Note: This is a reference cited in *AP 42, Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources.* AP42 is located on the EPA web site at www.epa.gov/ttn/chief/ap42/

The file name refers to the reference number, the AP42 chapter and section. The file name "ref02_c01s02.pdf" would mean the reference is from AP42 chapter 1 section 2. The reference may be from a previous version of the section and no longer cited. The primary source should always be checked.

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# 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

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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

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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.

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# 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]

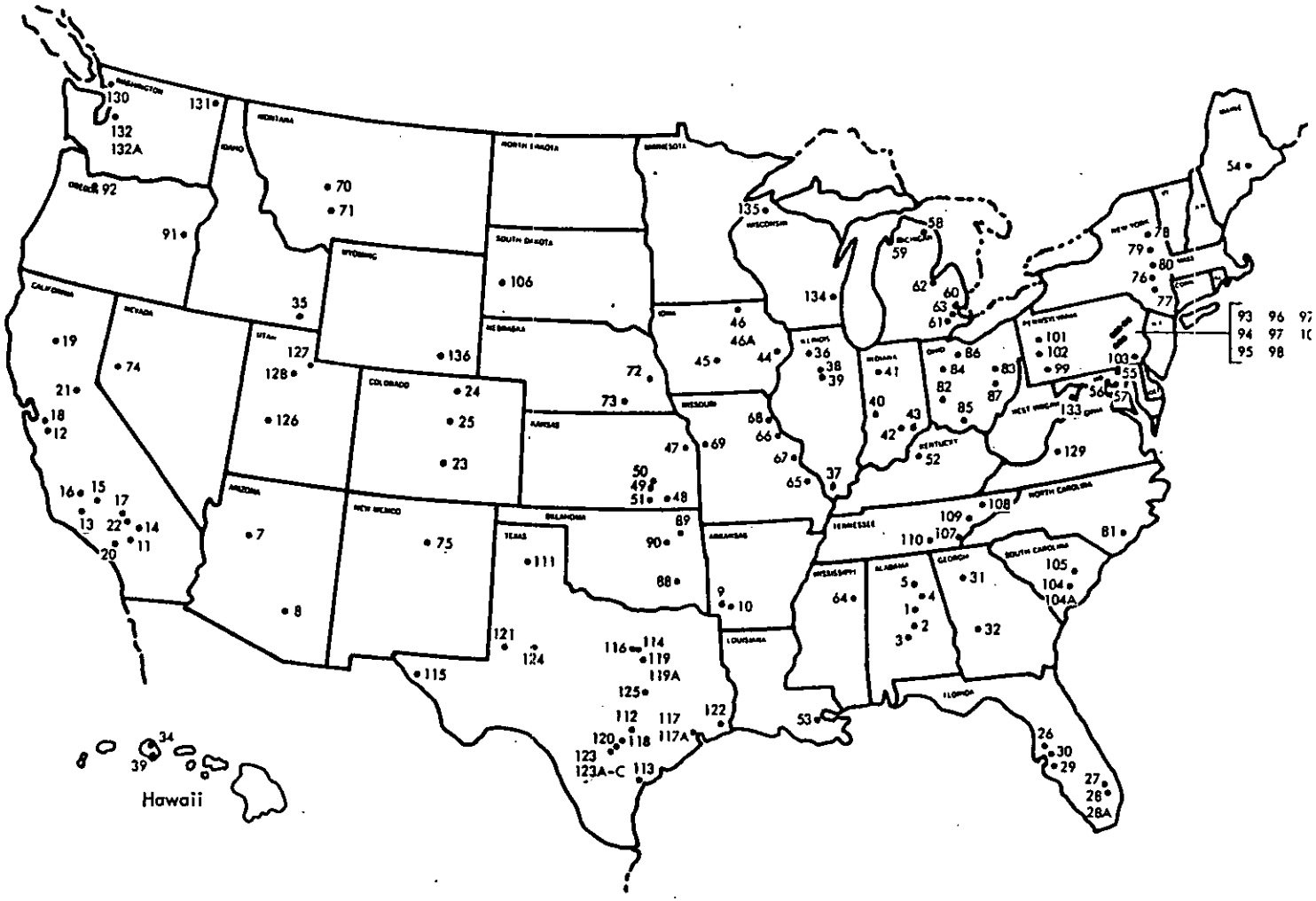


Figure 2-1. Geographical distribution of portland cement plants in the United States.

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: $10^3$ short tons | Production capacity: $10^3$ 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<br>920 | 1,500<br>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 | Type of process: Dry | Production capacity: $10^3$ short tons | Production capacity: $10^3$ 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 | Type of process: Dry | Production capacity: $10^3$ short tons | Production capacity: $10^3$ 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)

| 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 |
| 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] | | | Fuel consumed[a] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Quantity | | Percent of total | Coal[b] | | Fuel oil[c] | | Natural gas | |
| | | $10^3$ short tons | $10^3$ metric tons (Mg) | | $10^3$ short tons | $10^3$ metric tons (Mg) | $10^3$ bbl | $10^6$ ℓ | $10^6$ $ft^3$ | $10^6$ $m^3$ |
| 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 | $10^3$ 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]

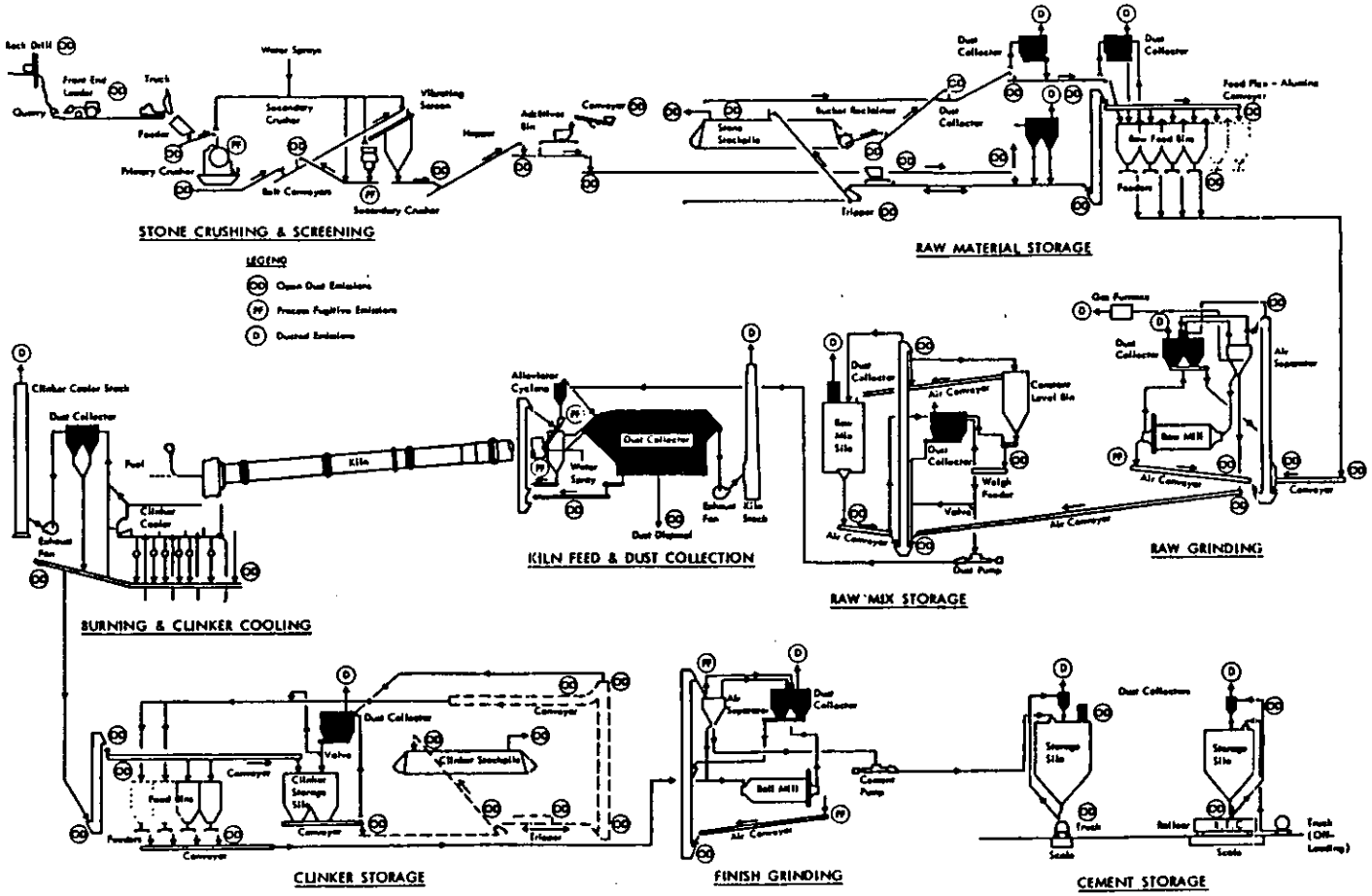


Figure 2-2. Flow diagram for dry process.[1]

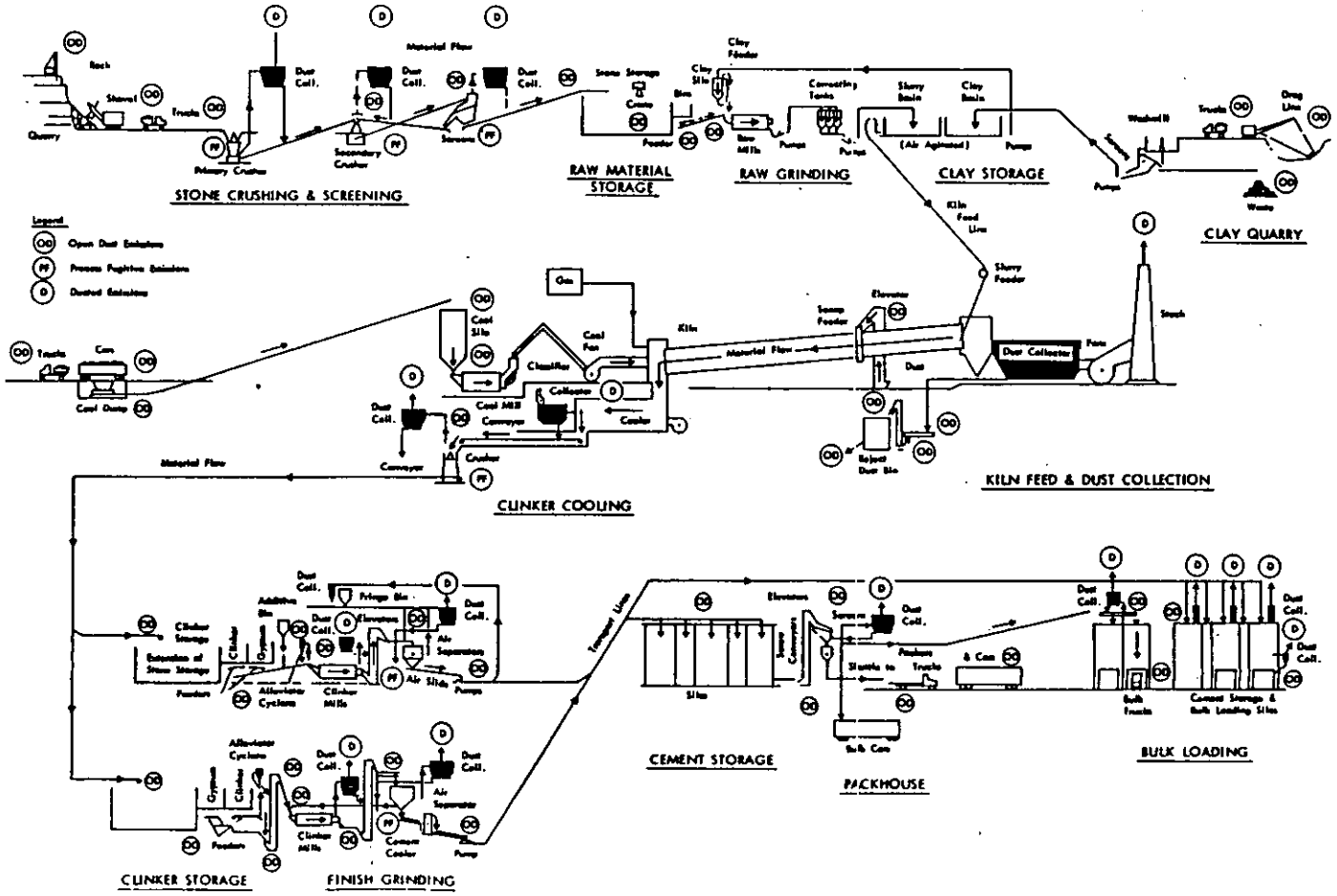


Figure 2-3. Flow diagram for wet process.[1]

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

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* 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

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* 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 additives | 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]

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

where:

$D_s$ = Stoke's diameter (cm)

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

$\eta$ = viscosity of the fluid (gm/cm·sec)

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

$\rho$ = density of the particle (gm/cm$^3$)

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

$$\cong 1 + \frac{2A\lambda}{D_s} \tag{3-2}$$

with:

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

$\alpha$ = empirical constant (dimensionless) $\cong$ 1.23 - 1.246
$\beta$ = empirical constant (dimensionless) $\cong$ 0.41 - 0.45
$\gamma$ = empirical constant (dimensionless) $\cong$ 0.88 - 1.08
$\lambda$ = mean free path of the fluid at stated conditions (cm)

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

$\lambda_o$ = mean free path at reference conditions (cm)
$\eta$ = gas viscosity at stated conditions (gm/cm·sec)
$\eta_o$ = 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:

$\rho$, $g$, $D_s$, and $\eta$ are as defined above; and

$\rho'$ = 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 $\eta$, $V_s$, 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)
$\rho$ = 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:

$$E_{TP} = \frac{e_{TP}}{R} \qquad (3\text{-}7)$$

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) | (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)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (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 Overland 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] Cut (μmA)[c] | Test 2-1[b] Cum. loading[d] (mg/dncm) | Test 2-2[b] Cut (μmA)[c] | Test 2-2[b] Cum. loading[d] (mg/dncm) | Test 3-1[b] Cut (μmA)[c] | Test 3-1[b] Cum. loading[d] (mg/dncm) | Test 3-2[b] Cut (μmA)[c] | Test 3-2[b] Cum. loading[d] (mg/dncm) | Test 3-3[b] Cut (μmA)[c] | Test 3-3[b] 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] Cut (μmA)[c] | Test 3-4[b] Cum. loading[d] (mg/dncm) | Test 4-1[b] Cut (μmA)[c] | Test 4-1[b] Cum. loading[d] (mg/dncm) | Test 4-2[b] Cut (μmA)[c] | Test 4-2[b] Cum. loading[d] (mg/dncm) | Test 4-3[b] Cut (μmA)[c] | Test 4-3[b] Cum. loading[d] (mg/dncm) | Test 4-4[b] Cut (μmA)[c] | Test 4-4[b] 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 | 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] Mass collected (mg) | Test 3-3[b] Cut-point (Dp-μmA)[e] | Test 3-3[b] Cumulative percent ≤ stated size | Test 9-1C[c] Mass collected (mg) | Test 9-1C[c] Cut-point (Dp-μmA)[e] | Test 9-1C[c] Cumulative percent ≤ stated size | Test 9-2G[d] Mass collected (mg) | Test 9-2G[d] Cut-point (Dp-μmA)[e] | Test 9-2G[d] 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<br>Particle size = Invalid[k,l,n] | | | Total mass = A<br>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] lb/ton | kg/Mg | Percent by weight in stated particle size range[c] > 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) | (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 Mass (mg)[b] | 15 μm Cyclone $D_{50}$ size (μm)[c] | 15 μm Cyclone Cum. % than[d] | Stage 1 Mass (mg)[b] | Stage 1 $D_{50}$ size (μm)[c] | Stage 1 Cum. % than[d] | Stage 2 Mass (mg)[b] | Stage 2 $D_{50}$ size (μm)[c] | Stage 2 Cum. % than[d] | Cyclone Mass (mg)[b] | Cyclone $D_{50}$ size (μm)[c] | Cyclone Cum. % than[d] | Filter Mass (mg)[b] | Filter $D_{50}$ 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 | 283.3 | < 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[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] |
| 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[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) |
| 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 Reference 46 (1983)

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 Mass[b] (mg) | 15 μm Cyclone $D_{50}$ size (μm)[c] | 15 μm Cyclone Cum. % less than[d] | Stage 1 Mass[b] (mg) | Stage 1 $D_{50}$ size (μm)[c] | Stage 1 Cum. % less than[d] | Stage 2 Mass[b] (mg) | Stage 2 $D_{50}$ size (μm)[c] | Stage 2 Cum. % less than[d] | Cyclone Mass[b] (mg) | Cyclone $D_{50}$ size (μm)[c] | Cyclone Cum. % less than[d] | Filter Mass[b] (mg) | Filter $D_{50}$ 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 (µm)[c] | Cum. % less than[d] | Mass[b] (mg) | $D_{50}$ Size (µm)[c] | Cum. % less than[d] | Mass[b] (mg) | $D_{50}$ Size (µm)[c] | Cum. % less than[d] | Mass[b] (mg) | $D_{50}$ Size (µm)[c] | Cum. % less than[d] | Mass[b] (mg) | $D_{50}$ Size (µm)[c] | 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 (µm)[c] | Cum. % less than[d] | Mass[b] (mg) | $D_{50}$ Size (µm)[c] | Cum. % less than[d] | Mass[b] (mg) | $D_{50}$ Size (µm)[c] | Cum. % less than[d] | Mass[b] (mg) | $D_{50}$ Size (µm)[c] | Cum. % less than[d] | Mass[b] (mg) | $D_{50}$ Size (µm)[c] |
| 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 by-passed). 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 | 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 | $5.05 \times 10^{-4}$ | NA | B | $5.1 \times 10^{-4}$ | NA | D |
| Primary limestone[d,h] screen | Baghouse | 18 | NA | 4 | $1.1 \times 10^{-4}$ | NA | B | $1.1 \times 10^{-4}$ | NA | D |
| Conveyor transfer[d,h] station | Baghouse | 18 | NA | 3 | $1.5 \times 10^{-5}$ | NA | B | $2.0 \times 10^{-5}$ | NA | D |
| Secondary limestone[d,h] screen and crusher | Baghouse | 18 | NA | 3 | $1.6 \times 10^{-4}$ | NA | B | $1.6 \times 10^{-4}$ | 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] | | | | | 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 | 2.5 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] 2.5 μmA | 5.0 μmA | 10.0 μmA | 15.0 μmA | 20.0 μmA | 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 | 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 ($\sigma$) | | | 0.24 | 0.45 | 1.7 | 3.2 | 4.1 | 0.011 | 0.018 | 0.074 | 0.15 | 0.19 | - |
| Standard geometric deviation ($\sigma_g$) | | | 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] 2.5 μmA | 5.0 μmA | 10.0 μmA | 15.0 μmA | 20.0 μmA | 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 | 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 4-21. CALCULATED PARTICLE SIZE DISTRIBUTIONS AND CONTROLLED EMISSION FACTORS FOR REFERENCE 27[a]

Data Rating: B

| ID No. | Type of fuel | Cumulative mass % equal to or less than stated size[b] | | | | | 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 | 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 4-22. CALCULATED EMISSION FACTORS FOR REFERENCE 42 - NO. 5 KILN BAGHOUSE INLET[a]

Data Rating: A

| Particle size run number | Total mass emission rate[b] (lb/hr) | Total mass emission rate[b] (kg/hr) | Production rate[c] (ton/hr) | Production rate[c] (Mg/hr) | Total mass emission factor[d] (lb/ton) | Total mass emission factor[d] (kg/Mg) | Cumulative emission factors equal to or less than stated size[e] 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 4-23. CALCULATED EMISSION FACTORS FOR REFERENCE 42 - NO. 5 KILN BAGHOUSE OUTLET[a]

Data Rating: A

| Particle size run number | Total mass emission rate[b] (lb/hr) | Total mass emission rate[b] (kg/hr) | Production rate[c] (ton/hr) | Production rate[c] (Mg/hr) | Total mass emission factor[d] (lb/ton) | Total mass emission factor[d] (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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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] (lb/hr) | Total mass emission rate[b] (kg/hr) | Production rate[c] (ton/hr) | Production rate[c] (Mg/hr) | Total mass emission factor[d] (lb/ton) | Total mass emission factor[d] (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-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) | (kg/Mg) | 10.0 μmA (lb/ton) | (kg/Mg) | 15.0 μmA (lb/ton) | (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] kg/Mg clinker | kg/Mg cement | Summary table No.[c] | Emission factor rating |
|---|---|---|---|---|---|
| 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[d] crusher | Baghouse | NA | $5.1\ (10)^{-4}$ | 4-16 | D |
| Primary limestone[d] screen | 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:

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

where: $\sigma$ = 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: $\sigma_g$ = 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] 2.5 μmA | 5.0 μmA | 10.0 μmA | 15.0 μmA | 20.0 μmA | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 ($\sigma$) | | | | 3.9 | 2.2 | 12 | 18 | 17 | - | 4.5 | 2.5 | 14 | 21 | 19 |
| Standard geometric deviation ($\sigma_g$) | | | | 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] 2.5 μmA | 10.0 μmA | 15.0 μmA | 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| 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 ($\sigma$) | | | | 2.7 | | 3.9 | - | 3.0 | 3.6 | 4.2 |
| Standard geometric deviation ($\sigma_g$) | | | | 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 ($\sigma$) | | | | 13 | 0.42 | 14 | 13 | 0.92 | - | 0.043 | 0.0 | 0.047 | 0.044 | 0.0 |
| Standard geometric deviation ($\sigma_g$) | | | | 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: C

| 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 ($\sigma$) | | | | 14 | 3.1 | 10 | 12 | 0.71 | - | 0.020 | 0.005 | 0.017 | 0.017 | 0.0 |
| Standard geometric deviation ($\sigma_g$) | | | | 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 ($\sigma$) | 15 | 13 | 9.7 | 7.8 | 6.9 | - | 0.024 | 0.021 | 0.015 | 0.013 | 0.011 |
| Std. geometric deviation ($\sigma_g$) | 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[e] | | Gravel bed filter[d] | |
| | Uncontrolled | 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.

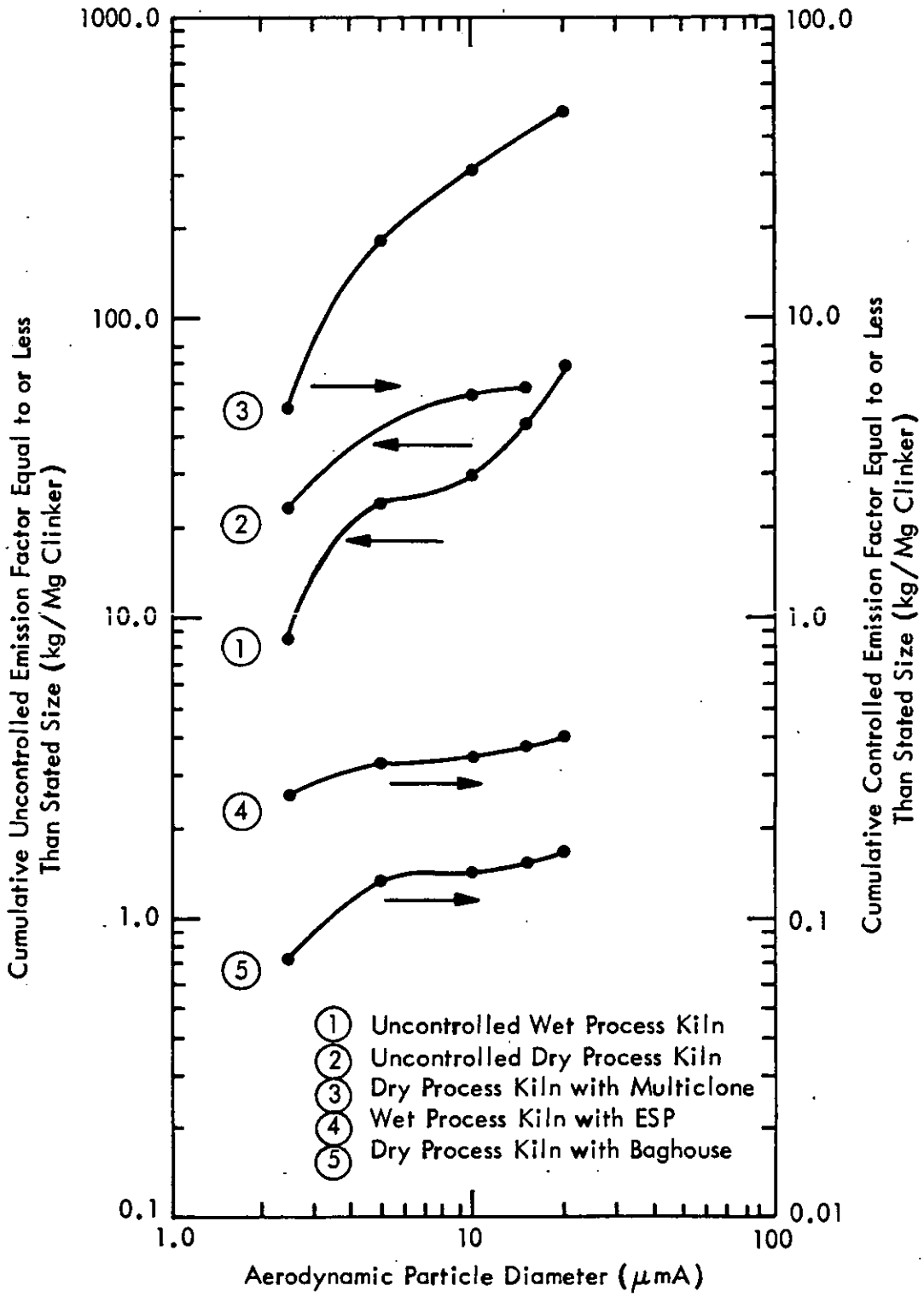


Figure 4-1. Size specific emission factors for cement kilns.

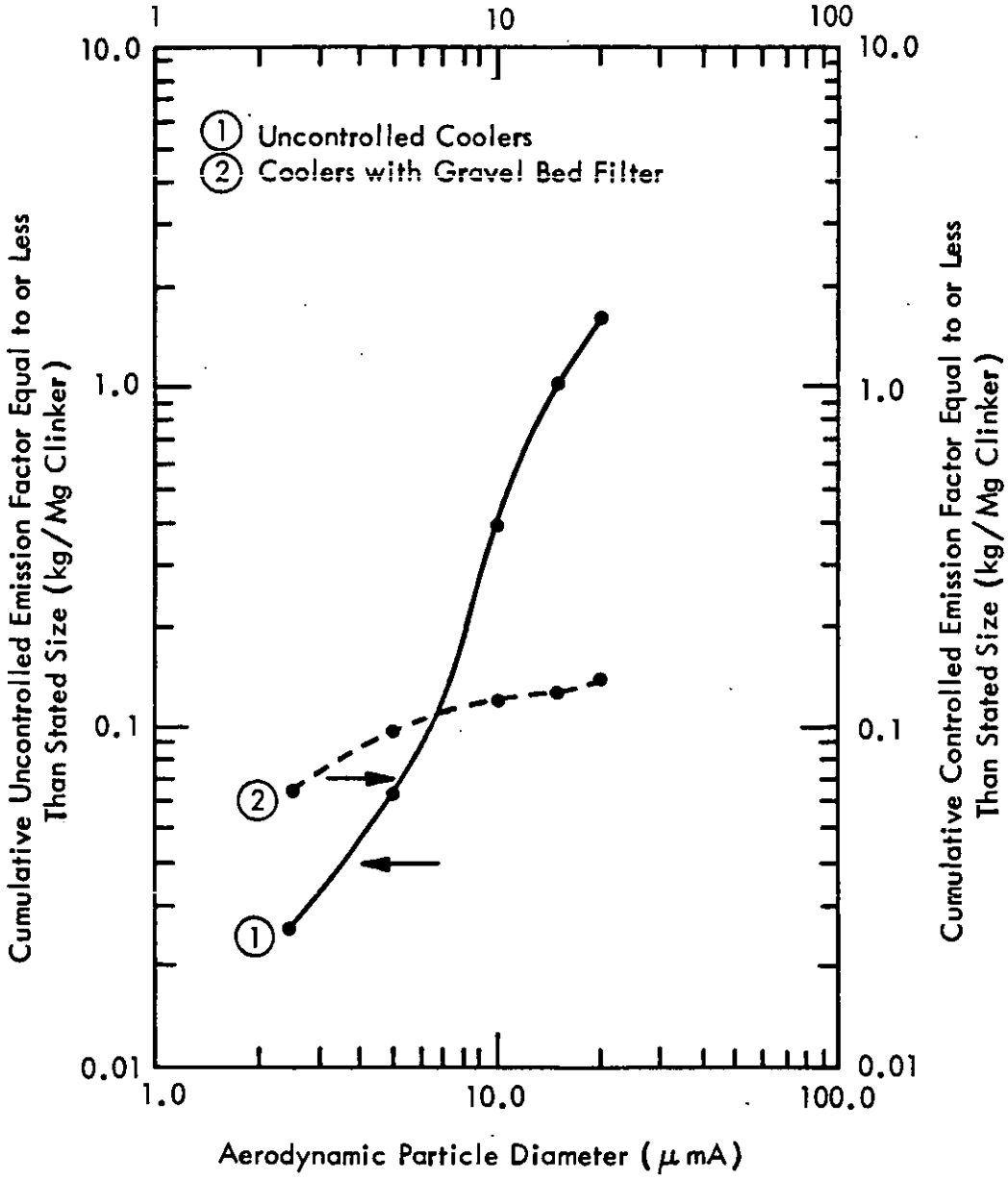


Figure 4-2. Size specific emission factors for clinker coolers.

## 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

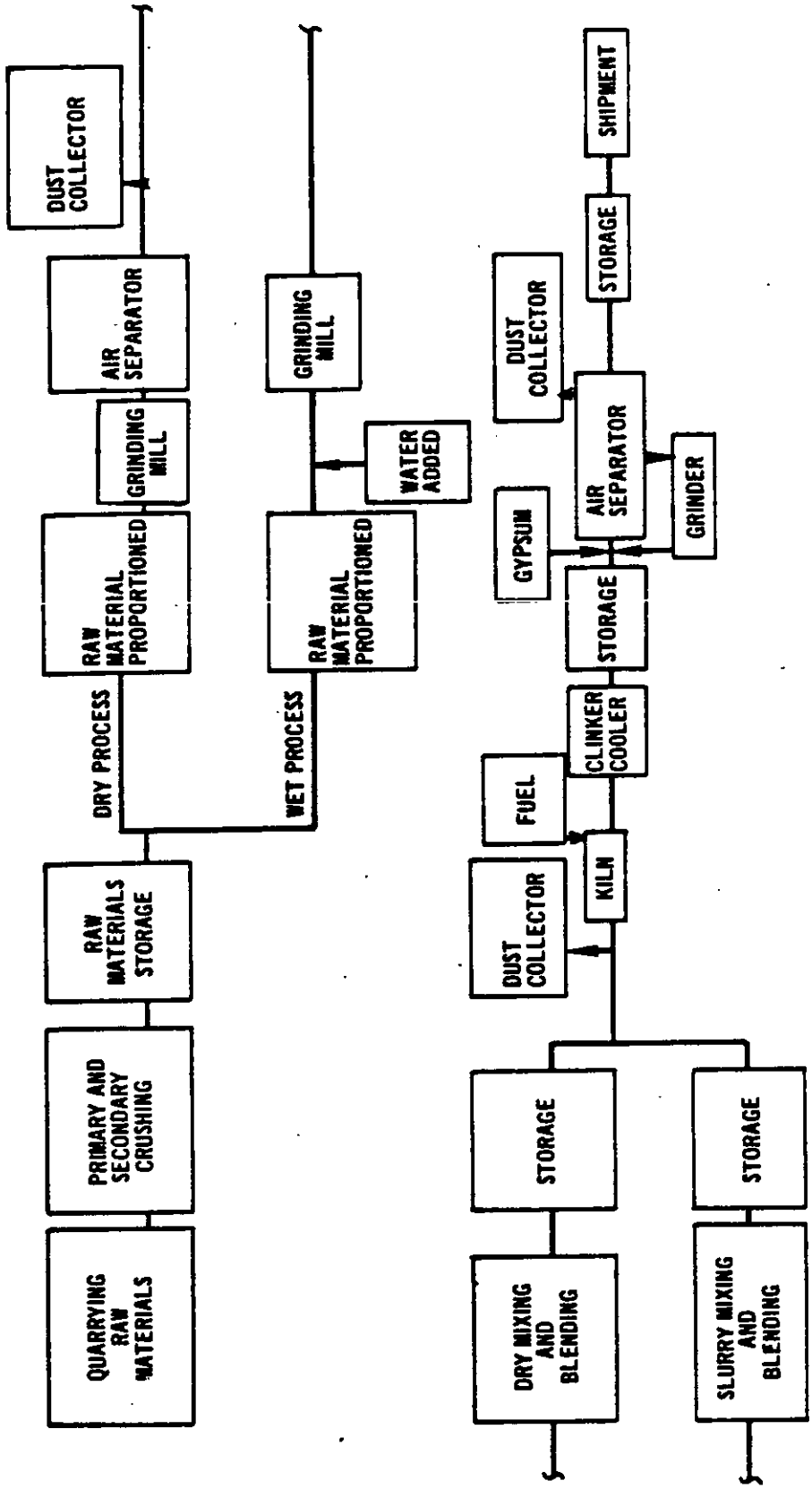


Figure 8.6-1. Basic flow diagram of portland cement manufacturing process.

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] | | | | | | | | Nitrogen oxides | | Lead | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mineral source[d] | | Gas combustion | | Oil combustion | | Coal combustion | | | | | |
| | 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] | | | | | | Cumulative emission factor < stated size[c] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Uncontrolled | | Dry process kiln with multiclone[d] | Wet process kiln with ESP | Baghouse | | Uncontrolled | | | | Dry process with multiclone[d] | | Wet process with ESP | | Baghouse | | | |
| | Wet process kiln | Dry process kiln | | | Wet process kiln | Dry process kiln | 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 | 7.0 | 18 | 3.8 | 64 | NA | 45 | 8.4 | 17 | 23 | 46 | 5.0 | 10 | 0.25 | 0.50 | NA | NA | 0.073 | 0.15 |
| 5.0 | 20 | NA | 14 | 83 | NA | 77 | 24 | 48 | - | - | 19 | 38 | 0.32 | 0.64 | NA | NA | 0.13 | 0.26 |
| 10.0 | 24 | 42 | 24 | 85 | NA | 84 | 29 | 58 | 54 | 108 | 32 | 64 | 0.33 | 0.66 | NA | NA | 0.14 | 0.28 |
| 15.0 | 35 | 44 | 31 | 91 | NA | 89 | 43 | 86 | 57 | 114 | 41 | 82 | 0.36 | 0.72 | NA | NA | 0.15 | 0.30 |
| 20.0 | 57 | NA | 38 | 98 | NA | 100 | 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.

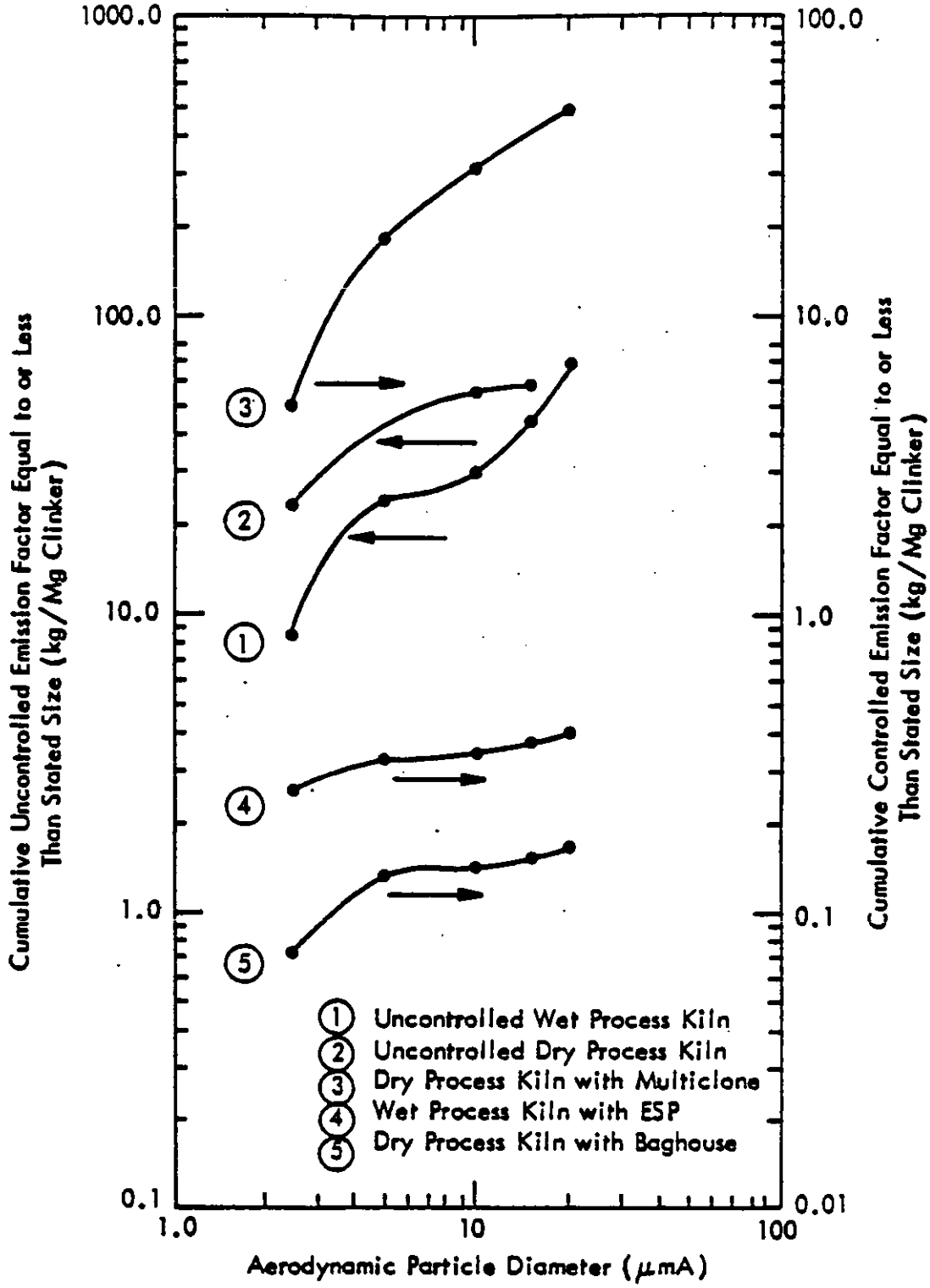


Figure 8.6-2. Size specific emission factors for cement kilns.

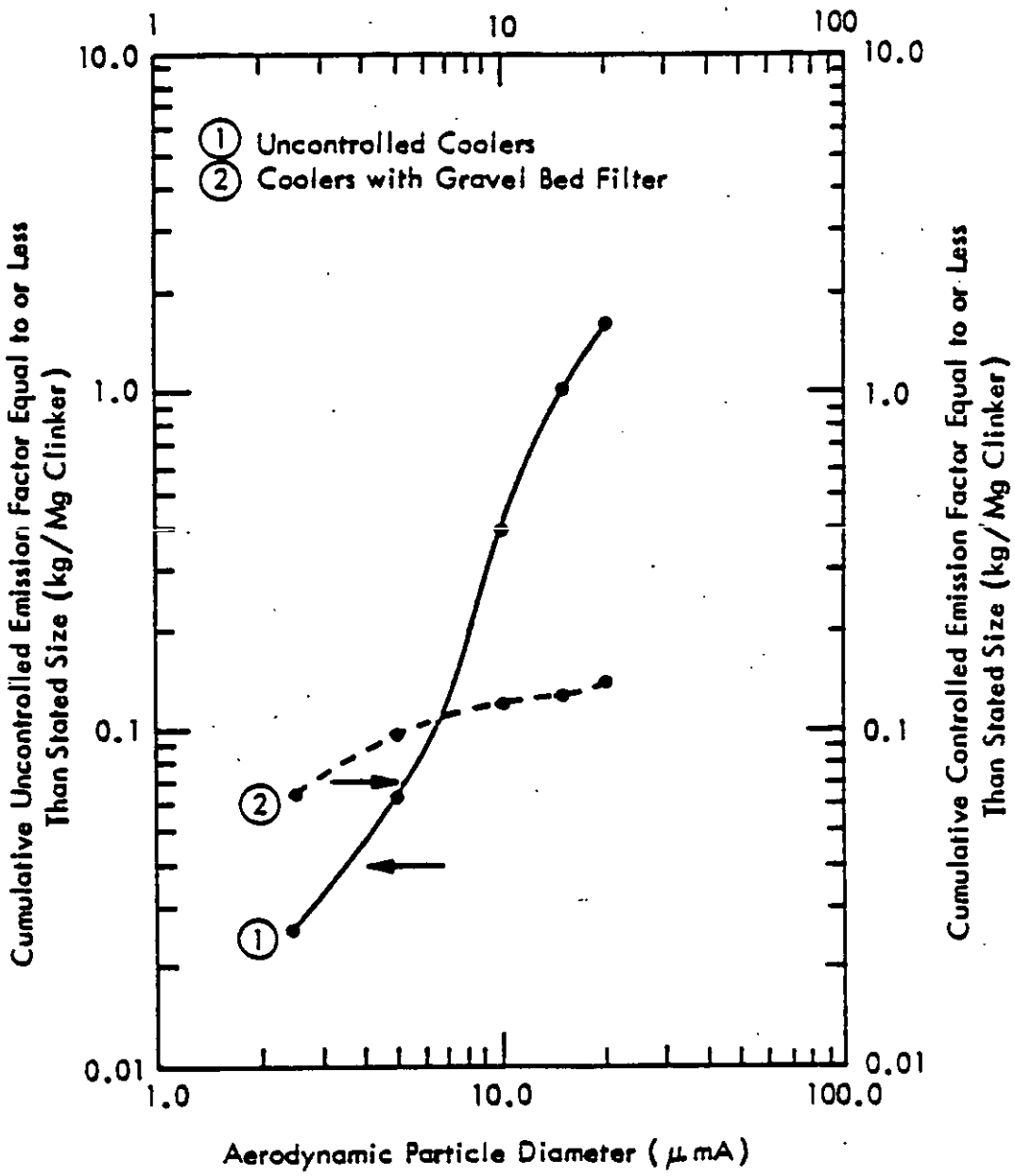


Figure 8.6-3. Size specific emission factors for clinker coolers.

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

EMISSION FACTOR RATING: E

| Particle size[b] (μm) | 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

| | 1 | 2 |
|---|---|---|
| Run Number | 3-8-71 | 3-8-71 |
| Date | NA | NA |
| Percent Excess Air | 106.2 | 103.5 |
| Percent Isokinetic | 10,517 | 10,587 |
| Stack Flow Rate - SCFM* dry | 12,791 | 12,936 |
| Stack Flow Rate - ACFM wet | 100.34 | 98.39 |
| Volume of Dry Gas Sampled - SCF* | 28.7 | 28.7 |
| Feed Rate - tons/hr | | |
| **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

| | 1 | 2 |
|---|---|---|
| Run Number | 3-5-71 | 3-5-71 |
| Date | — | — |
| Percent Excess Air | 107.8 | 110.9 |
| Percent Isokinetic | 9646 | 9588 |
| Stack Flow Rate - SCFM* dry | 12,250 | 12,256 |
| Stack Flow Rate - ACFM wet | 89.47 | 91.51 |
| Volume of Dry Gas Sampled - SCF* | 62.7 | 62.7 |
| Feed Rate - tons/hr | | |
| **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°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 | 58.8 | 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 - DSCFH[b] | 13,636 | 13,368 | 13,246 | 13,196 |
| Stack Volumetric Flow Rate - ACFH[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.

FPEIB TEST SERIES NO: 00080 STREAM NO: 01 TEST ID NO: 2 SAMPLE NO: 01 PAGE 20

SERIES FORM C7 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+14 |
| 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 | 8.19E-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 XD 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 | 1.88 | .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) | 93.68(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/DNM³

| 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 | | | 581[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 | 1.10 |
| 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 | 1.34 | 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/DSM³

| 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 | 0.01[2] | 9.45[2] | 2.56 | 0.96 | 1.15 |
| 11/3 | 1545 | 120 | 1.35 | NA | | 18.4[1] | 0.71 | 0.64 | 0.61 | 1.08 | 3.80 | 2.21 | 0.66 | 0.63 |
| 11/4 | 1130 | 240 | 1.39 | 9.6 | | 0.23 | 0.13 | 0.19 | 0.18 | 0.64 | 2.63 | 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 | 0.68 | 0.38 |
| 11/5 | 0945 | 240 | 1.32 | 14.0 | | 0.99 | 0.49 | 0.51 | 0.61 | 1.16 | 3.78 | 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 | 1.18 | 1.18** |
| | | | | | | 1.55 | .77 | 0.71 | .90 | 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 95% 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 | Dust Load 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 (900 tons/day)

| Test No. | Date 1976 | Process Load kg/s | Input MM | $O_2$ (%) | $CO_2$ (%) | $NO_x$ (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 | 1400 | 2250 | 1319 | 24 | 30 | 0 | 22.8 | 9805 | 750 | 672 | 2700 | 1700 | Baseline - part. test, 5-25% opacity |
| 9-1B | 8/11 | | | 6.1 | 16.0 | 2548 | 1494 | 2416 | 1417 | 13 | 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 | 2650 | 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 | 1441 | 846 | 21 | 29 | 0 | -- | | 750 | 672 | 2650 | 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 | 35 | 0 | -- | | 900/850 | 755/772 | 2940 | 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 | 1741 | 1021 | 17 | 43 | 0 | 20.9 | 9000 | 900/1000 | 755/811 | 2650 | 1617 | Particulate test, low $NO_x$, <5% opacity |
| 9-2G | 8/13 | | | 5.6 | 17.6 | 2044 | 1199 | 1929 | 1132 | 16 | 28 | 0 | -- | | 800/890 | 700/73[illegible] | 2650 | 1738 | 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 | 864 | 2960 | 1900 | 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 | 896 | 2980 | 1911 | SASS, ESP inlet |
| 9-5 | 10/4 | 9.2 | 57.2 | 6.8 | 14.1 | -- | -- | 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 33.2 x $10^{-9}$ $m^3$/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 x $10^{-9}$ $m^3$/J (8622 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 | 37.35 | 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 Rate, % | 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 (1.3631) | 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, $10^6$ g ($10^3$ 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 (385.11 | 199.4 (438.6) |
| Precipitator Catch $10^6$g ($10^3$lb) | 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 | | 23.5244 g | | 15.6896 g | | 4.2785 g | | 1381 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 | < 30 | < 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 | | 274 | | 9-4 A | |
| Sample Weight/Vol. | 17.4310 g | | 19.4157 g | | 12.6694 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 | 299 | 170000 |
| Chromium | 21 | 130 | 18 | 120 | 32 | 143 | 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 | 0.1 | 1500 |
| Lead | < 200 | < 1200 | < 200 | < 1300 | < 200 | < 870 | < 260 | < 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 | 950 | 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 | | 276 | | None | |
| Sample Weight (Kg) | 0.0123 g | | | | 0.5375 g | | 0.2062 | | | |
| Units | μg/g | μg/m³ | μg/g | μg/m³ | μg/g | μg/m³ | μg/g | μg/m³ | μg/gl | 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 | -- | -- | | | < 0.03 | < 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 PCM | | | | | | | | | | |
| 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 P+N+10μ SOLIDS | 4oz N. | 0.0214g | DISSOLVE IN 458 |
| | 458 | L P+N+10μ WASH | 16oz A. | 324ml | |
| | | 3μ SOLIDS | NONE | | |
| | 455 | L 3μ WASH | 16oz A | 271ml | |
| F * | 415 | S 1μ SOLIDS | 4oz N | 0.4049g | DISSOLVE IN 458 |
| | 458 | L 1μ WASH | 16oz A | 148ml | |
| | 275 | S #1 FILTER | PETRI | 0.1859g | 137.1855g TOT |
| | 365 | L FILT. HOUS. WASH | 8oz A | 15ml | |
| | 223 | L XAD MOD RINSE | 16oz A | 876ml | |
| | 300 | S XAD RESIN | 16oz AWM | 158g | 457-279 (tare) |
| A * | 220 | L XAD CONDENSATE | 16oz A | 186ml | 2275 ml TOT |
| | 439 | L " " | 1l N | 1036ml | |
| | 445 | L " | 1l N | 1053ml | |
| B * | 1024 | L IMPINGER #1 (1) | 1gal GLASS | 549ml | 4363 (1500ml ORIG). 4065 |
| | 1025 | L " #1 (2) | " | 3814ml | 298 RINSE |
| | 1026 | L IMPINGER #2 | " | 1843ml | 1164 = 679 RINSE |
| C * | 224 | L IMPINGER #3 (1) | 16oz A | 174ml | 421-305-816 RINSE |
| | 440 | L IMPINGER #3 (2) | 1l N | 947ml | |
| D * | 363 | L $H_2O$ IMPINGER WASH 2&3 | 8oz A | 148ml | 579 " |
| | 454 | L " " " | 16oz A | 431ml | |
| | 364 | LB IPA BLANK | 8oz A | 96ml | |
| | 1021 | P CEMENT FEED SLURRY | GLASS | 829.8g | |
| | 1022 | P CEMENT CLINKER | " | 768.5g | |
| | 1023 | P ESP CATCH | " | 494.8g | |
| | COUNT | S - 2 SOLID | 28 BOTTLES SENT | | |
| | | L - 10 LIQUIDS | * 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 $O_2$ | % | | H3-2$O_2$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 4-8.

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, $V_{lc}$ 65 (STO 1) ml Total Particulate, M 3417.6 (STO 2) m gm

Velocity Head, ΔP 0.8 (STO 3) iwg Stack Temp., Ts 1005 (STO 4) °R Stack Area, As 84 (STO 5) $ft^2$

Sample Volume, Vm 5.53 (STO 6) $ft^3$ Stack Press., Psg -6 (STO 7) iwg Excess $O_2$, $XO_2$% 18.65 (STO 8) %

Orifice Press. Diff., H .62 (STO 9) iwg ~~Stack Gas Sp. Gravity,~~ $\rho_{fuel}/\rho_{air}$ @ $T_s$ Gs 1.04 (STO A) n.d.

Sample Time, θ 10 (STO B) min Nozzle Dia., Dn 1/4 (STO C) in. Meter Temp., Tm (STO D) °F

| Select Fe | Oil (A) | Gas (B) | Coal (C) | Other: Coke/Gas |
|---|---|---|---|---|
| SC Feet/$10^4$ 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. $C = 2.205 \times 10^{-6}\ Mn/Vm_{std}$ | $1.396 \times 10^{-3}$ | lb/DSCF |
| | c. C = Eq. 4b x 16.018 x $10^3$ | 22.36 | grams/DSCM |
| 5. Abs. Stack Press. | $Ps = P_{bar} \times 13.6 + Psg$ | 387.7 | in. w abs. |
| 6. Stack Gas Speed | $Vs = 174\ Fs \sqrt{\Delta PTs} \sqrt{\frac{407}{Ps}} \times \frac{1.00}{Gs}$ | 4114 | ft/min |
| 7. Stack Gas Flow Rate @ 70°F | a. $Qsw$ = Eq. 6 x As x $\frac{530}{Ts} \times \frac{Ps}{407}$ | 173 602 | WSCF/min |
| | b. Qsd = Eq. 7a x (1. - Eq. 3) | 164228 | DSCF/min |
| 8. Material Flow | Ms = Eq. 7b x Eq. 4b x 60 | $1.376 \times 10^4$ | lb/hr |
| 9. $XO_2$ factor | $XO_2f = 2090/(20.9 - XO_2\%)$ | 298.3 | N.D. |
| 10. Emission | a. E = Eq. 4b x Fe x Eq. 9 | 46.96 | lb/MBtu |
| | b. E = Eq. 4c x Fm x Eq. 9 x 1000 | 10763 | 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 Ts and Tm to °R
2) Multiply EQ 1 by 530/Tm(°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 4-8.

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 ~~KILN DUST~~ KLINKER FLOW 60 T/hr klb/hr

IMPACTOR ORIENTATION HORIZ. FLOW THRU IMPACTOR 0.07 CFM

FLUE STATIC PRESSURE -6 $inH_2O$, VELOCITY 65 ft/sec.

NOZZLE DIA. 2 mm IMPACTOR PRESSURE DROP $13\frac{3}{4}$" $H_2O$ 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 | $\gamma_2$ | 61.98 | 30.91 |
| 3 | $\gamma_3$ | 25.93 | 11.75 |
| 4 | $\gamma_4$ | 5.63 | 3.74 |
| 5 | $\gamma_5$ | 3.31 | 2.00 |
| 6 | $\gamma_6$ | 1.70 | .97 |
| Filter | $\gamma_7$ | 1.45 | .44 |
| | Total | 100.00* | |

*Any discrepancy due to rounding off should be buried in the largest $\gamma$ cumulative % smaller than $D_{pc}$

| | |
|---|---|
| $\Sigma_2$ | 38.02 |
| $\Sigma_3$ | 12.09 |
| $\Sigma_4$ | 6.46 |
| $\Sigma_5$ | 3.15 |
| $\Sigma_6$ | 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 U.G. Load 83%

Pitot Factor, Fs .84 Barometric Pressure, $P_{bar}$ 29.99 in. Hg

Tot. Liquid Collected, $V_{lc}$ 130 ml Total Particulate, $M_n$ 6684.6 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 -6.4 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 $Vw_{std} = 0.0474\ V_{lc}$ 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. $C = 2.205 \times 10^{-6}\ Mn/Vm_{std}$ $1.853 \times 10^{-3}$ lb/DSCF
   c. C = Eq. 4b x 16.018 x $10^3$ 29.681 grams/DSCM
5. Abs. Stack Press. $Ps = P_{bar} \times 13.6 + Psg$ 401.46 in. w abs.
6. Stack Gas Speed $Vs = 174\ Fs\ \sqrt{\Delta PTs}\ \sqrt{\frac{407}{Ps} \times \frac{1.00}{Gs}}$ 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 $2.326 \times 10^3$ 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 |
|---|---|---|---|
| Fe SC Feet/$10^4$ Btu | 92.2 | 87.4 | 98.2 |
| Fm SC Meters/$10^4$ joules | 0.002475 | 0.002346 | 0.002636 |

Qsd+CO2 98.28

Note: Starting with test 9-1 a bigger brush for probe cleaning was used. It was felt that the older smaller brush did not completly 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

Test No. 9-2 Date 8-13-76 Location Gulf Coast Gen. 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, $M_n$ .5735 m gm

Velocity Head, ΔP .12 iwg Stack Temp., Ts 750 °R Stack Area, As 45 $ft^2$

Sample Volume, Vm 7.92 $ft^3$ 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. $C = 2.205 \times 10^{-6}\ Mn/Vm_{std}$ | $1.698 \times 10^{-3}$ | lb/DSCF |
| c. C = Eq. 4b x 16.018 x $10^3$ | 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. $Qsw = Eq.\ 6 \times As \times \frac{530}{Ts} \times \frac{Ps}{407}$ | 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 | $2.43 \times 10^2$ | lb/hr |
| 9. $XO_2$ factor $XO_2f = 2090/(20.9 - XO_2\%)$ | 125.15 | N.D. |
| 10. Emission per Dual a. E = Eq. 4b x Fs x Eq. 9 (20.89) | ~~10.573~~ | lb/MMBtu |
| b. E = Eq. 4c x Fm x Eq. 9 x 1000 (8979.5) | ~~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 |
|---|---|---|---|
| Fs SC Feet/$10^4$ Btu | 92.2 | ~~97.4~~ 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. BASELINE 9-1 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 52 %

FLUE GAS MOLECULAR WT. _____, TEMP. 310 °F, DENSITY _____ g/cc, VISCOSITY _____ POISE

FLUE GAS TEMP. 310 °F

Data used in Table 4-8

| | 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 | .0087 | | | |
| 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 | -0.1 | |
| 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% in less than 3 μ

60-20

TABLE 2 (Continued)

| | Symbol | Value | |
|---|---|---|---|
| % on a cup of the total sample collected | Cycl | | 49.7 |
| Stage 2 | $\gamma_2$ | 70.5 | 35.5 |
| 3 | $\gamma_3$ | 16.3 | 8.2 |
| 4 | $\gamma_4$ | 6.6 | 3.33 |
| 5 | $\gamma_5$ | 3.6 | 1.8 |
| 6 | $\gamma_6$ | 3.0 | 1.52 |
| Filter | $\gamma_7$ | 0 | |
| | Total | 100.00* | |

573.7

*Any discrepancy due to rounding off should be buried in the largest $\gamma$ cumulative % smaller than $D_{pc}$ cyclone ~ 7μ

| | | | |
|---|---|---|---|
| | | | 100 |
| | | | 50.55 |
| 2.81 | $\Sigma_2$ | 29.5 | 14.85 |
| 1.66 | $\Sigma_3$ | 13.2 | 6.65 |
| 1.13 | $\Sigma_4$ | 6.6 | 3.32 |
| .59 | $\Sigma_5$ | 3.0 | 1.52 |
| .37 | $\Sigma_6$ | 0 | 0 |

Data used in Table 4-8.

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. 41 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 | 3.6816 | 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

stage + 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 | $\gamma_2$ | 56.6 | 29.9 |
| 3 | $\gamma_3$ | 21.9 | 11.6 |
| 4 | $\gamma_4$ | 11.2 | 5.9 |
| 5 | $\gamma_5$ | 5.9 | 3.1 |
| 6 | $\gamma_6$ | 3.4 | 1.8 |
| Filter | $\gamma_7$ | 1.0 | .50 |
| | Total | 100.00* | |

*Any discrepancy due to rounding off should be buried in the largest $\gamma$ cumulative % smaller than $D_{pc}$

| | | |
|---|---|---|
| | | 100. |
| | | 52.8 |
| $\Sigma_2$ | 43.4 | 22.9 |
| $\Sigma_3$ | 21.5 | 11.3 |
| $\Sigma_4$ | 10.3 | 5.4 |
| $\Sigma_5$ | 4.4 | 2.3 |
| $\Sigma_6$ | 1.0 | .5 |

Data used in Table 4-8.

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 | 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 | 38.4 | 14 | |
| 5 ** | 326 | 192,000 | 20.3 | 14 | |
| 5 *** | 296 | 86,650 | 12.2 | 11 | |

DSCFM

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 | | | | | | |
| | | 2 | POSTPONED | | | | | |
| | | 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.

METCO

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<br>Probe, Cyclone & Filter Catch<br>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<br>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. | 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 |
|---|---|---|---|---|---|---|---|---|
| 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. | 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 |
|---|---|---|---|---|---|---|---|---|
| 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

| 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 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 Mass (mg)[a] | 15 μm Cyclone $D_{50}$ size (μm)[b] | 15 μm Cyclone Cum. % less than[c] | Stage 0 Mass (mg) | Stage 0 $D_{50}$ size (μm) | Stage 0 Cum. % less than | 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 | Stage 3 Mass (mg) | Stage 3 $D_{50}$ size (μm) | Stage 3 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 Mass (mg) | Stage 4 $D_{50}$ size (μm) | Stage 4 Cum. % less than | Stage 5 Mass (mg) | Stage 5 $D_{50}$ size (μm) | Stage 5 Cum. % less than | Stage 6 Mass (mg) | Stage 6 $D_{50}$ size (μm) | Stage 6 Cum. % less than | Stage 7 Mass (mg) | Stage 7 $D_{50}$ size (μm) | Stage 7 Cum. % less than | Filter Mass (mg) | Filter $D_{50}$ size (μm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 MCSS 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] | 10.0 μm (lb/ton) | 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 17FEB 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: [illegible]

Title/Position: PLANT 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

g: PULSE-JET

e-Positive _____ ~~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. YOUL

Signature: [signature]

Title/Position: PLANT ENGINEER

s 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*

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. VOLK

Signature: [illegible]

Title/Position: PLANT 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*<br>0.0094<br>0.0077<br>0.0086 | 0.0409*<br>0.0063<br>0.0057<br>0.0060 | | | 100.57*<br>16.96<br>13.72<br>15.34 | | | 0.45*<br>0.08<br>0.06<br>0.07 |
| Sulfate | | | | | | | | | | | | |
| $SO_2$ | | | | | | | 54.57<br>52.79<br>55.21<br>50.09<br>53.29 | | 111.45<br>112.76<br>102.29<br>108.83 | | | |
| $NO_x$ as $NO_2$ (dry) | | | | | | | 296.37<br>282.85<br>258.96<br>279.39 | 495.8<br>468.8<br>421.4<br>462.0 | 423.42<br>404.11<br>369.98<br>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

(Mojave)

Company California Portland Cement Test Date 5/26/83 APCD 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<br>0.0020<br>0.0029<br>0.0028 | 0<br>0<br>0<br>0 | | | 6.37<br>3.58<br>4.98<br>4.98 | | | 0.05<br>0.03<br>0.04<br>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 | 11.98 | 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 | 653.1 | 1.95 | 1.32 | 246.9 | < 1.95 |
| ESP-1-1-2 | 15,908.5 | 15.47 | 11.91 | 642.2 | 11.51 | 8.33 | 581.8 | 6.42 | 5.10 | 583.1 | 1.96 | 1.87 | 332.5 | < 1.96 |
| ESP-1-2-2 | 24,600.2 | 15.03 | 13.68 | 971.3 | 11.39 | 7.56 | 755.3 | 6.14 | 4.83 | 967.2 | 1.90 | 1.34 | 320.0 | < 1.90 |
| ESP-1-3-2 | 14,099.5 | 15.48 | 15.90 | 902.5 | 11.51 | 10.51 | 692.2 | 6.40 | 6.18 | 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 | 9.33 | 685.7 | 6.42 | 5.93 | 904.8 | 1.97 | 1.45 | 292.9 | < 1.97 |
| ESP-1-1-3(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-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 | 22,625.4 | 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 | 669.4 | 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 | 0.09 | 14.34 | 98.98 | 2.15 | 13.77 | 74.72 | 0.04 | 8.58 | 74.27 | 0.00 | 5.80 | 74.27 | 0.00 | 3.93 | 74.27 |
| ESP-0-4-1[d] | 289.72 | 14.81 | 7.27 | 7.86 | 14.14 | 4.76 | 1.60 | 8.81 | 4.24 | 2.72 | 5.95 | 3.37 | 1.66 | 4.04 | 2.84 |
| ESP-0-1-2 | 4.25 | 13.40 | 63.80 | 0.90 | 13.19 | 56.13 | 1.13 | 8.22 | 46.51 | 0.68 | 5.55 | 40.72 | 0.62 | 3.76 | 35.53 |
| ESP-0-2-2(B) | 1.45 | 15.58 | 89.44 | 0.43 | 15.09 | 86.31 | 0.21 | 9.41 | 84.78 | 0.46 | 6.37 | 81.43 | 0.50 | 4.32 | 77.79 |
| ESP-0-3-2 | 0.84 | 14.79 | 59.81 | 0.00 | 14.40 | 59.81 | 0.12 | 8.97 | 54.07 | 0.30 | 6.07 | 39.71 | 0.21 | 4.12 | 29.67 |
| ESP-0-4-2 | 1.84 | 15.11 | 74.34 | 0.80 | 14.58 | 63.18 | 0.18 | 9.09 | 60.67 | 0.45 | 6.15 | 54.39 | 0.47 | 4.17 | 47.84 |

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

[a] mg = Net weight milligrams.

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

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

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

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] | ≦ 10.0 μm (lb/ton) | ≦ 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.

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<br>Probe, Cyclone & Filter Catch<br>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<br>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<br>0.0062<br>0.0041<br>0.0048 | | | | 7.46<br>11.06<br>7.61<br>8.71 | | | 0.03<br>0.05<br>0.03<br>0.04 |
| Sulfate | | | | | 0.0010<br>0.0011<br>0.0010<br>0.0010 | | | | 1.88<br>1.89<br>1.90<br>1.89 | | | |
| $SO_2$ | | | | | | | 67.79<br>72.81<br>73.45<br>71.35 | | 143.76<br>154.17<br>154.80<br>150.91 | | | |
| $NO_x$ as $NO_2$ (dry) | | | | | | | 353.75<br>352.50<br>382.50<br>362.92 | 605.94<br>606.71<br>658.34<br>623.66 | 503.48<br>501.70<br>546.62<br>517.27 | | | |
| HC ($C_1$, >$C_1$) | | | | | | | 1.1/48.9<br>0.0/27.0<br>0.0/30.3<br>0.37/35.40 | | 0.54/24.20<br>0.00/13.36<br>0.00/15.06<br>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

| | 1 | 2 | 3 | Average |
|---|---|---|---|---|
| Test number | 1 | 2 | 3 | |
| 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 (°F) | 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<br>0.0014<br>0.0019<br>0.0017 | | | | 2.18<br>1.61<br>2.10<br>1.96 | | | 0.0087<br>0.0064<br>0.0084<br>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

| | 1 | 2 | 3 | Average |
|---|---|---|---|---|
| Test number | 1 | 2 | 3 | |
| 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
205/834-2870

Plant LEHIGH
Date 9/18/84 Run # 2
Sampling Location MAIN
LOESCHE MILL OFF

Sampling data
$T_s$ = 727 °R; $T_m$ = 528 °F
$C_p$ = 0.85; $(\overline{\Delta p})_{avg}$ = .7583
$P_s$ = 29.896 in. Hg; $H_a$ = 29.83 ft/mole
$A_s$ = 57.863 sq. ft.; $V_m$ = 44.171 cu. ft.
$H_2O$ (condensate) = 125 ml
$H_2O$ (silica gel) = 15.5 gm
$\Delta H_{avg}$ = 1.565 in. $H_2O$; $P_b$ = 29.94 in. Hg
Total particulate = 0.0756 grams

1. Calculate Stack gas velocity--

$$V_s = 85.49\ C_p\ (\sqrt{\Delta p})avg\sqrt{\frac{T_s}{P_s M_s}}$$

$$V_s = 85.49\ (0.85)(.7583)\sqrt{\frac{727}{29.896(29.83)}}$$

$V_s$ = 449.752 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)(125 + 15.5) = (0.0474) (140.5) = 6.66 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 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)(49.79)(57.863)(528/727)(29.896/29.92) = 6543110 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 $10^{-4}$) = $\boxed{24.61}$

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, $(\Delta p)_{avg}$ = 0.75
$P_b$ = 29.896 in Hg, $P_s$ = 29.89 in Hg
$A_s$ = 57.563 sq. ft., $V_m$ = 44.99 cu. ft.
$H_2O$ (condensate) = 118 ml
$H_2O$ (silica gel) = 15.0 gm
$\Delta H_{avg}$ = 1.64 in $H_2O$, $P_b$ = 29.94 in Hg
Total particulate = 0.0787 grams

1. Calculate Stack gas velocity--

$$V_s = 85.49\ C_p\ (\sqrt{\Delta p})avg \sqrt{\frac{T_s}{P_s M_s}}$$

$$V_s = 85.49\ (0.85)(0.75)\sqrt{\frac{728}{29.896(29.89)}}$$

$$V_s = 49.192 \text{ fps}$$

2. Calculate volume of water vapor in gas sample--

$$V_{wstd} = (0.0474)\left(\text{mls } H_2O \text{ condensate} + \text{grams } H_2O \text{ silica gel}\right)$$

$$V_{wstd} = (0.0474)(118 + 15) = (0.0474)(133) = 6.30 \text{ cu.ft.}$$

3. Calculate gas sample volume at standard conditions--

$$V_{mstd} = (17.64)(V_m)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m}\right)$$

$$V_{mstd} = (17.64)(44.99)\left(\frac{29.94 + \frac{1.64}{13.6}}{536}\right) = (\_\_\_\_)(0.0561) = 44.51 \text{ cu.ft.}$$

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--

$$Q_{stpd} = 3600(1-B_{ws})V_s A_s \frac{528}{T_s} \frac{P_s}{29.92}$$

$$Q_{stpd} = 3600\ (1-.124)(49.192)(57.563)(528/728)(29.896/29.92) = 6,505,131 \text{ cu.ft.}$$

6. Calculate grain loading--

$$\text{grains/sdcf} = (15.43)(\text{grams})/V_{mstd} = (15.43)(0.0787)/(44.51) = 0.0273$$

7. Calculate mass emission rate--

$$\text{lbs/hr} = (\text{grains/stdcf})(Q_{stpd})(1.43 \times 10^{-4})$$

$$\text{lbs/hr} = (6,505,131)(0.0273)(1.43 \times 10^{-4}) = \boxed{25.40}$$

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 Hg; $P_b$ = 29.37 #/ft-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
$\Delta H_{avg}$ = 1.52 in $H_2O$; $P_b$ = 29.94 in Hg
Total particulate = 0.0523 grams

1. Calculate Stack gas velocity--

$$V_s = 85.49\ C_p\ (\sqrt{\Delta p})avg\sqrt{\frac{T_s}{P_s M_s}}$$

$$V_s = 85.49\ (0.85)(0.73)\sqrt{\frac{730}{29.896(29.37)}}$$

$V_s$ = 48.368 fps

2. Calculate volume of water vapor in gas sample--

$$V_{wstd} = (0.0474)\left(\text{mls } H_2O \text{ condensate} + \text{grams } H_2O \text{ silica gel}\right)$$

$$V_{wstd} = (0.0474)(130 + 16.5) = (0.0474)(146.5) = 6.94 \text{ cu.ft.}$$

3. Calculate gas sample volume at standard conditions--

$$V_{mstd} = (17.64)(V_m)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m}\right)$$

$$V_{mstd} = (17.64)(44.305)\left(\frac{29.94 + \frac{1.52}{13.6}}{545}\right) = (\_\_\_\_)(0.0551) = 43.09 \text{ cu.ft.}$$

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--

$$Q_{stpd} = 3600(1-B_{ws})V_s A_s \frac{528}{T_s} \frac{P_s}{29.92}$$

$$Q_{stpd} = 3600\ (1-.14)(48.368)(57.86)(528/730)(29.896/29.92) = 6,261,813 \text{ cu.ft.}$$

6. Calculate grain loading--

grains/sdcf = (15.43)(grams)/$V_{mstd}$ = (15.43)(0.0523)/(43.09) = 0.0187

7. Calculate mass emission rate--

lbs/hr = (grains/stdcf)($Q_{stpd}$)($1.43 \times 10^{-4}$)
lbs/hr = (6261813)(0.0187)($1.43 \times 10^{-4}$) = $\boxed{16.74}$

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

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

Sampling data
$T_s$ = 730 °R, $T_m$ = 551 °R
$C_p$ = 0.85, $(\Delta p)_{avg}$ = 0.717
$P_b$ = 29.896 in. Hg, $P_s$ = 29.67 in. Hg abs
$A_s$ = 57.863 sq. ft., $V_m$ = 42.84 cu. ft.
$H_2O$ (condensate) = 130 ml
$H_2O$ (silica gel) = 14.0 grams
$\Delta H_{avg}$ = 1.47 in. $H_2O$, $P_b$ = 29.94 in. Hg
total particulate = 0.0488 grams

2. Calculate volume of water vapor in gas sample--

$V_{wstd} = (0.0474)\begin{pmatrix}\text{mls } H_2O \\ \text{condensate}\end{pmatrix} + \begin{pmatrix}\text{grams } H_2O \\ \text{silica gel}\end{pmatrix}$

$V_{wstd} = (0.0474)(130 + 14) = (0.0474)(144) =$ 6.83 cu.ft.

3. Calculate gas sample volume at standard conditions--

$V_{mstd} = (17.64)(V_m)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m}\right)$

$V_{mstd} = (17.64)(42.814)\left(\frac{29.94 + \frac{1.47}{13.6}}{551}\right) = (\_\_\_\_)(0.0545) =$ 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--

$Q_{stpd} = 3600(1-B_{ws})V_s A_s \frac{528}{T_s} \frac{P_s}{29.92}$

$Q_{stpd} = 3600\ (1-.14)(47.266)(57.863)(528/730)(29.896/29.92) =$ 6,119,463 cu.ft.

6. Calculate grain loading--

grains/sdcf = (15.43)(grams)/$V_{mstd}$ = (15.43)(0.0488)/(42.15) = 0.079

7. Calculate mass emission rate--

lbs/hr = (grains/stdcf)($Q_{stpd}$)(1.43 x $10^{-4}$)
lbs/hr = (6,119,463)(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

| TIME | PREHEATER | | | | | | | KILN | | | COOLER | | | | | | | | | | | SPRAY TOWER | | | COAL MILL | | | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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 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. | Test #2 Mill off (#1) |
| | t/h | RPM | "WC | "WC | °F | °F | % | RPM | RPM | A | % | °F | SPM | "WC | "WC | "WC | x 1000 CFM | x 1000 CFM | x 1000 CFM | x 1000 CFM | "WC | % | °F | °F | °F | GPM | t/h | °F | °F | "WC | A | % | % | °F | |
| 6 AM | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 AM | 142 | 1040 | -5 | 34 | 700 | 1500 | — | 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 | 140 TPH Average Feed to Kiln |
| 8 AM | 140 | 1040 | -5 | 33½ | 700 | 1500 | — | 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 | |
| 9 AM | 140 | 1040 | -5 | 33½ | 705 | 1500 | — | 680 | 118 | 8/10 | .6 | 1750 | 5 | 13½ | 14½ | 7.4 | — | 16 | 17 | 15 | .02 | 100 | 420 | 520 | 305 | 68 | 10.2 | 380 | 160 | .9 | 28 | 60 | 37 | 610 | |
| 10 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 | 520 | 525 | 305 | 64 | 10.2 | 380 | 155 | .7 | 29 | 60 | 37 | 650 | |
| 11 AM | 140 | 1040 | -5 | 33½ | 700 | 1505 | — | 680 | 118 | 7/11 | .5 | 1820 | 6 | 14.2 | 15.4 | 7.2 | — | 15 | 17½ | 15 | .07 | 92 | 520 | 526 | 305 | 62 | 10.2 | 370 | 155 | .7 | 29 | 60 | 37 | 620 | |
| 12 PM | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Data used for calculations in Appendix E.

# LEEDS KILN PROCESS DATA SHEET

DATE 9-18-84

MAIN STACK TEST

| TIME | PREHEATER | | | | | | | | KILN | | | COOLER | | | | | | | | | | | | SPRAY TOWER | | | COAL MILL | | | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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 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 | RPM | A | % | °F | SPM | "WC | "WC | "WC | 1000 CFM | 1000 CFM | 1000 CFM | 1000 CFM | "WC | % | °F | °F | °F | GPM | t/h | °F | °F | "WC | A | % | % | °F | |
| 9 AM | 140 | 1040 | -6 | 33½ | 700 | 1505 | .7 | 700 | 118 | 7/11 | | 1720 | 5 | 12½ | 13 | 5½ | | 16 | 20 | 17 | .06 | 100 | 430 | 520 | 305 | 62 | 10.2 | 245 | 155 | 1 | 28 | 60 | 37 | 650 | Test #3 |
| 10 AM | 138 | 1040 | -5 | 33½ | 700 | 1505 | .5 | 700 | 118 | 9/11 | | 1770 | 6 | 14.2 | 15.7 | 6.8 | | 17 | 18 | 15 | .04 | 95 | 440 | 525 | 305 | 64 | 10.2 | 470 | 155 | .9 | 28 | 60 | 37 | 660 | Mill off (O2) |
| 10 PM | 138 | 1040 | -5 | 33½ | 700 | 1505 | .5 | 640 | 118 | 7/10 | | 1800 | 5½ | 14 | 15.4 | 9.4 | | 16 | 17 | 14 | .06 | 90 | 410 | 520 | 305 | 64 | 10.2 | 415 | 155 | .8 | 27 | 60 | 37 | 660 | |
| 11 AM | 134 | 1040 | -5 | 33½ | 705 | 1505 | 1.1 | 640 | 118 | 9/12 | | 1700 | 5 | 12½ | 13½ | 5 | | 15½ | 17½ | 15 | .03 | 80 | 410 | 525 | 305 | 66 | 10.2 | 350 | 145 | 1.1 | 28 | 60 | 37 | 580 | 138 TPH Average Feed to Kiln |
| 11 PM | 136 | 1040 | -5 | 33 | 705 | 1505 | .9 | 640 | 118 | 9/12 | | 1720 | 5 | 12.8 | 14.6 | 5.8 | | 16 | 19 | 17 | .045 | 90 | 410 | 525 | 305 | 68 | 10.2 | 370 | 145 | .8 | 29 | 60 | 37 | 580 | |
| 4 PM | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 PM | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Data used for calculations in Appendix E.

# LEEDS KILN PROCESS DATA SHEET

Main Stack Test

DATE _____

| TIME | PREHEATER | | | | | | | | KILN | | | COOLER | | | | | | | | | | | | SPRAY TOWER | | | COAL MILL | | | | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed Rate | ID-30 Speed | ID-30 Draft | Stage 1 Exit Draft | Stage 1 Gas Temp. | Stage 4 Gas Temp. | 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. | Test #4 |
| | t/h | RPM | "WC | "WC | °F | °F | % | RPM | RPM | A | % | °F | SPM | "WC | "WC | "WC | CFM | CFM | CFM | CFM | "WC | % | °F | °F | °F | GPM | t/h | °F | °F | "WC | A | % | % | °F | |
| 1 PM | 135 | 10.40 | -5 | 33 | 710 | 1510 | 1.5 | 680 | 110 | 9/15 | | 1850 | 5 1/2 | 14 | 15 | 5.4 | | 16 | 19 | 15 | .06 | 95 | 550 | 540 | 305 | 72 | 10.2 | 360 | 140 | 1 | 28 | 60 | 37 | 640 | Mill off (#3) |
| 15 PM | 135 | 10.40 | -5 | 33 | 710 | 1510 | .6 | 680 | 110 | 9/16 | | 1900 | 7 | 13 | 15 | 9.5 | | 16 | 18 | 17 | .06 | 100 | 600 | 530 | 305 | 68 | 10.2 | 480 | 150 | .8 | 28 | 60 | 37 | 770 | |
| 30 PM | 135 | 10.40 | -5 | 33 | 710 | 1510 | 2.2 | 680 | 110 | 9/15 | | 1850 | 7 | 15.5 | 17 | 5 | | 15 1/2 | 16 1/2 | 15 | .07 | 90 | 590 | 530 | 305 | 68 | 10.2 | 355 | 140 | 1 | 28 | 60 | 37 | 590 | 135 TPH Feed to Kiln |
| 45 PM | 135 | 10.40 | -5 | 33 | 710 | 1510 | 1.3 | 680 | 110 | 9/15 | | 1800 | 5 | 12.2 | 13 | 6.5 | | 16 | 19 | 17 | .04 | 100 | 600 | 530 | 305 | 67 | 10.2 | 480 | 150 | 1 | 28 | 60 | 37 | 720 | |
| 1 PM | 135 | 10.40 | -5 | 32 1/2 | 710 | 1510 | .8 | 680 | 110 | 9/15 | | 1720 | 5 1/2 | 14.5 | 16.2 | 10 | | 17 | 18 | 17 | .01 | 86 | 550 | 540 | 305 | 68 | 10.2 | 470 | 150 | .8 | 27 | 60 | 37 | 730 | |
| 15 PM | 135 | 10.40 | -5 | 33 | 710 | 1510 | 2.3 | 680 | 110 | 9/12 | | 1750 | 5 | 13 | 14 | 4.9 | | 15 | 17 | 15 | .09 | 62 | 440 | 540 | 305 | 67 | 10.2 | 340 | 135 | .8 | 27 | 60 | 37 | 560 | |
| 30 PM | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Data used for calculations in Appendix E.

LEEDS KILN PROCESS DATA SHEET — Main Stack Test

DATE 2/19/84

| TIME | PREHEATER | | | | | | | | KILN | | | COOLER | | | | | | | | | | | | SPRAY TOWER | | | COAL MILL | | | | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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 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 | RPM | A | % | °F | SPM | "WC | "WC | "WC | CFM | CFM | CFM | CFM | "WC | % | °F | °F | °F | GPM | t/h | °F | °F | "WC | A | % | % | °F | |
| 9 AM | 135 | 1040 | -5 | 33 | 700 | 1500 | | 615 | 100 | 11/16 | 1 | 1375 | 5 | 13.8 | 14.6 | 7.5 | | 16 | 18 | 17 | .05 | 100 | 480 | 540 | 305 | 67 | 10.2 | 395 | 140 | .7 | 27 | 60 | 37 | 630 | Test #5 Mill off (#4) |
| 10 AM | 135 | 1040 | -5 | 33 | 700 | 1500 | | 615 | 103 | 11/16 | 1.1 | 1375 | 5 | 12.8 | 13 | 7.4 | | 16 | 16 | 16 | .06 | 90 | 440 | 540 | 305 | 65 | 10.2 | 380 | 140 | 1.1 | 27 | 60 | 37 | 670 | 134 TPH Feed to Kiln |
| 11 AM | 135 | 1040 | -5 | 32½ | 700 | 1500 | | 615 | 95 | 9/14 | 1.4 | 1350 | 5 | 12.2 | 12.8 | 9 | | 16 | 20 | 15 | .02 | 100 | 720 | 540 | 305 | 66 | 10.2 | 510 | 150 | .7 | 28 | 60 | 37 | 800 | |
| 12 PM | 132 | 1040 | -5 | 32½ | 700 | 1505 | | 615 | 90 | 11/16 | 1.6 | 1500 | 5 | 9.6 | 9.2 | 3.3 | | 15 | 16 | 15 | .08 | 70 | 420 | 540 | 300 | 68 | 10.2 | 370 | 140 | .9 | 27 | 60 | 37 | 590 | |
| 4 PM | 132 | 1040 | -5 | 32½ | 705 | 1505 | | 615 | 92 | 11/17 | 1.5 | 1610 | 5 | 12.2 | 13.5 | 6.6 | | 16 | 18 | 16 | .07 | 74 | 330 | 530 | 305 | 70 | 10.2 | 380 | 140 | .9 | 27 | 60 | 37 | 630 | |
| 5 PM | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

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 °F
$C_p$ = ~~1.10~~, $(\sqrt{\Delta p})_{avg}$ = 0.415
$P_s$ = 29.944 in. Hg, $M_s$ = 27.97 #/#-mole
$A_s$ = 68.417 sq. ft., $V_m$ = 27.944 cu. ft.
$H_2O$ (condensate) = 15
$H_2O$ (silica gel) = 12
$\Delta H_{avg}$ = 0.619 in. $H_2O$, $P_b$ = 29.96 in. Hg
Total particulate = 0.1892 grams

1. Calculate Stack gas velocity--

$$V_s = 85.49\, C_p\, (\sqrt{\Delta p})_{avg} \sqrt{\frac{T_s}{P_s M_s}}$$

$$V_s = 85.49\, (\cancel{1.10}\ 0.85)(0.415) \sqrt{\frac{787}{29.944(27.97)}}$$

$V_s$ = ~~37.83~~ 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)(27.944) $\left(\frac{29.96 + \frac{0.619}{13.6}}{563}\right)$ = ( ) (0.0528) = 26.04 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) (~~37.83~~ 29.23 Dm) (68.417) (528/ 737 ) (29.944/29.92) = ~~59.6154~~ 4606761 cu.ft./h

6. Calculate grain loading--

grains/sdcf = (15.43)(grams)/$V_{mstd}$ = (15.43)(0.1892)/(26.04) = 0.112

7. Calculate mass emission rate--

lbs/hr = (grains/stdcf)($Q_{stpd}$)(1.43 x $10^{-4}$)

lbs/hr = (~~59.6154~~ 4606761 Dm)(0.1121)(1.43 x $10^{-4}$) = ~~95.53~~ $\boxed{73.85\ \text{Dm}}$

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; $\bar{T}_m$ = 556 °R
$C_p$ = .85; $(\sqrt{\Delta p})_{avg}$ = .426
$P_s$ = 29.944 in. Hg; $M_s$ = 28.085 g/g-mole
$A_s$ = 68.417 sq. ft.; $V_m$ = 31.467 cu. ft.
$H_2O$ (condensate) = 10 ml
$H_2O$ (silica gel) = 13.5 gm
$\Delta H_{avg}$ = .785 in $H_2O$; $P_b$ = 29.96 in Hg
Total particulate = 0.1028 grams

1. Calculate Stack gas velocity--

$$V_s = 85.49\ C_p\ (\sqrt{\Delta p})_{avg}\sqrt{\frac{T_s}{P_s M_s}}$$

$$V_s = 85.49\ (.85)(.426)\sqrt{\frac{883}{(29.944)(28.085)}}$$

$V_s$ = 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) = 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) $\left(\frac{29.96 + \frac{.785}{13.6}}{556}\right)$ = (1)(.0540) = 29.920 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--

$$Q_{stpd} = 3600(1-B_{ws})V_s A_s \frac{528}{T_s} \frac{P_s}{29.92}$$

$Q_{stpd}$ = 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 $10^{-4}$) = $\boxed{38.92}$

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

1. Calculate Stack gas velocity--

$V_s = 85.49\ C_p\ (\sqrt{\Delta p})avg \sqrt{\frac{T_s}{P_s M_s}}$

$V_s = 85.49\ (\cancel{1.15}\ 1.45)(0.54)\sqrt{\frac{832}{29.944(28.09)}}$

$V_s =$ 50.50 fps
39.023

Sampling data
$T_s$ = 832 °R, $T_m$ = 555 °R
$C_p$ = ~~1.10~~ 1.45, $(\sqrt{\Delta p})_{avg}$ = 0.54
$P_s$ = 29.944 in Hg, $M_s$ = 28.09 g/g-mole
$A_s$ = 68.417 sq. ft., $V_m$ = 35.721 cu. ft.
$H_2O$ (condensate) = 15 ml
$H_2O$ (silica gel) = 12 gm
$\Delta H_{avg}$ = 1.034 in $H_2O$, $P_b$ = 29.96 in Hg
Total particulate = 0.1310 grams

2. Calculate volume of water vapor in gas sample--

$V_{wstd} = (0.0474)\left(\frac{\text{mls } H_2O \text{ condensate} + \text{grams } H_2O \text{ silica gel}}{}\right)$

$V_{wstd} = (0.0474)(15 + 12) = (0.0474)(27) = 1.28$ cu.ft.

3. Calculate gas sample volume at standard conditions--

$V_{mstd} = (17.64)(V_m)\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_m}\right)$

$V_{mstd} = (17.64)(35.721)\left(\frac{29.96 + \frac{1.034}{13.6}}{555}\right) = (\_\_\_)(0.0541) = 34.10$ 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--

$Q_{stpd} = 3600(1-B_{ws})V_s A_s \frac{528}{T_s} \frac{P_s}{29.92}$

$Q_{stpd} = 3600\ (1-.036)\left(\frac{52.5}{39.023}\right)(68.417)(528/832)(29.944/29.92) =$ ~~765418~~ 5,884,683 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)($Q_{stpd}$)($1.43 \times 10^{-4}$)

lbs/hr = $\left(\frac{\cancel{765418}}{5,884,683}\right)(0.059)(1.43 \times 10^{-4}) =$ ~~64.55~~ $\boxed{49.90}$

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

| TIME | PREHEATER | | | | | | | | | | | | | | KILN | | | | COOLER | | | | | | | | | | | | | SPRAY TOWER | | | COAL MILL | | | | | | | | | | PRECIP. | | REMARKS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | KILN FEED RATE | ID - 30 SPEED | ID - 30 AMPS | ID - 30 INLET TEMP. | DOWNCOMER SPRAY | ID - 30 DRAFT | STAGE 1 EXIT DRAFT | STAGE 3 EXIT DRAFT | STAGE 4 EXIT DRAFT | STAGE 1 GAS TEMP. | STAGE 3 GAS TEMP. | STAGE 4 GAS TEMP. | PREH. EXIT OXYGEN | ID - 24 SPEED | KILN SPEED | KILN AMPS | BURNING ZONE TEMP. | KILN EXIT OXYGEN | #1 GRATE SPEED | #2 GRATE SPEED | #1 UNDERGRATE PRESS. | #2 UNDERGRATE PRESS. | #4 UNDERGRATE PRESS. | #1 COOL. FAN AIRFLOW | #2 COOL. FAN AIRFLOW | #3 COOL. FAN AIRFLOW | #4 COOL. FAN AIRFLOW | SECONDARY AIR TEMP. | KILN HOOD DRAFT | VENT FAN DAMPER | FILTER DIFF. PRESSURE | FILTER INLET TEMP. | SPRAY TOWER INLET TEMP. | SPRAY TOWER OUTLET TEMP. | WATER SPRAY | COAL FEED | MILL DRIVE AMPS | MILL INLET TEMP. | MILL OUTLET TEMP. | MILL INLET DRAFT | MILL DIFF. PRESSURE | COAL CYCLONE DIFF. PRESS. | SYSTEM FAN DAMP. | PRIMARY AIR FAN DAMP. | PRIMARY AIR PRESSURE | DUST TRAP INLET TEMP. | KOPPERS OUTLET TEMP. | ID - 24 OXYGEN | CO, % | |
| | TPH | RPM | A | °F | GPM | "WC | "WC | "WC | "WC | °F | °F | °F | % | RPM | RPH | A | °F | % | SPM | SPM | "WC | "WC | "WC | CFM | CFM | CFM | CFM | °F | "WC | % | "WC | °F | °F | °F | GPM | TPH | A | °F | °F | "WC | "WC | "WC | % | % | "WC | °F | °F | % | | |
| 8:00 | 155 | 980 | 180 | 650 | — | -2 | 28 | 15 | 8½ | 710 | 710 | 190 | — | 1180 | 120 | 7/24 | — | 1.7 | 9 | 13 | 11½ | 14 | 12 | — | 15 | 14 | 14 | 1100 | .07 | 79 | 11½ | 600 | — | — | — | 12.1 | 27 | 550 | 190 | .8 | — | — | 62 | 44 | 41 | 500 | 160 | — | 4 | |
| 8:30 | 150 | 980 | 190 | 650 | — | -1½ | 27 | 13 | 8½ | 730 | 700 | 205 | — | 1182 | 120 | 7/17 | — | 2.2 | 5 | 11½ | 12½ | 14 | 5 | — | 16 | 16 | 14 | 1150 | .09 | 58 | 10 | 550 | — | — | — | 12.1 | 27 | 600 | 190 | .1 | — | — | 62 | 44 | 41 | 600 | 160 | — | 4 | |
| 9:00 | 155 | 980 | 175 | 650 | — | 2½ | 27½ | 14 | 9 | 730 | 700 | 205 | — | 1180 | 120 | 7/12 | — | 2.3 | 5 | 12½ | 13 | 14 | 2½ | — | 15 | 15 | 15 | 1100 | .06 | 42 | 8½ | 500 | — | — | — | 12.1 | 28 | 590 | 190 | .9 | — | — | 62 | 44 | 41 | 605 | 165 | — | 5 | |
| 9:30 | 155 | 980 | 180 | 650 | — | 2½ | 28 | 15 | 7½ | 730 | 700 | 205 | — | 1180 | 120 | 7/12 | — | 2.1 | 9 | 13 | 15 | 16½ | 8.6 | — | 16 | 17 | 16 | 1150 | .06 | 62 | 12 | 500 | — | — | — | 12.1 | 27 | 590 | 190 | .8 | — | — | 63 | 44 | 41 | 700 | 170 | — | 4 | |
| 10:00 | 155 | 980 | 180 | 650 | — | 2½ | 27½ | 15 | 9 | 730 | 700 | 205 | — | 1180 | 120 | 7/17 | — | 2.5 | 6 | 13 | 14 | 13 | 5½ | — | 16 | 16 | 17 | 1100 | .08 | 60 | 12 | 500 | — | — | — | 12.1 | 28 | 590 | 190 | .8 | — | — | 63 | 41 | 41 | 655 | 150 | — | 4 | |

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 | PREHEATER: KILN FEED RATE (TPH) | PREHEATER: ID-30 SPEED (RPM) | PREHEATER: ID-30 AMPS (A) | PREHEATER: ID-30 INLET TEMP. (°F) | PREHEATER: DOWNCOMER SPRAY (GPM) | PREHEATER: ID-30 DRAFT (WC) | PREHEATER: STAGE 1 EXIT DRAFT (WC) | PREHEATER: STAGE 3 EXIT DRAFT (WC) | PREHEATER: STAGE 4 EXIT DRAFT (WC) | PREHEATER: STAGE 1 GAS TEMP. (°F) | PREHEATER: STAGE 3 GAS TEMP. (°F) | PREHEATER: STAGE 4 GAS TEMP. (°F) | PREHEATER: PREH. EXIT OXYGEN (%) | PREHEATER: ID-24 SPEED (RPM) | KILN: KILN SPEED (RPH) | KILN: KILN AMPS (A) | KILN: BURNING ZONE TEMP. (°F) | KILN: KILN EXIT OXYGEN (%) | COOLER: #1 GRATE SPEED (SPM) | COOLER: #2 GRATE SPEED (SPM) | COOLER: #1 UNDERGRATE PRESS. (WC) | COOLER: #2 UNDERGRATE PRESS. (WC) | COOLER: #4 UNDERGRATE PRESS. (WC) | COOLER: #1 COOL-FAN AIRFLOW (CFM) | COOLER: #2 COOL-FAN AIRFLOW (CFM) | COOLER: #3 COOL-FAN AIRFLOW (CFM) | COOLER: #4 COOL-FAN AIRFLOW (CFM) | COOLER: SECONDARY AIR TEMP. (°F) | COOLER: KILN HOOD DRAFT (WC) | COOLER: VENT FAN DAMPER (%) | COOLER: FILTER DIFF. PRESSURE (WC) | COOLER: FILTER INLET TEMP. (°F) | SPRAY TOWER: SPRAY TOWER INLET TEMP. (°F) | SPRAY TOWER: SPRAY TOWER OUTLET TEMP. (°F) | SPRAY TOWER: WATER SPRAY (GPM) | COAL MILL: COAL FEED (TPH) | COAL MILL: MILL DRIVE AMPS (A) | COAL MILL: MILL INLET TEMP. (°F) | COAL MILL: MILL OUTLET TEMP. (°F) | COAL MILL: MILL INLET DRAFT (WC) | COAL MILL: MILL DIFF. PRESSURE (WC) | COAL MILL: COAL CYCLONE DIFF. PRESS. (WC) | COAL MILL: SYSTEM FAN DAMP. (%) | COAL MILL: PRIMARY AIR FAN DAMP. (%) | COAL MILL: PRIMARY AIR PRESSURE (WC) | COAL MILL: DUST TRAP INLET TEMP. (°F) | PRECIP.: KOPPERS OUTLET TEMP. (°F) | PRECIP.: ID-24 OXYGEN (%) | REMARKS: Opacity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10:10 | 160 | 980 | 180 | 650 | — | -2.2 | 28 | 15 | 9 | 720 | 1380 | 1520 | — | 980 | 110 | 11/17 | — | 1.5 | 8 | 12½ | 13.8 | 15 | 9.4 | — | 16 | 19 | 16 | 200 | .03 | 100 | 14 | 600 | — | — | — | 12.1 | 28 | 600 | 155 | 1 | — | — | 62 | 44 | 41 | 800 | 130 | — | 3 |
| 10:25 | 160 | 980 | 180 | 650 | — | -3 | 28½ | 13 | 8½ | 720 | 1380 | 1500 | — | 980 | 128 | 11/17 | — | 1.1 | 8 | 12½ | 14.3 | 15.6 | 8 | — | 15 | 17 | 16 | 200 | .05 | 100 | 14 | 580 | — | — | — | 12.1 | 30 | 450 | 150 | .8 | — | — | 63 | 44 | 41 | 800 | 130 | — | 4 |
| 10:40 | 160 | 980 | 180 | 650 | — | -2 | 28 | 16 | 9 | 720 | 1380 | 1520 | — | 980 | 128 | 11/17 | — | 1.9 | 7½ | 12½ | 14.3 | 15.6 | 7½ | — | 15 | 17 | 15 | 200 | .05 | 100 | 15 | 350 | — | — | — | 12.1 | 30 | 350 | 170 | 1 | — | — | 63 | 44 | 41 | 810 | 110 | — | 5 |
| 10:55 | 170 | 980 | 180 | 650 | — | -3 | 29 | 17 | 9.3 | 720 | 1380 | 1500 | — | 980 | 128 | 11/17 | — | 1.7 | 10 | 12½ | 16 | 18.2 | 9.8 | — | 14 | 16 | 16 | 200 | .07 | 94 | 14½ | 350 | — | — | — | 12.1 | 29 | 500 | 160 | .7 | — | — | 63 | 44 | 41 | 830 | 110 | — | 4 |
| 11:10 | 160 | 980 | 180 | 650 | — | -3 | 29 | 17 | 10 | 720 | 1380 | 1500 | — | 980 | 128 | 12/17 | — | 1.7 | 6 | 12½ | 16 | 18.2 | 9.8 | — | 14 | 16 | 16 | 200 | .07 | 100 | 13 | 320 | — | — | — | 12.1 | 29 | 450 | 150 | .1 | — | — | 63 | 44 | 41 | | | | 4 |
| 11:25 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Avg. Kiln Feed = 163 TPH

Data used for calculations in Appendix F.

~~Main~~ Cooler Stack Test

# LEEDS KILN PROCESS DATA SHEET

Test # 10

DATE 2/21/84

| TIME | PREHEATER | | | | | | | | | | | | | | KILN | | | | COOLER | | | | | | | | | | | | | | SPRAY TOWER | | | COAL MILL | | | | | | | | | | | PRECIP. | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | KILN FEED RATE | ID – 30 SPEED | ID – 30 AMPS | ID – 30 INLET TEMP. | DOWNCOMER SPRAY | ID – 30 DRAFT | STAGE 1 EXIT DRAFT | STAGE 3 EXIT DRAFT | STAGE 4 EXIT DRAFT | STAGE 1 GAS TEMP. | STAGE 3 GAS TEMP. | STAGE 4 GAS TEMP. | PREH. EXIT OXYGEN | ID – 24 SPEED | KILN SPEED | KILN AMPS | BURNING ZONE TEMP. | KILN EXIT OXYGEN | # 1 GRATE SPEED | # 2 GRATE SPEED | # 1 UNDERGRATE PRESS. | # 2 UNDERGRATE PRESS. | # 4 UNDERGRATE PRESS. | # 1 COOL - FAN AIRFLOW | # 2 COOL - FAN AIRFLOW | # 3 COOL - FAN AIRFLOW | # 4 COOL - FAN AIRFLOW | SECONDARY AIR TEMP. | KILN HOOD DRAFT | VENT FAN DAMPER | FILTER DIFF. PRESSURE | FILTER INLET TEMP. | SPRAY TOWER INLET TEMP. | SPRAY TOWER OUTLET TEMP. | WATER SPRAY | COAL FEED | MILL DRIVE AMPS | MILL INLET TEMP. | MILL OUTLET TEMP. | MILL INLET DRAFT | MILL DIFF. PRESSURE | COAL CYCLONE DIFF. PRESS. | SYSTEM FAN DAMP. | PRIMARY AIR FAN DAMP. | PRIMARY AIR PRESSURE | DUST TRAP INLET TEMP. | KOPPERS OUTLET TEMP. | ID – 24 OXYGEN | Opacity |
| | TPH | RPM | A | °F | GPM | "WC | "WC | "WC | "WC | °F | °F | °F | % | RPM | RPH | A | °F | % | SPM | SPM | "WC | "WC | "WC | CFM | CFM | CFM | CFM | °F | "WC | % | "WC | °F | °F | °F | GPM | TPH | A | °F | °F | "WC | "WC | "WC | % | % | "WC | °F | °F | % | |
| 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12:00 | 155 | 980 | 180 | 640 | — | -3 | 27 | 15 | 10 | 720 | 1360 | 1500 | — | 1980 | 120 | 11/17 | — | 3½ | 5 | 15 | 13.6 | 11.5 | 6 | — | 15 | 17 | 15 | 1500 | .05 | 100 | 13 | 420 | — | — | — | 11.1 | 27 | 370 | 140 | 1 | — | — | 62 | 44 | 41 | 900 | 110 | — | 4 | |
| 12:30 | 155 | 180 | 160 | 640 | — | -2 | 28 | 14 | 10 | 720 | 1360 | 1500 | — | 1980 | 120 | 11/14 | — | 2.2 | 5 | 13½ | 14 | 16 | 5.4 | — | 15 | 13 | 13 | 1950 | 1.1 | [illegible] | 14 | 300 | — | — | — | 11.9 | 27 | 380 | 140 | 1 | — | — | 62 | 44 | 41 | 800 | 110 | — | 5 | |
| 13:00 | 156 | 980 | 175 | 650 | — | -2 | 27½ | 14 | 9 | 720 | 1360 | 1500 | — | 1980 | 120 | 9/14 | — | 2½ | 9 | 13 | 12.1 | 14.6 | 13 | — | 14½ | 17 | 13 | 1500 | .04 | 100 | 16 | 700 | — | — | — | 11.9 | 27 | 525 | 145 | .8 | — | — | 62 | 44 | 40 | 800 | 110 | — | 5 | |
| 13:30 | 155 | 980 | 180 | 640 | — | -2½ | 27½ | 15 | 9.3 | 720 | 1380 | 1500 | — | 1980 | 125 | 14/10 | — | 3.4 | 5½ | 15 | 13.2 | 12.4 | 7.8 | — | 15 | 16 | 13 | 1800 | .05 | 100 | 15 | 520 | — | — | — | 11.7 | 26 | 400 | 145 | .9 | — | — | 62 | 44 | 41 | 780 | 115 | — | 5 | |
| 15:00 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

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 Emissions Gr/DSCF* | 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. 16006 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 |

KVB71-71500-2007 D304

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 | 4.82 | 4.820(-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 | 4.63 | 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 | | | |
| | gr/scf | @ 12% $CO_2$ | $ppm_v$ | | gr/scf | @ 12% $CO_2$ | $ppm_v$ | @ 3% $O_2$ | | | Inlet | Outlet |
| Particulate | | | | | 0.0034<br>0.0019<br>0.0034<br>0.0029 | | | | 5.88<br>3.25<br>5.86<br>5.00 | | | 0.03<br>0.02<br>0.03<br>0.02 |
| Sulfate | | | | | 0.0005<br>0.0003<br>0.0005<br>0.0004 | | | | 0.86<br>0.45<br>0.86<br>0.72 | | | |
| $SO_2$ | | | | | | | 15.64<br>16.83<br>16.90<br>16.40 | | 32.47<br>34.75<br>34.57<br>33.93 | | | |
| $NO_x$ as $NO_2$ (dry) | | | | | | | 387.50<br>395.33<br>394.33<br>892.39 | 633.45<br>649.21<br>633.05<br>638.57 | 532.11<br>540.35<br>533.36<br>535.27 | | | |
| HC ($C_1$,>$C_1$) | | | | | | | 2.75/18.70<br>1.74/17.41<br>2.26/15.06<br>2.25/17.06 | | 1.31/8.93<br>0.83/8.28<br>1.06/7.08<br>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 | | | |
| | gr/scf | @ 12% $CO_2$ | $ppm_v$ | | gr/scf | @ 12% $CO_2$ | $ppm_v$ | @ 3% $O_2$ | | | Inlet | Outlet |
| Particulate | | | | | 0.0024<br>0.0023<br>0.0024<br>0.0024 | | | | 2.66<br>2.62<br>2.71<br>2.66 | | | 0.0200<br>0.0200<br>0.0198<br>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 $H_2SO_4$) | 88.94 | 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.

| | Run #1 | Run #2 | Run #3 |
|---|---|---|---|
| DAY - FRIDAY - AUGUST 30, 1985 | | | |
| TIME | 8:45AM 10:03AM | 10:49AM 12:07PM | 12:50PM 2:15PM |
| TYPE OF FUEL | COAL | COAL | COAL |
| FUEL FEED RATE (TPH) | 15.2 | 15.15 | 15.0 |
| SULFUR CONTENT OF FUEL | 1.82 | 1.77 | 1.76 |
| KILN FEED RATE (TPH) | 133 | 133 | 133 |
| SULFUR CONTENT OF KILN FEED $SO_3$ | 0.14 | 0.15 | 0.18 |
| OXYGEN CONTENT OF FLUE GASES | 1.9 | 1.9 | 1.9 |
| CLINKER PRODUCTION RATE (TPH) | 86.7 | 86.7 | 86.7 |

Data used for calculations in Appendix E.

# APPENDIX B

## UNCONTROLLED TOTAL PARTICULATE EMISSION FACTOR CALCULATIONS

MIDWEST RESEARCH INSTITUTE

MRI-18

PROJECT DEVELOPMENT SKETCH

TITLE Emission Factor Calculations for Uncontrolled Sources (Refs. 21, 24, 26A/B, and 40)

PROJECT NO. 4892-L74/8481-L9 DRAWN JSK Orig. ~~APPR.~~ 6/8/83 Add. DATE 6/16/86

• Reference 21 - Rexnord Gravel Bed Filter Study

From p. 7, of Report EPA-600/2-76-164 - Uncontrolled

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) | 93.68(206.54) | 100.37(221.27) | 152.84(336.96) | 139.68(307.94) |

From p. 39, Appendix B, of Report EPA-600/2-76-164

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

Per Tele. Con. w/ Joe McCain @ SoRI - delete Run 1 since one of the kilns went down sometime during the day

Calculate Total Mass Emission Factor for each Run:

For Run #2: 8/26/75

$$93.68 \frac{kg}{hr.} \times \frac{1 \text{ day}}{533 \text{ tons cement}} \times 24 \frac{hrs}{day} \times \frac{1.102 \text{ tons}}{Mg} = 4.648 \text{ kg/Mg}$$

For Run #3: 8/26/75

$$100.37 \frac{kg}{hr.} \times \frac{1 \text{ day}}{533 \text{ tons cement}} \times 24 \frac{hrs}{day} \times \frac{1.102 \text{ tons}}{Mg} = 4.980 \text{ kg/Mg}$$

For Run #4: 8/27/75

$$152.84 \frac{kg}{hr.} \times \frac{1 \text{ day}}{961 \text{ tons cement}} \times 24 \frac{hrs}{day} \times \frac{1.102 \text{ tons}}{Mg} = 4.206 \text{ kg/Mg}$$

For Run #5: 8/27/75

$$139.68 \frac{kg}{hr.} \times \frac{1 \text{ day}}{961 \text{ tons cement}} \times 24 \frac{hrs}{day} \times \frac{1.102 \text{ tons}}{Mg} = 3.844 \text{ kg/Mg}$$

$$\overline{EF_u} = \frac{4.648 + 4.980 + 4.206 + 3.844}{4 \text{ tests}} = 4.42 \text{ kg/Mg}$$

From p. 8 of Report EPA-600/2-76-164 — Controlled

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) |

For Run #2: 8/26/75

$$2.91 \frac{kg}{hr.} \times \frac{1 \text{ day}}{533 \text{ tons cement}} \times 24 \frac{hrs}{day} \times \frac{1.102 \text{ tons}}{Mg} = 0.144 \text{ kg/Mg}$$

For Run #3: 8/26/75

$$4.89 \frac{kg}{hr.} \times \frac{1 \text{ day}}{533 \text{ tons cement}} \times 24 \frac{hrs}{day} \times \frac{1.102 \text{ tons}}{Mg} = 0.243 \text{ kg/Mg}$$

For Run #4: 8/27/75

$$3.87 \frac{kg}{hr.} \times \frac{1 \text{ day}}{961 \text{ tons cement}} \times 24 \frac{hrs}{day} \times \frac{1.102 \text{ tons}}{Mg} = 0.107 \text{ kg/Mg}$$

For Run #5: 8/27/75

$$2.74 \frac{kg}{hr.} \times \frac{1 \text{ day}}{961 \text{ tons cement}} \times 24 \frac{hrs}{day} \times \frac{1.102 \text{ tons}}{Mg} = 0.075 \text{ kg/Mg}$$

$$\overline{EF_c} = \frac{0.144 + 0.243 + 0.107 + 0.075}{4 \text{ tests}} = 0.142 \text{ kg/Mg}$$

Table A-1

Inlet Mass Loading By Size Interval From Andersen Impactor Data

Mass Loading In Indicated Size Interval, mg/DNM[1]

| 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 c |
| 8/27 | 1620 | 20 | | | 341[1] | 20.9 | 13.8 | 3.59 | 1.00 | 4.99 | dominated |
| 8/27 | 1730 | 20 | | | 313[1] | 14.5 | 11.4 | 2.43 | 1.42 | 2.23 | particles |
| 8/27 | 1800 | 20 | | | 581[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 |
| 8/28 | 1105 | 120 | | | 4252 | 11.1 | 7.82 | 2.66 | 0.52 | 3.84 | to avoid |
| 8/28 | 1440 | 120 | | | 2098 | 9.3 | 6.44 | 3.26 | 2.64 | 13.5 | stages. |
| 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 |
| | | | | | 3569 | 20.69 | 13.85 | 3.55 | 1.90 | 9.70 | 90% Uppe |
| | | | | | 2223 | 11.74 | 7.69 | 2.25 | 0.84 | 3.09 | 90% Lowe |
| 11/4 | 1100 | 65 | | | 2474 | 18.8 | 9.5 | 2.4 | 0.12 | 1.54 | [2]Nozzle |
| 11/4 | 1130 | 60 | | | 661[2] | 19.3 | 12.2 | 0.51 | 1.03 | 4.60 | directio |
| 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 |
| | | | | | 3650 | 18.31 | 11.72 | 3.23 | 2.41 | 1.05 | 90% Uppe |
| | | | | | 2031 | 13.27 | 8.61 | 1.50 | 0.19 | 8.14 | 90% Lowe |
| | | | Dia., µm | ρ=2.7 | >2.8 | 1.8-2.8 | 0.83-1.8 | .48-0.83 | .34-0.48 | <0.34 | |

Table A-2

Outlet Mass Loadings By Size Interval For August Test Series

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

| 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 | 1.10 |
| 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 | 1.34 | 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 |

Table A-3

Outlet Mass Loadings By Size Interval For November Test Series

Mass Loading* In Indicated Size Interval, mg/DNM[1]

| 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[5] | 9.45[5] | 2.56 | 0.96 | 1.15 |
| 11/3 | 1545 | 120 | 1.35 | NA | | 18.4[1] | 0.71 | 0.64 | 0.61 | 1.08 | 3.80 | 2.21 | 0.66 | 0.63 |
| 11/4 | 1130 | 240 | 1.39 | 9.6 | | 0.23 | 0.13 | 0.19 | 0.18 | 0.64 | 2.63 | 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 | 0.68 | 0.38 |
| 11/5 | 0945 | 240 | 1.32 | 14.0 | | 0.99 | 0.49 | 0.51 | 0.61 | 1.16 | 3.78 | 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 | 1.18 | 1.18** |
| | | | | | | 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 95% Confidence Level.

****Lower 90% Confidence Level.

[1]Nozzle scrapped port on entry

[5]Omitted from average

Table A-4

Inlet Mass Loading By Size Interval From Brink Impactor Data

Mass Loading In Indicated Size Interval, mg/DNM³

| 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



7

• Reference 24 - Greencastle Stack Emissions Survey

(1) Coal-fired, wet process kiln

From Table II, page 5 of test report:

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 | | Dust Load: 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 | 34 | 99.6 |
| Elevated Insufflation Rate: | | | | | | | |
| 15, 16 | 12 | 231,800 | 214,900 | 5.10 | .007 | 14 | 99.8 |
| 17, 18 | 12 | 224,100 | 215,100 | 4.99 | .021 | 42 | 99.6 |
| 19, 20 | 12 | 228,100 | 216,400 | 5.72 | .025 | 50 | 99.5 |
| Ave. | | | | 5.27 | .018 | 36 | 99.6 |
| Average for all 6 tests | | | | 5.15 | | | |

From Table III, page 6 of report

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 |
|---|---|---|---|---|---|---|---|
| 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 |

$$\therefore 5.15 \frac{\text{tons part.}}{\text{hr.}} \times \frac{1 \text{ hr.}}{75.7 \text{ ton clinker}} \times 908 \frac{\text{kg}}{\text{ton}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} = 68.1 \frac{\text{kg part.}}{\text{Mg clinker}}$$

$$68.1 \frac{\text{kg part.}}{\text{Mg clinker}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}} = 64.9 \frac{\text{kg part.}}{\text{Mg cement}}$$

(Assumes 5% gypsum added)

- Reference 26A/B - KVB Combustion Modification Study

Test No. 3: Dry Process Kiln
Coke / Natural Gas - Fired (66/33%)
Measurements taken downstream of multiclone

Method 5 Data - taken during second test period (per Table 4-1
of EPA-600/7-79-015a)

- From p. 48 of EPA-600/7-79-015b:

$$9.746 \frac{\text{gr}}{\text{dscf}} \times \frac{1 \text{ lb}}{7000 \text{ gr.}} \times 164228 \frac{\text{dscf}}{\text{min}} \times 60 \frac{\text{min}}{\text{hr.}} = 13719.14 \frac{\text{lb}}{\text{h}}$$

to baghouse

- From p. 43 of EPA-600/7-79-015b:

$$\text{Clinker production rate} = 53 \frac{\text{short tons}}{\text{hr.}} \times \frac{1 \text{ Mg}}{1.102 \text{ tons}} = 48 \frac{\text{Mg}}{\text{hr.}}$$

If ~ 5% (weight) gypsum added: $48 \frac{\text{Mg}}{\text{hr.}} \times 1.05 = 50 \frac{\text{Mg cem}}{\text{hr.}}$

$$\therefore 13719.14 \frac{\text{lbs}}{\text{hr.}} \times 0.454 \frac{\text{kg}}{\text{lb}} \times \frac{1 \text{ hr.}}{50 \text{ Mg}} = 124.57 \frac{\text{kg}}{\text{Mg}}$$ Total Mass Emissions

Particle Size Analysis - Test Run #3

- From p. 50-53 of EPA-600/7-79-015b: Brink Impactor

| | | | |
|---|---|---|---|
| Cyclone = | 0.4328 gm = | > 4.250 μmA | Dp |
| Stage 1 = | 0.1200 gm = | 4.25 μmA | Dp |
| " 2 = | 0.0502 gm = | 2.485 μmA | Dp |
| " 3 = | 0.0109 gm = | 1.679 μmA | Dp |
| " 4 = | 0.0064 gm = | 0.851 μmA | Dp |
| " 5 = | 0.0033 gm = | 0.505 μmA | Dp |
| Filter = | 0.0028 gm = | ≤ 170.3 μmA | Dp |

Particle Size Analysis: Test Run No. 3 (cont'd)

Total Catch = 0.4328 + 0.12 + 0.0502 + 0.0109 + 0.0064 + 0.0033 + 0.0028

= 0.6264 gm

| | % on Stage | Cumulative % < Size |
|---|---|---|
| ∴ > 4.25 μm = $\frac{0.4328}{0.6264} \times 100 =$ | 69.1% | 100% |
| 4.25 μm = $\frac{0.1200}{0.6264} \times 100 =$ | 19.2 | 30.9 % |
| 2.485 μm = $\frac{0.0502}{0.6264} \times 100 =$ | 8.01% | 11.7 % |
| 1.679 μm = $\frac{0.0109}{0.6264} \times 100 =$ | 1.74% | 3.73% |
| 0.851 μm = $\frac{0.0064}{0.6264} \times 100 =$ | 1.02% | 1.99% |
| 0.505 μm = $\frac{0.0033}{0.6264} \times 100 =$ | 0.527% | 0.974% |
| > 0.30 μm = $\frac{0.0028}{0.6264} \times 100 =$ | 0.447% | 0.447% |

Basically the same as that shown on p. 53 of EPA-600/7-79-0156. ∴ Use KVB data!

Test No. 9 : Wet Process Kiln w/ ESP (30% $H_2O$ Content)
Natural Gas-Fired
Measurements taken @ kiln outlet

Baseline Test #9-1 – Method 5 Data

- From p. 423 of EPA-600/7-79-0156:

$$12.941 \frac{gr}{dscf} \times 20918 \frac{dscf}{min} \times 2 \text{ ducts} \times 60 \frac{min}{hr.} \times \frac{1 \text{ lb.}}{7000 gr.} = 4640.6 \frac{lbs}{hr.} \text{ to ESP}$$

- From Table 4-20, p. 84 of EPA-600/7-79-015a:

$$9.4 \frac{kg \text{ clinker}}{sec.} \times 3600 \frac{sec.}{hr.} \times \frac{1 \text{ Mg}}{10^3 kg} = 34 \frac{Mg \text{ clinker}}{hr}$$

If 5% (weight) gypsum added: $34 \frac{Mg}{hr.} \times 1.05 = 36 \frac{Mg \text{ cement}}{hr.}$

$$\therefore \quad 4640.6 \frac{lbs}{hr.} \times 0.454 \frac{kg}{lb} \times \frac{1 \text{ hr.}}{36 \text{ Mg}} = 58.5 \frac{kg}{Mg} \text{ Total Mass Emissions}$$

Particle Size Analysis: Brink data (from p. 433 & 436 of EPA-600/7-79-0156)

| | | | | | | |
|---|---|---|---|---|---|---|
| Cyclone = | 0.2850 gm | = > 2.81 μmA | = | 49.7% | of total catch |
| Stage 1 = | 0.2035 gm | = 2.81 μmA | = | 35.5% | " " " |
| " 2 = | 0.0471 gm | = 1.66 μmA | = | 8.21% | " " " |
| " 3 = | 0.0191 gm | = 1.13 μmA | = | 3.33% | " " " |
| " 4 = | 0.0103 gm | = 0.59 μmA | = | 1.80% | " " " |
| " 5 = | 0.0087 gm | = 0.37 μmA | = | 1.52% | " " " |
| Filter = | N.I | | | | |

Total = 0.5737 gm

Kiln under upset condition during Brink run!

Low- $NO_x$ Test # 9-2: Method 5 Data

- From p. 426 of EPA-600/7-79-015b:

$$11.86 \frac{gr}{dscf} \times 238646 \frac{dscf}{min.} \times 2 \text{ ducts} \times 60 \frac{min}{hr.} \times \frac{1 \text{ lb}}{7000 gr.} = 4852 \frac{lbs}{hr.}$$

to ESP

- From Table 4-20, p. 84 of EPA-600/7-79-015a:

$$9.4 \frac{kg \text{ clinker}}{sec.} = 36 \frac{Mg \text{ cement}}{hr.} \text{ (as in Test 9-1 above)}$$

$$\therefore 4852.0 \frac{lbs}{hr.} \times 0.454 \frac{kg}{lb.} \times \frac{1 \text{ hr.}}{36 \text{ Mg}} = 61.19 \frac{kg}{Mg} \text{ Total Mass Emissions}$$

Particle Size Analysis: Brink data (from p. 438 & 441 of EPA-600/7-79-015b)

| | | | | | | |
|---|---|---|---|---|---|---|
| Cyclone | = 0.0658 gm | = | > 2.81 μmA | = | 47.3% | of total |
| Stage 1 | = 0.0416 gm | = | 2.81 μmA | = | 29.9% | " " |
| " 2 | = 0.0161 gm | = | 1.66 μmA | = | 11.6% | " " |
| " 3 | = 0.0082 gm | = | 1.13 μmA | = | 5.89% | " " |
| " 4 | = 0.0043 gm | = | 0.60 μmA | = | 3.09% | " " |
| " 5 | = 0.0025 gm | = | 0.38 μmA | = | 1.80% | " " |
| Filter | = 0.0007 gm | = | >0.3 μmA | = | 0.50% | " " |
| Total | = 0.1392 gm | | | | | |

Use cumulative % ≤ stated size shown on p. 436 and 441 for Runs 9-1 and 9-2 respectively!

SASS Train Data:

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From Table 4-21, page 92 of EPA-600/7-79-015a:
Calculate Total Mass Emission Factors from SASS Train Data

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

| [illegible] & G 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, % | 34.11 | 44.74 | 37.55 | 38.21 |
| Sample Time, min. | 75 | 75 | 300 | 300 |
| Cyclone Flow, acmm (acfm) | 0.102 (3.591) | 0.097 (3.425) | 0.087 (3.067) | 0.087 (3.076) |
| Isokinetic Ratio, % | 96.8 | 118.3 | 103.5 | 104.5 |
| 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) | 111 (00) | 119 (115) | 109 (97) | 110 (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 (1.3611) | 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/MCF) | 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] 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 $10^6$g ($10^3$lb) | 2.131 (4.688) | 2.131 (4.688) | 9.375 (20.63) | 9.375 (20.63) |

- For Test 9-3 @ ESP Inlet – SASS Train Total Mass (Clink

$$21.7 \frac{gm}{DNM^3} \times 20.1 \frac{DNM^3}{sec} \times \frac{4500 \text{ sec.}}{45.75 \text{ Mg clinker}} \times \frac{1 \text{ kg}}{10^3 \text{ gm}} = 42.9 \frac{\text{kg part.}}{\text{Mg clinker}}$$

- For Test 9-4 @ ESP Inlet – SASS Train Total Mass (Clinke

$$18.88 \frac{gm}{DNM^3} \times 19.0 \frac{DNM^3}{sec} \times \frac{4500 \text{ sec.}}{42.18 \text{ Mg clinker}} \times \frac{1 \text{ kg}}{10^3 \text{ gm}} = 38.27 \frac{\text{kg part.}}{\text{Mg clinke}}$$

- For Test 9-5 @ ESP Outlet - SASS Train Total Mass

$$0.0581 \frac{gm}{DNM^3} \times 21.1 \frac{DNM^3}{sec.} \times \frac{19008 \text{ sec.}}{175.0 \text{ Mg clinker}} \times \frac{1 \text{ kg}}{10^3 \text{ gm}} = 0.133 \frac{\text{kg part.}}{\text{Mg clinker}}$$

- For Test 9-6 @ ESP Outlet - SASS Train Total Mass

$$0.0766 \frac{gm}{DNM^3} \times 21.7 \frac{DNM^3}{sec.} \times \frac{18792 \text{ sec}}{199.4 \text{ Mg clinker}} \times \frac{1 \text{ kg}}{10^3 \text{ gm}} = 0.157 \frac{\text{kg part.}}{\text{Mg clinker}}$$

---

- For Test 9-3 @ ESP Inlet - SASS Train Total Mass (Cement) (assuming 5% (weight) gypsum added)

$$42.9 \frac{\text{kg part.}}{\text{Mg clinker}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}} = 40.86 \frac{\text{kg part.}}{\text{Mg cement}}$$

- For Test 9-4 @ ESP Inlet - SASS Train Total Mass (Cement)

$$38.27 \frac{\text{kg part.}}{\text{Mg clinker}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}} = 36.45 \frac{\text{kg part.}}{\text{Mg cement}}$$

- For Test 9-5 @ ESP Outlet - SASS Train Total Mass (Cement)

$$0.133 \frac{\text{kg part.}}{\text{Mg clinker}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}} = 0.127 \frac{\text{kg part.}}{\text{Mg cement}}$$

- For Test 9-6 @ ESP Outlet - SASS Train Total Mass (Cement)

$$0.157 \frac{\text{kg part.}}{\text{Mg clinker}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}} = 0.150 \frac{\text{kg part.}}{\text{Mg cement}}$$

Particle Size Distributions from SASS Data:

- For Test 9-3: From Table F-2, page 452 of EPA-600/7-79-015a

| | | |
|---|---|---|
| 10 μm Cyclone, Probe, & Nozzle | = | 20.2857 gm |
| 3 μm Cyclone | = | 23.5244 gm |
| 1 μm Cyclone | = | 15.6894 gm |
| Backup Filter | = | 4.2785 gm |
| Total Catch | | 63.7780 gm |

$\therefore$ $> 10\,\mu m = \frac{20.2857}{63.7780} \times 100 = 31.807\%$ of total catch

$< 10-3\,\mu m = \frac{23.5244}{63.7780} \times 100 = 36.885\%$ of total catch

$< 3-1\,\mu m = \frac{15.6894}{63.7780} \times 100 = 24.600\%$ of total catch

$< 1-0.3\,\mu m = \frac{4.2785}{63.7780} \times 100 = 6.708\%$ of total catch

- For Test 9-4: From Table F-8, page 458 of EPA-600/7-79-015c

10 μm Cyclone, Probe, & Nozzle = 17.6210 gm
3 μm Cyclone = 19.4157 gm
1 μm Cyclone = 12.6696 gm
Backup Filter = 4.4659 gm
Total Catch = 54.1722 gm

$\therefore$ $> 10\,\mu m = \frac{17.6210}{54.1722} \times 100 = 32.528\%$ of total catch

$< 10-3\,\mu m = \frac{19.4157}{54.1722} \times 100 = 35.841\%$ of total catch

$< 3-1\,\mu m = \frac{12.6696}{54.1722} \times 100 = 23.388\%$ of total catch

$< 1-0.3\,\mu m = \frac{4.4659}{54.1722} \times 100 = 8.244\%$ of total catch

- For Test 9-5: From data sheet, page 469 of EPA-600/7-79-0

10 μm Cyclone, Probe, and Nozzle = 0.0214 gm
3 μm Cyclone = -0-
1 μm Cyclone = 0.4049 gm
Backup Filter = 0.1859 gm
Total Catch = 0.6122 gm

$\therefore$ $>10\,\mu m = \frac{0.0214}{0.6122} \times 100 = 3.50\%$ of total catch

$<10-3\,\mu m = -0- = 0\%$ of total catch

$<3-1\,\mu m = \frac{0.4049}{0.6122} \times 100 = 66.14\%$ of total catch

$<1-0.3\,\mu m = \frac{0.1859}{0.6122} \times 100 = 30.37\%$ of total catch

- For Test 9-6: From Table F-14, page 464 of EPA-600/7-79-01

| | |
|---|---|
| 10 μm Cyclone, Probe, and Nozzle | = 0.0122 gm |
| 3 μm Cyclone | = No Sample |
| 1 μm Cyclone | = 0.5775 gm |
| Backup Filter | = 0.2042 gm |
| Total Catch | = 0.7939 gm |

$\therefore$ $>10\,\mu m = \frac{0.0122}{0.7939} \times 100 = 1.54\%$ of total catch

$<10-3\,\mu m = -0- = N/A$ of total catch

$<3-1\,\mu m = \frac{0.5775}{0.7939} \times 100 = 72.74\%$ of total catch

$<1-0.3\,\mu m = \frac{0.2042}{0.7939} \times 100 = 25.72\%$ of total catch

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- Reference 40 – Bonner Springs Stack Survey
Coal-fired wet process kiln – ASTM PTC-27
From Table T-1-A, page 16 of test report:

TABLE T-1-A

BONNER SPRINGS STACK EMISSION SURVEY

ELECTROSTATIC PRECIPITATOR EFFICIENCY DATA 1981

No. 4 KILN SYSTEM

| Run Nos. | Date | Precipitator Input Lbs/Hr. | Stack Lbs/Hr. | Precipitator Efficiency Input - Output / Input |
|---|---|---|---|---|
| 67,68 | 10-8 | 2613 | 32.2 | 98.7 |
| 73,74 | 10-9 | 2391 | 12.5 | 99.5 |
| 77,78 | 10-22 | 1864 | 5.5 | 99.7 |
| 83,84 | 10-23 | 1940 | 5.8 | 99.7 |
| AVERAGE | | 2202 | 14.0 | 99.4 |

From Table T-4, page 20 of test report:

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 |

Average clinker prod = 16.8 TPH

$$\therefore 2202 \frac{\text{lbs part}}{\text{hr.}} \times \frac{1 \text{ hr.}}{16.8 \text{ tons clinker}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}} = 62.42 \frac{\text{kg}}{\text{Mg cement}}$$

# APPENDIX C

## TOTAL PARTICULATE EMISSION FACTOR CALCULATIONS FOR CONTROLLED KILNS

MIDWEST RESEARCH INSTITUTE

MRI-18

PROJECT DEVELOPMENT SKETCH

TITLE Emission Factor Calculations for Controlled Cement Kilns

PROJECT NO. 4892-L74/8431-L9 DRAWN JSK Orig. ~~APPR.~~ 8/22/83 Add. DATE 6/17/86

- Report No. 71-MM-01: Wet Process Plant (Reference 10).

  Gas-fired kiln equipped w/ electrostatic precipitator

  From Table II, page 7 of test report:

  Run #1 = 0.634 lbs/short ton feed
  Run #2 = 1.019 " " " "
  Run #3 = 1.799 "

  Average = 1.151 lbs/short ton feed

  $$1.151 \frac{\text{lbs. part.}}{\text{short ton}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.576 \frac{\text{kg part.}}{\text{Mg feed}}$$

  Assuming: 2.45 Mg slurry / Mg cement (from EPA-600/2-77-023u, p. 20)

  $$0.576 \frac{\text{kg part.}}{\text{Mg slurry}} \times 2.45 \frac{\text{Mg slurry}}{\text{Mg cement}} = 1.41 \frac{\text{kg part.}}{\text{Mg cement}}$$

- Report No. 71-MM-03: Wet Process Plant (Reference 11)

  Gas-fired kiln equipped w/ electrostatic precipitator

  From Table 2, page viii of test report

  Run #1 = 0.844 lbs/short ton feed
  Run #2 = 0.924 lbs/short ton feed

  Average = 0.884 lbs/short ton feed

$$0.884 \frac{\text{lbs. part.}}{\text{short ton}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.442 \frac{\text{kg part.}}{\text{Mg feed}}$$

$$0.442 \frac{\text{kg part.}}{\text{Mg feed}} \times 2.45 \frac{\text{Mg slurry}}{\text{Mg cement}} = 1.08 \frac{\text{kg part.}}{\text{Mg cement}}$$

- Report 71-MM-05: Dry Process Plant (Reference 13)

  (2) Coal-fired kilns equipped w/ multiclones + bhouses

  From Table 1, p. vii of test report:

  Run #1 = 0.0942 lbs/short ton feed
  Run #2 = 0.0553 " " " "
  Run #3 = 0.0606 " " " "

  Average = 0.0700 " " " "

  $$0.07 \frac{\text{lbs. part.}}{\text{short ton}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.035 \frac{\text{kg part}}{\text{Mg feed}}$$

  Assuming: 1.7 Mg raw meal / Mg cement (from EPA-600/2-77-023u p. 20)

  $$0.035 \frac{\text{kg part.}}{\text{Mg feed}} \times 1.7 \frac{\text{Mg feed}}{\text{Mg cement}} = 0.0595 \checkmark \frac{\text{kg part.}}{\text{Mg feed}}$$

- Report 71-MM-07: Wet Process Plant (Reference 15)

  No. 4 Kiln – Gas & Oil-Fired – equipped w/ bhouse

  From Table I, page 5 of test report: 6 stacks tested

  Combined Nat. Gas = 0.536 lbs/short ton feed

  " No. 6 Oil = 0.513 lbs/short ton feed

Nat. Gas = $0.536 \frac{\text{lbs part.}}{\text{short ton}} \times 1.102 \frac{\text{short tons}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.268 \frac{\text{kg}}{\text{Mg}}$

$0.268 \frac{\text{kg part.}}{\text{Mg feed}} \times 2.45 \frac{\text{Mg feed}}{\text{Mg cement}} = 0.657 \frac{\text{kg part.}}{\text{Mg cement}}$

No. 6 Oil = $0.513 \frac{\text{lbs. part.}}{\text{short ton}} \times 1.102 \frac{\text{short tons}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.257 \frac{\text{kg}}{\text{Mg}}$

$0.257 \frac{\text{kg part.}}{\text{Mg feed}} \times 2.45 \frac{\text{Mg feed}}{\text{Mg cement}} = 0.630 \frac{\text{kg part.}}{\text{Mg cement}}$

- Report 71-MM-15: Wet Process Plant (Reference 16)

  Gas-fired kiln equipped with bhouse

  From Table I, page 5 of test report:

  Run # 4 = 0.247 lbs/short ton feed
  Run # 5 = 0.309 lbs/short ton feed
  Run # 6 = 0.261 lbs/short ton feed

  Average = 0.272 lbs/short ton feed

  $0.272 \frac{\text{lbs part.}}{\text{short ton feed}} \times 1.102 \frac{\text{short tons}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.136 \frac{\text{kg}}{\text{Mg}}$

  $0.136 \frac{\text{kg part.}}{\text{Mg feed}} \times 2.45 \frac{\text{Mg feed}}{\text{Mg cement}} = 0.333 \frac{\text{kg part.}}{\text{Mg cement}}$

- Greencastle Stack Emissions Survey (Reference 24)

  Coal-fired wet process kiln w/ESP – EPA Methods 1-5

  From Table 1, page 4 of report:

(4)

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 $X10^{-6}$ | Particulate Emission Rate Lbs/Hr. | Particulate Emission Rate Tons/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 |
| | | | | | Average of all 6 runs | | 33.54 |

From Table III, page 6 of report:

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 |
| 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 |

Average Clinker Production = $\frac{79.7 + 87.7}{2} \frac{\text{tons}}{\text{hr.}} = 83.7 \frac{\text{ton}}{\text{hr.}}$

$33.54 \frac{\text{lbs. part.}}{\text{hr.}} \times \frac{1 \text{ hr.}}{83.7 \text{ tons clinker}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.20 \frac{\text{kg part}}{\text{Mg clinker}}$

If 5% gypsum is added to clinker:

$0.20 \frac{\text{kg part.}}{\text{Mg clinker}} \times \frac{1.0 \text{ Mg clinker}}{1.05 \text{ Mg cement}} = 0.191 \frac{\text{kg}}{\text{Mg}}$ cement produced

- Nazareth Particulate Emission Test (Reference 25).

(4) Coal-fired, dry process kilns w/ multiclone + ESP
No. 2 & 3 = North Stack, No. 4 & 5 = South Stack
Method 5 tests both w/ & w/o impinger catch

From summary table on page 3 of test report:

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 | 233,400 | 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 |

From Table 2, page 11 of test report:

(6)

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 | | |

Total Clinker Production = 16.6 + 15.8 + 17.3 + 18.6 $\frac{\text{tons clinker}}{\text{hr}}$

= 68.3 tons/hr.

$\therefore$ 23.4 $\frac{\text{lbs part.}}{\text{hr.}} \times \frac{1 \text{ hr}}{68.3 \text{ tons clinker}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.171 \frac{\text{kg}}{\text{Mg}}$

0.171 $\frac{\text{kg part.}}{\text{Mg clinker}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}} = 0.163 \frac{\text{kg}}{\text{Mg}}$ cement produced

- Report EPA-600/7-79-015a and 015b: 2 Plants Tested (Reference 26A/B)

Test No. 3: Dry Process Kiln
Coke / Natural Gas- Fired (66/33%)
Measurements taken downstream of multiclone

Method 5 Data – taken during second test period (per Table 4-18 of EPA-600/7-79-015a)

- From p. 48 of EPA-600/7-79-015b:

$$9.746 \frac{gr}{dscf} \times \frac{1\ lb}{7000\ gr.} \times 164228 \frac{dscf}{min} \times 60 \frac{min}{hr.} = 13719.14 \frac{lbs}{hr.}$$

to baghouse

- From p. 43 of EPA-600/7-79-015b:

Clinker production rate = $53 \frac{\text{short tons}}{hr.} \times \frac{1\ Mg}{1.102\ tons} = 48 \frac{Mg}{hr.}$

If ~ 5% (weight) gypsum added: $48 \frac{Mg}{hr.} \times 1.05 = 50 \frac{Mg\ cement}{hr.}$

$\therefore$ $13719.14 \frac{lbs}{hr.} \times 0.454 \frac{kg}{lb.} \times \frac{1\ hr.}{50\ Mg} = 124.57 \frac{kg}{Mg}$ Total Mass Emissions

Test No. 9: Wet Process Kiln w/ ESP (30% $H_2O$ Content)
Natural Gas-Fired

SASS Train Data:

From Table 4-21, page 92 of EPA-600/7-79-015a:
Calculate Total Mass Emission Factors from SASS Train Data

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, $dam^3/s$ ($10^3$ SCFM) | 20.1 (42.6) | 19.0 (40.3) | 21.1 (44.7) | 21.7 (46.0) |
| Stack Temp. K (°F) | 415 (297) | 425 (305) | 411 (280) | 408 (274) |
| Oxygen Content, % | 4.5 | 2.3 | 6.8 | 6.6 |
| Moisture, % | 34.21 | 44.74 | 37.55 | 38.21 |
| Sample Time, min. | 75 | 75 | 300 | 300 |
| Cyclone Flow, acmm (acfm) | 0.102 (3.591) | 0.097 (3.435) | 0.087 (3.067) | 0.087 (3.076) |
| Isokinetic Ratio, % | 96.8 | 1[illegible].2 | 103.5 | 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 (100) | 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, acmm (acfm) | 0.0342 (1.2[illegible]) | 0.0386 (1.3631) | 0.0351 (1.2394) | 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 | 56.27 | 0.6122 | 0.7939 |
| Concentration, $g/dsm^3$ | 21.7 | 18.88 | 0.0581 | 0.0766 |
| Total Particulates, mg/J (lb/MMBtu) | 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] lb) | 76.64 (168.6) | 70.61 (155.6) | 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 (383.1) | 199.4 (438.6) |
| Precipitator Catch $10^6$g ($10^3$lb) | 2.131 (4.688) | 2.131 (4.688) | 9.375 (20.63) | 9.375 (20.63) |

- For Test 9-5 @ ESP Outlet – SASS Train Total Mass

$$0.0581 \frac{gm}{DNM^3} \times 21.1 \frac{DNM^3}{sec} \times \frac{19008\ sec}{175.0\ Mg\ clinker} \times \frac{1\ kg}{10^3\ gm} = 0.133 \frac{kg\ part.}{Mg\ clinker}$$

$$0.133 \frac{kg\ part.}{Mg\ clinker} \times \frac{1\ Mg\ clinker}{1.05\ Mg\ cement} = 0.127 \frac{kg\ part.}{Mg\ cement}$$

- For Test 9-6 @ ESP Outlet – SASS Train Total Mass

$$0.0766 \frac{gm}{DNM^3} \times 21.7 \frac{DNM^3}{sec.} \times \frac{18792\ sec}{199.4\ Mg\ clinker} \times \frac{1\ kg}{10^3 gm} = 0.157 \frac{kg\ part.}{Mg\ clinker}$$

$$0.157 \frac{\text{kg part.}}{\text{Mg clinker}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}} = 0.150 \frac{\text{kg part.}}{\text{Mg cement}}$$

$$\text{Average} = \frac{0.127 + 0.150 \text{ kg/Mg}}{2 \text{ tests}} = 0.139 \text{ kg/Mg cement}$$

- Report KVB 5806-783: Dry Process Plant (Reference 27)

  2 Tests on Same Kiln equipped w/ bhouse

  From page 4-113 of test report;

  Gas-Fired Operation = 0.21 lbs/short ton cement

  Coal-Fired Operation = 0.43 lbs/short ton cement

  $$\text{Nat. Gas} = 0.21 \frac{\text{lbs}}{\text{short ton}} \times 1.102 \frac{\text{short tons}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.11 \frac{\text{kg}}{\text{Mg}}$$

  $$\text{Coal} = 0.43 \frac{\text{lbs.}}{\text{short ton}} \times 1.102 \frac{\text{short tons}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.22 \frac{\text{kg}}{\text{Mg}}$$

- Maryneal, TX Source Emissions Survey (Reference 30)

  (3) Coal-fired dry process kilns w/ suspension preheaters & baghouses

  Hi-vols in three sections of each bhouse (positive pressure)

  From page 6 of test report for Kiln No. 1 bhouse:

(10)

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 | 68200 | 68300 |
| Preheater Flow Rate - DSCFM* | 26600 | 25700 | 23900 |
| Baghouse Flow Rate - ACFM | 125000 | 87100 | 95300 |
| Baghouse Flow Rate -DSCFM* | 80300 | 53100 | 51900 |
| % Water Vapor - %Vol. | 7.55 | 6.80 | 5.73 |
| % $CO_2$ - %Vol. @ Preheater | 23.6 | 19.0 | 17.6 |
| % $CO_2$ - %Vol. @ Baghouse | 7.6 | 9.2 | 8.1 |
| Baghouse Particulate Concentration - gr/dscf | 0.00281 | 0.00225 | 0.00290 |
| Baghouse Particulate Emission - lbs/hr | 1.94 | 1.02 | 1.24 |
| Kiln Feed Rate - Ton/hr | 36.6 | 39.0 | 40.4 |

} Avg. emissions = 1.40 lbs/hr.

Avg. feed = 38.6 TPH

Using conversion factor of feed to clinker of 0.54 as specified in Appendix E of test report:

$$\text{Average clinker production} = 38.6 \frac{\text{tons feed}}{\text{hr.}} \times 0.54$$

$$= 20.8 \frac{\text{tons clinker}}{\text{hr.}}$$

$$EF = 1.4 \frac{\text{lbs. part.}}{\text{hr.}} \times \frac{1 \text{ hr}}{20.8 \text{ tons clinker}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.0337 \frac{\text{kg}}{\text{Mg}}$$

$$0.0337 \frac{\text{kg part}}{\text{Mg clinker}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}} = 0.0321 \text{ kg/Mg cement}$$

From page 7 of test report for Kiln No. 2 bhouse:

SUMMARY OF RESULTS

Kiln Baghouse Number 2

| Run Number | 2 | 3 | |
|---|---|---|---|
| Date | 28 Sep 79 | 28 Sep 79 | |
| Time | 1530-1630 | 1735-1835 | |
| Preheater Flow Rate - ACFM | 71300 | 71000 | |
| Preheater Flow Rate - DSCFM* | 26800 | 26300 | |
| Baghouse Flow Rate - ACFM | 80300 | 138000 | |
| Baghouse Flow Rate -DSCFM* | 48600 | 84900 | |
| % Water Vapor - %Vol. | 6.65 | 6.86 | |
| % $CO_2$ - %Vol. @ Preheater | 19.6 | 25.2 | |
| % $CO_2$ - %Vol. @ Baghouse | 10.7 | 7.8 | |
| Baghouse Particulate Concentration - gr/dscf | 0.03642 | 0.00453 | |
| Baghouse Particulate Emission - lbs/hr | 2.67 | 3.29 | Avg. = 2.98 lbs/hr. |
| Kiln Feed Rate - Ton/hr | 34.8 | 36.1 | |

Avg. feed = 35.5 TPH

Average clinker production = $35.5 \frac{\text{tons feed}}{\text{hr}} \times 0.54 = 19.2 \frac{\text{tons}}{\text{hr}}$

$$\overline{EF} = 2.98 \frac{\text{lbs part}}{\text{hr}} \times \frac{1 \text{ hr}}{19.2 \text{ tons clinker}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}}$$

$$= 0.0739 \frac{\text{kg part}}{\text{Mg cement}}$$

From page 8 of test report for Kiln No. 3 bhouse:

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 | 27800 |
| Baghouse Flow Rate - ACFM | 82100 | 81600 | 81600 |
| Baghouse Flow Rate -DSCFM* | 48700 | 47700 | 52100 |
| % Water Vapor - %Vol. | 5.70 | 6.08 | 7.56 |
| % $CO_2$ - %Vol. @ Preheater * | 19.7 | 18.4 | 31.0 |
| % $CO_2$ - %Vol. @ Baghouse | 11.4 | 10.7 | -10.9 |
| Baghouse Particulate Concentration - gr/dscf | 0.00640 | 0.00324 | 0.00782 |
| Baghouse Particulate Emission - lbs/hr | 3.50 | 3.37 | 3.49 |
| Kiln Feed Rate - Ton/hr | 40.1 | 40.7 | 41.0 |

} Avg. emissions = $3.45 \frac{\text{lbs}}{\text{hr}}$

Avg. feed = 40.6 TPH

Average cement production = $40.6 \frac{\text{tons feed}}{\text{hr.}} \times 0.54 \times 1.05 \frac{\text{ton cement}}{\text{ton clinker}}$

$$= 23.0 \frac{\text{ton cement}}{\text{hr.}}$$

$$3.45 \frac{\text{lbs part.}}{\text{hr}} \times \frac{1 \text{ hr}}{23.0 \text{ tons cement}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.075 \frac{\text{kg}}{\text{Mg cement}}$$

$$\therefore \text{Average for 3 Kilns} = \frac{0.0321 + 0.0739 + 0.0750}{3} = 0.0603 \frac{\text{kg part}}{\text{Mg cement}}$$

- Roanoke No. 5 Gas Process Survey (Reference 31)

(3) Coal-fired dry process kilns w/ multiclone + ESP

(1) Coal-fired dry process kiln w/ Lepol sys. & ESP

EPA Methods 1-5

From summary table on page 2 (?) of report:

Results showed average conditions for each Kiln System as follows:

| Location Kiln Stack | Temp. °F | Volume ACFM | Emission Lbs/Hr | Opacity Laser 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 | 38.4 ✓ | 14 | |
| 5 ** | 326 | 192,000 | 20.3 | 14 | |
| 5 *** | 296 | 86,650 | 12.2 | 11 | |

* No Gas Bypass
** Gas Bypass to one Raw Mill
*** Gas Bypass to two Raw Mills

From Table 3, page T-3:

TABLE 3 T-3

ROANOKE EMISSION SURVEY

PROCESS DATA, CONSTRUCTION AND PRODUCTION

1979

| Run No. | Date | Kiln No. | Feed 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 | 5.4 | 20.7 | 0.39 | 13.8 | 25 |
| 49-50 | 10-1 | 1 | 3.4 | 8.8 | 21.0 | 0.54 | 14.0 | 26 |
| Average (Kiln #1) | | | 3.4 | 7.1 | 21.2 | 0.44 | 14.1 | 24 |
| | | 2 | | | | | | |
| | | 2 | POSTPONED | | | | | |
| | | 2 | | | | | | |
| Average (Kiln #2) | | | | | | | | |
| 31-32 | 10-4 | 3 | 2.7 | 7.3 | 22.1 | 0.53 | 14.7 | 26 |
| 33-34 | 10-11 | 3 | 2.8 | 7.2 | 23.9 | 0.53 | 14.6 | 25 |
| 35-36 | 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 | 0.43 | 17.3 | 26 |
| 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 | 27.8 | 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 | 8-15 | 5 | 9.9 | 5.2 | 105 | 0.34 | 66 | 49 |
| 23-24 | 9-7 | 5 | 9.8 | 6.8 | 110 | 0.36 | 69 | 50 |
| 25-26 | 9-3 | 5 | 9.5 | 5.1 | 110 | 0.42 | 69 | 50 |
| 31-32 | 9-4 | 5 | 9.4 | 6.4 | 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 | 5.3 | 100 | 0.36 | 63 | 61 |
| 12 | 8-5 | 5 | 9.5 | 4.8 | 102 | 0.37 | 64 | 44 |
| 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 | 0.37 | 69 | 51 |
| Average (Kiln #5) | | | 9.4 | 5.7 | 105 | 0.34 | 66 | 48 |

By-pass to 1 mill (Avg=66 TPH)

(Avg.=64 TPH) No by-pass

By-pass to 2 mills (Avg.=67 TPH)

- Kiln No. 1 Stack:

$$28.4 \frac{\text{lbs. part.}}{\text{hr.}} \times \frac{1 \text{ hr.}}{14.1 \text{ tons clinker}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 1.01 \frac{\text{kg part.}}{\text{Mg clinker}}$$

$$1.01 \frac{\text{kg part.}}{\text{Mg clinker}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}} = 0.962 \text{ kg part./Mg cement}$$

- Kiln No 3 Stack:

$$23.6 \frac{\text{lbs part}}{\text{hr.}} \times \frac{1 \text{ hr.}}{14.4 \text{ tons clinker}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.819 \frac{\text{kg}}{\text{Mg}}$$

$$0.819 \frac{\text{kg part.}}{\text{Mg clinker}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}} = 0.780 \text{ kg part./Mg cement}$$

- Kiln No. 4 Stack:

$$28.9 \frac{\text{lbs part}}{\text{hr}} \times \frac{1 \text{ hr}}{19.0 \text{ tons clinker}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.761 \frac{\text{kg}}{\text{Mg}}$$

$$0.761 \frac{\text{kg part}}{\text{Mg clinker}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}} = 0.724 \text{ kg part./Mg cement}$$

- Kiln No. 5 Stack: Use no by-pass scenario

$$33.4 \frac{\text{lbs part}}{\text{hr.}} \times \frac{1 \text{ hr}}{64 \text{ tons clinker}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.30 \frac{\text{kg}}{\text{Mg}}$$

$$0.30 \frac{\text{kg part}}{\text{Mg clinker}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}} = 0.286 \text{ kg part./Mg cement}$$

$$\therefore \overline{EF} = \frac{0.962 + 0.780 + 0.724 + 0.286}{4} = 0.688 \text{ kg part./Mg cement}$$

- OK Cement Source Emission Study (Reference 33) ✓

(1) Coal-fired dry process kiln w/ cyclones + baghouse

EPA Method 5 tests on baghouse stack

From Summary of Results, page 3 of report:

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<br>Probe, Cyclone & Filter Catch<br>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 |

Average Emission Rate = $\frac{6.9 + 6.6 + 6.1}{3} \frac{lbs}{hr.} = 6.5 \frac{lbs\ part}{hr.}$

From page 10 of test report:

PRODUCTION DATA FACTORS

During Jov 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

$\therefore \overline{EF} = 6.5 \frac{lbs\ part}{hr.} \times \frac{1\ hr.}{33.1\ tons\ clinker} \times 1.102 \frac{short\ ton}{Mg} \times 0.454 \frac{kg}{lb} \times \frac{1\ Mg\ clinker}{1.05\ Mg\ cement}$

$= 0.094$ kg part./Mg cement

- Lone Star, New Orleans Source Emission Survey (Reference 39)

(2) Coal-fired wet process kilns w/ ESPs — Method 5 tests

From page 5 of test report:

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 |

Assuming identical kilns & control equipment:

Average emission rate = $\frac{18.33 + 17.4}{2} \frac{lbs}{hr} = 17.9 \frac{lbs.}{hr.}$ for both kilns

From page 16 of test report:

Assume dry feed!

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 |

Average dry feed = 83 TPH

Kiln Number 1 Under State Regulations

Kiln Number 2 Installed after 1971, therefore, must abide by EPA Regulations.

81-107 -16-

Assuming: 1.7 Mg raw feed / Mg cement (per p. 20; EPA-600/2-77-023u)
(not including coal burned)

$\therefore 17.9 \frac{lbs\ part}{hr.} \times \frac{1\ hr.}{83.0\ tons\ feed} \times 1.102 \frac{short\ ton}{Mg} \times 0.454 \frac{kg}{Mg} \times 1.7 \frac{Mg\ feed}{Mg\ cement} = 0.183 \frac{kg}{Mg}$

- Bonner Springs Stack Emission Survey (Reference 40) ✓

(3) Coal-fired wet kilns w/ common ESP (No. 2 Stack)
(1) " " " kiln w/ ESP (No. 4 Stack)

EPA Method 5 Tests @ ESP Stacks

For No. 4 Kiln: from Table T-1, page 14 of test report:

(116)

TABLE T-1

BONNED SPRINGS STACK EMISSION SURVEY

PARTICULATE EMISSION RATE 1981

| Run No. | Test Location | Date | EXHAUST GAS Temp. °F | EXHAUST GAS Volume ACFM | PARTICULATE EMISSION RATE Grains/SCF Dry | PARTICULATE EMISSION RATE Lbs./SCF Dry $\times 10^{-4}$ | PARTICULATE EMISSION RATE Lbs./Hr. | PARTICULATE EMISSION RATE Ton/Day |
|---|---|---|---|---|---|---|---|---|
| 1 | No. 4 Kiln | 9-8 | — | — | — | — | — | — |
| 2 | " | " | 777 | 75,900 | 0.1642 | 33.5 | 53.0 | 0.64 |
| 3 | " | 9-9 | 772 | 64,100 | 0.0741 | 18.6 | 19.7 | 0.24 |
| 6 | " | " | 769 | 72,900 | 0.0490 | 9.9 | 21.2 | 0.25 |
| 9 | " | 9-10 | 776 | 66,700 | 0.0423 | 8.9 | 18.0 | 0.22 |
| 10 | " | " | 768 | 67,200 | 0.0764 | 16.9 | 31.0 | 0.25 |
| 15 | " | 9-11 | 764 | 63,500 | 0.0953 | 23.6 | 25.9 | 0.31 |
| 16 | " | " | 768 | 53,500 | 0.0221 | 3.2 | 4.7 | 0.06 |
| AVERAGE | | | 771 | 66,500 | 0.0805 | 11.5 | 23.4 | 0.31 |

From Table T-4, page 19 of test report:

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TABLE T-4

BONNED 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 Produced Ton/Hr. |
|---|---|---|---|---|---|---|---|
| 9-8 | No. 4 Kiln Sth. | 156 | 8.0 | 31.0 | 34.7 | 79.2 | 16.8 |
| 9-9 | " | 164 | 6.1 | 31.0 | 35.0 | 79.2 | 16.9 |
| 9-10 | " | 155 | 6.9 | 31.4 | 34.5 | 79.3 | 17.0 |
| 9-11 | " | 150 | 7.3 | 32.0 | 34.1 | 79.2 | 17.4 |

? Average clinker prod. rate = 17.0 TPH

$$\overline{EF} = 23.4 \frac{\text{lbs part}}{\text{hr}} \times \frac{1 \text{ hr}}{17.0 \text{ tons clinker}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}} = 0.656 \frac{\text{kg}}{\text{Mg}}$$

For Kilns 1, 2, & 3: From Table T-1, page 14 of test report

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 21 | No. 2 Stk. | 9-21 | 695 | 99,300 | 0.0308 | 4.4 | 16.3 | 0.20 |
| 22 | " | 9-21 | 697 | 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 | 633 | 90,300 | 0.0177 | 2.5 | 10.0 | 0.12 |
| 34 | " | 9-23 | 633 | 83,100 | 0.0199 | 2.8 | 10.7 | 0.13 |
| 39 | " | 9-24 | 677 | 106,900 | 0.0360 | 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 | 0.0251 | 3.6 | 21.0 | 0.25 |
| 51 | " | 10-5 | 720 | 124,700 | 0.0240 | 3.4 | 13.3 | 0.16 |
| 52 | " | 10-5 | 774 | 116,400 | 0.1069 | 15.4 | 67.6 | 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 | 1.0670 | 147.0 | 331* | 6.8 |
| 64 | " | 10-7 | 703 | 97,400 | 0.6930 | 99.0 | 3[illegible] | 4.2 |
| AVERAGE | | | 688 | 105,700 | 0.1472 | 20.8 | 27.3 | 0.93 |
| *average not including Runs 63 & 64 | | | | | 0.042 | | 23.3 lbs/hr. | |

ESP upset during runs 63 & 64!

From Table T-4, page 19 of test report:

(17)

| Date 1991 | System Under Test | Fuel Used: Coal lbs/min | Fuel Used: Moisture % | Raw Mix Used: Ton/hr. Dry | Raw Mix Used: Slurry Solids - % | Raw Mix Used: $CaCO_3$ % | Clinker Produced Ton/hr | Totals |
|---|---|---|---|---|---|---|---|---|
| 9-21 | No. 2 Kiln Sch. | | | | | | | |
| | Kiln 1-24 Hr. | 83 | 7.4 | 17.06 | 34.1 | 80.3 | 9.57 | 19.46 |
| | Kiln 2-24 Hr. | 88 | 7.4 | 17.17 | 34.1 | 80.3 | 9.34 | |
| | Kiln 3-0 Hr. | — | — | — | — | — | — | |
| 9-22 | Kiln 1-0 Hr. | — | — | — | — | — | — | 9.29 |
| | Kiln 2-24 Hr. | 84 | 5.8 | 16.72 | 34.5 | 80.4 | 9.39 | |
| | Kiln 3-0 Hr. | — | — | — | — | — | — | |
| 9-23 | Kiln 1-0Hr. | — | — | — | — | — | — | 18.05 |
| | Kiln 2-24 Hr. | 83 | 6.5 | 16.[illegible] | 34.0 | 80.3 | 9.38 | |
| | Kiln 3-12 Hr. | 90 | 6.5 | 15.41 | 34.0 | 80.3 | 8.67 | |
| 9-24 | Kiln 1-0 Hr. | — | — | — | — | — | — | 18.92 |
| | Kiln 2-24 Hr. | 84 | 8.0 | 17.17 | 34.1 | 80.3 | 9.34 | |
| | Kiln 3-24 Hr. | 80 | 8.0 | 16.88 | 34.1 | 80.3 | 9.38 | |
| 9-25 | Kiln 1-0 Hr. | — | — | — | — | — | — | 19.09 |
| | Kiln 2-24 Hr. | 84 | 7.8 | 17.41 | 34.0 | 80.3 | 9.57 | |
| | Kiln 3-24 Hr. | 77 | 7.8 | 16.96 | 34.0 | 80.3 | 9.42 | |
| 10-3 | Kiln 1-24 Hr. | 87 | 7.2 | 18.23 | 33.8 | 79.9 | 10.13 | 29.71 |
| | Kiln 2-24 Hr. | 88 | 7.2 | 17.69 | 33.8 | 79.9 | 9.83 | |
| | Kiln 3-20.5 Hr. | 80 | 7.2 | 17.35 | 33.8 | 79.9 | 9.75 | |
| 10-6 | Kiln 1-20 Hr. | 89 | 7.5 | 18.18 | 34.3 | 79.8 | 10.10 | 29.25 |
| | Kiln 2-24 Hr. | 87 | 7.5 | 17.26 | 34.3 | 79.8 | 9.59 | |
| | Kiln 3-23.75 Hr. | 84 | 7.5 | 17.22 | 34.3 | 79.8 | 9.56 | |
| 10-7 | Kiln 1-16 Hr. | 89 | 7.0 | 16.31 | 34.1 | 79.7 | 9.06 | Delete |
| | 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 | |

Average clinker prod. = 20.54 TPH

$$\overline{EF} = 25.2\,\frac{\text{lbs part.}}{\text{hr.}} \times \frac{1\text{ hr.}}{20.54\text{ tons clinker}} \times 1.102\,\frac{\text{short tons}}{\text{Mg}} \times 0.454\,\frac{\text{kg}}{\text{lb}} \times \frac{1\text{ Mg clinker}}{1.05\text{ Mg cement}} = 0.584\,\frac{\text{kg}}{\text{Mg}}$$

$$\text{Average of Two Kilns} = \frac{0.656 + 0.584}{2} = 0.620\ \text{kg/Mg cement}$$

- Mojave Annual Compliance Test (Reference 44)
  (1) Coal-fired, dry process kiln w/ suspension preheater, flash calciner, & bhouse (per Ref. 45)

From second page of test report: EPA Method 5 data

SUMMARY OF SOURCE TEST RESULTS

Company California Portland Cement Test Date 5/23-5/24/83 APCD No. 10030296A Unit No. Kiln Baghouse

| Pollutants | Emissions: Inlet: Concentration Wet gr/scf | Inlet: Concentration Wet @ 12% $CO_2$ | Inlet: Concentration Wet ppm$_v$ | Inlet: Mass Flow Rate lb/hr | Outlet: Concentration Wet gr/scf | Outlet: Concentration Wet @ 12% $CO_2$ | Outlet: Concentration Wet ppm$_v$ | Outlet: Concentration Wet @ 3% $O_2$ | Outlet: Mass Flow Rate lb/hr | Removal % | Emission Factor lb/ton: Inlet | Emission Factor lb/ton: Outlet |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Particulate | | | | | 0.0557* | 0.0409* | | | 100.57* | | | 0.05* |
| | | | | | 0.0046 | 0.0063 | | | 16.96 | | | 0.04 |
| | | | | | 0.0077 | 0.0157 | | | 13.72 | | | 0.06 |
| | | | | | 0.0086 | 0.0060 | | | 15.32 | | | 0.07 |
| Sulfate | | | | | | | gr/scf | | | | | |
| $SO_2$ | | | | | | | 52.29 | | 111.45 | | | |
| | | | | | | | 52.29 | | 112.76 | | | |
| | | | | | | | 50.09 | | 102.24 | | | |
| | | | | | | | 53.29 | | 108.83 | | | |
| $NO_x$ as $NO_2$ (dry) | | | | | | | 295.37 | 495.8 | 423.47 | | | |
| | | | | | | | 262.84 | 468.8 | 404.11 | | | |
| | | | | | | | 250.96 | 421.4 | 369.98 | | | |
| | | | | | | | 279.39 | 462.0 | 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 210 TPH (prorated).

→ Emission Factors w/ impinger catch

(3)

Assuming "Production Rate" is dry input to kiln and correcting for impinger catch:

Test No. 1 : Delete Data

Test No. 2: From weights on p. 3-6

$$\frac{0.08 \text{ lbs/ton}}{0.02949 \text{ gm}} = \frac{X \text{ lbs/ton}}{0.00848 \text{ gm}}$$

$$X = 0.02 \text{ lbs/ton dry meal}$$

$$0.02 \frac{\text{lbs part}}{\text{ton feed}} \times 1.7 \frac{\text{tons feed}}{\text{ton cement}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.02 \frac{\text{kg part}}{\text{Mg cement}}$$

Test No. 3: From weights on p. 3-9

$$\frac{0.06 \text{ lbs/ton}}{0.02398 \text{ gm}} = \frac{X \text{ lbs/ton}}{0.00691}$$

$$X = 0.02 \text{ lbs/ton dry meal}$$

$$0.02 \frac{\text{lbs part}}{\text{ton feed}} \times 1.7 \frac{\text{tons feed}}{\text{ton cement}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.02 \frac{\text{kg part}}{\text{Mg cement}}$$

(per EPA-600/2-77-023a)

Average of Test 2 & 3 = $\frac{0.02 + 0.02}{2} = 0.02$ kg/Mg

- Mojave Annual Compliance Test (Reference 50)

(1) Coal-fired dry process kiln w/ suspension preheater flash calciner, and bhouse

(3) EPA Method 5 Tests (including impinger catch)

From p. A-2 of test report: emission rate wo/impingers

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 (ft²) | 87.28 | 87.28 | 87.28 | |
| Elapsed sampling time (min) | 72 | 72 | 72 | |
| Volume gas sampled (dscf) | 47.1355 | 47.0806 | 46.2820 | |
| F factor | | | | |
| GAS DATA | | | | |
| Average gas velocity (fps) | 63.3 | 63.4 | 65.1 | 63.9 |
| Average gas temperature (°F) | 255.0 | 256.2 | 256.0 | 256.4 |
| Gas flowrate (dscfm) | 198625 | 199435 | 206805 | 201621 |
| Gas analysis (dry percent basis) | | | | |
| Carbon dioxide | 18.80 | 18.38 | 18.50 | |
| Oxygen | 10.45 | 10.90 | 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 |
| $SO_2$ (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 | 7.02 | [illegible] |
| Total particulate (lb/hr) | 7.45 | 11.06 | 7.61 | [illegible] |
| Total sulfate (lb/hr) | 1.88 | 1.89 | 1.90 | 1.89 |
| $SO_2$ (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 |

Average emission rate wo/impingers

From Summary of Source Test Results: feedrates for tests

SUMMARY OF SOURCE TEST RESULTS

Company California Portland Cement Test Date 5/15/84 APCD No. 10030268 Unit No. Kiln

| Pollutants | Emissions: Inlet, Concentration Wet, gr/scf | Inlet, Concentration Wet, P 12% $CO_2$ | Inlet, Concentration Wet, ppm$_v$ | Inlet, Mass Flow Rate lb/hr | Outlet, Concentration Wet, gr/scf | Outlet, Concentration Wet, P 12% $CO_2$ | Outlet, Concentration Wet, ppm$_v$ | Outlet, Concentration Wet, P 3% $O_2$ | Outlet, Mass Flow Rate lb/hr | Removal % | Emission Factor lb/ton, Inlet | Emission Factor lb/ton, Outlet |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Particulate | | | | | 0.0042<br>0.0042<br>0.0041<br>0.0048 | | | | 7.46<br>11.06<br>7.61<br>8.71 | | | 0.03<br>0.05<br>0.03<br>0.04 |
| Sulfate | | | | | 0.0010<br>0.0011<br>0.0018<br>0.0010 | | | | 1.88<br>1.89<br>1.90<br>1.89 | | | |
| $SO_2$ | | | | | | | 67.79<br>72.81<br>73.45<br>71.35 | | 143.76<br>154.17<br>154.80<br>150.91 | | | |
| $NO_x$ as $NO_2$ (dry) | | | | | | | 353.75<br>352.50<br>382.50<br>362.92 | 605.98<br>606.71<br>658.34<br>623.46 | 503.48<br>501.70<br>546.62<br>517.27 | | | |
| HC (Cl, >Cl) | | | | | | | 0.1/48.9<br>0.0/27.0<br>0.0/30.3<br>0.37/35.40 | | 0.54/24.20<br>0.00/13.36<br>0.00/15.06<br>0.18/17.54 | | | |

Includes impinger catch

Scrubber Liquor Analysis: Chlorides -- Specific Gravity --

For Kern County Use Only:

Remarks: Feed Rates = 231, 236, 245 tons/hour

Dry Kiln Feed.

$$\text{Average feed} = \frac{231 + 236 + 245}{3} \frac{\text{tons}}{\text{hr.}} = 237 \text{ short tons/hr.}$$

$$\therefore\ 7.47\ \frac{\text{lbs part}}{\text{hr.}} \times \frac{1\ \text{hr.}}{237\ \text{tons dry feed}} \times 1.7\ \frac{\text{tons feed}}{\text{ton cement}} \times 1.102\ \frac{\text{short tons}}{\text{Mg}} \times 0.454\ \frac{\text{kg}}{\text{lb}} = 0.0265\ \text{kg/Mg}$$

(average w/ impingers)

- Lehigh Particulate (Leeds) Compliance Test (Reference 51)

  (1) Coal-fired dry process kiln w/ ESP (Raw mill in series)

  EPA Method 5 test @ kiln stack - Loesche mill off

  From Calculation Sheets in Appendix B for Runs 2, 3, 4, & 5:

  $$\text{Average emission rate} = \frac{24.61 + 25.40 + 16.74 + 15.66}{4}\ \frac{\text{lbs}}{\text{hr.}}$$

  $$= 20.60\ \text{lbs part./hr.}$$

  From Process Records in Appendix D: Tests 2-5

  $$\text{Average feedrate} = \frac{140 + 133 + 135 + 134}{4}\ \frac{\text{short tons}}{\text{hr}} = 137\ \frac{\text{tons}}{\text{hr.}}$$

  $$\therefore\ 20.60\ \frac{\text{lbs part}}{\text{hr.}} \times \frac{1\ \text{hr.}}{137\ \text{tons feed}} \times 1.7\ \frac{\text{tons feed}}{\text{ton cement}} \times 1.102\ \frac{\text{short tons}}{\text{Mg}} \times 0.454\ \frac{\text{kg}}{\text{lb}} =$$

  $$0.1278\ \frac{\text{kg part}}{\text{Mg cement}} =$$

- Lehigh Portland (Cementon) Compliance Test (Reference 52)

  (1) Coal-fired wet process kiln w/ ESP

  EPA Method 5 Tests @ Kiln Stack

  From p. 2-1 of test report:

(21)

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

From p. 1-1 of test report:

1500 tons clinker/day ≅ 400 gpm slurry input

$$1500 \frac{\text{tons clinker}}{\text{day}} \times \frac{1 \text{ day}}{24 \text{ hrs}} = 63 \frac{\text{tons clinker}}{\text{hr.}}$$

From p. A-2, A-5, & A-8 of test report:

$$\text{Average kiln feed} = \frac{400 + 400 + 405}{3} \frac{\text{gal}}{\text{min}}$$

$$= 402 \text{ gal/min slurry to kiln}$$

$$\therefore \frac{63 \text{ TPH clinker}}{400 \text{ gpm}} = \frac{X \text{ TPH clinker}}{402 \text{ gpm}}$$

$$X = 63 \text{ tons clinker/hr.}$$

Average emission factor for kiln:

$$9.7 \frac{\text{lbs. part}}{\text{hr.}} \times \frac{1 \text{ hr.}}{63 \text{ tons clinker}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}} = 0.073 \frac{\text{kg/Mg}}{\text{cement}}$$

- Mojave Annual Compliance Test – 1985 (Reference 53)
  - (1) Coal-fired dry process kiln w/ suspension preheater, flash calciner, & bhouse
  - (2) EPA Method 5 Tests (includes impinger catch)

From Summary of Source Test Results:

(22)

SUMMARY OF SOURCE TEST RESULTS

Company CalMat Company Test Date 05/11/85 APCD No. 10030768 Unit No. File

| Pollutants | Emissions: Inlet, Concentration Wet, gr/scf | Inlet, Concentration Wet, P 12% $CO_2$ | Inlet, Concentration Wet, ppm$_v$ | Inlet, Mass Flow Rate lb/hr | Outlet, Concentration Wet, gr/scf | Outlet, Concentration Wet, P 12% $CO_2$ | Outlet, Concentration Wet, ppm$_v$ | Outlet, Concentration Wet, P 3% $O_2$ | Outlet, Mass Flow Rate lb/hr | Removal % | Emission Factor lb/MMBtu, Inlet | Emission Factor lb/MMBtu, Outlet |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Particulate | | | | | 0.0034<br>0.0013<br>0.0014<br>0.0029 | | | | 5.86<br>3.22<br>5.86<br>5.00 | | | 0.01<br>0.02<br>0.01<br>0.02 |
| Sulfate | | | | | 0.0005<br>0.0004<br>0.0001<br>0.0004 | | | | 0.86<br>0.45<br>0.86<br>0.77 | | | |
| $SO_2$ | | | | | | | 16.68<br>16.83<br>16.98<br>16.86 | | 32.47<br>34.75<br>38.57<br>33.93 | | | |
| $NO_x$ as $NO_2$ (dry) | | | | | | | 357.50<br>[illegible]<br>[illegible]<br>[illegible] | 633.45<br>[illegible]<br>[illegible]<br>638.57 | 532.11<br>[illegible]<br>[illegible]<br>[illegible] | | | |
| HC ($C_1$,$C_1$) | | | | | | 1.74/18.70<br>1.74/17.41<br>2.26/15.06<br>2.25/17.06 | | | 1.31/8.23<br>0.81/6.28<br>1.06/7.08<br>1.07/8.10 | | | |

Scrubber Liquor Analysis: Chlorides -- Specific Gravity --

For Kern County Use Only:

Remarks CO (mm, dry) = 179.17, 181.00, 191.67, Average 184.95
(lb/hr) = 149.73, 150.56, 160.24; Average 153.51

Test 1, 2, 3 216.0 TPH

includes impinger catch

Assume: Average feed to kiln (dry)

From p. A-5 of test report: correct for impinger catch

TEST 1, 2, 3

LOCATION Kiln

EMISSION RATE DATA -- 68°F

Standard Temperature, $S_t$ = 68°F; 29.92 inches Hg

| | | Test 1 | Test 2 | Test 3 | Average |
|---|---|---|---|---|---|
| RED FT | | | | | |
| RED RAT | | | | | |
| ENTER: R-17 $V_{m,std}$ | | 45.0046 | 45.0044 | 45.3177 | |
| R-26 $Q_s$ | | 151637.62 | 151637.62 | 149759.26 | |
| R-22 $O_2$% | | 9.95 | 10.0 | 9.75 | |
| LAB DATA | | | | | |
| Front Half Wash | (g) | 0.00707 | 0.00447 | 0.00036 | |
| Mass Filter | (g) | 0.00071 | 0.00005 | 0.00077 | |
| Back Half Catch | (g) | 0.00257 | 0.00134 | 0.00348 | |
| Front Half Sulfate | (mg $H_2SO_4$) | 0.49 | 0.84 | 0.00 | |
| Back Half Sulfate | (mg $H_2SO_4$) | 1.07 | 0.87 | 1.56 | |
| $H_2O_2$ Catch | (mg $H_2SO_4$) | 89.94 | 96.24 | 95.99 | |
| RESULTS | | | | | |
| F-Factor | 3 | | | | |
| Filt. Particulate gr/dscf | 6 | 0.0026 | 0.0015 | 0.0024 | 0.0022 |
| Filt. Particulate lb/hr | 7 | 3.80 | 2.53 | 3.64 | 3.59 |
| Total Particulate gr/dscf | 8 | 0.0036 | 0.0022 | 0.0036 | [illegible] |
| Total Particulate lb/hr | 10 | 5.86 | 3.27 | 5.86 | 5.00 |
| Total Sulfate gr/dscf | 11 | 0.0005 | 0.0008 | 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 | 18.85 | 18.34 | 17.85 |
| $SO_2$ lb/hr | 17 | 36.47 | 34.92 | 34.57 | 33.93 |
| $SO_2$ P3% $O_2$ | 18 | 29.75 | 29.97 | 29.45 | 29.06 |
| $SO_2$ lb/MMBtu | | | | | |
| S lb/MMBtu | | | | | |
| Filt. Particulate lb/MMBtu | | | | | |

Average emission rate w/ impingers

A-5

$$3.59\ \frac{\text{lbs part}}{\text{hr.}} \times \frac{1\ \text{hr}}{216\ \text{tons feed}} \times 1.7\ \frac{\text{ton feed}}{\text{ton cement}} \times 1.102\ \frac{\text{short ton}}{\text{Mg}} \times 0.454\ \frac{\text{kg}}{16} = 0.0141\ \frac{\text{kg}}{\text{Mg cement}}$$

(23)

- Lonestar Florida Stack Test (Reference 54)

(1) Coal-fired wet process kiln w/ESP

(3) EPA Method 5 Tests on ESP Stack

From p. 4 of test report:

IV. SUMMARY OF RESULTS
REPORT 810-5

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 |

From Appendix C, Process Data

| | Run #1 | Run #2 | Run #3 |
|---|---|---|---|
| -FRIDAY - AUGUST 30, 1985 | | | |
| E | 8:45 AM 10:02 AM | 10:49 AM 12:07 PM | 12:50 PM 2:15 PM |
| OF FUEL | COAL | COAL | COAL |
| FEED RATE (TPH) | 15.2 | 15.15 | 15.0 |
| FUR CONTENT OF FUEL | 1.82 | 1.77 | 1.76 |
| FEED RATE (TPH) | 133 | 133 | 133 |
| FUR CONTENT OF KILN FEED $SO_3$ | 0.14 | 0.15 | 0.18 |
| GEN CONTENT OF FLUE GASES | 1.9 | 1.9 | 1.9 |
| NKER PRODUCTION RATE (TPH) | 86.7 | 86.7 | 86.7 |

86.7 TPH Average Clinker Prod.

$$\therefore 19.90 \frac{\text{lbs part}}{\text{hr.}} \times \frac{1 \text{ hr}}{86.7 \text{ tons clinker}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}} = 0.109 \frac{\text{kg}}{\text{Mg cement}}$$

# APPENDIX D

## TOTAL PARTICULATE EMISSION FACTOR CALCULATIONS FOR CONTROLLED COOLERS, MILLS, AND CRUSHING/SCREENING

MIDWEST RESEARCH INSTITUTE

MRI-18

PROJECT DEVELOPMENT SKETCH

TITLE Emission Factor Calculations for Controlled Clinker Coolers, Mills, and Crushing / Screening

PROJECT NO. 4892-L74/8481-L9 DRAWN JSK Orig. 8/28/83 Rev. DATE 8/17/86

Clinker Coolers:

- Report 71-MM-01: Cooler w/ ESP on Wet Process Kiln (Reference No. 10)

From: Table I, page 6 of test report:

Run #1 = 0.106 lbs/short ton feed (clinker)
Run #2 = 0.102 " " " " "
Run #3 = 0.0798 " " " " "

Average = 0.0959 lbs/short ton feed "

$$0.0959 \frac{\text{lbs. part.}}{\text{short ton}} \times 1.102 \frac{\text{short tons}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.048 \frac{\text{kg part.}}{\text{Mg feed}}$$

Assuming: 0.95 Mg clinker/Mg cement (from EPA-600/2-77-02 p. 20)

$$0.048 \frac{\text{kg part.}}{\text{Mg clinker}} \times 0.95 \frac{\text{Mg clinker}}{\text{Mg cement}} = 0.0456 \frac{\text{kg part.}}{\text{Mg cement}}$$

- Report 71-MM-03: Cooler w/ Baghouse on Wet Process Kiln (Reference No. 11)

From Table 1, page vii of test report:

Run #1 = 0.406 lbs/short ton clinker
Run #2 = 0.452 " " " "
Run #3 = 0.536 " " " "

Average = 0.465 " " " "

$$0.465 \frac{\text{lbs. part.}}{\text{short ton}} \times 1.102 \frac{\text{short tons}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.233 \frac{\text{kg part}}{\text{Mg cl.}}$$

$$0.233 \frac{\text{kg part.}}{\text{Mg clinker}} \times 0.95 \frac{\text{Mg clinker}}{\text{Mg cement}} = 0.221 \frac{\text{kg part.}}{\text{Mg cement}}$$

(2)

- Report 71-MM-06: Cooler w/ Baghouse on Wet Process Kiln (Reference No. 14)

From Table I, page 5 of test report

Run #1 = 0.0253 lbs/ short ton clinker
Run #2 = 0.0448 " " " "
Run #3 = 0.0305 " " " "

Average = 0.0335 " " " "

$$0.0335 \frac{\text{lbs. part.}}{\text{short ton}} \times 1.102 \frac{\text{short tons}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb.}} = 0.0168 \frac{\text{kg}}{\text{Mg}}$$

$$0.0168 \frac{\text{kg part.}}{\text{Mg clinker}} \times 0.95 \frac{\text{Mg clinker}}{\text{Mg cement}} = 0.0160 \frac{\text{kg part.}}{\text{Mg cement}}$$

- Report EPA-600/2-76-164 - Evaluation of Rexnord Gravel Bed Filter (Reference No. 21)

From p. 39, Appendix B, of Report EPA-600/2-76-164

**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

From p. 8 of Report EPA-600/2-76-164 — Controlled

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(474( |
| SDCM/min(SCDFM) | 1239.3(43759) | 1326.4(46837) | 1017.5(35927) | 1174.2(41461) | 1049.7(370( |
| Grams/ACM(Grains/ACF) | 0.094(0.041) | 0.030(0.013) | 0.064(0.028) | 0.043(0.019) | 0.034(0.01 |
| Grams/SDCM(Grains/SDCF) | 0.121(0.053) | 0.037(0.016) | 0.080(0.035) | 0.055(0.024) | 0.043(0.01 |
| Kg/hr.(Lbs/hr.) | 9.02(19.88) | 2.91(6.42) | 4.89(10.78) | 3.87(8.53) | 2.74(6.04) |

For Run #2: 8/26/75

$$2.91 \frac{kg}{hr.} \times \frac{1 \text{ day}}{533 \text{ tons cement}} \times 24 \frac{hrs}{day} \times \frac{1.102 \text{ tons}}{Mg} = 0.144 \ kg/Mg$$

For Run #3: 8/26/75

$$4.89 \frac{kg}{hr.} \times \frac{1 \text{ day}}{533 \text{ tons cement}} \times 24 \frac{hrs}{day} \times \frac{1.102 \text{ tons}}{Mg} = 0.243 \ kg/Mg$$

For Run #4: 8/27/75

$$3.87 \frac{kg}{hr.} \times \frac{1 \text{ day}}{961 \text{ tons cement}} \times 24 \frac{hrs}{day} \times \frac{1.102 \text{ tons}}{Mg} = 0.107 \ kg/Mg$$

For Run #5: 8/27/75

$$2.74 \frac{kg}{hr.} \times \frac{1 \text{ day}}{961 \text{ tons cement}} \times 24 \frac{hrs}{day} \times \frac{1.102 \text{ tons}}{Mg} = 0.075 \ kg/M$$

$$\overline{EF_c} = \frac{0.144 + 0.243 + 0.107 + 0.075}{4 \text{ tests}} = 0.142 \ kg/Mg \text{ cement}$$

- OK Cement Stack Analysis (Reference 32)

(3) grate-type coolers w/ common gravel bed filter

From page 3 of test report:

Roxford
Pryor, Oklahoma

Particulate Emissions
Gravel Bed Filter
Page Three

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 |

$$\overline{ER} = \frac{14.8 + 13.6 + 12.9}{3} \frac{lbs}{hr.} = 13.8 \frac{lbs\ part}{hr.}$$

$$\therefore \overline{EF} = 13.8 \frac{lbs\ part}{hr} \times \frac{1\ hr}{83.8\ tons\ clinker} \times 1.102 \frac{short\ ton}{Mg} \times 0.454 \frac{kg}{lb}$$

$$= 0.0824 \frac{kg\ part}{Mg\ clinker} \times \frac{1\ Mg\ clinker}{1.05\ Mg\ cement} = 0.0784 \frac{kg\ part}{Mg\ cement}$$

- Lone Star Florida Compliance Test (Reference 36)

(1) unspecified cooler w/ bhouse

From page 5 of test report:

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 |

Since NSPS is in terms of dry feed to the kiln — Assume: Feed rate = dry TPH to kiln (no fuel)

Assuming: 1.7 Mg dry feed/Mg cement (per p. 20, EPA-600/2-77-023u)

$$\therefore \overline{EF} = 0.0997 \frac{\text{lbs part}}{\text{ton feed}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} \times 1.7 \frac{\text{Mg feed}}{\text{Mg cement}}$$

$$= 0.0848 \text{ kg part./Mg cement}$$

- Mason City NSPS Compliance Test (Reference 43),

(1) Unspecified cooler w/ bhouse

From Table 1, page 5 of test report:

Particulate Mass Flow from Kiln Cooler Stack (lb/hr)

| | |
|---|---|
| Run I | 2.7 |
| Run II | 1.0 |
| Run III | 1.0 |

$$\overline{ER} = \frac{2.7 + 1.0 + 1.0}{3} \frac{\text{lbs part}}{\text{hr.}} = 1.6 \text{ lbs part/hr.}$$

From Appendix E, pages E-1, E-3, + E-5:

Feed Rates to Kiln (dry) = 136.4, 139.2, + 138.1 tons/hr, respectively.

$$\text{Average feed rate} = \frac{136.4 + 139.2 + 138.1}{3} \frac{\text{tons}}{\text{hr}} = 137.9 \frac{\text{tons}}{\text{hr}}$$

$$\therefore \overline{EF} = 1.6 \frac{\text{lbs part}}{\text{hr}} \times \frac{1 \text{ hr}}{137.9 \text{ tons feed}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 5.8(10)^{-3} \frac{\text{kg}}{\text{Mg kiln feed}}$$

Assuming: 1.7 Mg dry feed / Mg cement (as above)

$$5.8(10)^{-3} \frac{\text{kg part}}{\text{Mg feed}} \times 1.7 \frac{\text{Mg feed}}{\text{Mg cement}} = 9.9(10)^{-3} \frac{\text{kg part}}{\text{Mg cement}}$$

- Mojave Annual Compliance Test (Reference 44).

(1) grate-type clinker cooler w/ bhouse

From page i of test report:

SUMMARY OF SOURCE TEST RESULTS
(Mojave)

Company California Portland Cement Test Date 5/26/83 APCD No. 1003027A Unit No. Clinker Baghouse

| Pollutants | Emissions | | | | | | | | | | Emission Factor lb/ton | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inlet | | | | Outlet | | | | | Removal % | | |
| | 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 | | | | | 0.0036<br>0.0020<br>0.0029<br>0.0028 | 0<br>0<br>0<br>0 | | | 6.37<br>3.58<br>4.98<br>4.98 | | | 0.05<br>0.03<br>0.04<br>0.04 |
| Sulfate | | | | | | | | | | | | |
| $SO_2$ | | | | | | | | | | | | |
| $NO_x$ as $NO_2$ (dry) | | | | | | | | | | | | |
| HC | | | | | | | | | | | | |

See below

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. → Assumed to be clinker!

Since above emission factors include impinger catch — a correction is necessary

∴ Subtracting impinger catch from total mass collected

Test No. 1: $\frac{0.05 \text{ lbs/ton}}{X \text{ lbs/ton}} = \frac{10.39 \text{ mg (w/impingers)}}{10.29 \text{ mg (wo/impingers)}}$ (Impinger catch from p. 5-5)

$X = 0.05$ lbs/ton

Test No. 2: No correction req'd

Test No. 3: $\frac{0.04 \text{ lbs/ton}}{X \text{ lbs/ton}} = \frac{7.79 \text{ mg}}{7.29 \text{ mg}}$ ← from p. 5-5 of report

$X = 0.04$ lbs/ton

∴ Above average is still correct!

$$\overline{EF} = 0.04 \frac{\text{lbs. part}}{\text{ton clinker}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}} = 0.02 \frac{\text{kg}}{\text{Mg cement}}$$

- Lehigh Cement Source Emissions Survey (Reference 48)

(1) Unspecified clinker cooler w/ gravel bed filter

From page 6 of test report:

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 | 40,434 |
| % 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 | 0.0170 | 0.0100 |
| grains/cf @ Stack Conditions | 0.0160 | 0.0135 | 0.0079 |
| lbs/hr | 7.7 | 6.6 | 3.8 |

Average = 6.0 lbs/hr.

From Appendix F of test report:

Kiln Parameters During Clinker Cooler (Gravel Bed) Stack Tests 8/3

| Test # | 1 | 2 | 3 |
|---|---|---|---|
| Feed Screw Revs. | 880 | 793 | 897 |
| Coal Usage | 7.44 Tons | 7.75 Tons | 7.36 |
| 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 |

} Average = 36.3 TPH clinker

$$\overline{EF} = 6.0 \frac{\text{lbs. part}}{\text{hr.}} \times \frac{1 \text{ hr.}}{36.3 \text{ tons clinker}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}}$$

$= 0.079$ kg part / Mg cement

- Mojave Annual Compliance Test (Reference 50)

(1) Unspecified cooler w/ baghouse

From page A-16 of test report:

TABLE A-3. SUMMARY OF SOURCE EMISSION TEST DATA

UNIT TESTED: Clinker Cooler LOCATION: Baghouse Outlet

| | 1 | 2 | 3 | Average |
|---|---|---|---|---|
| Test number | 1 | 2 | 3 | |
| 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 (ft²) | 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) | 0.0016 | 0.0014 | 0.0014 | 0.0015 |
| Total particulate (gr/dscf) | 0.0016 | 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 |

Average w/o impinger catch

From summary on page i of test report:

Average feedrate = 250 TPH Clinker

$$\therefore \overline{EF} = 1.8 \frac{\text{lbs. part.}}{\text{hr.}} \times \frac{1 \text{ hr.}}{250 \text{ tons clinker}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}}$$

$$= 3.4(10)^{-3} \text{ kg part./Mg cement}$$

- Lehigh Particulate Compliance Test (Reference 51)

(1) Grate-type cooler w/ cyclone + gravel bed filter

EPA Method 5 Tests @ gravel bed outlet

From Calculation Sheets in Appendix 3 for Runs 8, 9 & 10:

$$\text{Average emission rate} = \frac{73.35 + 33.92 + 49.90}{3} \frac{\text{lbs part}}{\text{hr}}$$

$$= 54.22 \text{ lbs/hr.}$$

(9)

From Process Records in Appendix D: Tests 8-10

Average kiln feedrate = $\frac{154 + 163 + 155}{3}$ $\frac{\text{short tons}}{\text{hr}}$

= 157 tons/hr. to kiln

$\therefore$ $54.22 \frac{\text{lbs part}}{\text{hr.}} \times \frac{1 \text{ hr.}}{157 \text{ tons feed}} \times 1.7 \frac{\text{tons feed}}{\text{ton cement}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.293$ kg/Mg cement

(assumes cooler prod. = kiln prod.)

- Mojave Annual Compliance Test - 1985 (Reference 53)

(1) Grate-type clinker cooler w/ baghouse

EPA Method 5 Tests (including impinger catch)

From p. A-13 of test report:

TEST 1, 2, 3

LOCATION Clinker

EMISSION RATE DATA -- 68°F

Standard Temperature, $T_s$ = 68°F; 29.52 inches Hg

| | Test 1 | Test 2 | Test 3 | Average |
|---|---|---|---|---|
| SEQ FF | | | | |
| SEQ RAT | | | | |
| ENTER: R-17 $V_{m,std}$ | 65.0182 | 66.0804 | 64.6381 | |
| R-26 $Q_s$ | 169535.53 | 186000.70 | 173420.76 | |
| R-22 $O_2$ | 20.9 | 20.9 | 20.9 | |
| LAB DATA | | | | |
| Front Half Wash (g) | 0.0004 | 0.00046 | 0.00023 | |
| Mass Filter (g) | 0.0246 | 0.0058 | 0.0057 | |
| Back Half Catch (g) | 0.0000 | 0.0000 | 0.0000 | |
| 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 | | | | |

Average emission rate w/o impinger catch

From Summary of Source Test Results:

(10)

SUMMARY OF SOURCE TEST RESULTS

Company CalMat Company Test Date 05/15/85 APCD No. 10030274 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 | | | |
| | gr/scf | @ 12% $CO_2$ | $ppm_v$ | | gr/scf | @ 12% $CO_2$ | $ppm_v$ | @ 3% $O_2$ | | | Inlet | Outlet |
| Particulate | | | | | 0.0024<br>0.0023<br>0.0024<br>0.0024 | | | | 2.66<br>3.6[illegible]<br>2.71<br>2.66 | | | 0.0200<br>0.0200<br>0.0198<br>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 1 132.73 TPH
Test 2 130.92 TPH
Test 3 136.68 TPH

Assume clinker feed to cooler!

Average feedrate = $\frac{132.73 + 130.92 + 136.68}{3}$ $\frac{\text{tons clinker}}{\text{hr.}}$

= 133.46 tons/hr.

$\therefore 2.66 \frac{\text{lbs part}}{\text{hr.}} \times \frac{1 \text{ hr}}{133.46 \text{ tons clinker}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{Mg}} \times \frac{1 \text{ Mg clinker}}{1.05 \text{ Mg cement}} =$

$0.00949 \frac{\text{kg part}}{\text{Mg cement}} =$

Finish Mill System (Includes Mill, Air Separators, Elevators & Weigh Feeders):

- Report 71-MM-04: Finish Mill on Wet Process (Reference 12)
  - No. 1 Mill Air Separator Baghouse A – From Table 1, page 5

Run # 1 = 0.0130 lbs/short ton cement
Run # 2 = 0.0255 " " " "
Run # 3 = 0.0245 " " " "

Average = 0.0210 " " " "

$$0.021 \frac{\text{lbs. part.}}{\text{short ton cement}} \times 1.102 \frac{\text{short tons}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.0105 \frac{\text{kg}}{\text{M}}$$

  - No. 1 Mill Air Separator Baghouse B – From Table 2, page 6 of

Run # 1 = 0.0214 lbs/short ton cement
Run # 2 = 0.0163 " " " "
Run # 3 = 0.0164 " " " "

Average = 0.0181 " " " "

$$0.0181 \frac{\text{lbs. part.}}{\text{short ton cement}} \times 1.102 \frac{\text{short tons}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.00906 \frac{\text{kg}}{\text{M}}$$

  - No. 1 Mill (and Elevator) Baghouse – From Table 3, page 7 of report

Run # 1 = 0.0135 lbs/short ton cement
Run # 2 = 0.0133 " " " "
Run # 3 = 0.0134 " " " "

Average = 0.0134 " " " "

$$0.0134 \frac{\text{lbs. part}}{\text{short ton cement}} \times 1.102 \frac{\text{short tons}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.0067 \frac{\text{k}}{\text{M}}$$

$$\text{Total System} = \underset{(\text{Bhouse A})}{0.0105} + \underset{(\text{Bhouse B})}{0.00906} + \underset{(\text{Mill + Elev.})}{0.0067} = 0.0263 \frac{\text{kg part.}}{\text{Mg cement}}$$

- Report 71-MM-06: No. 2 Finish Mill System w/ Baghouse (includes mill, air separators, and feeder) – Wet Process. (Reference 14)

From Table 2, page 6 of test report:

Run #1 = 0.0152 lbs/short ton cement
Run #2 = 0.0201 " " " "
Run #3 = 0.0120 " " " "

Average = 0.0158 " " " "

$$0.0158 \frac{\text{lbs. part.}}{\text{short ton cement}} \times 1.102 \frac{\text{short tons}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.0079 \frac{\text{kg P}}{\text{Mg cem}}$$

- Report 71-MM-02 – Ball Mill w/ Baghouses on Wet Proc (Reference 17)

– No. 2 Finish Mill BHouse – Per Table 4, page 5 of rep

Run # 2 = 0.00601 lbs/short ton cement
Run # 3 = 0.00601 " " " "

Average = 0.00601 " " " "

$$0.00601 \frac{\text{lbs part.}}{\text{short ton cement}} \times 1.102 \frac{\text{short tons}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.00301 \frac{\text{kg}}{\text{M}}$$

– No. 2 Mill Air Separator Baghouse – Per Table 5, page 6 of repo

Run #1 = 0.0173 lbs/short ton cement
Run #2 = 0.0164 " " " "

Average = 0.0169 " " " "

$$0.0169 \frac{\text{lbs. part.}}{\text{short ton cement}} \times 1.102 \frac{\text{short tons}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.00846 \frac{\text{kg}}{\text{M}}$$

— No. 2 Mill Weigh Feeder Baghouse – Per Table 6, page 7 of repo

Run #1 = 0.00953 lbs/short ton cement
Run #2 = 0.00922 " " " "

Average = 0.00938 " " " "

$$0.00938 \frac{\text{lbs. part}}{\text{short ton cement}} \times 1.102 \frac{\text{short tons}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.00469 \frac{\text{kg}}{\text{Mg}}$$

$$\therefore \text{Total System} = \underset{(\text{Mill})}{0.00301} + \underset{(\text{Air Sep})}{0.00846} + \underset{(\text{Feeder})}{0.00469} = 0.0162 \frac{\text{kg}}{\text{Mg}}$$

## Raw Mill System:

- Report 71-MM-02: No. 2 Raw Ball Mill – Dry Process Pla (Reference 17)

— No. 2 Raw Mill Baghouse – From Table 1, page 2 of repor

Run #1 = 0.0161 lbs/short ton raw material
Run #2 = 0.0183 " " " " "

Average = 0.0172 " " " " "

$$0.0172 \frac{\text{lbs. part.}}{\text{short ton}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.00861 \frac{\text{kg part}}{\text{Mg raw mat'l}}$$

Assuming: 1.7 Mg raw mat'l / Mg cement (per p.17 of EPA-600/2-77-023

$$\therefore 0.00861 \frac{\text{kg part}}{\text{Mg raw mat'l}} \times 1.7 \frac{\text{Mg raw mat'l}}{\text{Mg cement}} = 0.0146 \frac{\text{kg part}}{\text{Mg cement}}$$

— No. 2 Mill Air Separator Baghouse – From Table 2, page 3 of re

Run #1 = 0.0376 lbs/short ton raw material
Run #2 = 0.0265 " " " " "

Average = 0.0321 " " " " "

$$0.0321 \frac{\text{lbs. part.}}{\text{short ton}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.0161 \frac{\text{kg part}}{\text{Mg feed}}$$

$$0.0161 \frac{\text{kg part.}}{\text{Mg raw mat'l}} \times 1.7 \frac{\text{Mg raw mat'l}}{\text{Mg cement}} = 0.0274 \frac{\text{kg part}}{\text{Mg cement}}$$

— No. 2 Mill Weigh Feed Baghouse – From Table 3, page 4

Run #1 = 0.0226 lbs/short ton raw material
Run #2 = 0.0153 " " " " "

Average = 0.019 " " " " "

$$0.019 \frac{\text{lbs. part.}}{\text{short ton}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.00951 \frac{\text{kg part}}{\text{Mg feed}}$$

$$0.00951 \frac{\text{kg part.}}{\text{Mg raw mat'l}} \times 1.7 \frac{\text{Mg raw mat'l}}{\text{Mg cement}} = 0.0162 \frac{\text{kg part}}{\text{Mg cement}}$$

$\therefore$ Total System = 0.0146 + 0.0274 + 0.0162 = 0.0582 kg. par / Mg cem

= 0.00861 + 0.0161 + 0.00951 = 0.0342 kg/Mg raw ma

<u>Crushing and Screening:</u>

- Report 74-STN-1 : From summary Table 1, page 5 of repo (Reference 18)
  - Primary Limestone Crusher Baghouse:

$$0.00101 \frac{\text{lbs. part.}}{\text{short ton stone}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.000505 \frac{\text{kg}}{\text{M}}$$

— Primary Screen Baghouse:

$$0.00022 \frac{\text{lbs. part.}}{\text{short ton stone}} \times 1.102 \frac{\text{short ton}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.00011 \frac{\text{kg}}{\text{Mg}}$$

(15)

— Overland Conveyor Transfer Station Baghouse:

$$0.00003 \frac{\text{lbs. part.}}{\text{short ton stone}} \times 1.102 \frac{\text{short tons}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.00002 \frac{\text{k}}{\text{M}}$$

— Secondary Screen & Crusher Baghouse:

$$0.00031 \frac{\text{lbs. part.}}{\text{short ton stone}} \times 1.102 \frac{\text{short tons}}{\text{Mg}} \times 0.454 \frac{\text{kg}}{\text{lb}} = 0.00016 \frac{\text{kg}}{\text{M}}$$

# APPENDIX E

## COMPUTER PRINTOUTS OF SPLINE ANALYSES FOR PARTICLE SIZE DISTRIBUTIONS

## RESULTS OF SPLINE ANALYSES FOR 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.

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/27 1320 CLINKER COOLER UNCONT

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .63 | 13.5 | .382538 |
| .87 | 2.42 | .451112 |
| 1.4 | 4.84 | .588259 |
| 3.1 | 20.7 | 1.17482 |
| 4.7 | 28.6 | 1.98523 |
| 200 | 3459 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = 8.84 LB/T ( 4.42 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | .381043 | .0336842 | .0168421 |
| 1 | .483183 | .0427134 | .0213567 |
| 1.25 | .547183 | .0483709 | .0241855 |
| 2.5 | .936927 | .0828244 | .0414122 |
| 5 | 2.26136 | .199904 | .0999522 |
| 10 | 10.0105 | .88493 | .442465 |
| 15 | 22.069 | 1.9509 | .97545 |
| 20 | 33.9584 | 3.00192 | 1.50096 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/28 0950 CLINKER COOLER UNCONT.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .63 | 4.65 | .168622 |
| .87 | .48 | .186029 |
| 1.4 | 1.11 | .22628 |
| 3.1 | 5.2 | .414848 |
| 4.7 | 9.2 | .748466 |
| 200 | 2737 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = 8.84 LB/T ( 4.42 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | .168274 | .0148754 | 7.4377E-03 |
| 1 | .194842 | .017224 | 8.61202E-03 |
| 1.25 | .213681 | .0188894 | 9.44469E-03 |
| 2.5 | .330523 | .0292182 | .0146091 |
| 5 | .902135 | .0797488 | .0398744 |
| 10 | 6.87334 | .607604 | .303802 |
| 15 | 19.1685 | 1.69449 | .847246 |
| 20 | 32.3749 | 2.86194 | 1.43097 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/28 1105 CLINKER COOLER UNCONT.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .63 | 3.84 | .0897628 |
| .87 | .52 | .101918 |
| 1.4 | 2.66 | .164098 |
| 3.1 | 7.82 | .346896 |
| 4.7 | 11.1 | .606367 |
| 200 | 4252 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = 8.84 LB/T ( 4.42 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | .0896615 | 7.92608E-03 | 3.96304E-03 |
| 1 | .116167 | .0102692 | 5.13459E-03 |
| 1.25 | .146178 | .0129221 | 6.46107E-03 |
| 2.5 | .273728 | .0241976 | .0120988 |
| 5 | .738515 | .0652847 | .0326424 |
| 10 | 6.27328 | .554558 | .277279 |
| 15 | 18.5191 | 1.63709 | .818544 |
| 20 | 32.0187 | 2.83045 | 1.41522 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/28 1440 CLINKER COOLER UNCONT.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .63 | 13.5 | .63287 |
| .87 | 2.64 | .756631 |
| 1.4 | 3.26 | .909457 |
| 3.1 | 6.44 | 1.21136 |
| 4.7 | 9.3 | 1.64734 |
| 200 | 2098 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = 8.84 LB/T ( 4.42 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | .629739 | .0556689 | .0278345 |
| 1 | .801271 | .0708324 | .0354162 |
| 1.25 | .872015 | .0770861 | .038543 |
| 2.5 | 1.08396 | .0958217 | .0479108 |
| 5 | 1.86134 | .164543 | .0822714 |
| 10 | 8.43077 | .745281 | .37264 |
| 15 | 20.0571 | 1.77305 | .886523 |
| 20 | 32.1942 | 2.84597 | 1.42298 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/29 1015 CLINKER COOLER UNCONT.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .63 | 6.89 | .251287 |
| .87 | 2.04 | .325689 |
| 1.4 | 2.31 | .409938 |
| 3.1 | 7.44 | .681284 |
| 4.7 | 12.2 | 1.12623 |
| 200 | 2711 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = 8.84 LB/T ( 4.42 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | .24942 | .0220488 | .0110244 |
| 1 | .348808 | .0308347 | .0154173 |
| 1.25 | .387148 | .0342239 | .017112 |
| 2.5 | .563013 | .0497703 | .0248852 |
| 5 | 1.3178 | .116493 | .0582467 |
| 10 | 7.79999 | .689519 | .34476 |
| 15 | 19.8807 | 1.75745 | .878725 |
| 20 | 32.5291 | 2.87557 | 1.43778 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/29 1400 CLINKER COOLER UNCONT.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .63 | 1.43 | .0662341 |
| .87 | .42 | .0856874 |
| 1.4 | 2.42 | .197776 |
| 3.1 | 9.34 | .630382 |
| 4.7 | 14.4 | 1.29735 |
| 200 | 2131 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = 8.84 LB/T ( 4.42 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | .0660233 | 5.83646E-03 | 2.91823E-03 |
| 1 | .108576 | 9.59815E-03 | 4.79907E-03 |
| 1.25 | .162436 | .0143593 | 7.17967E-03 |
| 2.5 | .451709 | .039931 | .0199655 |
| 5 | 1.53142 | .135378 | .0676888 |
| 10 | 8.99977 | .795579 | .39779 |
| 15 | 21.502 | 1.90078 | .950389 |
| 20 | 33.9387 | 3.00018 | 1.50009 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 11/4 1100 CLINKER COOLER UNCONT.

INPUT DATA:

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .63 | 1.54 | .0614437 |
| .87 | .12 | .0662315 |
| 1.4 | 2.4 | .161988 |
| 3.1 | 9.5 | .541024 |
| 4.7 | 18.8 | 1.29112 |
| 109 | 2474 | 100 |

OUTPUT DATA:

| CUT (umA) | CUM. % < CUT |
|---|---|
| .625 | .0613896 |
| 1 | .0844318 |
| 1.25 | .130475 |
| 2.5 | .373483 |
| 5 | 1.58744 |
| 10 | 12.828 |
| 15 | 31.2133 |
| 20 | 47.3594 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 11/4 1430 CLINKER COOLER UNCONT.

INPUT DATA:

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .63 | 1.47 | .0745323 |
| .87 | .53 | .101404 |
| 1.4 | 3.7 | .289003 |
| 3.1 | 10.7 | .831517 |
| 4.7 | 14.9 | 1.58698 |
| 200 | 1941 | 100 |

OUTPUT DATA:

| CUT (umA) | CUM. % < CUT |
|---|---|
| .625 | .0742731 |
| 1 | .13809 |
| 1.25 | .229001 |
| 2.5 | .620457 |
| 5 | 1.84401 |
| 10 | 9.52588 |
| 15 | 21.8592 |
| 20 | 34.034 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 11/4 1435 CLINKER COOLER UNCONT.

INPUT DATA:

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .63 | 1.52 | .0836705 |
| .87 | .67 | .120552 |
| 1.4 | 2.53 | .259819 |
| 3.1 | 8.53 | .729365 |
| 4.7 | 12.4 | 1.41194 |
| 200 | 1791 | 100 |

OUTPUT DATA:

| CUT (umA) | CUM. % < CUT |
|---|---|
| .625 | .0830518 |
| 1 | .15098 |
| 1.25 | .217659 |
| 2.5 | .540163 |
| 5 | 1.65195 |
| 10 | 9.10763 |
| 15 | 21.4794 |
| 20 | 33.8098 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 11/5 0935 CLINKER COOLER UNCONT.

INPUT DATA:

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .63 | 1.37 | .0568387 |
| .87 | .23 | .066381 |
| 1.4 | 1.12 | .112848 |
| 3.1 | 14.5 | .714425 |
| 4.7 | 9.11 | 1.09238 |
| 200 | 2384 | 100 |

OUTPUT DATA:

| CUT (umA) | CUM. % < CUT |
|---|---|
| .625 | .05674 |
| 1 | .0743156 |
| 1.25 | .0957273 |
| 2.5 | .479315 |
| 5 | 1.27271 |
| 10 | 7.41557 |
| 15 | 19.3026 |
| 20 | 31.9932 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 11/5 0930 CLINKER COOLER UNCONT.

INPUT DATA:

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .63 | .69 | .0278546 |
| .87 | .03 | .0290657 |
| 1.4 | 1.32 | .0823527 |
| 3.1 | 7.51 | .385524 |
| 4.7 | 14.6 | .974911 |
| 200 | 2453 | 100 |

OUTPUT DATA:

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | .0278407 | 2.0268E-03 | 1.0134E-03 |
| 1 | .0382794 | 2.78674E-03 | 1.39337E-03 |
| 1.25 | .0636172 | 4.63133E-03 | 2.31566E-03 |
| 2.5 | .248899 | .0181198 | 9.05991E-03 |
| 5 | 1.18597 | .0863383 | .0431692 |
| 10 | 8.64826 | .629593 | .314797 |
| 15 | 21.5816 | 1.57114 | .78557 |
| 20 | 34.3767 | 2.50263 | 1.25131 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 11/5 1415 CLINKER COOLER UNCONT.

INPUT DATA:

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .63 | 11.2 | .24079 |
| .87 | 4.37 | .334742 |
| 1.4 | 3.31 | .405904 |
| 3.1 | 7.97 | .577252 |
| 4.7 | 17.5 | .953487 |
| 200 | 4607 | 100 |

OUTPUT DATA:

| CUT (umA) | CUM. % < CUT |
|---|---|
| .625 | .238355 |
| 1 | .35747 |
| 1.25 | .388784 |
| 2.5 | .524195 |
| 5 | 1.12431 |
| 10 | 7.30849 |
| 15 | 19.4183 |
| 20 | 32.297 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 11/5 1415 CLINKER COOLER UNCONT.

INPUT DATA:

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .63 | 14.4 | .336123 |
| .87 | 3.42 | .415953 |
| 1.4 | 4.02 | .509787 |
| 3.1 | 10.6 | .757212 |
| 4.7 | 19.7 | 1.21705 |
| 200 | 4232 | 100 |

OUTPUT DATA:

| CUT (umA) | CUM. % < CUT |
|---|---|
| .625 | .334103 |
| 1 | .442371 |
| 1.25 | .485414 |
| 2.5 | .641642 |
| 5 | 1.41512 |
| 10 | 7.96363 |
| 15 | 19.9808 |
| 20 | 32.525 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/25 1440 CLINKER COOLER CONTR.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .58 | 1.49 | 5.97195 |
| .82 | .96 | 9.81964 |
| 1.35 | 2.13 | 18.3567 |
| 2.9 | 4.41 | 36.0321 |
| 4.4 | 4.83 | 55.3908 |
| 6.2 | 2.9 | 67.014 |
| 10.1 | 2.57 | 77.3146 |
| 14.3 | 2.77 | 88.4168 |
| 200 | 2.89 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .284 LB/T ( .142 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 6.6775 | .0189641 | 9.48205E-03 |
| 1 | 12.805 | .0363661 | .0181831 |
| 1.25 | 16.8045 | .0477249 | .0238624 |
| 2.5 | 31.4062 | .0891936 | .0445968 |
| 5 | 60.0893 | .170654 | .0853268 |
| 10 | 77.207 | .219268 | .109634 |
| 15 | 89.6819 | .254697 | .127348 |
| 20 | 96.1154 | .272968 | .136484 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/25 1440 CLINKER COOLER CONTR.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .58 | 1.32 | 8.95522 |
| .82 | .15 | 9.97286 |
| 1.35 | 1.56 | 20.5563 |
| 2.9 | 3.07 | 41.384 |
| 4.4 | 1.76 | 53.3243 |
| 6.2 | .9 | 59.4301 |
| 10.1 | .45 | 62.4831 |
| 14.3 | 2.74 | 81.0719 |
| 200 | 2.79 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .284 LB/T ( .142 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 9.10535 | .0258592 | .0129296 |
| 1 | 13.2698 | .0376862 | .0188431 |
| 1.25 | 18.4785 | .052479 | .0262395 |
| 2.5 | 37.1069 | .105384 | .0526918 |
| 5 | 55.955 | .158912 | .0794561 |
| 10 | 63.5517 | .180487 | .0902434 |
| 15 | 83.2171 | .236336 | .118168 |
| 20 | 94.8029 | .26924 | .13462 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/26 1119 CLINKER COOLER CONTR.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .58 | .21 | .861009 |
| .82 | .94 | 4.71505 |
| 1.35 | 3.36 | 18.4912 |
| 2.9 | 4.21 | 35.7524 |
| 4.4 | 5.97 | 60.2296 |
| 6.2 | 3.55 | 74.7848 |
| 10.1 | 2.19 | 83.7639 |
| 14.3 | 1.57 | 90.2009 |
| 200 | 2.39 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .284 LB/T ( .142 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 1.30917 | 3.71804E-03 | 1.85902E-03 |
| 1 | 9.01402 | .0255998 | .0127999 |
| 1.25 | 15.7058 | .0446046 | .0223023 |
| 2.5 | 31.1306 | .088411 | .0442055 |
| 5 | 66.2842 | .188247 | .0941236 |
| 10 | 83.6507 | .237568 | .118784 |
| 15 | 90.9626 | .258334 | .129167 |
| 20 | 94.9789 | .26974 | .13487 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/26 1124 CLINKER COOLER CONTR.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .58 | .33 | 1.14345 |
| .82 | .71 | 3.6036 |
| 1.35 | 2.33 | 11.6771 |
| 2.9 | 5.46 | 30.596 |
| 4.4 | 6.45 | 52.9453 |
| 6.2 | 4.47 | 68.4338 |
| 10.1 | 3.06 | 79.0367 |
| 14.3 | 2.24 | 86.7983 |
| 200 | 3.81 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .284 LB/T ( .142 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 1.4989 | 4.25689E-03 | 2.12844E-03 |
| 1 | 6.08288 | .0172754 | 8.63769E-03 |
| 1.25 | 10.0044 | .0284126 | .0142063 |
| 2.5 | 25.5287 | .0725014 | .0362507 |
| 5 | 59.2083 | .168152 | .0840758 |
| 10 | 78.8946 | .224061 | .11203 |
| 15 | 87.7345 | .249166 | .124583 |
| 20 | 92.7485 | .263406 | .131703 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/26 1515 CLINKER COOLER CONTR.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .58 | 10.2 | 22.0207 |
| .82 | .97 | 24.1149 |
| 1.35 | 2.38 | 29.253 |
| 2.9 | 6.09 | 42.4007 |
| 4.4 | 7.64 | 58.8947 |
| 6.2 | 4.75 | 69.1494 |
| 10.1 | 2.86 | 75.3238 |
| 14.3 | 2.34 | 80.3757 |
| 200 | 9.09 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .284 LB/T ( .142 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 22.3893 | .0635856 | .0317928 |
| 1 | 25.8958 | .0735442 | .0367721 |
| 1.25 | 28.3023 | .0803785 | .0401893 |
| 2.5 | 38.6325 | .109716 | .0548582 |
| 5 | 63.1635 | .179384 | .0896922 |
| 10 | 75.2504 | .213711 | .106856 |
| 15 | 81.0395 | .230152 | .115076 |
| 20 | 84.8653 | .241017 | .120509 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/26 1515 CLINKER COOLER CONTR.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .58 | 1.1 | 2.98832 |
| .82 | 1.52 | 7.11763 |
| 1.35 | 3.11 | 15.5664 |
| 2.9 | 6.14 | 32.2467 |
| 4.4 | 6.21 | 49.1171 |
| 6.2 | 3.9 | 59.712 |
| 10.1 | 3.42 | 69.003 |
| 14.3 | 2.54 | 75.9033 |
| 200 | 8.87 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .284 LB/T ( .142 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 3.6858 | .0104677 | 5.23383E-03 |
| 1 | 10.0951 | .0286702 | .0143351 |
| 1.25 | 14.0287 | .0398415 | .0199208 |
| 2.5 | 28.0358 | .0796217 | .0398109 |
| 5 | 53.3807 | .151601 | .0758006 |
| 10 | 68.8504 | .195535 | .0977676 |
| 15 | 76.8012 | .218115 | .109058 |
| 20 | 81.9322 | .232688 | .116344 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/27 1100 CLINKER COOLER CONTR.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .58 | .93 | 2.12669 |
| .82 | 1.54 | 5.6483 |
| 1.35 | 3.48 | 13.6062 |
| 2.9 | 7.16 | 29.9794 |
| 4.4 | 7.8 | 47.8162 |
| 6.2 | 4.37 | 57.8093 |
| 10.1 | 3.14 | 64.9897 |
| 14.3 | 3.31 | 72.5589 |
| 200 | 12 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .284 LB/T ( .142 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 2.69324 | 7.6488E-03 | 3.8244E-03 |
| 1 | 8.37621 | .0237884 | .0118942 |
| 1.25 | 12.1146 | .0344056 | .0172028 |
| 2.5 | 25.7293 | .0730711 | .0365356 |
| 5 | 51.9623 | .147573 | .0737865 |
| 10 | 64.9145 | .184357 | .0921786 |
| 15 | 73.5565 | .208901 | .10445 |
| 20 | 79.3079 | .225234 | .112617 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/27 1150 CLINKER COOLER CONTR.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .58 | 1.43 | 3.30942 |
| .82 | 1.41 | 6.57255 |
| 1.35 | 4.14 | 16.1537 |
| 2.9 | 7.5 | 33.5108 |
| 4.4 | 6.31 | 48.1139 |
| 6.2 | 5.21 | 60.1713 |
| 10.1 | 3.93 | 69.2664 |
| 14.3 | 5.3 | 81.5321 |
| 200 | 7.98 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .284 LB/T ( .142 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 3.85397 | .0109453 | 5.47264E-03 |
| 1 | 9.72082 | .0276071 | .0138036 |
| 1.25 | 14.3243 | .0406809 | .0203405 |
| 2.5 | 29.4809 | .0837257 | .0418629 |
| 5 | 52.8883 | .150203 | .0751013 |
| 10 | 69.2193 | .196583 | .0982914 |
| 15 | 83.0278 | .235799 | .1179 |
| 20 | 91.0638 | .258621 | .129311 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/27 1515 CLINKER COOLER CONTR.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .58 | 1.54 | 4.07407 |
| .82 | 1.77 | 8.75662 |
| 1.35 | 4.36 | 20.291 |
| 2.9 | 7.43 | 39.9471 |
| 4.4 | 5.56 | 54.6561 |
| 6.2 | 4.02 | 65.291 |
| 10.1 | 2.89 | 72.9365 |
| 14.3 | 2.83 | 80.4233 |
| 200 | 7.4 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .284 LB/T ( .142 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 4.86637 | .0138205 | 6.91024E-03 |
| 1 | 12.703 | .0360766 | .0180383 |
| 1.25 | 18.1678 | .0515964 | .0257982 |
| 2.5 | 35.5927 | .101083 | .0505416 |
| 5 | 58.9552 | .167433 | .0837164 |
| 10 | 72.8557 | .20691 | .103455 |
| 15 | 81.372 | .231096 | .115548 |
| 20 | 86.6657 | .24613 | .123065 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/27 1515 CLINKER COOLER CONTR.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .58 | .9 | 2.26472 |
| .82 | 1.47 | 5.96377 |
| 1.35 | 4.01 | 16.0544 |
| 2.9 | 6.99 | 33.6437 |
| 4.4 | 7.11 | 51.535 |
| 6.2 | 3.12 | 59.386 |
| 10.1 | 2.48 | 65.6266 |
| 14.3 | 2.26 | 71.3136 |
| 200 | 11.4 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .284 LB/T ( .142 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 2.8458 | 8.08207E-03 | 4.04104E-03 |
| 1 | 9.30074 | .0264141 | .0132071 |
| 1.25 | 14.1216 | .0401054 | .0200527 |
| 2.5 | 29.2995 | .0832104 | .0416052 |
| 5 | 54.8729 | .155839 | .0779195 |
| 10 | 65.5378 | .186127 | .0930637 |
| 15 | 72.0945 | .204748 | .102374 |
| 20 | 76.7437 | .217952 | .108976 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/28 1045 CLINKER COOLER CONTR.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .58 | 1.61 | 5.09171 |
| .82 | 1.15 | 8.72865 |
| 1.35 | 2.71 | 17.2992 |
| 2.9 | 5.17 | 33.6496 |
| 4.4 | 6.23 | 53.3523 |
| 6.2 | 3.17 | 63.3776 |
| 10.1 | 2.2 | 70.3352 |
| 14.3 | 2.22 | 77.3561 |
| 200 | 7.16 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .284 LB/T ( .142 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 5.74516 | .0163162 | 8.15812E-03 |
| 1 | 11.7048 | .0332415 | .0166208 |
| 1.25 | 15.7337 | .0446838 | .0223419 |
| 2.5 | 29.2474 | .0830626 | .0415313 |
| 5 | 57.5773 | .163519 | .0817597 |
| 10 | 70.2614 | .199542 | .0997711 |
| 15 | 78.2653 | .222274 | .111137 |
| 20 | 83.4329 | .236949 | .118475 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/28 1045 CLINKER COOLER CONTR.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .58 | 1.79 | 5.71702 |
| .82 | .88 | 8.52763 |
| 1.35 | 2.58 | 16.7678 |
| 2.9 | 5.35 | 33.855 |
| 4.4 | 4.4 | 47.908 |
| 6.2 | 4.35 | 61.8014 |
| 10.1 | 2.25 | 68.9876 |
| 14.3 | 1.97 | 75.2795 |
| 200 | 7.74 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .284 LB/T ( .142 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 6.20215 | .0176141 | 8.80706E-03 |
| 1 | 11.2987 | .0320884 | .0160442 |
| 1.25 | 15.2334 | .0432627 | .0216314 |
| 2.5 | 29.8337 | .0847277 | .0423639 |
| 5 | 53.4467 | .151789 | .0758943 |
| 10 | 68.926 | .19575 | .0978749 |
| 15 | 76.1115 | .216157 | .108078 |
| 20 | 80.9371 | .229861 | .114931 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/28 1415 CLINKER COOLER CONTR.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .58 | 5.73 | 15.4074 |
| .82 | 1.92 | 20.57 |
| 1.35 | 3 | 28.6367 |
| 2.9 | 5.57 | 43.6139 |
| 4.4 | 5.26 | 57.7575 |
| 6.2 | 3.25 | 66.4964 |
| 10.1 | 2.6 | 73.4875 |
| 14.3 | 2.14 | 79.2417 |
| 200 | 7.72 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .284 LB/T ( .142 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 16.4663 | .0467642 | .0233821 |
| 1 | 23.6295 | .0671077 | .0335538 |
| 1.25 | 27.2883 | .0774988 | .0387494 |
| 2.5 | 39.9041 | .113328 | .0566639 |
| 5 | 61.3235 | .174159 | .0870793 |
| 10 | 73.3873 | .20842 | .10421 |
| 15 | 79.9919 | .227177 | .113588 |
| 20 | 84.2833 | .239365 | .119682 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/28 1415 CLINKER COOLER CONTR.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .58 | 4.67 | 13.3276 |
| .82 | 1.53 | 17.6941 |
| 1.35 | 2.7 | 25.3995 |
| 2.9 | 6.67 | 44.4349 |
| 4.4 | 4.88 | 58.3619 |
| 6.2 | 3.68 | 68.8642 |
| 10.1 | 2.26 | 75.3139 |
| 14.3 | 2.96 | 83.7614 |
| 200 | 5.69 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .284 LB/T ( .142 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 14.1999 | .0403277 | .0201638 |
| 1 | 20.4602 | .0581069 | .0290535 |
| 1.25 | 24.0315 | .0682494 | .0341247 |
| 2.5 | 40.0748 | .113813 | .0569063 |
| 5 | 62.6498 | .177925 | .0889627 |
| 10 | 75.2909 | .213826 | .106913 |
| 15 | 84.806 | .240849 | .120425 |
| 20 | 90.5017 | .257025 | .128512 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/29 1000 CLINKER COOLER CONTR.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .58 | 3.98 | 10.2869 |
| .82 | 1.7 | 14.6808 |
| 1.35 | 2.53 | 21.22 |
| 2.9 | 5.13 | 34.4792 |
| 4.4 | 5.77 | 49.3926 |
| 6.2 | 4.14 | 60.0931 |
| 10.1 | 3.11 | 68.1313 |
| 14.3 | 2.13 | 73.6366 |
| 200 | 10.2 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .284 LB/T ( .142 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 11.1847 | .0317644 | .0158822 |
| 1 | 17.1466 | .0486963 | .0243482 |
| 1.25 | 20.1058 | .0571006 | .0285503 |
| 2.5 | 30.9301 | .0878414 | .0439207 |
| 5 | 53.6993 | .152506 | .0762531 |
| 10 | 68.0011 | .193123 | .0965616 |
| 15 | 74.3824 | .211246 | .105623 |
| 20 | 78.7868 | .223755 | .111877 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/29 1000 CLINKER COOLER CONTR.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .58 | 3.82 | 12.2045 |
| .82 | 1.23 | 16.1342 |
| 1.35 | 2.57 | 24.345 |
| 2.9 | 5.21 | 40.9904 |
| 4.4 | 6.27 | 61.0224 |
| 6.2 | 3.05 | 70.7668 |
| 10.1 | 1.76 | 76.3898 |
| 14.3 | 1.6 | 81.5016 |
| 200 | 5.79 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .284 LB/T ( .142 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 12.9563 | .0367958 | .0183979 |
| 1 | 19.0967 | .0542347 | .0271173 |
| 1.25 | 22.9004 | .065037 | .0325185 |
| 2.5 | 36.4326 | .103469 | .0517343 |
| 5 | 65.2067 | .185187 | .0925936 |
| 10 | 76.3313 | .216781 | .10839 |
| 15 | 82.1678 | .233357 | .116678 |
| 20 | 85.9804 | .244184 | .122092 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/29 1400 CLINKER COOLER CONTR.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .58 | 1.27 | 7.53709 |
| .82 | 1.28 | 15.1335 |
| 1.35 | 2.3 | 28.7834 |
| 2.9 | 3.93 | 52.1068 |
| 4.4 | 1.55 | 61.3056 |
| 6.2 | 1.15 | 68.1306 |
| 10.1 | 1.17 | 75.0742 |
| 14.3 | 1.51 | 84.0356 |
| 200 | 2.69 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .284 LB/T ( .142 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 8.91414 | .0253162 | .0126581 |
| 1 | 20.1553 | .0572411 | .0286205 |
| 1.25 | 26.4484 | .0751136 | .0375568 |
| 2.5 | 47.8679 | .135945 | .0679725 |
| 5 | 63.9865 | .181722 | .0908608 |
| 10 | 75.0186 | .213053 | .106526 |
| 15 | 85.136 | .241786 | .120893 |
| 20 | 91.0908 | .258698 | .129349 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: REXNORD GRVL BED FLTR TEST 8/29 1400 CLINKER COOLER CONTR.

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .58 | 1.03 | 3.3409 |
| .82 | .93 | 6.35744 |
| 1.35 | 3.07 | 16.3153 |
| 2.9 | 6.1 | 36.1012 |
| 4.4 | 5.19 | 52.9355 |
| 6.2 | 3.35 | 63.8015 |
| 10.1 | 2.56 | 72.1051 |
| 14.3 | 1.68 | 77.5543 |
| 200 | 6.92 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .284 LB/T ( .142 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 3.8355 | .0108928 | 5.44641E-03 |
| 1 | 9.53263 | .0270727 | .0135363 |
| 1.25 | 14.36 | .0407823 | .0203911 |
| 2.5 | 31.4461 | .0893069 | .0446535 |
| 5 | 57.3494 | .162872 | .0814361 |
| 10 | 71.9675 | .204388 | .102194 |
| 15 | 78.2745 | .2223 | .11115 |
| 20 | 82.4492 | .234156 | .117078 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID:REXNORD GRVL BED FLTR TEST 11/3 1545 CLINKER COOLER CONTR.

INPUT DATA:

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .57 | 1.15 | 4.7817 |
| .79 | .96 | 8.77339 |
| 1.3 | 2.56 | 19.4179 |
| 2.8 | 9.45 | 58.711 |
| 4.2 | 8.01 | 92.0166 |
| 6 | .43 | 93.8046 |
| 9.8 | .4 | 95.4678 |
| 13.9 | .43 | 97.2557 |
| 200 | .66 | 100 |

OUTPUT DATA:

| CUT (umA) | CUM. % < CUT |
|---|---|
| .625 | 5.71449 |
| 1 | 12.9081 |
| 1.25 | 18.3125 |
| 2.5 | 50.9708 |
| 5 | 93.6688 |
| 10 | 95.5874 |
| 15 | 97.5884 |
| 20 | 98.6438 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID:REXNORD GRVL BED FLTR TEST 11/4 1130 CLINKER COOLER CONTR.

INPUT DATA:

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .57 | .57 | 6.97674 |
| .79 | 1.02 | 19.4614 |
| 1.3 | 2.58 | 51.0404 |
| 2.8 | 2.63 | 83.2313 |
| 4.2 | .64 | 91.0649 |
| 6 | .18 | 93.2681 |
| 9.8 | .19 | 95.5936 |
| 13.9 | .13 | 97.1848 |
| 200 | .23 | 100 |

OUTPUT DATA:

| CUT (umA) | CUM. % < CUT |
|---|---|
| .625 | 9.61859 |
| 1 | 32.9189 |
| 1.25 | 47.9794 |
| 2.5 | 79.9024 |
| 5 | 92.2836 |
| 10 | 95.696 |
| 15 | 97.4834 |
| 20 | 98.4505 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/92 V1

TEST ID:REXNORD GRVL BED FLTR TEST 11/4 1130 CLINKER COOLER CONTR.

INPUT DATA:

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .57 | .38 | 4.6285 |
| .79 | .68 | 12.9111 |
| 1.3 | 2.22 | 39.9513 |
| 2.8 | 3.36 | 80.877 |
| 4.2 | .92 | 92.0828 |
| 6 | .34 | 96.2241 |
| 9.8 | .16 | 98.173 |
| 13.9 | .14 | 99.8782 |
| 200 | .01 | 100 |

OUTPUT DATA:

| CUT (umA) | CUM. % < CUT |
|---|---|
| .625 | 6.32592 |
| 1 | 23.5358 |
| 1.25 | 37.0932 |
| 2.5 | 76.0017 |
| 5 | 94.4541 |
| 10 | 98.2987 |
| 15 | 100.05 |
| 20 | 100.425 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 01

TEST ID:REXNORD GRVL BED FLTR TEST 11/5 0945 CLINKER COOLER CONTR.

INPUT DATA:

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .57 | .97 | 8.16498 |
| .79 | .86 | 15.404 |
| 1.3 | 2.51 | 36.532 |
| 2.8 | 3.78 | 68.3502 |
| 4.2 | 1.16 | 78.1145 |
| 6 | .61 | 83.2492 |
| 9.8 | .51 | 87.5421 |
| 13.9 | .49 | 91.6667 |
| 200 | .99 | 100 |

OUTPUT DATA:

| CUT (umA) | CUM. % < CUT |
|---|---|
| .625 | |
| 1 | |
| 1.25 | |
| 2.5 | |
| 5 | |
| 10 | |
| 15 | |
| 20 | |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID:REXNORD GRVL BED FLTR TEST 11/5 0945 CLINKER COOLER CONTR.

INPUT DATA:

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW LOADING < CUT | CUM. % < CUT |
|---|---|---|
| .57 | 1.12 | 16.2319 |
| .79 | 1.03 | 31.1594 |
| 1.3 | 1.16 | 47.971 |
| 2.8 | .65 | 57.3913 |
| 4.2 | .2 | 60.2899 |
| 6 | .56 | 68.4058 |
| 9.8 | .38 | 73.9131 |
| 13.9 | .45 | 80.4348 |
| 200 | 1.35 | 100 |

OUTPUT DATA:

| CUT (umA) | CUM. % < CUT |
|---|---|
| .625 | 20.0986 |
| 1 | 39.8803 |
| 1.25 | 46.7291 |
| 2.5 | 56.4482 |
| 5 | 64.386 |
| 10 | 74.3669 |
| 15 | 81.7644 |
| 20 | 86.3878 |

END OF TEST SERIES

## RESULTS OF SPLINE ANALYSES FOR REFERENCE 26A AND 26B (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; and

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.

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: KVB/EPA TEST RUN 3-2 MULTICLONE OUTLET

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD./HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED SIZE DISTRIBUTION

| CUT(um) | CUM. % < CUT |
|---|---|
| .51 | .44 |
| .85 | .97 |
| 1.68 | 2 |
| 2.49 | 3.74 |
| 4.25 | 11.75 |
| 15 | 30.91 |
| 200 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = 249.2 LB/T ( 124.6 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | EMISSION FACTOR (KG/MT) |
|---|---|---|---|
| .625 | .618263 | 1.54071 | .770355 |
| 1 | 1.13034 | 2.8168 | 1.4084 |
| 1.25 | 1.40554 | 3.50261 | 1.7513 |
| 2.5 | 3.82099 | 9.5219 | 4.76095 |
| 5 | 14.3113 | 35.6637 | 17.8318 |
| 10 | 24.2585 | 60.4521 | 30.226 |
| 15 | 31.204 | 77.7603 | 38.8802 |
| 20 | 37.7452 | 94.0611 | 47.0305 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: KVB/EPA TEST RUN 9-1 KILN OUTLET

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD./HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED SIZE DISTRIBUTION

| CUT(um) | CUM. % < CUT |
|---|---|
| .37 | .01 |
| .59 | 1.52 |
| 1.13 | 3.32 |
| 1.66 | 6.65 |
| 2.81 | 14.85 |
| 15 | 50.35 |
| 200 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = 117 LB/T ( 58.5 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | EMISSION FACTOR (KG/MT) |
|---|---|---|---|
| .625 | 1.68966 | 1.9769 | .988451 |
| 1 | 2.95593 | 3.45844 | 1.72922 |
| 1.25 | 4.00466 | 4.68545 | 2.34272 |
| 2.5 | 12.6416 | 14.7907 | 7.39536 |
| 5 | 25.6618 | 30.0243 | 15.0122 |
| 10 | 40.3874 | 47.2533 | 23.6266 |
| 15 | 50.4207 | 58.9922 | 29.4961 |
| 20 | 58.021 | 67.8846 | 33.9423 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: KVB/EPA TEST RUN 9-2 KILN OUTLET

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD./HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED SIZE DISTRIBUTION

| CUT(um) | CUM. % < CUT |
|---|---|
| .38 | .5 |
| .6 | 2.3 |
| 1.13 | 5.4 |
| 1.66 | 11.3 |
| 2.81 | 22.9 |
| 15 | 52.8 |
| 200 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = 122.4 LB/T ( 61.2 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | EMISSION FACTOR (KG/MT) |
|---|---|---|---|
| .625 | 2.40487 | 2.94356 | 1.47178 |
| 1 | 4.50161 | 5.50997 | 2.75498 |
| 1.25 | 6.64121 | 8.12884 | 4.06442 |
| 2.5 | 19.9713 | 24.4449 | 12.2225 |
| 5 | 34.066 | 41.6968 | 20.8484 |
| 10 | 45.5373 | 55.7376 | 27.8688 |
| 15 | 53.0207 | 64.8974 | 32.4487 |
| 20 | 58.9687 | 72.1777 | 36.0889 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: KVB/EPA TEST 9-3 ESP INLET

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW % < CUT | CUM. % < CUT |
|---|---|---|
| 1 | 6.71 | 6.71 |
| 3 | 24.6 | 31.31 |
| 10 | 36.88 | 68.19 |
| 200 | 31.81 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = 81.72 LB/T ( 40.86 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 2.72561 | 2.22737 | 1.11368 |
| 1 | 6.71 | 5.48341 | 2.74171 |
| 1.25 | 9.78224 | 7.99405 | 3.99702 |
| 2.5 | 25.5771 | 20.9016 | 10.4508 |
| 5 | 46.1931 | 37.749 | 18.8745 |
| 10 | 68.0176 | 55.584 | 27.792 |
| 15 | 79.6645 | 65.1018 | 32.5509 |
| 20 | 86.3007 | 70.525 | 35.2625 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: KVB/EPA TEST 9-4 ESP INLET

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW % < CUT | CUM. % < CUT |
|---|---|---|
| 1 | 8.24 | 8.24 |
| 3 | 23.39 | 31.63 |
| 10 | 35.84 | 67.47 |
| 200 | 32.53 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = 72.9 LB/T ( 36.45 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 3.83047 | 2.79242 | 1.39621 |
| 1 | 8.24 | 6.00696 | 3.00348 |
| 1.25 | 11.3896 | 8.30304 | 4.15152 |
| 2.5 | 26.3925 | 19.2401 | 9.62006 |
| 5 | 45.9572 | 33.5028 | 16.7514 |
| 10 | 67.2939 | 49.0573 | 24.5286 |
| 15 | 78.7318 | 57.3955 | 28.6978 |
| 20 | 85.3165 | 62.1957 | 31.0979 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: KVB/EPA TEST 9-5 ESP OUTLET

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD./HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED SIZE DISTRIBUTION

| CUT(um) | CUM. % < CUT |
|---|---|
| 1 | 30.3639 |
| 3 | 96.4907 |
| 10 | 96.5007 |
| 200 | 100 |

PROCESS DATA NOT AVAILABLE;EMISSION FACTOR DIRECTLY INPUT

OUTPUT DATA: TP EMISSION FACTOR = .254 LB/T ( .127 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 28.564 | .0725526 | .0362763 |
| 1 | 41.137 | .104488 | .052244 |
| 1.25 | 47.545 | .120764 | .0603822 |
| 2.5 | 67.111 | .170462 | .085231 |
| 5 | 82.833 | .210396 | .105198 |
| 10 | 92.677 | .2354 | .1177 |
| 15 | 95.97 | .243764 | .121882 |
| 20 | 97.481 | .247602 | .123801 |

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

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: KVB/EPA TEST 9-6 ESP OUTLET

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD./HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED SIZE DISTRIBUTION

| CUT(um) | CUM. % < CUT |
|---|---|
| 1 | 25.7174 |
| 3 | 98.4502 |
| 10 | 98.4602 |
| 200 | 100 |

PROCESS DATA NOT AVAILABLE;EMISSION FACTOR DIRECTLY INPUT

OUTPUT DATA: TP EMISSION FACTOR = .3 LB/T ( .15 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 16.736 | .050208 | .025104 |
| 1 | 29.91 | .08973 | .044865 |
| 1.25 | 37.479 | .112437 | .0562185 |
| 2.5 | 62.788 | .188364 | .094182 |
| 5 | 83.439 | .250317 | .125159 |
| 10 | 94.707 | .284121 | .142061 |
| 15 | 97.696 | .293088 | .146544 |
| 20 | 98.817 | .296451 | .148226 |

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

## RESULTS OF SPLINE ANALYSES FOR 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.

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: KVB/ARB PULVERIZED COAL TEST 18 BAGHOUSE OUTLET

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW % < CUT | CUM. % < CUT |
|---|---|---|
| .99 | 34 | 34 |
| 3 | 34 | 68 |
| 10 | 24 | 92 |
| 200 | 8 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .44 LB/T ( .22 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 22.6933 | .0998505 | .0499253 |
| 1 | 34.2755 | .150812 | .0754061 |
| 1.25 | 40.6575 | .178893 | .0894466 |
| 2.5 | 62.3054 | .274144 | .137072 |
| 5 | 79.3977 | .34935 | .174675 |
| 10 | 91.8575 | .404173 | .202087 |
| 15 | 96.8591 | .42618 | .21309 |
| 20 | 98.9845 | .435532 | .217766 |

END OF TEST SERIES

SPLIN2 PROGRAM - 02/22/82 V1

TEST ID: KVB/ARB NATURAL GAS TEST 9 BAGHOUSE OUTLET

INPUT DATA: PROCESS WEIGHT RATE = 0 TONS PROD. /HR
TOTAL PARTICULATE EMISSION RATE = 0 LB/HR
PARTICLE DENSITY = 1 G/CC

MEASURED PARTICLE SIZE DISTRIBUTION

| CUT (um) | RAW % < CUT | CUM. % < CUT |
|---|---|---|
| .99 | 20 | 20 |
| 3 | 40 | 60 |
| 10 | 32 | 92 |
| 200 | 8 | 100 |

OUTPUT DATA: TP EMISSION FACTOR = .22 LB/T ( .11 KG/MT)

| CUT (umA) | CUM. % < CUT | EMISSION FACTOR (LB/T) | (KG/MT) |
|---|---|---|---|
| .625 | 10.3974 | .0228744 | .0114372 |
| 1 | 20.2616 | .0445755 | .0222878 |
| 1.25 | 26.6543 | .0586394 | .0293197 |
| 2.5 | 52.3879 | .115253 | .0576267 |
| 5 | 75.0083 | .165018 | .0825091 |
| 10 | 91.693 | .201725 | .100862 |
| 15 | 97.8964 | .215372 | .107686 |
| 20 | 100.057 | .220126 | .110063 |

END OF TEST SERIES

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

| | | |
|---|---|---|
| 1. REPORT NO. EPA-600/7-87-007 | 2. | 3. RECIPIENT'S ACCESSION NO. |
| 4. TITLE AND SUBTITLE Lime and Cement Industry Particulate Emissions: Source Category Report; Volume II. Cement Industry | | 5. REPORT DATE February 1987 |
| | | 6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S) John S. Kinsey | | 8. PERFORMING ORGANIZATION REPORT NO. |
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16. ABSTRACT

This volume of the report gives results of the development of 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 is presented, with emphasis on factors affecting the generation of emissions. A replacement for Section 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.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|---|
| Pollution | Emission | Pollution Control | 13B |
| Portland Cement | | Stationary Sources | 11B, 13C |
| Industrial Processes | | Emission Factors | 13H |
| Particles | | Inhalable Particulate | 14G |
| Dust | | | 11G |
| Aerosols | | | 07D |

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