.5	68.8		
	3	1	5-1-81	106.8	31.4	56.8	20
	4	1	5-2-81	101.4	48.5		
2	1	2	5-2-81	98.5	71.3		
	2	2	5-4-81	85.8	72.4		
	3	2	5-1-81	113.7	43.6	60.0	15
	4	2	5-2-81	98.1	52.7		
3	1	3(B)	5-4-81	106.3	110.2		
	2	3	5-5-81	85.4	70.4		
	3	3	5-5-81	104.4	75.0	87.6	24
	4	3	5-6-81	100.4	94.9		
4	1	4	5-4-81	114.1	98.2		
	2	4	5-5-81	86.4	80.3		
	3	4	5-5-81	103.4	48.6	78.9	11
	4	4	5-6-81	91.7	88.5		
						$\bar{X}$ = 70.8	
Outlet IP train (Andersen Mark III impactor with 15 μm preseparator)							
1	1	1(C)	5-6-81	99.5	0.0054		
	2	1(B)	5-6-81	100.3	0.0055		
	3	1	5-2-81	94.2	0.0028	0.0046	21
	4	1	5-4-81	102.0	0.11[c]		
2	1	2	5-4-81	109.2	0.0037		
	2	2(B)	5-6-81	99.7	0.0052		
	3	2	5-5-81	108.0	0.00072	0.003	21
	4	2	5-6-81	99.3	0.0025		
						$\bar{X}$ = 0.0038	

[a] gr/dscf = Grains per dry standard cubic foot.

[b] $\bar{X}$ = mean.

[c] The particulate loading from this run (ESP-O-4-1) was considered suspect data and was not used in calculating acceptance criteria.

A total mass emission factor was calculated for each run of each test using the data collected with the EPA Method 5 train (inlet test location) or the EPA Method 17 train (outlet test location) and the standard EPA Method 5 calculations (Appendix L). IP emission factors were calculated using the mass train emission factor rather than the particle sizing emission factor. The emission factor is presented in pounds per hour and pounds per ton of product. The product tonnage daily output was provided by Ideal Basic Industries, Inc. The emission factor calculation for each run is based on the stack velocities measured at the single sampling point of the quadrant being sampled. Since the stack was not traversed during the test, as per the testing protocol, the standard EPA Method 5 reduction of the data is based on the assumption that the overall average stack velocity was the same as the velocity measured at the single sampling point. Also, since the series of runs required for a test were collected over more than one day, it was assumed that operating conditions did not vary appreciably over the sample periods.

The mass collected on each stage of the particle size trains was determined and the cumulative percentage of the total mass for each stage calculated. The effective cut size (D_{50}) for each stage was also calculated.

The computer printouts in Appendix G indicate the cumulative percent greater than the stated D_{50}, whereas the graphs and tables indicate D_{50} as cumulative percent less than the stated size. The equations for the Andersen HCSS and Andersen Mark III impactor calculations are presented in Appendix L.

It should be noted that the particulate loading on some stages is low. In a few instances, application of the blank filter correction factor resulted in small negative weights. These were recorded as zero for calculation purposes.

The cumulative percentages for each stage were applied to the total mass emission factor (calculated from the appropriate EPA Method 5 or Method 17 train) to obtain an emission factor for each stage of the particle size device.

A spline equation was used to fit the data and to extrapolate, where required, to the desired cutpoints. Emission factors were calculated for 2.5, 10.0, and 15.0 µm. The particle diameter upper limit was set at 50.0 µm for the calculations using the spline equation. A program for handling impactor data using a spline fit has been developed by J. E. Johnson, et al., "A Computer Based Cascade Impactor Data Reduction System," EPA-600/7-78-042, March 1978.

3.2 TEST RESULTS

A change was made in the type of cement produced during the field tests. The data presented in the tables labeled Combined Product Test Results makes no differentiation between tests conducted during the production of Type I or Type II cement.

Although each test consisted of four separate runs, one per quadrant, the change in type of product resulted in some quadrants of a given test being sampled during production of different cement products.

At the outlet test location, for example, a mass train run in a particular quadrant was conducted during production of one type of cement product and the particle size run for that same test and quadrant was conducted during production of the other type of cement product. This was the direct result of repeating some runs that were suspect and, also, running both a mass train and an IP train simultaneously in different quadrants. The mass train would be run in a quadrant first and the IP train run in the previous mass train quadrant. At the end of any given testing day, therefore, it was likely that an IP train had not been run in the last mass train quadrant.

At the inlet test location, each quadrant sampled during a given test day was sampled with both a mass train and the two IP trains. Therefore, the change in type of cement product affected all of the data for a particular quadrant.

3.2.1 Summary of ESP Inlet Results

Table 3-2 presents the test data for the inlet of the ESP. Values are reported for each size location collected for the runs meeting the acceptance criteria. The values reported consist of the total mass collected, the calculated D_{50} particle size under sampling conditions, and the cumulative percent of the mass less than the stated particle size.

3.2.2 Summary of ESP Inlet Mass Emission Factors

Table 3-3 presents the mass emission factors for the inlet to the ESP. This table presents, for each run, the total mass emissions, the production rate during sampling, the total mass emission rate, the ratio of the IP mass to the total mass, and the emission factors for the three particle size ranges.

3.2.3 Graphic Presentation of ESP Inlet Results

Figures 3-1 through 3-5 present the results of the ESP inlet test graphically.

Figures 3-1 through 3-4 present the results of individual tests, and Figure 3-5 presents the average results of these four tests. Results are shown as particle diameter plotted versus cumulative percent less than the stated size and the cumulative emission factor.

3.2.4 Summary of ESP Outlet Results

Table 3-4 presents the test data from the outlet of the ESP. Values are reported for each size fraction collected for the runs meeting the acceptance criteria. The values reported consist of the total mass collected, the calculated D_{50} particle size under sampling conditions, and the cumulative percent of the mass less than the stated particle size.

TABLE 3-2. KILN NO. 2 ELECTROSTATIC PRECIPITATOR INLET--ANDERSEN HCSS IMPACTOR WITH 15 μm PRESEPARATOR PARTICLE SIZE TEST SAMPLING DATA--COMBINED PRODUCT TEST RESULTS

Particle size run No.	15 μm Cyclone			Stage 1			Stage 2			Cyclone			Filter	
	Mass (mg)[a]	D_{50} size (μm)[b]	Cum. % less than[c]	Mass (mg)	D_{50} size (μm)	Cum. % less than	Mass (mg)	D_{50} size (μm)	Cum. % less than	Mass (mg)	D_{50} size (μm)	Cum. % less than	Mass (mg)	D_{50} size (μm)
ESP-I-1-1	25,179.5	16.40	13.98	1,407.2	11.88	9.18	1,104.9	6.66	5.40	1,033.7	2.08	1.87	547.5	< 2.08
ESP-I-2-1	22,533.6	15.15	14.72	1,669.5	11.40	8.40	958.6	6.33	4.77	790.7	1.92	1.78	470.5	< 1.92
ESP-I-3-1	12,241.8	15.74	18.98	629.6	11.58	14.82	832.0	6.43	9.31	944.0	2.01	3.06	463.0	< 2.01
ESP-I-4-1	16,437.7	15.35	11.97	437.9	11.49	9.63	897.7	6.39	4.82	653.1	1.95	1.32	246.9	< 1.95
ESP-I-1-2	15,908.5	15.47	11.91	647.2	11.53	8.33	583.8	6.42	5.10	583.1	1.96	1.87	337.5	< 1.96
ESP-I-2-2	24,600.2	15.03	11.08	971.3	11.39	7.56	755.3	6.34	4.83	967.2	1.90	1.34	370.0	< 1.90
ESP-I-3-2	14,099.5	15.48	15.90	902.5	11.51	10.51	692.2	6.40	6.38	881.5	1.97	1.13	188.9	< 1.97
ESP-I-4-2	17,863.3	15.51	11.52	442.9	11.54	9.33	685.7	6.42	5.93	904.8	1.97	1.45	292.9	< 1.97
ESP-I-1-3(B)	22,787.9	15.89	10.95	1,053.7	11.72	6.84	817.3	6.56	3.64	775.8	2.01	0.61	156.2	< 2.01
ESP-I-2-3	20,446.9	15.41	10.33	864.0	11.64	6.54	613.6	6.54	3.85	722.5	1.94	0.68	155.4	< 1.94
ESP-I-3-3	22,625.6	15.05	8.52	604.2	11.40	6.07	604.0	6.34	3.63	651.1	1.90	1.00	247.2	< 1.90
ESP-I-4-3	25,731.7	14.73	21.41	4,056.4	11.26	9.02	1,317.4	6.24	4.99	1,315.5	1.87	0.87	283.5	< 1.87
ESP-I-1-4	21,330.2	15.52	9.50	767.2	11.58	6.24	707.0	6.47	3.24	631.1	1.96	0.56	132.6	< 1.96
ESP-I-2-4	23,297.9	15.81	10.56	705.6	11.77	7.85	1,066.1	6.62	3.76	776.1	1.99	0.78	202.1	< 1.99
ESP-I-3-4	13,848.2	15.25	10.83	377.1	11.56	8.40	510.8	6.48	5.11	649.4	1.92	0.93	143.8	< 1.92
ESP-I-4-4	21,972.4	16.17	13.26	1,088.4	11.85	8.97	1,004.2	6.66	5.00	871.1	2.04	1.56	395.8	< 2.04

[a] mg = Net weight milligrams.

[b] D_{50} size (μm) = 50% effective cutoff diameter micrometers.

[c] Cum. % less than = cumulative percent less than stated size.

TABLE 3-3. KILN NO. 2 ELECTROSTATIC PRECIPITATOR INLET EMISSION FACTORS BASED ON TOTAL MASS AND IMPACTOR SIZE DISTRIBUTION--COMBINED PRODUCT TEST RESULTS

Particle size run No.[a]	Total mass emission rate[b] (lb/hr)[c]	Production rate (ton/hr)	Total mass emission factor (lb/ton)[d]	Ratio of particle size train conc. to total mass conc.	Emission factors for ≦ 2.5 μm (lb/ton)[d]	Emission factors for ≦ 10.0 μm (lb/ton)	Emission factors for ≦ 15.0 μm (lb/ton)
ESP-I-1-1	52,000	35	1,500		30	120	180
ESP-I-2-1	57,000	35	1,600		32	110	220
ESP-I-3-1	21,000	35	590		24	77	110
ESP-I-4-1	24,000	35	690		14	55	83
Average	38,000	35	1,100	0.84	25	90	150
ESP-I-1-2	52,000	35	1,500		30	100	180
ESP-I-2-2	57,000	35	1,600		32	110	180
ESP-I-3-2	21,000	36	590		12	53	88
ESP-I-4-2	24,000	35	690		14	55	76
Average	38,000	35	1,100	0.89	22	80	130
ESP-I-1-3(B)	86,000	35	2,400		24	140	240
ESP-I-2-3	39,000	35	1,100		11	55	110
ESP-I-3-3	26,000	35	750		10	38	68
ESP-I-4-3	47,000	34	1,400		14	110	310
Average	50,000	35	1,400	0.98	15	86	180
ESP-I-1-4	86,000	35	2,400		24	120	220
ESP-I-2-4	39,000	35	1,100		11	66	110
ESP-I-3-4	26,000	35	750		10	52	82
ESP-I-4-4	47,000	34	1,400		28	98	170
Average	50,000	35	1,400	0.89	18	84	150
Total average	44,000	35	1,200	0.90	20	85	150

[a] Particle size test data obtained with an Andersen HCSS impactor with 15 μm preseparator.

[b] Total mass emission rate data obtained with an EPA Method 5 train.

[c] lb/hr = Emission rate pounds per hour.

[d] lb/ton = Pounds per ton of product.

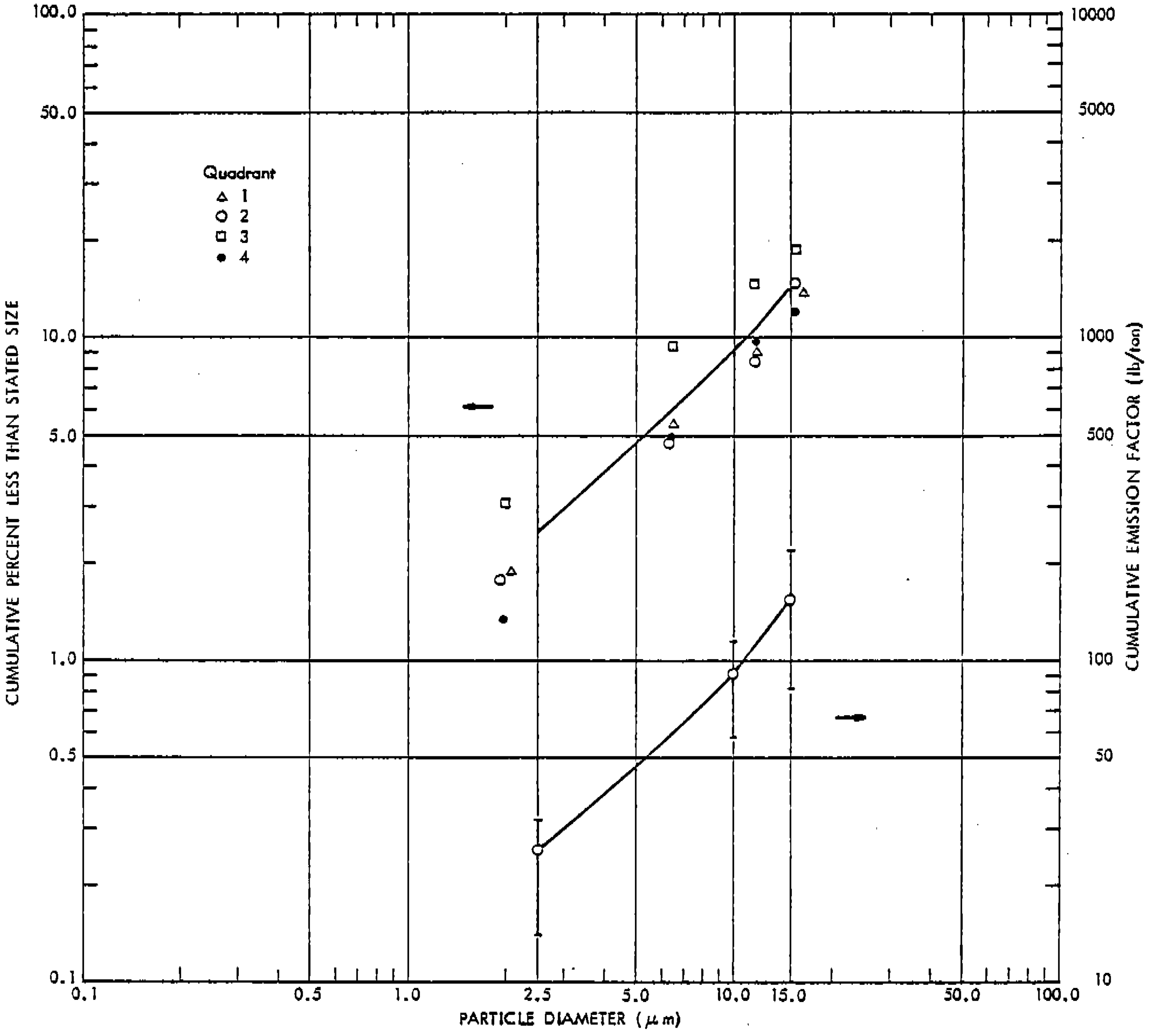


Figure 3-1. Kiln No. 2 electrostatic precipitator inlet, test one--combined product test results--cumulative percent less than stated size and cumulative emission factor versus particle diameter.

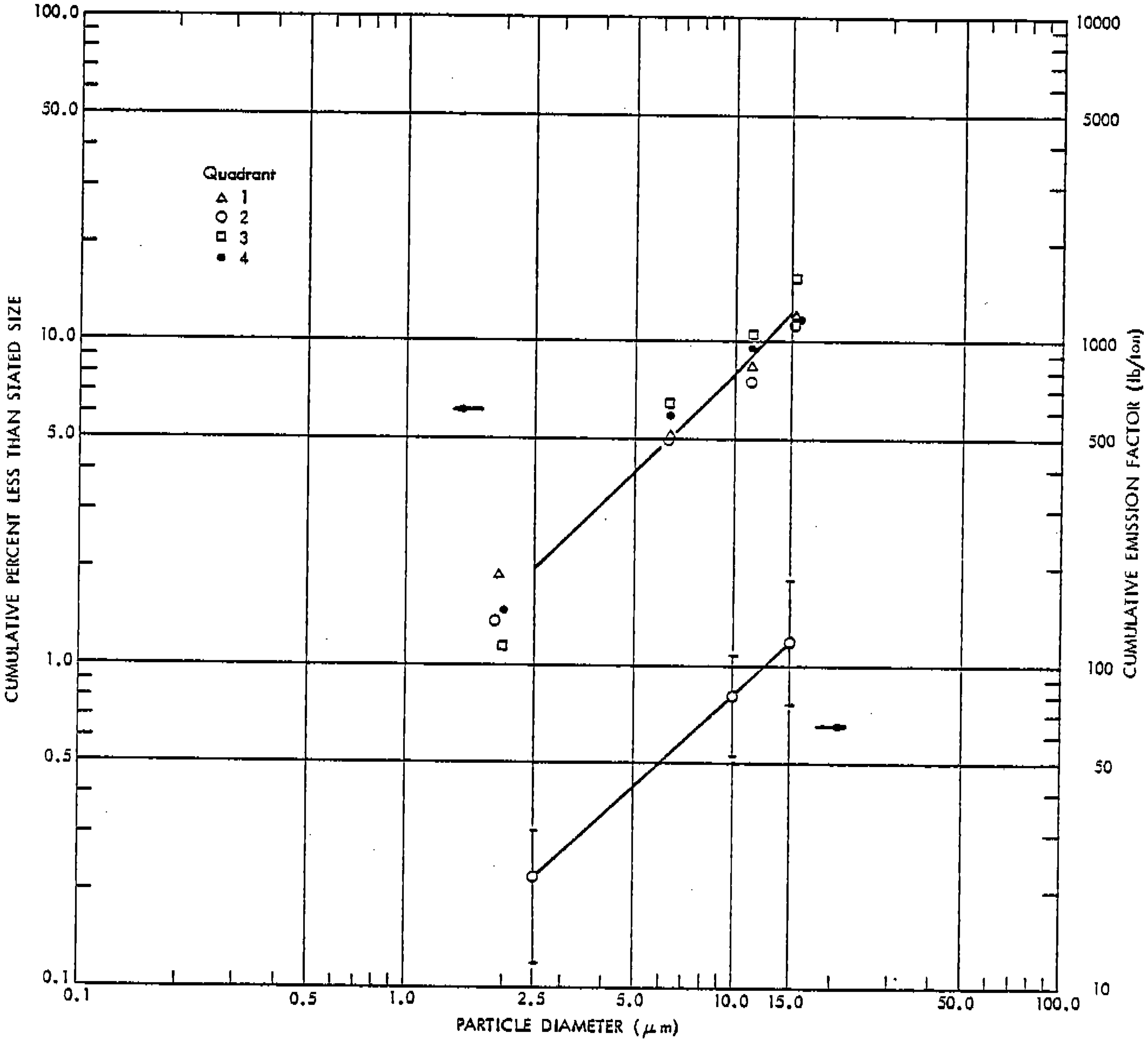


Figure 3-2. Kiln No. 2 electrostatic precipitator inlet, test two--combined product test results--cumulative percent less than stated size and cumulative emission factor versus particle diameter.

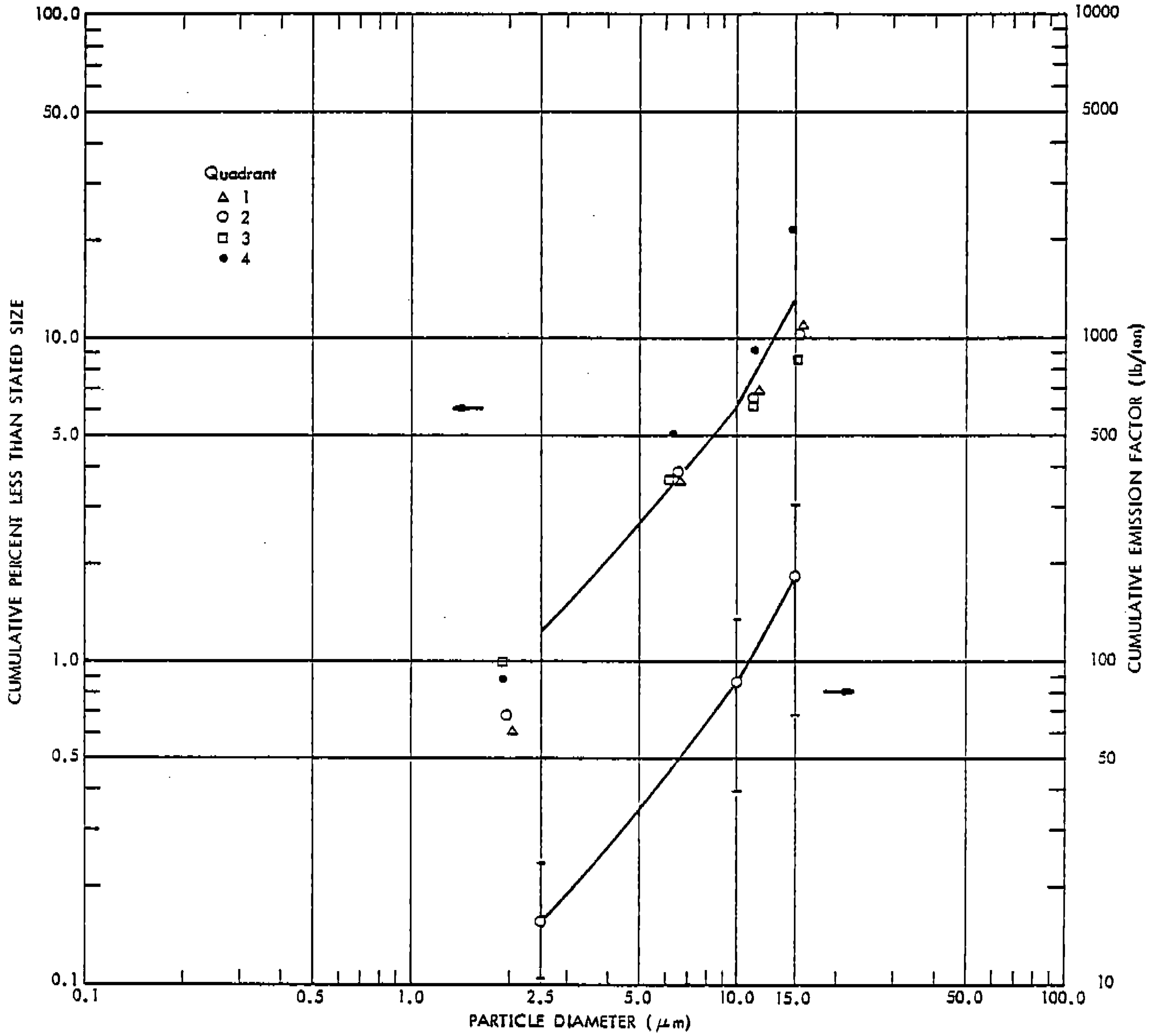


Figure 3-3. Kiln No. 2 electrostatic precipitator inlet, test three--combined product test results--cumulative percent less than stated size and cumulative emission factor versus particle diameter.

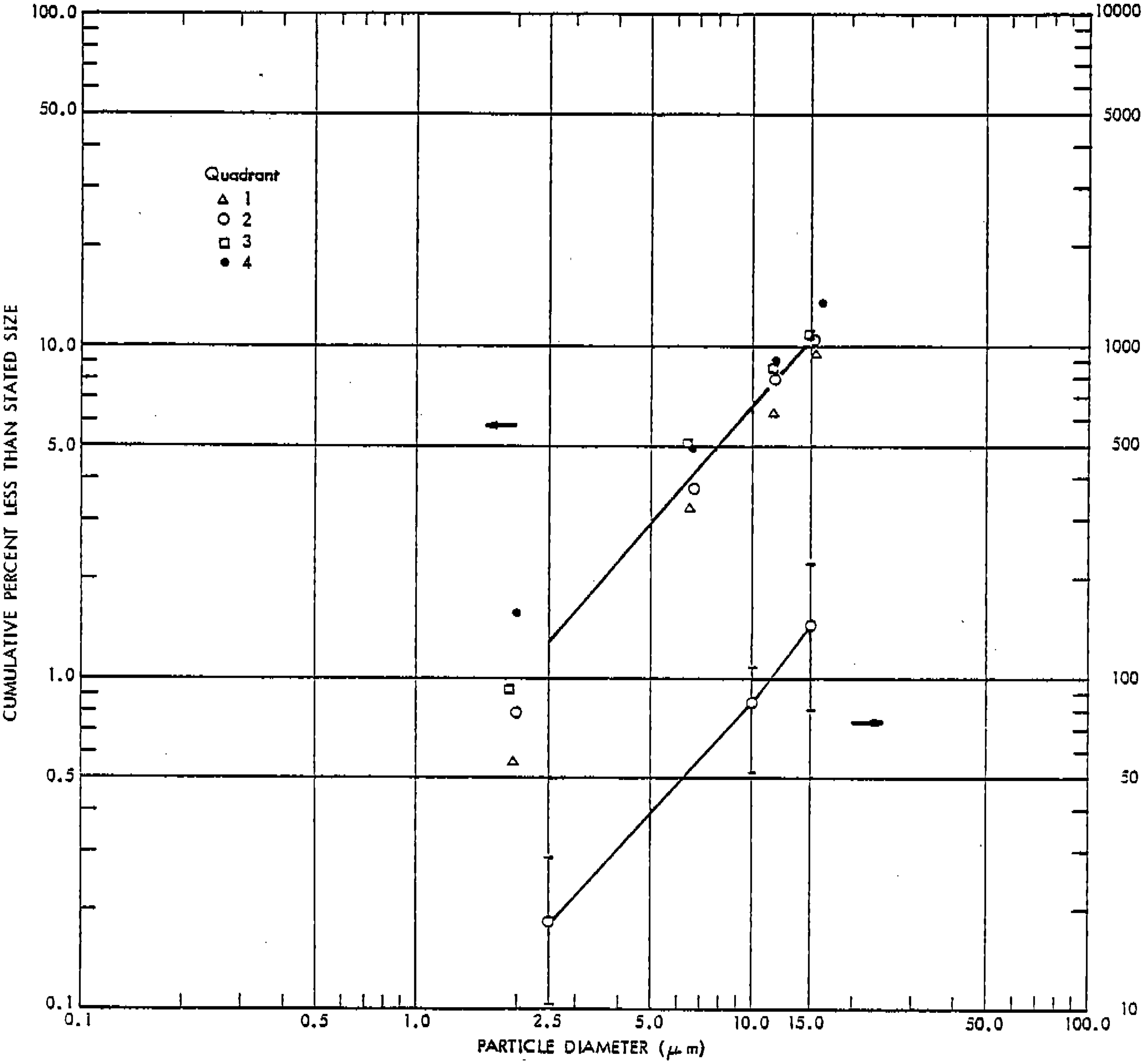


Figure 3-4. Kiln No. 2 electrostatic precipitator inlet, test four--combined product test results--cumulative percent less than stated size and cumulative emission factor versus particle diameter.

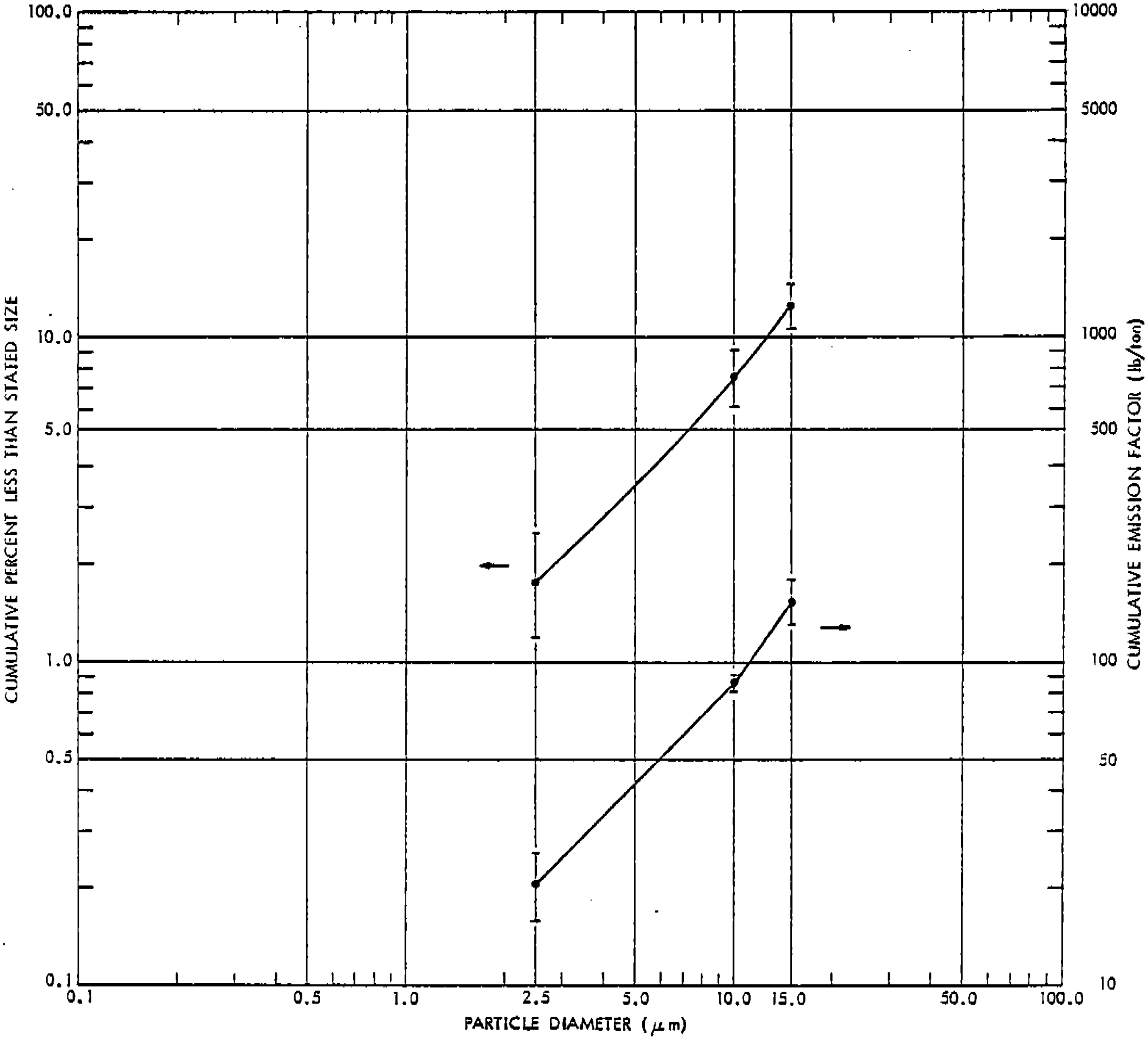


Figure 3-5. Kiln No. 2 electrostatic precipitator inlet, total test average--combined product test results--cumulative percent less than stated size and cumulative emission factor versus particle diameter.

TABLE 3-4. KILN NO. 2 ELECTROSTATIC PRECIPITATOR OUTLET--ANDERSEN MARK III IMPACTOR WITH 15 μm PRESEPARATOR PARTICLE SIZE TEST SAMPLING DATA--COMBINED PRODUCT TEST RESULTS

Particle size run No.	15 µm Cyclone			Stage 0			Stage 1			Stage 2			Stage 3		
	Mass (mg)[a]	D_{50} Size (µm)[b]	Cum. % less than[c]	Mass (mg)	D_{50} Size (µm)	Cum. % less than	Mass (mg)	D_{50} Size (µm)	Cum. % less than	Mass (mg)	D_{50} Size (µm)	Cum. % less than	Mass (mg)	D_{50} Size (µm)	Cum. % less than
ESP-0-1-1(C)	1.19	14.70	92.44	0.47	14.26	89.46	0.04	8.89	89.21	0.22	6.01	87.81	0.35	4.08	85.59
ESP-0-2-1(B)	0.51	15.86	96.54	0.31	15.03	94.44	0.16	9.37	93.36	0.34	6.34	91.05	0.33	4.30	88.81
ESP-0-3-1	0.09	14.34	98.98	2.15	13.77	74.72	0.04	8.58	74.27	0.00	5.80	74.27	0.00	3.93	74.27
ESP-0-4-1[d]	289.72	14.81	7.27	7.86	14.14	4.76	1.60	8.81	4.24	2.72	5.95	3.37	1.66	4.04	2.84
ESP-0-1-2	4.25	13.40	63.80	0.90	13.19	56.13	1.13	8.22	46.51	0.68	5.55	40.72	0.62	3.76	35.53
ESP-0-2-2(B)	1.45	15.58	89.44	0.43	15.09	86.31	0.21	9.41	84.78	0.46	6.37	81.43	0.50	4.32	77.79
ESP-0-3-2	0.84	14.79	59.81	0.00	14.40	59.81	0.12	8.97	54.07	0.30	6.07	39.71	0.21	4.12	29.67
ESP-0-4-2	1.84	15.11	74.34	0.80	14.58	63.18	0.18	9.09	60.67	0.45	6.15	54.39	0.47	4.17	47.84

Particle size run No.	Stage 4			Stage 5			Stage 6			Stage 7			Filter	
	Mass (mg)	D_{50} Size (µm)	Cum. % less than	Mass (mg)	D_{50} Size (µm)	Cum. % less than	Mass (mg)	D_{50} Size (µm)	Cum. % less than	Mass (mg)	D_{50} Size (µm)	Cum. % less than	Mass (mg)	D_{50} Size (µm)
ESP-0-1-1(C)	0.54	2.60	82.16	1.79	1.28	70.79	1.92	0.77	58.60	3.50	0.56	36.38	5.73	< 0.56
ESP-0-2-1(B)	0.71	2.75	84.00	2.92	1.35	64.20	2.06	0.82	50.24	2.38	0.60	34.10	5.03	< 0.60
ESP-0-3-1	0.02	2.51	74.04	0.05	1.23	73.48	0.00	0.74	73.48	0.00	0.53	73.48	6.51	< 0.53
ESP-0-4-1[d]	1.40	2.57	2.39	0.98	1.26	2.08	1.27	0.76	1.67	2.33	0.55	0.93	2.90	< 0.55
ESP-0-1-2	0.21	2.40	33.65	0.81	1.17	26.75	0.83	0.70	19.68	0.91	0.51	11.93	1.40	< 0.51
ESP-0-2-2(B)	0.66	2.76	72.98	2.12	1.36	57.54	1.79	0.82	44.50	2.02	0.61	29.79	4.09	< 0.61
ESP-0-3-2	0.14	2.63	22.97	0.08	1.29	19.14	0.05	0.78	16.75	0.00	0.57	16.75	0.35	< 0.57
ESP-0-4-2	0.43	2.66	41.84	0.83	1.31	30.26	0.76	0.79	19.66	0.51	0.58	12.55	0.90	< 0.58

[a] mg = Net weight milligrams.

[b] D_{50} size (µm) = 50% effective cutoff diameter micrometers.

[c] Cum. % less than = cumulative percent less than stated size.

[d] Not used in calculations due to suspect stage loading.

3.2.5 Summary of ESP Outlet Mass Emission Factors

Table 3-5 presents the mass emission factors for the outlet of the ESP. This table presents for each run the total mass emissions, the production rate during sampling, the total mass emission rate, the ratio of the IP mass to the total mass, and the emission factors for the three particle size ranges.

3.2.6 Graphic Presentation of ESP Inlet Results

Figures 3-6 through 3-8 present graphically the results of the ESP outlet test. Figures 3-6 and 3-7 present the results of individual tests, and Figure 3-8 presents the average results of these two tests. Results are shown as particle diameter plotted versus cumulative percent less than stated size and the cumulative emission factor.

3.3 TEST RESULTS BY CEMENT TYPE

As mentioned earlier in this report, two cement types (I and II) were being produced during the field tests. EPA requested that, where possible, particle size information and emission factor calculations be reported by cement type.

As a first step, therefore, the sampling runs were separated by cement type. Table 3-6 is a summary of test results by cement type. The table includes data from both the ESP inlet and outlet test locations. In all instances, each total mass and particle size run met the ± 20% isokinetic criterion. However, for reasons cited earlier, no averaging of the particulate grain loading for each set of four runs can be determined. The evaluation of individual total mass runs to determine their deviation from the mean (± 50% criterion) also cannot be determined.

Emission factors for both the inlet and outlet test locations were also calculated for sampling runs conducted during both types of cement production.

TABLE 3-5. KILN NO. 2 ELECTROSTATIC PRECIPITATOR OUTLET EMISSION FACTORS BASED ON TOTAL MASS AND IMPACTOR SIZE DISTRIBUTION--COMBINED PRODUCT TEST RESULTS

Particle size run No.[a]	Total mass emission rate[b] (lb/hr)[c]	Production rate (ton/hr)[d]	Total mass emission factor (lb/ton)[e]	Ratio of particle size train conc. to total mass conc.	Emission factors for ≦ 2.5 μm (lb/ton)[e]	Emission factors for ≦ 10.0 μm (lb/ton)[e]	Emission factors for ≦ 15.0 μm (lb/ton)[e]
ESP-0-1-1(C)	3.2	34	0.094		0.077	0.084	0.088
ESP-0-2-1(B)	2.1	34	0.062		0.051	0.058	0.059
ESP-0-3-1	5.4	35	0.15		0.11	0.12	0.15
ESP-0-4-1[f]	5.0	35	0.14		0.003	0.006	0.011
Average	3.6	34	0.10	0.63	0.079	0.087	0.099
ESP-0-1-2	8.5	35	0.24		0.082	0.13	0.16
ESP-0-2-2(B)	9.6	34	0.28		0.20	0.24	0.24
ESP-0-3-2	2.8	35	0.08		0.018	0.045	0.048
ESP-0-4-2	2.3	34	0.068		0.028	0.041	0.049
Average	5.8	34	0.17	0.23	0.082	0.11	0.12
Total average	4.7	34	0.14	0.43	0.08	0.098	0.11

[a] Particle size test data obtained with an Andersen Mark III impactor with 15 μm preseparator.

[b] Total mass emission rate data obtained with an EPA Method 17 train.

[c] lb/hr = Emission rate pounds per hour.

[d] The production rate (tons/hr) presented corresponds to the same date the total mass emission rate was determined from the mass train. This date may not necessarily be the same date the corresponding IP train was sampled in in that quadrant.

[e] lb/ton = Pounds per ton of product.

[f] Not used in calculations or averages due to suspect stage loading.

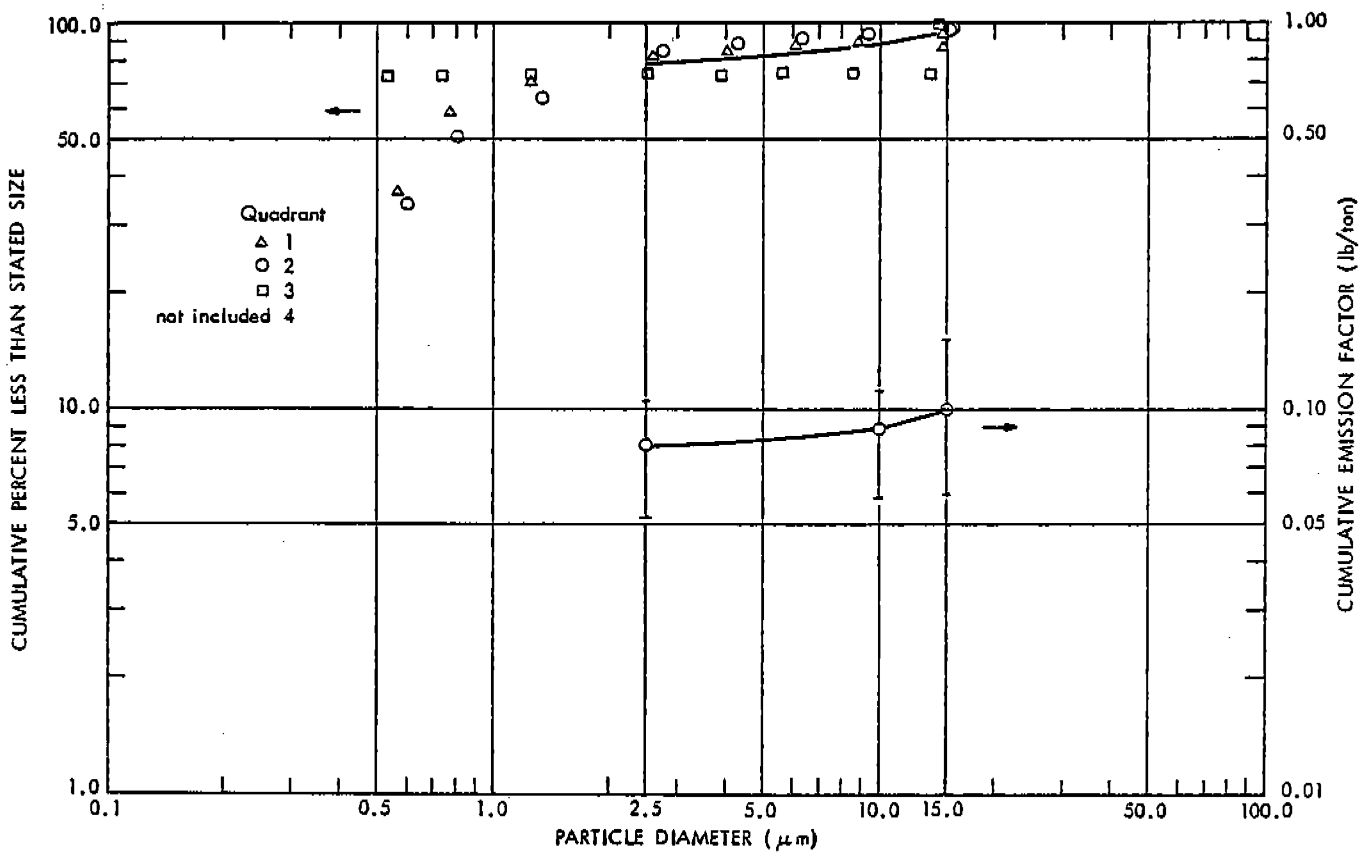


Figure 3-6. Kiln No. 2 electrostatic precipitator outlet, test one--combined product test results--cumulative percent less than stated size and cumulative emission factor versus particle diameter.

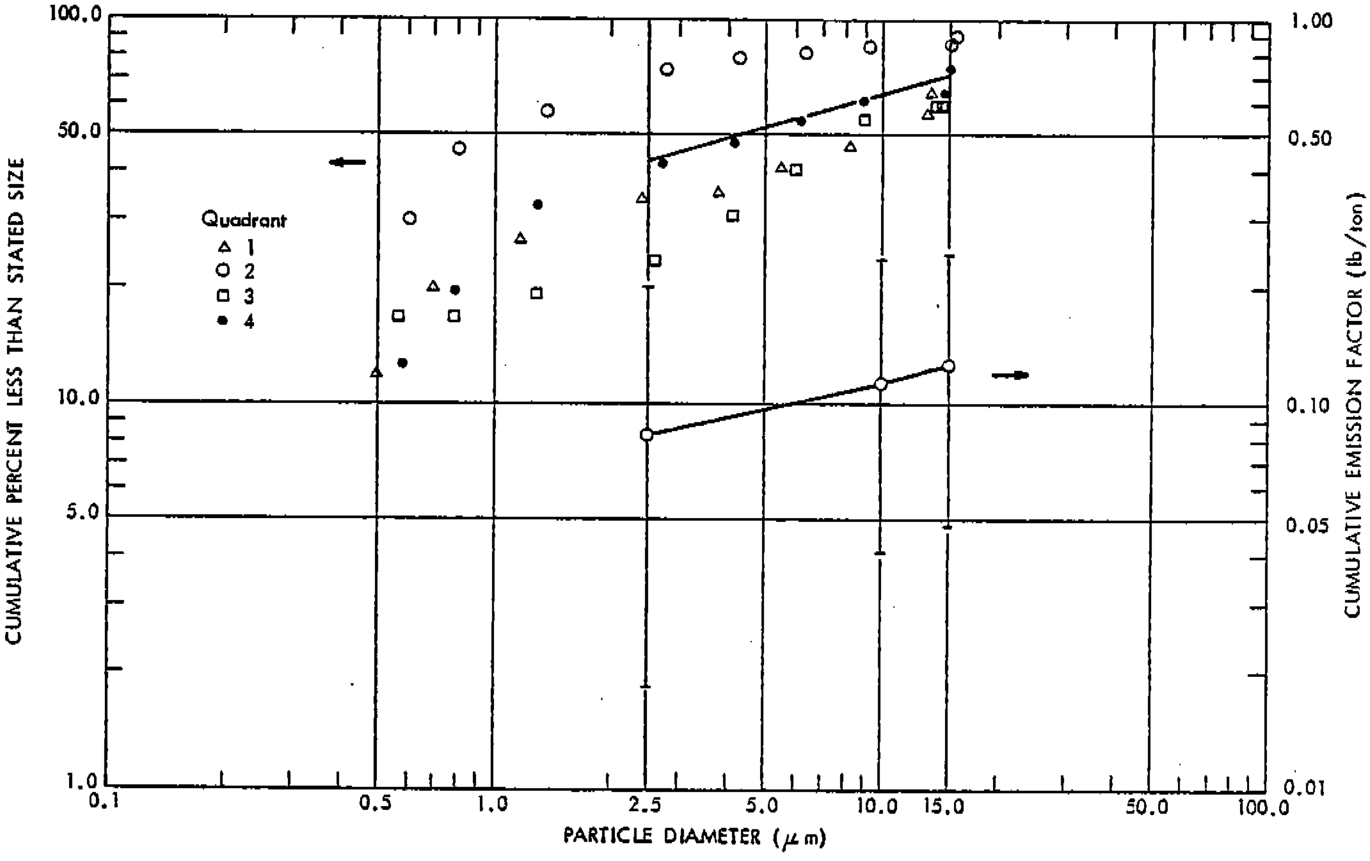


Figure 3-7. Kiln No. 2 electrostatic precipitator outlet, test two—combined product test results—cumulative percent less than stated size and cumulative emission factor versus particle diameter.

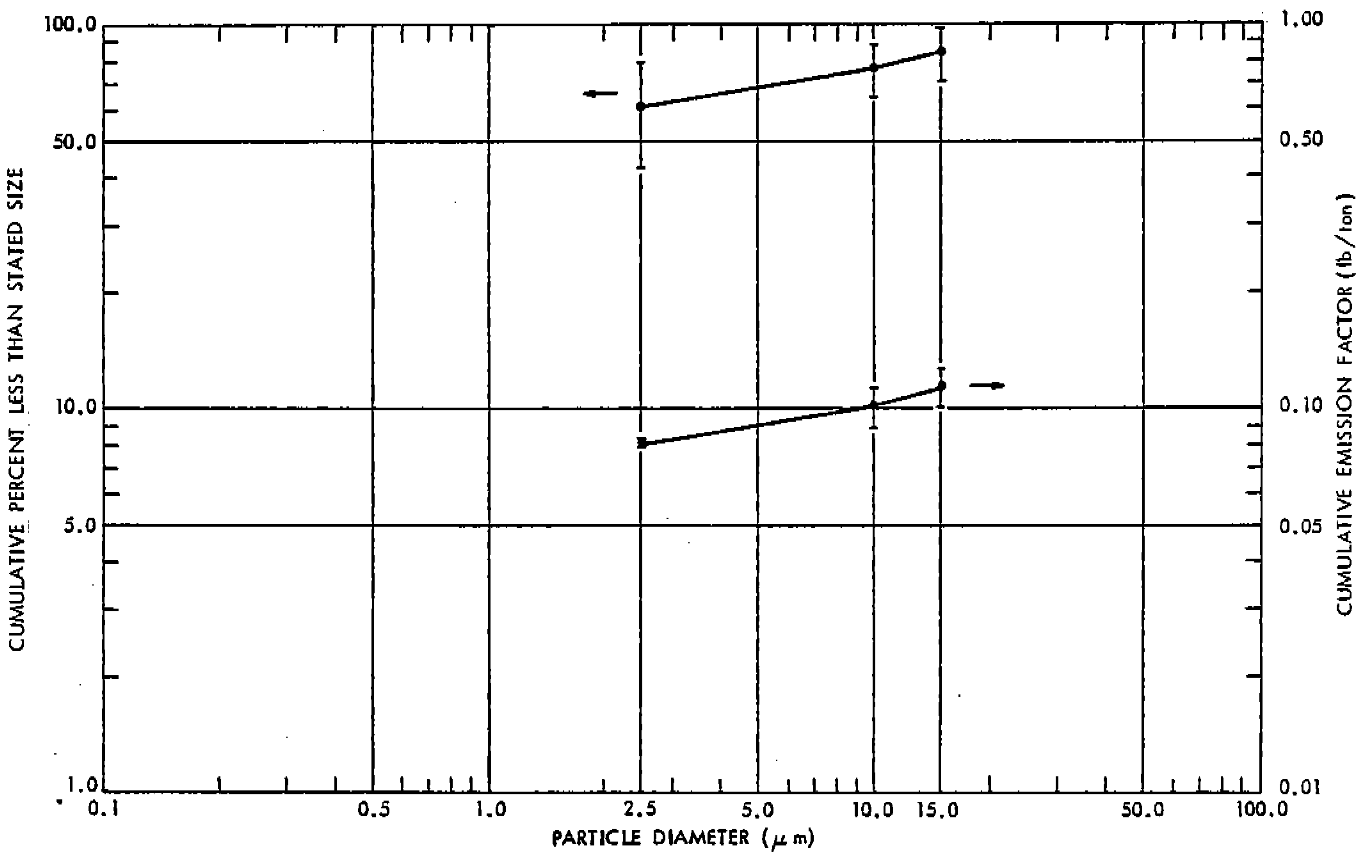


Figure 3-8. Kiln No. 2 electrostatic precipitator outlet, total test average--combined product test results--cumulative percent less than stated size and cumulative emission factor versus particle diameter.

TABLE 3-6. SUMMARY OF KILN NO. 2 ELECTROSTATIC PRECIPITATOR INLET AND OUTLET TEST RESULTS--TYPE I AND TYPE II CEMENT PRODUCT

Inlet mass train (EPA Method 5)

Run I.D. No.	Date	% Isokinetic	Particulate loading (gr/dscf)[a]
Type I cement product			
ESP-I-1-1	5-2-81	105.4	98.2
ESP-I-2-1	5-4-81	114.5	106.7
ESP-I-3-1	5-1-81	116.5	29.9
ESP-I-4-1	5-2-81	92.8	34.8
ESP-I-1-2	5-4-81	109.6	174.9
Type II cement product			
ESP-I-2-2	5-5-81	98.1	69.7
ESP-I-3-2	5-5-81	101.6	39.3
ESP-I-4-2	5-6-81	102.4	72.6

Outlet mass train (EPA Method 17)

Run I.D. No.	Date	% Isokinetic	Particulate loading (gr/dscf)[a]
Type I cement product			
ESP-0-2-1	5-1-81	108.8	0.0060
ESP-0-3-1	5-2-81	111.2	0.0099
ESP-0-4-1	5-2-81	102.5	0.0058
ESP-0-1-2	5-4-81	96.5	0.019
Type II cement product			
ESP-0-1-1(C)	5-6-81	103.5	0.0075
ESP-0-2-2(B)	5-6-81	112.1	0.024
ESP-0-3-2	5-5-81	99.8	0.0051
ESP-0-4-2	5-5-81	94.7	0.0028

Inlet IP train (Andersen high capacity stack sampler with 15 μm preseparator)

Run I.D. No.	Date	% Isokinetic	Particulate loading (gr/dscf)
Type I cement product			
ESP-I-1-1	5-2-81	84.1	78.6
ESP-I-2-1	5-4-81	98.5	68.8
ESP-I-3-1	5-1-81	106.8	31.4
ESP-I-4-1	5-2-81	101.4	48.5
ESP-I-1-2	5-2-81	98.5	71.3
ESP-I-2-2	5-4-81	85.8	72.4
ESP-I-3-2	5-1-81	113.7	43.6
ESP-I-4-2	5-2-81	98.1	52.7
ESP-I-1-3(B)	5-4-81	106.3	110.2
ESP-I-1-4	5-4-81	114.1	98.2
Type II cement product			
ESP-I-2-3	5-5-81	85.4	70.4
ESP-I-3-3	5-5-81	104.4	75.0
ESP-I-4-3	5-6-81	100.4	94.9
ESP-I-2-4	5-5-81	86.4	80.3
ESP-I-3-4	5-5-81	103.4	48.6
ESP-I-4-4	5-6-81	91.7	88.5

Outlet IP train (Andersen Mark III impactor with 15 μm preseparator)

Run I.D. No.	Date	% Isokinetic	Particulate loading (gr/dscf)
Type I cement product			
ESP-0-3-1	5-2-81	94.2	0.0028
ESP-0-4-1	5-4-81	102.0	0.11[b]
ESP-0-1-2	5-4-81	109.2	0.0037
Type II cement product			
ESP-0-1-1(C)	5-6-81	99.5	0.0054
ESP-0-2-1(B)	5-6-81	100.3	0.0055
ESP-0-2-2(B)	5-6-81	99.7	0.0052
ESP-0-3-2	5-5-81	108.0	0.00072
ESP-0-4-2	5-6-81	99.3	0.0025

[a] gr/dscf = Grains per dry standard cubic foot.

[b] The particulate loading from this run (ESP-0-4-1) was considered suspect data.

Since any quadrant was sampled by both mass and IP trains on any given test day, the emission factors for the inlet test location were calculated following normal procedures. In the case of the outlet test location, the calculation procedures used were different from those normally employed because a particular quadrant was not necessarily sampled by both a mass train and an IP train on the same day or during production of the same cement.

The total mass emission factors calculated for each type of cement product were summed and an average emission factor determined for both types of cement product. IP emission factors were calculated using this average product type total mass emission factor rather than individual run emission factors or the particle sizing emission factor. The daily production rates for the two types of cement product were also summed and averaged. This value was then applied to the average emission factor (in pounds per hour) to determine the average pounds of emission per ton of each type of product.

The cumulative percentages for each stage were then applied to the single averaged total mass emission factor (calculated for each type of cement product) to obtain an emission factor for each stage of the Andersen Mark III impactor.

3.3.1 Particle Size Results by Cement Type

The results of the particle size analysis by cement type are presented in Tables 3-7 and 3-8. Table 3-7 presents the particle analysis by cement type for the inlet to the ESP. Table 3-8 presents the particle analysis by cement type for the outlet of the ESP.

3.3.2 Emission Factors by Cement Type

Emission factors by cement type are presented in Tables 3-9 and 3-10. Table 3-9 presents emission factors by cement type for the inlet to the ESP, and Table 3-10 presents the same information for the ESP outlet.

TABLE 3-7. KILN NO. 2 ELECTROSTATIC PRECIPITATOR INLET--ANDERSEN HCSS IMPACTOR WITH 15 μm PRESEPARATOR PARTICLE SIZE TEST DATA--INDIVIDUAL CEMENT PRODUCT RESULTS

Particle size run No.	15 µm Cyclone			Stage 1			Stage 2			Cyclone			Filter	
	Mass (mg)[a]	D_{50} Size (µm)[b]	Cum. % less than[c]	Mass (mg)	D_{50} Size (µm)	Cum. % less than	Mass (mg)	D_{50} Size (µm)	Cum. % less than	Mass (mg)	D_{50} Size (µm)	Cum. % less than	Mass (mg)	D_{50} Size (µm)
Type I cement product														
ESP-I-1-1	25,179.5	16.40	13.98	1,407.2	11.88	9.18	1,104.9	6.66	5.40	1,033.7	2.08	1.87	547.5	< 2.08
ESP-I-2-1	22,533.6	15.15	14.72	1,669.5	11.40	8.40	958.6	6.33	4.77	790.7	1.92	1.78	470.5	< 1.92
ESP-I-3-1	12,241.8	15.74	18.98	629.6	11.58	14.82	832.0	6.43	9.31	944.0	2.01	3.06	463.0	< 2.01
ESP-I-4-1	16,437.7	15.35	11.97	437.9	11.49	9.63	897.7	6.39	4.82	653.1	1.95	1.32	246.9	< 1.95
ESP-I-1-2	15,908.5	15.47	11.91	647.2	11.53	8.33	583.8	6.42	5.10	583.1	1.96	1.87	337.5	< 1.96
ESP-I-2-2	24,600.2	15.03	11.08	971.3	11.39	7.56	755.3	6.34	4.83	967.2	1.90	1.34	370.0	< 1.90
ESP-I-3-2	14,099.5	15.48	15.90	902.5	11.51	10.51	692.2	6.40	6.38	881.5	1.97	1.13	188.9	< 1.97
ESP-I-4-2	17,863.3	15.51	11.52	442.9	11.54	9.33	685.7	6.42	5.93	904.8	1.97	1.45	292.9	< 1.97
ESP-I-1-3(B)	22,787.9	15.89	10.95	1,053.7	11.72	6.84	817.3	6.56	3.64	775.8	2.01	0.61	156.2	< 2.01
ESP-I-1-4	21,330.2	15.52	9.50	767.2	11.58	6.24	707.0	6.47	3.24	631.1	1.96	0.56	132.6	< 1.96
Type II cement product														
ESP-I-2-3	20,446.9	15.41	10.33	864.0	11.64	6.54	613.6	6.54	3.85	722.5	1.94	0.68	155.4	< 1.94
ESP-I-3-3	22,625.6	15.05	8.52	604.2	11.40	6.07	604.0	6.34	3.63	651.1	1.90	1.00	247.2	< 1.90
ESP-I-4-3	25,731.7	14.73	21.41	4,056.4	11.26	9.02	1,317.4	6.24	4.99	1,315.5	1.87	0.87	283.5	< 1.87
ESP-I-2-4	23,297.9	15.81	10.56	705.6	11.77	7.85	1,066.1	6.62	3.76	776.1	1.99	0.78	202.1	< 1.99
ESP-I-3-4	13,848.2	15.25	10.83	377.1	11.56	8.40	510.8	6.48	5.11	649.4	1.92	0.93	143.8	< 1.92
ESP-I-4-4	21,972.4	16.17	13.26	1,088.4	11.85	8.97	1,004.2	6.66	5.00	871.1	2.04	1.56	395.8	< 2.04

[a] mg = Net weight milligrams.

[b] D_{50} size (µm) = 50% effective cutoff diameter micrometers.

[c] Cum. % less than = cumulative percent less than stated size.

TABLE 3-8. KILN NO. 2 ELECTROSTATIC PRECIPITATOR OUTLET--ANDERSEN MARK III IMPACTOR WITH 15 μm PRESEPARATOR PARTICLE SIZE TEST DATA--INDIVIDUAL CEMENT PRODUCT RESULTS

Particle size run No.	15 μm Cyclone Mass (mg)[a]	15 μm Cyclone D Size (μm)[b]	15 μm Cyclone Cum. % less than[c]	Stage 0 Mass (mg)	Stage 0 D Size (μm)	Stage 0 Cum. % less than	Stage 1 Mass (mg)	Stage 1 D Size (μm)	Stage 1 Cum. % less than	Stage 2 Mass (mg)	Stage 2 D Size (μm)	Stage 2 Cum. % less than	Stage 3 Mass (mg)	Stage 3 D Size (μm)	Stage 3 Cum. % less than
Type I cement product															
ESP-0-3-1	0.09	14.34	98.98	2.15	13.77	74.72	0.04	8.58	74.27	0.00	5.80	74.27	0.00	3.93	74.27
ESP-0-4-1[d]	289.72	14.81	7.27	7.86	14.14	4.76	1.60	8.81	4.24	2.72	5.95	3.37	1.66	4.04	2.84
ESP-0-1-2	4.25	13.40	63.80	0.90	13.19	56.13	1.13	8.22	46.51	0.68	5.55	40.72	0.62	3.76	35.53
Type II cement product															
ESP-0-1-1(C)	1.19	14.70	92.44	0.47	14.26	89.46	0.04	8.89	89.21	0.22	6.01	87.81	0.35	4.08	85.59
ESP-0-2-1(B)	0.51	15.86	96.54	0.31	15.03	94.44	0.16	9.37	93.36	0.34	6.34	91.05	0.33	4.30	88.81
ESP-0-2-2(B)	1.45	15.58	89.44	0.43	15.09	86.31	0.21	9.41	84.78	0.46	6.37	81.43	0.50	4.32	77.79
ESP-0-3-2	0.84	14.79	59.81	0.00	14.40	59.81	0.12	8.97	54.07	0.30	6.07	39.71	0.21	4.12	29.67
ESP-0-4-2	1.84	15.11	74.34	0.80	14.58	63.18	0.18	9.09	60.67	0.45	6.15	54.39	0.47	4.17	47.84

Particle size run No.	Stage 4 Mass (mg)	Stage 4 D_{50} Size (μm)	Stage 4 Cum. % less than	Stage 5 Mass (mg)	Stage 5 D_{50} Size (μm)	Stage 5 Cum. % less than	Stage 6 Mass (mg)	Stage 6 D_{50} Size (μm)	Stage 6 Cum. % less than	Stage 7 Mass (mg)	Stage 7 D_{50} Size (μm)	Stage 7 Cum. % less than	Filter Mass (mg)	Filter D_{50} Size (μm)
Type I cement product														
ESP-0-3-1	0.02	2.51	74.04	0.05	1.23	73.48	0.00	0.74	73.48	0.00	0.53	73.48	6.51	< 0.53
ESP-0-4-1[d]	1.40	2.57	2.39	0.98	1.26	2.08	1.27	0.76	1.67	2.33	0.55	0.93	2.90	< 0.55
ESP-0-1-2	0.21	2.40	33.65	0.81	1.17	26.75	0.83	0.70	19.68	0.91	0.51	11.93	1.40	< 0.51
Type II cement product														
ESP-0-1-1(C)	0.54	2.60	82.16	1.79	1.28	70.79	1.92	0.77	58.60	3.50	0.56	36.38	5.73	< 0.56
ESP-0-2-1(B)	0.71	2.75	84.00	2.92	1.35	64.20	2.06	0.82	50.24	2.38	0.60	34.10	5.03	< 0.60
ESP-0-2-2(B)	0.66	2.76	72.98	2.12	1.36	57.54	1.79	0.82	44.50	2.02	0.61	29.79	4.09	< 0.61
ESP-0-3-2	0.14	2.63	22.97	0.08	1.29	19.14	0.05	0.78	16.75	0.00	0.57	16.75	0.35	< 0.57
ESP-0-4-2	0.43	2.66	41.84	0.83	1.31	30.26	0.76	0.79	19.66	0.51	0.58	12.55	0.90	< 0.58

[a] mg = Net weight milligrams.

[b] D_{50} size (μm) = 50% effective cutoff diameter micrometers.

[c] Cum. % less than = cumulative percent less than stated size.

[d] Not used in calculations due to suspect stage loading.

TABLE 3-9. KILN NO. 2 ELECTROSTATIC PRECIPITATOR INLET EMISSION FACTORS BASED ON TOTAL MASS AND IMPACTOR SIZE DISTRIBUTION--INDIVIDUAL CEMENT PRODUCT TEST RESULTS

Particle size run No.[a]	Total mass emission rate (lb/hr)[c]	Production rate (tons/hr)	Total mass emission factor (lb/ton)[d]	Emission factors for ≦ 2.5 μm (lb/ton)[d]	≦ 10.0 μm (lb/ton)	≦ 15.0 μm (lb/ton)
			Type I cement product			
ESP-I-1-1	52,000	35	1,500	30	120	180
ESP-I-2-1	57,000	35	1,600	32	110	220
ESP-I-3-1	21,000	35	590	24	77	110
ESP-I-4-1	24,000	35	690	14	55	83
ESP-I-1-2	52,000	35	1,500	30	100	180
ESP-I-2-2	57,000	35	1,600	32	110	180
ESP-I-3-2	21,000	36	590	12	53	88
ESP-I-4-2	24,000	35	690	14	55	76
ESP-I-1-3(B)	86,000	35	2,400	24	140	240
ESP-I-1-4	86,000	35	2,400	24	120	220
Average	48,000	35	1,400	24	94	160
			Type II cement product			
ESP-I-2-3	39,000	35	1,100	11	55	110
ESP-I-3-3	26,000	35	750	10	38	68
ESP-I-4-3	47,000	34	1,400	14	110	310
ESP-I-2-4	39,000	35	1,100	11	66	110
ESP-I-3-4	26,000	35	750	10	52	82
ESP-I-4-4	47,000	34	1,400	28	98	170
Average	37,000	35	1,100	14	70	140

[a] Particle size test data obtained with an Andersen HCSS impactor with 15 μm preseparator.

[b] Total mass emission rate data obtained with an EPA Method 5 train.

[c] lb/hr = Emission rate pounds per hour.

[d] lb/ton = Pounds per ton of product.

TABLE 3-10. KILN NO. 2 ELECTROSTATIC PRECIPITATOR OUTLET EMISSION FACTORS BASED ON TOTAL MASS AND IMPACTOR SIZE DISTRIBUTION--INDIVIDUAL CEMENT PRODUCT TEST RESULTS

Particle size run No.[a]	Average total mass emission rate[b] (lb/hr)[c]	Average production rate (tons/hr)[d]	Average total mass emission factor (lb/ton)[e]	Emission factors for		
				≦ 2.5 μm (lb/ton)[e]	≦ 10.0 μm (lb/ton)	≦ 15.0 μm (lb/ton)
Type I cement product						
ESP-0-3-1				0.11	0.12	0.15
ESP-0-4-1[f]	5.3	35	0.15	0.003	0.006	0.012
ESP-0-1-2				0.051	0.08	0.10
Average				0.08	0.10	0.12
Type II cement product						
ESP-0-1-1(C)				0.11	0.12	0.12
ESP-0-2-1(B)				0.11	0.12	0.12
ESP-0-2-2(B)	4.5	35	0.13	0.092	0.11	0.11
ESP-0-3-2				0.029	0.073	0.078
ESP-0-4-2				0.053	0.079	0.094
Average				0.079	0.10	0.10

a Particle size test data obtained with an Andersen Mark III impactor with 15 μm preseparator.

b Total mass emission rate data obtained with an EPA Method 17 train.

c lb/hr = Emission rate, pounds per hour.

d The average production rate (tons/hr) presented was determined from all of the mass train runs conducted during production of a specific type of cement product.

e lb/ton = Pounds per ton of product.

f Stage loading data from this particle size run were considered suspect. The data were not used in calculating averages.

3.4 SUMMARY OF EMISSION FACTORS

The emission factors for the inlet and outlet of the electrostatic precipitator on kiln No. 2 were calculated for particles less than 10.0 and 15.0 μm. An emission factor for fine particulates less than 2.5 μm was also calculated. Table 3-11 presents the summary of these calculated emission factors.

The emission factors for combined product test results at the inlet averaged 20 lb/ton for fine particulates, 85 lb/ton at 10.0 μm, and 150 lb/ton at 15.0 μm. The outlet averaged 0.08 lb/ton of fine particulates, and for 10.0 and 15.0 μm averages 0.098 and 0.11 lb/ton, respectively.

Test results during Type I cement product production at the inlet averaged 24 lb/ton of fine particulate, 94 lb/ton for 10.0 μm, and 160 lb/ton for 15.0 μm. At the outlet sampling site, an average of 0.08 lb/ton of fines, and 0.10 and 0.12 lb/ton for 10.0 and 15.0 μm, respectively, were emitted during Type I cement production.

During Type II cement production, the inlet averaged 14 lb/ton of fines, 70 lb/ton for 10.0 μm, and 140 lb/ton for 15.0 μm. The outlet averaged 0.079 lb/ton for fines, and 0.10 lb/ton for 10.0 and 15.0 μm during Type II cement production.

3.5 NONDUCTED SOURCES

This section presents the results of the nonducted source tests. The analytical methods used for analysis of the raw product and insufflation dust grab samples are presented in Appendix M. Appendices N and O present the raw data and computer printouts, respectively, for the paved road fugitive emission tests.

TABLE 3-11. SUMMARY OF EMISSION FACTORS--COMBINED AND INDIVIDUAL CEMENT PRODUCT TEST RESULTS

Kiln No. 2 sampling location	Test No.	Emission factors for Total (lb/ton)[a]	≦ 2.5 μm (lb/ton)	≦ 10.0 μm (lb/ton)	≦ 15.0 μm (lb/ton)
Combined cement product test results					
Electrostatic precipitator inlet	1	1,100	25	90	150
	2	1,100	22	80	130
	3	1,400	15	86	180
	4	1,400	18	84	150
Average		1,200	20	85	150
Electrostatic precipitator outlet	1	0.10	0.079	0.087	0.099
	2	0.17	0.082	0.11	0.12
Average		0.14	0.08	0.10	0.11
Individual Cement Product Test Results[b]					
Type I cement product					
Electrostatic precipitator inlet		1,400	24	94	160
Electrostatic precipitator outlet		0.15	0.08	0.10	0.12
Type II cement product					
Electrostatic precipitator inlet		1,100	14	70	140
Electrostatic precipitator outlet		0.13	0.079	0.10	0.10

[a] lb/ton = Pounds per ton of product.

[b] Data presented represent the average of all of the sampling runs conducted during the production of the specific type of cement.

3.5.1 Raw Product Samples

The raw product sample analytical results are presented in Table 3-12. The results are presented in weight percent.

3.5.2 Insufflation Dust Samples

The insufflation dust sample analytical results are presented in Table 3-13. The results are presented in weight percent.

3.5.3 Paved Road Fugitive Emissions

Emission factors for paved roads were predicted using an MRI experimentally determined emission factor equation.[1]

$$EF = 0.09\ I\ \frac{4}{N}\ \frac{s}{10}\ \frac{L}{1,000}\left(\frac{W}{3}\right)^{0.7}$$

where: EF = Emission factor (pounds per vehicle mile traveled)

I = The industrial road augmentation factor[2]

N = The number of active travel lanes

s = The silt content of the road surface material (% < 200 mesh)

L = Surface dust loadings on the traveled portion of the road (lb/mile)

W = The average vehicle weight (short tons)

1 "Manual for Characterization of Industrial Roads," Draft Report, November 7, 1980, prepared by Midwest Research Institute for Industrial Environmental Research Laboratory, EPA, Research Triangle Park, N.C.

2 Equals 7.0 for trucks coming from unpaved to paved roads and releasing dust from vehicle underbodies. Equals 3.5 when 20% of the vehicles are forced to travel temporarily with one set of wheels on the unpaved road berm while passing on narrow roads. Equals 1.0 for traffic entirely on the paved surface.

TABLE 3-12. RAW PRODUCT SAMPLE ANALYSIS RESULTS IN WEIGHT PERCENT[a]

	Type I product			Type II product	
Sample No.:	555	666	777	888	999
Date collected:	5-1-81	5-2-81	5-4-81	5-5-81	5-6-81
Plant shift:	First	First	Second	First	First
Shift hours:	0700-1500	0700-1500	1500-2300	0700-1500	0700-1500
Sample component					
Na_2O	0.29	0.29	0.30	0.29	0.24
K_2O	0.90	0.90	1.00	0.80	0.40
Li_2O	0.12	0.12	0.10	0.14	0.12
LOI[b]	34.08	34.34	33.89	34.72	34.51
Total S as SO_3	0.42	0.33	0.31	0.40	0.36
Cl	0.03	0.01	0.01	0.03	0.02
CaO	41.96	42.05	41.94	41.53	40.22
SiO_2	13.40	13.44	13.92	13.91	15.56
MgO	2.06	1.84	1.98	1.56	1.62
Al_2O_3	4.19	4.50	4.37	4.21	4.46
Fe_2O_3	2.09	1.67	1.72	1.97	2.17
TiO_2	0.22	0.19	0.19	0.20	0.21

[a] Analytical results provided by Spectrochemical Laboratories, Inc., 8350 Frankstown Avenue, Pittsburgh, Pennsylvania 15221.

[b] LOI = Loss on ignition.

TABLE 3-13. INSUFFLATION DUST SAMPLE ANALYSIS RESULTS IN WEIGHT PERCENT[a]

	Type I product		Type II product		
Sample No.:	111	222	333	444	1010[b]
Date collected:	5-1-81	5-4-81	5-5-81	5-6-81	5-6-81
Sample component					
Na_2O	0.60	0.55	0.55	0.55	0.50
K_2O	3.10	3.01	2.60	2.22	2.00
Li_2O	0.01[d]	0.01[d]	0.08	0.06	0.10
LOI[c]	22.15	23.03	21.60	24.00	22.34
Total S as SO_3	2.97	3.11	2.47	3.88	3.67
Cl	0.34	0.36	0.43	0.25	0.24
CaO	46.37	46.92	47.30	45.70	45.54
SiO_2	15.79	14.56	15.32	14.86	15.08
MgO	1.50	1.34	2.18	2.01	2.14
Al_2O_3	4.61	4.73	4.64	3.25	5.36
Fe_2O_3	2.19	1.97	2.29	2.77	2.57
TiO_2	0.24	0.22	0.25	0.21	0.19

[a] Analytical results provided by Spectrochemical Laboratories, Inc., 8350 Frankstown Avenue, Pittsburgh, Pennsylvania 15221.

[b] Sample No. 1010 is a duplicate of sample No. 444.

[c] LOI = Loss on ignition.

[d] Not detected. The number indicates the minimum limit of detection.

For this road the industrial road augmentation factor of 1.0 was chosen because traffic was observed to be traveling entirely on the paved surface. The number of active travel lanes was observed to be two. Estimates of the vehicle mix and of vehicle weights for this road were provided by Ideal Basic Industries, Inc., plant personnel. Plant personnel estimated an average of 40 trucks per day using this road. Of this traffic, they estimated that 80% were of the five-axle type weighing approximately 23,400 lb, and 20% were of the six-axle type weighing approximately 27,080 lb. From these values, an average unloaded vehicle weight of 24,136 lb was determined. The section of paved road sampled was only used by trucks entering the plant to be loaded. After loading, the trucks exited the plant via a different road.

Four vacuum bag samples of road dust were collected through a cross-sectional width of 20 ft. Each sample was individually dry sieved to determine silt content. The four samples were then composited to yield a total surface dust loading of 66.5 lb/mile on the two traveled lanes. The silt content of the composited sample was determined to be 19.2%. By applying these values to the MRI emission factor equation, an emission factor of 0.061 lb/VMT (pounds per vehicle mile traveled) was determined. Individual and composited bag sample results are presented in Table 3-14.

MRI wishes to gratefully acknowledge all those who participated in this project. A list of those individuals is presented in Appendix P.

TABLE 3-14. EMISSION FACTORS FOR PAVED ROAD FUGITIVE EMISSION TEST RESULTS

Sample bag No.	% Silt	Unloaded average vehicle wt (short tons)	Surface dust loading (lb/mile)[a]	No. of active travel lanes	Industrial road augmentation factor[b]	Emission factor (lb/VMT)[c]
29	28.4	12.07	109.2	2	1	0.148
30	19.6	12.07	55.4	2	1	0.052
31	10.0	12.07	49.4	2	1	0.024
32	18.8	12.07	52.0	2	1	0.047
Composite	19.20	12.07	66.5	2	1	0.061

[a] lb/mile = Surface dust loading on traveled portion of road, pounds per mile.

[b] The factor of 1 was used for traffic traveling entirely on paved surfaces.

[c] lb/VMT = Pounds per vehicle mile traveled.