Background Report Reference

AP-42 Section Number: 11.6

Background Chapter: 4

Reference Number: 79

Title: Lime and Cement Industry Particulate Emissions: Source Category Report, Volume II, Cement Industry

J. Kinsey

US EPA

February 1987

AP-42 Section 11.6
Reference NOT USED
Report Sect. 4
Reference 72

United States
Environmental Protection
Agency

EPA-600/7-87-7
February 1987

EPA

Research and Development

LIME AND CEMENT INDUSTRY
PARTICULATE EMISSIONS:
SOURCE CATEGORY REPORT
Volume II. Cement Industry

Prepared for

Office of Air Quality Planning and Standards

Prepared by

Air and Energy Engineering Research
Laboratory
Research Triangle Park NC 27711

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, U.S. Environmental Protection Agency, have been grouped into nine series. These nine broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The nine series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies
6. Scientific and Technical Assessment Reports (STAR)
7. Interagency Energy-Environment Research and Development
8. "Special" Reports
9. Miscellaneous Reports

This report has been assigned to the INTERAGENCY ENERGY-ENVIRONMENT RESEARCH AND DEVELOPMENT series. Reports in this series result from the effort funded under the 17-agency Federal Energy/Environment Research and Development Program. These studies relate to EPA's mission to protect the public health and welfare from adverse effects of pollutants associated with energy systems. The goal of the Program is to assure the rapid development of domestic energy supplies in an environmentally-compatible manner by providing the necessary environmental data and control technology. Investigations include analyses of the transport of energy-related pollutants and their health and ecological effects; assessments of, and development of, control technologies for energy systems; and integrated assessments of a wide range of energy-related environmental issues.

EPA REVIEW NOTICE

EPA-600/7-87-007
February 1987

LIME AND CEMENT INDUSTRY PARTICULATE EMISSIONS: SOURCE CATEGORY REPORT

Volume II. Cement Industry

by

John S. Kinsey
Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

Contract 68-02-3891
Work Assignment No. 9

EPA Project Officer: Dale L. Harmon
Air and Energy Engineering Research Laboratory
Research Triangle Park, North Carolina 27711

Prepared for
U.S. Environmental Protection Agency
Office of Research and Development
Washington, DC 20460

ABSTRACT

The objective of this study was to develop particulate emission factors based on cutoff size for inhalable particles for the cement industry. After a review of available information characterizing particulate emissions from cement plants, the data were summarized and rated in terms of reliability. Size specific emission factors were developed from these data for the major processes used in the manufacture of cement. A detailed process description was presented with emphasis on factors affecting the generation of emissions. A replacement for Sections 8.6 (Portland Cement Manufacturing) of EPA report AP-42, A Compilation of Air Pollutant Emissions Factors, was prepared, containing the size specific emission factors developed during this program.

CONTENTS

FIGURES

TABLES

TABLES (Concluded)

SECTION 1.0

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is in the process of reviewing the pertinent technical criteria and data bases to determine whether a revised National Ambient Air Quality Standard (NAAQS) for particulate matter based on particle size is warranted. Upon adoption of such a standard, the Clean Air Act requires that each state develop and submit State Implementation Plan (SIP) revisions which outline how they will attain and maintain the standard. Any revisions to the SIP would necessitate the collection and use of information related to size-selective particulate emissions from new and existing sources.

Since 1972 the document entitled "Compilation of Air Pollutant Emission Factors" (AP-42) has been published by the EPA. This document contains a compendium of emission factor reports for the most significant emission source categories. Supplements to AP-42 have been published both for new source categories and for updating existing emission factors as more information about sources and the control of emissions has become available. Up to this point, however, little information has been provided in AP-42 with regard to particle size characteristics of particulate emissions. To address the requirement for size-specific emission factors, the EPA is conducting research to characterize emissions in the inhalable particulate (IP) size range for a variety of industrial sources.

This report contains the existing particulate emission factor data base for portland cement plants, evaluates the available data, and provides a revised AP-42 Section (8.6) for this industry. Included in the revised

Section 8.6 are the best available particulate emission factors for portland cement plants.

This report is organized by section as follows:

Section 2.0 - Industry Description

Section 3.0 - General Data Review and Analysis Procedures

Section 4.0 - Particulate Emission Factor Development

Section 5.0 - Proposed AP-42 Section 8.6

The references are listed at the end of each section.

SECTION 2.0

INDUSTRY DESCRIPTION

2.1 INTRODUCTION AND INDUSTRY OVERVIEW

Hydraulic cement is the basic binding agent in concrete and masonry construction. There are several types of cement in use: portland cement; portland-pozzolan cement; high alumina cement; special or corrosion-resisting cements and mortars; expansive hydraulic cement; masonry cement; and slag cements.*

Roughly 95% of the cement produced in the United States is portland cement.[1] Portland cement is manufactured by the high temperature burning of calcareous material (e.g., limestone, oyster shells), argillaceous material (e.g., clay), siliceous material (e.g., sand, shale), and ferriferous materials to produce clinker. According to ASTM Specification C 219-84, portland cement is "a hydraulic cement produced by pulverizing portland cement clinker and usually containing calcium sulfate."

There are five basic types of portland cement. Type I, which is produced in the largest quantities, is used in general construction. Type II is formulated for moderate heat-of-hydration and moderate sulfate-resisting applications. Type III is high-early-strength (HES) cement. Type IV cement has a 15 to 35% lower heat of hydration than other types and has not been produced in the United States for about 20 years. Finally, Type V is highly sulfate-resistant.[1]

---

* None Produced since 1972.[1]

Air-entraining agents (e.g., resinous materials) can be added to portland cements in minute quantities. Air-entrainment increases the resistance of hardened concrete to scaling caused by alternate freezing and thawing and the use of de-icing salts. Air entraining cements are classified as Type IA, IIA, etc.[1]

According to the U.S. Bureau of Mines, 70.9 million metric tons (77.9 million short tons) of portland and masonary cement were produced in 1984.[2] The 1984 shipments of the various types of portland cement are shown in Table 2.1.[2] It can be seen that Types I and II are by far the most commonly used. Special cements such as pozzolan, high alumina, corrosion-resisting, and controlled cements are manufactured in relatively small amounts.

TABLE 2-1. 1984 PORTLAND CEMENT SHIPMENTS FROM PLANTS IN THE U.S.[2]

Type	Quantity[a]	
	10^3 Short tons	10^3 Metric tons (Mg)
General use and moderate heat (Types I and II)	70,648	64,290
High-early-strength (Type III)	2,505	2,280
Sulfate-resisting (Type V)	479	436
Oil well	2,273	2,068
White	278	253
Portland slag and portland pozzolan	808	735
Expansive	50	46
Miscellaneous[b]	839	763
Total or average[c]	77,881	70,872

[a] Includes Puerto Rico.

[b] Includes waterproof, low-heat (Type IV), and regulated fast-setting cement.

[c] Data may not add to totals shown due to independent rounding.

Virtually all portland cement is used in concrete for construction. Producers of ready-mix concrete are the primary customers and the remainder is purchased by concrete products manufacturers, highway contractors, building materials dealers and government agencies. Table 2-2 lists these customers and their relative share of total cement consumption.

TABLE 2-2. 1984 CEMENT USE BY CUSTOMER CATEGORY[2]

Customer	Percent of total purchases
Ready mixed concrete producers	69.3
Concrete products manufacturers	12.8
Building material dealers	5.7
Highway contractors	3.9
All others	8.3
	100.0

Source: U.S. Bureau of Mines, Minerals Yearbook 1984, Vol. I, U.S. Government Printing Office, Washington, D.C., 1985.

During 1982, there were 147 portland cement plants operating in the United States.[3] However, a number of these plants have now been shut down and thus this figure may not represent the industry at the present time. The geographical distribution of the various plants in operating during 1982 are shown in Figure 2-1 with the exact location, type of process, and production capacity listed in Table 2-3.[3] As shown by Table 2-3, both wet and dry processes are utilized for producing portland cement nationwide.

According to the U.S. Bureau of Mines (BOM), a combination of coal and natural gas was the type of fuel most used by U.S. plants in 1984 to produce cement clinker.[2] The amount of clinker produced in 1984, by fuel type, is shown in Table 2-4 using BOM statistics.[2]

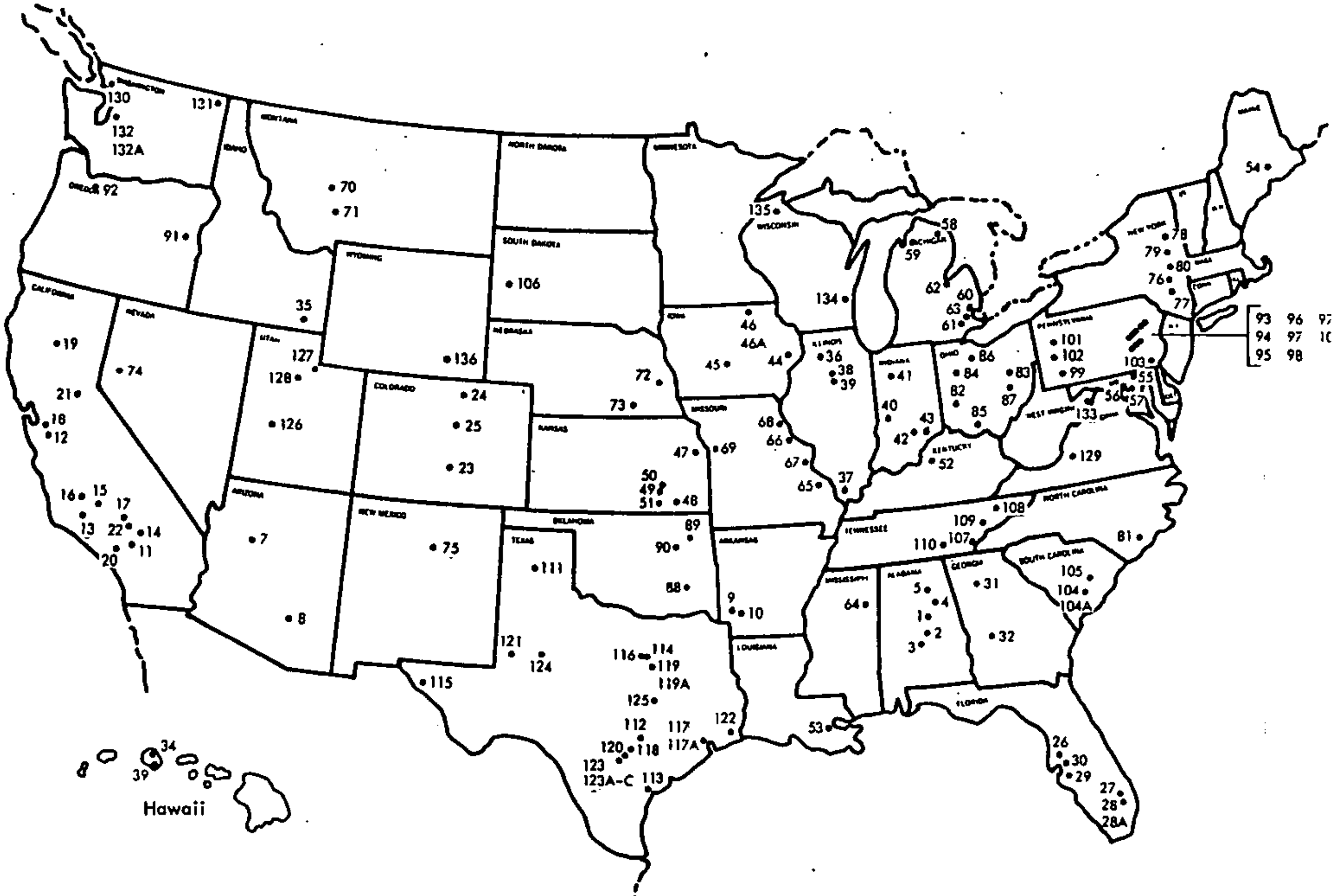

Figure 2-1. Geographical distribution of portland cement plants in the United States.

TABLE 2-3. PORTLAND CEMENT PRODUCERS (USA)[a]

State	Location Map index No. (Figure 2-1)	City	Plant	Type of process Wet	Type of process Dry	Production capacity 10³ short tons	Production capacity 10³ metric tons
Alabama	1	Birmingham	Allied Products	X		360	327
	2	Calera	Blue Circle Cement		X	686	622
	3	Demopolis	Citadel Cement		X	750	680
	4	Leeds	Lehigh Portland Cement		X	463	420
	5	Ragland	National Cement		X	800	726
	6	Theodore	Ideal Basic Ind.		X	1,500	1,361
Arizona	7	Clarkdale	Phoenix Cement Co.		X	542	492
	8	Rillito	California Portland Cement		X	1,700	1,542
Arkansas	9	Foreman	Arkansas Cement	X		850	771
	10	Okay	Ideal Basic Ind.	X		395	358
California	11	Colton	California Portland Cement		X	1,080	980
	12	Davenport	Lone Star Ind.		X	755	703
	13	Lebec	General Portland		X	610	553
	14	Lucerne Valley	Kaiser Cement Corp.	X	X	1,015 920	1,500 1,361
	15	Mojave	California Portland Cement		X	1,300	1,179
	16	Monolith	Monolith Portland Cement	X		500	454
	17	Oro Grande	Riverside Cement		X	1,149	1,042
	18	Permanente	Kaiser Cement Corp.		X	1,600	1,451
	19	Redding	Genstar Cement & Lime		X	600	544
	20	Riverside	Riverside Cement		X	838	760
	21	San Andreas	Genstar Cement & Lime	X		630	571
	22	Victorville	Southwestern Portland Cement	X	X	1,203	1,091
Colorado	23	Florence	Ideal Basic Ind.	X		885	803
	24	Fort Collins	Ideal Basic Ind.		X	460	417
	25	Lyons	Southwestern Portland Cement		X	470	426
Florida	26	Brooksville	Florida Mining & Materials		X	1,200	1,088
	27	Hialeah	Lone Star Ind.	X		1,200	1,088
	28	Miami	General Portland	X		1,200	1,088
	28A	Miami	Rinker Materials	X		580	526
	29	Palmetto	Nat. Portland Cement of Florida	NA	NA	-- Grinding only --	
	30	Tampa	General Portland	X		660	599
Georgia	31	Atlanta	Blue Circle Cement		X	630	571
	32	Clinchfield	Medusa Cement	X	X	790	717
Hawaii	33	Ewa Beach Oahu	Cypress Hawaiian Cement		X	280	254
	34	Waianae, Oahu	Kaiser Cement	X		320	290

(Continued)

TABLE 2-3. (continued)

Location				Type of process		Production capacity	
State	Map index No. (Figure 2-1)	City	Plant	Wet	Dry	10^3 short tons	10^3 metric tons
Idaho	35	Inkom	Oregon Portland Cement	X		210	191
Illinois	36	Dixon	Lone Star Inc.		X	600	544
	37	Joppa	Missouri Portland		X	1,314	1,192
	38	La Salle	Illinois Cement Co.		X	400	363
	39	Ogelsby	Lone Star Ind.		X	510	463
Indiana	40	Greencastle	Lone Star Ind.	X		752	682
	41	Logansport	Louisville Cement	X		460	417
	42	Mitchell	Lehigh Portland Cement		X	725	658
	43	Speed	Louisville Cement		X	1,260	1,143
Iowa	44	Davenport	Davenport Cement		X	850	771
	45	Des Moines	Monarch Cement	X		300	272
	46	Mason City	Lehigh Portland Cement		X	750	680
	46A	Mason City	Northwestern States Portland Cement		X	1,150	1,043
Kansas	47	Bonner Springs	Lone Star Ind.	X		451	409
	48	Chanute	Ash Grove Cement	X		516	468
	49	Freedonia	General Portland Inc.	X		407	369
	50	Humboldt	Monarch Cement		X	600	544
	51	Independence	Lehigh Portland		X	380	345
Kentucky	52	Kosmosdale	Kosmos Cement		X	670	608
Louisiana	53	New Orleans	Lone Star Ind.	X		750	680
Maine	54	Thomaston	Martin Marietta Cement	X		480	435
Maryland	55	Hagerstown	Lone Star Ind.		X	475	431
	56	Lime Kiln	Coplay Cement	X		1,100	998
	57	Union Bridge	Lehigh Portland Cement		X	950	862
Michigan	58	Alpena	National Gypsum		X	2,450	2,222
	59	Charlevoix	Medusa Cement		X	1,300	1,179
	60	Detroit	Peerless Cement	X		600	544
	61	Dundee	Dundee Cement	X		1,050	952
	62	Essexville	Aetna Cement	NA	NA	-- Grinding only --	
	63	Wyandotte	Wyandotte Cement	NA	NA	-- Grinding only --	
Mississippi	64	Artesia	Texas Ind.	X		480	435
Missouri	65	Cape Girardeau	Lone Star Ind.		X	1,000	907
	66	Clarksville	Dundee Cement	X		1,400	1,270
	67	Festus	River Cement		X	1,200	1,088
	68	Hannibal	Continental Cement	X		600	544
	69	Independence	Missouri Portland		X	564	512
Montana	70	Montana City	Kaiser Cement Corp.	X		320	290
	71	Trident	Ideal Basic Inc.	X		330	299

(Continued)

TABLE 2-3. (continued)

State	Location Map index No. (Figure 2-1)	City	Plant	Type of process Wet	Dry	Production capacity 10^3 short tons	10^3 metric tons
Nebraska	72	Louisville	Ash Grove Cement Co.	X		790	717
	73	Superior	Ideal Basic Inc.	X		235	213
Nevada	74	Fernley	Nevada Cement Co.		X	400	363
New Mexico	75	Tijeras	Ideal Basic Ind.		X	505	458
New York	76	Catskill	Lone Star Ind.	X		580	526
	77	Cementon	Lehigh Portland Cement	X		550	499
	78	Glens Falls	Glens Falls Portland Cement		X	450	408
	79	Howes Cave	Glens Falls Portland Cement	NA	NA	-- Grinding only --	
	80	Ravena	Atlantic Cement	X		1,500	1,361
North Carolina	81	Castle Hayne	Ideal Basic Ind.	X		550	499
Ohio	82	Fairborn	Southwestern Portland Cement	X	X	728	660
	83	Middlebranch	SME Cement		X	300	272
	84	Paulding	General Portland	X		554	503
	85	Superior	Lone Star Ind.		X	275	249
	86	Sylvania	SME Cement		X	280	254
	87	Zanesville	SME Cement	X		800	726
Oklahoma	88	Ada	Ideal Basic Ind.	X		610	553
	89	Pryor	Lone Star Ind.		X	725	658
	90	Tulsa	Blue Circle Cement		X	630	571
Oregon	91	Durkee	Oregon Portland Cement		X	500	454
	92	Lake Oswego	Oregon Portland Cement	X		418	379
Pennsylvania	93	Bath	Keystone Portland Cement	X		600	544
	94	Cementon	General Portland		X	790	717
	95	Egypt	Coplay Cement	NA	NA	-- Grinding only --	
	96	Evansville	National Gypsum		X	875	794
	97	Nazareth	Coplay Cement Co.		X	1,000	907
	97A	Nazareth	Lonestar Ind.		X	658	597
	98	Northampton	Martin Marietta Cement		X	---- Shut down ----	
	99	Pittsburgh	Lonestar Ind.	X		420	381
	100	Stockertown	Hercules Cement		X	700	635
	101	Wampum	Medusa Cement		X	715	649
	102	West Winfield	Penn-West Cement Co.	X		370	336
	103	York	Lehigh Portland Cement	X		136	123

(Continued)

TABLE 2-3. (continued)

State	Location Map index No. (Figure 2-1)	City	Plant	Type of process Wet	Dry	Production capacity 10^3 short tons	10^3 metric tons
South Carolina	104	Harleyville	Giant Portland Cement	X		855	776
	104A	Harleyville	Gifford-Hill & Co.		X	564	512
	105	Holly Hill	Sontee Portland Cement	X		1,550	1,406
South Dakota	106	Rapid City	South Dakota Cement	X	X	1,200	1,088
Tennessee	107	Chatanooga	Signal Mountain Cement	X		477	433
	108	Kingsport	Dixie Cement	X		330	299
	109	Knoxville	Ideal Basic Ind.		X	550	499
	110	Richard City	Dixie Cement Co.	X		200	181
Texas	111	Amarillo	Southwestern Portland Cement	X		218	198
	112	Buda	Texas Cement		X	470	426
	113	Corpus Christi	Centex Cement	X		300	272
	114	Dallas	General Portland	X		472	428
	115	El Paso	Southwestern Portland Cement		X	260	236
	116	Fort Worth	General Portland	X		731	663
	117	Houston	Gulf Coast Portland Cement	X		1,000	907
	117A	Houston	Lone Star Ind.	X		750	680
	118	Hunter	Texas Ind.	X		750	680
	119	Midlothian	Gifford-Hill Cement	X		846	767
	119A	Midlothian	Texas Ind.	X		1,200	1,088
	120	New Braunfels	General Portland		X	925	839
	121	Oddessa	Southwestern Portland Cement		X	553	502
	122	Orange	River Cement	NA	NA	-- Grinding only --	
	123	San Antonio	Alamo Cement	X		400	363
	123A	San Antonio	Alamo Cement		X	750	680
	123B	San Antonio	Capitol Cement Div.	X		338	307
	123C	San Antonio	Kaiser Cement		X	490	444
	124	Sweetwater	Lone Star Ind.		X	545	494
	125	Waco	Lehigh Portland Cement	X	X	420	381
Utah	126	Leamington	Southwestern Portland Cement		X	650	590
	127	Morgan	Ideal Basic Ind.	X		350	318
	128	Salt Lake City	Lone Star Ind.	X		420	381
Virginia	129	Roanoke	Lone Star Ind.		X	1,200	1,088
Washington	130	Bellingham	Columbia Cement	X		425	386
	131	Metaline Falls	Lehigh Portland Cement		X	215	195
	132	Seattle	Ideal Basic Ind.	X		490	444

(Continued)

TABLE 2-3. (continued)

State	Location: Map index No. (Figure 2-1)	Location: City	Plant	Type of process: Wet	Type of process: Dry	Production capacity: 10^3 short tons	Production capacity: 10^3 metric tons
Washington	132A	Seattle	Oregon Portland Cement	X		752	682
West Virginia	133	Martinsburg	Capitol Cement	X		935	848
Wisconsin	134	Milwaukee	St. Mary's Wisconsin Cement	NA	NA	-- Grinding only -	
	135	Superior	National Gypsum	NA	NA	-- Grinding only -	
Wyoming	136	Laramie	Monolith Portland	X		485	440

[a] Basic data taken from References 3 and 4 with updated information provided by industry personnel in 1985.

TABLE 2-4. 1984 CLINKER PRODUCTION BY TYPE OF FUEL[a]

Fuel	Plant active during year	Clinker produced[a] Quantity 10^3 short tons	Clinker produced[a] Quantity 10^3 metric tons (Mg)	Clinker produced[a] Percent of total	Fuel consumed[a] Coal[b] 10^3 short tons	Fuel consumed[a] Coal[b] 10^3 metric tons (Mg)	Fuel consumed[a] Fuel oil[c] 10^3 bbl	Fuel consumed[a] Fuel oil[c] 10^6 ℓ	Fuel consumed[a] Natural gas 10^6 ft³	Fuel consumed[a] Natural gas 10^6 m³
Coal	26	12,923	11,760	18.5	2,822	2,568	-	-	-	-
Oil	0	0	0	0	-	-	-	-	-	-
Natural gas	0	0	0	0	-	-	-	-	-	-
Coal and oil	29	15,454	14,063	22.2	2,862	2,604	373	59	-	-
Coal and natural gas	59	30,405	27,669	43.6	5,302	4,825	-	-	10,461	296
Oil and natural gas	1	72	66	0.1	-	-	56	9	95	3
Coal, oil natural gas	17	10,879	9,900	15.6	2,066	1,880	311	50	3,571	101
Total	132	69,733	63,458	100.0	13,052	11,877	740	118	14,127	400

[a] Includes Puerto Rico; 1 short ton = 2,000 lb, 1 metric ton = 10^6 g (Mg).

[b] Includes 0.6% anthracite, 94.7% bituminous, and 4.7% petroleum coke.

[c] $1(10)^3$ bbl = $42(10)^3$ gal. 10^6 ℓ = 1,000,000 liters.

2.2 RAW MATERIAL

Raw materials must provide, in suitable form and proportions, compounds containing lime, silica, alumina, and iron. Natural argillaceous deposits such as clay, shale, and slate, supply both silica and alumina. Natural deposits of limestone or marl (a calcareous clay) can occasionally supply all three basic ingredients at the correct proportion for the manufacture of "natural cement". Usually, however, it is necessary to combine raw materials to produce the desired mix. As a general rule, approximately 1.7 to 1.8 tons of dry raw materials are required to produce one ton of cement.[1,4] Table 2-5 lists the types and relative quantities of different raw materials used to achieve the proper blend of mineral components for the industry as a whole.[2]

As Table 2-5 shows, the calcareous component, particularly limestone, is the largest constituent in cement. Limestone and clay are abundant all over the world. Limestone is generally quarried at or near the cement plant since the low value-to-weight ratio results in high transportation costs. Underwater deposits of materials are excavated by barge-mounted dredging. Material is pumped or loaded onto barges and moved by tugboats to cement plants. Although a few limestone and gypsum deposits are mined underground by room-and-pillar methods, most raw materials for the cement industry are quarried using surface mining methods.[1]

2.3 PROCESS DESCRIPTION

There are basically two commercial cement manufacturing processes: the wet process and the dry process. The wet process involves the grinding of raw materials with water to form a slurry containing 30 to 40% moisture. The slurry is blended, as required, and subsequently fed to the kiln. The dry process, on the other hand, does not introduce water during grinding and the raw materials are fed to the kiln in the form of a powder.

Until recently, the wet process had advantages over the dry process due to ease of handling and blending of raw materials as well as yielding higher

TABLE 2-5. RAW MATERIALS USED IN PORTLAND CEMENT (1984)[2]

Type of raw material	Quantity[a] 10^3 short tons	Quantity[a] 10^3 metric tons (Mg)	Percent of total
Calcareous:			
Limestone	78,484	71,420	85.4
Cement rock (including marl)	27,010	24,579	
Oystershell	1,103	1,004	
Argillaceous:			
Clay	6,045	5,501	7.4
Shale	3,087	2,809	
Other	47	43	
Siliceous:			
Sand	1,958	1,782	2.1
Sandstone and quartz	696	633	
Ferrous:			
Iron ore, pyrites, millscale, and other material	1,232	1,121	1.0
Other:			
Gypsum and anhydrite	3,967	3,610	4.1
Blast furnace slag	27	25	
Fly ash	841	765	
Miscellaneous other	296	269	
Total	124,793	113,561	100.0

Source: U.S. Bureau of Mines, Minerals Yearbook 1984, U.S. Govenment Printing Office, Washington, D.C., 1985.

[a] 1 short ton = 2,000 lb.
1 metric ton = 10^6 g (Mg).

quality clinker. However, improvements in dry blending and material handling techniques, in combination with lower energy consumption used in the dry process, has served to minimize the advantages of the wet process over the dry process. Most new plants or production lines have turned to dry processes in view of increasing energy costs and favorable shifts in dry process technology.

Cement manufacturing involves four basic processing stages: quarrying and crushing; mixing and grinding; burning and cooling; and finish grinding, packaging, and shipping. General flow diagrams for both dry and wet processes are shown in Figures 2-2 and 2-3, respectively.[1] Each processing stage is briefly described in the following subsections.

As with most facilities in the mineral products industry, cement plants have two major categories of particulate emissions: those which are vented to the atmosphere through some type of stack, vent, or pipe (ducted sources); and those which are emitted directly from the source to the ambient air (fugitive sources) without such equipment. Ducted emissions are usually transported by an industrial ventilation system with one or more fans or air movers and emitted to the atmosphere through a stack. Fugitive sources, on the other hand, can either be process sources, which entail some form of physical or chemical change in the material being processed (i.e., crushers, screens, etc.), or open dust sources where no such change has taken place (i.e., roads, storage piles, etc.). The above definitions will be used throughout the remainder of this discussion.

2.3.1 Quarrying and Crushing

Cement production begins with extraction of the raw materials, generally from a quarry at or near the cement plant. The raw material is comprised of some combination of limestone, cement rock, marl, shale, clay, sand, and iron ore. Most deposits are worked in open quarries having face heights ranging from 9 to 60 m (30 to 200 ft) with overburden depths between 15 to 30 m (50 to 100 ft).[5]

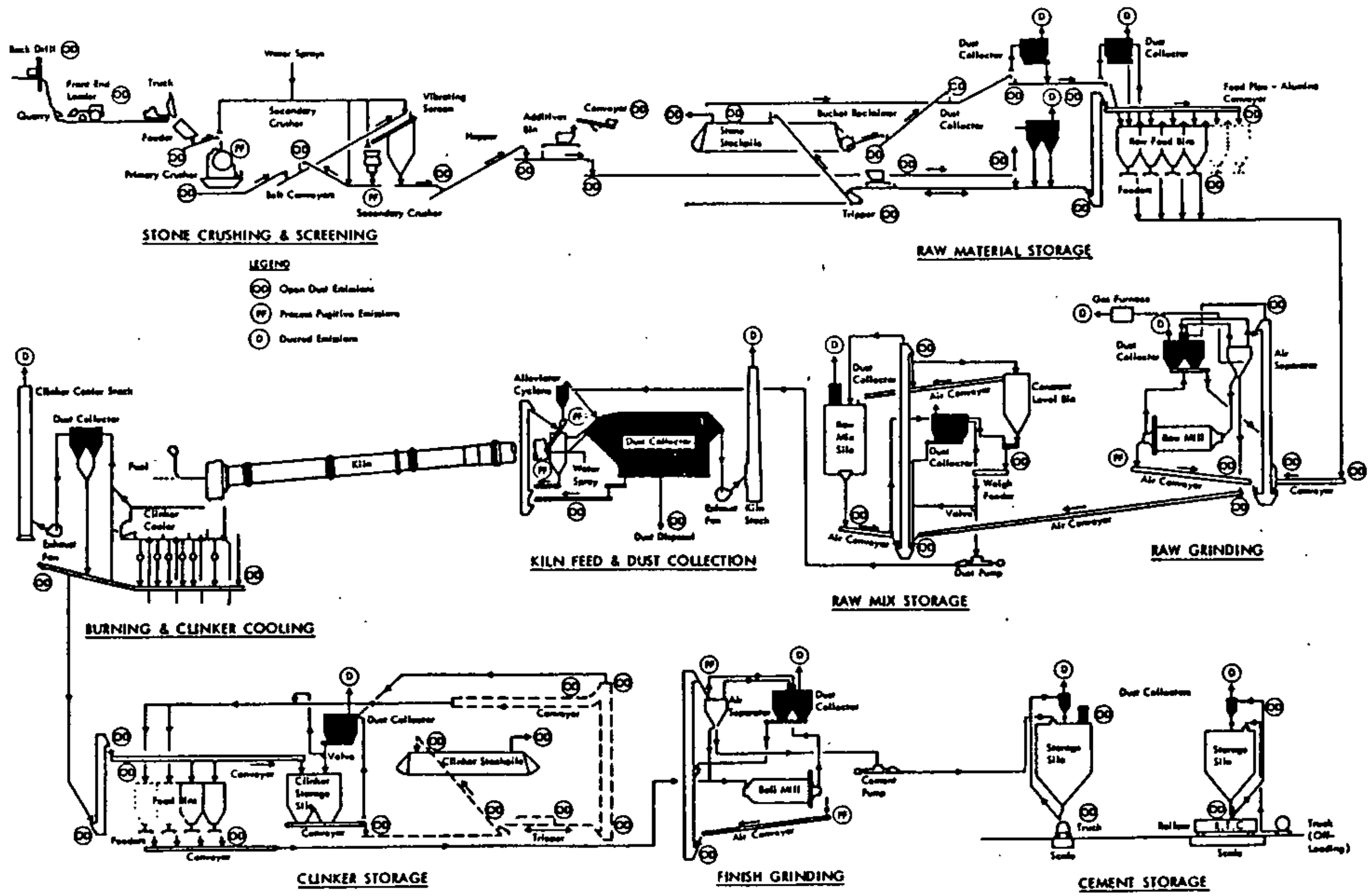

Figure 2-2. Flow diagram for dry process.[1]

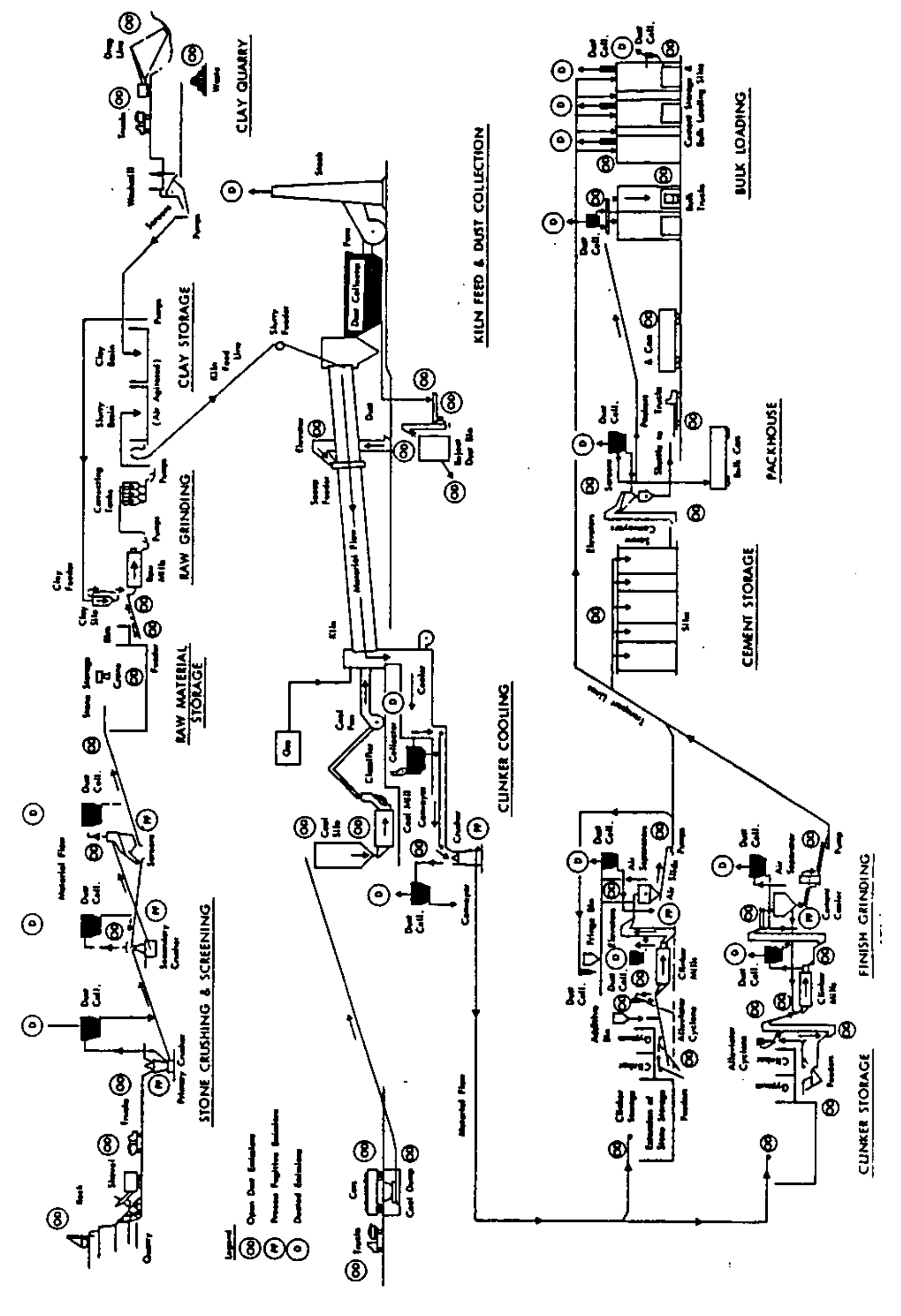

Figure 2-3. Flow diagram for wet process.[1]

Rock is usually transported by truck to a crushing plant either at the quarry or the cement plant. The primary crusher reduces rock from a maximum of 1.5 m (5 ft) in diameter to about 13 cm (5 in.) in diameter. A further reduction in size to about 1.3 cm (1/2 in.) diameter is effected, if required, using the secondary crusher. This material is then transported by belt conveyors and elevators and stored in stock piles or silos prior to mixing with other stored raw materials such as clay, silica, alumina, or iron ore.

Significant amounts of fugitive dust are generated during drilling, blasting, loading, crushing, screening, materials transport, stockpiling (including wind erosion) and reclaiming. Also included are the fugitive emissions associated with overburden removal, storage, handling, and deposal. Paved/unpaved roads associated with the quarrying operation usually account for most of the open dust source emissions.

2.3.2 Mixing and Grinding

The preparation of raw materials for the kiln involves drying, proportioning, grinding and blending of the various raw materials. Due to the variations in the chemical compositions of these raw materials, no single formula for cement manufacture can be applied.

This stage of the cement manufacturing process differs depending on whether the dry process or wet process is used. In the dry process, the free moisture content of the crushed raw materials is generally reduced to less than 1% before or during grinding. Direct-contact rotary dryers 1.8 to 2.4 m (6 to 8 ft) in diameter and 1.8 to 46 m (6 to 150 ft) long are used in the industry, although the trend in new plants is for simultaneous drying and grinding. Heat for either process may be derived from kiln gases, clinker cooler exhaust, or directly fired fuels. Figure 2-2 shows a natural gas-fired furnace providing hot process air in a system with a rotating raw mill which mixes and grinds the various raw materials.[1]

The dried materials are ground to final product fineness (70 to 90% < 74 μm) in one or more stages. Preliminary or first stage grinding may utilize a cylindrical ball mill, rod mill, or ring-roller mill.[5] The second- or final-stage unit is usually a ball mill or a "tube" mill, which is a ball mill with a higher length-to-diameter ratio. Most of the more recent installations follow the secondary or tertiary crushing operation with single-stage grinding using a roller mill.

Dry-process grinding units are usually operated in a closed circuit with air separators that split the mill output into coarse and fine fractions. The coarse fraction is returned to the mill for further grinding, and the fine fraction becomes finished raw-mix (raw meal). Various types of closed circuits have been used, with units in parallel, or series, or combination thereof, but the basic purpose is to minimize objectionable oversize and develop a product fineness best suited for effective combination in the kiln. This finely ground material is conveyed either pneumatically or by mechanical means to blending, homogenizing, and/or storage silos from which it is withdrawn as kiln feed.

Wet-process grinding uses ball mills or compartment mills that are essentially the same as those used in the dry process except for feeding and discharge arrangements. Water is added to the mill with the crushed feed to form a slurry. Where clay is used as a raw material, it is generally added in suspension as a slip. Grinding may be done in one or two stages. In some plants, mills are closed circuited with cyclones or screens that produce a final, more viscous, slurry that does not require thickeners.[5] The various crushed materials may be proportioned ahead of grinding, as in the dry process, or each major component may be ground into separate slurries that are then proportioned and blended. Finished slurry fed to kilns may contain 30 to 40% water, or it may be further de-watered in vacuum filters and fed to the kiln as a "cake" containing about 20% water; this is referred to as the "semi-wet" process.[5]

The major sources of ducted emissions during mixing and grinding are rotary dryers and the grinding mill circuits. The hot gases passing through rotary dryers will entrain dust from the limestone, shale, or other materials being dried. The concentration of dust in the exit gases is related to the velocity of the gases, the quantity and size of the fine particles, and their degree of dispersion in the gas stream. A heavier dust concentration may be expected in dryers utilizing kiln exit gases (waste-heat dryers) because of the dust carry-over from the kilns. Emissions from rotary dryers also include combustion-related pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compounds (VOC).

The most common dry grinding circuits, whether they use ball mills, compartment mills, or vertical units, are vented from mill discharge points to provide some air sweep through the mills to prevent mill dusting during grinding. In the normal closed circuits, vents may also be connected to mill discharge elevators, conveyors, and air separators to maintain the entire system under negative pressure. The heavily dust-laden air from these vents is conducted to a dust collector. In the case of "dry-in-the-mill" combination drying and grinding circuits, the final vent from the drying or closed-circuit separator or cyclone, which includes combustion-related gaseous pollutants as well as particulate matter, would be treated similarly. Condensed water vapor is also present in the exhaust from dry process raw mill circuits which produces a visible, opaque plume.

Fugitive emissions during mixing and grinding include the dust generated during materials handling, transfer (belt transfer points, airslides, elevators, etc.), and storage (enclosed) operations. Figures 2-2 and 2-3 indicate the various fugitive emission points in the process flow.[1]

2.3.3 Burning or Clinker Production

2.3.3.1 Rotary Kiln--

Blended and ground raw materials are fed to a rotary kiln. Rotary kilns are most commonly used in both the wet and dry manufacturing processes. Kiln length can be 30 to 230 m (90 to 750 ft) with diameters of 2 to 8 m (6 to 25 ft).[1,4] The kiln is erected horizontally with a gentle slope of 3.1 to 6.3% and rotates along its longitudinal axis.[5]

The kiln feed, commonly referred to as "slurry" for wet-process kilns or "raw meal" for dry-process kilns, is fed into the upper end of the kiln. As the feed flows slowly toward the lower end, it is exposed to increasing temperatures. During passage through the kiln (1 to 4 hr), the raw materials are heated, dried, calcined, and finally heated to a point of incipient fusion at about 1430° to 1480°C (2600° to 2700°F) at which point a new mineralogical substance called clinker is produced. At the lower end of the kiln, the combustion of coal, fuel oil, or gas must produce a process temperature of 1590° to 1930°C (2900° to 3500°F). The combustion gases pass though the kiln counter to the flow of material, and leave the kiln along with carbon dioxide (CO_2) driven off during calcination.

Two basic types of wet-process kilns are in use in the United States. Around 1930, short wet-process kilns were installed with waste-heat boilers similar to the waste-heat boilers in the short dry kilns. Shortly thereafter, the construction of short wet-process kilns yielded to the building of long wet-process kilns with internal chain preheaters. All of the newer wet-process kilns utilize a chain system to heat and convey the feed.* The system consists of a large number of chains suspended in the drying zone of the kiln and arranged so that, in addition to lifting the slurry into the path of the hot gases, they also convey the raw material to the burning zone. The slurry on the large exposed surface of the chains is thus in intimate contact with the combustion gases.[5]

As the hot waste gases pass through the kiln exit, they are sometimes utilized to preheat the kiln feed. These preheat systems can affect the quantity of emissions released from the kiln. The grate preheat (also referred to as the Lepol; semi-wet; or semi-dry) method uses a double-pass (or more) system whereby the gaseous effluents pass countercurrently through moist (12% water) nodules produced in a pan pelletizer. The first pass after exiting the kiln is to preheat and partially calcine the mix and the second to dry the mix. The suspension preheater system is used on dry-process kilns, whereby the dry mix is preheated (and partially calcined) by

---

* Chain systems have also been installed in some long, dry process kilns with a few using trefoils or crosses for heat exchange purposes.

direct contact with waste gases in a multistage cyclone-suspension process. The waste gases pass through one or more cylones (normally four) though which the mix passes countercurrently.

The largest single source of ducted emissions in portland cement plants is the rotary kiln. Pollutants generated in the kiln consist of particulate matter as well as some combustion-related gases such as SO_2, NO_x, CO, and VOC. Emissions of particulate matter from rotary kilns can be reduced by utilizing a larger kiln diameter (at the same feed and firing rate) which lowers the gas velocity and thus entrainment of dust in the effluent gas stream.* Modification of a rotary kiln or the addition of a suspension preheater that uses cyclones or moveable grate preheaters are also partially effective in controlling the dust generated in the kiln. Additional control equipment is normally used for satisfactory collection of kiln dust prior to discharge to the atmosphere.

Gaseous emissions from the combustion of fuel in the kiln are usually not sufficient to necessitate the addition of equipment to control such emissions. Most of the sulfur dioxide formed from the sulfur in the fuel is recovered as it combines with the alkalies and also with the lime when the alkali fume is low. Nitrogen oxides can form at kiln temperatuers of 1430 to 1650°C (2600° to 3000°F), and are of concern. Combustion modification to reduce NO_x emissions from cement kilns have been studied by the EPA.[6] Odoriferous hydrogen sulfide and polysulfides may also be produced in the drying of the slurry or in the drying of the dry-process raw material when the latter is composed of marl, sea shells, shale, clay, or other sulfur-containing material.

The greatest problem with fugitive emissions associated with rotary kilns involves the disposal of the dust collected in the air pollution control

* If any type of suspension preheater or flash calciner is retrofitted to an existing kiln, the length is generally reduced to achieve the proper thermal profile and retention time.

system. The most desirable method for disposing of the collected dust is to return it to the kiln. The alkali content of the cement product, however, must often be less than 0.6% by weight (calculated as sodium oxide). Where the alkali content of the raw material (e.g., clay) going into the kiln is high, recycling of kiln dust may not be possible. Practical methods of returning dust to the kiln are:

1. Direct dust return to kiln feed prior to kiln entry by mixing dry dust and kiln feed (either wet or dry).

2. Direct dust return to the kiln parallel to the kiln feed (either wet or dry).

3. Insufflation, which is the return of dry dust into the burning zone either through the fuel pipe (as is frequently the case in coal fired kilns on unit coal pulverizers) or by a separate pipe parallel to the burner. Here the dust entering the burning zone sinters into small grains of clinker and is discharged with the clinker to the cooler. In this process, the collected dust is usually pumped dry from the collecting unit at the feed end to the burner floor and into the burning zone through the kiln hood.

There is no single satisfactory method of returning all of the collected dust to the kiln; as a result, to control alkalies or improve kiln operation, at least part of the dust must be disposed in other ways.

Kiln dust has been, or can be, used in a number of different ways, including:[1]

- Landfill and soil stabilizer/neutralizer/fertilizer.

- Sub-base for roads.

- Dumped into strip mines to neutralize acid mine drainage.

- Fillers for bituminous paving materials and asphaltic roofing materials.

- Neutralize acidic waters of bogs, lakes, and streams (as appropriate).

- Neutralize certain industrial wastes such as spent pickle liquor, leather tanning waste and cotton seed delinting waste.

- Waste sludge stabilization.

- Substitute for lime in wastewater treatment systems.

- Absorption of SO_2 from stack gas in wet scrubber slurries.

- Replacement of soda in green glass.

Disposal of dust, unless it can be sold as a substitute for other materials such as those listed above, presents problems with fugitive emissions. Since the collected dust may range from a few hundred pounds per hour to many tons, disposal requires a waste area and a means of moving dust from the collector to the waste area. The collected dust may be mixed with water and pumped to waste ponds in a manner similar to fly ash disposal commonly practiced in power generating stations or pelletized prior to disposal using pan or drum pelletizers. It may also be pumped dry or hauled by truck to worked-out quarry areas where rain and weather concrete the disposal pile into a monolithic mass. Where trucks are used, usually the dust is dampened in a pug screw as it is discharged into the truck. An enclosed system has also been used for truck loading with the displaced air vented through a dust collector.

Fugitive emissions can also be generated during transport and handling of the dust from the collector hopper, truck loading and unloading operations, truck traffic across paved and unpaved roads, as well as wind erosion from the bed of open trucks during transport and from the disposal site itself.

2.3.3.2 Clinker Coolers--

As the clinker is discharged from the lower end of the kiln, it passes through a clinker cooler that serves the dual purpose of reducing the temperature of the clinker before it is stored and recovering the sensible heat for reuse inside the kiln as preheated primary or secondary combustion air as well as tertiary air for combustion in the precalciner. Planetary, vibrating, or grate type air-quenching coolers are used to permit a blast of cooling air to pass either through or over a moving bed or stream of hot clinker. The cooled clinker is then conveyed by drag chains, vibrating troughs, or conveyor belts to storage.

Like the kiln, the clinker cooler can be a significant source of ducted emissions. Effluent gas from grate coolers, which contains particulate, is vented through a separate dust collection device. Fugitive emissions associated with clinker coolers are generated by materials handling, transport, and storage operations which include stockpiling and recovery of clinker from open piles with the associated wind erosion losses (Figures 2-2 and 2-3). The storage of clinker in enclosed silos or partially enclosed buildings or halls for convenience in handling and for weather protection (and, indirectly, for the control of fugitive dust emissions) has become more prevalent in newer plants.

2.3.4 Finish Grinding, Packaging, and Shipping

In the final stage of cement manufacture, clinker is ground into cement. Interground with the clinker is a small amount of gypsum (normally 3 to 6%), which regulates the setting time of the cement when it is mixed with water and aggregate to make mortar or concrete.

Various grinding circuits are in use. The system may be two stage, with preliminary and secondary mills, or the entire process may be performed in a single compartment mill. Ball mills or tube mills normally are used. Crushers may be used ahead of the ball or tube mills. The grinding system may be open circuit, but most of the mills are closed-circuited with air separators. The final product has a fineness of about 90% less than 44 μm (minus 325 mesh).[5]

The finished cement is transported by pneumatic pumps, mechanical screws, or belt conveyors, to silos for storage until it is shipped. Some portland cement is packaged in 44-kg (96-lb) bags; however, most cement is transported in trucks, hopper cars, barges, and ships.

As with raw grinding, the major source of ducted emissions are the finish mills circuits. Clinker is ground in the same type of mills as used for the raw materials. The discharge from these mills is elevated to an air separator in closed-circuit grinding. Cement with the proper fineness is sent to storage, and the oversize is sent back to the mill for regrinding. The circuit is cooled by air passing through the mill and separator and finally into a dust collector.

Cement-material handling (such as pneumatic conveying of finished material, bagging, and bulk loading) is a potentially significant source of fugitive emissions. However, the high salvage value of the escaping material makes dust collection an economic necessity. Normally, material transfer points are completely enclosed and vented through dust collectors for product recovery. In-plant paved roads can also be a significant source of fugitive emission due to spillage of material during truck loading operations. Table 2-7 provides a summary of the air pollutant sources typically found in cement plants.

2.4 CONTROL TECHNOLOGY

2.4.1 Ducted and Process Fugitive Sources

2.4.1.1 Rotary Kilns--

Kiln dust is separated from exhaust gases using one or a combination of the following types of equipment: cyclone separators; electrostatic precipitators (ESPs); baghouse collectors; and settling chambers. A number of

TABLE 2-7. POTENTIAL SOURCES OF AIR POLLUTANTS IN CEMENT PLANTS[a]

Type of process	Emission source	Source classification[b]	Pollutants[c]
Quarry Operations	Drilling	OD	PM
	Blasting	OD	PM
	Loading of broken rock	OD	PM
	Transporting or conveying (to cement plant)	OD	PM
	Overburden disposal	OD	PM
Crushing Operations	Unloading rock from quarry	OD	PM
	Crushing	PF	PM
	Screening	PF	PM
	Conveying (to and from storage)	OD	PM
	Storage and reclaiming (i.e., stockpiling)	OD	PM
Preparation of Raw Materials	Drying operations	D	PM, SO_2, NO_x, CO, VOC
	Conveying and feeding (to dryers and grinding circuit)	OD	PM
	Grinding of raw materials[d]	D	PM, SO_2, NO_x, CO, VOC
	Conveying of ground material (dry process)	PF/OD	PM
Kiln Operation	Feeding raw material to kiln(s) - dry process	PF	PM
	Gases exhausted from kiln(s)	D	PM, SO_2, NO_x, CO, VOC
Clinker Cooling	Excess air exhausted clinker cooler(s)	D	PM
	Conveying clinker from cooler(s) to finish-grinding mill(s) or storage	OD	PM
	Clinker storage/stockpiling	OD	PM
Finish Grinding, Packaging, & Shipping	Recovery and conveying of clinker from storage to finish-grinding mill(s)	OD	PM

(Continued)

TABLE 2-7. (continued)

Type of process	Emission source	Source classification[b]	Pollutants[c]
	Finish grinding of clinker, gypsum, and addtives	D	PM
	Air classification of finished product and conveying to storage	PF/OD	PM
	Storage silo(s)	D	PM
	Bulk loading operations	OD	PM
Waste Dust Handling and Disposal	Handling, truck loading/unloading	OD	PM
Miscellaneous Operations	Paved and unpaved roads	OD	PM
	Wind erosion from stockpile and exposed areas	OD	PM

[a] Taken from Reference 1.

[b] OD - Open Dust Source
PF - Process Fugitive Source
D - Ducted Source

[c] PM - Particulate Matter
SO_2 - Sulfur Dioxide
NO_x - Nitrogen Oxides
CO - Carbon Monoxide
VOC - Volatile Organic Compounds

[d] Combustion-related pollutants for combination drying/grinding.

good references are available which describe the theory, operation and applicability of the control devices listed above and thus such will not be discussed here.[6,7]

As of 1975, the most widely used particulate collection system for rotary cement kilns consisted of cyclones followed by an electrostatic precipitator. The distribution of the various types of dust collection equipment used in the 101 cement plants surveyed by Southern Research Institute in 1975 is shown in Table 2-8.[1] Since this survey was conducted over 11 years ago, the data shown in Table 2-8 probably does not represent current industry practice.

The effectiveness of the control devices listed in Table 2-8 is dependent on the characteristics of the gas stream and the particulate matter--specifically the size of the particles, the moisture content of the gas, the resistivity of the dust, and the concentration and composition of the dust. Mechanical collectors are not effective on submicrometer particles and, therefore, are used only as a precleaner to a fabric filter or ESP. As stated previously, the dust collected by these precleaners can be recycled to the kiln when its chemical composition does not significantly alter that of the final product.

As stated above, no external equipment is generally used in the cement industry for the control of gaseous pollutants. However, due to the alkaline nature of the particles, some SO_2 removal can be achieved in the kiln and dust collection equipment. Various combustion modifications have been attempted for the control of NO_x in cement kilns but have been generally unsuccessful.[8]

2.4.1.2 Clinker Coolers--

The clinker cooler is another major air pollution source in cement plants. Dust collected from this source is returned to the process (usually clinker storage) rather than wasted. The types of air pollution control equipment used to handle clinker cooler off-gas include: settling chambers; cyclones; granular bed filters; baghouse collectors; and electrostatic precipitators.

TABLE 2-8. DISTRIBUTION OF KILN DUST COLLECTION SYSTEMS IN WET AND DRY PROCESS CEMENT PLANTS[1]

	Type of process and number of plants[a]	
Kiln-Dust Collection System	Wet	Dry
Single dust collector		
Cyclones	2	2
Precipitators	31	3
Baghouses	3	3
Wet scrubbers[b]	1	0
Settling chamber	1	0
Combinations of Dust Collectors		
Precipitators and wet scrubbers[b]	1	0
Cyclones and wet scrubbers[b]	1	0
Cyclones and precipitators	14	12
Cyclones and baghouses	4	16
Cyclones, baghouses, and precipitators	2	2
Baghouses and precipitators	1	1
Baghouses and wet scrubbers[b]	0	1

Source: Davis, T. A., and D. B. Hooks. Disposal and Utilization of Waste Kiln Dust from Cement Industry, EPA-670/2-75-043, U. S. Environmental Protection Agency, Cincinnati, Ohio, 1975.

[a] Data are extremely dated and probably do not represent current industry practice.

[b] It is doubtful whether any wet scrubbers are presently being used in operating cement plants.

2.4.1.3 Other Ducted and Process Fugitive Sources--

There are other ducted and process fugitive sources within cement plants. These sources were listed previously in Table 2-7. Capture and collection systems using baghouse collectors appear to be most frequently applied to control dust emissions from these various sources although wet suppression (with water, surfactants, foam, etc.) has been used successfully on crushing, screening, and materials handling operations.

2.4.2 Open Dust Sources

As stated above, there are a number of open dust sources associated with cement plants including: drilling; blasting; materials storage, handling, and transfer operations; truck load-in/load-out; clinker and raw material storage piles; vehicular traffic on paved and unpaved roads; and wind erosion. Fugitive emissions from materials handling, storage, loading and unloading operations can be reduced by a variety of different control technqieus. These include: enclosures and hoods ducted to dust collectors; wet dust suppression using water, foam, or chemicals; process modifications, improved housekeeping, and combinations of these and other controls. Plant roads can be paved, watered, treated with chemicals, or swept regularly to minimize dust reentrainment. References 7 and 8 provide guidance as to the various techniques applicable to such sources.

REFERENCES FOR SECTION 2.0

1. R. F. Smith, et al, Multimedia Assessment and Environmental Research Needs of the Cement Industry, EPA-600/2-79-111 (NTIS PB 299 210), U.S. Environmental Protection Agency, Cincinnati, OH, May 1979.

2. U.S. Bureau of Mines, Minerals Yearbook 1984, Volume I, Metals and Minerals, U.S. Government Printing Office, Washington, D.C., 1985.

3. Portland Cement Plants, Pit and Quarry Publications, Inc., Chicago, IL, 1982.

4. Muelberg, P. E., and B. P. Shepherd, Industrial Process Profiles for Environmental Use, Chapter 21, The Cement Industry, EPA-600/2-77-023u (NTIS PB 281 488), U.S. Environmental Protection Agency, Cincinnati, OH, February 1977.

5. T. E. Kreichelt, et al, Atmospheric Emissions from the Manufacture of Portland Cement, Report No. 999-AP-17 (NTIS PB 190 236), U.S. Department of Health, Education, and Welfare, Public Health Service, Cincinnati, Ohio, 1967.

6. Control Techniques for Particulate Emissions from Stationary Sources-Volume 1, EPA-450/3-81-005a (NTIS PB 83-127479), U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1982.

7. Control Techniques for Particulate Emissions from Stationary Sources-Volume 2, EPA-450/3-81-005b (NTIS PB 83-127480), U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1982.

8. S. C. Hunter, et al, Application of Combustion Modifications to Industrial Combustion Equipment, EPA-600/7-79-015a (NTIS PB 294 214), U.S. Environmental Protection Agency, Research Triangle Park, NC, January 1979.

SECTION 3.0

GENERAL DATA REVIEW AND ANALYSIS PROCEDURES

3.1 LITERATURE SEARCH AND SCREENING

The first step of this investigation was an extensive search of the available literature relating to the particulate emissions associated with portland cement plants. This search included: data collected under the inhalable particulate (IP) emission characterization program; information contained in the computerized Fine Particle Emission Inventory System (FPEIS); source test reports and background documents for Section 8.6 of AP-42 located in the files of the EPA's Office of Air Quality Planning and Standards (OAQPS); source test reports received industry; and MRI's own files (Kansas City and North Carolina). The search was thorough but not exhaustive. It is expected that certain additional information may also exist, but limitations in funding precluded further searching.

To reduce the large amount of literature collected to a final group of references pertinent to this report, the following general criteria were used:

1. Source testing must be a part of the referenced study. Some reports reiterate information from previous studies and thus were not considered.

2. The document must constitute the original source of test data. For example, a technical paper was not included if the original study was already contained in a previous document. If the exact source of the data could not be determined, the document was eliminated.

A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to the criteria stated above. This set of documents was further analyzed to derive candidate emission factors for particulate matter based on total mass and particle size.

3.2 EMISSION DATA QUALITY RATING SYSTEM

As part of MRI's analysis of the available data, the final set of reference documents were evaluated as to the quantity and quality of the information contained in them. The following data were always excluded from consideration.[1]

1. Test series averages reported in units that cannot be converted to the selected reporting units.

2. Test series representing incompatible test methods.

3. Test series of controlled emissions for which the control device is not specified.

4. Test series in which the source process is not clearly identified and described.

5. Test series in which it is not clear whether the emissions measured were controlled or uncontrolled.

If there was no reason to exclude a particular data set, each was assigned a rating as to its quality. The rating system used was that specified by the OAQPS for the preparation of AP-42 Sections.[1] The data were rated as follows:

A - Multiple tests performed on the same source using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily have to conform to the methodology specified in either the IP protocol documents, or by EPA reference test methods, although such were certainly used as a guide.

B - Tests that are performed by a generally sound methodology but lack enough detail for adequate validation.

C - Tests that are based on an untested or new methodology or that lack a significant amount of background data.

D - Tests that are based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

The following criteria were used to evaluate source test reports for sound methodology and adequate detail:

1. Source operation. The manner in which the source was operated is well documented in the report. The source was operating within typical parameters during the test.

2. Sampling procedures. The sampling procedures conformed to a generally accepted methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of how such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in the report. Many variations can occur without warning during testing and sometimes without being noticed. Such variations can induce wide deviations in sampling results. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and were given a lower rating.

4. Analysis and calculations. The test reports contain original raw data sheets. The nomenclature and equations used were compared to those specified by EPA (if any) to establish equivalency. The depth of review of the calculations was dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was based on factors such as consistency of results and completeness of other areas of the test report.

As a general rule, tests conducted strictly for the purpose of developing new source performance standards for a particular source category were not rated higher than B. This is due to the fact that these tests represent facilities which are considered as especially well-maintained, operated and controlled plants and thus may not be truly representative of the industry as a whole.

3.3 PARTICLE SIZE DETERMINATION

There is no one method which is universally accepted for the determination of particle size. A number of different techniques can be used which measure the size of particles according to their basic physical properties. Since there is no "standard" method for particle size analysis, a certain degree of subjective evaluation was used to determine if a test series was performed using a sound methodology for particle sizing. The following is a brief explanation of how particle size is defined and the various methods available for particle size measurement.

3.3.1 Particle Size Definitions

Examination of particles with the aid of an optical or electron microscope involves the physical measurement of a linear dimension of a particle. The measured "particle size" is related to the particle perimeter or to the particle projected area diameter. Particle size measurement in this manner does not account for variation in particle density or shape.[2]

All laws describing the properties of aerosols can be expressed most simply for particles of spherical shape. To accommodate nonspherical particles it is customary to define a "coefficient of sphericity" which is the ratio of the surface area of a sphere with the same volume as the given particle to the surface area of the particle.[2] An estimate of particle volume can be obtained from microscopic sizing, and by assuming a density, one can obtain an estimate of particle weight.

Because of large variations in particle density and the aggregated nature of atmospheric particles, it is useful to define other quantities as a measure of particle size based on their aerodynamic behavior. The Stoke's diameter is defined as the diameter of a sphere having the same settling velocity as the particle and a density equal to that of the bulk material from which the particle was formed, or:[3]

$$D_s = \sqrt{\frac{18\ V_s\ \eta}{g\ \rho\ C(D_s)}} \quad \text{for Re} \leq 0.5 \qquad (3\text{-}1)$$

where:

D_s = Stoke's diameter (cm)

V_s = terminal settling velocity of a particle in free fall (cm/sec)

η = viscosity of the fluid (gm/cm·sec)

g = gravitational constant (980.665 cm/sec^2)

ρ = density of the particle (gm/cm^3)

$C(D_s)$ = Cunningham's slip correction factor for spherical particles of diameter D_s (dimensionless)

$$\cong 1 + \frac{2A\lambda}{D_s} \qquad (3\text{-}2)$$

with:

$$A = \alpha + \beta \exp(-\gamma\ D_s/2\lambda) \qquad (3\text{-}3)$$

α = empirical constant (dimensionless) $\cong$ 1.23 - 1.246
β = empirical constant (dimensionless) $\cong$ 0.41 - 0.45
γ = empirical constant (dimensionless) $\cong$ 0.88 - 1.08
λ = mean free path of the fluid at stated conditions (cm)

$$\cong \lambda_o (\eta/\eta_o) (T/T_o)^{0.5} (P_o/P) , \quad (3\text{-}4)$$

λ_o = mean free path at reference conditions (cm)
η = gas viscosity at stated conditions (gm/cm·sec)
η_o = gas viscosity at reference conditions (gm/cm·sec)
T = absolute temperature (°K)
T_o = reference temperature = 296.16°K
P = absolute pressure (kPa)
P_o = reference pressure = 101.3 kPa
Re = Reynold's number (dimensionless)

For particles greater than a few microns in diameter, a less rigorous form of Equation 3-1 can be used with reasonable accuracy according to the relationship:[4,5]

$$D_s = \sqrt{\frac{18\ \eta\ V_s}{(\rho-\rho')g}} \qquad Re \leq 0.05 \qquad (3\text{-}5)$$

where:

ρ, g, D_s, and η are as defined above; and

ρ' = density of air at the appropriate temperature and pressure (gm/cm^3)

Since dispersion and condensation aerosols are usually formed from many materials of different densities, it is more useful to define another parameter called the aerodynamic diameter, which is the diameter of a sphere having the same settling velocity as the particle and a density equal to 1 g/cm^3.[2,3] The classical aerodynamic diameter differs from the Stoke's diameter only by virtue of difference in density, assumed equal to unity, and the slip correction factor, which, by convention, is calculated for the aerodynamic equivalent diameter. From Equation 3-1:[3]

$$D_{Ae} = \sqrt{\frac{18\eta V_s}{gC(D_{Ae})}} \qquad (3\text{-}6)$$

where D_{Ae} = "classical" aerodynamic equivalent diameter (cm), with η, V_s, g, C as previously defined in Equation 3-1.

Equations required for interconversion between Stoke's and aerodynamic diameters are presented in Table 3-1.[3]

TABLE 3-1. EQUATIONS USED FOR PARTICLE SIZE CONVERSIONS[3]

Diameter definition (given)	Conversion equation[a]	
	Stoke's diameter (D_s)	Classical aerodynamic equivalent diameter (D_{Ae})
Stoke's diameter	1.0	$D_{Ae} = D_s \left[\frac{\rho C(D_s)}{C(D_{Ae})}\right]^{1/2}$
Classical aerodynamic diameter (D_{Ae})	$D_s = D_{Ae} \left[\frac{C(D_{Ae})}{\rho C(D_s)}\right]^{1/2}$	1.0

[a] Notation: D_s = Stoke's diameter (μm)
D_{Ae} = Classical aerodynamic equivalent diameter (μm)
ρ = Particle density (g/cm³)
$C(D_s)$, $C(D_{Ae})$, = Slip correction factors (dimensionless)--see Equations 2, 3, and 4.

3.3.2 Particle Size Measurement

As stated previously above, particle size is determined by measuring certain physical properties of the particulate being analyzed, such as its inertial, light scattering, sedimentation, diffusional, and electrical characteristics. The size distribution of an aerosol can be determined either directly at the source (i.e., stack or vent) or indirectly by the collection of a bulk sample of the material for subsequent analysis in the laboratory. In either case, the instrument(s) utilized to make such a determination can be manual or automated depending on the individual technique.

The five basic methods for the direct measurement of particle size are:

1. Aerodynamic separators (cascade impactors, cyclones, elutriators, etc.)

2. Light-scattering optical particle counters

3. Electrical mobility analyzers

4. Condensation nuclei counters

5. Diffusion batteries

All of the above are extractive methods, with the exception of certain aerodynamic separators.

Indirect methods for the determination of particle size include:

1. Sieving (wet, dry, sonic)

2. Sedimentation

3. Centrifugation (inertial separation)

4. Microscopy (optical and electron)

5. Others (acoustic, thermal, spectrothermal emission)

Table 3-2 provides a guide as to the various methods for the determination of particle size based on certain physical properties of the particulate and notes the size range in which each is generally applicable.[6]

In most respects instruments that fractionate an aerosol on the basis of the aerodynamic properties of its components probably give the best practical assessment of size. Once flow conditions have been selected for the device, the terminal settling velocities of the particles collected in each stage or part of the instrument can be determined, even though particle specific gravity and shape factor are unknown.[3] Unless the particle shapes are extremely irregular, the details of precise geometric form can be bypassed and the likelihood of the particle's capture by a dust-collecting system can still be determined. Because the correct assessment of particle size properties is essential for the development of appropriate emission factors, an assessment by aerodynamic techniques was emphasized in reviewing and rating the individual data sets for sound methodology.

Examples of aerodynamic particle sizing instruments are centrifuges, cyclones, cascade impactors, and elutriators. Each of these instruments employs the unique relationship between a particle's diameter and mobility in gas or air to collect and classify the particles by size. For pollution studies, cyclones and impactors (primarily the latter) are more useful because they are rugged and compact enough for in situ sampling. In situ sampling is generally preferred because the measured size distribution may be distorted if a probe is used for sample extraction. In the following two subsections, methods of using impactors and cyclones are discussed.

3.3.2.1 Cascade Impactors--

Cascade impactors used for the determination of particle size in process streams consist of a series of plates or stages containing either small holes or slits with the size of the openings decreasing from one plate to the next. In each stage of an impactor, the gas stream passes through the orifice or slit to form a jet that is directed toward an impaction plate. For each stage there is a characteristic particle diameter that has a 50%

TABLE 3-2. GUIDE TO PARTICLE SIZE MEASUREMENT[6]

Method	Diameter of applicability (μm)
Optical	
Light imaging	0.5+
Electron imaging	0.001-15
Light scanning	1+
Electron scanning	0.1+
Direct photography	5+
Laser holography	3+
Sieving	2+
Light scattering	
Right angle	0.5+
Forward	0.3-10
Polarization	0.3-3
With condensation	0.01-0.1
Laser scan	5+
Electrical	
Current alteration	0.5+
Ion counting, unit charge	0.01-0.1
Ion counting, corona charging	0.015-1.2
Impaction	0.5+
Centrifugation	0.1+
Diffusion battery	0.001-0.5
Acoustical	
Orifice passage	15+
Sinusoidal vibration	1+
Thermal	0.1-1
Spectrothermal emission	0.1+

probability of impaction. This characteristic diameter is called the cut-point (D_{50}) of the stage. Typically, commercial instruments have six to eight impaction stages with a back-up filter to collect those particles which are either too small to be collected by the last stage or which are reentrained off the various impaction surfaces by the moving gas stream.[7]

The particle collection efficiency of a particular impactor jet-plate combination is determined by properties of the aerosol such as the particle shape and density, but the viscosity of the gas, and by the design of the impactor stage. There is also a slight dependence on the type of collection surface used (glass fiber, grease, metal, etc.). Reentrainment, or particle bounce, is a significant problem with cascade impactors especially in the case of high particulate loadings. This problem can be partially solved by using a preseparation device ahead of the impactor to reduce the overall loading of coarse particles.

3.3.2.2 Cyclone Separators--

Traditionally, cyclones have been used as a preseparator ahead of a cascade impactor to remove the larger particles. These cyclones are of the standard reverse-flow design whereby the aerosol sample enters the cyclone through a tangential inlet and forms a vortex flow pattern. Particles move outward toward the cyclone wall with a velocity that is determined by the geometry and flow rate in the cyclone and by their size. Large particles reach the wall and are collected.

A series of cyclones with progressively decreasing cut-points can be used also instead of impactors to obtain particle size distributions. The advantages are that larger samples are acquired, particle bounce is not a problem, and no substrates are required. Also, longer sampling times are possible with cyclones, which can be an advantage at very dusty streams, but a disadvantage at relatively clean streams. One such series cyclone system was developed by an EPA contractor specifically for the IP program.

3.4 PARTICLE SIZE DATA ANALYSIS METHODOLOGY

The particulate emission information contained in the various primary reference documents was reduced to a common format using a family of computer programs developed especially for this purpose (as shown in Table 3-3). These programs are fundamentally BASIC translations of the FORTRAN program SPLIN2 developed by Southern Research Institute.[8] The particular version translated is one that MRI modified earlier to operate utilizing as few as three data points. Additional changes were made to produce emission factors as functions of the aerodynamic particle diameter.

As mentioned above, SPLIN2 is the central portion of the program which uses the so-called "spline" fits. Spline fits result in cumulative mass size distributions very similar to those which would be drawn using a French curve and fully logarithmic graph paper. In effect, the logarithm of cumulative mass is plotted as a function of the logarithm of the particle size, and a smooth curve with a continuous, nonnegative derivative is drawn.

The process by which this smooth cumulative distribution is constructed involves passing an interpolation parabola through three measured data points at a time. The parabola is then used to interpolate additional points between measured values. When the set of interpolated points are added to the original set of data, a more satisfactory fit is obtained than would be the case using only the measured data.

The primary addition to the spline fitting procedure is the determination of size-specific emission factors once the size distribution is obtained by a spline fit. The user is prompted to input process and emission rate data. The program determines a total particulate emission factor by:

$$E_{TP} = \frac{e_{TP}}{R} \tag{3-7}$$

TABLE 3-3. COMPARISON OF COMPUTER PROGRAMS

Fitted size distribution	JSKPRG Spline	JSKRAW Spline	JSKLOG Log-normal
Input requirements:			
particle size data	Largest particle diameter; cumulative mass fractions; particle density	Largest particle diameter; incremental mass fractions; particle density	Completed log-normal size distribution
process data	Process and emission rates - or - emission factor	Process and emission rates - or - emission factor	Process and emission rates - or - emission factor
Output:	------------- Size-specific emission factors (English and metric units) for selected aerodynamic particle diameters -------------		

where: E_{TP} = total particulate emission factor (lb/ton)

e_{TP} = total particulate emission rate (lb/hr)

R = process weight rate (tons of cement produced/hr)

Emission factors for each particle size range are then obtained by multiplying E_{TP} by the mass fraction associated with that range. The programs automatically convert the size-specific emission factors obtained from English units (lb/ton) to the appropriate metric units (kg/metric ton), which are tabulated as a part of the output format (1 kg/metric ton = 1 kg/10^6 g = 1 kg/Mg). As an additional function, each program has the capability of converting from Stoke's diameter to aerodynamic diameter using the appropriate density correction (Table 3-1).

Most of the programs also require that a largest particle diameter be provided to complete the size distribution. A maximum size of 200 μmA (aerodynamic diameter) was assumed unless other data were available. This value was selected since this is the largest particle size which might be expected based on the limited data contained in the literature. A complete listing of each program is provided in Appendix A of Volume I with sample outputs shown in Figures 3-1 to 3-3.

Due to the nature of the spline fit routine, a large-scale extrapolation (i.e., order of magnitude) of the data can result in a negative slope of the cumulative size distribution curve. In such cases, JSKLOG was used in its place. In JSKLOG, the data input to the program have already been fitted to a standard log-normal distribution utilizing a separate program written for the Texas Instruments Model 59 (TI-59) programmable calculator. This program was used whenever a spline fit was determined not suitable to adequately represent the distribution in the smaller particle size ranges.

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: EXAMPLE OUTPUT OF "JSKPRG"

INPUT DATA: PROCESS WEIGHT RATE = 100 TONS PROD./HR
TOTAL PARTICULATE EMISSION RATE = 100 LB/HR
PARTICLE DENSITY = 2.44 G/CC

MEASURED SIZE DISTRIBUTION

CUT(um)	CUM. % < CUT
10	15
20	25
30	34
50	50

OUTPUT DATA: TP EMISSION FACTOR = 1 LB/T (.5 KG/MT)

CUT (umA)	CUM. % < CUT	EMISSION FACTOR (LB/T)	(KG/MT)
.625	1.78801	.0178801	8.94006E-03
1	2.3787	.023787	.0118935
1.25	2.73215	.0273215	.0136607
2.5	4.25364	.0425364	.0212682
5	6.74744	.0674744	.0337372
10	10.9053	.109053	.0545267
15	14.567	.14567	.0728348
20	17.9582	.179582	.0897908

END OF TEST SERIES

Figure 3-1. Example output of "JSKPRG."

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: EXAMPLE OUTPUT OF "JSKRAW"

INPUT DATA: PROCESS WEIGHT RATE = 100 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 100 LB/HR
PARTICLE DENSITY = 2.44 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

CUT (um)	RAW % < CUT	CUM. % < CUT
10	15	15
20	10	25
30	9	34
50	16	50
74	50	100

OUTPUT DATA: TP EMISSION FACTOR = 1 LB/T (.5 KG/MT)

CUT (umA)	CUM. % < CUT	EMISSION FACTOR (LB/T)	EMISSION FACTOR (KG/MT)
.625	1.78804	.0178804	8.94021E-03
1	2.37873	.0237873	.0118937
1.25	2.73218	.0273218	.0136609
2.5	4.25366	.0425366	.0212683
5	6.74745	.0674745	.0337373
10	10.9053	.109053	.0545267
15	14.567	.14567	.0728348
20	17.9581	.179581	.0897907

END OF TEST SERIES

Figure 3-2. Example output of "JSKRAW."

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: EXAMPLE OUTPUT OF "JSKLOG"

INPUT DATA: PROCESS WEIGHT RATE = 100 TONS PROD./HR
TOTAL PARTICULATE EMISSION RATE = 100 LB/HR
PARTICLE DENSITY = 2.44 G/CC

MEASURED SIZE DISTRIBUTION

CUT(um)	CUM. % < CUT
10	15
20	25
30	34
50	50

OUTPUT DATA: TP EMISSION FACTOR = 1 LB/T (.5 KG/MT)

		EMISSION FACTOR	
CUT (umA)	CUM. % < CUT	(LB/T)	(KG/MT)
.625	1.788	.01788	8.94E-03
1	2.379	.02379	.011895
1.25	2.732	.02732	.01366
2.5	4.254	.04254	.02127
5	6.747	.06747	.033735
10	10.9	.109	.0545
15	14.57	.1457	.07285
20	17.96	.1796	.0898

THIS DATA SET WAS FIT TO A LOG-NORMAL SIZE DISTRIBUTION

Figure 3-3. Example output of "JSKLOG."

3.5 EMISSION FACTOR QUALITY RATING SYSTEM

The quality of the emission factors developed from analysis of the test data was rated utilizing the following general criteria:[1]

- A - Excellent: Developed only from A-rated test data taken from many randomly chosen facilities in the industry population. The source category* is specific enough to minimize variability within the source category population.

- B - Above average: Developed only from A-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. As in the A-rating, the source category is specific enough to minimize variability within the source category population.

- C - Average: Developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. As in the A-rating, the source category is specific enough to minimize variability within the source category population.

- D - Below average: The emission factor was developed only from A- and B-rated test-data from a small number of facilities, and there is reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor are footnoted in the emission factor table.

---

* Source category: A category in the emission factor table for which an emission factor has been calculated (generally a single process).

- E - Poor: The emission factor was developed from C- and D-rated test data, and there is reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of these factors are always footnoted.

The use of the above criteria is somewhat subjective depending to a large extent on the individual reviewer. Details of how each candidate emission factor was rated are provided in each section of this report.

REFERENCES FOR SECTION 3.0

1. Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections, U.S. Environmental Protection Agency, Research Triangle Park, NC, April 1980.

2. S. Calvert, et al., Wet Scrubber Systems Study, Volume I: Scrubber Handbook, EPA-R2-72-118a (NTIS PB 213 016), U.S. Environmental Protection Agency, Research Triangle Park, NC, August 1972.

3. J. B. Galeski, Particle Size Definitions for Particulate Data Analysis, EPA-600/7-77-129 (NTIS PB 276 470), U.S. Environmental Protection Agency, Washington, D.C., November 1977.

4. J. P. Sheehy, et al., Handbook of Air Pollution, 999-AP-44 (NTIS PB 190 247), U.S. Department of Health, Education, and Welfare, Durham, NC, 1968.

5. H. L. Green, and W. R. Lane, Particulate Clouds: Dusts, Smokes and Mists, E.F.N. Spon, Ltd., London, 1964.

6. R. Dennis, Handbook on Aerosols, TID-26608, Energy Research and Development Administration, Washington, D.C., September 1978.

7. W. B. Smith, et al., Technical Manual: A Survey of Equipment and Methods for Particulate Sampling in Industrial Process Streams, EPA-600/7-78-043 (NTIS PB 282 501), U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1978.

8. J. W. Johnson, et al., A Computer-Based Cascade Impactor Data Reduction System, EPA-600/7-78-042 (NTIS PB 285 433), U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1978.

SECTION 4.0

PARTICULATE EMISSION FACTOR DEVELOPMENT

This section describes the test data and methodology used to develop particulate emission factors for the cement industry.

4.1 REVIEW OF SPECIFIC DATA SETS

A total of 55 reference documents were collected and reviewed during the literature search conducted as part of this study.[1-55] These documents are listed at the end of this section along with an indication as to whether the document contains particle size data.

The original group of 55 documents were reduced to a final set of primary references utilizing the criteria outlined in Section 3.0 of this report. For those reference documents not used, the following summarizes the reason(s) for their rejection:

Reference No.	Cause(s) for Rejection
1	No test method specified.
2	No test method or plants specified; ranges of emission rates only.
3	No test method specified.
4	No test method or fuel type specified.
5-7	No test method specified; little documentation; data for all kilns combined.
8	Not original source of test data.
9	Not original source of test data.
19	Not original source of test data.
22	Kiln dust disposal study -- no emissions data.
23	Not original source of test data.
28	Not original source of test data.

Reference No.	Cause(s) for Rejection
29	Not original source of test data.
34	SO_2/NO_x data only - no particulate tests.
35	Type of process and fuel not specified.
37	Type of process not specified.
38	Type of process not specified.
41	Type of control device not specified.
45	Process description only - no test data (used as reference for review of other test reports).
47	Data deleted due to nonconsistent combination of control devices.
49	Sources tested not specified.
55	Type of process not clearly specified (probably wet process).

The following is a discussion of the data contained in each of the primary references used to develop candidate emission factors, according to reference number and date of publication. Initially, all emission factor calculations were performed in terms of weight of pollutant per weight of cement produced. Later, the emission factors developed were converted to weight of pollutant per weight of clinker for those sources producing or processing this particular material (i.e., kilns and coolers).

4.1.1 References 10 through 17 (1971)

References 10 through 17 are source tests of nine different cement plants conducted by EPA contractors. The purpose of these tests was to gather emissions data on well controlled plants to develop New Source Performance Standards (NSPS) for the cement industry. All of the tests were performed using EPA reference test methods with sampling conducted at the outlet of some type of dust collector. Emission factors were presented in each report in terms of pounds of particulate matter per ton of feed material. A summary of the data contained in References 10 through 17 is shown in Table 4-1.

Upon review of References 10 through 17, it was determined that the sampling protocol used and test results obtained were fairly well documented in each report. It was noted, however, that very little process operating

TABLE 4-1. SUMMARY OF NSPS DATA COLLECTED BY EPA

Ref. No.[a]	EPA report No.	Plant name/location	Process type	Sources Tested	No. of tests	Controlled emission factor measurement[b] (lb/ton of feed)	Rating[c]	Control device[d]	Comments
10	71-MM-01	Maule Industries Hialiah, FL	Wet	Clinker Cooler Stack No. 1	3	0.106, 0.102, 0.0798	B	ESP	
				Gas-fired Rotary Kiln Stack No. 1	3	0.634, 1.019, 1.799	C	ESP	Frequent Upsets
17	71-MM-02	Ideal Cement Co. Tijeras, NM	Dry	No. 2 Finish Ball Mill	2	0.00601, 0.00601	B	BH	
				No. 2 Finish Ball Mill Air Separator	2	0.0173, 0.0164	B	BH	
				No. 2 Finish Ball Mill Feed-O-Wt	2	0.00953, 0.00922	B	BH	
				No. 2 Raw Ball Mill	2	0.0161, 0.0183	B	BH	
				No. 2 Raw Ball Mill Air Separator	2	0.0376, 0.0265	B	BH	
				No. 2 Raw Ball Mill Feed-O-Wt	2	0.0226, 0.0153	B	BH	
11	71-MM-03	Ideal Cement Co. Seattle, WA	Wet	Clinker Cooler	3	0.406, 0.452, 0.536	C	BH	Bad sampling location
				Gas-fired Rotary Kiln	2	0.844, 0.924	B	ESP	
12	71-MM-04	Ideal Cement Co. Castle Hayne, NC	Wet	No. 1 Finish Ball Mill Air Separator Stacks A&B	3	0.0344, 0.0418, 0.0409	B	BH	Combined emissions from both air separators
				No. 1 Finish Ball Mill and Elevator	3	0.0135, 0.0133, 0.0134	B	BH	
13	71-MM-05	Dragon Cement Co. Northampton, PA	Dry	No. 1 and No. 2 Coal-fired Rotary Kilns	3	0.0942, 0.0553, 0.0606	C	Multi-clone and BH	Horizontal duct; problems with particulate settled in duct

(continued)

TABLE 4-1. (continued)

Ref. No.[a]	EPA report No.	Plant name/location	Process type	Sources Tested	No. of tests	Controlled emission factor measurement[b] (lb/ton of feed)	Rating[c]	Control device[d]	Comments
14	71-MM-06	Ideal Cement Co. Houston, TX	Wet	No. 2 Clinker Cooler	3	0.0253, 0.0448, 0.0305	B	BH	
				No. 2 Finish Mill Grinding System	3	0.0152, 0.0201, 0.0120	B	BH	Includes both mill and air separators
15	71-MM-07	Giant Portland Cement Harleyville, SC	Wet	No. 4 Gas-fired Rotary Kiln	1	0.536	B	BH	Pressure BH; 6 stacks each tested once
				No. 4 Oil-fired Rotary Kiln	1	0.513	B	BH	Pressure BH; 6 stacks each tested once
16	71-MM-15	Oregon Portland Cement Lake Oswego, OR	Wet	No. 4 Gas-fired Rotary Kiln	3	0.247, 0.309, 0.261	B	BH	
18	74-STN-1	Arizona Portland Cement Rillito, AZ	Dry	Primary Limestone Crusher	4	0.00079, 0.00091, 0.00093, 0.00139	B	BH	
				Primary Limestone Screen	4	0.00018, 0.00023, 0.00022, 0.00026	B	BH	
				No. 2 Limestone Over-land Conveyor Transfer Station	3	0.00002, 0.00003, 0.00004	B	BH	
				Secondary Limestone Screen and Crushing Plant	3	0.00017, 0.00034, 0.00041	B	BH	

[a] References listed at the end of Section 4.

[b] Based on front-half of EPA Reference Method 5 sampling train. 1 lb/ton = 0.5 kg/Mg.

[c] All of these data were collected to support a NSPS and are therefore representative of the better controlled plants but not necessarily of the entire industry.

[d] BH = baghouse; ESP = electrostatic precipitator.

data were collected for the dates and times during which testing took place. For this reason and the fact that these particular facilities represent well controlled, operated, and maintained plants (as specified by NSPS), a rating of B was generally assigned to the data. For certain tests, where problems with either the operation of the process or in the collection of the samples was mentioned, a rating of C was assigned to the data (see Table 4-1). Copies of pertinent sections of each test report are included in Appendix A.

4.1.2 Reference 18 (1974)

Reference 18 is a report of source tests conducted by an EPA contractor at a cement plant located in Arizona. The purpose of these tests was to provide background data for the development of an NSPS for stone crushing. Individual sources tested in this study included: a primary crusher; a primary screen; a conveyor transfer point; and a secondary crushing and screening plant.

The total mass emissions from each source tested were determined at the outlet of a baghouse collector utilizing EPA Method 5. Four runs were conducted at each test location with emission factors calculated based on the total amount of feed material. A summary of the test data presented in Reference 18 has also been shown in Table 4-1. For reasons similar to those presented above for References 10 through 17, a rating of B was likewise assigned to the Method 5 data contained in Reference 18. Appropriate sections of the test report are contained in Appendix A.

Eight particle size tests of the uncontrolled emissions from the primary crusher were also conducted with five additional tests being performed on the emissions from the primary screen. In both cases the measurements were made upstream of a baghouse collector. No determination of total mass emissions were conducted at these sampling locations. The size distribution of the particulate emitted from each source was made using a Brink Model B cascade impactor with cyclone precollector. Since no Method 5 tests were conducted at the same locations as the Brink tests, the data contained in Reference 18 could not be used in the development of size-specific emission factors.

4.1.3 Reference 20 (1976)

Reference 20 is a study conducted by an EPA contractor to determine the performance characteristics of three industrial electrostatic precipitators (ESPs). One of the facilities tested in this program was a wet process cement kiln fired with a combination of coal and coke oven gas. Tests were conducted at the inlet and outlet of the precipitator which represented the uncontrolled and controlled emissions from the kiln. Unfortunately, no process data were collected during testing based on an agreement with plant management. Since the purpose of the study was to evaluate the performance of the ESP and not to characterize the source, the lack of process data did not create a serious problem for the contractor performing the study.

Testing at the inlet was conducted using a Brink Model BMS-11 cascade impactor fitted with a cyclone precollector. The Brink impactor is essentially a fine particle sampler and is generally not well suited to uncontrolled sources with a substantial population of large particles. A determination of total mass loading at the ESP inlet was not performed during the program. At the outlet of the ESP, total mass emissions were determined using EPA Reference Method 5 with an Andersen Mark III cascade impactor used for determining particle size.

The data collected in this study were not presented in any significant detail in Reference 20. However, these data were entered in the EADS-FPEIS data base (Test Series No. 80) from which a printout was obtained. Since no verification of the EADS data could be made, the values reported were accepted at face value. It was learned from conversations with the contractor that the test results obtained during the study were entered directly into EADS under a separate effort with the raw data never actually appearing in a published report.[30]

Based on a review of Reference 20 and telephone conversations with the contractor, it was determined that the particle size data collected at the outlet of the ESP were invalid.[56] These tests were invalidated due to the formation of artifacts on the fiberglass substrates used in the Andersen impactor during sampling, which created abnormally high loadings to be measured. For this reason, none of the outlet data for these tests are presented in this report or used in the development of candidate emission factors. A summary of the test results collected at the inlet to the ESP is provided in Table 4-2.

The information contained in Reference 20 and in the EADS printout were determined to be of fairly good quality. However, the conspicuous lack of documentation definitely lowered the overall rating which could be assigned to the data using the criteria established by OAQPS. Based on the factors stated above, a rating of C was given to the data contained in Reference 20 and the associated EADS printout. Copies of pertinent sections of Reference 20 and the EADS printout are also included in Appendix A.

4.1.4 Reference 21 (1976)

Reference 21 is a study conducted by an EPA contractor to determine the fractional efficiency characteristics of a gravel bed filter (Rexnord) controlling the emissions from a clinker cooler. Testing was conducted at both the inlet and outlet of the gravel bed using a number of different particle sizing instruments. Due to the nature of the source and its associated emissions, only the data collected by in situ sampling using cascade impactors are of interest in the development of size-specific emission factors.

During the sampling program, testing was conducted over a several day period in both August and November of 1975. In the August test series, both total mass emissions and particle size distributions were determined at the inlet and outlet of the gravel bed filter. In November, only the inlet and outlet particle size distribution was characterized.

The total mass emissions from the clinker cooler were measured at the inlet to the gravel bed and in the stack using EPA Reference Method 5. During the August tests, the inlet particle size distribution was determined using both a Brink and an Andersen cascade impactor with only an

TABLE 4-2. SUMMARY OF PARTICLE SIZE DATA FOR REFERENCE 20 - ESP INLET[a]

Data Rating: C

Impactor stage	Test 2-1[b]		Test 2-2[b]		Test 3-1[b]		Test 3-2[b]		Test 3-3[b]	
	Cut (μmA)[c]	Cum. loading[d] (mg/dncm)	Cut (μmA)[c]	Cum. loading[d] (mg/dncm)	Cut (μmA)[c]	Cum. loading[d] (mg/dncm)	Cut (μmA)[c]	Cum. loading[d] (mg/dncm)	Cut (μmA)[c]	Cum. loading[d] (mg/dncm)
Filter	0.13	0.00	0.13	0.00	0.12	0.00	0.13	0.00	0.10	0.00
Stage 7	0.25	569	0.25	344	0.24	297	0.26	269	0.24	693
Stage 6	0.68	1,290	0.68	546	0.64	604	0.67	431	0.65	1,090
Stage 5	0.97	1,700	0.97	787	0.91	1,260	0.95	748	0.91	1,770
Stage 4	1.86	2,640	1.86	1,050	1.75	2,290	1.83	1,440	1.76	2,870
Stage 3	2.70	4,290	2.70	1,410	2.54	3,550	2.65	2,410	2.55	3,930
Stage 2	4.59	8,050	4.59	1,910	4.32	5,730	4.50	3,080	4.33	7,330
Stage 1	8.11	12,800	8.11	2,330	7.62	8,900	7.93	5,390	7.65	9,600
Cyclone	> 11.49	20,300	> 11.49	2,750	> 10.80	16,800	> 11.23	9,330	> 10.83	13,100
Total catch[e]	Total	51,639	Total	11,127	Total	39,431	Total	23,098	Total	40,383

Impactor stage	Test 3-4[b]		Test 4-1[b]		Test 4-2[b]		Test 4-3[b]		Test 4-4[b]	
	Cut (μmA)[c]	Cum. loading[d] (mg/dncm)	Cut (μmA)[c]	Cum. loading[d] (mg/dncm)	Cut (μmA)[c]	Cum. loading[d] (mg/dncm)	Cut (μmA)[c]	Cum. loading[d] (mg/dncm)	Cut (μmA)[c]	Cum. loading[d] (mg/dncm)
Filter	0.13	0.00	0.12	0.00	0.13	0.00	0.13	0.00	0.13	0.00
Stage 7	0.26	607	0.24	617	0.25	423	0.25	723	0.25	359
Stage 6	0.68	978	0.64	850	0.69	685	0.65	1,150	0.69	539
Stage 5	0.96	1,630	0.91	1,200	0.97	922	0.92	1,500	0.98	967
Stage 4	1.84	2,580	1.75	1,470	1.87	1,380	1.76	1,980	1.88	2,020
Stage 3	2.67	3,350	2.54	1,920	2.70	1,930	2.55	2,700	2.72	3,240
Stage 2	4.54	6,060	4.32	2,390	4.59	3,170	4.34	5,730	4.62	4,200
Stage 1	8.00	10,900	7.63	2,860	8.11	7,420	7.67	10,100	8.15	10,200
Cyclone	> 11.33	13,100	> 10.82	3,080	> 11.48	10,000	> 10.87	16,100	> 11.54	10,500
Total catch[e]	Total	39,205	Total	14,387	Total	25,930	Total	39,983	Total	32,025

[a] Data taken from FPEIS Test Series 80, pages 20, 23, 37, 40, 43, 46, 63, 66, 69, and 72 (Appendix C). Measurements made on a wet process, coal/coke oven gas fired kiln upstream of the ESP using a Brink Model BMS-11 cascade impactor with cyclone precollector. No data available for total mass emissions (i.e., Method 5). No process data available.

[b] Indicates test ID No. and sample No. included in FPEIS printout. For example: Test ID No. 2, Sample No. 1 = Test 2-1.

[c] Aerodynamic diameter.

[d] Cum. loading = cumulative mass loading less than or equal to stated size taken from FPEIS printout in milligrams per dry normal cubic meter (dncm).

[e] Total loading collected in cyclone and impactor stages. Sum of individual loadings in column.

Andersen unit used at the outlet. In November, the Brink impactor was eliminated from the program.

A total of 17 tests were conducted at the inlet to the gravel bed filter using the Andersen impactor and eight tests with the Brink. At the outlet, a total of 24 tests were conducted using the Andersen impactor. The data obtained from these tests are summarized in Tables 4-3 through 4-7 for both the August and November tests.

The main purpose of the study described in Reference 21 was to evaluate the efficiency of the control device not to characterize the emissions from the source. For this reason, the process data included in the report were at best minimal. In addition, the cyclone precollectors used in conjunction with the Brink or Andersen impactor were either not calibrated or otherwise had an undefined cut-point at the time of testing. Also, as stated above, the use of a Brink impactor is not the best choice for testing of uncontrolled sources. For this reason the Brink impactor data were eliminated from consideration in the development of candidate emission factors.

It was also mentioned in the report that a problem with particle bounce had been observed with the impactor samples collected as evidenced by the unusually high loadings on the backup filters. This problem is not uncommon with these types of tests, but can definitely bias the results obtained. For the above reasons, a rating of C was assigned to the data in Reference 21. A copy of appropriate portions of the report have been included in Appendix A.

4.1.5 Reference 24 (1977)

Reference 24 is an in-house compliance test performed on a coal-fired, wet process cement kiln equipped with an ESP. Emissions tests for total particulate were conducted both upstream and downstream of the ESP utilizing EPA Method 5 protocol. Twelve test runs were performed of the uncontrolled emissions from the kiln with an additional six runs conducted of the controlled effluent.

TABLE 4-3. SUMMARY OF PARTICLE SIZE DATA FOR REFERENCE 21 - UNCONTROLLED CLINKER COOLER (BRINK IMPACTOR - AUGUST TESTS)[a]

Data Rating: C

Date	Time	Total mass loading (mg/DNM³)[b]	Mass loading by particle size range (mg/DNM³)[c]								
			> 17.8 µmA[d]	12.6-17.8 µmA	7.2-12.6 µmA	4.3-7.2 µmA	3.0-4.3 µmA	1.6-3.0 µmA	1.14-1.6 µmA	0.67-1.14 µmA	< 0.67 µmA
8/26	1010	2,168.92	2,020	36.6	28.1	22.1	13.6	14.5	7.66	20.4	5.96
8/26	1700	2,265.10	2,160	38.9	15.2	17.2	6.1	3.0	3.5	8.6	12.6
8/27	1045	1,011.23	963	17.7	7.7	8.2	7.0	2.6	1.2	1.0	2.83
8/27	1605	961.60	824	65.9	22.4	29.3	9.4	2.6	1.8	2.2	4.00
8/28	0945	1,810.90	1,720	50.8	17.8	11.4	4.3	1.9	1.1	0.8	2.8
8/28	1310	687.00	597	48.2	12.3	14.7	3.3	1.9	1.6	1.6	6.4
8/29	1000	3,816.60	3,640	49.5	84.3	22.5	6.9	2.5	2.0	2.0	6.9
8/29	1400	1,322.30	1,150	116	19.2	15.4	6.1	2.6	0.6	0.6	11.8
Average total mass emission factor (kg/Mg)			4.42[e]								

[a] Particle size data taken from Table A-4, page 37 of Reference 21 (Appendix A). Total mass emissions data taken from Table 2, page 7 of same report. Measurements taken at inlet to gravel bed filter. Data not used in the development of candidate emission factors.

[b] Sum of mass loadings in the various particle size ranges contained in the following columns.

[c] Aerodynamic diameter.

[d] Cut-point of cyclone questionable.

[e] Arithmetic mean calculated from Method 5 Runs 2-5 and process data contained in Appendix B of report (see calculations in Appendix B). Kilograms of pollutant per Mg (10^6 g) of cement produced.

TABLE 4-4. SUMMARY OF PARTICLE SIZE DATA FOR REFERENCE 21 - UNCONTROLLED CLINKER COOLER (ANDERSEN IMPACTOR DATA - AUGUST TESTS)[a]

Data Rating: C

Date	Start	Total mass loading (mg/DNM³)[b]	Mass loading by particle size range (mg/DNM³)[c] > 4.70 μmA[d]	3.1-4.7 μmA	1.4-3.1 μmA	0.87-1.4 μmA	0.63-0.87 μmA	< 0.63[e] μmA
8/27	1320	3,529.06	3,459[f]	28.6	20.7	4.84	2.42	13.5
8/27	1620	385.28	341[f]	20.9	13.8	3.59	1.00	4.99
8/27	1730	344.98	313[f]	14.5	11.4	2.43	1.42	2.23
8/27	1800	629.01	581[f]	25.8	14.8	3.5	1.39	2.52
8/28	0950	2,757.64	2,737	9.2	5.20	1.11	0.48	4.65
8/28	1105	4,277.94	4,252	11.1	7.82	2.66	0.52	3.84
8/28	1440	2,133.14	2,098	9.3	6.44	3.26	2.64	13.5
8/29	1015	2,741.88	2,711	12.2	7.44	2.31	2.04	6.89
8/29	1400	2,159.01	2,131	14.4	9.34	2.42	0.42	1.43
Average total mass emission factor (kg/mg)				4.42[g]				

[a] Particle size data taken from Table A-1, page 34 of Reference 21 (Appendix A). Total mass emissions data taken from Table 2, page 7 of same report. Measurements taken at inlet to gravel bed filter.

[b] Sum of mass loading values in the various particle size ranges contained in the following columns.

[c] Aerodynamic diameter.

[d] Includes cyclone catch and first two impactor stages.

[e] May be dominated by oversize particles.

[f] Invalid data - nozzle not pointed directly into flow.

[g] Arithmetic mean calculated from Method 5, Runs 2-5 and process data contained in Appendix B of report (see calculations in Appendix B). Kilograms of pollutant per Mg (10^6 g) of cement produced.

TABLE 4-5. SUMMARY OF PARTICLE SIZE DATA FOR REFERENCE 21 - UNCONTROLLED CLINKER COOLER (ANDERSEN IMPACTOR DATA - NOVEMBER TESTS)[a]

Data Rating: C

Date	Start	Total mass loading (mg/DNM³)[b]	Mass loading by particle size range (mg/DNM³)[c] > 4.70 μmA[d]	3.1-4.7 μmA	1.4-3.1 μmA	0.87-1.4 μmA	0.63-0.87 μmA	< 0.63[e] μmA
11/4	1100	2,506.36	2,474	18.8	9.5	2.4	0.12	1.54
11/4	1130	698.64	661[f]	19.3	12.2	0.51	1.03	4.60
11/4	1430	1,972.30	1,941	14.9	10.7	3.7	0.53	1.47
11/4	1435	1,816.65	1,791	12.4	8.53	2.53	0.67	1.52
11/5	0935	2,410.33	2,384	9.11	14.5	1.12	0.23	1.37
11/5	0930	2,477.15	2,453	14.6	7.51	1.32	0.03	0.69
11/5	1415	4,651.35	4,607	17.5	7.97	3.31	4.37	11.2
11/5	1415	4,284.14	4,232	19.7	10.6	4.02	3.42	14.4

[a] Particle size data taken from Table A-1, page 34 of Reference 21 (Appendix A). Measurements taken at inlet to gravel bed filter.

[b] Sum of mass loading values in the various particle size ranges contained in the following columns.

[c] Aerodynamic diameter.

[d] Includes cyclone catch and first two impactor stages.

[e] May be dominated by oversize particles.

[f] Invalid data - nozzle not pointed directly into flow.

TABLE 4-6. SUMMARY OF PARTICLE SIZE DATA FOR REFERENCE 21 - CLINKER COOLER CONTROLLED BY GRAVEL BED FILTER (AUGUST TEST SERIES)[a]

Data Rating: C

Date	Start time	Dilution correction factor[b]	Total mass loading (mg/DNM³)[c]	Mass loading by particle size range (mg/DNM³)[d] > 14.3 μmA	10.1-14.3 μmA	6.2-10.1 μmA	4.4-6.2 μmA	2.9-4.4 μmA	1.35-2.9 μmA	0.82-1.35 μmA	0.58-0.82 μmA	< 0.58 μmA
8/25	1440	1.32	24.95	2.89	2.77	2.57	2.90	4.83	4.41	2.13	0.96	1.49
8/25	1440	1.32	14.74	2.79	2.74	0.45	0.90	1.76	3.07	1.56	0.15	1.32
8/26	1119	1.22	24.39	2.39	1.57	2.19	3.55	5.97	4.21	3.36	0.94	0.21
8/26	1124	1.34	28.86	3.81	2.24	3.06	4.47	6.45	5.46	2.33	0.71	0.33
8/26	1515	1.34	46.32	9.09	2.34	2.86	4.75	7.64	6.09	2.38	0.97	10.2
8/26	1515	1.34	36.81	8.87	2.54	3.42	3.90	6.21	6.14	3.11	1.52	1.10
8/27	1100	1.34	43.73	12.0	3.31	3.14	4.37	7.80	7.16	3.48	1.54	0.93
8/27	1150	1.34	43.21	7.98	5.30	3.93	5.21	6.31	7.50	4.14	1.41	1.43
8/27	1515	1.42	37.80	7.40	2.83	2.89	4.02	5.56	7.43	4.36	1.77	1.54
8/27	1515	1.42	39.74	11.4	2.26	2.48	3.12	7.11	6.99	4.01	1.47	0.90
8/28	1045	1.31	31.62	7.16	2.22	2.20	3.17	6.23	5.17	2.71	1.15	1.61
8/28	1045	1.31	31.31	7.74	1.97	2.25	4.35	4.40	5.35	2.58	0.88	1.79
8/28	1415	1.47	37.19	7.72	2.14	2.60	3.25	5.26	5.57	3.00	1.92	5.73
8/28	1415	1.47	35.04	5.69	2.96	2.26	3.68	4.88	6.67	2.70	1.53	4.67
8/29	1000	1.27	38.69	10.2	2.13	3.11	4.14	5.77	5.13	2.53	1.70	3.98
8/29	1000	1.27	31.30	5.79	1.60	1.76	3.05	6.27	5.21	2.57	1.23	3.82
8/29	1400	1.41	16.85	2.69	1.51	1.17	1.15	1.55	3.93	2.30	1.28	1.27
8/29	1400	1.41	30.83	6.92	1.68	2.56	3.35	5.19	6.10	3.07	0.93	1.03
Average total mass emission factor (kg/Mg)							0.142[e]					

[a] Particle size data taken from Table A-2, page 35 of Reference 21 (Appendix A). Total mass data taken from Table 3, page 8 of same report. Measurements taken at outlet of gravel bed filter utilizing an Andersen impactor.

[b] Because of the dilution that results from the addition of the backwash air, the results from the outlet impactors must be adjusted to compensate for the difference in inlet and outlet gas flows before comparisons among the various operating conditions can be made and before fractional collection efficiencies can be calculated. The correction factor by which the measured outlet concentrations must be multiplied in order to effect this adjustment are given for each impactor run in the table.

[c] Sum of mass loadings in the various particle size ranges contained in the following columns.

[d] Aerodynamic diameter.

[e] Arithmetic mean calculated from Method 5 Runs 2-5 and process data contained in Appendix B of report (see calculations in Appendix B). Kilograms of pollutant per Mg (10^6 g) of cement produced.

TABLE 4-7. SUMMARY OF PARTICLE SIZE DATA FOR REFERENCE 21 - CLINKER COOLER CONTROLLED BY GRAVEL BED FILTER (NOVEMBER TEST SERIES)[a]

Data Rating: C

Date	Start	Duration	Dilution correction factor[b]	Total mass loading (mg/DNM³)[c]	Mass loading by particle size range (mg/DNM³)[d] > 13.9 µmA	9.8-13.9 µmA	6.0-9.8 µmA	4.2-6.0 µmA	2.8-4.2 µmA	1.3-2.8 µmA	0.79-1.3 µmA	0.57-0.79 µmA	< 0.57 µmA
11/3	1545	120	1.35	24.05	0.66	0.43	0.40	0.43	8.01	9.45	2.56	0.96	1.15
11/3	1545	120	1.35	28.74	18.4[e]	0.71	0.64	0.61	1.08	3.80	2.21	0.66	0.63
11/4	1130	240	1.39	8.17	0.23	0.13	0.19	0.18	0.64	2.63	2.58	1.02	0.57
11/4	1130	240	1.39	8.20	0.00	0.14	0.16	0.34	0.92	3.36	2.22	0.68	0.38
11/5	0945	240	1.32	11.88	0.99	0.49	0.51	0.61	1.16	3.78	2.51	0.86	0.97
11/5	0945	240	1.32	6.90	1.35	0.45	0.38	0.56	0.20	0.65	1.16	1.03	1.12

[a] Particle size data taken from Table A-3, page 36 of Reference 21 (Appendix A). No total mass data available for November tests. Measurements taken at outlet of gravel bed filter using an Andersen impactor.

[b] Because of the dilution that results from the addition of the backwash air, the results from the outlet impactors must be adjusted to compensate for the difference in inlet and outlet gas flows before comparisons among the various operating conditions can be made and before fractional collection efficiencies can be calculated. The correction factor by which the measured outlet concentrations must be multiplied in order to effect this adjustment are given for each impactor run in the table.

[c] Sum of mass loadings in the various particle size ranges contained in following columns.

[d] Aerodynamic diameter.

[e] Invalid data - nozzle scraped port on entry.

Results of these tests showed an average uncontrolled emission rate of 4.57 Mg/hr (5.03 tons/hr) with normal insufflation and 4.79 Mg/hr (5.27 tons/hr) at elevated insufflation rates. For the controlled emissions, an average emission rate of 13.03 kg/hr (28.70 lb/hr) was obtained for normal operation with a value of 17.51 kg/hr (38.57 lb/hr) obtained after upgrading the ESP. Appropriate excerpts from the test report have been provided in Appendix A.

A review of Reference 24 showed the data to be of good quality but somewhat lacking in documentation. A detailed description of the process was not provided which was also the case for calibration of the test equipment. Given the above factors, a rating of B was assigned to the test data contained in Reference 24.

4.1.6 Reference 25 (1977)

Reference 25 reports the results of in-house compliance tests conducted on four coal-fired, dry process cement kilns equipped with a combination multiclone and ESP. The effluent gases from Kiln Nos. 2 and 3 are discharged through the north stack while Kiln Nos. 4 and 5 utilize the south stack for this purpose. Three test runs for total particulate were conducted on both the north and south stacks using EPA Reference Method 5.

The results of the above tests showed an average plant emission rate of 10.6 kg/hr (23.4 lb/hr) for all four kilns. The clinker production rate during these tests was 15.1 Mg/hr (16.6 tons/hr), 14.3 Mg/hr (15.8 tons/hr), 15.7 Mg/hr (17.3 tons/hr), and 16.9 Mg/hr (18.6 tons/hr) for Kiln Nos. 4, 5, 2, and 3, respectively. Applicable portions of the test report have been provided in Appendix A.

It was found that the test data collected in the above study were obtained using sound methodology and that adequate documentation was provided in the report. However, since calibration sheets for the test equipment were not included, a rating of B was assigned to the data contained in Reference 25.

4.1.7 Reference 26A/B (1979)

Reference 26A/B is the two volume report of a study conducted by an EPA contractor of the effectiveness of various combustion modifications as a means of improving thermal efficiency and controlling emissions in industrial combustion equipment. The program provided for tests on a total of 22 different industrial combustion devices, some of which included analysis for trace element and organic emissions. Of the 22 devices tested, two were rotary cement kilns.

The first unit tested (Location 3) was a dry process kiln fired with a combination of approximately 66% coke and the remainder natural gas. Testing for both total mass emissions and particle size distribution was conducted between the multiclone and baghouse. Total mass emissions were determined using EPA Reference Method 5 and particle size with a Brink Model BMS-11 cascade impactor. One Method 5 run (Test 3-2) and one Brink impactor test (Test 3-3) were conducted during the program with no major sampling problems noted. A summary of the results obtained for the Location 3 kiln is provided in Table 4-8.

The second unit tested (Location 9) was a wet process kiln fired with natural gas and equipped with an ESP. Two series of tests were conducted on the Location 9 kiln. The first series of tests were performed at the kiln outlet (inlet to ESP), and thus represent an uncontrolled facility. The sampling port used for these tests was located in one of two ducts joining the kiln and ESP. Two Method 5 and two particle size tests were conducted during the first test series. The first Method 5 and impactor run (Tests 9-1A&C) were representative of normal kiln operation with the other two tests (Tests 9-2F&G) performed at reduced excess combustion air. Procedures and equipment identical to those described above for the Location 3 kiln were used in both cases. A summary of the results of these tests is likewise shown in Table 4-8.

TABLE 4-8. SUMMARY OF PARTICLE SIZE DATA FOR REFERENCE 26 - LOCATIONS 3 AND 9 (BRINK DATA)[a]

Impactor stage	Test 3-3[b]			Test 9-1C[c]			Test 9-2G[d]		
	Mass collected (mg)	Cut-point (Dp-μmA)[e]	Cumulative percent ≤ stated size	Mass collected (mg)	Cut-point (Dp-μmA)[e]	Cumulative percent ≤ stated size	Mass collected (mg)	Cut-point (Dp-μmA)[e]	Cumulative percent ≤ stated size
Cyclone	432.8	15.0[m]	100	285.0	15.0[m]	100	65.8	15.0[m]	100
Stage 1	120.0	4.25	30.91	203.5	2.81	50.35	41.6	2.81	52.8
Stage 2	50.2	2.49	11.75	47.1	1.66	14.85	16.1	1.66	22.9
Stage 3	10.9	1.68	3.74	19.1	1.13	6.65	8.2	1.13	11.3
Stage 4	6.4	0.85	2.00	10.3	0.59	3.32	4.3	0.60	5.4
Stage 5	3.3	0.51	0.97	8.7	0.37	1.52	2.5	0.38	2.3
Filter	2.8	0.30	0.44	0	0.30	0	0.7	0.30	0.5
Type of process	Dry			Wet			Wet		
Type of fuel	Coke/natural gas[f]			Natural gas			Natural gas		
Sampling location	Between multiclone and baghouse			Outlet of kiln			Outlet of kiln		
Total mass emission factor (kg/Mg)[g]	124.6[h]			58.5[i]			61.2[j]		
Data quality rating	B			Total mass = A Particle size = Invalid[k,l,n]			Total mass = A Particle size = Invalid[k,n]		

[a] Particle size measurements made with a Brink Model BMS-11 cascade impactor with cyclone precollector.

[b] Data from pages 50 and 53 of Reference 26B (Appendix A).

[c] Data taken from pages 433 and 436 of Reference 26B (Appendix A).

[d] Data taken from pages 438 and 441 of Reference 26B (Appendix A).

[e] Aerodynamic diameter.

[f] Approximately 66% coke and 33% natural gas.

[g] Kilograms of particulate matter per Mg (10^6 g) of cement produced assuming 5% (weight) of gypsum added to clinker for production of finished cement (see calculations in Appendices B and C).

[h] Raw data taken from pages 43 and 48 of Reference 26B for Test 3-2 (Appendix A).

[i] Raw data taken from page 423 of Reference 26B and Table 4-20, page 84 of Reference 26A for Test 9-1A (Appendix A).

[j] Raw data taken from page 426 of Reference 26B and Table 4-20, page 84 of Reference 26A for Test 9-2F (Appendix A).

[k] Impactor plugged.

[l] Kiln under upset condition.

[m] Assumed based on FPEIS Test Series Nos. 00157 and 00158.

[n] Not used in emission factor development.

The second series of tests at the Location 9 kiln (Tests 9-3 to 9-6) were conducted at both the inlet and outlet of the ESP using the EPA's Source Assessment Sampling System (SASS) train and a modified Level I/Level II assessment for trace elements and organics. The SASS train consists of a series of cyclones with nominal cut-points of 10, 3, and 1 μmA, respectively. The results of the tests using the SASS train are shown in Table 4-9.

There were a number of problems noted with the data in Reference 26 for the tests conducted at Location 9. The first major problem involved the plugging of the Brink impactor during Tests 9-1C and 9-2G and of the SASS train during Tests 9-3 and 9-4. This plugging occurred as a result of the extremely high loadings encountered at the kiln outlet which resulted in termination of each test. Since the SASS train was also relied upon for determining total mass emissions, these results are, likewise, invalid for Tests 9-3 and 9-4. In addition, during Test 9-1C the kiln was experiencing an upset condition. For the reasons stated, the data from Tests 9-1C, 9-2G, 9-3, and 9-4 were determined to be questionable and thus not used in the development of candidate emission factors.

The remainder of the test data contained in Reference 26 were found to be of generally good quality with adequate documentation. The only major problem found was the fact that only one test was performed for total mass and particle size on the Location 3 kiln. For this reason a rating of B was assigned to Test 3-2 and 3-3 and a rating of A to the remainder of the usable data in Reference 26. Copies of appropriate sections of the two reports are provided in Appendix A.

4.1.8 Reference 27 (1979)

Reference 27 is a study of the fine particle emissions from a variety of source categories in the South Coast Air Basin (Los Angeles) of California as conducted by a contractor to the California Air Resources Board (CARB). Two of the tests included in this study were of the emissions from a dry process cement kiln controlled by a baghouse dust collector.

TABLE 4-9. SUMMARY OF PARTICLE SIZE DATA FOR REFERENCE 26 - LOCATION 9 (SASS DATA)[a]

Test No.	Sampling location	Total mass emission factor (kg/Mg)[b]		Percent by weight in stated particle size range[c]				Data rating
		Clinker	Cement	> 10 μmA[d]	10-3 μmA	3-1 μmA	1-0.3 μmA	
9-3[e]	ESP inlet	42.90	40.86	31.81	36.88	24.60	6.71	Invalid
9-4[e]	ESP inlet	38.27	36.45	32.53	35.84	23.39	8.24	Invalid
9-5	ESP outlet	0.133	0.127	3.50	0	66.14	30.37	A
9-6	ESP outlet	0.157	0.150	1.54	NA[f]	72.74	25.72	A

[a] Measurements taken on a wet process cement kiln both upstream and downstream of an electrostatic precipitator (ESP) using the EPA Source Assessment Sampling System (SASS).

[b] Kilograms of particulate matter per metric ton (kg/Mg) of clinker or cement produced assuming 5% by weight of gypsum in finished cement. Data taken from Table 4-21, page 92, of Reference 26A (see calculations in Appendices B and C).

[c] Aerodynamic diameter. Particle size data taken from Tables F-2, F-8, and F-14 on pages 452, 458, and 464 of Reference 26A and data sheet on page 469 of Reference 26B (see calculations in Appendix B).

[d] Includes probe and nozzle.

[e] 1 μmA cyclone plugged thus terminating test run per discussion on p. 91 of Reference 26A (Appendix A). Data not used in the development of candidate emission factors.

[f] No sample collected.

During the sampling program, tests were run at the outlet of the baghouse while the kiln was firing coal and while firing natural gas. One test was performed for each type of fuel. The size distribution of the particulate emanating from the kiln baghouse was determined using a SASS train.

The data obtained from the CARB study were entered into the EADS-FPEIS system from which a printout was obtained. A summary of the data contained in Reference 27 is provided in Table 4-10 with a copy of the pertinent sections of the draft report included in Appendix A. Upon checking with the contractor it was learned that the data for Test Runs 9 and 18 were not changed in the final report from that included in the draft as shown in Appendix A.

From an analysis of Reference 27, it was determined that the particle size measurements were made using sound methodology, and the document does contain adequate information for validation. However, since only one test was conducted for each type of fuel, a rating of B was assigned to the data.

4.1.9 Reference 30 (1979)

Reference 30 is the report of a source test conducted on three coal-fired, dry process cement kilns equipped with suspension preheaters and baghouse dust collectors. The kiln baghouses were operated under a positive pressure with the effluent gases vented to the atmosphere through a roof monitor instead of a stack(s).

Since the above baghouses were not equipped with a stack, standard source testing procedures were not used. Instead, high volume-type air samplers were installed in three of the six cells of each baghouse to measure the particulate emission rate from the kilns. A total of three tests were conducted on Baghouse Nos. 1 and 3 with two tests conducted on Baghouse No. 2. The results of these tests are summarized below:

TABLE 4-10. SUMMARY OF PARTICLE SIZE DATA FOR REFERENCE 27 - DRY PROCESS KILN CONTROLLED BY A BAGHOUSE COLLECTOR[a]

Data Rating: B

KVB test No.	Type of fuel	Total mass emission factor[b]		Percent by weight in stated particle size range[c]			
		lb/ton	kg/Mg	> 10 μmA	10-3 μmA	3-1 μmA	< 1 μmA
9	Natural gas	0.21	0.11	8	32	40	20
18	Pulverized coal	0.43	0.22	8	24	34	34

[a] Reference 27 (Appendix A). Measurements made using a SASS train downstream of the baghouse. Both tests on the same dry process kiln firing two different types of fuel. One test per fuel type.

[b] Data taken from p. 4-113 of report (Appendix A). Assumed to be calculated based on cement not clinker production rate. 1 lb/short ton = 0.5 kg/Mg.

[c] Aerodynamic particle diameter. Data taken from p. 4-108 of report (Appendix A). Assumed to be calculated based on cement not clinker production rate.

Baghouse/ Kiln No.	Run No.	Total Particulate Emission Rate lb/hr	kg/hr	Kiln Feedrate tons/hr	Mg/hr
1	1	1.94	0.881	36.5	33.1
	2	1.02	0.463	39.0	35.4
	3	1.24	0.563	40.4	36.7
2	2	2.67	1.21	34.8	31.6
	3	3.29	1.49	36.1	32.8
3	3	3.50	1.59	40.1	36.4
	4	3.37	1.53	40.7	36.9
	5	3.49	1.58	41.0	37.2

Applicable portions of the test report are provided in Appendix A.

It was determined from an evaluation of the information contained in Reference 30 that the measurements were conducted using a generally sound although nonstandard methodology. In addition, certain problems were noted with calibration of the sampling equipment used. Based on these factors, a rating of C was assigned to the data contained in Reference 30.

4.1.10 Reference 31 (1979)

Reference 31 is an internal report of source tests conducted on four coal-fired, dry process kilns located at a plant in Virginia. Three of the kilns (Nos. 1, 3, and 4) were equipped with a cooling/conditioning tower, multiple cyclone dust collector, and electrostatic precipitator connected in series. The fifth kiln (No. 5) was equipped with a Lepol preheater/pelletizer and double chamber ESP.

A minimum of six test runs were conducted on each kiln stack utilizing EPA Method 5. For the No. 5 kiln, testing was performed both with and without flue gas being bypassed to a raw grinding mill circuit(s). Results of these tests are summarized below:

Kiln Stack No.*	Total Particulate Emission Rate lb/hr	kg/hr	Average Clinker Production Rate tons/hr	Mg/hr
1	28.4	12.9	14.1	12.8
3	23.6	10.7	14.4	13.1
4	28.9	13.1	19.0	17.2
5a	38.4	17.4	64	58
5b	20.3	9.2	66	60
5c	12.2	5.54	67	61

* 5a = No gas bypass; 5b = Gas bypassed to one raw mill; 5c = Gas bypassed to two raw mills.

Inlet tests were also conducted during the sampling program on the Kiln No. 5 ESP, but the data were deleted from consideration due to lack of adequate documentation. Appropriate excerpts from the test report have been included in Appendix A.

Upon review of the stack data contained in Reference 31, it was determined that the tests were conducted using a generally sound methodology. However, some of the raw data sheets for the No. 5 kiln tests were found to be missing from the report. Also, no calibration data were included for the stack testing equipment. Based on these deficiencies, a rating of B was assigned to these data.

4.1.11 Reference 32 (1980)

Reference 32 is a source test conducted of the effluent from a gravel bed filter controlling the emissions from three grate-type clinker coolers. Three EPA Method 5 tests were performed during the study. Results of these tests were 6.72 kg/hr (14.8 lb/hr), 6.17 kg/hr (13.6 lb/hr), and 5.86 kg/hr (12.9 lb/hr), respectively, for an average clinker feedrate of 76.0 Mg/hr (83.8 tons/hr). Applicable portions of the test report are provided in Appendix A.

It was determined that the data contained in Reference 32 were of good quality and the tests were well documented. Therefore, a rating of A was assigned to the results of the above tests.

4.1.12 Reference 33 (1980)

Reference 33 is a companion study to that described in Reference 32 above. Three EPA Method 5 tests were performed of the emissions from a coal-fired, dry process kiln equipped with cyclones and baghouse dust collector. Results of these tests indicated controlled emission rates of 3.1, 3.0, and 2.8 kg/hr (6.9, 6.6, and 6.1 lb/hr), respectively, at an average clinker production rate of 30.0 Mg/hr (33.1 tons/hr). Excerpts from the test report are provided in Appendix A.

Upon evaluation of the information contained in Reference 33, it was determined that the test protocol was sound and adequate documentation was provided. Using the criteria developed by OAQPS, a rating of A was assigned to the test data included in Reference 33.

4.1.13 Reference 36 (1980)

Reference 36 is the report of a source test conducted of the controlled emissions from a clinker cooler equipped with a baghouse. Three tests were performed of the emissions from the cooler baghouse using EPA Method 5. Results of these tests indicated an average particulate emission rate of 0.0499 kg/Mg of feed (0.0997 lb/ton of feed). Appropriate portions of the test report are included in Appendix A.

It was determined from a review of Reference 36 that the tests were probably performed using a sound technical approach. However, a thorough evaluation could not be performed due to the lack of adequate documentation with regard to the process tested, throughput rates, calibration of the test equipment, etc. Also, it was inferred from information contained in the report that EPA Method 5 protocol was used, although this fact was never clearly stated. For the above reasons, a rating of D was assigned to the test data included in Reference 36.

4.1.14 Reference 39 (1981)

Reference 39 provides the results of source tests performed on two coal-fired, wet process kilns equipped with ESPs. Three EPA Method 5 tests were conducted on each ESP stack for a total of six test runs. Results of these tests showed an average particulate emission rate of 8.322 kg/hr (18.33 lb/hr) and 7.90 kg/hr (17.4 lb/hr) for Kiln Nos. 1 and 2, respectively. Excerpts from the test report are shown in Appendix A.

It was determined that the tests reported in Reference 39 were generally of good quality. However, documentation of process data on clinker production (or an appropriate conversion factor to calculate such) was lacking. Assumptions had to be made, therefore, to calculate appropriate emission factors from the available data. For the above reason, a rating of C was assigned to the test data in Reference 39.

4.1.15 Reference 40 (1981)

Reference 40 is the report of a source test conducted at a cement plant located in Kansas. Testing was performed on a total of four coal-fired, wet process kilns. Three of the kilns were controlled by a common ESP (No. 2 stack) with the fourth kiln being equipped with a separate ESP (No. 4 stack).

Eight test runs were conducted on the No. 4 stack with an additional 16 runs performed on the No. 2 stack using EPA Method 5. Inlet samples were also collected upstream of the No. 4 precipitator using ASTM Power Test Code 27. Finally, six Method 5 tests were performed of the emissions from the Nos. 1 and 4 clinker cooler stack. These data were deleted, however, since no control device was specified. Results of the kiln tests performed during the study are summarized below:

Test Location	Average Total Particulate Emission Rate (lb/hr)	Average Total Particulate Emission Rate (kg/hr)
No. 4 ESP inlet	2,202	999.7
No. 4 stack	23.4	10.6
No. 2 stack	25.2	11.4

It was determined that the data contained in Reference 40 were of reasonably good quality but suffered from a lack of adequate documentation. Also, no raw test data were included in the report which prevented validation of the sampling results. A rating of C was, therefore, assigned to the test data in Reference 40.

4.1.16 Reference 42 (1983)

Reference 42 is a study conducted under the IP program of the emissions from a dry process cement kiln equipped with suspension preheater and baghouse collector (10-cell). The kiln was fired with solid fuel consisting of a combination of coal and coke. This particular kiln is somewhat unique in that the flue gas temperature to the main baghouse (10-cell) is controlled with a by-pass system containing water sprays and its own separate 3-cell baghouse collector. Effluent gas from the by-pass system is vented to the atmosphere through a common stack with the main particulate control device. Testing was conducted only at the inlet to the main (10-cell) baghouse and in the stack. A separate velocity traverse was performed in the inlet duct of the by-pass system baghouse such that the total uncontrolled emissions from the kiln could be calculated.

The general sampling protocol used in this study was that developed for the IP program. At the inlet, the total uncontrolled emissions from the process were determined utilizing EPA Method 5. The particle size distribution was obtained from samples collected by an Andersen High Capacity Stack Sampler (HCSS) equipped with a Sierra Instruments 15-μmA preseparator. Two Method 5 and four particle size tests were conducted at each of four sampling quadrants for a total of 8 and 16, respectively.

At the outlet of the baghouse, the total mass emissions (controlled) from the kiln were determined utilizing proposed EPA Method 17, with two tests being conducted at each of four sampling quadrants. The particle size distribution was likewise obtained using an Andersen Mark III cascade impactor and Sierra Instruments 15 μmA preseparator. A total of eight total mass and eight particle size tests were performed at the baghouse outlet.

Tables 4-11 and 4-12 provide a summary of the results of this study with applicable portions of the document included in Appendix A. Since the tests in Reference 42 were conducted according to the protocol developed for the IP program and are well documented, a rating of A was assigned to the data.

4.1.17 Reference 43 (1983)

Reference 43 is the report of a compliance test conducted at a cement plant located in Iowa. Tests were conducted of the controlled emissions from a coal-fired, dry process kiln equipped with an ESP and baghouse connected in parallel. Additional tests were also performed of the total emissions from a clinker cooler equipped with a baghouse dust collector. Because the emissions from the kiln were controlled by both an ESP and a baghouse, coupled with the fact that the test locations were not clearly defined, the data from the kiln tests were determined to be unsuitable for the development of consistent emission factors. Thus, these data were deleted from further consideration.

For the clinker cooler, three test runs were performed of the total mass emissions from the baghouse using EPA Method 5. Results of these tests were 1.2, 0.45, and 0.45 kg/hr (2.7, 1.0, and 1.0 lb/hr), respectively. Appropriate portions of the test report have been included in Appendix A.

It was determined that the tests reported in Reference 43 were conducted using sound methodology and that adequate documentation was provided. Therefore, a rating of A was assigned to the test data.

4.1.18 References 44 and 45 (1983)

Reference 44 provides the results of an annual compliance test conducted on a coal-fired, dry process kiln equipped with a suspension preheater/flash

TABLE 4-11. SUMMARY OF PARTICLE SIZE DATA FOR REFERENCE 42 - NO. 5 KILN BAGHOUSE INLET[a]

Data Rating: A

Particle size run number	15 µm Cyclone			Stage 1			Stage 2			Cyclone			Filter	
	Mass (mg)[b]	D_{50} size (µm)[c]	Cum. % than[d]	Mass (mg)[b]	D_{50} size (µm)[c]	Cum. % than[d]	Mass (mg)[b]	D_{50} size (µm)[c]	Cum. % than[d]	Mass (mg)[b]	D_{50} size (µm)[c]	Cum. % than[d]	Mass (mg)[b]	D_{50} size (µm)[c]
I-1-1	731.6	15.29	62.31	40.8	11.04	60.21	60.7	5.98	57.08	526.6	2.03	29.95	581.4	< 2.03
I-2-1	3,744.2	14.97	30.84	71.0	10.99	29.53	277.1	6.05	24.41	1,030.0	1.77	5.38	291.5	< 1.77
I-3-1	3,003.5	15.38	42.24	82.1	11.02	40.66	394.6	5.97	33.08	986.0	2.12	14.12	734.1	< 2.12
I-4-1	2,905.4	14.72	41.95	81.6	10.73	40.32	266.3	5.81	35.00	918.0	2.03	16.66	834.0	< 2.03
I-1-2	2,086.8	15.83	45.69	82.2	11.35	43.56	309.5	6.21	35.50	1,019.6	2.02	8.97	344.6	< 2.02
I-2-2	1,937.0	15.66	42.78	67.3	11.29	40.79	207.0	6.33	34.67	879.6	1.78	8.69	294.0	< 1.78
I-3-2	2,227.4	15.81	40.10	75.0	11.29	38.09	277.5	6.12	30.63	449.5	2.15	18.54	689.4	< 2.15
I-4-2	2,358.3	15.81	39.51	71.7	11.34	37.67	244.8	6.15	31.39	891.2	2.13	8.53	332.7	< 2.13
I-1-3	3,659.5	15.34	33.95	97.4	11.14	32.19	383.0	6.04	25.28	1,112.4	1.99	5.20	288.3	< 1.99
I-2-3	2,699.9	15.62	45.67	135.9	11.27	42.93	414.2	6.24	34.60	1,067.6	1.87	13.11	651.7	< 1.87
I-3-3	2,099.7	15.59	49.68	79.9	11.24	47.77	341.6	6.20	39.58	442.7	1.89	28.97	1,209.0	< 1.89
I-4-3	797.8	15.84	59.17	34.8	11.35	57.39	61.9	6.20	54.22	671.4	2.03	19.85	387.9	< 2.03
I-1-4	2,087.2	17.56	47.41	81.4	12.05	45.36	367.3	6.74	36.11	982.4	2.19	11.36	450.8	< 2.19
I-2-4	1,404.3	16.13	48.65	59.0	11.44	46.50	150.1	6.37	41.01	785.2	1.92	12.30	336.3	< 1.92
I-3-4	1,948.0	15.27	47.00	70.1	11.13	45.09	245.6	6.07	38.41	684.5	1.93	19.79	727.2	< 1.93
I-4-4	1,679.6	15.67	49.48	71.5	11.25	47.33	191.7	6.10	41.56	840.8	2.07	16.28	541.1	< 2.07

[a] Reproduced from Table 3-2, page 48 of test report (Appendix A). Measurements taken at inlet of the No. 5 preheater baghouse using an Andersen HCSS with 15 µmA cyclone preseparator. Dry process kiln.

[b] mg = net weight in milligrams.

[c] Effective cut-point of cyclone or impactor stage in micrometers (µm) aerodynamic diameter.

[d] Cumulative percent less than or equal to stated size.

TABLE 4-12. SUMMARY OF PARTICLE SIZE DATA FOR REFERENCE 42 - NO. 5 KILN BAGHOUSE OUTLET[a]

Data Rating: A

Particle size run No.	15 µm Cyclone			Stage 0			Stage 1			Stage 2			Stage 3		
	Mass (mg)[b]	D_{50} size (µm)[c]	Cum. % less than[d]	Mass (mg)[b]	D_{50} size (µm)[c]	Cum. % less than[d]	Mass (mg)[b]	D_{50} size (µm)[c]	Cum. % less than[d]	Mass (mg)[b]	D_{50} size (µm)[c]	Cum. % less than[d]	Mass (mg)[b]	D_{50} size (µm)[c]	Cum. % less than[d]
0-1-1	5.38	15.62	76.40	0.04	14.22	76.23	0.00	8.85	76.23	1.31	5.98	70.48	2.29	4.06	60.44
0-2-1	4.87	15.67	75.43	0.00	14.33	75.43	0.06	8.93	75.13	1.76	6.04	66.25	2.57	4.10	53.28
0-3-1	7.48	15.99	49.25	0.02	14.50	49.12	0.00	9.03	49.12	0.25	6.11	47.42	0.82	4.14	41.86
0-4-1	4.34	16.36	87.69	0.70	14.79	85.71	0.77	9.21	83.53	2.29	6.23	77.03	3.91	4.23	65.95
0-1-2	4.61	16.08	84.74	0.00	14.56	84.74	0.19	9.07	84.11	4.43	6.13	69.44	4.90	4.16	53.21
0-2-2	3.78	15.54	84.43	0.00	14.17	84.43	0.00	8.82	84.43	1.70	5.96	77.42	3.68	4.05	62.26
0-3-2	5.97	15.81	81.83	0.27	14.37	81.01	0.00	8.95	81.01	1.60	6.05	76.14	2.40	4.10	68.84
0-4-2	6.58	15.63	82.23	0.00	14.27	82.23	0.00	8.89	82.23	2.56	6.01	75.32	11.92	4.08	43.13

Particle size run No.	Stage 4			Stage 5			Stage 6			Stage 7			Filter	
	Mass (mg)[b]	D_{50} size (µm)[c]	Cum. % less than[d]	Mass (mg)[b]	D_{50} size (µm)[c]	Cum. % less than[d]	Mass (mg)[b]	D_{50} size (µm)[c]	Cum. % less than[d]	Mass (mg)[b]	D_{50} size (µm)[c]	Cum. % less than[d]	Mass (mg)[b]	D_{50} size (µm)[c]
0-1-1	5.74	2.59	35.26	5.57	1.27	10.83	2.18	0.76	1.27	0.01	0.55	1.23	0.28	< 0.55
0-2-1	4.08	2.61	32.69	3.68	1.28	14.13	0.96	0.77	9.28	0.00	0.56	9.28	1.84	< 0.56
0-3-1	3.24	2.64	19.88	2.53	1.30	2.71	0.37	0.78	0.20	0.00	0.57	0.20	0.03	< 0.57
0-4-1	7.46	2.70	44.80	7.14	1.32	24.55	4.49	0.79	11.82	0.92	0.58	9.21	3.25	< 0.58
0-1-2	7.35	2.65	28.87	6.48	1.30	7.42	2.24	0.78	0.00	0.00	0.57	0.00	0.00	< 0.57
0-2-2	6.36	2.58	36.05	5.92	1.26	11.66	2.83	0.76	0.00	0.00	0.55	0.00	0.00	< 0.55
0-3-2	5.90	2.62	50.88	7.57	1.28	27.85	4.69	0.77	13.57	2.02	0.56	7.43	2.44	< 0.56
0-4-2	6.14	2.60	26.55	7.01	1.27	7.62	2.82	0.76	0.00	0.00	0.56	0.00	0.00	< 0.56

[a] Reproduced from Table 3-4, page 55 of test report (Appendix A). Samples collected from common stack of both preheater and by-pass baghouses using an Andersen Mark III cascade impactor with 15 µmA cyclone preseparator. Dry process kiln.

[b] mg = net weight in milligrams.

[c] Effective cut-off point of cyclone or impactor stage in micrometers (µm) aerodynamic diameter.

[d] Cumulative percent less than or equal to stated size.

calciner and baghouse dust collector. Other sources tested were an unspecified crusher equipped with a baghouse and Fuller grate-type clinker cooler also equipped with a baghouse. Since no process description was provided in the test report itself, a technical paper (Reference 45) was used to derive this information.

During sampling, three test runs were performed of the emissions from each of the above baghouses using EPA Reference Method 5 (including impinger catch). Since the type of crusher and material being processed was not specified, these particular data were deleted from consideration. Otherwise, the results of the tests indicated an average total mass emission rate of 0.04 kg/Mg (0.07 lb/ton) and 0.02 kg/Mg (0.04 lb/ton) for the kiln and cooler, respectively. Applicable portions of the test report have been included in Appendix A.

Based on a review of the information contained in Reference 44, it was determined that the tests were conducted using standard EPA protocol with the exception that the impinger catch was used to calculate the emission rates. In addition, certain of the kiln tests showed negative net filter weights obtained during gravimetric analyses. The above factors, coupled with the fact that adequate process data (or description) was not included in the test report, resulted in a rating of C being assigned to the test data contained in Reference 44.

4.1.19 <u>Reference 46 (1983)</u>

Another reference used in the development of candidate emission factors is a study conducted under the IP program of a wet process cement kiln equipped with an ESP. The kiln was fired with pulverized coal with preheat supplied by a grate-type clinker cooler. A certain portion of the dust collected in the first two fields of the ESP is insufflated back to the kiln for reprocessing. Testing was conducted at both the inlet and outlet of the precipitator to characterize the uncontrolled and controlled emissions from the process.

Like Reference 42 above, the general sampling protocol used in this study was that developed for the IP program.[58] At the inlet, the total uncontrolled emissions from the process were determined utilizing EPA Method 5. The particle size distribution was obtained from samples collected by an Andersen High Capacity Stack Sampler equipped with a Sierra Instruments 15-µmA preseparator. Two Method 5 and four particle size tests were conducted at each of four sampling quadrants for a total of eight and 16 test runs, respectively.

At the outlet of the ESP, the total mass emissions (controlled) from the kiln were determined utilizing proposed EPA Method 17, with two tests being conducted at each of four sampling quadrants. The particle size distribution was obtained using an Andersen Mark III cascade impactor and Sierra Instruments 15-µmA preseparator. A total of eight tests were performed for both total mass and particle size at the outlet of the ESP during the sampling program.

The only problem noted with the above study were difficulties in sample collection caused by a layer of dust which had deposited in the bottom of the ductwork at the inlet to the ESP. To prevent contamination of the sampling probe during entry and withdrawal from the duct, a steel sleeve was inserted through the test ports. However, the dust deposit inhibited the accurate measurement of gas velocity at this sampling location. To accommodate the portion of the duct containing the dust layer, the sampling points were moved farther into the unobstructed part of the duct where testing was finally conducted. It is not known exactly how these various factors influenced the test results, but it is suspected that the data does contain a positive bias which is reflected in the unusually high uncontrolled emission factor obtained for total particulate emissions.

Tables 4-13 and 4-14 provide a summary of the results of this study with applicable portions of the document included in Appendix C. Since the tests in Reference 46 were conducted according to the protocol developed for the IP program and are well documented, a rating of A was assigned to the outlet data and a rating of B to the inlet data included in the test report.

TABLE 4-13. SUMMARY OF PARTICLE SIZE DATA FOR REFERENCE 46 - KILN NO. 2 ELECTROSTATIC PRECIPITATOR INLET[a]

Data Rating: B

Particle size run No.	15 μm Cyclone			Stage 1			Stage 2			Cyclone			Filter	
	Mass (mg)[b]	D_{50} size (μm)[c]	Cum. % less than[d]	Mass (mg)[b]	D_{50} size (μm)[c]	Cum. % less than[d]	Mass (mg)[b]	D_{50} size (μm)[c]	Cum. % less than[d]	Mass (mg)[b]	D_{50} size (μm)[c]	Cum. % less than[d]	Mass (mg)[b]	D_{50} size (μm)[c]
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] Reproduced from Table 3-2, page 33 of test report (Appendix A). Measurements made on wet process kiln using an Andersen HCSS with 15 μmA cyclone preseparator.

[b] mg = net weight in milligrams.

[c] Effective cut-point of cyclone or impactor stage in micrometers (μm) aerodynamic diameter.

[d] Cumulative percent less than or equal to stated size.

TABLE 4-14. SUMMARY OF PARTICLE SIZE DATA FOR REFERENCE 46 - KILN NO. 2 ELECTROSTATIC PRECIPITATOR OUTLET[a]

Data Rating: A

Particle size run No.	15 µm Cyclone			Stage 0			Stage 1			Stage 2			Stage 3		
	Mass[b] (mg)	D_{50} Size[c] (µm)	Cum. % less than[d]	Mass[b] (mg)	D_{50} Size[c] (µm)	Cum. % less than[d]	Mass[b] (mg)	D_{50} Size[c] (µm)	Cum. % less than[d]	Mass[b] (mg)	D_{50} Size[c] (µm)	Cum. % less than[d]	Mass[b] (mg)	D_{50} Size[c] (µm)	Cum. % less than[d]
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[e]	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[b] (mg)	D_{50} Size[c] (µm)	Cum. % less than[d]	Mass[b] (mg)	D_{50} Size[c] (µm)	Cum. % less than[d]	Mass[b] (mg)	D_{50} Size[c] (µm)	Cum. % less than[d]	Mass[b] (mg)	D_{50} Size[c] (µm)	Cum. % less than[d]	Mass[b] (mg)	D_{50} Size[c] (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[e]	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] Reproduced from Table 3-4, page 40 of test report (Appendix A). Measurements made using an Andersen Mark III cascade impactor with 15 µmA preseparator.

[b] mg = net weight in milligrams.

[c] Effective cut-point of cyclone or impactor stage in micrometers (µm) aerodynamic diameter.

[d] Cumulative percent less than or equal to stated size.

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

4.1.20 Reference 48 (1983)

Reference 48 is a source emissions survey conducted at a plant located in Texas. Testing was conducted on two coal-fired cement kilns equipped with a baghouse dust collector(s). Additional tests were also performed on a clinker cooler with the emissions controlled by a gravel bed filter. Since the type of cement manufacturing process was not specified in the report, the kiln data could not be used in the development of candidate emission factors. Therefore, only the data from the clinker cooler will be addressed.

Three tests were conducted of the total particulate emissions from the clinker cooler stack using EPA Method 5. Results of the tests showed emission rates of 3.5, 3.0, and 1.7 kg/hr (7.7, 6.6, and 3.8 lb/hr) for the three runs, respectively. Portions of the test report have been included in Appendix A for reference purposes.

Upon review of the cooler test data contained in Reference 48, it was determined that the sampling methodology was sound. However, documentation regarding the process and its operation during testing was somewhat lacking. Therefore, a rating of B was assigned to the cooler emissions data in Reference 48.

4.1.21 Reference 50 (1984)

Reference 50 is the report of another annual compliance test of the same plant and sources described in Reference 44 above. Again, only the emissions data from the kiln and cooler were found to be appropriate for the development of candidate emission factors.

As with the previous study, three EPA Method 5 tests were conducted on each source which included the impinger catch. Results of these tests showed an average controlled emission rate of 0.02 kg/Mg (0.04 lb/ton) for the kiln and 0.0040 kg/Mg (0.0079 lb/ton) for the clinker cooler. Excerpts from the test report are provided in Appendix A.

The above tests were conducted by the same contractor and with similar documentation to that found in Reference 44 above. However, in this case, no negative filter weights were reported. Thus, a rating of B was assigned to the test data contained in Reference 50.

4.1.22 Reference 51 (1984)

Reference 51 reports the results of compliance tests conducted of the emissions from a Loesche (raw grinding) mill, grate-type clinker cooler, and coal-fired, dry process cement kiln at a plant located in Alabama. The emissions from the mill and kiln were controlled by a common ESP (kiln off-gas could be routed through the mill to the ESP or the mill could be bypassed). The cooler was equipped with a combination cyclone and gravel bed filter for the control of particulate emissions. Due to certain discrepancies found in the test data for the kiln with ("mill on") and without the mill in operation ("mill off"), only the "mill off" tests performed on the "main stack" were used to determine the emissions from the kiln itself.

A total of four tests were conducted on the main kiln stack with an additional three tests performed of the controlled emissions from the clinker cooler. All tests were run using standard EPA Method 5 protocol. Results of these tests are summarized below:

Run No.	Sampling Location	Total Particulate Emission Rate kg/hr	Total Particulate Emission Rate lb/hr
2	Main stack*	11.17	24.61
3	Main stack*	11.53	25.40
4	Main stack*	7.600	16.74
5	Main stack*	7.110	15.66
8	Cooler stack	33.53	73.85
9	Cooler stack	17.67	38.92
10	Cooler stack	22.65	49.90

* Loesche mill off.

Copies of appropriate portions of the test report are included in Appendix A.

It was determined from a thorough review of Reference 51 that certain portions of the report were missing. This made calculation of applicable emission factors from the data much more difficult but not impossible. However, from the information that was available, all indications are that the tests were sound and adequately documented. For these reasons, a rating of B was assigned to the test results included in Reference 51.

4.1.23 Reference 52 (1984)

This reference document is the report of a particulate compliance test conducted of the emissions from a coal-fired, wet process kiln equipped with an ESP. Three tests were performed of the emissions from the kiln downstream of the ESP using EPA Method 5 protocol. Results of these tests indicated an average total mass emission rate of 4.4 kg/hr (9.7 lb/hr) for the three runs. Appropriate portions of the test report can be found in Appendix A.

It was determined from the information contained in Reference 52 that sound technical methodology was used and the test data were adequately documented. However, the major problem noted was the fact that the kiln feedrate was expressed in terms of gallons per minute without a conversion factor to mass per unit time. Assumptions had to be made, therefore, in the emission factor calculations based on the rated daily production rate for the kiln. For this reason, a rating of C was assigned to the test results provided in Reference 52.

4.1.24 Reference 53 (1985)

Reference 53 reports the results of the 1985 annual compliance tests conducted by the same contractor, on the same sources, at the same plant as that discussed above for References 44 and 50. As with the other tests, EPA Method 5 protocol (with impinger catch) was used to sample the emissions from the kiln, crusher, and clinker cooler baghouses. Results of these tests indicated controlled emission rates of 0.01 kg/Mg (0.02 lb/ton) and 0.00995 kg/Mg (0.0199 lb/ton) for the kiln and clinker cooler, respectively. Excerpts from the test report are shown in Appendix A.

As was the case for the other two reference documents discussed previously, the tests reported in Reference 53 were found to be generally sound but with some deficiencies with regard to documentation of the processes tested and their operation during the study period. For these reasons, a rating of B was assigned to the test data.

4.1.25 Reference 54 (1985)

The final reference document used to develop candidate particulate emission factors for the cement industry is a compliance test of a coal-fired, wet process kiln equipped with an ESP. Three EPA Method 5 tests were conducted on the ESP stack which resulted in an average emission rate of 9.03 kg/hr (19.90 lb/hr). Appropriate portions of the test report are included in Appendix A.

Upon review of the information contained in Reference 54, it was determined that the tests were performed using sound methodology and were reasonably well documented. However, like many reports of this type, documentation of the process and its operation during testing was minimal. For this reason, a rating of D was assigned to the data provided in Reference 54.

4.2 RESULTS OF DATA ANALYSIS

4.2.1 Total Mass Emissions Data

Both uncontrolled and controlled particulate emission factors were determined from the data contained in each of the reference documents described above. In the case of uncontrolled emissions, only References 21, 24, 26, 40, 42, and 46 contained useful data. For References 21, 24, 26, and 40, the emission factors were determined from the raw test data by hand calculation. A copy of these calculations and any assumptions made are shown in Appendix B. For the sake of consistency, all calculations were performed in terms of cement produced.

With regard to References 42 and 46, appropriate uncontrolled emission factors were extracted directly from the test reports (after conversion to metric units). A summary of the available uncontrolled emission factors for total particulate matter as determined from the various reference documents is shown in Table 4-15.

For controlled processes, a procedure similar to that described above for determining uncontrolled emission factors was used. References 10 through 18, 21, 24, 25, 26A/B, 27, 30, 31, 32, 33, 36, 39, 40, 42, 43, 44/45, 46, 48, 50, 51, 52, 53, and 54 contained useful data. Except for References 27, 42, and 46, the controlled emission factors were calculated by hand from either emission factors expressed in terms other than mass of pollutant per metric ton of cement produced or from the raw test data. These calculations are shown in Appendix C for controlled cement kilns and Appendix D for other controlled emission sources. A complete summary of all available controlled emission factors for total particulate matter is shown in Table 4-16 in terms of mass of particulate matter per mass of cement or clinker produced. All hand calculations were verified by a second analyst for quality assurance purposes.

4.2.2 Particle Size Data

Each of the specific data sets described above were processed through the appropriate computer program (described in Section 3.0) to obtain both the particle size distribution and size-specific emission factors (where available) for selected particle diameters. Copies of the individual computer printouts have been included in Appendix E with the results of the computer analyses summarized in Tables 4-17 through 4-25 in terms of cement produced. Any calculations needed to convert the raw data to the proper format for input to the computer were conducted manually and are also included in Appendix E.

TABLE 4-15. SUMMARY OF UNCONTROLLED TOTAL PARTICULATE EMISSION FACTORS FOR CEMENT PLANTS

Source type	Fuel type	Ref. No.	Raw data table Nos.[a]	Average total particulate emission factor[b] kg/Mg cement	kg/Mg clinker[c]
Wet process kilns	Gas	26A/B	4-8	60	63
	Coal	24	d	65	68
		40	d	62	65
		46	4-24	600[e]	630
Dry process kiln	Coal/coke	42	4-22	130[e]	140
Clinker cooler	-	21	4-3 and 4-4	4.4	4.6

[a] Table number(s) from which the original emission factor was reproduced.

[b] Total mass emission factor calculated in terms of either kg of pollutant per Mg of cement or clinker produced. Rounded to two significant figures.

[c] Calculated from the emission factors in previous column assuming 5% (wt.) gypsum in finished cement.

[d] Emission factors derived by hand calculation from the raw test data (see Appendix B). For Reference 24, the raw data were taken from Tables II and III, pages 5 and 6 of the test report. For Reference 40, the raw data was taken from Tables T-1-A and T-4, pages 16 and 20 of the test report.

[e] Individual emission factors included in average consists of the arithmetic mean of four separate test runs (i.e., one run/quadrant at four quadrants) making up a single test.

TABLE 4-16. SUMMARY OF CONTROLLED TOTAL PARTICULATE EMISSION FACTORS FOR CEMENT PLANTS

Source type	Control technology	Ref. No.	Type of fuel	No. of tests	Average measured emission factor[a] kg/Mg cement	Average measured emission factor[a] kg/Mg clinker	Data quality rating	Candidate emission factor[b] kg/Mg cement	Candidate emission factor[b] kg/Mg clinker	Emission factor rating
Wet process kilns	Electrostatic precipitator	10	Gas	3	1.41	1.48	C	0.37	0.39	C
		11	Gas	2	1.08	1.13	B			
		24	Coal	6	0.191	0.201	B			
		26	Gas	2	0.139	0.146	A			
		39	Coal	6	0.183	0.192	C			
		40	Coal	24	0.620	0.651	C			
		46	Coal	8	0.070	0.0735	A			
		52	Coal	3	0.073[c]	0.077	C			
		54	Coal	3	0.109	0.114	D			
	Baghouse	15	Gas	6	0.657	0.690	B	0.54	0.57	C
		15	Oil	6	0.630	0.662	B			
		16	Gas	3	0.333	0.350	B			
Dry process kilns	Multiclone	26	Coke/gas	1	125	131	B	130	130	D
	Multiclone + electrostatic precipitator	25	Coal	6	0.163	0.171	B	0.33	0.34	C
		31	Coal	43	0.688	0.722	B			
		51[c]	Coal	4	0.128	0.134	B			
	Baghouse[d]	13	Coal	3	0.060	0.063	C	0.15	0.16	B
		27	Gas	1	0.11	0.12	B			
		27	Coal	1	0.22	0.23	B			
		30	Coal	9	0.060	0.063	C			
		33[e]	Coal	3	0.094	0.099	A			
		42	Coal/coke	8	0.44	0.46	A			
		44[f]	Coal	3	0.02	0.02	C			
		50	Coal	3	0.027	0.028	B			
		53	Coal	3	0.014	0.015	B			
Clinker coolers	Electrostatic precipitator	10	NA	3	0.0456	0.0480	B	0.046	0.048	D
	Baghouse	11	NA	3	0.221	0.232	C	0.0097	0.010	C
		14	NA	3	0.0160	0.0168	B			
		36	NA	3	0.0848	0.0890	D			
		43[d]	NA	3	0.0099	0.010	A			
		44[f]	NA	3	0.02	0.02	C			
		50[d]	NA	3	0.0034	0.0036	B			
		53	NA	3	0.00949	0.00997	B			

(continued)

TABLE 4-16. (continued)

Source type	Control technology	Ref. No.	Type of fuel	No. of tests	Average measured emission factor[a] kg/Mg cement	Average measured emission factor[a] kg/Mg clinker	Data quality rating	Candidate emission factor[b] kg/Mg cement	Candidate emission factor[b] kg/Mg clinker	Emission factor rating
Clinker coolers (continued)	Gravel bed filter	21	NA	4	0.142	0.149	C	0.15	0.16	C
		32	NA	3	0.0784	0.0823	A			
		48[d]	NA	3	0.079	0.083	B			
		51[g]	NA	3	0.294	0.309	B			
Finish mill system	Baghouse	17	NA	2	0.0162	NA	B	0.017	NA	C
		12	NA	3	0.0263	NA	B			
		14	NA	3	0.0079	NA	B			
Raw mill system[h]	Baghouse	17	NA	2	0.0342	NA	B	0.034	NA	D
Primary limestone[h] crusher	Baghouse	18	NA	4	5.05×10^{-4}	NA	B	5.1×10^{-4}	NA	D
Primary limestone[d,h] screen	Baghouse	18	NA	4	1.1×10^{-4}	NA	B	1.1×10^{-4}	NA	D
Conveyor transfer[d,h] station	Baghouse	18	NA	3	1.5×10^{-5}	NA	B	2.0×10^{-5}	NA	D
Secondary limestone[d,h] screen and crusher	Baghouse	18	NA	3	1.6×10^{-4}	NA	B	1.6×10^{-4}	NA	D

[a] Average emission factor calculated from raw data contained in the reference document. See calculations in Appendices C and D. All calculations performed in terms of mass of cement produced. Emission factors in terms of clinker production assumes 5% gypsum in finished cement. NA = not applicable.

[b] Arithmetic mean of average measured emission factors for A- and B-rated data sets shown in previous columns. Rounded to two significant figures.

[c] Kiln not equipped with cyclones upstream of ESP.

[d] Emission factor(s) rounded to two significant figures.

[e] Cyclones + baghouse collector.

[f] Rounded to one significant figure.

[g] Cooler equipped with cyclone collector upstream of a gravel bed filter.

[h] Expressed in terms of kilograms of particulate matter per metric ton (Mg) of raw material processed.

TABLE 4-17. CALCULATED PARTICLE SIZE DISTRIBUTIONS FOR REFERENCE 20 - ESP INLET[a]

Data Rating: C

Test ID No.[b]	Cumulative mass % equal to or less than stated size[c] 2.5 µmA	5.0 µmA	10.0 µmA	15.0 µmA	20.0 µmA	Mass loading equal to or less than stated size (mg/dncm)[d] 2.5 µmA	5.0 µmA	10.0 µmA	15.0 µmA	20.0 µmA
2-1	7.51	17.7	33.7	49.8	60.0	3,880	9,130	17,400	25,700	31,000
2-2	12.0	18.6	23.3	27.8	31.3	1,340	2,070	2,590	3,090	3,480
3-1	8.90	19.2	38.4	60.2	73.0	3,500	7,570	15,100	23,700	28,700
3-2	9.87	15.7	34.9	54.6	68.4	2,280	3,620	8,060	12,600	15,800
3-3	9.53	20.1	30.2	44.3	59.7	3,850	8,110	12,200	17,900	24,100
3-4	8.01	22.1	31.1	40.3	52.0	3,140	8,660	12,200	15,800	20,400
4-1	13.3	18.6	21.1	23.3	25.6	1,910	2,680	3,030	3,350	3,680
4-2	6.90	19.9	34.4	49.0	64.4	1,790	5,170	8,920	12,700	16,700
4-3	6.58	18.5	36.5	57.8	77.5	2,630	7,380	14,600	23,100	31,000
4-4	9.37	24.3	32.5	39.3	57.5	3,000	7,770	10,400	12,600	18,400

[a] Data taken directly from FPEIS Test Series 80, pages 17, 34, and 60. Wet process kiln.

[b] See footnote in Table 4-2.

[c] Aerodynamic diameter. Calculated from mass loadings on impactor stages or in cyclone shown in following columns.

[d] From Table 4-2. mg/dncm = milligrams of particulate matter per dry normal cubic meter of flue gas. No process data available with which to calculate emission factors.

TABLE 4-18. CALCULATED PARTICLE SIZE DISTRIBUTIONS AND UNCONTROLLED EMISSION FACTORS FOR REFERENCE 21[a]

Data Rating: C

Type of impactor	Test date	Test ID No.[b]	Cumulative mass % equal to or less than stated size[c]					Cumulative emission factor equal to or less than stated size (kg/Mg)[d]					
			2.5 µmA	5.0 µmA	10.0 µmA	15.0 µmA	20.0 µmA	2.5 µmA	5.0 µmA	10.0 µmA	15.0 µmA	20.0 µmA	Total mass emission factor[e]
Andersen	8/27	1320	0.937	2.46	10.0	22.1	34.0	0.042	0.10	0.44	0.98	1.5	4.4
	8/28	0950	0.331	0.902	6.87	19.2	32.4	0.015	0.040	0.30	0.85	1.4	4.4
		1105	0.274	0.740	6.27	18.5	32.0	0.012	0.033	0.28	0.82	1.4	4.4
		1440	1.08	1.86	8.43	20.1	32.2	0.048	0.082	0.37	0.89	1.4	4.4
	8/29	1015	0.563	1.32	7.80	19.9	32.5	0.025	0.058	0.35	0.88	1.4	4.4
		1400	0.452	1.53	9.00	21.5	33.9	0.020	0.068	0.40	0.95	1.5	4.4
	11/4[f]	1100	0.373	1.59	12.8	31.2	47.4	0.017	0.070	0.57	1.4	2.1	4.4
	11/5[f]	1430	0.620	1.84	9.53	21.9	34.0	0.027	0.081	0.42	0.97	1.5	4.4
		1435	0.540	1.65	9.11	21.5	33.8	0.024	0.073	0.40	0.95	1.5	4.4
		0935	0.479	1.27	7.41	19.3	32.0	0.021	0.056	0.33	0.85	1.4	4.4
		0930	0.249	1.19	8.65	21.6	34.4	0.011	0.053	0.38	0.95	1.5	4.4
		1415	0.524	1.12	7.31	19.4	32.3	0.023	0.050	0.32	0.86	1.4	4.4
		1415	0.642	1.42	7.96	20.0	32.5	0.028	0.063	0.35	0.88	1.4	4.4
Arithmetic mean ($\bar{x}$)			0.54	1.5	8.6	21	34	0.024	0.064	0.38	0.94	1.5	-
Geometric mean ($\bar{x}_g$)			0.50	1.4	8.4	21	34	0.022	0.061	0.37	0.93	1.5	-
Standard deviation (σ)			0.24	0.45	1.7	3.2	4.1	0.011	0.018	0.074	0.15	0.19	-
Standard geometric deviation (σ_g)			1.5	1.4	1.2	1.1	1.1	1.5	1.4	1.2	1.1	1.1	-

[a] From computer printouts included in Appendix E. Brink impactor data not used.

[b] Measured at inlet of a gravel bed filter (Rexnord) used to control emissions from a clinker cooler.

[c] Aerodynamic diameter.

[d] Kilograms of particulate matter per Mg (10^6 g) of cement produced. Reduced to two significant figures.

[e] From Table 4-3.

[f] No Method 5 data available for these tests. Cumulative emission factors calculated from particle size data (Appendix E) assuming a total mass emission factor of 4.42 kg/Mg as determined during the August test series (see Table 4-4).

TABLE 4-19. CALCULATED PARTICLE SIZE DISTRIBUTIONS AND CONTROLLED EMISSION FACTORS FOR REFERENCE 21[a]

Data Rating: C

Test date	Test ID No.[b]	Cumulative mass % equal to or less than stated size[c]					Cumulative emission factor equal to or less than stated size (kg/Mg)[d]					
		2.5 µmA	5.0 µmA	10.0 µmA	15.0 µmA	20.0 µmA	2.5 µmA	5.0 µmA	10.0 µmA	15.0 µmA	20.0 µmA	Total mass emission factor[e]
8/25	1440	31.4	60.1	77.2	89.7	96.1	0.045	0.085	0.11	0.13	0.14	0.14
	1440	37.1	56.0	63.6	83.2	94.8	0.053	0.080	0.090	0.12	0.14	0.14
8/26	1119	31.1	66.3	83.7	91.0	95.0	0.044	0.094	0.12	0.13	0.14	0.14
	1124	25.5	59.2	78.9	87.7	92.7	0.036	0.084	0.11	0.13	0.13	0.14
	1515	38.6	63.2	75.3	81.0	84.9	0.055	0.090	0.11	0.12	0.12	0.14
	1515	28.0	53.4	68.9	76.8	81.9	0.040	0.076	0.10	0.11	0.12	0.14
8/27	1100	25.7	52.0	64.9	73.6	79.3	0.037	0.074	0.092	0.10	0.11	0.14
	1150	29.5	52.9	69.2	83.0	91.1	0.042	0.075	0.098	0.12	0.13	0.14
	1515	35.6	59.0	72.9	81.4	86.7	0.051	0.084	0.10	0.12	0.12	0.14
	1515	29.3	54.9	65.5	72.1	76.7	0.042	0.078	0.093	0.10	0.11	0.14
8/28	1045	29.2	57.6	70.3	78.3	83.4	0.042	0.082	0.10	0.11	0.12	0.14
	1045	29.8	53.4	68.9	76.1	80.9	0.042	0.076	0.098	0.11	0.12	0.14
	1415	39.9	61.3	73.4	80.0	84.3	0.057	0.087	0.10	0.11	0.12	0.14
	1415	40.1	62.6	75.3	84.8	90.5	0.057	0.089	0.10	0.12	0.13	0.14
8/29	1000	30.9	53.7	68.0	74.4	78.8	0.044	0.076	0.097	0.11	0.11	0.14
	1000	36.4	65.2	76.3	82.2	86.0	0.052	0.093	0.11	0.12	0.12	0.14
	1400	47.9	64.0	75.0	85.1	91.1	0.068	0.091	0.11	0.12	0.13	0.14
	1400	31.4	57.3	72.0	78.3	82.4	0.045	0.081	0.10	0.11	0.12	0.14
11/3	1545[f]	51.0	93.7	95.6	97.6	98.6	0.072	0.13	0.14	0.14	0.14	0.14
11/4	1130[f]	79.9	92.3	95.7	97.5	98.5	0.11	0.13	0.14	0.14	0.14	0.14
	1130[f]	76.0	94.5	98.3	100.0	100.0	0.11	0.13	0.14	0.14	0.14	0.14
11/5	0945[f]	64.4	80.9	87.8	92.5	95.1	0.092	0.12	0.13	0.13	0.14	0.14
	0945[f]	56.4	64.4	74.4	81.8	86.4	0.080	0.092	0.11	0.12	0.12	0.14
Average[g]		40	64	76	84	89	0.057	0.091	0.11	0.12	0.13	-

[a] From computer printouts included in Appendix E.

[b] Measured at outlet of a gravel bed filter (Rexnord) used to control emissions from a clinker cooler.

[c] Aerodynamic diameter.

[d] Kilograms of particulate matter per Mg (10^6 g) of cement produced. Reduced to two significant figures.

[e] From Table 4-6.

[f] No Method 5 data available for these tests. Cumulative emission factors calculated from particle size data (Appendix E) assuming a total mass emission factor of 0.142 kg/Mg as determined during the August test series (see Table 4-6).

[g] Two significant figures.

TABLE 4-20. CALCULATED PARTICLE SIZE DISTRIBUTIONS AND EMISSION FACTORS FOR REFERENCE 26[a]

ID No.	Measurement location	Cumulative mass % equal to or less than stated size[b]					Cumulative emission factor equal to or less than stated size (kg/Mg)[c]						Data rating
		2.5 μmA	5.0 μmA	10.0 μmA	15.0 μmA	20.0 μmA	2.5 μmA	5.0 μmA	10.0 μmA	15.0 μmA	20.0 μmA	Total mass emission factor	
3-3[d]	Multiclone outlet	3.82	14.3	24.3	31.2	37.7	4.76	17.8	30.2	38.9	47.0	125[f]	B
9-5[e]	ESP outlet	67.1	82.8	92.7	96.0	97.5	0.0852	0.105	0.118	0.122	0.124	0.127[g]	A
9-6[e]		62.8	83.4	94.7	97.7	98.8	0.0942	0.125	0.142	0.147	0.148	0.150[g]	A

[a] From computer printouts included in Appendix E. Rounded to three significant figures.

[b] Aerodynamic diameter.

[c] Kilograms of particulate matter per Mg (10^6 g) of cement produced.

[d] Test conducted with Brink impactor. Dry process kiln.

[e] Test conducted with SASS train. Data fit to log-normal distribution in place of SPLINE routine. Wet process kiln.

[f] From Table 4-8. Rounded to three significant figures.

[g] From Table 4-9.

TABLE 4-22. CALCULATED EMISSION FACTORS FOR REFERENCE 42 - NO. 5 KILN BAGHOUSE INLET[a]

Data Rating: A

Particle size	Total mass emission rate[b]		Production rate[c]		Total mass emission factor[d]		Cumulative emission factors equal to or less than stated size[e]					
							2.5 μmA		10.0 μmA		15.0 μmA	
run number	(lb/hr)	(kg/hr)	(ton/hr)	(Mg/hr)	(lb/ton)	(kg/Mg)	(lb/ton)	(kg/Mg)	(lb/ton)	(kg/Mg)	(lb/ton)	(kg/Mg)
I-1-1	7,600	3,500	34	31	220	110	79	40	130	66	140	69
I-2-1	10,000	4,700	33	30	310	160	30	15	90	45	97	49
I-3-1	9,000	4,100	36	33	250	130	42	21	100	50	110	53
I-4-1	8,100	3,700	35	32	230	120	47	24	92	46	98	49
Average	8,800	4,000	34	31	260	130	50	25	100	52	110	55
I-1-2	7,600	3,500	34	31	220	110	28	14	93	47	99	50
I-2-2	10,000	4,700	33	30	310	160	45	23	120	62	130	66
I-3-2	9,000	4,100	36	33	250	130	50	25	92	46	99	50
I-4-2	8,100	3,700	35	32	230	120	26	13	85	43	90	45
Average	8,800	4,000	34	31	260	130	37	19	98	49	110	53
I-1-3	8,300	3,800	34	31	240	120	20	10	75	38	81	41
I-2-3	9,000	4,100	33	30	270	140	48	24	110	56	120	61
I-3-3	7,400	3,400	33	30	220	110	68	34	100	51	110	55
I-4-3	7,700	3,500	33	30	230	120	60	30	130	66	140	68
Average	8,100	3,700	33	30	240	120	49	25	110	53	110	56
I-1-4	8,300	3,800	34	31	240	120	33	17	100	52	110	56
I-2-4	9,000	4,100	33	30	270	140	48	24	120	62	130	65
I-3-4	7,400	3,400	33	30	220	110	53	27	97	49	100	52
I-4-4	7,700	3,500	33	30	230	120	47	24	110	54	110	57
Average	8,100	3,700	33	30	240	120	45	23	110	54	110	57
Total average	8,400	3,800	34	31	250	130	45	23	100	52	110	55

a Reproduced from Table 3-3, page 49 of test report (Appendix A). Particle size test data obtained with an Andersen HCSS impactor with 15 μm preseparator. Dry process kiln.

b Total mass emission rate data obtained with an EPA Method 5 train. Emission rate corrected to total emissions from No. 5 kiln; pounds per hour (lb/hr) or kilograms per hour (kg/hr).

c Short tons (2,000 lb) of cement produced per hour or Mg (10^6 g) of cement produced per hour.

d Pounds of particulate matter per short ton (2,000 lb) of cement produced or kilograms of particulate matter per Mg (10^6 g) of cement produced.

e Aerodynamic diameter.

TABLE 4-21. CALCULATED PARTICLE SIZE DISTRIBUTIONS AND CONTROLLED EMISSION FACTORS FOR REFERENCE 27[a]

Data Rating: B

		Cumulative mass % equal to or less than stated size[b]					Cumulative emission factor equal to or less than stated size (kg/Mg)[c]					
ID No.	Type of fuel	2.5 μmA	5.0 μmA	10.0 μmA	15.0 μmA	20.0 μmA	2.5 μmA	5.0 μmA	10.0 μmA	15.0 μmA	20.0 μmA	Total mass emission factor[d]
9	Natural gas	52.4	75.0	91.7	97.9	100	0.058	0.083	0.10	0.11	0.11	0.11
18	Coal	62.3	79.4	91.9	96.9	99.0	0.14	0.18	0.20	0.21	0.22	0.22

[a] From computer printouts in Appendix E. Emissions from a dry process cement kiln measured at the outlet of a baghouse collector.

[b] Aerodynamic diameter.

[c] Kilograms of particulate matter per Mg (10^6 g) of cement produced. Rounded to two significant figures.

[d] From Table 4-10.

TABLE 4-23. CALCULATED EMISSION FACTORS FOR REFERENCE 42 - NO. 5 KILN BAGHOUSE OUTLET[a]

Data Rating: A

Particle size	Total mass emission rate[b]		Production rate[c]		Total mass emission factor[d]		Cumulative emission factors equal to or less than stated size[d]					
							2.5 µmA		10.0 µmA		15.0 µmA	
run number	(lb/hr)	(kg/hr)	(ton/hr)	(Mg/hr)	(lb/ton)	(kg/Mg)	(lb/ton)	(kg/Mg)	(lb/ton)	(kg/Mg)	(lb/ton)	(kg/Mg)
0-1-1	26	12	33	30	0.79	0.40	0.27	0.14	0.60	0.30	0.62	0.31
0-2-1	25	11	35	32	0.71	0.36	0.22	0.11	0.54	0.27	0.54	0.27
0-3-1	26	12	36	33	0.72	0.36	0.13	0.065	0.35	0.18	0.36	0.18
0-4-1	25	11	35	32	0.71	0.36	0.30	0.15	0.60	0.30	0.62	0.31
Average	26	12	35	33	0.74	0.37	0.23	0.12	0.52	0.26	0.54	0.27
0-1-2	27	12	33	30	0.82	0.41	0.23	0.12	0.69	0.35	0.70	0.35
0-2-2	30	14	33	30	0.91	0.46	0.33	0.17	0.77	0.39	0.82	0.41
0-3-2	41	19	33	30	1.24	0.62	0.61	0.31	1.01	0.51	1.02	0.51
0-4-2	39	18	33	30	1.18	0.59	0.31	0.16	0.97	0.49	1.04	0.52
Average	34	15	33	30	1.03	0.52	0.37	0.19	0.86	0.43	0.90	0.45
Total average	30	14	34	31	0.88	0.44	0.30	0.15	0.69	0.35	0.72	0.36

[a] Reproduced from Table 3-5, page 56 of test report (Appendix A). Particle size test data obtained with an Andersen Mark III impactor with 15 µm preseparator. Dry process kiln.

[b] Total mass emission rate data obtained with an EPA Method 17 train. Total mass emission rate from 10-cell (main) baghouse and 3-cell (by-pass) baghouse, pounds per hour (lb/hr) or kilograms per hour (kg/hr).

[c] Short tons (2,000 lb) of cement produced per hour or Mg (10^6 g) of cement produced per hour.

[d] Pounds of particulate matter per short ton (2,000 lb) of cement produced or kilograms of particulate matter per Mg (10^6 g) of cement produced. Aerodynamic diameter.

TABLE 4-24. CALCULATED EMISSION FACTORS FOR REFERENCE 46 - KILN NO. 2 ELECTROSTATIC PRECIPITATOR INLET[a]

Data Rating: B

Particle size run No.	Total mass emission rate[b]		Production rate[c]		Total mass emission factor[d]		Cumulative emission factors equal to or less than stated size[d] 2.5 μmA		10.0 μmA		15.0 μmA	
	(lb/hr)	(kg/hr)	(ton/hr)	(Mg/hr)	(lb/ton)	(kg/Mg)	(lb/ton)	(kg/Mg)	(lb/ton)	(kg/Mg)	(lb/ton)	(kg/Mg)
ESP-I-1-1	52,000	24,000	35	32	1,500	750	30	15	120	60	180	90
ESP-I-2-1	57,000	26,000	35	32	1,600	800	32	16	110	55	220	110
ESP-I-3-1	21,000	9,500	35	32	590	300	24	12	77	39	110	55
ESP-I-4-1	24,000	11,000	35	32	690	350	14	7.0	55	28	83	42
Average	38,000	17,000	35	32	1,100	550	25	13	90	45	150	75
ESP-I-1-2	52,000	24,000	35	32	1,500	750	30	15	100	50	180	90
ESP-I-2-2	57,000	26,000	35	32	1,600	800	32	16	110	55	180	90
ESP-I-3-2	21,000	9,500	36	33	590	300	12	6.0	53	27	88	44
ESP-I-4-2	24,000	11,000	35	32	690	350	14	7.0	55	27	76	38
Average	38,000	17,000	35	32	1,100	550	22	11	80	40	130	65
ESP-I-1-3(B)	86,000	39,000	35	32	2,400	1,200	24	12	140	70	240	120
ESP-I-2-3	39,000	18,000	35	32	1,100	550	11	5.5	55	28	110	55
ESP-I-3-3	26,000	12,000	35	32	750	380	10	5.0	38	19	68	34
ESP-I-4-3	47,000	21,000	34	31	1,400	700	14	7	110	55	310	160
Average	50,000	23,000	35	32	1,400	700	15	7.5	86	43	180	90
ESP-I-1-4	86,000	39,000	35	32	2,400	1,200	24	12	120	60	220	110
ESP-I-2-4	39,000	18,000	35	32	1,100	550	11	5.5	66	33	110	55
ESP-I-3-4	26,000	12,000	35	32	750	380	10	5.0	52	26	82	41
ESP-I-4-4	47,000	21,000	34	31	1,400	700	28	14	98	49	170	85
Average	50,000	23,000	35	32	1,400	700	18	9.0	84	42	150	75
Total average	44,000	20,000	35	32	1,200	600	20	10	85	43	150	75

[a] Reproduced from Table 3-3, page 34 of test report (Appendix A). Particle size test data obtained with an Andersen HCSS impactor with 15 μm preseparator. Wet process kiln.

[b] Total mass emission rate obtained with an EPA Method 5 train; pounds per hour (lb/hr) or kilograms per hour (kg/hr).

[c] Short tons (2,000 lb) of cement produced per hour or Mg (10^6 g) of cement produced per hour.

[d] Pounds of particulate matter per short ton (2,000 lb) of cement produced or kilograms of particulate matter per Mg (10^6 g) of cement produced.

TABLE 4-25. CALCULATED EMISSION FACTORS FOR REFERENCE 46 - KILN NO. 2 ELECTROSTATIC PRECIPITATOR OUTLET[a]

Data Rating: A

Particle size run No.	Total mass emission rate[b] (lb/hr)	(kg/hr)	Production rate[c] (ton/hr)	(Mg/hr)	Total mass emission factor[d] (lb/ton)	(kg/Mg)	Cumulative emission factors equal to or less than stated size[d] 2.5 µmA (lb/ton)	2.5 µmA (kg/Mg)	10.0 µmA (lb/ton)	10.0 µmA (kg/Mg)	15.0 µmA (lb/ton)	15.0 µmA (kg/Mg)
ESP-0-1-1(C)	3.2	1.5	34	31	0.094	0.047	0.077	0.039	0.084	0.042	0.088	0.044
ESP-0-2-1(B)	2.1	0.95	34	31	0.062	0.031	0.051	0.026	0.058	0.029	0.059	0.030
ESP-0-3-1	5.4	2.5	35	32	0.15	0.075	0.11	0.055	0.12	0.060	0.15	0.075
ESP-0-4-1[e]	5.0	2.3	35	32	0.14	0.070	0.003	0.0015	0.006	0.003	0.011	0.0055
Average	3.6	1.6	34	31	0.10	0.050	0.079	0.040	0.087	0.044	0.099	0.050
ESP-0-1-2	8.5	3.9	35	32	0.24	0.12	0.082	0.041	0.13	0.065	0.16	0.080
ESP-0-2-2(b)	9.6	4.4	34	31	0.28	0.14	0.20	0.10	0.24	0.12	0.24	0.12
ESP-0-2-3	2.8	1.3	35	32	0.08	0.04	0.018	0.009	0.045	0.023	0.048	0.024
ESP-0-4-2	2.3	1.0	34	31	0.068	0.034	0.028	0.014	0.041	0.021	0.049	0.025
Average	5.8	2.6	34	31	0.17	0.085	0.082	0.041	0.11	0.055	0.12	0.060
Total average	4.7	2.1	34	31	0.14	0.070	0.080	0.040	0.098	0.049	0.11	0.056

[a] Reproduced from Table 3-5, page 42 of test report (Appendix A). Particle size test data obtained with an Andersen Mark III impactor with 15 µm preseparator. Wet process kiln.

[b] Total mass emission rate data obtained with an EPA Method 17 train; pounds per hour (lb/hr) or kilograms per hour (kg/hr).

[c] Short tons (2,000 lb) of cement produced per hour or Mg (10^6 g) of cement produced per hour. The production rate presented corresponds to the same date on which the total mass emission rate was determined. This date may not necessarily be the same as the corresponding particle size run in that quadrant.

[d] Pounds of particulate matter per short ton (2,000 lb) of cement produced or kilograms of particulate matter per Mg (10^6 g) of cement produced.

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

A number of notations should be made regarding the particle size data shown in Tables 4-17 through 4-25. First, only data for particles larger than 2.5 μm (aerodynamic diameter) have been reported even though the spline equation was asked to predict values below that size range. This particular lower cut-off was selected since this is the smallest particle diameter specified by the EPA. In addition, the size-specific emission factors calculated from the test data have also been reported in each table even though they may not actually be used in the development of the candidate emission factors for the process (see Section 4.3 below). In those cases where the emission factors were not used, the values have been included only for the sake of information.

Another notion which should be made is in regard to the data contained in Tables 4-17, 4-22, 4-23, 4-24, and 4-25 for References 20, 42, and 46, respectively. Since the test results have already been analyzed by the SPLINE routine either through the PADRE portion of the EADS software or as part of the study itself, no further data analyses were conducted. In the case of Reference 20, the cumulative mass loadings have been reproduced from the EADS printout and the associated cumulative percentages back-calculated by hand based on these data. For References 42 and 46, the size-specific emission factors presented in each report have been reproduced from the test reports in Tables 4-22 through 4-25.

4.3 DEVELOPMENT OF CANDIDATE EMISSION FACTORS

4.3.1 Total Mass Emissions

The most ideal situation for the development of candidate emission factors would be to have a large number of A-rated data sets from which to derive such. As shown by the above discussion, such data were not available for the purpose of this study. In the case of uncontrolled rotary kilns, data from only four test series (representing two types of fuel) for wet process kilns and one test series for dry process units were found during the literature search (in addition to that already contained in the original data base used to develop the existing AP-42 emission factors). It was felt that these data did not significantly improve the existing data base, and thus no change is proposed for those factors already presented in Table 8.6-1 (page 8.6-3) of AP-42 for uncontrolled kilns.

For uncontrolled clinker coolers, the current version of Section 8.6 of AP-42 does not contain a specific emission factor. As stated above, MRI found only one report which quantifies the uncontrolled emissions from clinker coolers. In this instance, it was felt that the addition of an uncontrolled emission factor for clinker coolers was justified. This factor was developed simply by taking an arithmetic mean of the data from the four Method 5 tests conducted on the clinker cooler described in Reference 21.

In the case of controlled emissions, the data base developed during the program is somewhat more extensive. Not all of these data are of the highest quality, however, with some sources having only one series of tests from which to develop an appropriate emission factor. Controlled emission factors were derived for: wet and dry process kilns; clinker coolers; primary limestone crushers and screens; secondary limestone crushers and screens; limestone conveyor transfer; raw mill system; and finish mill system. These factors were developed by taking an arithmetic mean of all available A- and B-rated data sets for each specific control device, as shown previously in Table 4-16. The factors thus obtained are being proposed for inclusion in AP-42. A summary of all candidate uncontrolled and controlled emission factors for cement plants according to type of process and control equipment are shown in Table 4-26.

4.3.2 Size-Specific Emissions

As mentioned above, only limited particle size data were collected during the literature search for cement plants consisting of a total of nine test series. In the case of uncontrolled kilns, one A-rated (Reference 46) and one C-rated test series (Reference 20) were contained in the information gathered for wet process kilns with one additional A-rated test series (Reference 42) obtained for dry process units. For controlled kilns, two A-rated tests (References 26 and 46) were included in the data base for wet process

TABLE 4-26. SUMMARY OF CANDIDATE EMISSION FACTORS FOR TOTAL PARTICULATE MATTER

Type of source	Control technology[a]	Candidate total particulate emission factor[b]		Summary table No.[c]	Emission factor rating
		kg/Mg clinker	kg/Mg cement		
Wet process kiln	Baghouse	0.57	0.54	4-16	C
	ESP	0.39	0.37	4-16	C
Dry process kiln	Multiclone	130	130	4-16	D
	Multiclone + ESP	0.34	0.33	4-16	C
	Baghouse	0.16	0.15	4-16	B
Clinker cooler	Uncontrolled	4.6	4.4	4-15	D
	Gravel bed filter	0.16	0.15	4-16	C
	ESP	0.048	0.046	4-16	D
	Baghouse	0.010	0.0097	4-16	C
Primary limestone crusher[d]	Baghouse	NA	$5.1 (10)^{-4}$	4-16	D
Primary limestone screen[d]	Baghouse	NA	$1.1 (10)^{-4}$	4-16	D
Secondary limestone screen and crusher[d]	Baghouse	NA	$1.6 (10)^{-4}$	4-16	D
Conveyor transfer[d]	Baghouse	NA	$2.0 (10)^{-5}$	4-16	D
Raw mill system[d,e]	Baghouse	NA	0.034	4-16	D
Finish mill system[f]	Baghouse	NA	0.017	4-16	C

[a] ESP = electrostatic precipitator.

[b] Emission factor proposed for inclusion into AP-42 in kilograms of particulate matter per metric ton ($Mg = 10^6$ g) of cement or clinker produced. Two significant figures. NA = Not applicable.

[c] Table in this report from which the emission factor was taken.

[d] Emission factor expressed in mass of pollutant per mass of raw material processed.

[e] Includes mill, air separator, and weigh feeder.

[f] Includes mill, air separator(s), and one or more material transfer operations.

kilns with ESPs, as well as two additional A-rated tests (References 27 and 42) for dry process units with baghouses. Finally, only one C-rated test of the same clinker cooler (Reference 21) is included in the data base representing both the uncontrolled emissions from the process, as well as emissions control utilizing a gravel bed filter.

According to the OAQPS guidelines, A- and B-rated data should not be combined with C- or D-rated data to develop emission factors for a particular source. However, in the case of uncontrolled wet process kilns, it was found necessary to combine B-rated data with C-rated data in order to improve the overall quality of the emission factor. This was deemed appropriate since it was felt that the inclusion of the C data would significantly enhance the overall applicability of the emission factor to a greater number of facilities and would not decrease the overall rating of the emission factor obtained.

To derive each emission factor, the information contained in Tables 4-17 through 4-25 was tabulated according to the type of process and control equipment, and the arithmetic mean and standard deviation calculated, wherever possible, for each particle size increment. The arithmetic mean was calculated from the data in each column according to the relationship:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i \qquad (1)$$

where: $\bar{x}$ = arithmetic mean

n = number of measurements

x_i = individual measurements

The standard deviation was calculated according to the relationship:

$$\sigma = \left[\frac{\Sigma x_i^2 - \frac{(\Sigma x_i)^2}{n}}{n-1}\right]^{1/2} \qquad (2)$$

where: σ = standard deviation with x_i and n as defined as Equation (1)

The geometric mean and standard deviation were also calculated, with the standard geometric deviation being indicative of the overall variance in the data. The geometric mean was calculated from the data in each column according to the relationship:

$$\bar{x}_g = \exp \frac{1}{n} \sum_{i=1}^{n} \ln x_i \qquad (3)$$

where: $\bar{x}_g$ = geometric mean with x_i and n as defined in Equation (1)

The standard geometric deviation was calculated according to the relationship:

$$\sigma_g = \exp \sum_{i=1}^{n} \left[\frac{\ln x_i - \overline{\ln x}^{\,2}}{n-1}\right]^{1/2} \qquad (4)$$

where: σ_g = standard geometric deviation with x_i and n as defined in Equation (1)

Rather than utilizing the emission factors actually derived from each study, the candidate emission factor for each size increment was obtained by applying the particle size distribution from the various data sets to either the existing uncontrolled AP-42 emission factor (after conversion to weight of pollutant/unit weight of clinker instead of cement produced) or to those emission factors derived during this study (Table 4-26). This approach was used to take advantage of the generally more extensive data base which exists for total particulate emissions. It was felt that the emission factors produced by this technique would be more representative of the total industry. The results of the above analysis are shown in Table 4-27 through 4-31.

In the case of uncontrolled clinker coolers, the above statistics have been included in Table 4-18. The reader is directed to that table for the candidate emission factors for uncontrolled coolers. A summary of the candidate emission factors for cement kilns and clinker coolers are shown in Tables 4-32 and 4-33, respectively, and graphically in Figures 4-1 and 4-2.

TABLE 4-27. CANDIDATE SIZE-SPECIFIC EMISSION FACTORS FOR UNCONTROLLED WET PROCESS CEMENT KILNS

Emission Factor Rating: D

Ref. No.	Data quality rating	Summary data table No.[a]	Test ID No.	Cumulative mass % of equal to or less than stated size[b]					Total mass emission factor (kg/Mg)[c]	Cumulative emission factor equal to or less than stated size (kg/Mg)[d]				
				2.5 μmA	5.0 μmA	10.0 μmA	15.0 μmA	20.0 μmA		2.5 μmA	5.0 μmA	10.0 μmA	15.0 μmA	20.0 μmA
20	C	4-17	2-1	7.5	18	34	50	60	119.7	9.0	22	41	60	72
	C		2-2	12	19	23	28	31	119.7	14	23	28	34	37
	C		3-1	8.9	19	38	60	73	119.7	11	23	45	72	87
	C		3-2	9.9	16	34	55	68	119.7	12	19	41	66	83
	C		3-3	9.5	20	30	44	60	119.7	11	24	36	53	72
20	C	4-17	3-4	8.0	22	31	40	52	119.7	9.6	26	37	48	62
	C		4-1	13	19	21	23	26	119.7	16	23	25	28	31
	C		4-2	6.9	20	34	49	64	119.7	8.3	24	41	59	77
	C		4-3	6.6	18	36	58	78	119.7	7.9	22	43	69	93
	C		4-4	9.4	24	33	39	58	119.7	11	29	40	47	69
46	B	4-24	ESP-I-1[e]	2.3	-	8.2	14	-	119.7	2.8	-	9.8	17	-
	B		ESP-I-2[e]	2.0	-	7.3	12	-	119.7	2.4	-	8.7	14	-
	B		ESP-I-3[e]	1.1	-	6.1	13	-	119.7	1.3	-	7.3	16	-
	B		ESP-I-4[e]	1.3	-	6.0	11	-	119.7	1.6	-	7.2	13	-
Arithmetic mean ($\bar{x}$)				7.0	20	24	35	57	-	8.4	24	29	43	68
Geometric mean (x_g)				5.5	19	20	30	54	-	6.6	23	24	36	65
Standard deviation (σ)				3.9	2.2	12	18	17	-	4.5	2.5	14	21	19
Standard geometric deviation (σ_g)				2.3	1.1	2.1	1.9	1.4	-	2.3	1.1	2.0	1.8	1.4

[a] Table in this report from which reduced data was taken.

[b] Aerodynamic diameter. Percentages reduced to two significant figures.

[c] Based on a total mass emission factor of 114.0 kg of particulate matter per metric ton (Mg) of cement produced per Table 8.6-1, page 8.6-3 of AP-42 and converted to mass of pollutant per mass of clinker assuming 5% gypsum in finished cement.

[d] Calculated using the total mass emission factor shown in previous column. Results rounded to two significant figures.

[e] Average of four tests. Percentages back-calculated from emission factors originally presented in test report.

TABLE 4-28. CANDIDATE SIZE-SPECIFIC EMISSION FACTORS FOR UNCONTROLLED DRY PROCESS CEMENT KILNS

Emission Factor Rating: D

Ref. No.	Data quality rating	Summary data table No.[a]	Test ID No.	Cumulative mass % equal to or less than stated size[b]			Total mass emission factor (kg/Mg)[c]	Cumulative emission factor equal to or less than stated size (kg/Mg)[d]		
				2.5 μmA	10.0 μmA	15.0 μmA		2.5 μmA	10.0 μmA	15.0 μmA
42	A	4-22	I-1[e]	19	40	42	128.1	24	51	54
			I-2[e]	14	38	40	128.1	18	49	51
			I-3[e]	20	44	47	128.1	26	56	60
			I-4[e]	19	45	48	128.1	24	58	61
Arithmetic mean ($\bar{x}$)				18	42	44	-	23	54	57
Geometric mean (x_g)				18	42	44	-	23	53	56
Standard deviation (σ)				2.7		3.9	-	3.0	3.6	4.2
Standard geometric deviation (σ_g)				1.2	1.1	1.1	-	1.2	1.1	1.1

[a] Table in this report from which reduced data were taken.

[b] Aerodynamic diameter.

[c] Based on a total mass emission factor of 122.0 kg of particulate matter per metric ton (Mg) of cement produced per Table 8.6-1, page 8.6-3 of AP-42 and converted to mass of pollutant per mass of clinker assuming 5% gypsum in finished cement.

[d] Calculated using the total mass emission factor shown in previous column. Rounded to two significant figures.

[e] Average of four tests. Percentages back-calculated from emission factors originally presented in test report.

TABLE 4-29. CANDIDATE SIZE-SPECIFIC EMISSION FACTORS FOR WET PROCESS KILNS CONTROLLED BY ELECTROSTATIC PRECIPITATORS

Emission Factor Rating: D

Ref. No.	Data quality rating	Summary data table No.[a]	Test ID No.	Cumulative mass % equal to or less than stated size[b] 2.5 µmA	5.0 µmA	10.0 µmA	15.0 µmA	20.0 µmA	Total mass emission factor[c] (kg/Mg)	Cumulative emission factor equal to or less than stated size (kg/Mg)[d] 2.5 µmA	5.0 µmA	10.0 µmA	15.0 µmA	20.0 µmA
26	A	4-20	9-5	67	83	93	96	98	0.39	0.26	0.32	0.36	0.37	0.38
			9-6	63	83	95	98	99	0.39	0.25	0.32	0.37	0.38	0.39
46	A	4-25	ESP-0-1[e]	79	-	87	99	-	0.39	0.31	-	0.34	0.39	-
			ESP-0-2[e]	48	-	65	71	-	0.39	0.19	-	0.25	0.28	-
Arithmetic mean ($\bar{x}$)				64	83	85	91	98	-	0.25	0.32	0.33	0.36	0.39
Geometric mean (x_g)				63	83	84	90	98	-	0.25	0.32	0.33	0.35	0.38
Standard deviation (σ)				13	0.42	14	13	0.92	-	0.043	0.0	0.047	0.044	0.0
Standard geometric deviation (σ_g)				1.2	1.0	1.2	1.2	1.0	-	1.2	1.0	1.2	1.1	1.0

[a] Table in this report from which reduced data were taken.

[b] *Aerodynamic diameter.* Percentages rounded to two significant figures.

[c] Expressed in kg of particulate matter per metric ton (Mg) of clinker produced per Table 4-26 of this report.

[d] Calculated using the total mass emission factor shown in previous column. Rounded to two significant figures.

[e] Average of four tests. Percentages back-calculated from emission factors originally presented in test report.

TABLE 4-30. CANDIDATE SIZE-SPECIFIC EMISSION FACTORS FOR DRY PROCESS CEMENT KILNS CONTROLLED BY BAGHOUSE COLLECTORS

Emission Factor Rating: D

Ref. No.	Data quality rating	Summary data table No.[a]	Test ID No.	Cumulative mass % equal to or less than stated size[b] 2.5 µmA	5.0 µmA	10.0 µmA	15.0 µmA	20.0 µmA	Total mass emission factor[c] (kg/Mg)	Cumulative emission factor equal to or less than stated size (kg/Mg)[d] 2.5 µmA	5.0 µmA	10.0 µmA	15.0 µmA	20.0 µmA
27	B	4-21	9[e]	52	75	92	98	100	0.16	0.083	0.12	0.15	0.16	0.16
			18[f]	62	79	92	97	99	0.16	0.099	0.13	0.15	0.16	0.16
42	A	4-23	0-1[g]	31	-	70	73	-	0.16	0.050	-	0.11	0.12	-
			0-2[g]	36	-	84	87	-	0.16	0.058	-	0.13	0.14	-
Arithmetic mean ($\bar{x}$)				45	77	84	89	100	-	0.073	0.13	0.14	0.15	0.16
Geometric mean (x_g)				44	77	84	88	99	-	0.070	0.12	0.13	0.14	0.16
Standard deviation (σ)				14	3.1	10	12	0.71	-	0.020	0.005	0.017	0.017	0.0
Standard geometric deviation (σ_g)				1.4	1.0	1.1	1.1	0.0071	-	1.3	1.0	1.1	1.1	1.0

[a] Table in this report from which reduced data were taken.

[b] Aerodynamic diameter. Percentages rounded to two significant figures.

[c] Expressed in kg of particulate matter per metric ton (Mg) of clinker produced per Table 4-26 of this report.

[d] Calculated using the total mass emission factor shown in previous column. Rounded to two significant figures.

[e] Fuel = natural gas (see Table 4-21).

[f] Fuel = pulverized coal (see Table 4-21).

[g] Average of four tests. Percentages back-calculated from emission factors originally presented in test report.

TABLE 4-31. CANDIDATE SIZE-SPECIFIC EMISSION FACTORS FOR CLINKER COOLERS CONTROLLED BY A GRAVEL BED FILTER

Emission Factor Rating: E

Test ID No.	Cumulative mass % equal to or less than stated size[a] 2.5 µmA	5.0 µmA	10.0 µmA	15.0 µmA	20.0 µmA	Total mass emission factor[b] (kg/Mg)	Cumulative emission factor equal to or less than stated size (kg/Mg)[c] 2.5 µmA	5.0 µmA	10.0 µmA	15.0 µmA	20.0 µmA
1440	31	60	77	90	96	0.16	0.050	0.096	0.12	0.14	0.15
1440	37	56	64	83	95	0.16	0.059	0.090	0.10	0.13	0.15
1119	31	66	84	91	95	0.16	0.050	0.11	0.13	0.15	0.15
1124	26	59	79	88	93	0.16	0.041	0.094	0.13	0.14	0.15
1515	39	63	75	81	85	0.16	0.062	0.10	0.12	0.13	0.14
1515	28	53	69	77	82	0.16	0.045	0.085	0.11	0.12	0.13
1100	26	52	65	74	79	0.16	0.041	0.083	0.10	0.12	0.13
1150	30	53	69	83	91	0.16	0.048	0.085	0.11	0.13	0.15
1515	36	59	73	81	87	0.16	0.058	0.094	0.12	0.13	0.14
1515	29	55	66	72	77	0.16	0.046	0.088	0.11	0.12	0.12
1045	29	58	70	78	83	0.16	0.046	0.093	0.11	0.12	0.13
1045	30	53	69	76	81	0.16	0.048	0.085	0.11	0.12	0.13
1415	40	61	73	80	84	0.16	0.064	0.098	0.12	0.13	0.13
1415	40	63	75	85	91	0.16	0.064	0.10	0.12	0.14	0.15
1000	31	54	68	74	79	0.16	0.050	0.086	0.11	0.12	0.13
1000	36	65	76	82	86	0.16	0.058	0.10	0.12	0.13	0.14
1400	48	64	75	85	91	0.16	0.077	0.10	0.12	0.14	0.15
1400	31	57	72	78	82	0.16	0.050	0.091	0.12	0.12	0.13
1545	51	94	96	98	99	0.16	0.082	0.15	0.15	0.16	0.16
1130	80	92	96	98	99	0.16	0.13	0.15	0.15	0.16	0.16
1130	76	95	98	100	100	0.16	0.12	0.15	0.16	0.16	0.16
0945	64	81	88	93	95	0.16	0.10	0.13	0.14	0.15	0.15
0945	56	64	74	82	86	0.16	0.090	0.10	0.12	0.13	0.14
Arithmetic mean ($\bar{x}$)	40	64	76	84	89	-	0.064	0.10	0.12	0.13	0.14
Geometric mean ($\bar{x}_g$)	38	63	76	84	88	-	0.061	0.10	0.12	0.13	0.14
Std. deviation (σ)	15	13	9.7	7.8	6.9	-	0.024	0.021	0.015	0.013	0.011
Std. geometric deviation (σ_g)	1.4	1.2	1.1	1.1	1.1	-	1.4	1.2	1.1	1.1	1.1

[a] From Table 4-19. Aerodynamic diameter. Rounded to two significant figures. All data from the same test series.

[b] Kilograms of particulate matter per Mg (10^6 g) of clinker produced per Table 4-26 of this report.

[c] Calculated using total mass emission factor shown in previous column. Rounded to two significant figures.

TABLE 4-32. SUMMARY OF CANDIDATE SIZE-SPECIFIC EMISSION FACTORS FOR CEMENT KILNS

Emission Factor Rating: D

Particle size (µmA)	Cumulative mass % equal to or less than stated size[a]						Cumulative emission factor equal to or less than stated size[b]											
	Uncontrolled		Dry process kiln with multiclone[e]	Wet process kiln with ESP[f]	Baghouse collector		Uncontrolled				Dry process with multiclone[e]		Wet process with ESP[f]		Baghouse collector			
	Wet process kiln[c]	Dry process kiln[d]			Wet process kiln	Dry process kiln[g]	Wet process[c]		Dry process[d]						Wet process		Dry process[g]	
							lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg
2.5	7.0	18	3.8	64	-	45	17	8.4	46	23	10	5.0	0.50	0.25	-	-	0.15	0.073
5.0	20	-	14	83	-	77	48	24	-	-	38	19	0.64	0.32	-	-	0.26	0.13
10.0	24	42	24	85	-	84	58	29	108	54	64	32	0.66	0.33	-	-	0.28	0.14
15.0	35	44	31	91	-	89	86	43	114	57	82	41	0.72	0.36	-	-	0.30	0.15
20.0	57	-	38	98	-	100	136	68	-	-	98	49	0.78	0.39	-	-	0.32	0.16
Total mass emission factor							240	120	256	128	260	130[h]	0.78	0.39[h]	1.1	0.57[h]	0.32	0.16[h]

[a] Aerodynamic diameter. All percentages rounded to two significant figures.

[b] Rounded to two significant figures. Unit weight of particulate matter per unit weight of clinker produced.

[c] From Table 4-27.

[d] From Table 4-28.

[e] From Table 4-20. Emission factors converted to kg of particulate matter per metric ton (Mg) of clinker produced.

[f] ESP = electrostatic precipitator. From Table 4-29.

[g] From Table 4-30.

[h] From Table 4-26. Two significant figures.

TABLE 4-33. SUMMARY OF CANDIDATE EMISSION FACTORS FOR CLINKER COOLERS

Emission Factor Rating: E

Particle size (μmA)[a]	Cumulative mass % equal to or less than stated size[b]		Cumulative emission factor equal to or less than stated size[c]			
	Uncontrolled	Gravel bed filter[d]	Uncontrolled[e]		Gravel bed filter[d]	
			kg/Mg	lb/ton	kg/Mg	lb/ton
2.5	0.54	40	0.025	0.050	0.064	0.13
5.0	1.5	64	0.067	0.13	0.10	0.20
10.0	8.6	76	0.40	0.80	0.12	0.24
15.0	21	84	0.99	2.0	0.13	0.26
20.0	34	89	1.6	3.2	0.14	0.28
Total mass emission factor			4.6	9.2	0.16	0.32

[a] Aerodynamic diameter.

[b] Rounded to two significant figures. From Tables 4-18 and 4-31.

[c] Unit weight of pollutant per unit weight of clinker produced. Rounded to two significant figures.

[d] From Table 4-31.

[e] Converted from unit weight of pollutant per unit weight of cement (from Table 4-18) to weight/weight of clinker produced assuming 5% gypsum in finished cement.

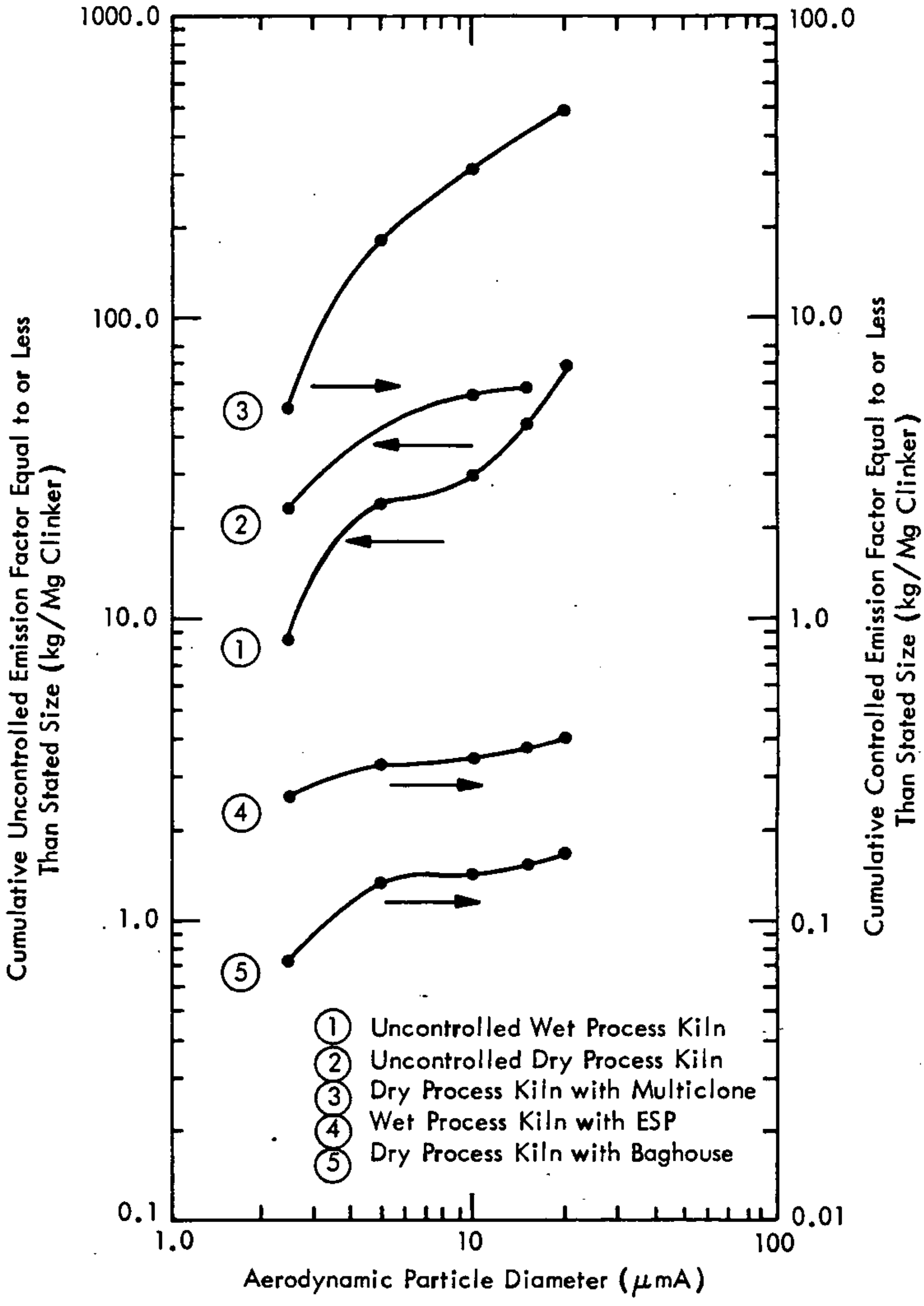

Figure 4-1. Size specific emission factors for cement kilns.

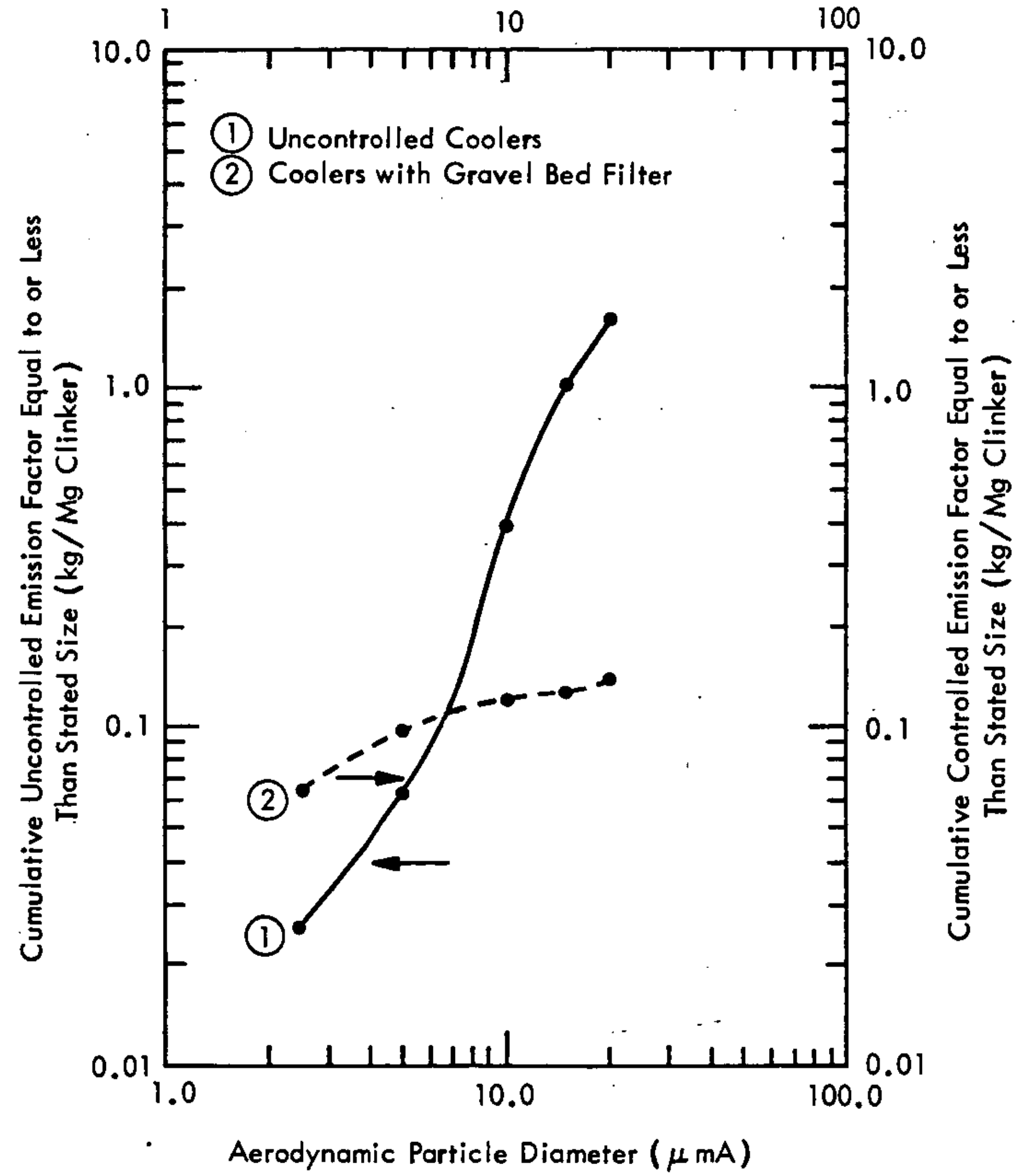

Figure 4-2. Size specific emission factors for clinker coolers.

4.4 EMISSION FACTOR QUALITY RATING

The quality of the average emission factors contained in Tables 4-27 through 4-31 were rated utilizing the general criteria established by OAQPS as outlined in Section 3.0. In the case of uncontrolled wet process kilns, it was found necessary to apply some lower quality particle size data to a B-rated emission factor. Because of this large difference in data quality, it became difficult to ascertain what the overall rating of the resultant emission factor should be. Generally, a B-rated emission factor should not be combined with C or D particle size data. For this reason, a certain amount of engineering judgment was employed to rate the quality of the emission factors obtained. Even though the particle size data were sometimes only marginally acceptable, they were applied to a high quality emission factor. It would be expected, therefore, that something better than an order-of-magnitude estimate would be provided by such a procedure. For this reason, it was determined that a minimum of D would be the most appropriate for the resulting emission factors where large differences in data quality existed.

For the remainder of the candidate emission factors developed in this study for cement kilns, generally high quality particle size data were applied to a lower quality total particulate emission factor. Also, the existing data base for particle size distribution was found to be extremely limited in most cases. Therefore, a rating of D was assigned to the resultant size-specific factors for cement kilns. In the case of clinker coolers, for which the original particle size data were rated C, a rating of E was assigned to the size-specific emission factors utilizing the criteria developed by the OAQPS.

REFERENCES FOR SECTION 4.0

1. Burke, E., "Dust Arrestment in the Cement Industry," Chem. Indus., 1312-1319, October 15, 1955.

*2. Verein Deutscher Ingenieure - Richtlinien, Dust Prevention - Cement Industry, VDI 2094, VDI - Kommission Reinhaltung der Luft, Federal Republic of West Germany, June 1961.

3. Harrison, B. P., Jr., "Baghouse Cleans 500°+ Cement Kiln Gases," Air Eng., p. 14-16, March 1963.

*4. Kreichelt, T. E., et al., Atmospheric Emissions from the Manufacture of Portland Cement, Publ. No. 999-AP-17 (NTIS PB 190 236), U.S Department of Health, Education and Welfare, Public Health Service, Cincinnati, OH, 1967.

5. Vandegrift, A. E., et al., Particulate Pollutant System Study, Volume I: Mass Emissions, APTD-0743 (NTIS PB 203 128), U.S. Environmental Protection Agency, Research Triangle Park, NC, May 1971.

*6. Vandegrift, A. E., et al., Particulate Pollutant System Study, Volume III: Handbook of Emission Properties, APTD-0745 (NTIS PB 203 522), U.S. Environmental Protection Agency, Research Triangle Park, NC, May 1971.

*7. Shannon, L. J., et al., Particulate Pollutant System Study, Volume II: Fine Particle Emissions, APTD-0744 (NTIS PB 203 521), U.S. Environmental Protection Agency, Research Triangle Park, NC, May 1971.

* Indicates reports containing particle size data.

8. Background Information for Proposed New Source Performance Standards: Steam Generators, Incinerators, Portland Cement Plants, Nitric Acid Plants, and Sulfuric Acid Plants, APTD-0711 (NTIS PB 202459), U.S. Environmental Protection Agency, Research Triangle Park, NC, August 1971.

9. Standards of Performance for New and Substantially Modified Portland Cement Plants, Draft, U.S. Environmental Protection Agency, Bureau of Stationary Source Compliance, Durham, NC, August 1971.

10. Emissions from Wet Process Cement Kiln and Clinker Cooler at Maule Industries, Hialeah, Florida, ETB Test No. 71-MM-01, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1972.

11. Emissions from Wet Process Cement Kiln and Clinker Cooler at Ideal Cement Company, Seattle, Washington, ETB Test No. 71-MM-03, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1972.

12. Emissions from Wet Process Cement Kiln and Finish Mill Systems at Ideal Cement Company, Castle Hayne, North Carolina, ETB Test No. 71-MM-04, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1972.

13. Emissions from Dry Process Cement Kiln at Dragon Cement Company, Northhampton, Pennsylvania, ETB Test No. 71-MM-05, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1972.

14. Emissions from Wet Process Clinker Cooler and Finish Mill Systems at Ideal Cement Company, Houston, Texas, ETB Test No. 71-MM-06, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1972.

15. Emissions from Wet Process Cement Kiln at Giant Portland Cement, Harleyville, South Carolina, ETB Test No. 71-MM-07, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1972.

16. Emissions from Wet Process Cement Kiln at Oregon Portland Cement Company, Lake Oswego, Oregon, ETB Test No. 71-MM-15, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1972.

17. Emissions from Dry Process Raw Mill and Finish Mill Systems at Ideal Cement Company, Tijeras, New Mexico, ETB Test No. 71-MM-02, U.S. Environmental Protection Agency, Research Triangle Park, NC, April 1972.

*18. Air Pollution Emission Test, Arizona Portland Cement, Rillito, Arizona, EPA Project Report 74-STN-1, U.S. Environmental Protection Agency, Research Triangle Park, NC, June 1974.

*19. Davis, T. A., et al., Disposal and Utilization of Waste Kiln Dust from Cement Industry, EPA-670/2-75-043 (NTIS PB 242825), U.S. Environmental Protection Agency, Cincinnati, OH, May 1975.

*20. Nichols, G. B., and J. D. McCain, Particulate Collection Efficiency Measurements on Three Electrostatic Precipitators, EPA-600/2-75-056 (NTIS PB 248 220), U.S. Environmental Protection Agency, Washington, D.C., October 1975.

*21. McCain, J. D., Evaluation of Rexnord Gravel Bed Filter, EPA-600/2-76-164 (NTIS PB 255 095), U.S. Environmental Protection Agency, Research Triangle Park, NC, June 1976.

*22. Greening, N. R., et al., Elimination of Water Pollution by Recycling Cement Plant Kiln Dust, EPA-600/2-76-194 (NTIS PB 259 080), U.S. Environmental Protection Agency, Cincinnati, OH, July 1976.

23. Muelberg, P. E., et al., Industrial Process Profiles for Environmental Use, Chapter 21, The Cement Industry, EPA-600/2-77-023u (NTIS PB 281 488), U.S. Environmental Protection Agency, Cincinnati, OH, February 1977.

24. Hurst, W. W., Particulate Emissions Testing, Greencastle Plant, Lone Star Industries, Houston, TX, July 1977.

25. Hurst, W. W., Particulate Emissions Testing, Nazareth Plant, Lone Star Industries, Houston, TX, January 1978.

*26A. Hunter, S. C., et al., Application of Combustion Modifications to Industrial Combustion Equipment, EPA-600/7-79-015a (NTIS PB 294 214), U.S. Environmental Protection Agency, Research Triangle Park, NC, January 1979.

*26B. Hunter, S. C., et al., Application of Combustion Modifications to Industrial Combustion Equipment: Data Supplement A, EPA-600/7-79-015b (NTIS PB 293888), U. S. Environmental Protection Agency, Research Triangle Park, NC, February 1979.

*27. Taback, H. J., et al., Fine Particle Emissions from Stationary and Miscellaneous Sources in the South Coast Air Basin, KVB 5806-783 (NTIS PB 293 923), California State Air Resources Board, Sacramento, CA, February 1979.

*28. Barrett, K. W., A Review of Standards of Performance of New Stationary Sources - Portland Cement Industry, EPA-450/3-79-012 (NTIS PB 80-112089), U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1979.

*29. Smith, R. F., and J. E. Levin, Multimedia Assessment and Environmental Needs of the Cement Industry, EPA-600/2-79-111 (NTIS PB 299 210), U.S. Environmental Protection Agency, Cincinnati, OH, May 1979.

30. Stack Emissions Survey of Lone Star Industries, Inc., Portland Cement Plant, Maryneal, Texas, File No. EA 795-09, Ecology Audits, Inc., Dallas, TX, September 1979.

31. Hurst, W. W., Gas Process Survey, Roanoke No. 5 Kiln System, Lone Star Cement, Inc., Cloverdale, VA, October 1979.

32. Mease, M. J., Test Report Stack Analysis for Particulate Emission, Clinker Coolers/Gravel Bed Filter, Mease Engineering Associates, Port Matilda, PA, March 1980.

33. Source Emissions Survey of Oklahoma Cement Company, Kiln No. 3 Stack, Pryor, Oklahoma, Mullins Environmental Testing Company, Addison, TX, March 1980.

34. Mullins, B. J., Source Emissions Survey of Lone Star Industries, Inc., Kilns 1, 2, and 3, Maryneal, Texas, Mullins Environmental Testing Company, Addison, TX, June 1980.

35. Arlington, W. D., Compliance Stack Test, Lone Star Florida, Inc., Report 275-S, Kiln No. 3, South Florida Environmental Services, Inc., Belle Glade, FL, July 1980.

36. Arlington, W. D., Compliance Stack Test, Lone Star Florida, Inc., Report 276-S, Cooler No. 3, South Florida Environmental Services, Inc., Belle Glade, FL, July 1980.

37. Compliance Stack Test Lone Star Florida/Pennsuco, Inc., Report 387-S, Kiln No. 3, South Florida Environmental Services, Inc., West Palm Beach, FL, July 1981.

38. Preliminary Stack Test, Lone Star Florida/Pennsuco, Inc., Report 391-P, Kiln No. 3, Precipitator Inlet Stack Outlet, South Florida Environmental Services, Inc., West Palm Beach, FL, July 1981.

39. Mullins, B. J., Source Emissions Survey of Lone Star Industries, Inc., New Orleans, Louisiana, Mullins Environmental Testing Company, Addison, TX, November 1981.

40. Hurst, W. W., Stack Emission Survey and Precipitator Efficiency Testing at Bonner Springs Plant, Lone Star Industries, Inc., Houston, TX, November 1981.

41. Johnson, L. A., Field Data Source Test, Chemecology Corporation, Pittsburg, CA, May 1982.

*42. Hansen, M. D., and J. S. Kinsey, Characterization of Inhalable Particulate Matter Emissions from a Dry Process Cement Plant, Volumes I and II, EPA-600/X-85-332a and 332b, U. S. Environmental Protection Agency, Research Triangle Park, NC, February 1983.

43. Lonnes, P., Results of the February 17 and 18, 1983, NSPS Particulate Emission Compliance Test on the No. 8 Kiln at the Lehigh Portland Cement Plant in Mason City, Iowa, Interpoll, Inc., Blaine, MN, March 1983.

44. Steiner, J., Mojave Plant (Kiln, Clinker, and Crusher Baghouses) Annual Compliance Test, Report PS-83-93/Project 5081-83, Pape and Steiner Environmental Services, Bakersfield, CA, May 1983.

45. Levine, S., "New Mojave Plant of California Portland Under Computer Control," Pit & Quarry, 82-87, July 1983.

*46. Hansen, M. D., et al., Characterization of Inhalable Particulate Matter Emissions from a Wet Process Cement Plant, Volumes I, II, and III, EPA-600/X-85-343a, 343b, and 343c, U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1983.

47. Lonnes, P., Results of the June 22-24, 1983, NSPS Particulate Emission Compliance Test on the No. 8 Kiln at the Lehigh Portland Cement Plant in Mason City, Iowa, Interpoll, Inc., Circle Pines, MN, July 1983.

48. Source Emissions Survey of Lehigh Portland Cement Company, Waco, Texas, Mullins Environmental Testing Company, Addison, TX, August 1983.

49. Borrelli, L., Field Data Source Test, Chemecology Corporation, Pittsburg, CA, August 1983.

50. Steiner, J., Mojave Plant (Kiln, Clinker, and Crusher Baghouses) Annual Compliance Test, Report PS-84-249/Project 5233-84, Pape and Steiner Environmental Services, Bakersfield, CA, May 1984.

51. Lehigh Portland Cement Company, Leeds, Alabama, Particulate Compliance Test, CH_2M Hill, Montgomery, AL, October 1984.

52. Baker, R. L., Compliance Test Results, Particulate and Sulfur Oxide Emissions, Cementon Kiln, KVB, Inc., Engineering and Research Division, Irvine, CA, December 1984.

53. Steiner, J., Mojave Plant (Kiln, Crusher, and Clinker Baghouses) Annual Compliance Test, Report PS-85-469/Project 5451-85, Pape and Steiner Environmental Services, Bakersfield, CA, May 1985.

54. Arlington, W. D., Lone Star Florida Holding, Inc., Stack Tests for Particulate, SO_2, NO_x, and Visible Emissions, Report 810-S, Kiln No. 3, South Florida Environmental Services, Inc., West Palm Beach, FL, August 1985.

55. Quarterly Testing for Lone Star Cement, Davenport, California, Report PS-85-539/Project 5509-85, Pape and Steiner Environmental Services, Bakersfield, CA, September 1985.

56. Telephone communication between Joe McCain, Southern Research Institute, Birmingham, AL, and John Kinsey, Midwest Research Institute, Kansas City, MO, July 28, 1983.

SECTION.5.0

PROPOSED AP-42 SECTION 8.6

The proposed revision to Section 8.6 of AP-42 is presented in the following pages as it would appear in the document.

8.6 PORTLAND CEMENT MANUFACTURING

8.6.1 Process Description[1-3]

Portland cement manufacture accounts for about 95 percent of the cement production in the United States. The more than 30 raw materials used to make cement may be divided into four basic components: line (calcareous), silica (siliceous), alumina (argillaceous), and iron (ferriferous). Approximately 1575 kilograms (3500 pounds) of dry raw materials are required to produce 1 metric ton (2200 pounds of cement). Between 45 and 65 percent of raw material weight is removed as carbon dioxide and water vapor. As shown in Figure 8.6-1, the raw materials undergo separate crushing after the quarrying operation, and, when needed for processing, are proportioned, ground and blended by either a dry or wet process. One barrel of cement weighs 171 kilograms (376 pounds).

In the dry process, moisture content of the raw material is reduced to less than 1 percent, either before or during grinding. The dried materials are then pulverized and fed directly into a rotary kiln. The kiln is a long steel cylinder with a refractory brick lining. It is slightly inclined, rotating about the longitudinal axis. The pulverized raw materials are fed into the upper end, traveling slowly to the lower end. Kilns are fired from the lower end, so that the rising hot gases pass through the raw material. Drying, decarbonating and calcining are accomplished as the material travels through the heated kiln and finally burns to incipient fusion and forms the clinker. The clinker is cooled, mixed with about 5 weight percent gypsum and ground to the desired fineness. The product, cement, is then stored for later packaging and shipment.

With the wet process, a slurry is made by adding water to the initial grinding operation. Proportioning may take place before or after the grinding step. After the materials are mixed, excess water is removed and final adjustments are made to obtain a desired composition. This final homogeneous mixture is fed to the kilns as a slurry of 30 to 40 percent moisture or as a wet filtrate of about 20 percent moisture. The burning, cooling, addition of gypsum, and storage are then carried out, as in the dry process.

The trend in the Portland cement industry is toward the use of the dry process of clinker production. Eighty percent of the kilns built since 1971 use the dry process, compared to 46 percent of earlier kilns. Dry process kilns that have become subject to new source performance standards (NSPS) since 1979 commonly are either preheater or preheater/precalciner systems. Both systems allow the sensible heat in kiln exhast gases to heat, and partially to calcine, the raw feed before it enters the kiln.

Addition of a preheater to a dry process kiln permits use of a kiln one half to two thirds shorter than those without a preheater, because heat transfer to the dry feed is more efficient in a preheater than in the preheating zone of the kiln.[4] Also, because of the increased heat transfer efficiency, a preheater kiln system requires less energy than either a wet kiln or a dry kiln without a preheater to achieve the same amount of calcination. Wet raw feed (of 20 to 40 percent moisture) requires a longer residence time for preheating, which is best provided in the kiln itself. Therefore, wet process plants do not use

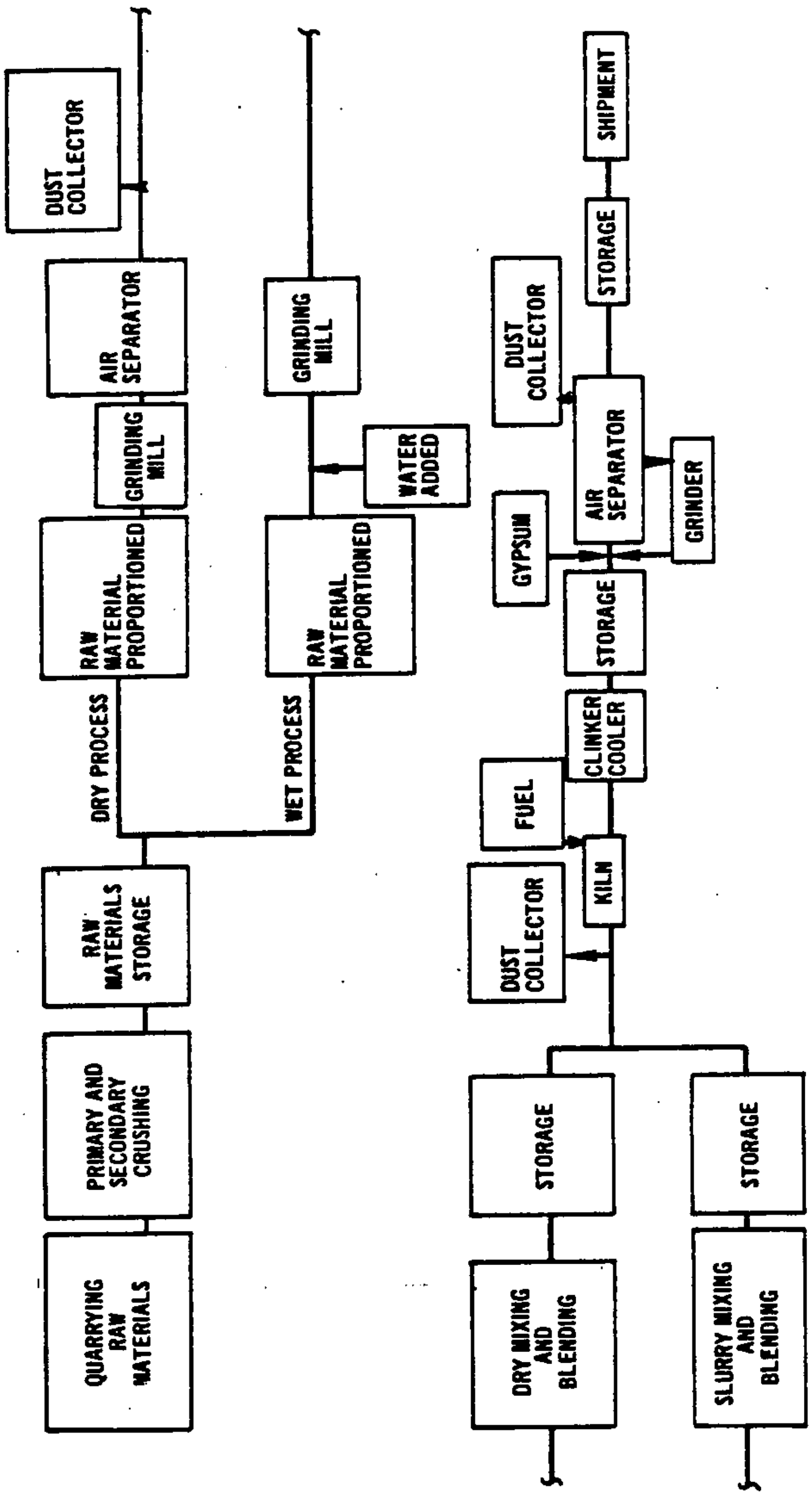

Figure 8.6-1. Basic flow diagram of portland cement manufacturing process.

preheater systems. A dry process kiln with a preheater system can use 50 percent less fuel than a wet process kiln.

8.6.2 Emissions And Controls[1-2,5]

Particulate matter is the primary emission in the manufacture of Portland cement. Emissions also include the normal combustion products of the fuel used for heat in the kiln and in drying operations, including oxides of nitrogen and small amounts of oxides of sulfur.

Sources of dust at cement plants are 1) quarrying and crushing, 2) raw material storage, 3) grinding and blending (dry process only), 4) clinker production and cooling, 5) finish grinding, and 6) packaging. The largest single point of emissions is the kiln, which may be considered to have three units, the feed system, the fuel firing system, and the clinker cooling and handling system. The most desirable method of disposing of the dust collected by an emissions control system is injection into the kiln burning zone for inclusion in the clinker. If the alkali content of the raw materials is too high, however, some of the dust is discarded or treated before its return to the kiln. The maximum alkali content of dust that can be recycled is 0.6 percent (calculated as sodium oxide). Additional sources of dust emissions are quarrying, raw material and clinker storage piles, conveyors, storage silos, loading/unloading facilities, and paved/unpaved roads.

The complications of kiln burning and the large volumes of material handled have led to the use of many control systems for dust collection. The cement industry generally uses mechanical collectors, electric precipitators, fabric filter (baghouse) collectors, or combinations of these to control emissions.

To avoid excessive alkali and sulfur buildup in the raw feed, some systems have an alkali bypass exhaust gas system added between the kiln and the preheater. Some of the kiln exhaust gases are ducted to the alkali bypass before the preheater, thus reducing the alkali fraction passing through the feed. Particulate emissions from the bypass are collected by a separate control device.

Tables 8.6-1 through 8.6-4 give emission factors for cement manufacturing, including factors based on particle size. Size distributions for particulate emissions from controlled and uncontrolled kilns and clinker coolers are also shown in Figures 8.6-2 and 8.6-3.

Sulfur dioxide (SO_2) may come from sulfur compounds in the ores and in the fuel combusted. The sulfur content of both will vary from plant to plant and from region to region. Information on the efficacy of particulate control devices on SO_2 emissions from cement kilns is inconclusive. This is because of variability of factors such as feed sulfur content, temperature, moisture, and feed chemical composition. Control extent will vary, of course, according to the alkali and sulfur content of the raw materials and fuel.[6]

Nitrogen oxides (NO_x) are also formed during fuel combustion in rotary cement kilns. The NO_x emissions result from the oxidation of nitrogen in the fuel (fuel NO_x) as well as in incoming combustion air (thermal NO_x). The quantity of NO_x formed depends on the type of fuel, its nitrogen content, combustion temperature, etc. Like SO_2, a certain portion of the NO_x reacts with the alkaline cement and thus is removed from the gas stream.

TABLE 8.6-1. UNCONTROLLED EMISSION FACTORS FOR CEMENT MANUFACTURING[a]

EMISSION FACTOR RATING: E

Process	Particulate[b]		Sulfur dioxide[c]: Mineral source[d]		Sulfur dioxide[c]: Gas combustion		Sulfur dioxide[c]: Oil combustion		Sulfur dioxide[c]: Coal combustion		Nitrogen oxides		Lead	
	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
Dry process kiln	128	256	5.4	10.8	Neg	Neg	2.2S	4.4S	3.6S	7.2S	1.4	2.8	0.06	0.12
Wet process kiln	120	240	5.4	10.8	Neg	Neg	2.2S	4.4S	3.6S	7.2S	1.4	2.8	0.05	0.10
Clinker cooler[e]	4.6	9.2	-	-	-	-	-	-	-	-	-	-	-	-
Dryers, grinders, etc.[f]														
Wet process	16.0	32.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.01	0.02
Dry process	48.0	96.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.02	0.04

[a] References 1-2. Expressed in terms of units of clinker produced, assuming 5% gypsum in finished cement. Includes fuel combustion emissions, which should not be calculated separately. Neg = negligible. S = % sulfur in fuel. Dash = no data. NA = not applicable.

[b] Emission Factor Rating: B

[c] Factors account for reactions with alkaline dust, with no controls. One test series for gas and oil fired wet process kilns, with limited data, suggests that 21-45% of SO_2 can be removed by reactions with the alkaline filter cake, if baghouses are used.

[d] From sulfur in raw materials, which varies with their sources. Factors account for some residual sulfur, because of its alkalinity and affinity for SO_2.

[e] Reference 8. Emission Factor Rating: D.

[f] Expressed in terms of units of cement produced.

TABLE 8.6-2. CONTROLLED PARTICULATE EMISSION FACTORS FOR CEMENT MANUFACTURING[a]

Type of source	Control technology	Particulate kg/Mg clinker	Particulate lb/ton clinker	Emission Factor Rating
Wet process kiln	Baghouse	0.57	1.1	C
	ESP	0.39	0.78	C
Dry process kiln	Multiclone	130[b]	260[b]	D
	Multicyclone + ESP	0.34	0.68	C
	Baghouse	0.16	0.32	B
Clinker cooler	Gravel bed filter	0.16	0.32	C
	ESP	0.048	0.096	D
	Baghouse	0.010	0.020	C
Primary limestone crusher[c]	Baghouse	0.00051	0.0010	D
Primary limestone screen[c]	Baghouse	0.00011	0.00022	D
Secondary limestone screen and crusher[c]	Baghouse	0.00016	0.00032	D
Conveyor transfer[c]	Baghouse	0.000020	0.000040	D
Raw mill system[c,d]	Baghouse	0.034	0.068	D
Finish mill system[e]	Baghouse	0.017	0.034	C

[a]Reference 8. Expressed as kg particulate/Mg (lb particulate/ton) of clinker produced, except as noted. ESP = electrostatic precipitator.
[b]Based on a single test of a dry process kiln fired with a combination of coke and natural gas. Not generally applicable to a broad cross section of the cement industry.
[c]Expressed as mass of pollutant/mass of raw material processed.
[d]Includes mill, air separator and weigh feeder.
[e]Includes mill, air separator(s) and one or more material transfer operations. Expressed in terms of units of cement produced.

TABLE 8.6-3. SIZE SPECIFIC PARTICULATE EMISSION FACTORS FOR CEMENT KILNS[a]

EMISSION FACTOR RATING: D

Particle size (um)	Cumulative mass % < stated size[b]					
	Uncontrolled		Dry process kiln with multiclone[d]	Wet process kiln with ESP	Baghouse	
	Wet process kiln	Dry process kiln			Wet process kiln	Dry process kiln
2.5	7.0	18	3.8	64	NA	45
5.0	20	NA	14	83	NA	77
10.0	24	42	24	85	NA	84
15.0	35	44	31	91	NA	89
20.0	57	NA	38	98	NA	100

Particle size (um)	Cumulative emission factor < stated size[c]											
	Uncontrolled				Dry process with multiclone[d]		Wet process with ESP		Baghouse			
	Wet Process		Dry Process						Wet process		Dry process	
	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
2.5	8.4	17	23	46	5.0	10	0.25	0.50	NA	NA	0.073	0.15
5.0	24	48	-	-	19	38	0.32	0.64	NA	NA	0.13	0.26
10.0	29	58	54	108	32	64	0.33	0.66	NA	NA	0.14	0.28
15.0	43	86	57	114	41	82	0.36	0.72	NA	NA	0.15	0.30
20.0	68	136	-	-	49	98	0.39	0.78	NA	NA	0.16	0.32
Total mass emission factor	120[e]	240[e]	128[e]	256[e]	130[f]	260[f]	0.39[f]	0.78[f]	0.57[f]	1.1[f]	0.16[f]	0.32[f]

[a]Reference 8. ESP = electrostatic precipitator. NA = not available. Dash = no data.
[b]Aerodynamic diameter. Percentages rounded to two significant figures.
[c]Expressed as unit weight of particulate/unit weight of clinker produced, assuming 5% gypsum in finished cement. Rounded to two significant figures.
[d]Based on a single test, and should be used with caution.
[e]From Table 8.6-1.
[f]From Table 8.6-2.

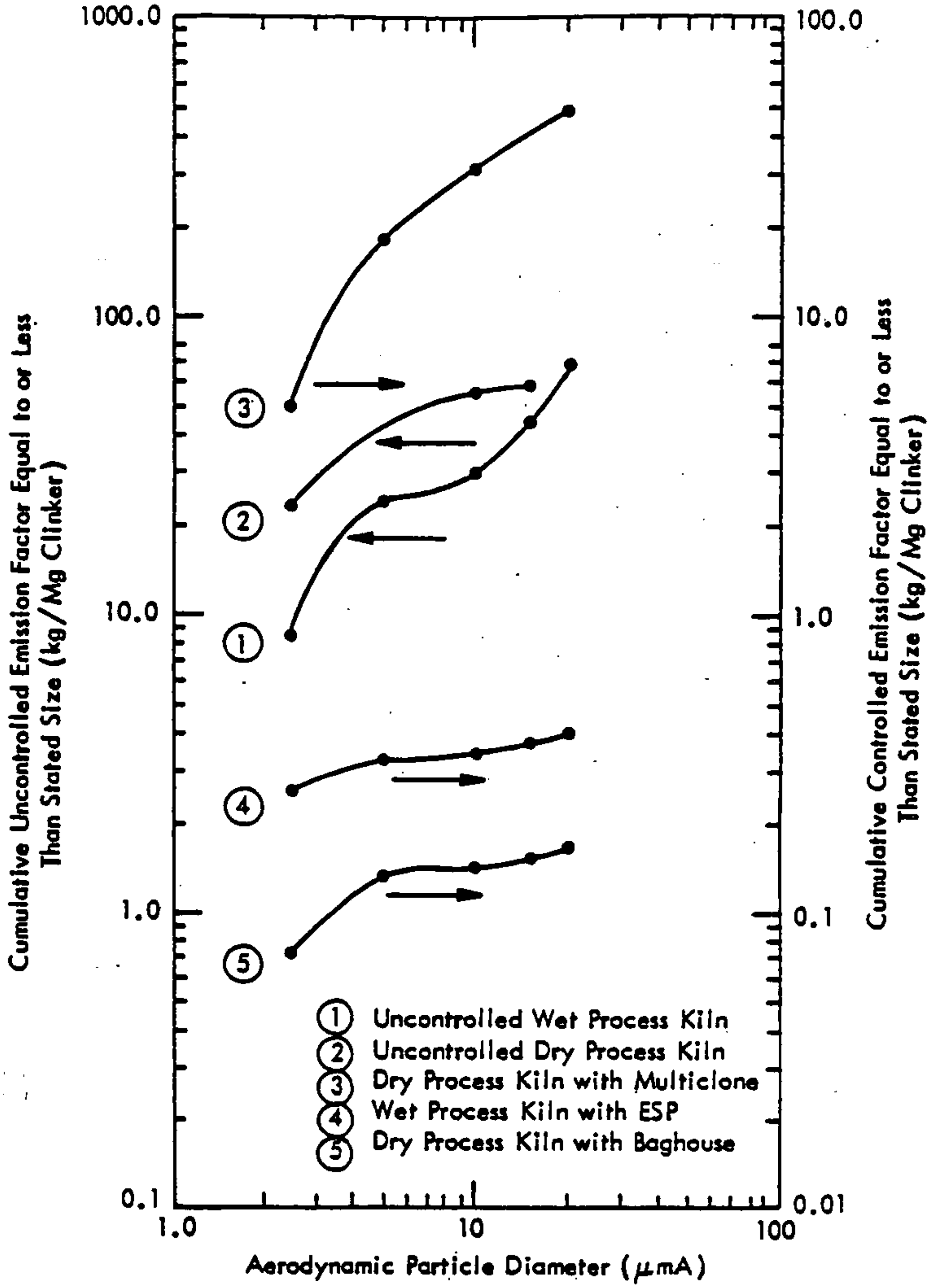

Figure 8.6-2. Size specific emission factors for cement kilns.

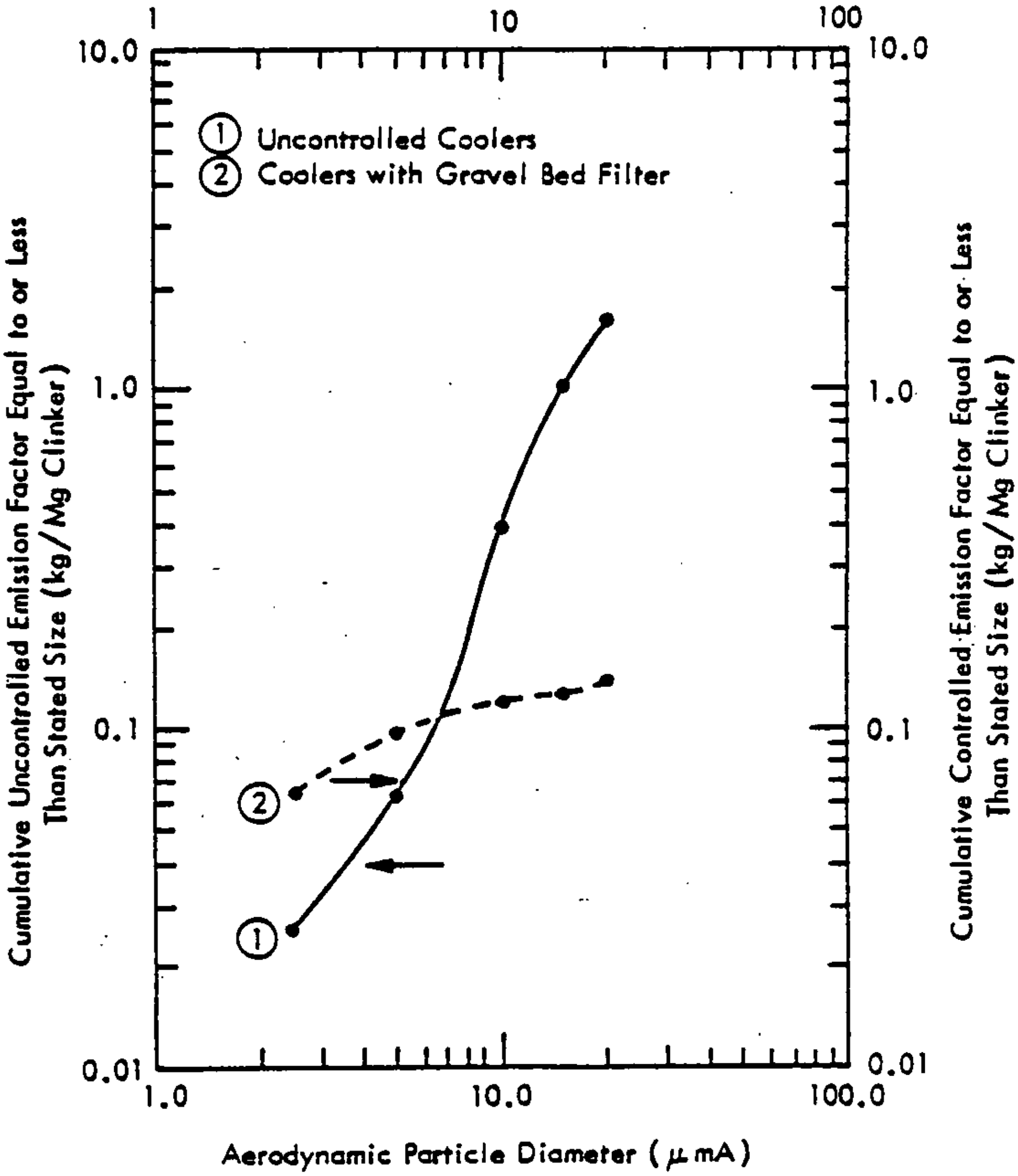

Figure 8.6-3. Size specific emission factors for clinker coolers.

TABLE 8.6-4. SIZE SPECIFIC EMISSION FACTORS FOR CLINKER COOLERS[a]

EMISSION FACTOR RATING: E

Particle size[b] (um)	Cumulative mass % < stated size[c]		Cumulative emission factor < stated size[d]			
	Uncontrolled	Gravel bed filter	Uncontrolled		Gravel bed filter	
			kg/Mg	lb/ton	kg/Mg	lb/ton
2.5	0.54	40	0.025	0.050	0.064	0.13
5.0	1.5	64	0.067	0.13	0.10	0.20
10.0	8.6	76	0.40	0.80	0.12	0.24
15.0	21	84	0.99	2.0	0.13	0.26
20.0	34	89	1.6	3.2	0.14	0.28
Total mass emission factor			4.6[e]	9.2[e]	0.16[f]	0.32[f]

[a]Reference 8.
[b]Aerodynamic diameter
[c]Rounded to two significant figures.
[d]Unit weight of pollutant/unit weight of clinker produced. Rounded to two significant figures.
[e]From Table 8.6-1.
[f]From Table 8.6-2.

References for Section 8.6

1. T. E. Kreichelt, et al., Atmospheric Emissions from the Manufacture of Portland Cement, 999-AP-17, U. S. Environmental Protection Agency, Cincinnati, OH, 1967.

2. Background Information For Proposed New Source Performance Standards: Portland Cement Plants, APTD-0711, U. S. Environmental Protection Agency, Research Triangle Park, NC, August 1971.

3. A Study of the Cement Industry in the State of Missouri, Resources Research, Inc., Reston, VA, December 1967.

4. Portland Cement Plants - Background Information for Proposed Revisions to Standards, EPA-450/3-85-003a, U. S. Environmental Protection Agency, Research Triangle Park, NC, May 1985.

5. Standards of Performance for New Stationary Sources, 36 FR 28476, December 23, 1971.

6. Particulate Pollutant System Study, Volume I, APTD 0743, U. S. Environmental Protection Agency, Research Triangle Park, NC, May 1971.

7. Restriction of Emissions from Portland Cement Works, VDI Richtlinien, Duesseldorf, West Germany, February 1967.

8. J. S. Kinsey, Lime and Cement Industry - Source Category Report, Vol. II, EPA Contract No. 68-02-3891, Midwest Research Institute, Kansas City, MO, August 14, 1986.

APPENDIX A

EXCERPTS FROM REFERENCE DOCUMENTS USED IN THE DEVELOPMENT OF PARTICULATE EMISSION FACTORS

Excerpts from

REFERENCE 10 (SECTION 4.0)

Emissions from Wet Process Cement Kiln and Clinker Cooler at Maule Industries, Hialeah, Florida, ETB Test No. 71-MM-01, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1972.

TABLE I

RESULTS FOR CLINKER COOLER STACK NO. 1

Run Number	1	2	3
Date	2-25-71	2-25-71	2-25-71
Percent Excess Air	NA	NA	NA
Percent Isokinetic	106.2	110.0	103.7
Stack Flow Rate - SCFM* dry	19,473	17,369	18,996
Stack Flow Rate - ACFM wet	23,898	21,360	23,216
Volume of Dry Gas Sampled - SCF*	74.90	69.25	71.41
Feed Rate - tons/hr	41.2	41.2	41.2
Particulates			
Probe, Cyclone, & Filter Catch			
mg	128	127	94
gr/SCF* dry	0.0263	0.0282	0.0203
gr/CF @ Stack Conditions	0.0214	0.0229	0.0166
lbs/hr	4.381	4.203	3.286
lbs/ton feed	0.106	0.102	0.0798
Total Catch			
mg	134	138	104
gr/SCF* dry	0.0276	0.0307	0.0224
gr/CF @ Stack Conditions	0.0224	0.0249	0.0183
lbs/hr	4.596	4.551	3.647
lbs/ton feed	0.112	0.110	0.0885
% Impinger Catch	4.5	8.0	9.6

Data used in Table 4-1.

*70°F, 29.92" Hg
NA - Not Applicable

TABLE II

RESULTS FOR KILN STACK NO. 1

Run Number	1	2	3
Date	2-26-71	2-26-71	2-26-71
Percent Excess Air	181	181	181
Percent Isokinetic	96.1	94.5	96.2
Stack Flow Rate - SCFM* dry	55,031	54,413	52,018
Stack Flow Rate - ACFM wet	126,208	122,704	118,324
Volume of Dry Gas Sampled - SCF*	48.84	47.49	46.17
Feed Rate - tons/hr	40.3	40.3	40.3
Particulates			
Probe, Cyclone, & Filter Catch			
mg	172	272	488
gr/SCF* dry	0.0542	0.0882	0.163
gr/CF @ Stack Conditions	0.0236	0.0391	0.0715
lbs/hr	25.53	41.08	72.51
lbs/ton feed	0.634	1.019	1.799
Total Catch			
mg	189	321	518
gr/SCF* dry	0.0596	0.104	0.173
gr/CF @ Stack Conditions	0.0260	0.0461	0.0759
lbs/hr	28.07	48.54	76.99
lbs/ton feed	0.696	1.204	1.910
% Impinger Catch	9.0	15.3	5.8

Data used in Table 4-1.

* 70°F, 29.92" Hg

Excerpts from

REFERENCE 17 (SECTION 4.0)

Emissions from Dry Process Raw Mill and Finish Mill Systems at Ideal Cement Company, Tijeras, New Mexico, ETB Test No. 71-MM-02, U.S. Environmental Protection Agency, Research Triangle Park, NC, April 1972.

Table 4

SUMMARY OF PARTICULATE DATA FOR NO. 2 FINISH MILL

Run Number	1 (TRIAL)	2	3
Date	3-2-71	3-3-71	3-3-71
Percent Excess Air	—	—	—
Percent Isokinetic	105.0	102.9	103.6
Stack Flow Rate - SCFM* dry	4886	5261	5089
Stack Flow Rate - ACFM wet	6406	6843	6631
Volume of Dry Gas Sampled - SCF*	36.62	115.95	112.88
Feed Rate - tons/hr	Not Measured	34.6	34.6
Particulates			
Probe, Cyclone, & Filter Catch			
mg	39.7	34.7	35.0
gr/SCF* dry	0.0167	0.00461	0.00477
gr/CF @ Stack Conditions	0.0127	0.00354	0.00366
lbs/hr.	0.699	0.208	0.208
lbs/ton feed	--	0.00601	0.00601
Total Catch			
mg	74.6	51.0	51.2
gr/SCF* dry	0.0314	0.00677	0.00698
gr/CF @ Stack Conditions	0.0239	0.00520	0.00536
lbs/hr	1.31	0.305	0.304
lbs/ton feed	--	0.00882	0.00879
% Impinger Catch	46.8	32.0	31.6

Data used in Table 4-1.

* 70°F, 29.92" Hg

Table 5

SUMMARY OF PARTICULATE DATA FOR NO. 2 FINISH MILL AIR SEPARATOR

Run Number	1	2
Date	3-6-71	3-6-71
Percent Excess Air	—	—
Percent Isokinetic	114.3	111.6
Stack Flow Rate - SCFM* dry	14,178	13,838
Stack Flow Rate - ACFM wet	19,267	18,842
Volume of Dry Gas Sampled - SCF*	77.56	73.95
Feed Rate - tons/hr	32.8	32.8
Particulates		
Probe, Cyclone, & Filter Catch		
mg	23.6	21.8
gr/SCF* dry	0.00468	0.00454
gr/CF @ Stack Conditions	0.00344	0.00333
lbs/hr.	0.569	0.538
lbs/ton feed	0.0173	0.0164
Total Catch		
mg	44.1	41.6
gr/SCF* dry	0.00876	0.00866
gr/CF @ Stack Conditions	0.00644	0.00636
lbs/hr	1.063	1.024
lbs/ton feed	0.0324	0.0312
% Impinger Catch	46.5	47.6

Data used in Table 4-1.

* 70°F, 29.92" Hg

Table 6

SUMMARY OF PARTICULATE DATA FOR NO. 2 FINISH MILL FEED-O-WEIGHT

Run Number	1	2
Date	3-8-71	3-8-71
Percent Excess Air	NA	NA
Percent Isokinetic	106.2	103.5
Stack Flow Rate - SCFM* dry	10,517	10,587
Stack Flow Rate - ACFM wet	12,791	12,936
Volume of Dry Gas Sampled - SCF*	100.34	98.39
Feed Rate - tons/hr	28.7	28.7
Particulates		
Probe, Cyclone, & Filter Catch		
mg	20.1	18.8
gr/SCF* dry	0.00308	0.00294
gr/CF @ Stack Conditions	0.00253	0.00240
lbs/hr.	0.273	0.265
lbs/ton feed	0.00953	0.00922
Total Catch		
mg	33.7	31.1
gr/SCF* dry	0.00517	0.00487
gr/CF @ Stack Conditions	0.00425	0.00398
lbs/hr	0.463	0.434
lbs/ton feed	0.0161	0.0151
% Impinger Catch	40.4	39.5

Data used in Table 4-1.

* 70°F, 29.92" Hg

Table 1

SUMMARY OF PARTICULATE DATA FOR NO. 2 RAW MILL

Run Number	1	2
Date	3-9-71	3-10-71
Percent Excess Air	—	—
Percent Isokinetic	109.6	108.2
Stack Flow Rate - SCFM* dry	3177	3210
Stack Flow Rate - ACFM wet	4684	4708
Volume of Dry Gas Sampled - SCF*	84.47	79.33
Feed Rate - tons/hr	53.1	57.2
Particulates		
Probe, Cyclone, & Filter Catch		
mg	172.5	197.1
gr/SCF* dry	0.0314	0.0383
gr/CF @ Stack Conditions	0.0213	0.0261
lbs/hr.	0.855	1.049
lbs/ton feed	0.0161	0.0183
Total Catch		
mg	201.1	213.9
gr/SCF* dry	0.0367	0.0415
gr/CF @ Stack Conditions	0.0248	0.0283
lbs/hr	0.998	1.140
lbs/ton feed	0.0188	0.0199
% Impinger Catch	14.2	7.9

Data used in Table 4-1.

* 70°F, 29.92" Hg

Table 2

SUMMARY OF PARTICULATE DATA FOR NO. 2 RAW-MILL AIR SEPARATOR

Run Number	1	2
Date	3-11-71	3-11-71
Percent Excess Air	—	—
Percent Isokinetic	98.6	100.3
Stack Flow Rate - SCFM* dry	9799	9615
Stack Flow Rate - ACFM wet	14,902	14,623
Volume of Dry Gas Sampled - SCF*	83.56	83.42
Feed Rate - tons/hr	62.1	62.1
Particulates		
Probe, Cyclone, & Filter Catch		
mg	151.0	108.2
gr/SCF* dry	0.0278	0.0199
gr/CF @ Stack Conditions	0.0183	0.0131
lbs/hr.	2.332	1.644
lbs/ton feed	0.0376	0.0265
Total Catch		
mg	163.7	121.2
gr/SCF* dry	0.0302	0.0224
gr/CF @ Stack Conditions	0.0198	0.0147
lbs/hr	2.528	1.836
lbs/ton feed	0.0407	0.0296
% Impinger Catch	7.8	10.7

Data used in Table 4-1.

* 70°F, 29.92" Hg

Table 3

SUMMARY OF PARTICULATE DATA FOR NO. 2 RAW MILL FEED-O-WEIGHT

Run Number	1	2
Date	3-5-71	3-5-71
Percent Excess Air	—	—
Percent Isokinetic	107.8	110.9
Stack Flow Rate - SCFM* dry	9646	9588
Stack Flow Rate - ACFM wet	12,250	12,256
Volume of Dry Gas Sampled - SCF*	89.47	91.51
Feed Rate - tons/hr	62.7	62.7
Particulates		
Probe, Cyclone, & Filter Catch		
mg	99.7	69.5
gr/SCF* dry	0.0172	0.0117
gr/CF @ Stack Conditions	0.0135	0.00914
lbs/hr.	1.418	0.959
lbs/ton feed	0.0226	0.0153
Total Catch		
mg	112.1	81.6
gr/SCF* dry	0.0193	0.0137
gr/CF @ Stack Conditions	0.0152	0.0107
lbs/hr	1.592	1.122
lbs/ton feed	0.0254	0.0179
% Impinger Catch	11.1	14.8

Data used in Table 4-1.

* 70°F, 29.92" Hg

Excerpts from

REFERENCE 11 (SECTION 4.0)

Emissions from Wet Process Cement Kiln and Clinker Cooler at Ideal Cement Company, Seattle, Washington, ETB Test No. 71-MM-03, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1972.

TABLE 1

SUMMARY OF PARTICULATE DATA FOR CLINKER COOLER

Run number	1	2	3
Date	3-18-71	3-19-71	3-19-71
Percent Excess Air	NA	NA	NA
Percent Isokinetic	105.7	105.3	101.9
Stack Flow Rate-SCFM* dry	95,699	94,971	94,100
Stack Flow Rate-ACFM wet	108,307	105,121	104,555
Volume of Dry Gas Sampled SCF*	105.39	104.21	100.03
Feed Rate - tons/hr	103.4	102.8	104.9
Particulates			
Probe, Cyclone, & Filter Catch			
mg	351.0	386.0	453.3
gr/SCF* dry	0.0513	0.0571	0.0698
gr/CF @Stack Conditions	0.0453	0.0516	0.0628
lbs/hr	42.0	46.4	56.3
lbs/ton feed	0.406	0.452	0.536
Total Catch			
mg	374.3	400.6	462.7
gr/SCF* dry	0.0547	0.0592	0.0712
gr/CF @Stack Conditions	0.0483	0.0534	0.0641
lbs/hr	44.8	48.2	57.4
lbs/ton feed	0.433	0.468	0.547
% Impinger Catch	6.22	3.49	2.03

Data used in Table 4-1.

* 70°F, 29.92" Hg
NA--Not Applicable.

TABLE 2

SUMMARY OF PARTICULATE DATA FOR KILN STACK

Run Number	1	2
Date	3-24-71	3-24-71
Percent Excess Air	67.8	67.8
Percent Isokinetic	93.5	89.9
Stack Flow Rate - SCFM* dry	107,179	103,085
Stack Flow Rate - ACFM wet	286,431	288,505
Volume of Dry Gas Sampled - SCF*	39.69	36.68
Feed Rate - tons/hr	101.7	101.7
Particulates		
Probe, Cyclone, & Filter Catch		
mg	241	253.5
gr/SCF* dry	0.0935	0.1064
gr/CF @Stack Conditions	0.0350	0.0380
lbs/hr	85.9	94.0
lbs/ton feed	0.844	0.924
Total Catch		
mg	262	281.8
gr/SCF* dry	0.1016	0.1183
gr/CF @Stack Conditions	0.0380	0.0422
lbs/hr	93.4	104.4
lbs/ton feed	0.918	1.027
% Impinger Catch	8.01	10.04

Data used in Table 4-1.

* $70^{\circ}F$, 29.92" Hg

Excerpts from

REFERENCE 12 (SECTION 4.0)

Emissions from Wet Process Cement Kiln and Finish Mill Systems at Ideal Cement Company, Castle Hayne, North Carolina, ETB Test No. 71-MM-04, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1972.

SUMMARY OF PARTICULATE DATA FOR NO. 1 MILL AIR SEPARATOR STACK A

Run Number	1	2	3
Date	4-13-71	4-14-71	4-14-71
Percent Excess Air	—	—	—
Percent Isokinetic	96.9	100.8	97.4
Stack Flow Rate - SCFM* dry	14,478	14,876	14,453
Stack Flow Rate - ACFM wet	17,554	17,636	16,677
Volume of Dry Gas Sampled - SCF*	56.931	60.857	54.777
Feed Rate - tons/hr	30.0	28.6	30.1
Particulates			
Probe, Cyclone, & Filter Catch			
mg	11.8	22.9	21.4
gr/SCF* dry	0.00319	0.00579	0.00602
gr/CF @ Stack Conditions	0.00263	0.00488	0.00521
lbs/hr.	0.391	0.729	0.737
lbs/ton feed	0.0130	0.0255	0.0245
Total Catch			
mg	24.1	34.0	35.8
gr/SCF* dry	0.00652	0.00860	0.01010
gr/CF @ Stack Conditions	0.00537	0.00725	0.00871
lbs/hr	0.796	1.086	1.243
lbs/ton feed	0.0265	0.0380	0.0413
% Impinger catch	51.0	32.6	40.2

Data used in Table 4-1.

* 70°F, 29.92" Hg

SUMMARY OF PARTICULATE DATA FOR NO. 1 MILL AIR SEPARATOR STACK B

Run Number	1	2	3
Date	4-13-71	4-14-71	4-14-71
Percent Excess Air	—	—	—
Percent Isokinetic	90.7	94.6	95.4
Stack Flow Rate - SCFM* dry	11,700	11,664	11,727
Stack Flow Rate - ACFM wet	13,484	13,554	13,474
Volume of Dry Gas Sampled - SCF*	74.277	77.276	75.106
Feed Rate - tons/hr	30.0	28.6	30.1
Particulates			
Probe, Cyclone, & Filter Catch			
mg	31.2	23.9	24.2
gr/SCF* dry	0.00647	0.00476	0.00496
gr/CF @ Stack Conditions	0.00561	0.00409	0.00431
lbs/hr.	0.643	0.467	0.493
lbs/ton feed	0.0214	0.0163	0.0164
Total Catch			
mg	68.8	39.3	38.9
gr/SCF* dry	0.0122	0.00783	0.00798
gr/CF @ Stack Conditions	0.0106	0.00673	0.00693
lbs/hr	1.217	0.781	0.797
lbs/ton feed	0.0406	0.0273	0.0265
% Impinger Catch	46.9	39.2	37.8

Data used in Table 4-1.

* 70°F, 29.92" Hg

Table 3
SUMMARY OF PARTICULATE DATA FOR NO. 1
MILL-GRINDER and DUST COLLECTOR

Run Number	1	2	3
Date	4-15-71	4-15-71	4-15-71
Percent Excess Air	—	—	—
Percent Isokinetic	103.5	100.1	100.8
Stack Flow Rate - SCFM* dry	5853	6087	5727
Stack Flow Rate - ACFM wet	6827	7073	6739
Volume of Dry Gas Sampled - SCF*	65.059	65.470	61.995
Feed Rate - tons/hr	31.1	30.7	31.7
Particulates			
Probe, Cyclone, & Filter Catch			
mg	35.5	33.7	34.9
gr/SCF* dry	0.00840	0.00793	0.00867
gr/CF @ Stack Conditions	0.00719	0.00681	0.00736
lbs/hr.	0.421	0.408	0.424
lbs/ton feed	0.0135	0.0133	0.0134
Total Catch			
mg	54.2	54.6	56.0
gr/SCF* dry	0.0128	0.0128	0.0139
gr/CF @ Stack Conditions	0.0110	0.0110	0.0118
lbs/hr	0.638	0.669	0.682
lbs/ton feed	0.0205	0.0218	0.0215
% Impinger Catch	34.5	38.3	37.7

Data used in Tble 4-1.

* 70°F, 29.92" Hg

Excerpts from

REFERENCE 13 (SECTION 4.0)

Emissions from Dry Process Cement Kiln at Dragon Cement Company, Northhampton, Pennsylvania, ETB Test No. 71-MM-05, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1972.

TABLE 1

SUMMARY OF PARTICULATE DATA FOR KILN STACK

Run Number	1	2	3
Date	4-29-71	4-29-71	4-30-71
Percent Excess Air	322	322	466
Percent Isokinetic	95.3	95.4	95.4
Stack Flow Rate - SCFM* dry	51,187	50,643	50,013
Stack Flow Rate - ACFM wet	69,470	69,169	69,269
Volume of Dry Gas Sampled - SCF*	89.75	88.92	87.79
Feed Rate - tons/hr	44.03	45.75	42.93
Particulates			
Probe, Cyclone, & Filter Catch			
mg	55.6	34.2	34.6
gr/SCF* dry	0.00954	0.00592	0.00607
gr/CF @ Stack Conditions	0.00702	0.00433	0.00438
lbs/hr	4.146	2.532	2.601
lbs/ton feed	0.0942	0.0553	0.0606
Total Catch			
mg	118.5	106.7	100.1
gr/SCF* dry	0.0203	0.0185	0.0176
gr/CF @ Stack Conditions	0.0150	0.0135	0.0127
lbs/hr	8.907	8.002	7.502
lbs/ton feed	0.202	0.175	0.175
% Impinger Catch	53.1	67.9	65.4

Data used in Table 4-1.

* 70°F, 29.92" Hg

Excerpts from

REFERENCE 14 (SECTION 4.0)

Emissions from Wet Process Clinker Cooler and Finish Mill Systems at Ideal Cement Company, Houston, Texas, ETB Test No. 71-MM-06, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1972.

TABLE I

SUMMARY OF RESULTS FOR CLINKER COOLER

Run Number	1	2	3
Date	5-18-71	5-18-71	5-18-71
Percent Excess Air	NA	NA	NA
Percent Isokinetic	102.1	98.5	98.8
Stack Flow Rate - SCFM* dry	104,057	100,432	102,165
Stack Flow Rate - ACFM wet	127,032	126,664	128,672
Volume of Dry Gas Sampled - SCF	101.07	94.15	96.05
Feed Rate - tons/hr	61.8	62.7	63.7
Particulates			
Probe, Cyclone, & Filter Catch			
mg	11.8	20.5	14.2
gr/SCF* dry	0.00180	0.00335	0.00228
gr/CF @ Stack Conditions	0.00147	0.00266	0.00180
lbs/hr.	1.561	2.812	1.941
lbs/ton feed	0.0253	0.0448	0.0305
Total Catch			
mg	26.3	38.1	23.3
gr/SCF* dry	0.00401	0.00623	0.00373
gr/CF @ Stack Conditions	0.00328	0.00494	0.00296
lbs/hr	3.538	5.323	3.269
lbs/ton feed	0.0572	0.0849	0.0513
% Impinger Catch	55.1	46.2	39.1

Data used in Table 4-1.

* 70°F, 29.92" Hg

NA - Not Applicable

TABLE 2

SUMMARY OF RESULTS FOR FINISH MILL GRINDING SYSTEM

Run Number	1	2	3
Date	5-19-72	5-19-71	5-20-71
Percent Excess Air	NA	NA	NA
Percent Isokinetic	109.0	102.9	98.9
Stack Flow Rate - SCFM* dry	26,360	26,252	26,244
Stack Flow Rate - ACFM wet	35,185	35,679	35,780
Volume of Dry Gas Sampled - SCF	140.35	131.99	126.82
Feed Rate - tons/hr	34.6	33.9	37.2
Particulates			
Probe, Cyclone, & Filter Catch			
mg	22.0	26.9	17.1
gr/SCF* dry	0.00241	0.00314	0.00208
gr/CF @ Stack Conditions	0.00181	0.00231	0.00152
lbs/hr.	0.527	0.683	0.446
lbs/ton feed	0.0152	0.0201	0.0120
Total Catch			
mg	32.9	37.8	27.9
gr/SCF* dry	0.00361	0.00441	0.00339
gr/CF @ Stack Conditions	0.00270	0.00324	0.00248
lbs/hr	0.791	0.971	0.761
lbs/ton feed	0.0229	0.0287	0.0205
% Impinger Catch	33.1	28.8	38.7

Data used in Table 4-1.

* 70°F, 29.92" Hg

NA - Not Applicable

Excerpts from

REFERENCE 15 (SECTION 4.0)

Emissions from Wet Process Cement Kiln at Giant Portland Cement, Harleyville, South Carolina, ETB Test No. 71-MM-07, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1972.

TABLE I

Summary of Combined Particulate Emissions

Kiln fuel	Natural Gas	No. 6 Fuel Oil
Volume of Gas Sampled - DSCF[a]	488.76	464.54
Percent Moisture by Volume	41.43	36.98
Average Stack Temperature - °F	429.	420.
Stack Volumetric Flow Rate - DSCFM[b]	48,132	56,282
Stack Volumetric Flow Rate - ACFM[c]	137,500	146,754
Percent Isokinetic	96.8	90.2
Percent Excess Air	24.90	26.48
Percent Opacity	5-25	5-25
Feed Rate - ton/hr	40.33	40.00
Particulates - probe, cyclone, and filter catch		
mg	1818.3	1375.9
gr/DSCF	0.0524	0.0395
gr/ACF	0.0195	0.0152
lb/hr	21.6	20.5
lb/ton feed	0.536	0.513
Particulates - total catch		
mg	3808.4	2866.5
gr/DSCF	0.117	0.0914
gr/ACF	0.0408	0.350
lb/hr	48.6	45.8
lb/ton feed	1.21	1.14
Percent impinger catch	52.3	52.0

Data used in Table 4-1.

Excerpts from

REFERENCE 16 (SECTION 4.0)

Emissions from Wet Process Cement Kiln at Oregon Portland Cement Company, Lake Oswego, Oregon, ETB Test No. 71-MM-15, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1972.

TABLE I
SUMMARY OF PARTICULATE TESTING

Run Number	4	5	6
Date	10-7,10-8-71	10-8-71	10-8-71
Percent Excess Air	33.0	34.3	34.3
Percent Isokinetic	106.7	101.2	101.6
Stack Flow Rate - SCFM* dry	46,976	54,699	55,577
Stack Flow Rate - ACFM wet	120,135	133,718	135,988
Volume of Dry Gas Sampled - SCF*	73.449	78.702	80.246
Feed Rate - tons/hr	52.1	57.0	58.0
Particulates			
Probe, Cyclone, & Filter Catch			
mg	152.6	192.9	165.4
gr/SCF* dry	0.0319	0.0377	0.0317
gr/CF @ Stack Conditions	0.0125	0.0154	0.0129
lbs/hr.	12.87	17.67	15.12
lbs/ton feed	0.247	0.309	0.261
Total Catch			
mg	330.2	224.4	185.4
gr/SCF* dry	0.0692	0.0439	0.0356
gr/CF @ Stack Conditions	0.0270	0.0179	0.0145
lbs/hr	27.86	20.57	16.90
lbs/ton feed	0.535	0.361	0.291
% Impinger Catch	53.8	14.0	10.8

Data used in Table 4-1.

* 70°F, 29.92" Hg

Excerpts from

REFERENCE 18 (SECTION 4.0)

Air Pollution Emission Test, Arizona Portland Cement, Rillito, Arizona, EPA Project Report 74-STN-1, U.S. Environmental Protection Agency, Research Triangle Park, NC, June 1974.

TABLE 2
SUMMARY OF TEST RESULTS
PRIMARY CRUSHER

Run Number	1	2	3	4
Date	6-4-74	6-10-74	6-11-74	6-12-74
Volume of Gas Sampled - DSCF[a]	286.20	245.71	186.74	141.82
Percent Moisture by Volume	2.4	2.5	3.0	3.3
Average Stack Temperature - °F	79.0	81.0	88.0	88.0
Stack Volumetric Flow Rate - DSCFM[b]	23,469	22,351	22,140	22,502
Stack Volumetric Flow Rate - ACFM[c]	27,198	26,430	26,653	27.142
Percent Isokinetic	114.3	109.1	104.7	104.3
Percent Excess Air	---	---	---	---
Percent Opacity	0	0	0	0
Feed Rate - ton/hr	978.0	994.0	1028.0	1010.0
Particulates - probe, and filter catch				
mg	66.06	75.13	61.13	66.91
gr/DSCF	0.00355	0.00471	0.00504	0.00727
gr/ACF	0.00307	0.00398	0.00419	0.00602
lb/hr	0.77[d]	0.90	0.96	1.40
lb/ton feed	0.00079	0.00091	0.00093	0.00139
Particulates - total catch				
mg	72.61	e	72.34	77.25
gr/DSCF	0.00391	e	0.00597	0.00839
gr/ACF	0.00337	e	0.00495	0.00695
lb/hr	0.85[d]	e	1.13	1.62
lb/ton feed	0.00087	e	0.00110	0.00160
Percent impinger catch	9.0	e	15.5	13.4

Data used in Table 4-1.

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

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

[c] Actual cubic feet per minute

[d] Calculated by averaging the concentration and area ratio results

[e] Impinger water erroneously discarded

TABLE 3
SUMMARY OF TEST RESULTS
PRIMARY SCREEN

Run Number	1	2	3	4
Date	6-4-74	6-10-74	6-11-74	6-12-74
Volume of Gas Sampled - DSCF[a]	328.07	331.80	257.81	196.69
Percent Moisture by Volume	1.7	1.4	2.1	2.5
Average Stack Temperature - °F	82.0	90.0	90.0	94.0
Stack Volumetric Flow Rate - DSCFM[b]	13,636	13,368	13,246	13,196
Stack Volumetric Flow Rate - ACFM[c]	15,682	15,797	15,771	15,866
Percent Isokinetic	116.8	115.1	111.5	113.8
Percent Excess Air	---	---	---	---
Percent Opacity	0	0	0	0
Feed Rate - ton/hr	967.0	965.0	1023.0	1056.0
Particulates - probe, and filter catch				
mg	27.82	37.94	31.51	28.34
gr/DSCF	0.00131	0.00176	0.00188	0.00222
gr/ACF	0.00113	0.00149	0.00158	0.00184
lb/hr	0.17[d]	0.22[d]	0.23[d]	0.27[d]
lb/ton feed	0.00018	0.00023	0.00022	0.00026
Particulates - total catch				
mg	30.38	e	39.28	40.11
gr/DSCF	0.00143	e	0.00235	0.00314
gr/ACF	0.00124	e	0.00197	0.00261
lb/hr	0.19[d]	e	0.29[d]	0.39[d]
lb/ton feed	0.00020	e	0.00028	0.00037
Percent impinger catch	8.4	e	19.8	29.3

Data used in Table 4-1.

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

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

[c] Actual cubic feet per minute

[d] Calculated by averaging the concentration and area ratio results

[e] Impinger water erroneously discarded

TABLE 4
SUMMARY OF TEST RESULTS
PRIMARY TRANSFER CONVEYOR

Run Number	1	2	3
Date	6-10-74	6-11-74	6-12-74
Volume of Gas Sampled - DSCF[a]	273.32	223.12	231.50
Percent Moisture by Volume	2.4	2.4	2.3
Average Stack Temperature - °F	98.0	101.0	97.0
Stack Volumetric Flow Rate - DSCFM[b]	1,900.	1,902.	2,003.
Stack Volumetric Flow Rate - ACFM[c]	2,303.	2,313.	2,422.
Percent Isokinetic	105.9	107.9	106.3
Percent Excess Air	---	---	---
Percent Opacity	0	0	0
Feed Rate - ton/hr	909.0	914.0	873.0
Particulates - probe, and filter catch			
mg	16.83	23.54	31.14
gr/DSCF	0.00095	0.00162	0.00207
gr/ACF	0.00078	0.00134	0.00171
lb/hr	0.02	0.03	0.04
lb/ton feed	0.00002	0.00003	0.00004
Particulates - total catch			
mg	d	27.59	38.93
gr/DSCF	d	0.00190	0.00259
gr/ACF	d	0.00156	0.00214
lb/hr	d	0.03	0.04
lb/ton feed	d	0.00003	0.00005
Percent impinger catch	d	14.7	20.0

Data used in Table 4-1.

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

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

[c] Actual cubic feet per minute

[d] Impinger water erroneously discarded

TABLE 5
SUMMARY OF TEST RESULTS
SECONDARY SCREEN AND CRUSHER

Run Number	1	2	3
Date	6-6-74	6-7-74	6-8-74
Volume of Gas Sampled - DSCF[a]	201.05	173.87	216.14
Percent Moisture by Volume	2.3	2.2	2.1
Average Stack Temperature - °F	81.0	77.0	80.0
Stack Volumetric Flow Rate - DSCFM[b]	9,277.	8,711.	9,656.
Stack Volumetric Flow Rate - ACFM[c]	10,579.	9,971.	11,045.
Percent Isokinetic	102.2	99.8	105.6
Percent Excess Air	---	---	---
Percent Opacity	0	0	0
Feed Rate - ton/hr	170.0	162.0	152.0
Particulates - probe, and filter catch			
mg	4.69	8.44	10.44
gr/DSCF	0.00036	0.00075	0.00074
gr/ACF	0.00031	0.00065	0.00065
lb/hr	0.03	0.06	0.06
lb/ton feed	0.00017	0.00034	0.00041
Particulates - total catch			
mg	6.12	12.25	d
gr/DSCF	0.00047	0.00109	d
gr/ACF	0.00041	0.00095	d
lb/hr	0.04	0.08	d
lb/ton feed	0.00022	0.00050	d
Percent impinger catch	23.4	31.1	d

Data used in Table 4-1.

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

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

[c] Actual cubic feet per minute

Excerpts from

REFERENCE 20 (SECTION 4.0)

Nichols, G. B., and J. D. McCain, Particulate Collection Efficiency Measurements on Three Electrostatic Precipitators, EPA-600/2-75-056 (NTIS PB 248 220), U.S. Environmental Protection Agency, Washington, D.C., October 1975.

Data used in Table 4-2.

FPEIS TEST SERIES NO: 00080   STREAM NO: 01   TEST ID NO: 2   SAMPLE NO: 01   SERIES FORM C7   PAGE 20   DATE 05/25/83

PARTICLE SIZE TABLE---------

STAGE #	1	2	3	4	5	6	7	8	9
D50(MICRONS)	11.49	8.11	4.59	2.70	1.86	.97	.68	.25	.13
MICROGRAMS/DNCM/STAGE	2.55E+07	7.46E+06	4.75E+06	3.76E+06	1.65E+06	9.37E+05	4.11E+05	7.20E+05	5.69E+05
NUMBER/DNCM/STAGE	4.82E+11	6.09E+12	1.54E+13	6.33E+13	1.08E+14	2.84E+14	5.64E+14	7.55E+15	7.13E+16
CUM. %MASS<D50									
CUM. MICROGRAMS/DNCM<D50	2.03E+07	1.28E+07	8.05E+06	4.29E+06	2.64E+06	1.70E+06	1.29E+06	5.69E+05	0.00E+00
GEOM D50	3.39E+01	9.65E+00	6.10E+00	3.52E+00	2.24E+00	1.34E+00	8.12E-01	4.12E-01	1.80E-01
DM/DLOGD-(UG/DNM3)	2.71E+07	4.93E+07	1.92E+07	1.63E+07	1.02E+07	3.31E+06	2.66E+06	1.66E+06	2.00E+06
DN-LOGD/(NUMBER/DNM3)	5.13E+11	4.03E+13	6.21E+13	2.75E+14	6.65E+14	1.00E+15	3.65E+15	1.74E+16	2.51E+17

FPEIS TEST SERIES NO: 00080 STREAM NO: 01 TEST ID NO: 2 SAMPLE NO: 02

SERIES FORM C7

PARTICLE SIZE TABLE---------

STAGE #	1	2	3	4	5	6	7	8	9
D50(MICRONS)	11.49	8.11	4.59	2.70	1.86	.97	.68	.25	.13
MICROGRAMS/DNCM/STAGE	2.17E+06	4.23E+05	4.15E+05	5.02E+05	3.64E+05	2.61E+05	2.41E+05	2.02E+05	3.44E+05
NUMBER/DNCM/STAGE	4.10E+10	3.45E+11	1.34E+12	8.45E+12	2.38E+13	7.91E+13	3.30E+14	2.12E+15	4.31E+16
CUM. %MASS<D50									
CUM. MICROGRAMS/DNCM<D50	2.75E+06	2.33E+06	1.91E+06	1.41E+06	1.05E+06	7.87E+05	5.46E+05	3.44E+05	0.00E+00
GEOM D50	3.39E+01	9.65E+00	6.10E+00	3.52E+00	2.24E+00	1.34E+00	8.12E-01	4.12E-01	1.80E-01
DM/DLOGD-(UG/DNM3)	2.31E+06	2.80E+06	1.68E+06	2.18E+06	2.25E+06	9.23E+05	1.56E+06	4.65E+05	1.21E+06
DN-LOGD/(NUMBER/DNM3)	4.36E+10	2.28E+12	5.43E+12	3.67E+13	1.47E+14	2.80E+14	2.14E+15	4.87E+15	1.52E+17

Data used in Table 4-2.

FPEIS TEST SERIES NO: 00080   STREAM NO: 01   TEST ID NO: 3   SAMPLE NO: 01

SERIES FORM C7

PARTICLE SIZE TABLE---------

STAGE #	1	2	3	4	5	6	7	8	9
D50(MICRONS)	10.80	7.62	4.32	2.54	1.75	.91	.64	.24	.12
MICROGRAMS/DNCM/STAGE	2.47E+07	7.89E+06	3.17E+06	2.18E+06	1.26E+06	1.03E+06	6.61E+05	3.07E+05	2.97E+05
NUMBER/DNCM/STAGE	5.12E+11	7.76E+12	1.23E+13	4.41E+13	9.88E+13	3.76E+14	1.09E+15	3.75E+15	4.46E+16
CUM. %MASS<D50									
CUM. MICROGRAMS/DNCM<D50	1.68E+07	8.90E+06	5.73E+06	3.55E+06	2.29E+06	1.26E+06	6.04E+05	2.97E+05	0.00E+00
GEOM D50	3.28E+01	9.07E+00	5.74E+00	3.31E+00	2.11E+00	1.26E+00	7.63E-01	3.92E-01	1.70E-01
DM/DLOGD-(UG/DNM3)	2.56E+07	5.21E+07	1.29E+07	9.45E+06	7.79E+06	3.63E+06	4.32E+06	7.21E+05	9.87E+05
DN-LOGD/(NUMBER/DNM3)	5.30E+11	5.13E+13	5.00E+13	1.91E+14	6.10E+14	1.33E+15	7.15E+15	8.79E+15	1.48E+17

Data used in Table 4-2.

FPEIS TEST SERIES NO: 00080   STREAM NO: 01   TEST ID NO: 3   SAMPLE NO: 02

SERIES FORM C7

PARTICLE SIZE TABLE---------

STAGE #	1	2	3	4	5	6	7	8	9
D50(MICRONS)	11.23	7.93	4.50	2.65	1.83	.95	.67	.26	.13
MICROGRAMS/DNCM/STAGE	1.71E+07	3.94E+06	2.31E+06	6.74E+05	9.71E+05	6.90E+05	3.17E+05	1.62E+05	2.69E+05
NUMBER/DNCM/STAGE	3.34E+11	3.44E+12	7.96E+12	1.20E+13	6.68E+13	2.21E+14	4.59E+14	1.64E+15	3.18E+16
CUM. %MASS<D50									
CUM. MICROGRAMS/DNCM<D50	9.33E+06	5.39E+06	3.08E+06	2.41E+06	1.44E+06	7.48E+05	4.31E+05	2.69E+05	0.00E+00
GEOM D50	3.35E+01	9.44E+00	5.97E+00	3.45E+00	2.20E+00	1.32E+00	7.98E-01	4.17E-01	1.84E-01
DM/DLOGD-(UG/DNM3)	1.80E+07	2.61E+07	9.39E+06	2.93E+06	6.04E+06	2.42E+06	2.09E+06	3.94E+05	8.94E+05
DN-LOGD/(NUMBER/DNM3)	3.52E+11	2.28E+13	3.23E+13	5.23E+13	4.15E+14	7.77E+14	3.02E+15	3.98E+15	1.06E+17

Data used in Table 4-2.

FPEIS TEST SERIES NO: 00080   STREAM NO: 01   TEST ID NO: 3   SAMPLE NO: 03

SERIES FORM C7

PARTICLE SIZE TABLE---------

STAGE #	1	2	3	4	5	6	7	8	9
D50(MICRONS)	10.83	7.65	4.33	2.55	1.76	.91	.65	.24	.10
MICROGRAMS/DNCM/STAGE	4.16E+07	3.48E+06	2.27E+06	3.40E+06	1.06E+06	1.10E+06	6.86E+05	3.93E+05	6.93E+05
NUMBER/DNCM/STAGE	8.59E+11	3.39E+12	8.75E+12	6.81E+13	8.19E+13	3.99E+14	1.11E+15	4.69E+15	1.37E+17
CUM. %MASS<D50									
CUM. MICROGRAMS/DNCM<D50	1.31E+07	9.60E+06	7.33E+06	3.93E+06	2.87E+06	1.77E+06	1.09E+06	6.93E+05	0.00E+00
GEOM D50	3.29E+01	9.10E+00	5.76E+00	3.32E+00	2.12E+00	1.27E+00	7.69E-01	3.95E-01	1.55E-01
DM/DLOGD-(UG/DNM3)	4.31E+07	2.31E+07	9.18E+06	1.48E+07	6.58E+06	3.84E+06	4.69E+06	9.08E+05	1.82E+06
DN-LOGD/(NUMBER/DNM3)	8.90E+11	2.25E+13	3.54E+13	2.96E+14	5.09E+14	1.39E+15	7.58E+15	1.08E+16	3.60E+17

Data used in Table 4-2.

FPEIS TEST SERIES NO: 00080   STREAM NO: 01   TEST ID NO: 3   SAMPLE NO: 04

SERIES FORM C7

PARTICLE SIZE TABLE---------

STAGE #	1	2	3	4	5	6	7	8	9
D50(MICRONS)	11.33	8.00	4.54	2.67	1.84	.96	.68	.26	.13
MICROGRAMS/DNCM/STAGE	3.20E+07	2.15E+06	4.86E+06	2.71E+06	7.67E+05	9.44E+05	6.57E+05	3.71E+05	6.07E+05
NUMBER/DNCM/STAGE	6.17E+11	1.83E+12	1.63E+13	4.72E+13	5.17E+13	2.95E+14	9.15E+14	3.67E+15	7.18E+16
CUM. %MASS<D50									
CUM. MICROGRAMS/DNCM<D50	1.31E+07	1.09E+07	6.06E+06	3.35E+06	2.58E+06	1.63E+06	9.78E+05	6.07E+05	0.00E+00
GEOM D50	3.36E+01	9.52E+00	6.03E+00	3.48E+00	2.22E+00	1.33E+00	8.08E-01	4.20E-01	1.84E-01
DM/DLOGD-(UG/DNM3)	3.39E+07	1.42E+07	1.98E+07	1.18E+07	4.74E+06	3.34E+06	4.39E+06	8.89E+05	2.02E+06
DN-LOGD/(NUMBER/DNM3)	6.53E+11	1.21E+13	6.63E+13	2.05E+14	3.20E+14	1.05E+15	6.11E+15	8.78E+15	2.38E+17

Data used in Table 4-2.

FPEIS TEST SERIES NO: 00080 STREAM NO: 01 TEST ID NO: 4 SAMPLE NO: 01

SERIES FORM C7

PARTICLE SIZE TABLE---------

STAGE #	1	2	3	4	5	6	7	8	9
D50(MICRONS)	10.82	7.63	4.32	2.54	1.75	.91	.64	.24	.12
MICROGRAMS/DNCM/STAGE	2.19E+06	2.11E+05	4.74E+05	4.66E+05	4.51E+05	2.78E+05	3.46E+05	2.33E+05	6.17E+05
NUMBER/DNCM/STAGE	4.53E+10	2.07E+11	1.84E+12	9.42E+12	3.54E+13	1.02E+14	5.72E+14	2.84E+15	9.27E+16
CUM. %MASS<D50									
CUM. MICROGRAMS/DNCM<D50	3.08E+06	2.86E+06	2.39E+06	1.92E+06	1.47E+06	1.20E+06	8.50E+05	6.17E+05	0.00E+00
GEOM D50	3.29E+01	9.09E+00	5.74E+00	3.31E+00	2.11E+00	1.26E+00	7.63E-01	3.92E-01	1.70E-01
DM/DLOGD-(UG/DNM3)	2.27E+06	1.39E+06	1.92E+06	2.02E+06	2.79E+06	9.79E+05	2.26E+06	5.47E+05	2.05E+06
DN-LOGD/(NUMBER/DNM3)	4.69E+10	1.36E+12	7.45E+12	4.08E+13	2.18E+14	3.58E+14	3.74E+15	6.67E+15	3.08E+17

Data used in Table 4-2.

FPEIS TEST SERIES NO: 00080   STREAM NO: 01   TEST ID NO: 4   SAMPLE NO: 02

SERIES FORM C7

PARTICLE SIZE TABLE---------

STAGE #	1	2	3	4	5	6	7	8	9
D50(MICRONS)	11.48	8.11	4.59	2.70	1.87	.97	.69	.25	.13
MICROGRAMS/DNCM/STAGE	2.71E+07	2.59E+06	4.25E+06	1.24E+06	5.50E+05	4.57E+05	2.37E+05	2.62E+05	4.23E+05
NUMBER/DNCM/STAGE	5.13E+11	2.12E+12	1.37E+13	2.09E+13	3.56E+13	1.37E+14	3.18E+14	2.69E+15	5.30E+16
CUM. %MASS<D50									
CUM. MICROGRAMS/DNCM<D50	1.00E+07	7.42E+06	3.17E+06	1.93E+06	1.38E+06	9.22E+05	6.85E+05	4.23E+05	0.00E+00
GEOM D50	3.39E+01	9.65E+00	6.10E+00	3.52E+00	2.25E+00	1.35E+00	8.18E-01	4.15E-01	1.80E-01
DM/DLOGD-(UG/DNM3)	2.88E+07	1.72E+07	1.72E+07	5.38E+06	3.45E+06	1.60E+06	1.60E+06	5.94E+05	1.49E+06
DN-LOGD/(NUMBER/DNM3)	5.45E+11	1.40E+13	5.56E+13	9.06E+13	2.23E+14	4.82E+14	2.15E+15	6.09E+15	1.87E+17

Data used in Table 4-2.

FPEIS TEST SERIES NO: 00080 STREAM NO: 01 TEST ID NO: 4 SAMPLE NO: 03

SERIES FORM C7

PARTICLE SIZE TABLE---------

STAGE #	1	2	3	4	5	6	7	8	9
D50(MICRONS)	10.87	7.67	4.34	2.55	1.76	.92	.65	.25	.13
MICROGRAMS/DNCM/STAGE	5.03E+07	6.02E+06	4.37E+06	3.03E+06	7.23E+05	4.78E+05	3.51E+05	4.25E+05	7.23E+05
NUMBER/DNCM/STAGE	1.03E+12	5.81E+12	1.67E+13	6.05E+13	5.59E+13	1.70E+14	5.58E+14	4.77E+15	9.06E+16
CUM. %MASS<D50									
CUM. MICROGRAMS/DNCM<D50	1.61E+07	1.01E+07	5.73E+06	2.70E+06	1.98E+06	1.50E+06	1.15E+06	7.23E+05	0.00E+00
GEOM D50	3.30E+01	9.13E+00	5.77E+00	3.33E+00	2.12E+00	1.27E+00	7.73E-01	4.03E-01	1.80E-01
DM/DLOGD-(UG/DNM3)	5.22E+07	3.98E+07	1.77E+07	1.31E+07	4.49E+06	1.70E+06	2.33E+06	1.02E+06	2.55E+06
DN-LOGD/(NUMBER/DNM3)	1.07E+12	3.84E+13	6.76E+13	2.62E+14	3.47E+14	6.05E+14	3.70E+15	1.15E+16	3.19E+17

Data used in Table 4-2.

FPEIS TEST SERIES NO: 00080 STREAM NO: 01 TEST ID NO: 4 SAMPLE NO: 04

SERIES FORM C7

PARTICLE SIZE TABLE---------

STAGE #	1	2	3	4	5	6	7	8	9
D50(MICRONS)	11.54	8.15	4.62	2.72	1.89	.98	.69	.25	.13
MICROGRAMS/DNCM/STAGE	4.67E+07	3.68E+05	5.95E+06	9.67E+05	1.22E+06	1.05E+06	4.28E+05	1.80E+05	3.59E+05
NUMBER/DNCM/STAGE	8.76E+11	2.96E+11	1.89E+13	1.59E+13	7.75E+13	3.08E+14	5.65E+14	1.85E+15	4.50E+16
CUM. %MASS<D50									
CUM. MICROGRAMS/DNCM<D50	1.05E+07	1.02E+07	4.20E+06	3.24E+06	2.02E+06	9.67E+05	5.39E+05	3.59E+05	0.00E+00
GEOM D50	3.40E+01	9.70E+00	6.14E+00	3.54E+00	2.26E+00	1.36E+00	8.22E-01	4.15E-01	1.80E-01
DM/DLOGD-(UG/DNM3)	4.98E+07	2.44E+06	2.41E+07	4.20E+06	7.61E+06	3.71E+06	2.81E+06	4.08E+05	1.26E+06
DN-LOGD/(NUMBER/DNM3)	9.35E+11	1.96E+12	7.67E+13	6.93E+13	4.83E+14	1.09E+15	3.71E+15	4.19E+15	1.58E+17

Data used in Table 4-2.

Excerpts from

REFERENCE 21 (SECTION 4.0)

McCain, J. D., Evaluation of Rexnord Gravel Bed Filter, EPA-600/2-76-164 (NTIS PB 255 095), U.S. Environmental Protection Agency, Research Triangle Park, NC, June 1976.

Table 2

Mass Emission Tests - Method 5

Inlet

Run #	1	2	3	4	5
Date	8-25-75	8-26-75	8-26-75	8-27-75	8-27-75
Time	1350	1015	1435	1050	1515
%, Moisture	2.33	1.65	2.60	1.54	1.80
Velocity, m/s (f/s)	10.44(34.24)	9.70(31.48)	7.42(24.35)	8.50(27.89)	7.97(26.15)
ACM/min (ACFM)	1467.3(51812)	1364.5(48140)	1043.5(36847)	1195.2(42203)	1120.6(39570)
SDCM/min (SDCFM)	937.1(33089)	1088.4(38431)	761.6(26891)	875.3(30906)	739.9(26128)
Grams/ACM (Grains/ACF)	2.039(0.891)	1.144(0.500)	1.602(0.700)	2.130(0.931)	2.078(0.908)
Grams/SDCM (Grains/SDCF)	3.192(1.395)	1.435(0.627)	2.197(0.960)	2.911(1.272)	3.146(1.375
Kg/hr. (Lbs/hr.)	179.46(395.65)	91.68(206.54)	100.37(221.27)	152.84(336.96)	139.68(307.94)

Data used in calculations for data in Tables 4-3 and 4-4.

Table 3

Mass Emission Tests - Method 5

Outlet

Run #	1	2	3	4	5
Date	8-25-75	8-26-75	8-26-75	8-27-75	8-27-75
Time	1400	1015	1445	1100	1515
Velocity, m/s(f/s)	8.82(28.94)	8.76(28.73)	6.79(22.29)	7.98(26.18)	7.26(23.81)
%, Moisture	2.29	1.83	1.86	1.64	1.38
* ACM/min(ACFM)	1631.7(57619)	1619.9(57201)	1256.8(44379)	1476.2(52124)	1342.5(47405)
SDCM/min(SCDFM)	1239.3(43759)	1326.4(46837)	1017.5(35927)	1174.2(41461)	1049.7(37067)
Grams/ACM(Grains/ACF)	0.094(0.041)	0.030(0.013)	0.064(0.028)	0.043(0.019)	0.034(0.015)
Grams/SDCM(Grains/SDCF)	0.121(0.053)	0.037(0.016)	0.080(0.035)	0.055(0.024)	0.043(0.019)
Kg/hr. (Lbs/hr.)	9.02(19.88)	2.91(6.42)	4.89(10.78)	3.87(8.53)	2.74(6.04)
No. of Active Modules	7	7	4	7	7
Average Flow per Active Module in ACM/min(ACFM)*	233.1(8230)	231.4(8170)	314.2(11095)	210.8(7445)	191.7(6770)
Efficiency	95.00	96.9	95.1	97.5	98.0

*Includes backflush air.

Data used in calculations for data in Tables 4-6.

Table A-1

Inlet Mass Loading By Size Interval From Andersen Impactor Data

Mass Loading In Indicated Size Interval, mg/DNM^3

Date	Start	Duration (Minutes)	Dia., µm	ρ=1.0	>4.70	3.1-4.7	1.4-3.1	.87-1.4	.63-.87	<.63*	
8/27	1320	20			3459	28.6	20.7	4.84	2.42	13.5	*Filter catches - May be dominated by oversize particles.
8/27	1620	20			341[1]	20.9	13.8	3.59	1.00	4.99	
8/27	1730	20			313[1]	14.5	11.4	2.43	1.42	2.23	
8/27	1800	20			501[1]	25.8	14.8	3.5	1.39	2.52	
8/28	0950	45			2737	9.2	5.20	1.11	0.48	4.65	[1]Nozzles turned downstream to avoid overloading upper stages.
8/28	1105	120			4252	11.1	7.82	2.66	0.52	3.84	
8/28	1440	120			2098	9.3	6.44	3.26	2.64	13.5	
8/29	1015	120			2711	12.2	7.44	2.31	2.04	6.89	
8/29	1400	120			2131	14.4	9.34	2.42	0.42	1.43	
					2896	16.22	10.77	2.90	1.37	5.94	Average 8/27-8/29
					3569	20.69	13.85	3.55	1.90	9.70	90% Upper Confidence Limit
					2223	11.74	7.69	2.25	0.84	3.09	90% Lower Confidence Limit
11/4	1100	65			2474	18.8	9.5	2.4	0.12	1.54	[2]Nozzle pointed wrong direction.
11/4	1130	60			661[2]	19.3	12.2	0.51	1.03	4.60	
11/4	1430	135			1941	14.9	10.7	3.7	0.53	1.47	
11/4	1435	120			1791	12.4	8.53	2.53	0.67	1.52	
11/5	0935	120			2384	9.11	14.5	1.12	0.23	1.37	
11/5	0930	120			2453	14.6	7.51	1.32	0.03	0.69	
11/5	1415	120			4607	17.5	7.97	3.31	4.37	11.2	
11/5	1415	120			4232	19.7	10.6	4.02	3.42	14.4	
					2840	15.79	10.19	2.36	1.30	4.60	Average 11/4-11/5
					3650	18.31	11.72	3.23	2.41	1.05	90% Upper Confidence Limit
					2031	13.27	8.61	1.50	0.19	8.14	90% Lower Confidence Limit
			Dia., µm	ρ=2.7	>2.8	1.8-2.8	0.83-1.8	.48-0.83	.34-0.48	<0.34	

Entire table used in Tables 4-4 and 4-5.

Table A-2

Outlet Mass Loadings By Size Interval For August Test Series

Mass Loading* In Indicated Size Interval, mg/DNM³

Date	Start Time	Duration	Dilution Correction Factor	Pres. Drop	Dia. ρ=1.0	>14.3	10.1-14.3	6.2-10.1	4.4-6.2	2.9-4.4	1.35-2.9	.82-1.35	.58-.82	<.58*
8/25	1440	120	1.32	16.5		2.89	2.77	2.57	2.90	4.83	4.41	2.13	0.96	1.49
8/25	1440	120	1.32	16.5		2.79	2.74	0.45	0.90	1.76	3.07	1.56	0.15	1.32
8/26	1119	84	1.22	17.0		2.39	1.57	2.19	3.55	5.97	4.21	3.36	0.94	0.21
8/26	1124	84	1.22	17.0		3.81	2.24	3.06	4.47	6.45	5.46	2.33	0.71	0.33
8/26[1]	1515	120	1.34	15.8		9.09	2.34	2.86	4.75	7.64	6.09	2.38	0.97	10.2
8/26[1]	1515	120	1.34	15.8		8.87	2.54	3.42	3.90	6.21	6.14	3.11	1.52	1.18
8/27	1100	120	1.34	15.8		12.0	3.31	3.14	4.37	7.80	7.16	3.48	1.54	0.93
8/27	1150	120	1.38	15.8		7.98	5.30	3.93	5.21	6.31	7.50	4.14	1.41	1.43
8/27	1515	120	1.42	12.9		7.40	2.83	2.89	4.02	5.56	7.43	4.36	1.77	1.54
8/27	1515	120	1.42	12.9		11.4	2.26	2.48	3.12	7.11	6.99	4.01	1.47	0.90
8/28	1045	120	1.31	17.3		7.16	2.22	2.20	3.17	6.23	5.17	2.71	1.15	1.61
8/28	1045	120	1.31	17.3		7.74	1.97	2.25	4.35	4.40	5.35	2.58	0.88	1.79
8/28	1415	120	1.47	12.8		7.72	2.14	2.60	3.25	5.26	5.57	3.00	1.92	5.73
8/28	1415	120	1.47	12.8		5.69	2.96	2.26	3.68	4.88	6.67	2.76	1.53	4.67
8/29	1000	120	1.27	17.6		10.2	2.13	3.11	4.14	5.77	5.13	2.53	1.70	3.98
8/29	1000	120	1.27	17.6		5.79	1.60	1.76	3.05	6.27	5.21	2.57	1.23	3.82
8/29	1400	120	1.41	11.6		2.69	1.51	1.17	1.15	1.55	3.93	2.30	1.28	1.27
8/29	1400	120	1.41	11.6		6.92	1.68	2.56	3.35	5.19	6.10	3.07	0.93	1.03
						8.85	3.31	3.24	4.58	7.15	7.55	3.77	1.66	2.74**
						10.71	3.87	3.73	5.23	8.13	8.43	4.34	1.95	3.76***
						6.99	2.74	2.76	3.93	6.17	6.67	3.19	1.37	1.73****
					Dia. ρ=2.7	>8.6	6.1-8.6	3.7-6.1	2.6-3.7	1.7-2.6	.78-1.7	.46-.78	.32-.46	<.32

*Because of the dilution that results from the addition of the backwash air, the results from the outlet impactors must be adjusted to compensate for the difference in inlet and outlet gas flows before comparisons among the various operating conditions can be made and before fractional collection efficiencies can be calculated. The correction factor by which the measured outlet concentrations must be multiplied in order to effect this adjustment are given for each impactor run in the table.

**Average after correcting for dilution.

***Upper 90% Confidence Limit.

****Lower 90% Confidence Limit.

Entire table used in Table 4-6.

Table A-3

Outlet Mass Loadings By Size Interval For November Test Series

Mass Loading* In Indicated Size Interval, mg/DNM[3]

Date	Start	Duration	Dilution Correction Factor	System Pres. Drop	Dia., μm ρ=1.0	>13.9	9.8-13.9	6.0-9.8	4.2-6.0	2.8-4.2	1.3-2.8	.79-1.3	.57-.79	<.57*
11/3	1545	120	1.35	NA		0.66	0.43	0.40	0.43	8.01[2]	9.45[2]	2.56	0.96	1.15
11/3	1545	120	1.35	NA		10.4[1]	0.71	0.64	0.61	1.08	3.80	2.31	0.66	0.63
11/4	1130	240	1.39	9.6		0.23	0.13	0.19	0.18	0.64	3.63	2.58	1.02	0.57
11/4	1130	240	1.39	9.6		0.00	0.14	0.16	0.34	0.92	3.36	2.22	0.60	0.38
11/5	0945	240	1.32	14.0		0.99	0.49	0.51	0.61	1.16	3.70	2.51	0.86	0.97
11/5	0945	240	1.32	14.0		1.35	0.45	0.38	0.56	0.20	0.65	1.16	1.03	1.12
						.86	.53	0.51	.61	1.08	3.60	2.99	1.10	1.10**
						1.55	.77	0.71	.80	1.59	5.19	3.61	1.36	1.51***
						.17	.28	0.31	.43	.58	2.00	2.37	0.99	.85****
					Dia., μm ρ=2.7	>8.4	5.9-8.4	3.6-5.9	2.6-3.6	1.7-2.6	.76-1.7	.44-.76	.31-.44	<.31

* (Same as for Table A-2).

**Average after correcting for dilution.

***Upper 90% Confidence Level.

****Lower 90% Confidence Level.

[1]Nozzle scrapped port on entry

[2]Omitted from average

Entire table used in Table 4-7.

Table A-4

Inlet Mass Loading By Size Interval From Brink Impactor Data

Mass Loading In Indicated Size Interval, mg/DNM^3

Date	Time	Duration	Dia., ρ=1	>17.8	12.6-17.8	7.2-12.6	4.3-7.2	3.0-4.3	1.6-3.0	1.14-1.6	0.67-1.14	<.67
8/26	1010	20		2020	36.6	28.1	22.1	13.6	14.5	7.66	20.4	5.96
8/26	1700	40		2160	38.9	15.2	17.2	6.1	3.0	3.5	8.6	12.6
8/27	1045	180		963	17.7	7.7	8.2	7.0	2.6	1.2	1.0	2.83
8/27	1605	180		824	65.9	22.4	29.3	9.4	2.6	1.8	2.2	4.00
8/28	0945	180		1720	50.8	17.8	11.4	4.3	1.9	1.1	0.8	2.8
8/28	1310	180		597	48.2	12.3	14.7	3.3	1.9	1.6	1.6	6.4
8/29	1000	180		3640	49.5	84.3	22.5	6.9	2.5	2.0	2.0	6.9
8/29	1400	180		1150	116	19.2	15.4	6.1	2.6	.6	.6	11.8
				1634	53.0	25.9	17.6	7.09	4.06	2.43	4.65	6.66*
				2301	72.5	42.3	22.2	9.24	6.92	3.97	9.28	9.19**
				967	33.4	9.4	13.0	4.93	1.20	0.90	0.02	4.13***
			Dia., ρ=2.7	>10.8	7.6-10.8	4.3-7.6	2.6-4.3	1.8-2.6	.92-1.8	.65-92	.36-.65	<.36

*Average
**Upper 90% Confidence Limit
***Lower 90% Confidence Limit

Entire table used in Table 4-3.

(Data not used to develop candidate emission factors)

All data used in calculations for data in Tables 4-3 and 4-4.

APPENDIX B

PLANT PRODUCTION DATA

Date	8/25	8/26	8/27	2/28	8/29	11/4	11/5
Production Tons/Day	742	533*	961	1031	1064	1063	995

*Single kiln

Excerpts from

REFERENCE 24 (SECTION 4.0)

Hurst, W. W., Particulate Emissions Testing, Greencastle Plant, Lone Star Industries, Houston, TX, July 1977.

TABLE I

GREENCASTLE STACK EMISSIONS SURVEY

PARTICULATE EMISSION RATE

1977

Run No.	Date (1977)	Exhaust Gas Temp. °F	Exhaust Gas Volume ACFM	Particulate Emission Rate Grains/ SCF Dry	Particulate Emission Rate lbs/SCF Dry x 10^{-6}	Particulate Emission Rate lbs/ hr.	Particulate Emission Rate Ton/ Day
Normal Operation:							
1	5 - 8	332	239,200	.020	2.87	21.05	0.25
3	5 - 9	331	249,100	.058	8.29	56.24	0.68
5	5 - 10	334	240,700	.009	1.31	8.82	0.11
Ave.			243,000			28.70	0.35
Operation Following Precipitator Upgrading:							
21	6 - 20	310	232,900	.043	6.16	42.24	0.51
23	6 - 21	316	239,900	.032	4.65	30.98	0.37
25	6 - 22	307	236,700	.042	6.00	41.90	0.50
Ave.			236,500			38.37	0.46

These data mentioned in Section 4.1.5 and used for calculations in Appendix E.

TABLE II

GREENCASTLE EMISSION SURVEY

PRECIPITATOR PERFORMANCE

Run No.	Insufflation Rate T/Hr	Exhaust Gas Precip. Input ACFM	Exhaust Gas Precip. Output ACFM	Dust Load Precip. Input T/Hr	Dust Load Precip. Output T/Hr	Precip. Efficiency %
Normal Insufflation Rate:						
9, 10	6	238,300	216,800	4.90	.007	99.8
11, 12	6	234,300	222,200	5.01	.014	99.7
13, 14	6	228,800	219,900	5.17	.031	99.4
Ave.				5.03	.017	99.6
Elevated Insufflation Rate:						
15, 16	12	231,800	214,900	5.10	.007	99.8
17, 18	12	224,100	215,100	4.99	.021	99.6
19, 20	12	228,100	216,400	5.72	.025	99.5
Ave.				5.27	.018	99.6

These data mentioned in Section 4.1.5 and used for calculations in Appendix D.

TABLE III

GREENCASTLE EMISSION SURVEY

PROCESS RATES, CONSUMPTION AND PRODUCTION

Run No.	Date (1977)	Type of Fuel	Fuel Rate T/Hr	Kiln Feed T/Hr	% Slurry Water	Clinker Produced T/Hr	Dust Disposed T/Hr
1	5 - 8	Coal	18.5	135	31.1	81	.146
3	5 - 9	Coal	18.0	135	33.3	79	.146
5	5 - 10	Coal	17.5	135	33.3	79	.146
Ave.			18.0	135	32.6	79.7	.146
7	5 - 12	Coal	18.0	135	33.3	77	.146
9, 10	5 - 19	Coal	16.5	125	33.1	74	.146
11, 12	5 - 20	Coal	16.0	125	33.1	75	.146
13, 14	5 - 21	Coal	15.75	125	33.5	76	.146
15, 16	5 - 22	Coal	16.0	125	33.1	76	.146
17, 18	5 - 23	Coal	16.0	125	33.4	75	.146
19, 20	5 - 24	Coal	16.5	125	33.1	77	.146
Ave.			16.4	126	33.2	75.7	.146
21	6 - 20	Coal	18.75	138	33.2	88	.125
23	6 - 21	Coal	18.75	138	33.2	87	.125
25	6 - 22	Coal	19.50	138	33.3	88	.125
Ave.			19.00	138	33.2	87.7	.125

Data used for calculations in Appendices D and E.

Excerpts from

REFERENCE 25 (SECTION 4.0)

Hurst, W. W., Particulate Emissions Testing, Nazareth Plant, Lone Star Industries, Houston, TX, January 1978.

NAZARETH, PENNA PLANT

CONSOLIDATED SUMMARY - PARTICULATE EMISSIONS
PERIOD OF OCTOBER 6 thru OCTOBER 15, 1977

TEST LOCATION	PARTICULATE EMISSION RATE lbs/Hr. Probe Catch	Impinger Catch	Total Catch	gr/SCF Total Catch	KILN FEED RATE T/H	COAL RATE T/H	VOLUME ACFM	TEMP Deg.F.	ISOKINETIC %
NORTH STACK Total / Avg	16.6	29.7	46.3	0.045	61.8	8.3	213,400	365	89.5
No. 2 Kiln					29.8	4.1			
No. 3 Kiln					32.0	4.2			
SOUTH STACK Total / Avg	6.8	8.6	15.4	0.019	55.8	6.5	165,300	373	95.8
No. 4 Kiln					28.6	3.3			
No. 5 Kiln					27.2	3.2			
PLANT TOTAL	23.4	38.3	61.7	0.032	117.6	14.8	378,700	369	92.6

W. W. Hurst 1/13/78

These data mentioned in Section 4.1.6 and used for calculations in Appendix E.

TABLE 2

NAZARETH STACK EMISSION SURVEY

PROCESS RATES, CONSUMPTION AND PRODUCTION

1977

Run No.	Date	Kiln No.	Coal * Fuel Rate T/Hr	Kiln Feed T/Hr	Clinker Produced T/Hr	Clinker Dust T/Hr	Precip.& Multiclone Dust T/Hr
PA/6	10-6	4	3.1	27.6	16.0	---	---
		5	3.1	27.3	15.9	---	---
PA/7	10-7	4	3.3	29.9	17.3	0.2	0.2
		5	3.3	27.5	15.9	0.2	0.2
PA/15	10-15	4	3.4	28.3	16.4	---	---
		5	3.2	26.8	15.5	---	---
Ave. Kiln # 4			3.3	28.6	16.6		
Ave. Kiln # 5			3.2	27.2	15.8		
PA/10	10-10	2	4.2	30.0	17.4	0.1	---
		3	4.6	32.9	19.1	0.2	---
PA/11	10-11	2	4.1	29.3	17.0	0.1	2.0
		3	4.0	30.5	17.7	0.2	1.0
PA/12	10-12	2	4.0	30.1	17.5	0.1	2.2
		3	3.9	32.5	18.9	0.2	1.1
Ave. Kiln # 2			4.1	29.8	17.3		
Ave. Kiln # 3			4.2	32.0	18.6		

These data mentioned in Section 4.1.6 and used for calculations in Appendix E.

*Coal Mill Feed Moisture (Ave.) for PA/6,7,15 was 5.0%

" " " " " for PA/10,11,12 was 7.0%

Excerpts from

REFERENCE 26A (SECTION 4.0)

Hunter, S. C., et al., Application of Combustion Modifications to Industrial Combustion Equipment, EPA-600/7-79-015a (NTIS PB 294 214), U.S. Environmental Protection Agency, Research Triangle Park, NC, January 1979.

TABLE 4-20. SUMMARY OF EMISSIONS FROM WET PROCESS ROTARY KILN, LOCATION 9

Rated Load 9.4 kg/s (909 tons/day)

Test No.	Date 1976	Process Load kg/s	Input MW	O_2 (%)	CO_2 (%)	NO_x (ppm)	NO_x (ng/J)	NO (ppm)	NO (ng/J)	HC (ppm)	CO (ppm)	SO_2 (ppm)	Particulate lb/10^6 Btu	Particulate (ng/J)	Comb. Air Temp. (°F)	Comb. Air Temp. (K)	Kiln Temp. (°F)	Kiln Temp. (K)	Comments
9-1A	8/11	9.4	59	6.0	16.0	2400	1408	2250	1319	24	30	0	22.8	9803	730	672	2700	1756	Baseline - part. test, 5-25% opacity
9-1B	8/11	↓	↓	6.1	16.0	2548	1494	2416	1417	12	34	0	--		810	706	2900	1867	Baseline test
9-1C	8/11			5.2	18.0	1729	1014	1709	1003	11	34	0	--		720	656	2450	1617	Upset kiln condition - cascade impactor test
9-2A	8/12			6.0	15.2	1409	826	1290	757	24	29	0	--		740	667	2200	1478	Low kiln temperature
9-2B	8/12			5.1	15.6	1386	813	1443	846	23	29	0	--		750	672	2450	1617	Low O_2 condition
9-2C	8/12			4.5	18.0	1858	1090	1936	1136	20	32	0	--		900	755	2750	1783	High combustion air temp, low O_2
9-2D	8/12			5.7	16.8	2819	1654	2588	1518	21	36	0	--		900/ 930	755/ 772	2900	1867	High combustion air temperature
9-2E	8/12			5.7	17.9	2650	1554	2265	1329	20	28	0	--		930	772	2840	1833	High combustion air temperature
9-2F	8/13			4.2	19.3	1826	1070	1761	1031	17	43	0	20.9	9000	900/ 1000	755/ 811	2450	1617	Particulate test, low NO_x, <5% opacity
9-2G	8/13			5.6	17.8	2046	1199	1929	1132	14	28	0	--		800/ 890	700/ 72?	2650	1728	Cascade impactor test, low NO_x
9-3	9/29	10.2	60.1	4.5	17.6	1230	720	1172	687	--	26	--	17	7307	1095	844	2960	1930	SASS, ESP inlet
9-4	9/30	9.4	62.6	2.3	19.6	693	406	674	395	48	507	--	12.9	5548	1150	894	2980	1911	SASS, ESP inlet
9-5	10/4	9.2	57.2	6.8	14.3	--	--	1740	1020	0	3	0	0.053	22.7	1005	814	2763	1790	SASS, ESP outlet
9-6	10/5	10.6	58.5	6.6	16.8	--	--	1062	623	44	50	0	0.069	29.5	928	771	2612	1707	SASS, ESP outlet

NOTES: 1. ppm values for NO_x, NO, HC, CO, and SO_2 are corrected to 3% O_2 dry basis.

2. All emissions were measured upstream of an electrostatic precipitator.

3. Conversion from ppm to ng/J includes added CO_2 of 32.2×10^{-9} m^3/J (1207 SCF/10^6 Btu) for CO_2 released from $CaCO_3$ in kiln feed, in addition to gas from the fuel combustion of 231×10^{-9} m^3/J (8623 SCF/10^6 Btu).

Data used in calculations for data in Table 4-8.

Natural Gas Rate - Strip charts on the main gas line to the facility measure the total natural gas demand. Aside from several space heaters, this demand represents the natural gas flow to the kiln. (These space heaters were not in service during the test period.) The natural gas flow is manually set by the operator based primarily on his visual observation of clinker brightness and quality (e.g., size, adherence to the kiln wall, etc.) in the burning zone. As such, the operator is manually compensating for changes in feed rate, feed moisture content, etc.

Table 4-21 presents the trace specie sample train data and process weights. The following sections discuss each test. The total particulate weight for Tests 9-3 and 9-4 (upstream) of 7307 and 5548 ng/J, respectively, are somewhat lower than the Method 5 result of 9000-9800 ng/J.

Precipitator Inlet Test Conditions--

Test 9-3 was to be terminated when two filters had been plugged. After 75 minutes elapsed time, the vacuum pump inlet pressure limit, 76 kPa (22.5 in. HgVac) had been reached. An examination of the 1 μm cyclone cup revealed that it, and not the filter, had plugged the system. The test was terminated based on this condition. The largest nozzle size available (19.1 mm, 3/4 inch) was not large enough to produce the nominal cyclone flow rate due to the relatively low gas velocity.

Control room data for this test are shown in Figure 4-23 and indicate a 2.9% increase in kiln discharge temperature over the test period (75 min.). Combustion air preheat is accomplished by passing the air through the hot clinker discharged from the kiln. Thus, combustion air temperature entering the kiln will increase as the clinker temperature increases, and vice versa. This is borne out by the observed 2.1% increase in combustion air temperature.

Test 9-4, a repeat of Test 9-3, was also terminated at 75 minutes elapsed time by a plugged 1 μm cyclone. The gas moisture content for this test was significantly higher than the previous day's test (44.7% versus 34.3%). This effect caused a more marked departure from isokinetic sampling (119.3% versus 96.8%).

Data used in Table 4-9.

TABLE 4-21. TRACE SPECIES AND ORGANICS SAMPLING CONDITIONS LOCATION 9 - ROTARY CEMENT KILN

TS & O Run No.	5	6	7	8
Test Number	9-3	9-4	9-5	9-6
Date (1976)	9/29	9/30	10/4	10/5
Port Location	ESP inlet	ESP inlet	ESP outlet	ESP outlet
Velocity, m/s(f/s)	5.17 (16.95)	5.06 (16.60)	17.48 (57.35)	17.41 (57.10)
Stack Flow, dNm^3/s (10^3 SCFM)	20.1 (42.6)	19.0 (40.3)	21.1 (44.7)	21.7 (46.0)
Stack Temp. K (°F)	415 (287)	425 (305)	411 (280)	408 (274)
Oxygen Content, %	4.5	2.3	6.8	6.6
Moisture, %	34.31	44.74	37.55	38.21
Sample Time, min.	75	75	300	300
Cyclone Flow, awcum (awcfm)	0.102 (3.591)	0.097 (3.435)	0.087(3.067)	0.087 (3.076)
Isokinetic Ratio, %	96.8	118.[illegible]	105.5	1[illegible]4.5
Oven Temp., K (°F)	478 (400)	478 (400)	478 (400)	478 (400)
XAD2 Temp., K (°F)	303 (85)	297 (75)	299 (77)	294 (69)
Meter Temp., K (°F)	311 (00)	319 (115)	309 (97)	310 (99)
Nozzle Size, mm (in.)	19.05 (0.75)	19.05 (0.75)	9.53 (0.375)	9.53 (0.375)
No. of Filters Used	1	1	1	1
Sample Flow, dry, scmm (scfm)	0.0342(1.382)	0.0386 (1.363[illegible])	0.0351 (1.2384)	0.0345(1.2185)
Volume Collected, dry, scm (scf)	2.937 (103.64)	2.897 (102.23)	10.529 (371.53)	10.359 (365.55)
Particulate Catch, g	63.7780	54.17	0.6122	0.7939
Concentration, g/dNm^3	21.7	18.88	0.0581	0.0766
Total Particulates, ng/J(lb/MMB)	7307 (17.0)	5548 (12.9)	22.7 (0.053)	29.47 (0.069)
Unit Conditions:				
Test Time, min	75	75	316.8	313.2
Nat. Gas scm(10^3 scf)	7.241 (255.5)	7.754 (273.6)	27.60 (973.7)	(28.46 (1004.1)
Dry Feed, [illegible] (10^3 lb)	76.64 (168.6)	70.61 (155.4)	293.7 (646.0)	334.2 (735.2)
Slurry Feed, 10^6 g (10^3 lb)	119.0 (261.8)	108.6 (239.0)	462.5 (1017.4)	517.3 (1138.0)
Slurry Moisture, %, weight	35.6	35.0	36.5	35.4
Clinker, 10^6 g (10^3 lb)	45.75 (100.7)	42.18 (92.69)	175.0 (385.1)	199.4 (438.6)
Precipitator Catch 10^6g (10^3lb)	2.131 (4.688)	2.131 (4.688)	9.375 (20.63)	9.375 (20.63)

Data used in Table 4-9.

TABLE F-2. TRACE SPECIES AND ORGANIC EMISSIONS, SASS SOLIDS SECTION COLLECTION TEST 9-3, CEMENT KILN

Sample Type	Nozzle, Probe, 10 µm Cyclone Solids		3 µm Cyclone Solids		1 µm Cyclone Solids		Filters		Solid Section Wash	
Sample Number	384		386		393		373		9-3 O	
Sample Weight/Vol.	20.2857 g		21.5244 g		15.6034 g		4.2785 g		1301 ml	
Units	µg/g	µg/m³	µg/g	µg/m³	µg/g	µg/m³	µg/g	µg/m³	µg/ml	µg/m³
Antimony	< 50	< 350	< 50	< 400	< 50	< 270	< 50	< 73	0	0
Arsenic	2.0	14	1.6	13	3.0	16	4.0	5.8	< 8	0
Barium	< 20	< 140	< 20	< 160	< 20	< 110	< 20	< 29	< 8	0
Beryllium	< 0.5	< 3.5	0.6	4.8	1.2	6.4	2.9	4.2	< 0.005	< 2.4
Cadmium	4.4	30	4.6	37	4.7	25	5.1	7.4	0	0
Calcium	310,000	2,100,000	420,000	3,400,000	250,000	1,300,000	250,000	360,000	560	260,000
Chromium	31	210	20	160	31	170	80	120	< 8	0
Cobalt	38	260	24	192	30	160	55	80	< 0.08	38
Copper	11	76	11	88	13	69	17	25	0.02	9.4
Iron	12,000	83,000	13,000	100,000	18,000	96,000	22,000	32,000	19	8900
Lead	< 200	< 1400	< 200	< 1600	< 200	< 1100	< 200	< 290	0.16	75
Manganese	82	570	83	660	70	370	140	200	0.18	85
Mercury	< 0.2	< 1.4	< 0.2	< 160	< 0.2	< 1.1	< 0.2	< 2.9	< 0.005	< 2.4
Nickel	24	170	30	240	30	160	39	57	0.09	42
Selenium	< 4	< 28	< 4	< 32	< 4	< 21	< 4	< 5.8	< 0.04	< 19
Tellurium	< 50	< 350	< 50	< 400	< 50	< 270	< 50	< 73	< 2	< 940
Tin	< 50	< 350	< 50	< 400	< 50	< 270	< 50	< 73	< 1	< 470
Titanium	1,900	13,000	2,100	17,000	2,700	14,000	3,000	4,400	0.85	400
Vanadium	30	210	30	240	55	290	90	130	< 0.1	< 47
Zinc	40	280	42	340	40	210	45	65	0.01	4.7
Chloride	709	4,900	1,210	9,700	2,810	15,000	21,000	31,000	11	5,200
Fluoride	150	1,000	290	2,300	256	1,400	420	610	3.8	1,800
Nitrates	8.7	60	8.1	65	13.0	69	28	41	< 0.2	< 94
Sulfates	< 50	< 350	< 50	< 400	< 50	< 270	52,000	76,000	< 6	< 2,800
Total POM	0.1	0.69	0.1	0.80	0.1	0.53	< 1	< 1.5	0.010	4.7
Total PCB	< 1	< 6.9	< 1	< 8.0	< 1	< 5.3	< 1	< 1.5	< 0.001	< 0.47

See notes on Table F-1

Data used in calculations for data in Table 4-9.

TABLE F-8. TRACE SPECIES AND ORGANIC EMISSIONS, SASS SOLIDS SECTION COLLECTION TEST 9-4, CEMENT KILN

Sample Type	Nozzle, Probe, 10 μm Cyclone Solids		3 μm Cyclone Solids		1 μm Cyclone Solids		Filters		Solid Section Wash	
Sample Number	394		410		407		374		9-4 A	
Sample Weight/Vol.	17.6210 g		19.4152 g		12.6696 g		4.4659 g		1625 ml	
Units	μg/g	μg/m³	μg/g	μg/m³	μg/g	μg/m³	μg/g	μg/m³	μg/ml	μg/m³
Antimony	< 50	< 300	< 50	< 340	< 50	< 220	< 50	< 77	0.1	56
Arsenic	< 0.5	< 3.0	2.5	17	1.0	4.4	1.0	1.5	= B	0
Barium	< 20	< 120	< 20	< 130	< 20	< 87	< 20	< 31	< B	0
Beryllium	1.7	10	2.0	13	1.5	6.6	2.3	3.5	< 0.005	< 2.8
Cadmium	4.5	27	3.0	20	3.7	16	3.6	55	0.005	2.8
Calcium	480000	2900000	260000	1700000	290000	1300000	210000	320000	293	170000
Chromium	21	130	18	120	32	140	42	65	< B	0
Cobalt	36	220	31	210	34	150	34	52	0.03	17
Copper	14	85	12	80	14	61	17	26	0.01	5.6
Iron	10000	61000	10000	67000	17000	74000	22000	34000	8.1	2500
Lead	< 200	< 1200	< 200	< 1300	< 200	< 870	< 200	< 310	0.07	39
Manganese	90	550	48	320	65	280	100	150	0.09	50
Mercury	< 0.2	< 1.2	< 0.2	< 1.3	< 0.2	< 0.87	< 0.2	< 0.31	< 0.005	< 2.8
Nickel	29	180	22	150	29	130	31	48	0.01	5.6
Selenium	< 4	< 24	< 4	< 27	< 4	< 17	< 4	< 6.2	< 0.04	< 22
Tellurium	< 50	< 300	< 50	< 340	< 50	< 220	< 50	< 77	< 2	< 1100
Tin	< 50	< 300	< 50	< 340	< 50	< 220	< 50	< 77	< 1	< 560
Titanium	1900	12000	2000	13000	2600	11000	3000	4600	< 0.45	< 250
Vanadium	40	240	50	340	70	310	80	120	< 0.1	< 56
Zinc	40	240	35	230	41	180	42	65	= B	0
Chloride	990	6000	1400	9400	3200	14000	24000	37000	1.1	620
Fluoride	140	850	160	1100	220	960	330	510	0.48	270
Nitrates	6.6	40	7.3	49	8.4	37	16	25	< 0.2	< 110
Sulfates	50	300	< 50	< 340	170	740	32000	49000	6	3400
Total POM	NR	--	NR	--	NR	--	NR	--	NR	--
Total PCB	NR	--	NR	--	NR	--	NR	--	NR	--

See notes on Table F-1

Data used in calculations for data in Table 4-9.

TABLE F-14. TRACE SPECIES AND ORGANIC EMISSIONS, SASS SOLIDS SECTION COLLECTION TEST 9-6, CEMENT KILN

Sample Type	Nozzle, Probe, 10 µm Cyclone Solids		3 µm Cyclone Solids		1 µm Cyclone Solids		Filters		Solid Section Wash	
Sample Number	409		None		408		376		None	
Sample Weight (Vol)	0.0122 g				0.5225 g		0.2042			
Units	µg/g	µg/m³	µg/g	µg/m³	µg/g	µg/m³	µg/g	µg/m³	µg/ml	µg/m³
Antimony	≤ 0.8	≤ 0.001			< 26	< 1.6	< 500	< 11		
Arsenic	20	0.026			0.65	0.040	10	0.22		
Barium	120	0.16			< 65	< 4.0	< 20	< 0.44		
Beryllium	0.5	0.00065			< 0.7	< 0.043	16	0.35		
Cadmium	≤ 0.7	≤ 0.00091			< 1.3	< 0.080	16	0.35		
Calcium	NC	--			260000	16000	440000	9600		
Chromium	66	0.086			100	6.2	240	5.2		
Cobalt	3	0.0039			26.0	1.6	230	5.0		
Copper	15	0.020			21.0	1.3	70	1.5		
Iron	NC	--			8800	540	17000	370		
Lead	26	0.034			< 13	< 0.80	< 2000	< 44		
Manganese	490	0.64			100	6.2	320	7.0		
Mercury	--	--			< 0.02	< 0.012	< 2	< 0.044		
Nickel	14	0.018			65	4.0	140	3.0		
Selenium	2	0.0026			< 0.5	< 0.031	< 4	< 0.087		
Tellurium	--	--			< 65	< 4.0	< 500	< 11		
Tin	≤ 0.9	≤ 0.0012			< 65	< 4.0	< 500	< 11		
Titanium	NC	--			3600	220	4000	87		
Vanadium	44	0.057			81	5.0	100	2.2		
Zinc	63	0.082			36	2.2	230	5.0		
Chloride	NC	--			--	--	61000	1300		
Fluoride	NC	--			--	--	--	--		
Nitrates	--	--			--	--	5850	110		
Sulfates	NC	--			--	--	--	--		
Total POM										
Total PCB										

See notes on Table F-1

Data used in calculations for data in Table 4-9.

TRACE SPECIES AND ORGANICS TEST
SAMPLE RECOVERY LOG
REVISED 2/28/77

Test No. 9-5 Date 10/4/76 Location ⊖ CEMENT KILN

Sample Port Position OUTLET OF ESP

NO SSMS ON THESE SAMPLES

	Container Number	Sample Description	Container Type	Net wt/vol.	Comment
E*	400	S D+N + 10μ SOLIDS	4oz. N.	0.0214g	Dissolve in 459
E*	459	L D+N + 10μ WASH	16 Oz A.	324ml.	
		3μ SOLIDS	NONE		
	455	L 3μ WASH	16oz. A	271ml.	
F*	415	S 1μ SOLIDS	4oz N	0.4049g	Dissolve in 458
F*	458	L 1μ WASH	16oz A	148ml.	
	275	S #1 FILTER	PETRI	0.1859g	157.1855g Tot
	365	L FILT. HOUS. WASH	8oz A	15ml.	
	223	L XAD MOD RINSE	16Oz A	876ml	
	300	S XAD RESIN	16 Oz AWM	158g	437-279(tare)
A*	220	L XAD CONDENSATE	16 Oz A	186ml	2275 ml TOT
A*	439	L " "	1 L N	1036ml	
A*	445	L "	1 L N	1058ml	
B*	1024	L IMPINGER #1 (1)	1gal GLASS	549ml	4262 (500 ml rinse). 4064
B*	1025	L " #1 (2)	"	3814ml	298 RINSE
	1026	L IMPINGER #2	"	1843ml	1164 = 679 Rinse
C*	224	L IMPINGER #3 (1)	16oz A	174ml	421-305 = 815 Rinse
C*	440	L IMPINGER #3 (2)	1 L N	947ml	
D*	363	L H_2O IMPINGER WASH 2&3	8oz A	148ml	579 "
D*	454	L " " "	16oz A	431ml	
	364	LB IPA BLANK	8oz A	96ml	
	1021	P Cement Feed SLURRY	GLASS	829g	
	1022	P CEMENT CLINKER	"	768.5g	
	1023	P ESP CATCH	"	494g	
	COUNT	S - 2 SOLID	28 BOTTLES SENT		
		L - 10 LIQUID	* COMBINE SAMPLES INDICATED		
		LB - 1 LIQ. BLANK			
		P - 3 PROCESS SOLIDS			

16 ANALYSES

Data Sheet XVB 6002-15

Data used in calculations for data in Table 4-9.

Excerpts from

REFERENCE 26B (SECTION 4.0)

Hunter, S. C., et al., Application of Combustion Modifications to Industrial Combustion Equipment: Data Supplement A, EPA-600/7-79-015b (NTIS PB 293888), U. S. Environmental Protection Agency, Research Triangle Park, NC, February 1979.

LOCATION NO. 3
CONTROL ROOM DATA SHEET

DATE 5-6-76

TEST NO. 3-2 B TIME 15:18

Parameter	Units	Meter Legend	Meter No.	Reading
1. Coke Rate	tons/hr	"Coal Mill Feed Rate"	H3-K2-BS1	5.7
2. Cyclone Tempering Air Temp.	°F			610 °F
3. Coal Mill Outlet Temp.				157 °F
4. Coal Mill Inlet Temp.				300 °F
5. Coal Mill Motor Amp				24
6. Coal Mill Inlet Pressure				1.9
7. Coal Mill Outlet Pressure				8.6
8. Coal Mill Fan Inlet Damper				50
9. Fan Amps				130
10. Fan Damper Position			H5-2-D01-POSR	33
11. Kiln Exit O_2	%		H3-20$_2$R	1.1 ÷ 1.4
12. Klin Feeder Speed	RPM			20
13. Kiln Speed	RPH			94
14. Max. Kiln Shell Temp.	°F			580
15. Cooler Undergrate Air Temp				198
16. Cooler Undergrate Air Pressure				6"
17. Material Temp			H3-2-TSM	2630
18. Gas Fuel Rate	SCFH (70°F)			71
19. Clinker Rate	tons/hr	"Clinker Belt Scale Int"	H2-2-BSI-INT	53
20. Feed Rate	tons/hr	(From Operator)		~58
21. BAGHOUSE INLET TEMP. °F				550

Data used in calculations for data in Table 4-3.

EP-67 KEYED CALCULATION SHEET*

PARTICULATE EMISSION CALCULATIONS

Test No. 3-2 Date 5-6-76 Location Dry Cement Kiln Engr. WAC

Unit No. HV-2 Fuel Coke/Gas Sampling Train and Method Method 5

Pitot Factor, Fs .83 Barometric Pressure, P_{bar} 28.95 (STO 0) in. Hg

Tot. Liquid Collected, V_{lc} 6.5 (STO 1) ml Total Particulate, M_n 3417.6 (STO 2) m gm

Velocity Head, ΔP 0.8 (STO 3) iwg Stack Temp., Ts 1005 (STO 4) °F Stack Area, As 84 (STO 5) ft²

Sample Volume, Vm 5.58 (STO 6) ft³ Stack Press., Psg -6 (STO 7) iwg Excess O_2, XO_2% 13.65 (STO 8) %

Orifice Press. Diff., H .62 (STO 9) iwg ~~Stack Gas Sp. Gravity~~, Gs ρ_{flue}/ρ_{air} @ T 1.04 (STO A) n.d.

Sample Time, θ 10 (STO B) min Nozzle Dia., Dn 1/4 (STO C) in. Meter Temp., T_m (STO D) °F

Select Fe	Oil (A)	Gas (B)	Coal (C)	Other: Coke/Gas
SC Feet/10⁴ Btu	92.2	87.4	98.2	114.2 (D)

Press (E) if meter is not temperature compensated.

1. Sample Gas Volume	$Vm_{std} = 0.0334\ Vm(P_{bar} + H/13.6)$	5.40	SCF
2. Water Vapor	$Vw_{std} = 0.0474\ V_{lc}$	0.31	SCF
3. Moisture Content	Bwo = Eq. 2/(Eq. 1 + Eq. 2)	0.54	N.D.
4. Concentration	a. $C = 0.0154\ Mn/Vm_{std}$	9.746	grains/DSCF
	b. $C = 2.205 \times 10^{-6}\ Mn/Vm_{std}$	1.396×10^{-3}	lb/DSCF
	c. $C = \text{Eq. 4b} \times 16.018 \times 10^3$	22.36	grams/DSCM
5. Abs. Stack Press.	$Ps = P_{bar} \times 13.6 + Psg$	387.7	in. w abs.
6. Stack Gas Speed	$Vs = 174\ Fs\ \sqrt{\Delta P\,Ts}\ \sqrt{\frac{407}{Ps} \times \frac{1.00}{Gs}}$	4114	ft/min
7. Stack Gas Flow Rate @ 70°F	a. $Qsw = \text{Eq. 6} \times As \times \frac{530}{Ts} \times \frac{Ps}{407}$	173 602	WSCF/min
	b. $Qsd = \text{Eq. 7a} \times (1 - \text{Eq. 3})$	164228	DSCF/min
8. Material Flow	$Ms = \text{Eq. 7b} \times \text{Eq. 4b} \times 60$	1.376×10^4	lb/hr
9. XO_2 factor	$XO_2f = 2090/(20.9 - XO_2\%)$	288.3	N.D.
10. Emission	a. $E = \text{Eq. 4b} \times Fe \times \text{Eq. 9}$	45.96	lb/MMBtu
	b. $E = \text{Eq. 4c} \times Fm \times \text{Eq. 9} \times 1000$	19763	ng/joule
11. % Isokinetic	$I = \frac{14077 \times Ts(Vm_{std} + Vw_{std})}{\theta \times Vs \times Ps \times Dn^2}$	81.	%

*If calculating by hand:
1) Convert T_s and T_m to °R
2) Multiply EQ 1 by $530/T_m$(°R) if meter not temperature compensated.
3) $F_m = 2.684 \times 10^{-5} \times F_e$

Data Sheet 6002-4
Revised 2/15/78

Data used in calculations for Data in Table 4-3.

Test No. 3

CASCADE IMPACTOR DATA SHEET

TEST RUN NO. 3-3 LOCATION 3 DATE 5-7-76 TIME 13:50

IMPACTOR NO. 1 CYCLONE NO. 1 OPERATOR

SAMPLE POINT LOCATION DOWNSTREAM OF MULTICLONE

SUBSTRATE COATING NONE FUEL COKE, GAS ~~TEST LOAD~~ KLINKER FLOW 60 T/hr klb/hr

IMPACTOR ORIENTATION HORIZ. FLOW THRU IMPACTOR 0.07 CFM

FLUE STATIC PRESSURE -6 inH$_2$O, VELOCITY 65 ft/sec.

NOZZLE DIA. 2 mm IMPACTOR PRESSURE DROP 13¾" H$_2$O END TIME 13:40

GAS METER END 7.01 CF START TIME 13:50

GAS METER START 0 CF DURATION 10 MIN

GAS VOLUME 7.01 CF FLOW RATE 0.07 CFM

AMBIENT TEMPERATURE 77 °F (WET BULB 64 °F) PRESSURE 28.99 IN Hg. HUMIDITY 50 %

FLUE GAS MOLECULAR WT. ____, TEMP. 550 °F, DENSITY ____ g/cc, VISCOSITY ____ POISE

PUMP PRESS. 26.5" Hg METER TEMP. 91°F

	Stage Number 1	2	3	4	5			Stage Blank
CUP ~~Foil~~ + Sample, g	3.3677	3.8063	3.2598	3.6594	3.6679			
Unused Foil, g	3.2477	3.7561	3.2389	3.6530	3.6646			
Sample, g	0.1200	0.0502	0.0109	0.0064	0.0033			
Correction for Blank, g								
Final Sample, g								

FILTER NO.	Sample	Blank
FILTER + SAMPLE, g	.0422	
FILTER TARE, g	.0394	
SAMPLE, g	.0028	
CORRECTION FOR BLANK, g		
FINAL SAMPLE, g		

FULL CONTAINER, g ____

EMPTY CONTAINER, g ____

CYCLONE CATCH, g 0.4328

Data used in Table 4-8.

TABLE 2 (Continued)

	Symbol	Value	CUM %
% on a cup of the total sample collected	CYCLONE		100
Stage 2	γ_2	61.98	30.91
3	γ_3	25.93	11.75
4	γ_4	5.63	3.74
5	γ_5	3.31	2.00
6	γ_6	1.70	.97
Filter	γ_7	1.45	.44
	Total	100.00*	

*Any discrepancy due to rounding off should be buried in the largest γ cumulative % smaller than D_{pc}

Σ_2	38.02
Σ_3	12.09
Σ_4	6.46
Σ_5	3.15
Σ_6	1.45

Data used in Table 4-8

PARTICULATE EMISSION CALCULATIONS (Method 5) Test No. 9-1

Test No. 9-1 Date 8-11-76 Location Gulf Coast Cement Engr. K.

Unit No. 1 Fuel N. G. Load 83%

Pitot Factor, Fs .84 Barometric Pressure, P_{bar} 29.99 in. Hg

Tot. Liquid Collected, V_{1c} 130 ml Total Particulate, M_n 6689.6 m gm

Velocity Head, ΔP .09 iwg Stack Temp., Ts 760 °R Stack Area, As 45 ft^2

Sample Volume, Vm 7.93 ft^3 Stack Press., Psg -6.6 iwg Excess O_2, XO_2% 6.0 %

Orifice Press. Diff., H .62 iwg Stack Gas Sp. Gravity, Gs 1.03 n.d.

Sample Time, θ 15 min Nozzle Diameter, Dn .375 in.

1. Sample Gas Volume	$Vm_{std} = 0.0334\ Vm(P_{bar} + H/13.6)$	7.955	SCF
2. Water Vapor	$Vw_{std} = 0.0474\ V_{1c}$	6.162	SCF
3. Moisture Content	Bwo = Eq. 2/(Eq. 1 + Eq. 2)	.4365	N.D.
4. Concentration	a. $C = 0.0154\ Mn/Vm_{std}$	12.941	grains/DSCF
	b. $C = 2.205 \times 10^{-6}\ Mn/Vm_{std}$	1.853×10^{-3}	lb/DSCF
	c. $C = Eq.\ 4b \times 16.018 \times 10^3$	29.681	grams/DSCM
5. Abs. Stack Press.	$Ps = P_{bar} \times 13.6 + Psg$	401.46	in. w abs.
6. Stack Gas Speed	$Vs = 174\ Fs\ \sqrt{\Delta P Ts}\sqrt{\frac{407}{Ps} \times \frac{1.00}{Gs}}$	1199.26	ft/min
7. Stack Gas Flow Rate @ 70°F	a. $Qsw = Eq.\ 6 \times As \times \frac{530}{Ts} \times \frac{Ps}{407}$	37122	WSCF/min
	b. Qsd = Eq. 7a x (1. - Eq. 3)	20918	DSCF/min/duct
8. Material Flow	Ms = Eq. 7b x Eq. 4b x 60	2.326×10^3	lb/hr
9. XO_2 factor	$XO_2f = 2090/(20.9 - XO_2\%)$	140.27	N.D.
10. Emission per duct	a. E = Eq. 4b x Fe x Eq. 9	25.54 ~~22.717~~	lb/MMBtu
	b. E = Eq. 4c x Fm x Eq. 9 x 1000	10983. ~~9767.2~~	ng/joule
11. % Isokinetic	$I = \frac{14077 \times Ts(Vm_{std} + Vw_{std})}{\theta \times Vs \times Ps \times Dn^2}$	148.72	%

	Oil	Gas	Coal	Gas + CO2
Fe SC Feet/10^4 Btu	92.2	87.4	98.2	98.28
Fm SC Meters/10^4 joules	0.002475	0.002346	0.002636	

Note: Starting with test 9-1 a bigger brush for probe cleaning was used. It was felt that the older smaller brush did not completely clean probe at acetone wash.

Data Sheet 6002-4

Data used in calculations for data in Table 4-8.

PARTICULATE EMISSION CALCULATIONS Test No. *9-2*

Meth. 5

Test No. *9-2* Date *8-13-76* Location *Gulf Coast Conv.* Engr. *K.*

Unit No. *1* Fuel *N.G.* Load *83%*

Pitot Factor, Fs *.84* Barometric Pressure, P_{bar} *29.89* in. Hg

Tot. Liquid Collected, V_{lc} *126.5* ml Total Particulate, M_n *57.35* m gm

Velocity Head, ΔP *.12* iwg Stack Temp., Ts *750* °R Stack Area, As *45* ft²

Sample Volume, Vm *7.42* ft³ Stack Press., Psg *-6.4* iwg Excess O_2, XO_2% *4.2* %

Orifice Press. Diff., H *.54* iwg Stack Gas Sp. Gravity, Gs *1.03* n.d.

Sample Time, θ *15* min Nozzle Diameter, Dn *.375* in.

1. Sample Gas Volume	$Vm_{std} = 0.0334\ Vm(P_{bar} + H/13.6)$	*7.447*	SCF
2. Water Vapor	$Vw_{std} = 0.0474\ V_{lc}$	*5.996*	SCF
3. Moisture Content	Bwo = Eq. 2/(Eq. 1 + Eq. 2)	*.446*	N.D.
4. Concentration	a. $C = 0.0154\ Mn/Vm_{std}$	*11.86*	grains/DSCF
	b. $C = 2.205 \times 10^{-6}\ Mn/Vm_{std}$	*1.698 x 10⁻³*	lb/DSCF
	c. C = Eq. 4b x 16.018×10^3	*27.199*	grams/DSCM
5. Abs. Stack Press.	$Ps = P_{bar} \times 13.6 + Psg$	*400.10*	in. w abs.
6. Stack Gas Speed	$Vs = 174\ Fs\ \sqrt{\Delta P Ts}\ \sqrt{\frac{407}{Ps} \times \frac{1.00}{Gs}}$	*1377.98*	ft/min
7. Stack Gas Flow Rate @ 70°F	a. Qsw = Eq. 6 x As x $\frac{530}{Ts} \times \frac{Ps}{407}$	*43076.9*	WSCF/min
	b. Qsd = Eq. 7a x (1. - Eq. 3)	*23864.6*	DSCF/min
8. Material Flow	Ms = Eq. 7b x Eq. 4b x 60	*2.43 x 10³*	lb/hr
9. XO_2 factor	$XO_2f = 2090/(20.9 - XO_2\%)$	*125.15*	N.D.
10. Emission *per Anal*	a. E = Eq. 4b x Fe x Eq. 9 *20.89*	*~~19.573~~*	lb/MMBtu
	b. E = Eq. 4c x Fm x Eq. 9 x 1000 *8979.8*	*~~7985.68~~*	ng/joule
11. % Isokinetic	$I = \frac{14077 \times Ts(Vm_{std} + Vw_{std})}{\theta \times Vs \times Ps \times Dn^2}$	*122.0*	%

	Oil	Gas	Coal
Fe SC Feet/10^4 Btu	92.2	~~87.4~~ *98.28*	98.2
Fm SC Meters/10^4 joules	0.002475	0.002346	0.002636

Data Sheet 6002-4

Data used in calculations for data in Table 4-8.

Test No. 9-1

CASCADE IMPACTOR DATA SHEET

TEST RUN NO. 9-1 (BASELINE) LOCATION 9 DATE 8-11-76

IMPACTOR NO. 1 CYCLONE NO. 1 OPERATOR RAY

SAMPLE POINT LOCATION UPSTREAM OF PRECIPITATOR

SUBSTRATE COATING — FUEL N.G. TEST LOAD 84% klb/hr

IMPACTOR ORIENTATION VERTIC. FLOW THRU IMPACTOR .1 CFM

FLUE STATIC PRESSURE -6.4 inH_2O, VELOCITY 20.3 ft/sec. in duct

NOZZLE DIA. 4 mm IMPACTOR PRESSURE DROP 14 "H_2O END TIME 13.58

GAS METER END 1340.55 CF START TIME 13.50

GAS METER START 1339.85 CF DURATION ~8 min

GAS VOLUME .70 CF FLOW RATE .1 CFM

AMBIENT TEMPERATURE 95 °F PRESSURE 29.76 IN Hg. HUMIDITY [illegible] %

FLUE GAS MOLECULAR WT. ____, TEMP. 310 °F, DENSITY ____ g/cc, VISCOSITY ____ POISE

FLUE GAS TEMP. 310 °F

	Stage Number 1	2	3	4	5			Stage Blank
Foil + Sample, g	4.2899	3.7296	4.0949	3.6708	4.1842			
Unused Foil, g	4.0864	3.6825	4.0758	3.6605	4.1755			
Sample, g	.2035	.0471	.0191	.0103	.0057			
Correction for Blank, g								
Final Sample, g	.2035	.0471	.0191	.0103	.0087			
D_{pc}	2.81	1.66	1.13	.59	.37			
% of TOTAL	35.5	8.2	3.3	1.8	1.5			
	50.3	14.8	6.6	3.3				

FILTER NO.	Sample	Blank
FILTER + SAMPLE, g	1.2199	
FILTER TARE, g	1.2200	
SAMPLE, g	-0	
CORRECTION FOR BLANK, g		
FINAL SAMPLE, g		

FULL CONTAINER, g .7310

EMPTY CONTAINER, g .4460

CYCLONE CATCH, g .2850 49.7%

CUPS .2887

.5737 g

stages + cyclone = 0.5737 g

~60.% is less than 3 μ

60-20

Data used in Table 4-8

TABLE 2 (Continued)

	Symbol	Value	
% on a cup of the total sample collected	Cycl		49.7
Stage 2	Υ_2	70.5	35.5
3	Υ_3	16.3	8.2
4	Υ_4	6.6	3.33
573.7 5	Υ_5	3.6	1.8
6	Υ_6	3.0	1.52
Filter	Υ_7	0	—
	Total	100.00*	

*Any discrepancy due to rounding off should be buried in the largest Υ cumulative % smaller than D_{pc} cyclone ~ 7μ

			Data used in Table 4-8.
			100
			50.35
2.81	Σ_2	29.5	14.85
1.66	Σ_3	13.2	6.65
1.13	Σ_4	6.6	3.32
.59	Σ_5	3.0	1.52
.37	Σ_6	0	0

Test No. 9-2

CASCADE IMPACTOR DATA SHEET

TEST RUN NO. 9-2 LOCATION 9 DATE 8-13-76

IMPACTOR NO. 1 CYCLONE NO. 1 OPERATOR R. PIONESSA

SAMPLE POINT LOCATION UPSTREAM OF PRICIPITATOR

SUBSTRATE COATING NONE FUEL NAT. GAS TEST LOAD 83% ~~klb/hr~~

IMPACTOR ORIENTATION VERTICAL FLOW THRU IMPACTOR .1125 CFM

FLUE STATIC PRESSURE -6.3 inH_2O, VELOCITY 23.26 ft/sec

NOZZLE DIA. 4 mm IMPACTOR PRESSURE DROP 14"H_2O END TIME 1154

GAS METER END 1350.14 CF START TIME 1150

GAS METER START 1349.69 CF DURATION 4 MIN

GAS VOLUME .45 CF FLOW RATE .1125 CFM

AMBIENT TEMPERATURE 92 °F PRESSURE 29.87 IN Hg. HUMIDITY 56 %

FLUE GAS MOLECULAR WT. ____, TEMP. 300 °F, DENSITY ____ g/cc, VISCOSITY ____ POISE

	Stage Number 1	2	3	4	5			Stage Blank
Foil + Sample, g	4.1295	3.6866	4.0867	4.1835	4.1835			
Unused Foil, g	4.0879	3.6705	4.0785	3.6692	4.1810			
Sample, g	.0416	.0161	.0082	.0043	.0025			
Correction for Blank, g								
Final Sample, g	.0416	.0161	.0082	.0043	.0025			
	.0727	.0311	.0150	.0068				

FILTER NO.	Sample	Blank
FILTER + SAMPLE, g	.0394	
FILTER TARE, g	.0387	
SAMPLE, g	.0007	
CORRECTION FOR BLANK, g	0	
FINAL SAMPLE, g	.0007	

FULL CONTAINER, g .4986

EMPTY CONTAINER, g .4328

CYCLONE CATCH, g .0658 ✓

catch 50% low re method 5

stages + cyclone = .01385 g
+ filter = .1392

60-20

Data used in Table 4-8.

TABLE 2 (Continued)

	Symbol	Value	
% on a cup of the total sample collected	cyclone		47.3
Stage 2	Υ_2	56.6	29.9
3	Υ_3	21.9	11.6
4	Υ_4	11.2	5.9
5	Υ_5	5.9	3.1
6	Υ_6	3.4	1.8
Filter	Υ_7	1.0	.50
	Total	100.00*	

*Any discrepancy due to rounding off should be buried in the largest Υ cumulative % smaller than D_{pc}

		Data used in Table 4-8.
		100.
		52.8
Σ_2	43.4	22.9
Σ_3	21.5	11.3
Σ_4	10.3	5.4
Σ_5	4.4	2.3
Σ_6	1.0	.5

Excerpts from

REFERENCE 27 (SECTION 4.0)

Taback, H. J., et al., Fine Particle Emissions from Stationary and Miscellaneous Sources in the South Coast Air Basin, KVB 5806-783 (NTIS PB 293 923), California State Air Resources Board, Sacramento, CA, February 1979.

B. Particulate test set-up--

Two tests were done on the same cement kiln operating at approximately the same conditions, and at the same position on the stack downstream of the baghouse at about 100 ft above ground level on the straight section leading to the atmosphere. Natural gas was used as the fuel source for the first test, Test 9, and coal was used for the second test, Test 18. The velocity profiles in the stack for the two tests are listed in Table 4-41. Velocity points greater than 72 inches were not able to be measured for Test 9 and velocity points greater than 121 inches were not able to be measured even with the pitot tube extension for Test 18. Note that for Test 18, coal firing, the mean velocity in the stack is somewhat higher than the gas fired Test 9. This is as expected, considering the additional air needed to stoichiometrically combust the coal to produce the same Btu value as natural gas for operating the process. For both tests the SASS sampling train was used with a 5/8" nozzle at Velocity Point #4.

C. Particulate Test Results--

The results of the two tests discussed in this section are listed in Table 4-1. Major elemental composition, sulfate, nitrate and carbon analysis were determined for all fractions of particulate catches which contained weights in excess of 100 mg. The details for these procedures are discussed in Section 3.2.2. Tables 4-42 and 4-43 list the results from this analysis.

D. Discussion of Results--

1. Particle size distribution--Figure 4-31 is a plot of particle size (μm) vs. accumulated weight percent, the latter plotted on a probability scale as explained in Section 3.2.3 B. Two curves are presented, one including the impinger catch, and the other ignoring it. The size distribution curve for both tests ignoring the impinger catch are identical. However, when the impinger catch is included the curve shifts to the right; more so for the coal firing than gas. The breakdown of the particle size distribution including the impinger taken from Figure 4-31 is as follows:

	Percent of Particles			
	>10μm	10-3μm	3-1μm	<1μm
Test 9, gas fired	8	32	40	20
Test 18, coal fired	8	24	34	34

Data used in Table 4-10.

The mean particle size, including the impinger, for Test 18 is 15μm and 23μm for Test 9; ignoring the impinger catch it is 27μm for both tests. These results are similar to other size distribution data available in the literature (Ref. 4-13 and 4-14).

2. Chemical Composition-- Tables 4-42 and 4-43 list the results from the chemical analysis of the particulate fraction for each of the tests discussed in this section. Calcium is the most predominant species, as one would expect. Carbon is second most abundant. Its origin is most likely from the uncombusted fuel. The concentration of carbon is slightly more for coal firing than natural gas firing. Sulfate is third most abundant and tends to concentrate in the impingers. As expected, sulfate concentration is higher for coal firing than gas firing, due to higher sulfur content of the fuel. Nitrates also tend to end up in the impinger. Iron and potassium are in the range of 1% of the total particulates. All other elements listed were detected in trace amounts.

3. Emissions and emission factors—Emissions and emission factors can be listed with several different units. The following lists some of these emissions and factors based on these two tests alone.

	Test 9 (gas)	Test 18 (coal)
gr/DSCF	0.0056	0.0099
T/yr	22	48
lb/hr	5.9	12.5
lb/ton produced	0.21	0.43
lb/bbl produced	0.041	0.084

Data used in Table 4-10.

4.2.7 Calcination of Gypsum

Gypsum is a mineral that occurs in large deposits throughout the world. It is hydrated calcium sulfate, with the formula $CaSO_4 \cdot 2H_2O$. When heated slightly, the following reaction occurs:

$$CaSO_4 \cdot 2H_2O \rightarrow CaSO_4 \cdot 1/2\ H_2O + 1\text{-}1/2\ H_2O(g);\ \Delta H = +19,700\ \text{cal.}$$

Excerpts from

REFERENCE 30 (SECTION 4.0)

Stack Emissions Survey of Lone Star Industries, Inc., Portland Cement Plant, Maryneal, Texas, File No. EA 795-09, Ecology Audits, Inc., Dallas, TX, September 1979.

SUMMARY OF RESULTS

Kiln Baghouse Number 1

Run Number	1	2	3
Date	27 Sep 79	27 Sep 79	27 Sep 79
Time	1255-1355	1455-1555	1650-1750
Preheater Flow Rate - ACFM	70300	69200	69200
Preheater Flow Rate - DSCFM*	25600	25700	23900
Baghouse Flow Rate - ACFM	128000	87100	95300
Baghouse Flow Rate -DSCFM*	80300	53100	51900
% Water Vapor - %Vol.	7.55	6.80	5.73
% CO_2 - %Vol. @ Preheater	23.8	19.0	17.6
% CO_2 - %Vol. @ Baghouse	7.6	9.2	8.1
Baghouse Particulate Concentration - gr/dscf	0.00281	0.00225	0.00280
Baghouse Particulate Emission - lbs/hr	1.94	1.02	1.24
Kiln Feed Rate - Ton/hr	36.5	39.0	40.4

Data mentioned in Section 4.1.9 and used for calculations in Appendix E.

SUMMARY OF RESULTS

Kiln Baghouse Number 2

Run Number	2	3	
Date	28 Sep 79	28 Sep 79	
Time	1550-1650	1735-1835	
Preheater Flow Rate - ACFM	71300	71000	
Preheater Flow Rate - DSCFM*	26500	26300	
Baghouse Flow Rate - ACFM	80300	138000	
Baghouse Flow Rate -DSCFM*	48600	84900	
% Water Vapor - %Vol.	6.65	6.56	
% CO_2 - %Vol. @ Preheater	19.6	25.2	
% CO_2 - %Vol. @ Baghouse	10.7	7.8	
Baghouse Particulate Concentration - gr/dscf	0.00642	0.00453	
Baghouse Particulate Emission - lbs/hr	2.67	3.29	
Kiln Feed Rate - Ton/hr	34.8	36.1	

Data mentioned in Section 4.1.9 and used for calculations in Appendix E.

SUMMARY OF RESULTS

Kiln Baghouse Number 3

Run Number	3	4	5
Date	26 Sep 79	26 Sep 79	26 Sep 79
Time	1041-1141	1255-1355	1510-1610
Preheater Flow Rate - ACFM	76200	72700	74500
Preheater Flow Rate - DSCFM*	28900	27200	27000
Baghouse Flow Rate - ACFM	82100	81600	91600
Baghouse Flow Rate -DSCFM*	48700	47700	52100
% Water Vapor - %Vol.	5.70	6.08	7.56
% CO_2 - %Vol. @ Preheater	19.2	18.8	21.0
% CO_2 - %Vol. @ Baghouse	11.4	10.7	10.9
Baghouse Particulate Concentration - gr/dscf	0.00840	0.00824	0.00782
Baghouse Particulate Emission - lbs/hr	3.50	3.37	3.49
Kiln Feed Rate - Ton/hr	40.1	40.7	41.0

Data mentioned in Section 4.1.9 and used for calculations in Appendix E.

Excerpts from

REFERENCE 31 (SECTION 4.0)

Hurst, W. W., Gas Process Survey, Roanoke No. 5 Kiln System, Lone Star Cement, Inc., Cloverdale, VA, October 1979.

Results showed average conditions for each Kiln System as follows:

Location Kiln Stack	Temp. °F	Volume ACFM	DSCFM	Emission Lbs/Hr	Opacity Lear Sieg.	Opacity OBS
1	401	65,700		28.4	34	
2				Postponed		
3	420	60,700		23.6	25	15.7
4	413	70,900		28.9	31	19.9
5 *	332	288,600	161,700	38.4	14	
5 **	326	192,000	10[illegible],150	20.3	14	
5 ***	296	86,650	5[illegible],580	12.2	11	

TABLE 5

* No Gas Bypass
** Gas Bypass to one Raw Mill
*** Gas Bypass to two Raw Mills

Respectfully submitted,

W. W. Hurst, P. E.

WWH/tab

Data mentioned in Section 4.1.10 and used for calculations in Appendix E.

TABLE 3

ROANOKE EMISSION SURVEY

PROCESS RATE, CONSUMPTION AND PRODUCTION

1979

Run No.	Date	Kiln No.	Fuel Rate T/H	% Water In Coal	Feed Rate T/H	% Water In Raw Mix	Clinker Production Rate T/H	Cooling Water Gal/Min
45-46	9-29	1	3.3	6.9	21.9	0.42	14.6	22
47-48	9-30	1	3.4	5.6	20.7	0.39	13.8	25
49-50	10-1	1	3.4	8.8	21.0	0.56	14.0	26
Average	(Kiln #1)		3.4	7.1	21.2	0.46	14.1	24
		2	POSTPONED					
		2						
		2						
Average	(Kiln #2)							
51-52	10-4	3	2.7	7.3	22.1	0.53	14.7	26
53-54	10-11	3	2.8	7.2	21.9	0.52	14.6	25
55-56	10-12	3	2.8	7.4	20.7	0.48	13.8	24
Average	(Kiln #3)		2.8	7.3	21.6	0.51	14.4	25
39-40	9-19	4	3.0	5.4	26.0	0.45	17.3	24
41-42	9-20	4	2.9	6.3	25.6	0.38	18.4	25
43-44	9-27	4	3.0	6.6	32.1	0.38	21.4	29
Average	(Kiln #4)		3.0	6.1	27.9	0.40	19.0	26
1-2	7-22	5	8.5	4.9	95	0.30	59	37
3-4	7-24	5	9.3	5.0	105	0.28	66	48
5-6	7-25	5	9.4	7.3	105	0.32	66	49
15-16	8-18	5	9.9	5.2	105	0.34	66	49
23-24	9-2	5	9.8	6.8	110	0.38	69	50
25-26	9-3	5	9.5	5.1	110	0.42	69	50
31-32	9-4	5	9.4	6.6	110	0.38	69	51
7-8	7-26	5	9.5	5.0	102	0.29	64	44
10	8-4	5	9.3	5.2	100	0.36	63	61
12	8-5	5	9.5	4.8	102	0.32	64	46
14	8-6	5	9.3	8.3	105	0.38	66	47
17-18	8-22	5	9.5	3.7	105	0.36	66	45
19-20	8-23	5	9.7	7.2	105	0.38	66	44
21-22	8-30	5	8.7	4.4	110	0.52	69	51
Average	(Kiln #5)		9.4	5.7	105	0.36	66	48

Data used for calculations in Appendix E.

Excerpts from

REFERENCE 32 (SECTION 4.0)

Mease, M. J., Test Report Stack Analysis for Particulate Emission, Clinker Coolers/Gravel Bed Filter, Mease Engineering Associates, Port Matilda, PA, March 1980.

EMISSIONS SUMMARY

	Run #1	Run #2	Run #3
Kiln Feed Rate, Tons/Hour	148.8	148.8	148.8
Clinker Feed Rate, Tons/Hour	83.8	83.8	83.8
Allowable Emission Rate, Lb./Hr. (EPA Regulations)	14.9	14.9	14.9
Allowable Emission Rate, Lb./Hr. (State of Oklahoma Regulation)	117.7	117.7	117.7
Actual Emission Rate, Lb./Hr. (Front Half of Train)	14.8	13.6	12.9
Actual Emission Rate, Lb./Hr. (Entire Sampling Train)	15.2	14.8	13.9
Particulate Concentration, Grains/SCF (Front Half of Train)	0.012	0.011	0.011
Particulate Concentration, Grains/SCF (Entire Sampling Train)	0.012	0.012	0.012
Particulate Concentration, Grains/ACF (Front Half of Train)	0.008	0.008	0.007
Particulate Concentration, Grains/ACF (Entire Sampling Train)	0.009	0.008	0.008

Data mentioned in Section 4.1.11 and used for calculations in Appendix F.

OKLAHOMA PROCESS DATA

FOR

REXNORD GRAVEL BED

	KILN #1	KILN #2	KILN #3	TOTAL KILN FEED RATE
Raw Feed Tons/Hr	40.2	40.9	51.9	133.0
Coal Feed Tons/Hr	4.5	5.1	6.2	15.8
TOTAL FEED RATE	44.7	46.0	58.1	148.8
Clinker Prod. Tons	25.3	25.8	32.7	83.8
Cooler Feed Rate Okla.				
Allowable Emissions Clinker Cooler EPA 0.1 Lb/Ton kiln Feed with Coal				14.9 lbs/hr
Oklahoma Allowable Process Wt. Table Clinker Production 83.8 Tons/Hr	38.4	38.6	40.7	117.7 lbs/hr

Production rates are during time of testing 11 a.m. to 6 p.m. 3/25, 1980. Representatives present during time of test were - GCA representing EPA, Dr. Joyce Sheedy, Oklahoma Air Control, Chris Rayner, Kaiser Engineers.

Data mentioned in Section 4.1.11 and used for calculations in Appendix F.

Excerpts from

REFERENCE 33 (SECTION 4.0)

Source Emissions Survey of Oklahoma Cement Company, Kiln No. 3 Stack, Pryor, Oklahoma, Mullins Environmental Testing Company, Addison, TX, March 1980.

SUMMARY OF RESULTS

Kiln Number 3 Stack

Run Number	2	3	4
Stack Flow Rate - ACFM	127,830	128,487	125,015
Stack Flow Rate - DSCFM*	70,239	70,405	70,003
% Water Vapor - % Vol.	6.7	7.0	6.0
% CO_2 - % Vol.	11.0	12.4	12.4
% O_2 - % Vol.	13.7	13.0	13.2
% Excess Air @ Sampling Point	219	192	203
Particulates Probe, Cyclone & Filter Catch grains/dscf*	0.0115	0.0109	0.0102
grains/cf @ Stack Conditions	0.0063	0.0059	0.0057
lbs/hr	6.9	6.6	6.1
Total Catch grains/dscf*	0.0580	0.0574	0.0639
grains/cf @ Stack Conditions	0.0318	0.0313	0.0357
lbs/hr	34.9	34.6	38.3
Kiln Feed Rate as Provided by Oklahoma Cement Company - tons/hr	58.5	58.5	58.5
Allowable Emission Rate State of Oklahoma - lbs/hr	46.1	46.1	46.1
Emission Rate - lbs/ton of kiln feed	0.118	0.113	0.104
Allowable Emission Rate - EPA 40 CFR 60 - lbs/ton of kiln feed	0.30	0.30	0.30
Sulfur Dioxide Emissions - lbs/hr	26.9	5.3	5.3

* 29.92 "Hg, 68°F

Data mentioned in Section 4.1.12 and used for calculations in Appendix E.

PRODUCTION DATA FACTORS

During Joy Baghouse Emission Test

Production Rates - For eight hours operation 11:00 a.m. - 7:00 p.m. (3-28-80)

#3 Kiln

Raw Feeder Counts -

419.1 ÷ 8 = 52.5 tons raw per hour

= 52.5 tons/hr x 0.63 = **33.1 clinker tons/hr**

Coal Feeder Counts -

$47.89 = \frac{47.89}{8} = 6.0$ Tons coal/hr used

Total kiln feed rate 58.5 tons/hr

Data used for calculations in Appendix E.

Excerpts from

REFERENCE 36 (SECTION 4.0)

Arlington, W. D., Compliance Stack Test, Lone Star Florida, Inc., Report 276-S, Cooler No. 3, South Florida Environmental Services, Inc., Belle Glade, FL, July 1980.

SUMMARY OF RESULTS

	RUN 1	RUN 2	RUN 3	AVERAGE
DATE OF TEST	7-9-80	7-9-80	7-9-80	
EMISSION RATE (LBS./HR.)	11.68	20.81	18.46	16.98
ALLOWABLE EMISSION RATE (LBS./HR.)	17.03	17.03	17.03	17.03
EMISSION RATE (LBS./TON OF FEED)	.0686	.1222	.1084	.0997
ALLOWABLE EMISSION RATE (LBS./TON)	.1000	.1000	.1000	.1000
PERCENT ISOKINETIC	92.37	93.70	92.65	92.91

Data mentioned in Section 4.1.13 and used for calculations in Appendix F.

Excerpts from

REFERENCE 39 (SECTION 4.0)

Mullins, B. J., Source Emissions Survey of Lone Star Industries, Inc., New Orleans, Louisiana, Mullins Environmental Testing Company, Addison, TX, November 1981.

SUMMARY OF EMISSION TESTS
New Orleans
November 9th - 13, 1981

	Kiln No. 1		Kiln No. 2	
Stack Flow ACFM	252076		229817	
Stack Flow DSCFM	125468		112262	
% Water Vapor %Vol	23.2		22.8	
Particulates Front Half				
Grains/Cf @Stack Conditions	0.0085		0.0088	
Emissions lbs/hr.	18.33		17.4	
Kiln Feed Rate	94.0 (La.)		83.0 (EPA)	
Allowable Emission Rate lbs/hr.	50.7 (La.)			
Allowable Emission Rate lbs/hr			24.9 (EPA	
Sulfur Dioxide Emissions lbs/hr.				
Allowed by Louisiana State	325 - 340		325 - 340	
Sulfur Dioxide Emissions by Test lbs/hr.	254.5		95.4	
	lbs/hr	ppm	lbs/hr	ppm
Ammonium lbs/hr - ppm	1.51(4.78)*	2.67(7.7)*	0.77(3.94)*	1.3(7.3)*
Chlorides lbs/hr - ppm	23.9	33.7	16.5	25.0
Potassium lbs/hr - ppm	2.02	2.67	2.01	2.3
Sodium lbs/hr - ppm	2.27	5.0	2.06	5.0
Sulfate lbs/hr - ppm	16.3	11.3	7.3	5.3

Data mentioned in Section 4.1.14 and used for calculations in Appendix E.

Pounds of NH_3 picked up in the first impinger had already began to form compounds with SO_2 and Cl.

Kiln Number 2 during emission testing was 83.0 tons per hour. Coal is not considered part of the process weight under EPA Regulations.

Identity of Emissions

Emissions from the process are fine particulates and combustion gases. Coal is used as a source of fuel which contains some sulfur; consequently, the combustion gases are a mixture of water vapor, oxygen, carbon dioxide, and sulfur dioxide. The particulates are composed of calcined or semi-calcined aragonite and clay.

Plant Operation

Plant operations were normal except for a time when the induced draft fan cut out on Kiln Number 1. Emission testing was discontinued until the Kiln was back to normal operations.

PRODUCTION DATA DURING TESTING

	Raw Feed (tons/hr)	Coal Feed (tons/hr)	Total Feed (tons/hr)	Allowable Emissions (lbs/hr)
Kiln Number 1	83.0	11.0	94.0	Louisiana Regulation 50.66
Kiln Number 2	83.0	11.0	83.0	EPA Regulation 24.9

Kiln Number 1 Under State Regulations

Kiln Number 2 Installed after 1971, therefore, must abide by EPA Regulations.

Data used for calculations in Appendix E.

Excerpts from

REFERENCE 40 (SECTION 4.0)

Hurst, W. W., Stack Emission Survey and Precipitator Efficiency Testing at Bonner Springs Plant, Lone Star Industries, Inc., Houston, TX, November 1981.

TABLE T-1

BONNER SPRINGS STACK EMISSION SURVEY

PARTICULATE EMISSION RATE 1981

Run No.	Test Location	Date	EXHAUST GAS Temp. °F.	Volume ACFM	PARTICULATE EMISSION RATE Grains/ SCF Dry	Lbs./SCF Dry X 10^{-6}	Lbs./Hr.	Ton/Day
1	No. 4 Stk.	9-8	—	—	—	—	—	—
2	"	"	777	75,900	0.1642	23.5	53.0	0.64
5	"	9-9	772	64,100	0.0741	10.6	19.7	0.24
6	"	"	769	72,900	0.0690	9.9	21.2	0.25
9	"	9-10	776	66,700	0.0623	8.9	18.0	0.22
10	"	"	768	67,200	0.0764	10.9	21.0	0.25
15	"	9-11	766	63,500	0.0955	13.6	25.9	0.31
16	"	"	768	55,500	0.0222	3.2	4.7	0.06
AVERAGE			771	66.500	0.0805	11.5	23.4	0.31
21	No. 2 Stk.	9-21	695	99,300	0.0308	4.4	16.3	0.20
22	"	9-21	692	105.400	0.0748	10.7	40.6	0.48
27	"	9-22	668	96,100	0.0206	2.9	11.6	0.14
28	"	9-22	666	100,900	0.0301	4.3	18.4	0.22
33	"	9-23	635	90,300	0.0177	2.5	10.0	0.12
34	"	9-23	635	85,100	0.0199	2.8	10.7	0.13
39	"	9-24	677	108,900	0.0340	4.9	20.4	0.25
40	"	9-24	676	110,600	0.0329	4.7	20.1	0.24
45	"	9-25	680	103,700	0.0607	8.4	34.4	0.41
46	"	9-25	679	111,400	0.0351	5.0	21.0	0.25
51	"	10-5	720	114,700	0.0240	3.4	13.1	0.16
52	"	10-5	724	118,400	0.1080	15.4	62.6	0.75
57	"	10-6	734	119,000	0.0788	11.3	44.8	0.54
58	"	10-6	734	127,200	0.0488	7.0	29.0	0.35
63	"	10-7	702	102,600	1.0470	147.0	531*	6.8
64	"	10-7	703	97,400	0.6930	99.0	352*	4.2
AVERAGE			688	105,700	0.1472	20.8	77.25	0.93
*Average not including Runs 63 & 64					0.042		25.2	

Data mentioned in Section 4.1.15 and used for calculations in Appendix E.

TABLE T-1 (Continued)

BONNER SPRINGS STACK EMISSION SURVEY

PARTICULATE EMISSION RATE 1981

Run No.	Test Location	Date	EXHAUST GAS Temp. °F.	Volume ACFM	PARTICULATE EMISSION RATE Grains/ SCF Dry	Lbs./SCF Dry X 10^{-6}	Lbs./Hr.	Ton/Day
67	No. 4 Stk.	10-8	734	70,500	.1032	14.7	32.2	.386
68	No. 4 Pptr.	10-8	722	106,100	5.469	781	2613	31.4
73	No. 4 Stk.	10-9	742	75,500	0.0413	5.9	12.5	.15
74	No. 4 Pptr.	10-9	795	80,200	7.960	1137	2.391	28.7
77	No. 4 Stk.	10-22	758	74,900	.0177	2.5	5.5	.06
78	No. 4 Pptr.	10-22	780	71,600	6.804	972	1864	22.4
83	No. 4 Stk.	10-23	751	74,700	.0183	2.6	5.8	.06
84	No. 4 Pptr.	10-23	761	74,400	6.446	920	1940	23.3
AVERAGE - Stack			746	73,900	0.0451	6.4	14.0	0.17
AVERAGE - Pptr.			765	83,000	6.67	953	2202	26.4
87	No. 1	11-2	638	47,200	0.0092	1.31	3.0	.04
88	& 4	11-2	638	52,300	0.0167	2.39	6.0	.07
89	Cooler	11-3	635	48,400	0.0024	0.34	0.8	.01
90	Stack	11-3	637	52,100	0.0039	0.55	1.4	.02
91	"	11-4	671	51,100	0.0027	0.39	0.9	.01
92	"	11-4	672	57,600	0.0034	0.48	1.3	.02
AVERAGE			649	51,500	0.0063	0.91	2.2	.03

Data used for calculations in Appendix D.

TABLE T-4

BONNER SPRINGS STACK EMISSION SURVEY

RATE PRODUCTION AND CONSUMPTION 1981

		Fuel Used		Raw Mix Used			Clinker
Date 1981	System Under Test	Coal Lbs/Min.	Moisture %	Ton/Hr. Dry	Slurry Moist - %	$CaCO_3$ %	Produced Ton/Hr.
9-8	No. 4 Kiln Stk.	156	8.0	31.0	34.7	79.2	16.8
9-9	"	146	6.1	31.0	35.0	79.2	16.9
9-10	"	150	8.0	31.4	34.5	79.3	17.0
9-11	"	150	7.1	32.0	34.1	79.2	17.4
9-21	No. 2 Kiln Stk.						
	Kiln 1-24 Hr.	83	7.4	17.86	34.1	80.3	9.92
	Kiln 2-24 Hr.	88	7.4	17.17	34.1	80.3	9.54
	Kiln 3-0 Hr.	—	—	—	—	—	—
9-22	Kiln 1-0 Hr.	—	—	—	—	—	—
	Kiln 2-24 Hr.	84	5.8	16.72	34.5	80.4	9.29
	Kiln 3-0 Hr.	—	—	—	—	—	—
9-23	Kiln 1-0Hr.	—	—	—	—	—	—
	Kiln 2-24 Hr.	85	6.5	16.88	34.0	80.3	9.38
	Kiln 3-12 Hr.	90	6.5	15.61	34.0	80.3	8.67
9-24	Kiln 1-0 Hr.	—	—	—	—	—	—
	Kiln 2-24 Hr.	84	8.0	17.17	34.1	80.3	9.54
	Kiln 3-24 Hr.	80	8.0	16.88	34.1	80.3	9.38
9-25	Kiln 1-0 Hr.	—	—	—	—	—	—
	Kiln 2-24 Hr.	84	7.8	17.41	34.0	80.3	9.67
	Kiln 3-24 Hr.	77	7.8	16.96	34.0	80.3	9.42
10-5	Kiln 1-24 Hr.	87	7.2	18.23	33.8	79.9	10.13
	Kiln 2-24 Hr.	88	7.2	17.69	33.8	79.9	9.83
	Kiln 3-20.5 Hr.	80	7.2	17.55	33.8	79.9	9.75
10-6	Kiln 1-20 Hr.	89	7.5	18.18	34.3	79.8	10.10
	Kiln 2-24 Hr.	87	7.5	17.26	34.3	79.8	9.59
	Kiln 3-23.75 Hr.	84	7.5	17.21	34.3	79.8	9.56
10-7	Kiln 1-18 Hr.	89	7.0	16.31	34.1	79.7	9.06
	Kiln 2-23 Hr.	82	7.0	17.14	34.1	79.7	9.52
	Kiln 3-24 Hr.	84	7.0	16.43	34.1	79.7	9.13

Data used for calculations in Appendix E.

TABLE T-4 (Continued)

BONNER SPRINGS STACK EMISSION SURVEY

RATE PRODUCTION AND CONSUMPTION 1981

Date 1981	System Under Test	Fuel Used: Coal Lbs/Min.	Fuel Used: Moisture %	Raw Mix Used: Ton/Hr. Dry	Raw Mix Used: Slurry Moist - %	Raw Mix Used: $CaCO_3$ %	Clinker Produce Ton/Hr.
10-8	No. 4 Stack & Pptr. Input	151	8.3	31.3	33.9	79.7	17.0
10-9	"	150	7.8	30.7	33.7	79.6	16.7
10-22	"	154	8.0	30.6	35.3	79.9	16.6
10-23	"	155	7.8	30.1	35.0	79.9	16.7
11-2	No. 1 & 4 Clinker Cooler Stack	150	8.5	31.1	33.7	79.9	17.3
11-3	"	130	7.2	29.0	34.1	79.8	16.1
11-4	"	149	7.7	30.8	34.4	79.6	17.0

Data used for calculations in Appendix D.

Excerpts from

REFERENCE 42 (SECTION 4.0)

Hansen, M. D., and J. S. Kinsey, Characterization of Inhalable Particulate Matter Emissions from a Dry Process Cement Plant, Volumes I and II, EPA-600/X-85-332a and 332b, U. S. Environmental Protection Agency, Research Triangle Park, NC, February 1983.

TABLE 3-2. NO. 5 KILN 10-CELL BAGHOUSE INLET IMPACTOR PARTICLE SIZE TEST SAMPLING DATA

Particle size run number	15 μm Cyclone			Stage 1			Stage 2			Cyclone			Filter	
	Mass (mg)[a]	D_{50} size (μm)[b]	Cum. % than[c]	Mass (mg)	D_{50} size (μm)	Cum. % than	Mass (mg)	D_{50} size (μm)	Cum. % than	Mass (mg)	D_{50} size (μm)	Cum. % than	Mass (mg)	D_{50} size (μm)
I-1-1	731.6	15.29	62.31	40.8	11.04	60.21	60.7	5.98	57.08	526.6	2.03	29.95	581.4	< 2.03
I-2-1	3,744.2	14.97	30.84	71.0	10.99	29.53	277.1	6.05	24.41	1,030.0	1.77	5.38	291.5	< 1.77
I-3-1	3,003.5	15.38	42.24	82.1	11.02	40.66	394.6	5.97	33.08	986.0	2.12	14.12	734.1	< 2.12
I-4-1	2,905.4	14.72	41.95	81.6	10.73	40.32	266.3	5.81	35.00	918.0	2.03	16.66	834.0	< 2.03
I-1-2	2,086.8	15.83	45.69	82.2	11.35	43.56	309.5	6.21	35.50	1,019.6	2.02	8.97	344.6	< 2.02
I-2-2	1,937.0	15.66	42.78	67.3	11.29	40.79	207.0	6.33	34.67	879.6	1.78	8.69	294.0	< 1.78
I-3-2	2,227.4	15.81	40.10	75.0	11.29	38.09	277.5	6.12	30.63	449.5	2.15	18.54	689.4	< 2.15
I-4-2	2,358.3	15.81	39.51	71.7	11.34	37.67	244.8	6.15	31.39	891.2	2.13	8.53	332.7	< 2.13
I-1-3	3,659.5	15.34	33.95	97.4	11.14	32.19	383.0	6.04	25.28	1,112.4	1.99	5.20	288.3	< 1.99
I-2-3	2,699.9	15.62	45.67	135.9	11.27	42.93	414.2	6.24	34.60	1,067.6	1.87	13.11	651.7	< 1.87
I-3-3	2,099.7	15.59	49.68	79.9	11.24	47.77	341.6	6.20	39.58	442.7	1.89	28.97	1,209.0	< 1.89
I-4-3	797.8	15.84	59.17	34.8	11.35	57.39	61.9	6.20	54.22	671.4	2.03	19.85	387.9	< 2.03
I-1-4	2,087.2	17.56	47.41	81.4	12.05	45.36	367.3	6.74	36.11	982.4	2.19	11.36	450.8	< 2.19
I-2-4	1,404.3	16.13	48.65	59.0	11.44	46.50	150.1	6.37	41.01	785.2	1.92	12.30	336.3	< 1.92
I-3-4	1,948.0	15.27	47.00	70.1	11.13	45.09	245.6	6.07	38.41	684.5	1.93	19.79	727.2	< 1.93
I-4-4	1,679.6	15.67	49.48	71.5	11.25	47.33	191.7	6.10	41.56	840.8	2.07	16.28	541.1	< 2.07

[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.

Entire table used in Table 4-11.

TABLE 3-4. NO. 5 KILN COMMON BAGHOUSE OUTLET IMPACTOR PARTICLE TEST SAMPLING DATA

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
0-1-1	5.38	15.62	76.40	0.04	14.22	76.23	0.00	8.85	76.23	1.31	5.98	70.48	2.29	4.06	60.44
0-2-1	4.87	15.67	75.43	0.00	14.33	75.43	0.06	8.93	75.13	1.76	6.04	66.25	2.57	4.10	53.28
0-3-1	7.48	15.99	49.25	0.02	14.50	49.12	0.00	9.03	49.12	0.25	6.11	47.42	0.82	4.14	41.86
0-4-1	4.34	16.36	87.69	0.70	14.79	85.71	0.77	9.21	83.53	2.29	6.23	77.03	3.91	4.23	65.95
0-1-2	4.61	16.08	84.74	0.00	14.56	84.74	0.19	9.07	84.11	4.43	6.13	69.44	4.90	4.16	53.21
0-2-2	3.78	15.54	84.43	0.00	14.17	84.43	0.00	8.82	84.43	1.70	5.96	77.42	3.68	4.05	62.26
0-3-2	5.97	15.81	81.83	0.27	14.37	81.01	0.00	8.95	81.01	1.60	6.05	76.14	2.40	4.10	68.84
0-4-2	6.58	15.63	82.23	0.00	14.27	82.23	0.00	8.89	82.23	2.56	6.01	75.32	11.92	4.08	43.13

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)
0-1-1	5.74	2.59	35.26	5.57	1.27	10.83	2.18	0.76	1.27	0.01	0.55	1.23	0.28	< 0.55
0-2-1	4.08	2.61	32.69	3.68	1.28	14.13	0.96	0.77	9.28	0.00	0.56	9.28	1.84	< 0.56
0-3-1	3.24	2.64	19.88	2.53	1.30	2.71	0.37	0.78	0.20	0.00	0.57	0.20	0.03	< 0.57
0-4-1	7.46	2.70	44.80	7.14	1.32	24.55	4.49	0.79	11.82	0.92	0.58	9.21	3.25	< 0.58
0-1-2	7.35	2.65	28.87	6.48	1.30	7.42	2.24	0.78	0.00	0.00	0.57	0.00	0.00	< 0.57
0-2-2	6.36	2.58	36.05	5.92	1.26	11.66	2.83	0.76	0.00	0.00	0.55	0.00	0.00	< 0.55
0-3-2	5.90	2.62	50.88	7.57	1.28	27.85	4.69	0.77	13.57	2.02	0.56	7.43	2.44	< 0.56
0-4-2	6.14	2.60	26.55	7.01	1.27	7.62	2.82	0.76	0.00	0.00	0.56	0.00	0.00	< 0.56

[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.

Entire table used in Table 4-12.

TABLE 3-3. NO. 5 KILN BAGHOUSE INLET EMISSION FACTORS BASED ON TOTAL MASS AND IMPACTOR SIZE DISTRIBUTION

Particle size run number[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]	10.0 μm (lb/ton)	15.0 μm (lb/ton)
I-1-1	7,600	34	220		79	131	137
I-2-1	10,300	33	310		30	90	97
I-3-1	9,000	36	250		42	100	106
I-4-1	8,100	35	230		47	92	98
Average	8,800	34	260	1.1	50	103	110
I-1-2	7,600	34	220		28	93	99
I-2-2	10,300	33	310		45	123	131
I-3-2	9,000	36	250		50	92	99
I-4-2	8,100	35	230		26	85	90
Average	8,800	34	260	1.0	37	98	105
I-1-3	8,300	34	240		20	75	81
I-2-3	9,000	33	270		48	112	122
I-3-3	7,400	33	220		68	102	109
I-4-3	7,700	33	230		60	131	135
Average	8,100	33	240	1.1	49	105	112
I-1-4	8,300	34	240		33	103	112
I-2-4	9,000	33	270		48	123	129
I-3-4	7,400	33	220		53	97	103
I-4-4	7,700	33	230		47	107	113
Average	8,100	33	240	1.0	45	108	114
Total Average	8,400	34	250	1.0	45	104	110

[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] Emission rate corrected to total emissions from No. 5 kiln, pounds per hour.

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

ENTIRE TABLE REPRODUCED IN TABLE 4-22.

TABLE 3-5. NO. 5 KILN 10-CELL BAGHOUSE OUTLET EMISSION FACTORS BASED ON TOTAL MASS AND IMPACTOR SIZE DISTRIBUTION

Particle size run number[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)
0-1-1	26	33	0.79		0.27	0.60	0.62
0-2-1	25	35	0.71		0.22	0.54	0.54
0-3-1	26	36	0.72		0.13	0.35	0.36
0-4-1	25	35	0.71		0.30	0.60	0.62
Average	26	35	0.74	0.60	0.23	0.52	0.54
0-1-2	27	33	0.82		0.23	0.69	0.70
0-2-2	30	33	0.91		0.33	0.77	0.82
0-3-2	41	33	1.24		0.61	1.01	1.02
0-4-2	39	33	1.18		0.31	0.97	1.04
Average	34	33	1.03	0.58	0.37	0.86	0.90
Total Average	30	34	0.88	0.59	0.30	0.69	0.72

[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] Total mass emission rate of 10-cell baghouse and 3-cell baghouse, pounds per hour.

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

ENTIRE TABLE REPRODUCED IN TABLE 4-23.

Excerpts from

REFERENCE 43 (SECTION 4.0)

Lonnes, P., Results of the February 17 and 18, 1983, NSPS Particulate Emission Compliance Test on the No. 8 Kiln at the Lehigh Portland Cement Plant in Mason City, Iowa, Interpoll, Inc., Blaine, MN, March 1983.

Data mentioned in Section 4.1.17 and used for calculations in Appendix F

Table 1. Summary of the Results of the February 17, 1983 Particulate Emission Compliance Test on the No. 8 Kiln Cooler Stack

	Run 1	Run 2	Run 3
Volumetric flow			
Actual (ACFM)	80,000	81,500	82,400
Standard (DSCFM)	60,400	59,800	60,400
Kiln feed rate (tons/hr)	136.4	139.2	138.1
Gas Temperature (Deg-F)	193	214	214
Moisture Content (% v/v)	2.70	2.44	2.58
Gas Composition (% v/v, dry)			
Carbon dioxide	0.03	0.03	0.03
Oxygen	20.90	20.90	20.90
Nitrogen	79.07	79.07	79.07
Isokinetic variation (%)	97.6	101.3	102.3
Particulate mass flow (lb/hr)	2.7	1.0	1.0
Particulate concentration			
Actual (gr/ACF)	0.004	0.001	0.001
Standard (gr/DSCF)	0.005	0.002	0.002

IOWA DEPARTMENT OF ENVIRONMENTAL QUALITY

AIR POLLUTION CONTROL EQUIPMENT OPERATING DATA*

Plant LEHIGH CEMENT CO Location MASON CITY, IA

Source Type COOLER BAGHOUSE Rated Production 130 TPH (FEED)

Date 17 FEB 83 Time 1000 - 1123 Actual Production 136.4

Air Flow Data ______ Run No. 1

Mechanical Collector:

Tube Diameter ___ in. No. of Tubes ___. Design Δp. ___ in. H_2O @ Gas Temp. ___ F.

Observed Δp ___ in H_2O. Design cfm/tube @ Observed Δp ___ @ ___ °F.

Fan Rated H.P. ___. Operating Volts ___. Operating Amps ___.

Electrostatic Precipitator:

Field No.	Primary Voltage (volts)	Primary Current (amps)	Secondary Voltage (KV)	Secondary Current (ma)	Spark Rate (per min.)

Scrubber:

Type ___. Δp (across scrubber) ___ in. H_2O.

Fan Rated H.P. ___. Operating Volts ___. Operating Amps ___.

Liquid Circulation Rate ___ gal/min. % Make-up ___. Blowdown ___ gpm.

Scrubbing Water Change Interval ___.

Settling Tank Cleaning Interval ___.

Baghouse:

Pressure-Positive ___ ~~Negative~~ PULSE-JET X. No Compartments 4.

Type Cleaning COMP. AIR PULSE. Clean Cycle N/A min.

Avg. Baghouse Δp -1.35 in H_2O. Δp Range -4/+4 in. H_2O.

Fan: Rated H.P. 500. Operating Volts 500. Operating Amps 175.

Cyclone:

Type ___. Δp ___ in. H_2O. Diameter ___.

Fan Rated H.P. ___. Operating Volts ___. Operating Amps ___.

Person Responsible for Data: K. W. Volk

Signature: [signature]

Title/Position: KILN ENGINEER

*Averages of operating data taken during actual test run unless requested otherwise.

Data used for calculations in Appendix F.

IOWA DEPARTMENT OF ENVIRONMENTAL QUALITY

AIR POLLUTION CONTROL EQUIPMENT OPERATING DATA*

LEHIGH CEMENT CO Location MASON CITY, IA

Type COOLER BAGHOUSE Rated Production 130 TPH (FEED)

FEB 83 Time 1220-1356 Actual Production 139.2

Run No. 2

Data used for calculations in Appendix F

g:

e-Positive ______ PULSE-JET ~~Negative~~ X. No Compartments 4.

eaning COMP. AIR PULSE. Clean Cycle N/A min.

ghouse Δp -1.41 in H_2O. Δp Range -4/+4 in. H_2O.

ated H.P. 500. Operating Volts 500. Operating Amps 183.

:

______. Δp ______ in. H_2O. Diameter ______.

ed H.P. ______. Operating Volts ______. Operating Amps ______.

Person Responsible for Data: K.W. York

Signature: [signature]

Title/Position: KILN ENGINEER

s of operating data taken during actual test run unless requested otherwise.

IOWA DEPARTMENT OF ENVIRONMENTAL QUALITY

"AIR POLLUTION CONTROL EQUIPMENT OPERATING DATA*

Plant Lehigh Cement Co Location Mason City, IA

Source Type Cooler Baghouse Rated Production 130 TPH (Feed)

Date 17 Feb 83 Time 1425-1556 Actual Production 138.1

Air Flow Data ____ Run No. 3

Mechanical Collector:

Tube Diameter ___ in. No. of Tubes ___. Design Δp. ___ in. H_2O @ Gas Temp. ___ F.

Observed Δp ___ in H_2O. Design cfm/tube @ Observed Δp ___ @ ___ °F.

Fan Rated H.P. ___. Operating Volts ___. Operating Amps ___.

Electrostatic Precipitator:

Field No.	Primary Voltage (volts)	Primary Current (amps)	Secondary Voltage (KV)	Secondary Current (ma)	Spark Rate (per min.)

Scrubber:

Type ___. Δp (across scrubber) ___ in. H_2O.

Fan Rated H.P. ___. Operating Volts ___. Operating Amps ___.

Liquid Circulation Rate ___ gal/min. % Make-up ___. Blowdown ___ gpm.

Scrubbing Water Change Interval ___.

Settling Tank Cleaning Interval ___.

Baghouse:

Pressure-Positive ___ ~~Negative~~ Pulse-Jet X. No Compartments 4.

Type Cleaning Comp. Air Pulse. Clean Cycle N/A min.

Avg. Baghouse Δp -1.53 in H_2O. Δp Range -4/+4 in. H_2O.

Fan: Rated H.P. 500. Operating Volts 500. Operating Amps 195.

Cyclone:

Type ___. Δp ___ in. H_2O. Diameter ___.

Fan Rated H.P. ___. Operating Volts ___. Operating Amps ___.

Person Responsible for Data: K.W. Voll

Signature: [signature]

Title/Position: Kiln Engineer

*Averages of operating data taken during actual test run unless requested otherwise.

Data used for calculations in Appendix F.

Excerpts from

REFERENCE 44 (SECTION 4.0)

Steiner, J., Mojave Plant (Kiln, Clinker, and Crusher Baghouses) Annual Compliance Test, Report PS-83-93/Project 5081-83, Pape and Steiner Environmental Services, Bakersfield, CA, May 1983.

Data mentioned in Section 4.1.18 and used for calculations in Appendix E.

SUMMARY OF SOURCE TEST RESULTS

Company California Portland Cement . Test Date 5/23-5/24/83 APCD No. 1003026A Unit No. Kiln Baghouse

Pollutants	Emissions									Removal %	Emission Factor lb/ton	
	Inlet				Outlet							
	Concentration Wet			Mass Flow Rate lb/hr	Concentration Wet				Mass Flow Rate lb/hr			
	gr/scf	@ 12% CO_2	ppm_v		gr/scf	@ 12% CO_2	ppm_v	@ 3% O_2			Inlet	Outlet
Particulate					0.0551* 0.0094 0.0077 0.0086	0.0409* 0.0063 0.0057 0.0060			100.57* 16.96 13.72 15.34			0.45* 0.08 0.06 0.07
Sulfate												
SO_2							54.57 52.79 55.21 50.09 53.29		111.45 112.76 102.29 108.83			
NO_x as NO_2 (dry)							296.37 282.85 258.96 279.39	495.8 468.8 421.4 462.0	423.42 404.11 369.98 399.17			
HC												

Scrubber Liquor Analysis: Chlorides -- Specific Gravity --

For Kern County Use Only:

Remarks *Test 1 not included in average; probe/filter catch from test 1 agreed well with probe/filter catch from tests 2 & 3; however, impinger catch from test 1 was 9 times greater than tests 2 & 3, which agreed well; the cause of this large difference is unknown but obviously incorrect; therefore test 1 was eliminated; production rate for test 1 & 2 was 225 TPH; production rate for test 3 was 218 TPH (prorated).

Data used for calculations in Appendix F.

SUMMARY OF SOURCE TEST RESULTS

Company California Portland Cement (Mojave) Test Date 5/26/83 APCO No. 1003027A Unit No. Clinker Baghouse

Pollutants	Emissions									Removal %	Emission Factor lb/ton	
	Inlet				Outlet							
	Concentration Wet			Mass Flow Rate lb/hr	Concentration Wet				Mass Flow Rate lb/hr			
	gr/scf	@ 12% CO_2	ppm_v		gr/scf	@ 12% CO_2	ppm_v	@ 3% O_2			Inlet	Outlet
Particulate					0.0036 0.0020 0.0029 0.0028	0 0 0 0			6.37 3.58 4.98 4.98			0.05 0.03 0.04 0.04
Sulfate												
SO_2												
NO_x as NO_2 (dry)												
HC												

Scrubber Liquor Analysis: Chlorides -- Specific Gravity --

For Kern County Use Only:

Remarks

Production rate was 123 TPH for tests 1 and 2; rate was 126 TPH for test 3.

Excerpts from

REFERENCE 46 (SECTION 4.0)

Hansen, M. D., et al., Characterization of Inhalable Particulate Matter Emissions from a Wet Process Cement Plant, Volumes I, II, and III, EPA 600/X-85-343a, 343b, and 343c, U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1983.

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 Mass (mg)[a]	15 μm Cyclone D_{50} size (μm)[b]	15 μm Cyclone Cum. % less than[c]	Stage 1 Mass (mg)	Stage 1 D_{50} size (μm)	Stage 1 Cum. % less than	Stage 2 Mass (mg)	Stage 2 D_{50} size (μm)	Stage 2 Cum. % less than	Cyclone Mass (mg)	Cyclone D_{50} size (μm)	Cyclone Cum. % less than	Filter Mass (mg)	Filter D_{50} size (μm)
ESP-1-1-1	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-1-2-1	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-1-3-1	12,241.8	15.74	18.98	629.6	11.58	14.82	812.0	6.43	9.31	944.0	2.01	3.06	463.0	< 2.01
ESP-1-4-1	16,437.7	15.35	11.97	437.9	11.49	9.63	897.7	6.39	4.82	654.1	1.95	1.32	246.9	< 1.95
ESP-1-1-2	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-1-2-2	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-1-3-2	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-1-4-2	17,863.3	15.51	11.52	442.9	11.54	9.13	685.7	6.42	5.93	904.8	1.97	1.45	292.9	< 1.97
ESP-1-1-3(R)	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-1-2-3	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-1-3-3	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-1-4-3	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-1-1-4	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-1-2-4	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-1-3-4	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-1-4-4	21,972.4	16.17	11.26	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.

Entire table used in Table 4-13.

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[d]	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[d]	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.

Entire table used in Table 4-14

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.

ENTIRE TABLE REPRODUCED IN TABLE 4-24

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]	≤ 10.0 μm (lb/ton)[e]	≤ 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.

ENTIRE TABLE REPRODUCED IN TABLE 4-25.

Excerpts from

REFERENCE 48 (SECTION 4.0)

Source Emissions Survey of Lehigh Portland Cement Company, Waco, Texas, Mullins Environmental Testing Company, Addison, TX, August 1983.

METCO

SUMMARY OF RESULTS

Clinker Cooler Stack

Run Number	1	2	3
Stack Flow Rate - ACFM	55,941	56,955	55,515
Stack Flow Rate - DSCFM*	41,604	43,249	40,424
% Water Vapor - % Vol.	2.5	2.3	2.9
% CO_2 - % Vol.	0.0	0.0	0.0
% O_2 - % Vol.	20.8	20.8	20.8
% Excess Air @ Sampling Point	------	------	------
Particulates Probe, Cyclone & Filter Catch grains/dscf*	0.0216	0.0178	0.0109
grains/cf @ Stack Conditions	0.0160	0.0135	0.0079
lbs/hr	7.7	6.6	3.8
Total Catch grains/dscf*	0.0225	0.0186	0.0130
grains/cf @ Stack Conditions	0.0167	0.0141	0.0094
lbs/hr	8.0	6.9	4.5
Allowable Particulate Emission Rate - TACB Permit - lbs/hr	26.7	26.7	26.7
Opacity - %	5.0	------	------

* 29.92 "Hg, 68°F (760 mm Hg, 20°C)

Data mentioned in Section 4.1.20 and used for calculations in Appendix F.

Data used for calculations in Appendix F.

LEHIGH

LEHIGH PORTLAND CEMENT COMPANY

P.O. BOX 8178
HIGHWAY 84 WEST
WACO, TEXAS 76710
817: 772-1110

August 8, 1983

Mr. Bill Mullins
Mullins Testing
METCO
Addison, Texas

Dear Sir:

Below, please find test results on stack testing that was performed on August 2 and 3, 1983.

Kiln & Raw Material Parameters During Kiln Stack Tests on 8-2-83

Test #	1	2	3
Feed Screw Revs.	1361	1364	1445
Coal Usage	10.78 tons	10.78 tons	10.6 Tons
Clinker Production	53.5 tons	56 tons	59.4 Tons
Dryer Feed Rate	84 TPH	86 TPH	77 TPH
#1 ID Fan Inlet Temp.	415	430	430
#2 ID Fan Inlet Temp.	450	455	450
% O_2 #1 Kiln	2.1%	1.8%	2.1%
% O_2 #2 Kiln	2.5%	2.1%	2.4%
Time	8:39-10:18	11:00-12:41	13:22 -15:00

While conducting the three kiln stack sampling tests both kilns and the three dryers were operating under normal plant practices There were no kiln upsets or delays.

Kiln Parameters During Clinker Cooler (Gravel Bed) Stack Tests 8/3/83

Test #	1	2	3
Feed Screw Revs.	880	793	897
Coal Usage	7.34 Tons	7.25 Tons	7.26
Clinker Production	36.2 Tons	36 Tons	36.8 Tons
Dryer Feed Rate	---	---	---
#1 ID Fan Inlet Temp.	498	502	500
#2 ID Fan Inlet Temp.	502	505	495
% O_2 #1 Kiln	2%	2.4%	3.2%
% O_2 #2 Kiln	3%	2.5%	2.8%
Time	9:05-10:13	11:09-Not rec.	13:15 - 14:26

During the first two clinker cooler (gravel bed) stack sampling tests there were no unusual kiln upsets or delays. Both kilns were operating under normal conditions. While conducting the third test, after 4 points had been taken, the back wash fans on the gravel bed dust collector shorted out and kicked off. The sampling probe was pulled from the stack at 13:23 and an upset condition was called. After evaluating the problem the decision was made to conduct the remainder of test 3 without the back wash fans. At 13:28 the probe was placed back in the stack and all operating parameters re-set.

Excerpts from

REFERENCE 50 (SECTION 4.0)

Steiner, J., Mojave Plant (Kiln, Clinker, and Crusher Bahouses) Annual Compliance Test, Report PS-84-249/Project 5233-84, Pape and Steiner Environmental Services, Bakersfield, CA, May 1984.

SUMMARY OF SOURCE TEST RESULTS

Company California Portland Cement Test Date 5/15/84 APCD No. 1003026A Unit No. Kiln

Pollutants	Emissions									Removal %	Emission Factor lb/Ton	
	Inlet				Outlet							
	Concentration Wet			Mass Flow Rate lb/hr	Concentration Wet				Mass Flow Rate lb/hr			
	gr/scf	@ 12% CO_2	ppm_v		gr/scf	@ 12% CO_2	ppm_v	@ 3% O_2			Inlet	Outlet
Particulate					0.0042 0.0062 0.0041 0.0048				7.46 11.06 7.61 8.71			0.03 0.05 0.03 0.04
Sulfate					0.0010 0.0011 0.0010 0.0010				1.88 1.89 1.90 1.89			
SO_2							67.79 72.81 73.45 71.35		143.76 154.17 154.80 150.91			
NO_x as NO_2 (dry)							353.75 352.50 382.50 362.92	605.94 606.71 658.34 623.66	503.48 501.70 546.62 517.27			
HC (C_1, $>C_1$)							1.1/48.9 0.0/27.0 0.0/30.3 0.37/35.40		0.54/24.20 0.00/13.36 0.00/15.06 0.18/17.54			
Scrubber Liquor Analysis: Chlorides --						Specific Gravity --						
For Kern County Use Only:												
Remarks	Feed Rates = 231, 236, 245 Tons/hour											

Data mentioned in Section 4.1.21 and used for calculations in Appendix E.

TABLE A-1. SUMMARY OF SOURCE EMISSION TEST DATA

UNIT TESTED: Kiln LOCATION: Baghouse Outlet

Test number	1	2	3	Average
Date	5/15/84	5/15/84	5/15/84	
Test condition	231 TPH	236 TPH	245 TPH	
Barometric pressure (in. Hg)	26.20	26.20	26.20	
Stack pressure (in. Hg)	26.11	26.11	26.11	
Stack area (Ft^2)	87.28	87.28	87.28	
Elapsed sampling time (min)	72	72	72	
Volume gas sampled (dscf)	47.1355	47.0808	48.2880	
F factor				
GAS DATA				
Average gas velocity (fps)	63.3	63.4	65.1	63.9
Average gas temperature (^oF)	259.0	258.2	258.0	258.4
Gas flowrate (dscfm)	198625	199435	206805	201621
Gas analysis (dry percent basis)				
Carbon dioxide	18.80	18.38	18.50	
Oxygen	10.45	10.50	11.10	
Carbon monoxide	0.00	0.00	0.00	
Water	6.49	6.35	5.53	
EMISSION CONCENTRATION				
Filterable particulate (gr/dscf)	0.0029	0.0062	0.0040	0.0044
Total particulate (gr/dscf)	0.0044	0.0065	0.0043	0.0051
Total sulfate (gr/dscf)	0.0011	0.0011	0.0011	0.0011
SO_3 (ppm)	0.20	0.20	0.20	0.20
SO_2 (ppm)	67.79	72.81	73.45	71.35
NO_x (ppm)	353.75	352.50	382.50	362.92
EMISSION RATE				
Filterable particulate (lb/hr)	4.88	10.53	7.00	7.47
Total particulate (lb/hr)	7.46	11.06	7.61	8.71
Total sulfate (lb/hr)	1.88	1.89	1.90	1.89
SO_3 (lb/hr)	0.50	0.44	0.58	0.51
SO_2 (lb/hr)	143.76	154.17	154.80	150.91
NO_x (lb/hr)	503.48	501.70	546.62	517.27
Lb/MMBtu-EMISSION FACTOR				
Filterable particulate				
Total particulate				
Total sulfate				
SO_2				
NO_x				
Lb/Bbl-EMISSION FACTOR				
Total particulate				
Total sulfate				
SO_2				
NO_x				

Data used for calculations in Appendix E.

SUMMARY OF SOURCE TEST RESULTS

Company California Portland Cement Test Date 5/17-18/84 APCD No. 1003027A Unit No. Clinker

Pollutants	Emissions									Removal %	Emission Factor lb/Ton	
	Inlet				Outlet							
	Concentration Wet			Mass Flow Rate lb/hr	Concentration Wet				Mass Flow Rate lb/hr		Inlet	Outlet
	gr/scf	@ 12% CO_2	ppm_v		gr/scf	@ 12% CO_2	ppm_v	@ 3% O_2				
Particulate					0.0019 0.0014 0.0019 0.0017				2.18 1.61 2.10 1.96			0.0087 0.0064 0.0084 0.0079
Sulfate												
SO_2												
NO_x as NO_2 (dry)												
HC												

Scrubber Liquor Analysis: Chlorides -- Specific Gravity --

For Kern County Use Only:

Remarks: Clinker Feedrate was 250 tons/hour on 5/17 and 18

Data mentioned in Section 4.1.21 and used in calculations in Appendix F.

TABLE A-3. SUMMARY OF SOURCE EMISSION TEST DATA

UNIT TESTED: Clinker Cooler LOCATION: Baghouse Outlet

Test number	1	2	3	Average
Date	5/17/84	5/17/84	5/18/84	
Test condition	250 TPH	250 TPH	250 TPH	
Barometric pressure (in. Hg)	26.26	26.26	26.38	
Stack pressure (in. Hg)	26.25	26.25	26.36	
Stack area (Ft^2)	106.14	106.14	106.14	
Elapsed sampling time (min)	72	72	72	
Volume gas sampled (dscf)	63.9903	62.1795	61.9962	
F factor				
GAS DATA				
Average gas velocity (fps)	32.7	31.8	31.2	31.9
Average gas temperature (°F)	237.6	234.4	234.5	235.5
Gas flowrate (dscfm)	137895	134259	131953	134702
Gas analysis (dry percent basis)				
Carbon dioxide	0.0	0.0	0.0	
Oxygen	20.9	20.9	20.9	
Carbon monoxide	0.0	0.0	0.0	
Water	0.38	0.66	0.88	
EMISSION CONCENTRATION				
Filterable particulate (gr/dscf)	0.0018	0.0014	0.0014	0.0015
Total particulate (gr/dscf)	0.0018	0.0014	0.0019	0.0017
Total sulfate (gr/dscf)				
SO_3 (ppm)				
SO_2 (ppm)				
NO_x (ppm)				
EMISSION RATE				
Filterable particulate (lb/hr)	2.18	1.61	1.60	1.80
Total particulate (lb/hr)	2.18	1.61	2.10	1.96
Total sulfate (lb/hr)				
SO_3 (lb/hr)				
SO_2 (lb/hr)				
NO_x (lb/hr)				
Lb/MMBtu-EMISSION FACTOR				
Filterable particulate				
Total particulate				
Total sulfate				
SO_2				
NO_x				
Lb/Bbl-EMISSION FACTOR				
Total particulate				
Total sulfate				
SO_2				
NO_x				

Data used for calculations in Appendix F.

Excerpts from

REFERENCE 51 (SECTION 4.0)

Lehigh Portland Cement Company, Leeds, Alabama, Particulate Compliance Test, CH_2M Hill, Montgomery, AL, October 1984.

PARTICULATE EMISSION DATA CALCULATION SHEET

CH2M HILL
MONTGOMERY OFFICE
807 SOUTH McDONOUGH STREET
MONTGOMERY, ALABAMA 36104
205/834-2670

Plant *LEHIGH*

Date *9/18/84* Run # *2*

Sampling Location *MAIN*
LOESCHE MILL OFF

Sampling Data

T_s = *727* °R, T_m = *528* °R

C_p = *0.85*, $(\sqrt{\Delta p})_{avg}$ = *.7583*

P_s = *29.896* in.Hg, M_s = *29.83* g/g-mole

A_s = *57.863* sq.ft., V_m = *44.171* cu.ft.

H_2O (condensate) = *125* mls

H_2O (silica gel) = *15.5* grams

ΔH_{avg} = *1.565* in H_2O, P_b = *29.94* in Hg

Total particulate = *0.0756* grams

1. Calculate Stack gas velocity--

$$V_s = 85.49\ C_p\ (\sqrt{\Delta p})_{avg}\sqrt{\frac{T_s}{P_s M_s}}$$

$$V_s = 85.49\ (0.85)(.7583)\sqrt{\frac{727}{29.896(29.83)}}$$

V_s = *49.752* fps

2. Calculate volume of water vapor in gas sample--

$$V_{wstd} = (0.0474)\left(\text{mls } H_2O \text{ condensate} + \text{grams } H_2O \text{ silica gel}\right)$$

$$V_{wstd} = (0.0474)(125 + 15.5) = (0.0474)(140.5) = 6.66 \text{ cu.ft.}$$

3. Calculate gas sample volume at standard conditions--

$$V_{mstd} = (17.64)(V_m)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m}\right)$$

$$V_{mstd} = (17.64)(44.171)\left(\frac{29.94 + \frac{1.565}{13.6}}{528}\right) = (\_\_\_\_)(0.0569) = 44.35 \text{ cu.ft.}$$

4. Calculate percent moisture in gas stream--

$$B_{ws} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}} = \frac{6.66}{44.35 + 6.66} = 0.1307 = 13\ \%$$

5. Calculate stack gas volumetric flow rate, dry basis, std. conditions--

$$Q_{stpd} = 3600(1-B_{ws})V_s A_s \frac{528}{T_s}\ \frac{P_s}{29.92}$$

$$Q_{stpd} = 3600\ (1-.13)(49.752)(57.863)(528/727)(29.896/29.92) = 6543110 \text{ cu.ft.}$$

6. Calculate grain loading--

grains/sdcf = (15.43)(grams)/V_{mstd} = (15.43)(0.0756)/(44.35) = *0.0263*

7. Calculate mass emission rate--

lbs/hr = (grains/stdcf)(Q_{stpd})(1.43 x 10^{-4})

lbs/hr = (6543110)(0.0263)(1.43 x 10^{-4}) = **24.61**

Data mentioned in Section 4.1.22 and used for calculations in Appendix E.

PARTICULATE EMISSION DATA CALCULATION SHEET

CH2M HILL
MONTGOMERY OFFICE
807 SOUTH McDONOUGH STREET
MONTGOMERY, ALABAMA 36104
205/834-2870

Plant LEHIGH
Date 9/18/84 Run # 3
Sampling Location MAIN,
LOESCHE MILL OFF

Sampling Data

T_s = 728 °R, T_m = 536 °R
C_p = 0.85, $(\sqrt{\Delta p})_{avg}$ = 0.75
P_s = 29.896 in. Hg, M_s = 29.89
A_s = 57.963 sq.ft., V_m = 44.994 cu.ft.
H_2O (condensate) = 118 mls
H_2O (silica gel) = 15.0 grams
ΔH_{avg} = 1.64 in H_2O, P_b = 29.94 in Hg
Total particulate = 0.0787 grams

1. Calculate Stack gas velocity--

$$V_s = 85.49\ C_p\ (\sqrt{\Delta p})avg\sqrt{\frac{T_s}{P_sM_s}}$$

$$V_s = 85.49\ (0.85)(0.75)\sqrt{\frac{728}{29.896(29.89)}}$$

V_s = 49.192 fps

2. Calculate volume of water vapor in gas sample--

$$V_{wstd} = (0.0474)\left(\text{mls } H_2O \text{ condensate} + \text{grams } H_2O \text{ silica gel}\right)$$

V_{wstd} = (0.0474)(118 + 15) = (0.0474) (133) = 6.30 cu.ft.

3. Calculate gas sample volume at standard conditions--

$$V_{mstd} = (17.64)(V_m)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m}\right)$$

$$V_{mstd} = (17.64)(44.99)\left(\frac{29.94 + \frac{1.64}{13.6}}{536}\right) = (\quad)(0.0561) = 44.51 \text{ cu.ft.}$$

4. Calculate percent moisture in gas stream--

$$B_{ws} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}} = \frac{6.30}{44.51 + 6.30} = 0.124 = 12.4\%$$

5. Calculate stack gas volumetric flow rate, dry basis, std. conditions--

$$Q_{stpd} = 3600(1-B_{ws})V_sA_s\ \frac{528}{T_s}\ \frac{P_s}{29.92}$$

Q_{stpd} = 3600 (1- .124) (49.192) (57.963) (528/ 728) (29.896/29.92) = 6,505,134 cu.ft.

6. Calculate grain loading--

grains/sdcf = (15.43)(grams)/V_{mstd} = (15.43)(0.0787)/(44.51) = 0.0273

7. Calculate mass emission rate--

lbs/hr = (grains/stdcf)(Q_{stpd})(1.43 x 10^{-4})
lbs/hr = (6,505,131)(0.0273)(1.43 x 10^{-4}) = 25.40

Data used for calculations in Appendix E.

PARTICULATE EMISSION DATA CALCULATION SHEET

CH2M HILL

MONTGOMERY OFFICE

807 SOUTH McDONOUGH STREET
MONTGOMERY, ALABAMA 36104
205/834-2870

Plant LEHIGH

Date 9/18/84 Run # 4

Sampling Location MAIN: LOESCHE MILL OFF

Sampling Data

T_s = 730 °R; T_m = 545 °R
C_p = 0.85; $(\sqrt{\Delta p})_{avg}$ = 0.73
P_s = 29.896 in.Hg; M_s = 29.37 g/g-mole
A_s = 57.863 sq.ft.; V_m = 44.305 cu.ft.
H_2O (condensate) = 130 mls
H_2O (silica gel) = 16.5 grams
ΔH_{avg} = 1.52 in H_2O; P_b = 29.94 in Hg
Total particulate = 0.0523 grams

1. Calculate Stack gas velocity--

$$V_s = 85.49\ C_p\ (\sqrt{\Delta p})avg\sqrt{\frac{T_s}{P_sM_s}}$$

$$V_s = 85.49\ (0.85)(0.73)\sqrt{\frac{730}{29.896(29.37)}}$$

V_s = 48.368 fps

2. Calculate volume of water vapor in gas sample--

$$V_{wstd} = (0.0474)\left(\begin{matrix}\text{mls } H_2O \\ \text{condensate}\end{matrix} + \begin{matrix}\text{grams } H_2O \\ \text{silica gel}\end{matrix}\right)$$

V_{wstd} = (0.0474)(130 + 16.5) = (0.0474) (146.5) = 6.94 cu.ft.

3. Calculate gas sample volume at standard conditions--

$$V_{mstd} = (17.64)(V_m)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m}\right)$$

$$V_{mstd} = (17.64)(44.305)\left(\frac{29.94 + \frac{1.52}{13.6}}{545}\right) = (\_\_\_\_)(0.0551) = 43.09 \text{ cu.ft.}$$

4. Calculate percent moisture in gas stream--

$$B_{ws} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}} = \frac{6.94}{43.09 + 6.94} = 0.139 = 14\ \%$$

5. Calculate stack gas volumetric flow rate, dry basis, std. conditions--

$$Q_{stpd} = 3600(1-B_{ws})V_sA_s\ \frac{528}{T_s}\ \frac{P_s}{29.92}$$

Q_{stpd} = 3600 (1- .14)(48.368)(57.86)(528/ 730)(29.896/29.92)= 6,261,813 cu.ft.

6. Calculate grain loading--

grains/sdcf = (15.43)(grams)/V_{mstd} = (15.43)(.0523)/(43.09)= 0.0187

7. Calculate mass emission rate--

lbs/hr = (grains/stdcf)(Q_{stpd})(1.43 x 10^{-4})
lbs/hr = (6261813)(0.0187)(1.43 x 10^{-4}) = 16.74

Data mentioned in Section 4.1.22 and used for calculations in Appendix E.

PARTICULATE EMISSION DATA CALCULATION SHEET

CH2M HILL
MONTGOMERY OFFICE
807 SOUTH McDONOUGH STREET
MONTGOMERY, ALABAMA 36104
205/834-2870

Plant LEHIGH
Date 9/18/84 Run # 5
Sampling Location MAIN; LOESCHE MILL OFF

Sampling data
T_s = 730 °R, T_m = 551 °R
C_p = 0.85, $(\sqrt{\Delta p})_{avg}$ = 0.717
P_s = 29.896 in. Hg, M_s = 29.67
A_s = 57.962 sq. ft., V_m = 42.84 cu. ft.
H_2O (condensate) = 130 mls
H_2O (silica gel) = 14.0 grams
ΔH_{avg} = 1.47 in. H_2O, P_b = 29.94 in. Hg
Total particulate = 0.0458 grams

1. Calculate Stack gas velocity--

$V_s = 85.49\ C_p\ (\sqrt{\Delta p})avg \sqrt{\frac{T_s}{P_s M_s}}$

$V_s = 85.49\ (0.85)(0.717) \sqrt{\frac{730}{29.896(29.67)}}$

V_s = 47.266 fps

2. Calculate volume of water vapor in gas sample--

$V_{wstd} = (0.0474) \left(\text{mls } H_2O \text{ condensate} + \text{grams } H_2O \text{ silica gel}\right)$

V_{wstd} = (0.0474)(130 + 14) (0.0474) (144) = 6.83 cu.ft.

3. Calculate gas sample volume at standard conditions--

$V_{mstd} = (17.64)(V_m)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m}\right)$

$V_{mstd} = (17.64)(42.9(1?))\left(\frac{29.94 + \frac{1.47}{13.6}}{551}\right)$ = (____)(0.515?) = 42.15 cu.ft.

4. Calculate percent moisture in gas stream--

$B_{ws} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}} = \frac{6.83}{42.15 + 6.83}$ = 0.1395 = 14

5. Calculate stack gas volumetric flow rate, dry basis, std. conditions--

$Q_{stpd} = 3600(1-B_{ws})V_s A_s \frac{528}{T_s} \frac{P_s}{29.92}$

Q_{stpd} = 3600 (1-.14)([illegible])(57.963)(528/730)(29.896/29.92)= 6,119,463 cu.ft.

6. Calculate grain loading--

grains/sdcf = (15.43)(grams)/V_{mstd} = (15.43)(0.0458?)/(42.15) = 0.079

7. Calculate mass emission rate--

lbs/hr = (grains/stdcf)(Q_{stpd})(1.43 x 10^{-4})

lbs/hr = ([illegible])(0.079)(1.43 x 10^{-4}) = 15.66

Data mentioned in Section 4.1.22 and used for calculations in Appendix E.

Data used for calculations in Appendix E.

LEEDS KILN PROCESS DATA SHEET

Main Stack Test

DATE 9/18/84

	PREHEATER								KILN			COOLER												SPRAY TOWER			COAL MILL							
TIME	Feed Rate	ID-30 Speed	ID-30 Draft	Stage I Exit Draft	Stage I Gas Temp.	Stage 4 Gas Temp.	Preh. Exit O2	ID-24 Speed	Kiln Speed	Kiln Amps	Kiln Exit O2	Sec. Air Temp.	#1 Grate Speed	#1 Undergrate Press.	#2 Undergrate Press.	#4 Undergrate Press.	#1 Fan Flow	#2 Fan Flow	#3 Fan Flow	#4 Fan Flow	Kiln Hood Draft	Vent Fan Damper	Filter Inlet Temp.	Spray Tower Inlet Temp.	Spray Tower Outlet Temp.	Water Spray	Coal Feed	Mill Inlet Temp.	Mill Outlet Temp.	Mill Inlet Draft	Mill Drive Amps	System Fan Damper	Prim. Air Fan Damper	Dust Trap Temp.
	t/h	RPM	"WC	"WC	°F	°F	%	RPM	RPH	A	%	°F	SPH	"WC	"WC	"WC	x1000 CFM	x1000 CFM	x1000 CFM	x1000 CFM	"WC	%	°F	°F	°F	GPM	t/h	°F	°F	"WC	A	%	%	°F
7:30 AM																																		
7:45 AM	142	1040	-5	31	700	1505	—	680	118	9/10	.5	1800	5	13.5	14.5	7.2	—	16	19	18	.05	100	520	520	305	68	10.2	380	155	.8	29	60	37	630
8 AM	140	1040	-5	33½	700	1505	—	680	118	9/10	.5	1800	5½	14½	15½	7.8	—	16	16	17	.04	92	420	525	305	64	10.2	370	150	.8	29	60	37	630
8:15 AM	140	1040	-5	33½	705	1505	—	680	118	8/10	.6	1150	5	13½	14½	7.4	—	16	17	15	.02	100	420	510	305	68	10.2	389	160	.9	28	60	37	610
8:30 AM	140	1040	-5	33½	700	1505	—	680	118	7/10	.5	1800	5	14.2	15.2	7.2	—	15	19	16	.05	95	510	525	305	64	10.2	388	155	.7	29	60	37	650
8:45 AM	140	1040	-5	33½	700	1505	—	680	118	7/11	.5	1800	6	14.2	15.4	7.2	—	15	17½	15	.07	92	520	516	305	62	10.2	370	155	.7	29	60	37	620
9 AM																																		

REMARKS

Test #2

Mill off (#1)

140 TPH Average Feed to Kiln

Data used for calculations in Appendix E.

LEEDS KILN PROCESS DATA SHEET

MAIN STACK TEST

DATE 9-11-84

PREHEATER / KILN / COOLER

TIME	Feed Rate (t/h)	ID-30 Speed (RPM)	ID-30 Draft ("WC)	Stage 1 Exit Draft ("WC)	Stage 1 Gas Temp. (°F)	Stage 4 Gas Temp. (°F)	Preh. Exit O2 (%)	ID-24 Speed (RPM)	Kiln Speed (RPH)	Kiln Amps (A)	Kiln Exit O2 (%)	Sec. Air Temp. (°F)	#1 Grate Speed (SPM)	#1 Undergrate Press. ("WC)	#2 Undergrate Press. ("WC)	#4 Undergrate Press. ("WC)	#1 Fan Flow (x1000 CFM)
10:15 AM	140	1040	-6	33½	700	1505	.7	700	118	7/11		1720	5	12½	13	5½	
10:30 AM	138	1040	-5	33½	700	1505	.5	700	118	9/11		1770	6	14.6	15.7	6.8	
10:45 PM	138	1040	-5	33½	710	1505	.5	640	118	7/10		1800	5½	14	15.4	9.4	
11 AM	134	1040	-5	33½	705	1505	1.1	640	118	9/12		1700	5	12½	13½	5	
11:15 PM	136	1040	-5	33	705	1505	.9	640	118	9/12		1700	5	12.8	14.6	5.8	
11:30 PM																	
8 PM																	

COOLER / SPRAY TOWER / COAL MILL

TIME	#2 Fan Flow (x1000 CFM)	#3 Fan Flow (x1000 CFM)	#4 Fan Flow (x1000 CFM)	Kiln Hood Draft ("WC)	Vent Fan Damper (%)	Filter Inlet Temp. (°F)	Spray Tower Inlet Temp. (°F)	Spray Tower Outlet Temp. (°F)	Water Spray (GPM)	Coal Feed (t/h)	Mill Inlet Temp. (°F)	Mill Outlet Temp. (°F)	Mill Inlet Draft ("WC)	Mill Drive Amps (A)	System Fan Damper (%)	Prim. Air Fan Damper (%)	Dust Trap Temp. (°F)
10:15 AM	16	20	17	.06	100	430	520	305	62	10.2	475	155	1	28	60	37	650
10:30 AM	17	18	15	.04	95	440	525	305	64	10.2	470	155	.9	28	60	37	660
10:45 PM	16	17	14	.06	90	470	520	305	64	10.2	475	155	.8	27	60	37	660
11 AM	15½	17½	15	.07	80	400	525	305	66	10.2	350	145	1.1	28	60	37	520
11:15 PM	16	19	17	.045	90	420	525	305	68	10.2	370	145	.8	29	60	37	580
11:30 PM																	
8 PM																	

REMARKS

Test #3

Mill Off(?)

138 TPH Average Feed to Kiln

Data used for calculations in Appendix E.

LEEDS KILN PROCESS DATA SHEET

Main Stack Test

DATE ________

TIME	PREHEATER: Feed Rate	PREHEATER: ID-30 Speed	PREHEATER: ID-30 Draft	PREHEATER: Stage 1 Exit Draft	PREHEATER: Stage 1 Gas Temp.	PREHEATER: Stage 4 Gas Temp.	PREHEATER: Kiln Exit O2	PREHEATER: ID-24 Speed	KILN: Kiln Speed	KILN: Kiln Amps	KILN: Kiln Exit O2
	t/h	RPM	"WC	"WC	°F	°F	%	RPM	RPH	A	%
1 PM	135	1040	-5	33	710	1510	1.5	690	110	9/15	
1 PM	135	1040	-5	33	910	1510	.6	680	110	10/16	
1:30 PM	135	1040	-5	33	710	1510	2.2	680	110	10/11	
1:45 PM	135	1040	-5	33	710	1510	1.3	680	110	9/15	
2 PM	135	1040	-5	32 1/2	710	1510	.8	680	110	8/15	
2:15 PM	135	1040	-5	33	710	1510	2.3	680	110	6/12	
2:30 PM											

TIME	COOLER: Sec. Air Temp.	COOLER: #1 Grate Speed	COOLER: #1 Undergrate Press.	COOLER: #2 Undergrate Press.	COOLER: #4 Undergrate Press.	COOLER: #1 Fan Flow	COOLER: #2 Fan Flow	COOLER: #3 Fan Flow	COOLER: #4 Fan Flow	COOLER: Kiln Hood Draft	COOLER: Vent Fan Damper	COOLER: Filter Inlet Temp.
	°F	SPM	"WC	"WC	"WC	x1000 CFM	x1000 CFM	x1000 CFM	x1000 CFM	"WC	%	°F
1 PM	1850	5 1/2	14	15	5.4		16	19	15	.06	95	550
1 PM	1900	7	13	15	9.5		16	18	17	.06	100	600
1:30 PM	1850	7	15.5	17	5		15 1/2	16 1/2	15	.07	90	510
1:45 PM	1800	5	11.2	13	6.5		16	19	17	.04	100	600
2 PM	1700	9 1/2	14.5	16.2	10		17	18	17	.09	86	550
2:15 PM	1750	5	13	14	4.9		15	17	15	.09	62	440
2:30 PM												

TIME	SPRAY TOWER: Spray Tower Inlet Temp.	SPRAY TOWER: Spray Tower Outlet Temp.	SPRAY TOWER: Water Spray	COAL MILL: Coal Feed	COAL MILL: Mill Inlet Temp.	COAL MILL: Mill Outlet Temp.	COAL MILL: Mill Inlet Draft	COAL MILL: Mill Drive Amps	COAL MILL: System Fan Damper	COAL MILL: Prim. Air Fan Damper	COAL MILL: Dust-Trap Temp.
	°F	°F	GPM	t/h	°F	°F	"WC	A	%	%	°F
1 PM	540	305	72	10.2	360	140	1	28	60	37	640
1 PM	550	305	68	10.2	480	150	.8	28	60	37	730
1:30 PM	530	305	68	10.2	355	140	1	28	60	37	590
1:45 PM	530	305	67	10.2	482	150	1	28	60	37	720
2 PM	540	305	68	10.2	470	150	.8	27	60	37	730
2:15 PM	540	305	67	10.1	340	135	.8	27	60	37	560
2:30 PM											

REMARKS

Test #4

Mill off (#3)

135 TPH Feed to Kiln

Data used for calculations in Appendix E.

LEEDS KILN PROCESS DATA SHEET

Main Stack Test

DATE 2/19/84

TIME	PREHEATER: Feed Rate	ID-30 Speed	ID-30 Draft	Stage 1 Exit Draft	Stage 1 Gas Temp.	Stage 4 Gas Temp.	Preh. Exit O2	ID-24 Speed	KILN: Kiln Speed	Kiln Amps	Kiln Exit O2	COOLER: Sec. Air Temp.	#1 Grate Speed	#1 Undergrate Press.	#2 Undergrate Press.	#4 Undergrate Press.	#1 Fan Flow	#2 Fan Flow	#3 Fan Flow	#4 Fan Flow	Kiln Hood Draft	Vent Fan Damper	Filter Inlet Temp.
	t/h	RPM	"WC	"WC	°F	°F	%	RPM	RPH	A	%	°F	SPM	"WC	"WC	"WC	x1000 CFM	x1000 CFM	x1000 CFM	x1000 CFM	"WC	%	°F
3:10 PM	135	1040	-5	33	700	1500		695	100	10/16	1	1775	5	13.8	14.6	7.5		16	18	17	.05	100	480
3:25 PM	135	1040	-5	33	700	1500		695	103	11/16	1.1	1775	5	12.8	13	9.4		16	16	16	.06	90	440
3:40 PM	135	1040	-5	32¼	700	1510		695	95	9/14	1.4	1750	5	12.2	11.8	9		16	20	15	.02	100	720
3:55 PM	132	1040	-5	32½	700	1505		695	90	10/16	1.6	1500	5	9.6	9.2	3.3		15	16	15	.08	70	420
4:10 PM	132	1040	-5	32½	705	1505		695	92	11/17	1.5	1610	5	12.2	13.5	6.6		16	18	16	.07	74	330
4:25 PM																							

TIME	SPRAY TOWER: Spray Tower Inlet Temp.	Spray Tower Outlet Temp.	Water Spray	COAL MILL: Coal Feed	Mill Inlet Temp.	Mill Outlet Temp.	Mill Inlet Draft	Mill Drive Amps	System Fan Damper	Prim. Air Fan Damper	Dust Trap Temp.
	°F	°F	GPM	t/h	°F	°F	"WC	A	%	%	°F
3:10 PM	340	305	67	10.2	335	140	.7	27	60	37	630
3:25 PM	540	305	65	10.2	380	140	1.1	27	60	37	670
3:40 PM	540	305	66	10.2	510	150	.7	28	60	37	800
3:55 PM	340	300	68	10.2	370	140	.9	27	60	37	590
4:10 PM	550	305	70	10.2	380	140	.9	27	60	37	630
4:25 PM											

REMARKS:

Test #5

Mill OFF (#4)

134 TPH Feed to Kiln

PARTICULATE EMISSION DATA CALCULATION SHEET

CH2M HILL

MONTGOMERY OFFICE
807 SOUTH McDONOUGH STREET
MONTGOMERY, ALABAMA 36104
205/834-2870

Plant LEHIGH

Date 9/21/84 Run # 1

Sampling Location CLINKER COOLER

Sampling Data

T_s = 737 °R, T_m = 563 °R
C_p = ~~1.15~~, $(\sqrt{\Delta p})_{avg}$ = 0.415
P_s = 29.942 in. Hg; M_s = 27.97 #/lb-mole
A_s = 68.417 sq.ft.; V_m = 27.644 cu.ft.
H_2O (condensate) = 15
H_2O (silica gel) = 12
ΔH_{avg} = .0619 in H_2O; P_b = 29.96 in Hg
Total particulate = 0.1392 grams

1. Calculate Stack gas velocity--

$$V_s = 85.49\ C_p\ (\sqrt{\Delta p})_{avg}\sqrt{\frac{T_s}{P_s M_s}}$$

$$V_s = 85.49\ (\text{~~1.15~~ } 0.85)(.0415)\sqrt{\frac{737}{29.944(27.97)}}$$

V_s = ~~37.03~~ 29.23 fps Dm

2. Calculate volume of water vapor in gas sample--

$$V_{wstd} = (0.0474)\left(\begin{matrix}\text{mls } H_2O \\ \text{condensate}\end{matrix} + \begin{matrix}\text{grams } H_2O \\ \text{silica gel}\end{matrix}\right)$$

V_{wstd} = (0.0474)(15 + 12) = (0.0474) (27) = 1.28 cu.ft.

3. Calculate gas sample volume at standard conditions--

$$V_{mstd} = (17.64)(V_m)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m}\right)$$

$$V_{mstd} = (17.64)(27.644)\left(\frac{29.96 + \frac{0.619}{13.6}}{563}\right) = (\_\_\_\_)(0.0533) = 26.04 \text{ cu.ft.}$$

4. Calculate percent moisture in gas stream--

$$B_{ws} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}} = \frac{1.28}{26.04 + 1.28} = 0.047 = 4.7\ \%$$

5. Calculate stack gas volumetric flow rate, dry basis, std. conditions--

$$Q_{stpd} = 3600(1-B_{ws})V_s A_s \frac{528}{T_s}\ \frac{P_s}{29.92}$$

Q_{stpd} = 3600 (1- .047) (~~37.03~~ 29.23 Dm) (68.417) (528/ 737) (29.944 /29.92) = ~~5[illegible]~~ 4606761 cu.ft./hr

6. Calculate grain loading--

grains/sdcf = (15.43)(grams)/V_{mstd} = (15.43)(0.1392)/(26.04) = 0.112

7. Calculate mass emission rate--

lbs/hr = (grains/stdcf)(Q_{stpd})(1.43 x 10^{-4})

lbs/hr = (~~5[illegible]~~ 4606761 Dm)(0.1121)(1.43 x 10^{-4}) = ~~95.53~~ **73.85** Dm

Data mentioned in Section 4.1.22 and used in calculations in Appendix F.

PARTICULATE EMISSION DATA CALCULATION SHEET

CH2M HILL
MONTGOMERY OFFICE
807 SOUTH McDONOUGH STREET
MONTGOMERY, ALABAMA 36104
205/834-2870

Plant Lehigh
Date 9/21/84 Run # 2 (9)
Sampling Location Clinker Cooler.

Sampling Data
T_s = 883 °R, T_m = 556
C_p = .85, $(\sqrt{\Delta p})_{avg}$ = .426
P_s = 29.944 in. Hg, M_s = 28.085 lb/lb-mole
A_s = 68.417 sq. ft., V_m = 31.467 cu. ft.
H_2O (condensate) = 10 mls
H_2O (silica gel) = 13.5
ΔH_{avg} = .785 in H_2O, P_b = 29.96 in Hg
Total particulate = 0.1028 grams

1. Calculate Stack gas velocity--

$V_s = 85.49\ C_p\ (\sqrt{\Delta p})avg\sqrt{\frac{T_s}{P_sM_s}}$

$V_s = 85.49\ (.85)(.426)\sqrt{\frac{883}{(29.944)(28.085)}}$

V_s = 36.188 fps

2. Calculate volume of water vapor in gas sample--

$V_{wstd} = (0.0474)\left(\text{mls } H_2O \text{ condensate} + \text{grams } H_2O \text{ silica gel}\right)$

V_{wstd} = (0.0474)(10 + 13.5) = (0.0474) (23.5) = ~~39~~ 1.11 cu.ft.

3. Calculate gas sample volume at standard conditions--

$V_{mstd} = (17.64)(V_m)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m}\right)$

$V_{mstd} = (17.64)(31.467)\left(\frac{29.96 + \frac{.785}{13.6}}{556}\right)$ = ( ) (.0540) = 29.970 cu.ft.

4. Calculate percent moisture in gas stream--

$B_{ws} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}} = \frac{1.11}{29.97 + 1.11}$ = 0.0357 = 3.6

5. Calculate stack gas volumetric flow rate, dry basis, std. conditions--

$Q_{stpd} = 3600(1-B_{ws})V_sA_s\ \frac{528}{T_s}\ \frac{P_s}{29.92}$

Q_{stpd} = 3600 (1-.036)(36.188)(68.417)(528/883)(29.944/29.92)= 5,141,971 cu.ft./

6. Calculate grain loading--

grains/sdcf = (15.43)(grams)/V_{mstd} = (15.43)(.1028)/(29.97)= 0.0529

7. Calculate mass emission rate--

lbs/hr = (grains/stdcf)(Q_{stpd})(1.43 x 10^{-4})

lbs/hr = (.0529)(5,141,971)(1.43 x 10^{-4}) = 38.92

Data mentioned in Section 4.1.22 and used for calculations in Appendix F.

PARTICULATE EMISSION DATA CALCULATION SHEET

CH2M HILL
MONTGOMERY OFFICE
807 SOUTH McDONOUGH STREET
MONTGOMERY, ALABAMA 36104
205/834-2870

Plant LEHIGH
Date 9/21/84 Run # 3
Sampling Location CLINKER COOLER

Sampling data

T_s = 532 °R	T_m = 555 °R
C_p = ~~.119~~ .85	$(\sqrt{\Delta p})_{avg}$ = 0.54
P_s = 29.944 in. Hg	M_s = 28.09 lb/lb-mole
A_s = 68.417 sq. ft.	V_m = 35.721 cu. ft.
H_2O (condensate) = 15 mls	
H_2O (silica gel) = 12 grams	
ΔH_{avg} = 1.034 in. H_2O	P_b = 29.96 in. Hg
Total particulate = 0.1310 grams	

1. Calculate Stack gas velocity--

$$V_s = 85.49\ C_p\ (\sqrt{\Delta p})_{avg}\sqrt{\frac{T_s}{P_s M_s}}$$

$$V_s = 85.49\ (\cancel{.119}\ .85)\ (0.54)\ \sqrt{\frac{532}{29.944(28.09)}}$$

V_s = ~~50.50~~ 39.023 fps

2. Calculate volume of water vapor in gas sample--

$$V_{wstd} = (0.0474)\left(\text{mls } H_2O \text{ condensate} + \text{grams } H_2O \text{ silica gel}\right)$$

V_{wstd} = (0.0474)(15 + 12) = (0.0474) (27) = 1.28 cu.ft.

3. Calculate gas sample volume at standard conditions--

$$V_{mstd} = (17.64)(V_m)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m}\right)$$

$$V_{mstd} = (17.64)(35.721)\left(\frac{29.96 + \frac{1.034}{13.6}}{555}\right) = (\_\_\_\_)(0.0541) = 34.10 \text{ cu.ft.}$$

4. Calculate percent moisture in gas stream--

$$B_{ws} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}} = \frac{1.28}{34.10 + 1.28} = 0.0362 = 3.6\ \%$$

5. Calculate stack gas volumetric flow rate, dry basis, std. conditions--

$$Q_{stpd} = 3600(1-B_{ws})V_s A_s \frac{528}{T_s}\ \frac{P_s}{29.92}$$

Q_{stpd} = 3600 (1-.036) (~~50.5~~ 39.023) (68.417) (528/532) (29.944/29.92) = ~~7,615,418~~ 5,889,683 cu.ft

6. Calculate grain loading--

grains/sdcf = (15.43)(grams)/V_{mstd} = (15.43) (0.1310) / (34.10) = 0.059

7. Calculate mass emission rate--

lbs/hr = (grains/stdcf)(Q_{stpd})(1.43 x 10^{-4})

lbs/hr = (~~7,615,418~~ 5,884,683)(0.0593)(1.43 x 10^{-4}) = ~~64.55~~ **49.90**

Data mentioned in Section 4.1.22 and used for calculations in Appendix F.

Data used for calculations in Appendix F.

Cooler Stack Test

LEEDS KILN PROCESS DATA SHEET Test #8

DATE 2/21/84

PREHEATER

TIME	KILN FEED RATE (TPH)	ID-30 SPEED (RPM)	ID-30 AMPS (A)	ID-30 INLET TEMP. (°F)	DOWNCOMER SPRAY (GPM)	ID-30 DRAFT ("WC)	STAGE 1 EXIT DRAFT ("WC)	STAGE 3 EXIT DRAFT ("WC)	STAGE 4 EXIT DRAFT ("WC)	STAGE 1 GAS TEMP. (°F)	STAGE 3 GAS TEMP. (°F)	STAGE 4 GAS TEMP. (°F)	PREH. EXIT OXYGEN (%)	ID-24 SPEED (RPM)
[illegible]	155	980	180	650	—	-2	28	15	8½	710	1100	1190	—	1180
8:25	150	980	180	650	—	-1.5	27	13	8½	730	1400	905	—	1174
8:40	155	980	175	650	—	2½	27½	14	9	710	1400	1305	—	1180
8:55	155	980	181	650	—	2½	28	15	7½	710	1400	1305	—	1180
9:10	155	980	180	650	—	2½	27½	15	9	710	1400	1305	—	1180
9:25														

KILN / COOLER

TIME	KILN SPEED (RPH)	KILN AMPS (A)	BURNING ZONE TEMP. (°F)	KILN EXIT OXYGEN (%)	#1 GRATE SPEED (SPM)	#2 GRATE SPEED (SPM)	#1 UNDERGRATE PRESS. ("WC)	#2 UNDERGRATE PRESS. ("WC)	#4 UNDERGRATE PRESS. ("WC)	#1 COOL. FAN AIRFLOW (CFM)	#2 COOL. FAN AIRFLOW (CFM)	#3 COOL. FAN AIRFLOW (CFM)	#4 COOL. FAN AIRFLOW (CFM)	SECONDARY AIR TEMP. (°F)	KILN HOOD DRAFT ("WC)	VENT FAN DAMPER (%)	FILTER DIFF. PRESSURE ("WC)	FILTER INLET TEMP. (°F)
[illegible]	120	7/14	—	1.7	9	13	11½	14	12	—	15	15	19	1100	.07	79	11½	600
8:25	110	9/17	—	2.2	5	11½	11½	14	5	—	16	16	19	1100	.09	58	10	550
8:40	120	9/12	—	2.3	5	12½	13	14	3½	—	15	15	15	1100	.06	42	8½	300
8:55	110	7/12	—	2.1	9	13	15	16	8.6	—	16	17	16	1150	.06	62	12	400
9:10	110	9/17	—	2.5	6	13	14	13	5.8		16	16	17	1100	.06	60	12	[illegible]
9:25																		

SPRAY TOWER / COAL MILL / PRECIP. / REMARKS

TIME	SPRAY TOWER INLET TEMP. (°F)	SPRAY TOWER OUTLET TEMP. (°F)	WATER SPRAY (GPM)	COAL FEED (TPH)	MILL DRIVE AMPS (A)	MILL INLET TEMP. (°F)	MILL OUTLET TEMP. (°F)	MILL INLET DRAFT ("WC)	MILL DIFF. PRESSURE ("WC)	COAL CYCLONE DIFF. PRESS. ("WC)	SYSTEM FAN DAMP. (%)	PRIMARY AIR FAN DAMP. (%)	PRIMARY AIR PRESSURE ("WC)	DUST TRAP INLET TEMP. (°F)	KOPPERS OUTLET TEMP. (°F)	ID-24 OXYGEN (%)	OPACITY	REMARKS
[illegible]	—	—	—	12.1	27	550	150	.8	—	—	62	44	41	600	160	—	4	
8:25	—	—	—	12.1	27	400	140	1	—	—	62	44	42	610	160	—	4	
8:40	—	—	—	11.1	28	350	140	.9	—	—	62	44	41	605	160	—	5	
8:55	—	—	—	12.1	27	490	140	.8	—	—	63	44	41	700	150	—	4	
9:10	—	—	—	12.1	28	[illegible]	[illegible]	.8	—	—	62	44	41	650	150	—	4	
9:25																		

Avg. Kiln Feed = 154 TPH

Data used for calculations in Appendix F.

Cooler Stack Test

LEEDS KILN PROCESS DATA SHEET

Test #9

DATE 2/21/84

TIME	KILN FEED RATE (TPH)	ID-30 SPEED (RPM)	ID-30 AMPS (A)	ID-30 INLET TEMP. (°F)	DOWNCOMER SPRAY (GPM)	ID-30 DRAFT ("WC)	STAGE 1 EXIT DRAFT ("WC)	STAGE 3 EXIT DRAFT ("WC)	STAGE 4 EXIT DRAFT ("WC)	STAGE 1 GAS TEMP. (°F)	STAGE 3 GAS TEMP. (°F)	STAGE 4 GAS TEMP. (°F)	PREH. EXIT OXYGEN (%)	ID-24 SPEED (RPM)
10:10	60	980	180	650	—	-1.8	28	15	9	720	1350	1520	—	980
10:25	160	980	180	650	—	-3	28½	13	8½	720	1380	1500	—	980
10:40 A	160	980	180	650	—	-2	28	13	9	720	1340	1520	—	980
10:55 A	170	980	180	650	—	-3	29	17	9.3	720	1380	1500	—	980
11:10 A	160	983	180	650	—	-3	29	17	10	720	1380	1500	—	980
11:25 A														

TIME	KILN SPEED (RPH)	KILN AMPS (A)	BURNING ZONE TEMP. (°F)	KILN EXIT OXYGEN (%)	#1 GRATE SPEED (SPM)	#2 GRATE SPEED (SPM)	#1 UNDERGRATE PRESS. ("WC)	#2 UNDERGRATE PRESS. ("WC)	#4 UNDERGRATE PRESS. ("WC)	#1 COOL. FAN AIRFLOW (CFM)	#2 COOL. FAN AIRFLOW (CFM)	#3 COOL. FAN AIRFLOW (CFM)	#4 COOL. FAN AIRFLOW (CFM)	SECONDARY AIR TEMP. (°F)	KILN HOOD DRAFT ("WC)	VENT FAN DAMPER (%)	FILTER DIFF. PRESSURE ("WC)	FILTER INLET TEMP. (°F)
10:10	110	11/17	—	1.5	8	12¼	13.8	15	9.4	—	16	19	16	2000	.03	100	14	600
10:25	138	11/17	—	1.1	8	11½	14.3	15.6	9	—	15	17	16	2050	.05	100	14	580
10:40 A	138	11/17	—	1.9	7½	11½	14.3	15.6	9½	—	15	17	15	2000	.05	100	15	550
10:55 A	138	11/17	—	1.7	10	11½	16	18.2	9.8	—	14	16	16	2000	.07	94	14	550
11:10 A	128	11/17	—	1.7	6	[illegible]	16	18.3	9.8	—	14	16	16	2000	.07	100	13	500
11:25 A																		

TIME	SPRAY TOWER INLET TEMP. (°F)	SPRAY TOWER OUTLET TEMP. (°F)	WATER SPRAY (GPM)	COAL FEED (TPH)	MILL DRIVE AMPS (A)	MILL INLET TEMP. (°F)	MILL OUTLET TEMP. (°F)	MILL INLET DRAFT ("WC)	MILL DIFF. PRESSURE ("WC)	COAL CYCLONE DIFF. PRESS. ("WC)	SYSTEM FAN DAMP. (%)	PRIMARY AIR FAN DAMP. (%)	PRIMARY AIR PRESSURE ("WC)	DUST TRAP INLET TEMP. (°F)	KOPPERS OUTLET TEMP. (°F)	ID-26 OXYGEN (%)	REMARKS: Opacity
10:10	—	—	—	11.1	28	600	155	1	—	—	62	44	41	800	130	—	3
10:25	—	—	—	12.1	30	450	150	.8	—	—	63	44	41	800	130	—	4
10:40 A	—	—	—	11.1	30	350	130	1	—	—	63	44	41	810	110	—	5
10:55 A	—	—	—	12.1	29	500	160	.7	—	—	63	44	41	810	110	—	4
11:10 A	—	—	—	12.1	29	450	150	.1	—	—	63	44	41				4
11:25 A																	

Avg. Kiln Feed = 163 TPH

Data used for calculations in Appendix F.

~~Mason~~ Cooler Stack ~~Test~~ LEEDS KILN PROCESS DATA SHEET Test # 10 DATE 2/21/84

PREHEATER / KILN

TIME	KILN FEED RATE (TPH)	ID-30 SPEED (RPM)	ID-30 AMPS (A)	ID-30 INLET TEMP. (°F)	DOWNCOMER SPRAY (GPM)	ID-30 DRAFT ("WC)	STAGE 1 EXIT DRAFT ("WC)	STAGE 3 EXIT DRAFT ("WC)	STAGE 4 EXIT DRAFT ("WC)	STAGE 1 GAS TEMP. (°F)	STAGE 3 GAS TEMP. (°F)	STAGE 4 GAS TEMP. (°F)	PREH. EXIT OXYGEN (%)	ID-34 SPEED (RPM)	KILN SPEED (RPH)	KILN AMPS (A)	BURNING ZONE TEMP. (°F)	KILN EXIT OXYGEN (%)
[illegible]																		
[illegible]																		
12:00	157	980	193	840	—	-3	27	15	10	720	1360	1590	—	980	120	11/11	—	3½
[illegible]	155	980	180	840	—	-2	28	14	18	720	1380	1540	—	980	120	9/14	—	2.2
[illegible]	156	980	175	157	—	-2	27½	14	9	720	1360	1500	—	980	120	9/14	—	2½
[illegible]	155	980	180	1440	—	-2½	27½	15	9.5	720	1380	1500	—	980	115	14/10	—	3.4
[illegible]	.																	

COOLER / SPRAY TOWER

TIME	#1 GRATE SPEED (SPM)	#2 GRATE SPEED (SPM)	#1 UNDERGRATE PRESS. ("WC)	#2 UNDERGRATE PRESS. ("WC)	#4 UNDERGRATE PRESS. ("WC)	#1 COOL.-FAN AIRFLOW (CFM)	#2 COOL.-FAN AIRFLOW (CFM)	#3 COOL.-FAN AIRFLOW (CFM)	#4 COOL.-FAN AIRFLOW (CFM)	SECONDARY AIR TEMP. (°F)	KILN HOOD DRAFT ("WC)	VENT FAN DAMPER (%)	FILTER DIFF. PRESSURE ("WC)	FILTER INLET TEMP. (°F)	SPRAY TOWER INLET TEMP. (°F)	SPRAY TOWER OUTLET TEMP. (°F)	WATER SPRAY (GPM)
[illegible]																	
[illegible]																	
12:00	5	15	13.6	14.5	6	—	15	17	15	1500	.45	100	13	420	—	—	—
[illegible]	5	13½	14	16	5.4	—	15	13	13	1950	1.1	60/60	14	390	—	—	—
[illegible]	9	13	11.1	14.6	13	—	14½	17	13	1500	.04	100	16	700	—	—	—
[illegible]	5½	15	13.2	13.4	7.8	—	15	16	13	1500	.05	100	15	510	—	—	—
[illegible]																	

COAL MILL / PRECIP. / REMARKS

TIME	COAL FEED* (TPH)	MILL DRIVE AMPS (A)	MILL INLET TEMP. (°F)	MILL OUTLET TEMP. (°F)	MILL INLET DRAFT ("WC)	MILL DIFF. PRESSURE ("WC)	COAL CYCLONE DIFF. PRESS. ("WC)	SYSTEM FAN DAMP. (%)	PRIMARY AIR FAN DAMP. (%)	PRIMARY AIR PRESSURE ("WC)	DUST TRAP INLET TEMP. (°F)	KOPPERS OUTLET TEMP. (°F)	ID-36 OXYGEN (%)	REMARKS: Opacity
[illegible]														
[illegible]														
12:00	11.1	27	370	140	1	—	—	61	44	41	900	110	—	4
[illegible]	11.9	27	390	140	1	—	—	62	44	41	800	110	—	5
[illegible]	11.7	27	525	145	.8	—	—	62	44	40	800	110	—	5
[illegible]	11.7	26	400	145	.9	—	—	62	44	41	800	115	—	5
[illegible]														

Avg Kiln Feed = 155 TPH

Excerpts from

REFERENCE 52 (SECTION 4.0)

Baker, R. L., Compliance Test Results, Particulate and Sulfur Oxide Emissions, Cementon Kiln, KVB, Inc., Engineering and Research Division, Irvine, CA, December 1984.

SECTION 2.0

SUMMARY OF TEST RESULTS

The results of the particulate emission compliance test conducted on the kiln exhaust stack of Lehigh's Cementon facility in Cementon, New York, are presented in Table 2-1. This data represents the emission level of the kiln exhaust stack while firing pulverized coal to produce approximately 1500 tons per day of Portland cement. The applicable emissions limitation for this facility is 0.05 grains per dry standard cubic foot.

TABLE 2-1. PARTICULATE EMISSIONS RESULTS

Date	Test No.	Time Period (hr)	Particulate Gr/DSCF*	Emissions lb/hr**
11/8/84	LC Comp 1	1525 - 1657	0.009	8.5
11/9/84	LC Comp 2	1316 - 1428	0.010	8.6
11/9/84	LC Comp 3	1610 - 1722	0.013	12.0
AVERAGE			0.011	9.7

*Standard conditions 68°F and 29.92 in Hg at stack oxygen level

**Based on stack velocity method of analysis

The emissions levels in Table 2-1 were computed through KVB's Emission Data Reduction Computer Program (See Appendix A and H) which is in accordance with the appropriate EPA methods. The raw test data taken during each test appears in Appendix B.

A representative of the NYS DEC Region IV was present at the test site during the initial compliance testing day and was fully cognizant of the testing procedures used. The results indicate that the particulate emission levels for the Cementon kiln are well below the 0.05 GR/DSCF limit. The compliance test filters are being preserved and are available for inspection by the NYS DEC upon request.

Data mentioned in Section 4.1.23 and used for calculations in Appendix E.

Data used for calculations in Appendix E.

KVB, INC. 18006 SKYPARK BLVD. IRVINE, C.A. 92714 (714) 250-6200

********* PARTICULATE EMISSIONS DATA REDUCTION PROGRAM *********

COMPANY - LEHIGH PORTLAND CEMENT
LOCATION - CEMENTON NY
UNIT(S) - KILN EXHAUST STACK
TEST DATE - 11-8-84
TEST NO. - COMPLIANCE 1
TEST SITE - STACK

***************** FUEL ANALYSIS *****************

COAL	PCT BY WT	MOLES/LB-FUEL
CARBON	69.39	5.783(-02)
HYDROGEN	4.73	4.730(-02)
SULFUR	2.66	8.313(-04)
OXYGEN	5.81	1.816(-03)
NITROGEN	1.26	4.500(-04)
ASH	16.15	

HIGH HEATING VALUE(BTU/LB)	12606.00
EPA 'F FACTOR' (DSCF/MBTU)	9702.0

**************** ORSAT ANALYSIS *****************

	PCT BY VOLUME
CARBON DIOXIDE	16.10
OXYGEN	8.00
CARBON MONOXIDE	0.02
NITROGEN	47.62
WATER	28.26

**************** TEST CONDITIONS ****************

KILN FEED(GPM)	400.0
TOTAL HEAT INPUT(KBTU/HR)	423561.6
FUEL FLOW(LB/HR)	33600.0
BAROMETRIC PRESSURE(IN. HG)	29.85
STACK GAS STATIC PRESS(IN H2O)	-0.55
NOZZLE DIAMETER(IN)	0.376
PITOT TUBE COEFFICIENT	0.840
DUCT AREA AT SAMPLING PLANE(SQ. FT)	122.7
PROBE LENGTH (FT)	14.0
PROBE MATERIAL	INCONEL

************** FLUE GAS PARAMETERS ***************

MOLECULAR WEIGHT DRY(COMBINED)	31.60
MOLECULAR WEIGHT WET(COMBINED)	27.76
MOLECULAR WEIGHT DRY(ORSAT)	32.04
MOLECULAR WEIGHT WET(ORSAT)	28.07
PERCENT MOISTURE(MEASURED)	28.26
ACFM AT SAMPLING PLANE BASED ON:	
FUEL FLOW AND COMBUSTION CHEMISTRY	192765.2
STACK VELOCITY	237043.9

Data used for calculations in Appendix E.

KVB, INC. 18006 SKYPARK BLVD. IRVINE, C.A. 92714 (714) 250-6200

********* PARTICULATE EMISSIONS DATA REDUCTION PROGRAM *********

COMPANY - LEHIGH CEM COMP3
LOCATION - CEMENTON NY
UNIT(S) - KILN EXHAUST STACK
TEST DATE - 11-9-84
TEST NO. - COMPLIANCE 3
TEST SITE - STACK

**************** FUEL ANALYSIS *****************

COAL	PCT BY WT	MOLES/LB-FUEL
CARBON	70.68	5.890(-02)
HYDROGEN	4.83	4.830(-02)
SULFUR	2.40	7.500(-04)
OXYGEN	5.53	1.728(-03)
NITROGEN	1.30	4.643(-04)
ASH	15.26	

HIGH HEATING VALUE(BTU/LB)	12812.00
EPA 'F FACTOR'(DSCF/MBTU)	9727.0

**************** ORSAT ANALYSIS *****************

	PCT BY VOLUME
CARBON DIOXIDE	16.10
OXYGEN	7.50
CARBON MONOXIDE	0.03
NITROGEN	46.27
WATER	30.10

**************** TEST CONDITIONS ****************

KILN FEED(GPM)	405.0
TOTAL HEAT INPUT(KBTU/HR)	420233.6
FUEL FLOW(LB/HR)	32800.0
BAROMETRIC PRESSURE(IN. HG)	29.79
STACK GAS STATIC PRESS(IN H2O)	-0.80
NOZZLE DIAMETER(IN)	0.376
PITOT TUBE COEFFICIENT	0.840
DUCT AREA AT SAMPLING PLANE(SQ. FT)	122.7
PROBE LENGTH (FT)	14.0
PROBE MATERIAL	INCONEL

************** FLUE GAS PARAMETERS **************

MOLECULAR WEIGHT DRY(COMBINED)	31.58
MOLECULAR WEIGHT WET(COMBINED)	27.49
MOLECULAR WEIGHT DRY(ORSAT)	32.11
MOLECULAR WEIGHT WET(ORSAT)	27.87
PERCENT MOISTURE(MEASURED)	30.10
ACFM AT SAMPLING PLANE BASED ON:	
FUEL FLOW AND COMBUSTION CHEMISTRY	188154.5
STACK VELOCITY	243087.8

Data used for calculations in Appendix E.

KVB, INC. 18006 SKYPARK BLVD. IRVINE, C.A. 92714 (714) 250-6200

********* PARTICULATE EMISSIONS DATA REDUCTION PROGRAM *********

COMPANY - LEHIGH PORTLAND CEMENT
LOCATION - CEMENTON NY
UNIT(S) - KILN EXHAUST STACK
TEST DATE - 11-9-84
TEST NO. - COMPLIANCE 2
TEST SITE - STACK

***************** FUEL ANALYSIS *****************

COAL	PCT BY WT	MOLES/LB-FUEL
CARBON	70.68	5.890(-02)
HYDROGEN	4.83	4.830(-02)
SULFUR	2.40	7.500(-04)
OXYGEN	5.53	1.728(-03)
NITROGEN	1.30	4.643(-04)
ASH	15.26	

HIGH HEATING VALUE(BTU/LB)	12812.00
EPA 'F FACTOR'(DSCF/MBTU)	9727.0

**************** ORSAT ANALYSIS *****************

	PCT BY VOLUME
CARBON DIOXIDE	14.30
OXYGEN	7.80
CARBON MONOXIDE	0.07
NITROGEN	48.03
WATER	29.80

**************** TEST CONDITIONS ****************

KILN FEED(GPM)	400.0
TOTAL HEAT INPUT(KBTU/HR)	420233.6
FUEL FLOW(LB/HR)	32800.0
BAROMETRIC PRESSURE(IN. HG)	29.79
STACK GAS STATIC PRESS(IN H2O)	-0.70
NOZZLE DIAMETER(IN)	0.376
PITOT TUBE COEFFICIENT	0.840
DUCT AREA AT SAMPLING PLANE(SQ. FT)	122.7
PROBE LENGTH (FT)	14.0
PROBE MATERIAL	INCONEL

************** FLUE GAS PARAMETERS **************

MOLECULAR WEIGHT DRY(COMBINED)	31.00
MOLECULAR WEIGHT WET(COMBINED)	27.12
MOLECULAR WEIGHT DRY(ORSAT)	31.70
MOLECULAR WEIGHT WET(ORSAT)	27.62
PERCENT MOISTURE(MEASURED)	29.80
ACFM AT SAMPLING PLANE BASED ON:	
FUEL FLOW AND COMBUSTION CHEMISTRY	175733.0
STACK VELOCITY	223463.0

Excerpts from

REFERENCE 53 (SECTION 4.0)

Steiner, J., Mojave Plant (Kiln, Crusher, and Clinker Baghouses) Annual Compliance Test, Report PS-85-469/Project 5451-85, Pape and Steiner Environmental Services, Bakersfield, CA, May 1985.

SUMMARY OF SOURCE TEST RESULTS

Company CalMat Company Test Date 05/13/85 APCD No. 1003026A Unit No. Kiln

Pollutants	Emissions									Removal %	Emission Factor lb/~~MMBtu~~ ton	
	Inlet				Outlet							
	Concentration Wet			Mass Flow Rate lb/hr	Concentration Wet				Mass Flow Rate lb/hr		Inlet	Outlet
	gr/scf	@ 12% CO_2	ppm_v		gr/scf	@ 12% CO_2	ppm_v	@ 3% O_2				
Particulate					0.0034 0.0019 0.0034 0.0029				5.88 3.25 5.86 5.00			0.03 0.02 0.03 0.02
Sulfate					0.0005 0.0003 0.0005 0.0004				0.86 0.45 0.86 0.72			
SO_2							15.64 16.83 16.90 16.40		32.47 34.75 34.57 33.93			
NO_x as NO_2 (dry)							387.50 395.33 394.33 892.39	633.45 649.21 633.05 638.57	532.11 540.35 533.36 535.27			
HC (C_1,>C_i)							2.75/18.70 1.74/17.41 2.26/15.06 2.25/17.06		1.31/8.93 0.83/8.28 1.06/7.08 1.07/8.10			

Scrubber Liquor Analysis: Chlorides -- Specific Gravity --

For Kern County Use Only:

Remarks CO (ppm, dry) = 179.17, 181.00, 194.67; Average 184.95
(lb/hr) = 149.73, 150.56, 160.24; Average 153.51 Test 1, 2, 3 216.0 TPH

Data mentioned in Section 4.1.24 and used for calculations in Appendix E.

SUMMARY OF SOURCE TEST RESULTS

Company CalMat Company Test Date 05/15/85 APCD No. 1003027A Unit No. Clinker

Pollutants	Emissions									Removal %	Emission Factor lb/MMBtu	
	Inlet				Outlet							
	Concentration Wet			Mass Flow Rate lb/hr	Concentration Wet				Mass Flow Rate lb/hr		Inlet	Outlet
	gr/scf	@ 12% CO_2	ppm_v		gr/scf	@ 12% CO_2	ppm_v	@ 3% O_2				
Particulate					0.0024 0.0023 0.0024 0.0024				2.66 2.62 2.71 2.66			0.0200 0.0200 0.0198 0.0199
Sulfate												
SO_2												
NO_x as NO_2 (dry)												
HC												

Scrubber Liquor Analysis: Chlorides -- Specific Gravity --

For Kern County Use Only:

Remarks

Test 1 132.78 TPH
Test 2 130.92 TPH
Test 3 136.68 TPH

Data mentioned in Section 4.1.24 and used for calculation in Appendix F.

Pape & Steiner Environmental Services

TEST 1,2,3

LOCATION Kiln

EMISSION RATE DATA -- 68°F

Standard Temperature, S_t = 68°F; 29.92 inches Hg

XEQ FF

XEQ RAT

			Test 1	Test 2	Test 3	Average
ENTER: R-17 $V_{m,std}$			45.8840	45.6644	45.3177	
R-26 Q_s			191637.62	191637.62	188759.26	
R-22 O_2%			9.95	10.0	9.75	
LAB DATA						
Front Half Wash	(g)		0.00707	0.00447	0.00638	
Mass Filter	(g)		0.00071	0.00008	0.00077	
Back Half Catch	(g)		0.00287	0.00134	0.00348	
Front Half Sulfate	(mg H_2SO_4)		0.49	0.24	0.00	
Back Half Sulfate	(mg H_2SO_4)		1.07	0.57	1.56	
H_2O_2 Catch	(mg H_2SO_4)		89.94	96.24	95.99	
RESULTS						
F-Factor		1				
Filt. Particulate	gr/dscf	6	0.0026	0.0015	0.0024	0.0022
Filt. Particulate	lb/hr	7	4.30	2.53	3.94	3.59
Total Particulate	gr/dscf	8	0.0036	0.0020	0.0036	0.0031
Total Particulate	lb/hr	10	5.88	3.27	5.86	5.00
Total Sulfate	gr/dscf	11	0.0005	0.0003	0.0005	0.0004
Total Sulfate	lb/hr	13	0.86	0.45	0.86	0.72
SO_3	ppm	14	0.2	0.1	0.3	0.2
SO_3	lb/hr	15	0.48	0.26	0.70	0.48
SO_2	ppm	16	16.97	18.25	18.34	17.85
SO_2	lb/hr	17	32.47	34.92	34.57	33.93
SO_2	@3% O_2	18	27.75	29.97	29.45	29.06
SO_2	lb/MMBtu					
S	lb/MMBtu					
Filt. Particulate	lb/MMBtu					

Data used for calculations in Appendix E.

Pape & Steiner Environmental Services

TEST 1, 2, 3

LOCATION Clinker

EMISSION RATE DATA -- 68°F

Standard Temperature, S_t = 68°F; 29.92 inches Hg

XEQ FF

XEQ RAT

			Test 1	Test 2	Test 3	Average
ENTER: R-17 $V_{m,std}$			65.0182	66.9864	64.6381	
R-26 Q_s			129535.52	136000.50	133620.76	
R-22 O_2%			20.9	20.9	20.9	
LAB DATA						
Front Half Wash	(g)		0.00944	0.00945	0.00933	
Mass Filter	(g)		0.00065	0.00032	0.00057	
Back Half Catch	(g)		0.00000	0.00000	0.00000	
Front Half Sulfate	(mg H_2SO_4)					
Back Half Sulfate	(mg H_2SO_4)					
H_2O_2 Catch	(mg H_2SO_4)					
RESULTS						
F-Factor		1				
Filt. Particulate	gr/dscf	6	0.0024	0.0023	0.0024	0.0024
Filt. Particulate	lb/hr	7	2.66	2.62	2.71	2.66
Total Particulate	gr/dscf	8	0.0024	0.0024	0.0024	0.0024
Total Particulate	lb/hr	10	2.66	2.62	2.71	2.66
Total Sulfate	gr/dscf	11				
Total Sulfate	lb/hr	13				
SO_3	ppm	14				
SO_3	lb/hr	15				
SO_2	ppm	16				
SO_2	lb/hr	17				
SO_2	@3% O_2	18				
SO_2	lb/MMBtu					
S	lb/MMBtu					
Filt. Particulate	lb/MMBtu					

Data used for calculations in Appendix F.

Excerpts from

REFERENCE 54 (SECTION 4.0)

Arlington, W. D., Lone Star Florida Holding, Inc., Stack Tests for Particulate, SO_2, NO_x, and Visible Emissions, Report 810-S, Kiln No. 3, South Florida Environmental Services, Inc., West Palm Beach, FL, August 1985.

IV. SUMMARY OF RESULTS
REPORT 810-S

PARTICULATE

Run	Emission Rate lbs./hr.	Allowable Emission Rate lbs./hr.
1	17.25	39.90
2	19.97	39.90
3	22.47	39.90
Average	19.90	39.90

SULFUR DIOXIDE

Run	Emission Rate lbs./hr.	Allowable Emisison Rate lbs./hr.
1	380.86	398.82
2	367.01	398.82
3	393.62	398.82
Average	380.50	398.82

OXIDES OF NITROGEN

Run	Emission Rate lbs./hr.	Allowable Emission Rate lbs./hr.
1	548.53	586.95
2	592.98	586.95
3	601.61	586.95
Average	581.04	586.95

OPACITY

Emission Rate	Allowable Emissions
0%	< 20%

Data mentioned in Section 4.1.25 and used for calculations in Appendix E.