AP42 Section: **11.6 Portland Cement Manufacturing**

Title: **Review of Proposed revision to AP-42 Section 8.6 (11.6, 5th edition) Portland Cement**

MRI

September 1980

AUG 1 0 1993

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

OFFICE OF
AIR QUALITY PLANNING
AND STANDARDS

DRAFT

Mr. Robert W. Crolius
Vice President
American Portland Cement Alliance
1212 New York Avenue, N.W., Suite 500
Washington, D.C. 20005

Dear Mr. Crolius:

As you know, the Emission Inventory Branch of the U. S. Environmental Protection Agency (EPA) is in the process of updating the document *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources* (known more commonly as AP-42). As part of this process, we are now seeking comments on the draft sections that are to be included in this update of AP-42.

Chapter eight of AP-42 addresses the mineral products industry and is one of the chapters being updated. Enclosed is a copy of the draft Section 8.6, Portland Cement Manufacturing, and the corresponding background report for the section. We would appreciate it if you would distribute copies of the enclosed draft AP-42 section and background report among your members for review and send us your comments. Unfortunately, we are on a very tight schedule, and it is important that we have all comments by September 30, 1993 if we are to include a revised Section 8.6 in the fifth edition of AP-42, which is scheduled for publication this fall.

We appreciate the assistance provided by your organization in compiling data for the 1991 revision to AP-42 Section 8.6, and we look forward to your assistance in reviewing the enclosed draft AP-42 section. In preparing the enclosed background report and draft AP-42 section on portland cement manufacturing, a number of issues were raised that could not be resolved with the information on hand. The following paragraphs describe the more important of these issues. In order to make the fullest use of the test data and other information available to us for this revision, several assumptions were made about how the data should be interpreted. We would appreciate your input on the validity of these assumptions and on other information you can provide to improve the draft AP-42 section.

With few exceptions, the emission factors presented in AP-42 are based upon results from validated tests or other emission evaluations that are similar to EPA reference test methods, and revisions to the emission factors presented in AP-42 sections must be supported with documented test results. At a minimum, each emission factor in AP-42 is defined in terms of a unique combination of emission source, pollutant, and air pollution control device. As you can see from the enclosed background report, approximately 80 emission test reports were reviewed in the process of developing the revised draft AP-42 section on portland cement manufacturing, and many of the emission factors presented in the draft AP-42 section are based on several emission tests. We are reasonably confident that the emission factors based on several tests (ten or more) are representative of the portland cement manufacturing industry. However, due to the sparsity of data, the majority of the emission factors in the enclosed draft AP-42 section are based on no more than five emission tests. For many of these emission factors, we have no reason to suspect that the data are not representative. However, in a number of cases of emission factors based on a small number of tests, there are inconsistencies in the data that cannot be rectified using only the data presented in the individual tests reports. In such cases, we would like your assistance in identifying the likely reasons for these inconsistencies. If you believe that some of the test data used in developing emission factors for the draft AP-42 section should be excluded, we request that you provide the engineering basis for excluding the test results in question.

An example of apparent inconsistencies in test data is the emission factor for SO_2 emissions from long dry process kilns. An average emission factor of 6.9 kilograms per megagram of clinker produced (kg/Mg) (14 pounds per ton [lb/ton]) was developed from the data on long dry process kilns. (In the current AP-42 section, the emission factor for SO_2 emissions from long dry process kilns is 3.5 kg/Mg [7.0 lb/ton].) The revised emission factor is based on the results of five emission tests. The data in each of two of the tests (both conducted in 1977 on two kilns at the same facility) resulted emission factors of 14 kg/Mg (28 lb/ton). The SO_2 emission factors developed from the other three tests averaged 2.1 kg/Mg (4.2 lb/ton), which is more comparable to the SO_2 emission factor for long dry process kilns in the current AP-42 section and is likely a more representative value. However, using only the information included in the test reports, there is no basis by which we can exclude the 1977 test data or average the results with the other test data in a more appropriate fashion. Please suggest alternative methods for handling these data that you feel would improve the estimate.

The CO_2 emission factors for the different types of kilns are another example of inconsistencies between the data and expected results. As energy efficiency increases, the CO_2 emission factor would be expected to decrease. However, the

emission factors for long, dry process kilns, dry preheater process kilns, and dry preheater/precalciner process kilns are essentially equal. Are these results reasonable based on your understanding of the relative energy requirements of these processes?

The issue of estimating SO_2 emissions from portland cement kilns also has been the subject of controversy for several years. Our understanding is that the magnitude of SO_2 emissions from portland cement kilns is primarily a function of the sulfur content of the fuel used to fire the kiln, the sulfur content of the raw material, which varies enormously, and other operating conditions. We would like your assistance in identifying how we can evaluate material and process parameters to develop a more reliable method for estimating SO_2 emissions from portland cement kilns. Please note that several of the emission test reports reviewed for this revision to AP-42 included fuel sulfur contents, as indicated in the background report. However, none of the reports provided a chemical analysis of the raw materials, and very little information is included on operating parameters during the emission tests.

As is the case in previous versions of AP-42 Section 8.6, the enclosed draft section presents kiln emission factors on the basis of mass of pollutant emitted per mass of clinker produced. However, many of the test reports reviewed provided process rates on the basis of raw material feed only. In order to convert the process rates from a feed to a production basis, the reports that provided both feed and production rates were used to develop conversion factors of 1.7 (feed to production) for wet, preheater, and precalciner process kilns and 1.6 (feed to production) for long dry process kilns. If your knowledge of the industry indicates that these conversion factors are inaccurate, we would appreciate your input on how we should convert raw material feed rates to clinker production rates.

In the enclosed draft AP-42 section, emission factors for criteria pollutants are provided for each of the four types of pyroprocesses (wet, long dry, dry preheater, and dry preheater/ precalciner) for which data were available. However, because of the sparsity of data and the relative consistency of emission rates among different types of pyroprocesses, we developed the emission factors for emissions of metals and organics by combining the emission data on all types of kilns. We would appreciate hearing your comments on the efficacy of this approach to combining (or not combining) data on different pyroprocess types. Any information you could provide on which pollutants (or groups of pollutants) are likely to be unaffected by type of pyroprocess would be helpful; combining data from tests on different pyroprocess types would increase our data base and thereby improve the emission factors in AP-42.

A final issue that we would like to highlight concerns the effects of fuel type on emission characteristics. In the enclosed draft AP-42 section, we have not differentiated emission factors by fuel type. The primary reason for disregarding fuel type is that the majority of the tests documented were conducted on coal-fired kilns, and the data on emissions from kilns fired with other fuel types (other than waste derived fuels) were sparse and generally dated. As for waste derived fuels, the available data indicate that emissions of metals and organic pollutants from kilns fired with waste derived fuels are comparable to emissions from kilns fired with conventional fuels (coal, oil, and gas). However, until we can research this matter further, we have decided not to include emission data from kilns fired with waste fuels. Please comment on the need to provide kiln emission factors by fuel type and your understanding of the effects that different fuels types may have on emission characteristics.

We appreciate your cooperation and look forward to receiving your comments. If you have any questions, I can be reached by telephone at (919) 541-5407 or by fax at (919) 541-0684.

Sincerely,

Ronald E. Myers
Emission Factors and Methodologies Section
Emission Inventory Branch

2 Enclosures

cc: Mr. Walter L. Greer
Mr. Mallory S. May

OAQPS/TSD/EIB:RMyers, rm 455B, 4201 Bldg., 541-5407, MD-14
(MRI/RMarinshaw/LKaufman/677-0249/08/06/93)

MRI REPORT

Review of Proposed Revision to AP-42, Section 8.6, Portland Cement

Final Report

For U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards

Contract No. 68-02-4395
Work Assignment No. 49
MRI Project No. 8987-49

September 30, 1990

MIDWEST RESEARCH INSTITUTE 425 Volker Boulevard, Kansas City, MO 64110-2299 • (816) 753-7600

MRI REPORT

Review of Proposed Revision to AP-42, Section 8.6, Portland Cement

Final Report

by

Fred J. Bergman

For U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

Attn: Mr. Dennis R. Shipman

Contract No. 68-02-4395
Work Assignment No. 49
MRI Project No. 8987-49

September 30, 1990

MIDWEST RESEARCH INSTITUTE 425 Volker Boulevard, Kansas City, MO 64110-2299 • (816) 753-7600

PREFACE

This report was prepared by Midwest Research Institute (MRI) for the Environmental Protection Agency's (EPA's) Office of Air Quality Planning and Standards under EPA Contract No. 68-02-4395, Work Assignment No. 9. Mr. Dennis R. Shipman was the Project Officer for this review. The work was performed in MRI's Air Quality Assessment Section. The author of the report was Mr. Fred Bergman. Mr. John Kinsey provided technical support and review.

Approved for:

MIDWEST RESEARCH INSTITUTE

Charles F. Holt, Ph.D., Director
Engineering and Environmental
Technology Department

September 30, 1990

SECTION 1

INTRODUCTION

The Criteria Emissions Section of the Monitoring and Reports Branch (MRB) has responsibility for developing and maintaining the document *Compilation of Air Pollutant Emissions Factors*, AP-42, which is a basic source of emission factors used in preparation of State Implementation Plans (SIPs), review of Prevention of Significant Deterioration (PSD) applications, New Source Review Permit Applications, and other Federal, State, and local assessments of air pollution sources.

This report presents a review of a proposed revision for Section 8.6 of AP-42. The proposed revision was prepared by a consultant of the Portland Cement Association. The review covered (1) evaluation of the appropriateness of the emission data used, (2) evaluation of the data treatment, (3) evaluation of the background document, (4) review of the emission factor rating, and (5) a review of the section text.

SECTION 2

EMISSION DATA EVALUATION

2.1 REVIEW OF INDIVIDUAL DATA SETS

The report on testing at the Cal Met/Coulton Plant did not contain calibration data to support the continuous emission monitors (CEMs) results. The statement made that the CEMs were granted certification by the District Engineers was insufficient to justify an A rating for the report. The results were, therefore, lowered to a B rating.

The Gilford-Hill/Riverside plant report contained a number of deficiencies. The coal analysis was reported to be done by the Kjeldahl Method. This method consists of three parts: digestion, distillation (to remove interferences), and measurement (titration). The testing organization performed the digestion and then used instrumental methods for analysis without the distillation. The report stated the presence of interferences degraded the results. The results of the nitrogen analysis is questionable.

Also at the Gilford-Hill/Riverside plant, there was no certifications of the CEMs, the main flow calculations were in error, and the NO_x method used was nonstandard. An integrated bag (Mylar) sample was collected for later analysis. (Note that losses of NO_x in Mylar have been documented and published.) There were also no holding times provided on the bag samples and no sample stability (decay rate) information provided.

Finally, the Gilford-Hill test report identified cyclonic flow at the test location, and the test organization either took no correction action or did not report the action taken. Moisture in the stack was also not measured in the same time frame as the NO_x sampling occurred. In addition, the report

stated in "Discussion of the Test Program" that all data were collected during upset conditions. Because of the above factors, the rating of the test was lowered from A to D.

The Lafarge Corp./Alpena, Michigan and the Lehigh Plant/Waco, Texas retained B ratings. We also agreed with the decision to omit the Oklahoma Cement/Pryor data.

The Southwest (SW)/Black Mountain, California report retained a B rating for the October 9, 1980, test. The other two tests retained a B rating for NO_x measurements, but the SO_2 data were reduced to a D rating. This reduction was based on observations that the method employed for SO_2 probably measured total sulfates.

The test results from Gilford Hill/TX were reviewed. We agreed with the decision to eliminate the Gilford Hill/TX test data.

Data from Lehigh/Camenton retained a B rating. However, Lonestar, Miami, Florida was reduced from an A to a B rating. This reduction was made because the report consisted of data only.

The Lonestar/New Orleans tests performed on November 11 and November 13, 1981, were given a C rating because they did not use standard procedures. The tests performed in May of 1982 and March of 1984 were reduced from B to C ratings. This reduction was made because the method employed for SO_2 was nonstandard.

The Southwestern/Victorville test performed on August 5, 1980, was reduced from a B rating to a C. This reduction was made because the NO_x sample was collected in a Tedlar bag for later analysis (nonstandard) and the SO_2 was collected in a nonstandard and incorrect train. The SW test performed on October 9, 1980, was reduced from a B to a C for the same reason.

The Ashgrove/Durkee and the Calaveres/Bedding tests retained their B ratings.

The Lehigh/Buda, Texas plant report was reduced from a B to a C rating because the report contained no supporting data, and no even the methods used.

The Lonestar/Maryneal, Texas report was not reviewed (could not be located) and the SW/Fairborn test remained rated B.

The SW Florida Mining and the SW/Kosmosdale were reduced from a B to a C rating. The reduction was made because the reports contained only data with no supporting information.

The SW/Odessa values for NO_x remained rated A but the SO_2 data were reduced to a C rating. The reduction was made because the SO_2 train varied from the EPA method making the results questionable.

The Cal Mat/Majave test remained B, as did the Lonestar/Davenport data.

The SO_2 data from the Marquette/Cape Girardeau and Lonestar/Cap Girardeau both remained rated B.

SW/Leamington remained an A but the SW/Victorville tests conducted in 1985 and 1987 were reduced from an A to a D. The reduction was made because the CEMs were not certified at this source. The test organization calculated an F factor using CEM data which is specifically forbidden (only Orsat is acceptable). In addition, the probe washings were evaporated on a hot plate.

? Victorville ? Leamington seems OK

Also in the SW/Leamington report the test organization stated the CO analyzer was CO_2-corrected but did not correct for the water interference. The CO data should be obtained on a dry gas stream not one provided by a preconditioner operating at 70°F. In addition, if the correction made on the CO data by calculation were acceptable, how does the test organization explain drifts of ±75 ppm and errors of 100% when the system was spanned at 200 ppm? A final problem was the report's conclusion that the NO_x values were valid because they were checked using EPA Method 20, when Method 7 should have been used. The same problems were observed in all of the tests performed during this reported test period.

2.2 REVIEW OF THE DATA TREATMENT REPORT

The main thrust of the Data Treatment Report was the use of a statistical evaluation of the data. This approach was employed partially to overcome the variability of the data. However, it was our finding that much of the variability was eliminated during the above data reassessment. The NO_x data of A and B ratings varied from 2.31 to 6.70 lb/ton. This compares to the previous values of 1.68 to 17.5 lb/ton. In the case of SO_2 the new evaluation ranged from 0.32 to 7.25 lb/ton where the previous values were 0.03 to 18 lb/ton. As can be seen, the data variability was diminished by the new ratings discussed in Section 2.2.

2.3 REVIEW OF THE BACKGROUND DOCUMENT

There seems to be a problem within the treatment of sulfur oxide in the Background Document. It was our understanding that the emission factor was to be developed for sulfur dioxide (SO_2) not SO_x. However, most references in the Background Document and the Proposed Section Revision uses the summary term sulfur oxides (SO_x). This term includes sulfur dioxide, sulfur trioxide, and sulfates. In fact, only Section 1.4.2 in the Background Document uses the term SO_2. In addition, Reference 3 of the Background Document uses the term SO_x but the test refers to these data as SO_2. References 7, 11, 22, and 23 refer to SO_x in their titles and references 14, 17, 27, 29, and 31 refer to SO_2. In reality, the term used in various titles seldom represents the form measured during the tests.

EPA Method 6 and CEMs are the correct way to measure SO_2. Method 8 measures SO_2 plus sulfuric acid mists (the form of SO_3 found in a gas stream containing moisture). To obtain total SO_x would require the use of a Method 8 train plus a sulfate determination on the particulate catch. In addition, the determination of so-called SO_x using a CEM, as is reported in many of the documents, is not possible since the conditioning system used would remove any SO_3.

The reference documents and the background were, therefore, reviewed with these facts in mind. Much of the sulfur oxide data was lowered to either a C

or a D rating because it did not represent SO_2 concentrations. It is, therefore, recommended that all references to SO_x in both the Background Document and the proposed Section 8.5 of AP-42 be changed to SO_2.

We are in agreement to the exclusions of data from Oklahoma Cement/Pryor and Gilford-Hills No. 3 kiln described in the Background Document Section 1.4.2. In addition we excluded data from Gilford-Hill Riverside, the SO_2 data from SW Back Mountain, and the SW Victorville kiln No. 2 data. Explanation for these exclusions were provided in Section 2.1.

The proposed values in Section 1.5 of the Background Document should be changed to reflect the change in data resulting from this review.

Table 1 contains all A and B rated emission factors derived from the experimental data.

TABLE 1. A AND B EMISSION FACTORS FOR PORTLAND CEMENT KILNS

Kiln type	SO_2 lb/ton	Reference No.[a]	NO_x lb/tons	Reference No.[a]
Dry process	6.72	4	6.60	1
	7.25	5	6.70	1
	-	-	4.25	4
	-	-	6.16	5
	-	-	5.17	8
	-	-	5.16	9
	Average 7.0		Average 5.7	
Wet process	4.51	20	5.23	15
Preheater	-	-	5.78	32
	-	-	5.64	33
	-	-	Average 5.5	
Precalciner	0.77	36	2.81	36
	1.00	36	3.43	36
	1.45	36	4.49	36
	0.32	37	8.62	39
	1.25	38		
	Average 1.0		Average 4.8	

[a] See Table 1 of Appendix for reference numbering.

round down to 2.5

Because of the scarcity of data rated A and B, C rated data were used to develop emission factors for SO_2 and NO_x for wet process kilns and a SO_2 factor for preheaters. The individual C rated values and their averages are presented in Table 2.

TABLE 2. C RATED EMISSION FACTORS FOR WET PROCESS CEMENT KILNS AND PREHEATER KILNS

Kiln type	SO_2 lb/ton	Reference No.[a]	NO_x lb/tons	Reference No.[a]
Wet process	2.76	12	5.23	15
	18.08	13	5.63	15
	4.54	15	7.71	15
	0.40	15	3.69	17
	1.93	15	3.40	17
	4.70	16	9.10	22
	1.76	16	4.05	22
	6.12	17	14.70	22
	5.32	17	17.30	23
	14.20	19	11.00	23
	0.39	22	-	
	0.48	22	-	
	0.99	22	-	
	8.02	23	-	
	2.71	23	-	
	3.60	21	-	
	8.80	21	-	
	15.90	21	-	
	5.40	21	-	
	13.70	21	-	
Average	6.0		Average 8.2	
Preheaters	0.85	25		
	1.59	26		
	2.04	29		
	0.07	31		
	0.09	32		
	0.01	82		
Average	0.8			

[a] See Table 1 of Appendix for reference numbering.

Based on the above data we propose that the emission factors given in Table 3 be used in place of those provided in the document reviewed.

TABLE 3. PROPOSED EMISSION FACTORS

Kiln type	SO_2 lb/ton (kg/Mg)	Rating	NO_x lb/ton (kg/Mg)	Rating
Dry process	7.0 (2.9)	B	5.7 (2.4)	B
Wet process	6.9 (2.5)	C	8.2 (3.4)	C
Preheater	0.8 (0.3)	C	5.5 (2.3)	B
Precalciner	1.0 (0.4)	B	4.8 (1.7)	B

SECTION 3

AP-42 SECTION

The text of the proposed AP-42 section has been reviewed and revised to that shown in the following pages. A number of editorial changes have been included. The figure numbers have also been changed to match the text and the discussion of alternate fuels was changed to eliminate the implication that kilns are operated on 100% alternate fuels. To our knowledge kilns are not been operated on 100% waste.

Table 1, Emission Factors for Cement Manufacturing for Particulate, NO_x, and SO_x (Appendix), does not provide units for the proposed numbers. Comparisons with the units in Table III of the Methodology Development Document implies that the unit of lb/ton is correct. The term SO_x in the table heading should also be changed to SO_2.

The values for particulates given in Table III do not agree with the values currently contained in Table 8.6-1 of AP-42. There was no discussion in the documents reviewed to explain the different numbers. It is, therefore, proposed that the particulate levels provided in the existing Table 8.6-1 be retained with the NO_x and SO_2 values changed to reflect the new data.

8.6 PORTLAND CEMENT MANUFACTURING

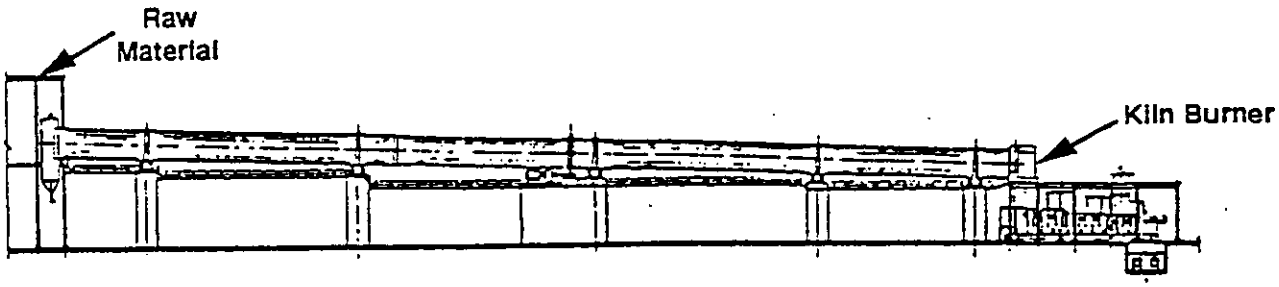
8.6.1 Process Description

Most of the hydraulic cement in the United States is portland cement. Portland cement, a cementitious, crystalline compound composed of metallic oxides, is produced by a pyroprocess in a rotary kiln from raw materials, e.g., limestone, shale, clay and sand, containing calcium carbonate and aluminum, iron, and silicon oxides. The steps of this process are shown in Figure 1. This manufacturing process may be conveniently divided into five stages correlated with location and temperature of the materials in the rotary kiln:

1. Evaporation of uncombined water from raw materials occurs as material temperature increases to 212°F.
2. As the material temperature increases from 212°F to approximately 800°F, dehydration and precalcination occur.
3. Between 800° and 1650°F, calcination occurs in which carbon dioxide is liberated from the carbonates.
4. Following calcination, sintering of the oxides occurs at temperatures up to 2750°F in the burning zone of the rotary kiln.
5. Following sintering, cement clinker is produced as the temperature of the material decreases from 2750° to 2500°F.

The raw material mix enters the kiln at the elevated end (Figure 8.6-1), and the burner is at the opposite end. The raw materials are then changed into cementitious oxides of metals by a countercurrent, heat-exchange process. The materials are continuously and slowly moved to the lower end by the rotary movement of the kiln. The fuel burned in the kiln is natural gas, oil, or coal. Since 1974, many cement plants have converted to coal but recently supplemental fuels such as waste solvents, chipped rubber, shredded municipal garbage, and coke have been used.

There are three variations in the cement manufacturing process, i.e., wet, dry, and dry preheater/precalciner processes. These processes are essentially identical relative to the manufacture of cement from raw materials. However, the type of process does change the equipment design, the method of operation, and the consumption of fuel. Fuel combustion is different between wet and dry processes and the preheater/precalciner process. In the former, all fuel combustion occurs in the kiln. In the latter, some fuel combustion occurs in a precalcining or calcining vessel before the materials enter the kiln (Figure 8.6-2). Generally speaking, the length of the rotary kiln and the consumption of fuel decrease as the manufacturing process changes from wet to dry to preheater/precalciner equipment for the same mix design of raw materials. However, the relationship is not linear. The Btu/ton significantly decreases as plant configuration changes from wet to dry to preheater/precalciner.



Figures 8.6-1. Conventional kiln.

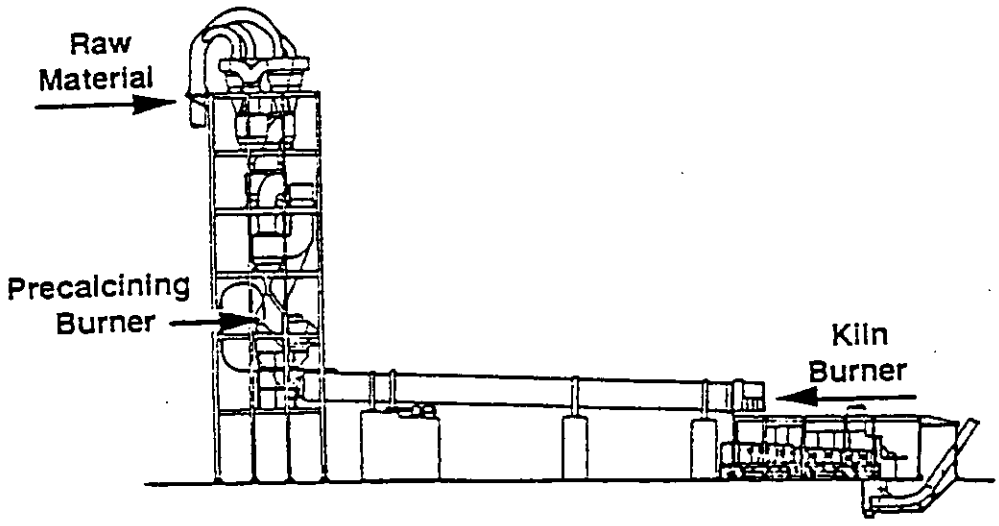


Figure 8.6-2. Preheater/precalciner.

8.6.2 Emissions and Controls

Particulate matter, NO_x and SO_2, CO and CO_2, are the primary emissions in the manufacture of portland cement. But, emissions may also include minute materials form the fuel and raw materials.

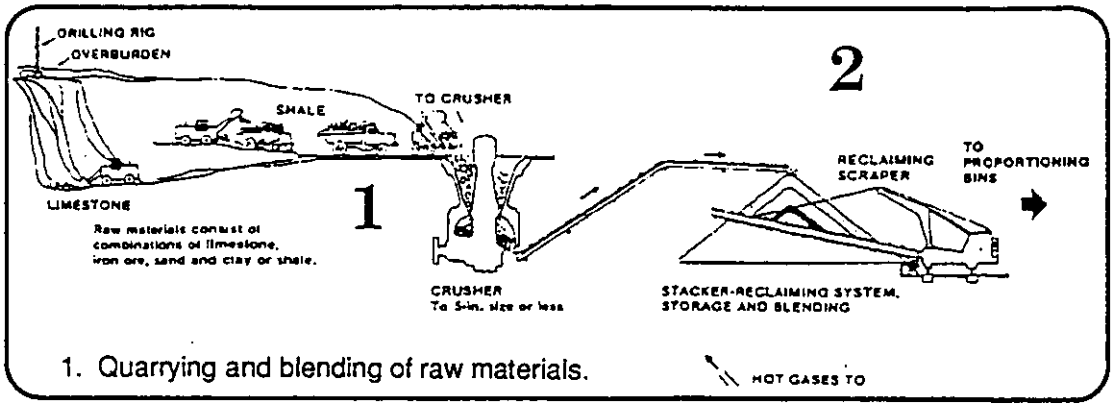
Sources of dust at cement plants include (1) quarrying and crushing, (2) raw material storage, (3) grinding and blending (dry process only), (4) clinker production, (5) finish grinding, and (6) packaging (see Figure 8.6-3). The largest source of emissions within cement plants is the kiln operation, which has three units: the feed system, the fuel-firing system, and the clinker-cooling and handling system. The most desirable method of disposing of the collected dust is injection into the burning zone of the kiln and production of clinkers from the dust. If the alkali content of the raw materials is too high, however, some of the dust is discarded or leached before returning to the kiln. In many instances, the maximum allowable cement alkali content of 0.6 percent (calculated as sodium oxide) restricts the amount of dust that can be recycled. Additional sources of dust emissions are raw material storage piles, conveyors, storage silos, and loading/unloading facilities.

The complications of kiln burning and the large volumes of materials handled have led to the adoption of many control systems for dust collection. Depending upon the emission, the temperature of the effluents in the plant in question, and the particulate emission standards in the community, the cement industry generally uses mechanical collectors, electrical precipitators, fabric filter (baghouse) collectors, or combinations of these devices to control emissions.

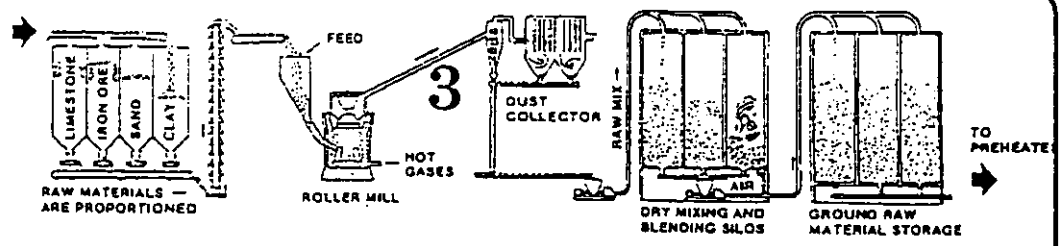
Oxides of nitrogen (NO_x) are generated during the fuel combustion by oxidation of chemically bound nitrogen in the fuel and by thermal fixation of nitrogen in the combustion air. As the flame temperature increases, the amount of thermally generated NO_x increases, and the amount of NO_x generated from fuel increases as the quantity of nitrogen in the fuel increases. In the cement manufacturing process, there are two combustion zones in which NO_x may be generated, i.e., the burning zone of the kiln and the burning zone of a precalcining vessel (Figure 1). Also, the type of fuel burned will affect the quantity and type of NO_x generated. Natural gas combustion with a high flame temperature and low fuel nitrogen may generate a different quantity of NO_x than oil or coal, which have higher fuel nitrogen but lower flame temperatures.

The fuels vary in the cement manufacturing process. Generally, natural gas is used only in the kiln, while coal and oil are used in the kiln and precalcining vessel. Therefore, the generation and emission of NO_x are related to the type of fuel burned and to the extent that fuel affects the flame temperature and contains chemically bound nitrogen.

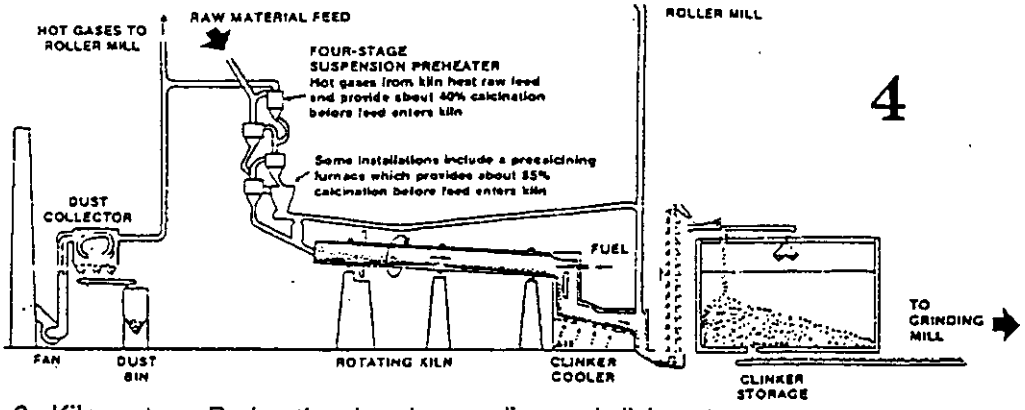
Presently, there are data to support only two types of reduction of NO_x in the cement industry. First, for conventional wet and dry-process kilns, NO_x emissions are reduced by fuel conversion with coal producing the least amount of NO_x. With new construction, the data are not yet clear. Some preheater/precalciner systems have low emissions; others have high emissions.



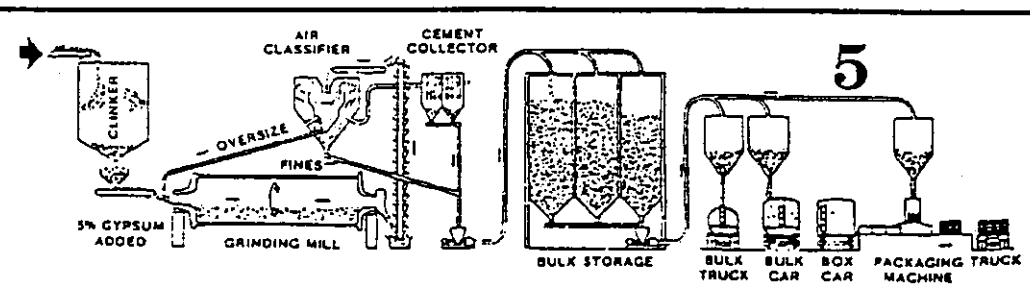
1. Quarrying and blending of raw materials.



2. Proportioning and fine grinding of raw materials.



3. Kiln system. Preheating, burning, cooling and clinker storage.



4. Finish grinding and shipping.

Figure 8.6-3. Steps in the manufacture of portland cement by dry process using preheater.

There is not a single type of preheater/precalciner system used in the cement industry, instead there are at least ten different systems. Each system appears to have unique emissions properties. However, it does appear that for a single system, oil in the calciner produces less NO_x than coal. The No_x emissions from the preheater/precalciner appear to be related to their design. Some have very low emissions and others have emissions in a mid-range of some conventional or wet processes. At the present time, there are insufficient data to choose a NSP system to minimize NO_x emissions.

Sulfur dioxide may be generated from the sulfur compounds in the raw materials, as well as from combustion of fuel. The sulfur content of both raw materials and fuels will vary from plant to plant and with geographic location. The alkaline nature of the cement, however, provides for direct absorption of SO_2 into the product. If a baghouse that allows the SO_2 to come in contact with the cement dust is used, the overall control inherent in the process is approximately 75 percent or greater of the available sulfur in raw materials and fuel. Control, of course, will vary according to the alkali and sulfur content of the raw materials and fuel.

The CO emissions are associated with the efficiency of the combustion process, and the CO_2 is generally a release of 33 percent of the weight of the limestone in the calcining process. Currently, there are no methods available for reducing CO or CO_2 except process control for CO and reduction of production for CO_2.

8.6.3 Emissions Factors

Table 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 8.6-4 and 8.6-5.

TABLE 8.6-1. UNCONTROLLED EMISSION FACTORS FOR CEMENT MANUFACTURING[a]--COAL COMBUSTION
Emission Factor Rating: E

Process	Particulate[b]		Sulfur dioxide		Nitrogen oxide		Lead	
	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
Dry process kiln	128	256	3.5[c]	7.0[c]	2.9[c]	5.7[c]	0.06	0.12
dryer[d]	48	96	-	-	-	-	0.02	0.04
Wet process kiln	120	240	3.0[e]	6.0[e]	4.1[e]	8.2[e]	0.05	0.10
dryer[d]	16	32	-	-	-	-	0.01	0.02
Clunker cooler[f]	4.6	9.2	-	-	-	-	-	-
Preheater kiln	-	-	0.4[e]	0.8[e]	2.8[c]	5.5[c]	-	-
Precalciner kiln	-	-	0.5[c]	1.0[c]	2.4[c]	4.8[c]	-	-

[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. Dash indicates no data.
[b]Emission Factor Rating: B
[c]Emission Factor Rating: B per Reference 13.
[d]Expressed in terms of units of cement produced.
[e]Emission Factor Rating: C per Reference 13.
[f]Reference 8. Emission Factor Rating: D.

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 (μm)	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.

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

EMISSION FACTOR RATING: E

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

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

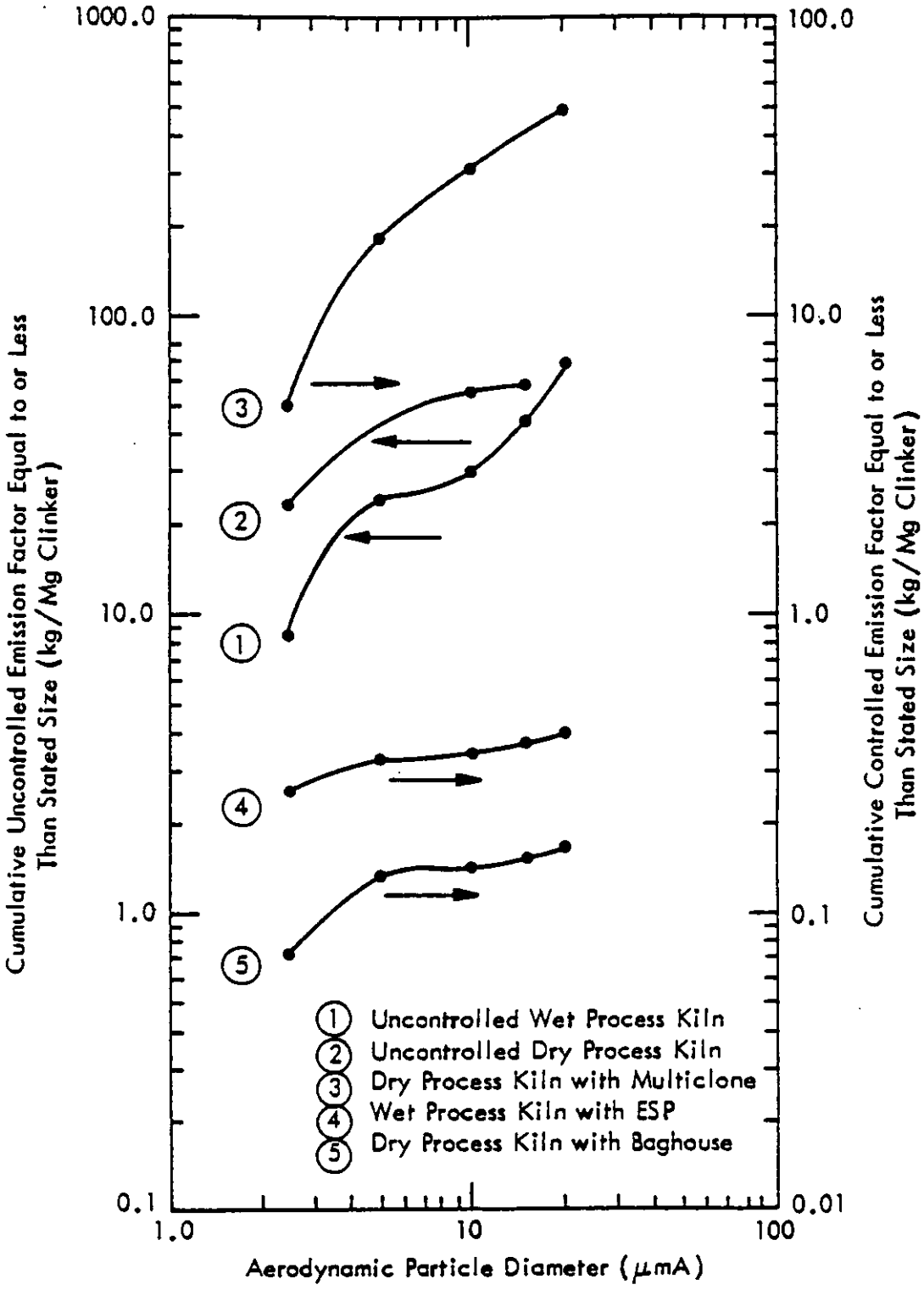


Figure 8.6-4. Size specific emission factors for cement kilns.

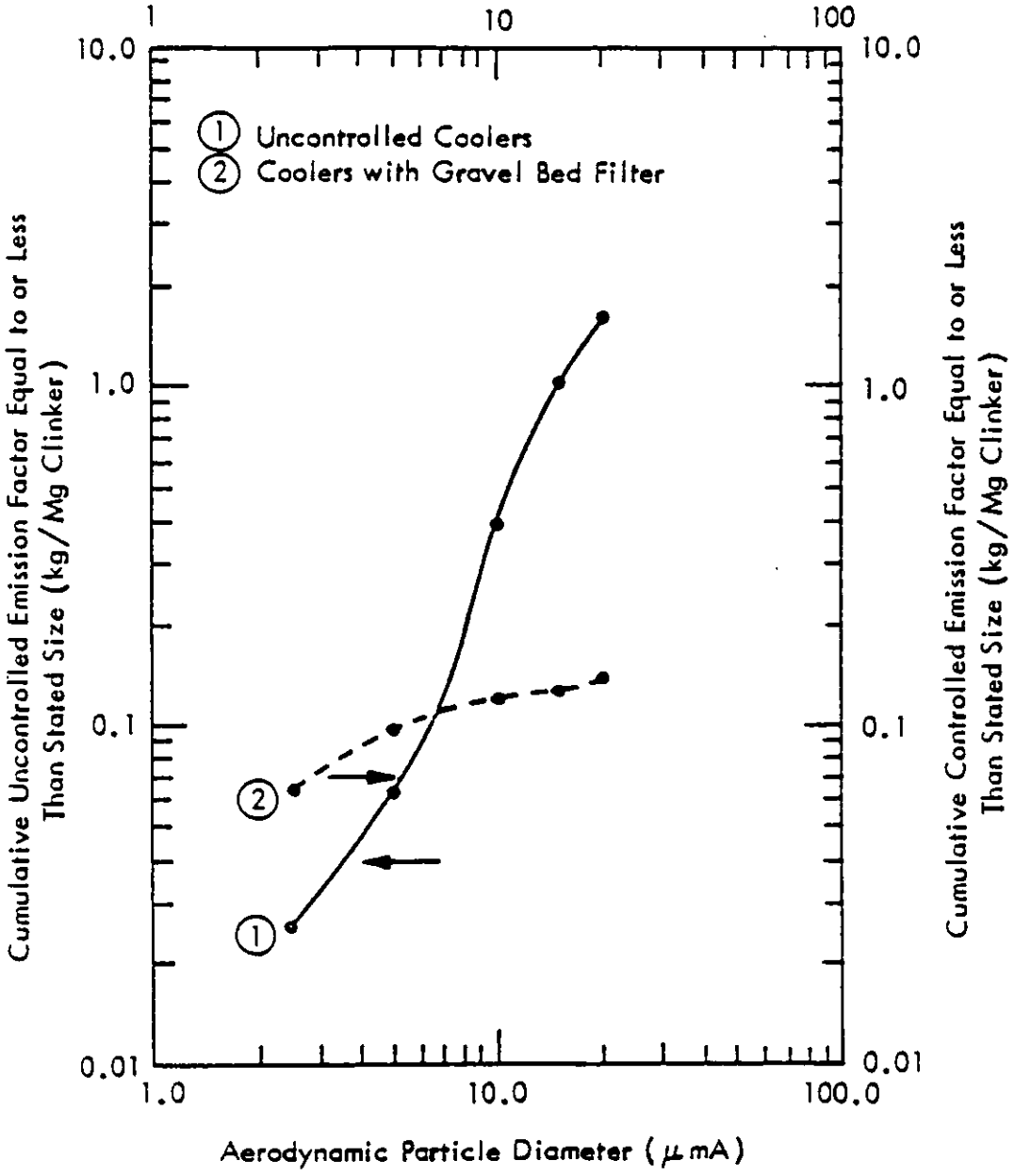


Figure 8.6-5. Size specific emission factors for clinker coolers.

REFERENCES

1. Kreichelt, T.E., 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 1971.

6. Particulate Pollutant System Study. EPA Contract No. CPA-22-69-104, Midwest Research Institute, Kansas City, MO, May 1971.

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

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

9. May, M.S., NO_x Generation, Emission and Control from Cement Kilns in the United States. In: Proceedings of the 1982 Joint Symposium on Stationary Combustion NO_x Control. Prepared by Electric Power Research Institute, Palo Alto, CA.

10. May, M.S., J.M. Croom, R. MacMann, J.C. Phillips, and G.L. Young, Nitrogen Oxide Emissions from Cement Kiln Exhaust Gases by Process Modification. In: Proceedings of the 1987 Joint Symposium on Stationary Combustion NO_x Control. Prepared by Electric Power Research Institute, Palo Alto, CA.

11. Croom, J., M. May, G. Young, C. Phillips, and R. MacMann, NO_x Formulation in a Cement Kiln: Regression Analysis. In: Proceedings of the 1987 Joint Symposium on Stationary Combustion NO_x Control. Prepared by Electric Power Research Institute, Palo Alto, CA.

12. Methodology for Development of SO_x/NO_x Emission Factor, PSM International, Inc., Dallas, TX, July 26, 1990.

13. Bergman, F., Review of Proposed Revision to AP-42 Section 8.6, Portland Cement Manufacturing, EPA Contract No. 68-02-4395, Midwest Research Institute, Kansas City, MO, September 30, 1990.

APPENDIX

METHODOLOGY FOR DEVELOPMENT OF SO_x/NO_x EMISSION FACTORS PREPARED BY PSM INTERNATIONAL, INC.

METHODOLOGY FOR DEVELOPMENT OF SO_x/NO_x EMISSION FACTORS

by

PSM International, Inc.

703 McKinney Ave. Suite 430-436

Dallas, TX 75202

26 July 1990

This study and report have been prepared on the behalf of, and for the exclusive use of the Environmental Protection Agency and the Portland Cement Association. This report and its finds may be used for the purpose for which it was prepared: The revision of the Emission Factors for Air Pollutant Emissions from the portland Cement Manufacturing Process. This report and its findings shall not in whole or part, be used by any party in whole or in part, for any other purpose, without prior written consent of PSM. No warranty, expressed or implied , is made.

METHODOLOGY FOR DEVELOPMENT OF SO_X/NO_X EMISSION FACTORS

1.0 INTRODUCTION

This report provides the methodology for development of the emission factors for SO_x and NO_x as provided in revisions of AP42 Section 8.6 by PSM International, Inc. This includes rationale for cement kiln subdivision, criteria for rating and selecting data, and emission factor estimation. Emissions were standardized to pounds (and kilograms) of emission species per ton (and metric tons) of clinker produced lbs/T or (kgs/MT).

1.1 EMISSION FACTORS ESTIMATION

1.1.1 DISTRIBUTIONAL ANOMALIES OF EMISSION FACTORS

Distributional anomalies of SO_x and NO_x data made estimation of emission factors difficult and uncertain. Figure 1 shows the distribution in class intervals of all facility data for SO_x and NO_x data. NO_x (18 estimates from 25 facilities) exhibits an even distribution with five observations each in intervals 2 - 4, 4 - 6, and 6 - 8 lbs/T and three observations greater than 8 lbs/T. No transformation applies to an even distribution to normalize its variation; the arithmetic mean or average adequately estimates its central tendency. All of the data reviewed is shown in Table I.

The distribution of SO_x emissions for the facilities (22 estimates from 25 facilities) did not fit any reasonable distribution. While it resembles a Poisson or hypergeometric distribution, it fits neither of these well; therefore, no transformation could be applied to normalize SO_x data either. Plots of data for each facility by process type failed to reveal any more information regarding distribution (Figures 2, 3, 4, and 5).

1.1.2 ESTIMATION OF EMISSION FACTORS

Application of normal statistics to either of the data distributions discussed above would result in an over estimation of the variance (dispersion about the distribution's central tendency). Consequently, application of the standard approach to calculation of the upper 95% confidence limit (one-tailed) would have resulted in an emission factor higher than it should be. However, premise of the 95% confidence limit was accepted as a basis for development of an alternative approach to emission factor estimation.

By definition, the 95% confidence limit identifies 5% of legitimate observations as lying outside the acceptable range about the mean. In the case of the SO_x and NO_x data in Table I (the same data as are plotted in Figures 2, 3, 4, and 5), application of the above premise would result in approximately one each observation of SO_x and NO_x being identified as higher than its emission factor. By trial and error, it was determined that the arithmetic mean plus one standard deviation was a good first approximation to application of the 95% confidence interval premise. For NO_x, one of eighteen facility estimates was identified as higher than its process emission factor (Table II). For NO_x, the mean plus one standard deviation estimate worked satisfactorily.

For SO_x, the mean plus one standard deviation did not work as well; three of twenty-two facility estimates were identified as higher than their respective process emission factors (Table I). From Table I, one estimate from wet process clearly exceeds its emission factor while one each estimate for preheater and precalciners exceed each of their relatively low emission factors (1.5 and 1.6 lbs/T, respectively). For these two processes with their relatively low SO_x emissions, the "mean plus one" approach is too restrictive. Adding a second standard deviation to the means for these two processes results in emission factors which do not exclude any of the facility estimates for preheaters and precalciners. Therefore for SO_x, applying the approach of the "mean plus one" to dry and wet processes and the "mean plus two" to preheater and precalciner processes, results in emission factors identify only one facility estimateabove the proposed emission factor. While cumbersome, the application of these two criteria for estimating SO_x emission factors meets the premise of the 95% confidence limit satisfactorily.

Table I
Summary of All Data Review

Plant Site	TFRT Date	SOx Run 1	SOx Run 2	SOx Run 3	SOx Average	Facility Average	Type Average	NOx Run 1	NOx Run 2	NOx Run 3	NOx Average	Kiln Average	Type Average	Comments
Dry Process														
CalMat Colton, #1	1987.00							6.70	6.10	7.10	6.80	6.65		A
#2	1987.00							6.80	6.50	6.90	6.70			A
Gifford-Hill, Riverside	1985			0.18	0.18					7.80	7.80			A Indirect lbs 5.80
Lafarge, Alpena	3/8/89	6.66	8.94	4.59	6.72	6.72		3.59	3.39	5.77	4.25	4.25		B
Lehigh, Waco	8/2/83	7.64	7.32	6.76	7.25	7.25		5.85	6.09	6.57	6.16	6.16		B
Oklahoma Cement, Pryor	3/28/80													
SW, Black Mtn., CA	10/9/80	0.84			0.84	0.40		7.35			7.35	5.89		B
	6/13/84	0.23			0.23			5.17			5.17		6.15	B
	7/25/84	0.02	0.03	0.04	0.03			5.57	5.36	4.54	5.16			B
Wet Process														
Alpha, Cementon, NY	1/26/82	3.14	2.50	2.63	2.76									
Gifford-Hill, TX #1	3/78	0.16			0.16	4.51								
#1	1/79	0.27			0.27									
#2	3/78	8.01			8.01									
#2	3/85	9.59			9.59				9.86			9.86		
#3	3/78													
#3	3/85													
#3	8/85													
Lehigh, Cementon	11/9/84	19.92	19.00	15.39	18.08	18.08								B
LS Florida, Miami	7/15/81	5.66	4.36	3.56	4.54	2.29		3.71	5.84	6.13	5.23	6.19		A
	7/29/81	3.12	5.37	4.80	0.40			6.44	5.59	4.84	5.63			
	12/18/86	2.00	1.97	1.81	1.93			7.85	7.86	7.31	7.71			
LS New Orleans #1	11/11/81	3.20	5.76	5.21	4.70	6.32								
#2	11/13/81	3.28	1.56	0.48	1.78									
#1	5/20/82	4.91	6.52	3.93	5.12			4.17	3.56	3.32	3.69	3.55		B
#2	5/25/82	6.62	4.60	6.25	5.82			4.12	3.15	2.92	3.40			B
#1	3/20/84	15.00	12.10	15.00	14.20									
SW Victorville #6	8/5/80	0.39			0.39	2.52		9.10			9.10	11.23		B
#7	8/5/80	0.48			0.48			4.05			4.05			B
#9	8/5/80	0.99			0.99			14.70			14.70			B
#5	10/9/80	8.02			8.02			17.30			17.30			B
#8	10/9/80	2.71			2.71			11.00			11.00			B
St. Marys, Detroit	10/26/82	3.00	2.90	4.80	3.60	9.48								
	10/4/82	9.00	7.60	9.90	8.80									
	11/7/84	20.30	10.90	16.50	15.90									
	9/24/85	6.00	5.60	4.60	5.40									
	12/22/86	11.70	13.80	15.60	13.70									
Preheaters														
Ashgrove, Durkee	9/15/85							4.24	4.72	6.10	5.02	5.02		B
Calaveras, Redding, CA	5/15/81				0.85	0.85					2.40	2.40		B
Lehigh, Buda, TX	7/2/86	1.10	1.37	2.31	1.59	1.59		3.89	3.68	3.84	3.80	3.80		B
LS Maryneal, TX #1	6/20/80	0.021	0.070	0.027	0.039	0.03								B
#2	6/20/80	0.020	0.010	0.040	0.024									B
#3	6/18/80	0.012	0.038	0.010	0.020									B
SW Fairborn, OH	6/10/86	2.20	1.92	1.98	2.04	2.04								B
SW Florida Mining #2	82-89	0.07			0.07	0.07		2.41			2.41	2.41		B
SW Kosmosdale, KY	6/8/89	0.17	0.05	0.06	0.09	0.09		6.44	5.78	5.11	5.78	5.78		B
SW Odessa, TX	2/22/83	0.02	0.01	0.010	0.01	0.01		6.07	5.71	5.15	5.64	5.64	4.18	A
Precalciner														
CalMat, Mojave, CA	5/23/83	0.78	0.79	0.72	0.77	1.07		2.98	2.85	2.61	2.81	3.58		B
	5/15/84	0.98	1.03	0.99	1.00			3.43	3.34	3.51	3.43			B
	6/28/8	1.54	1.41	1.40	1.45			6.03	3.82	3.63	4.49			B
LS Davenport, CA	8/4/82	0.57	0.57	0.73	0.63			3.36	3.47	3.92	3.58			B R.M.O.
	5/13/82	1.69	1.36	1.54	1.53			2.27	2.13	2.02	2.15			B R.M.O.
	8/22/82	0.41	0.56	0.71	0.56			2.13	2.55	1.82	2.17			B R.M.O.
	8/23/83	2.54	2.62	2.45	2.54			1.53	2.28	1.88	1.90			B R.M.O.
	12/20/83	2.82	3.00	3.08	2.97			2.69	2.35	2.21	2.42			B R.M.O.
	12/21/83	4.38	2.80	3.12	3.43			2.18	1.35	1.52	1.68			B R.M.O.
	3/20/84	3.10	3.15	3.06	3.10	Wt.Avg.		2.14	1.65	1.92	1.97	Wt.Avg.		B R.M.O.
	3/21/84	1.45	1.36	1.40	1.40	1.71		2.06	2.07	1.78	1.87	2.38		B R.M.O.
Marquette, Cape Girardeau	12/16/81	0.32	0.30	0.35	0.32	0.32								B
LS Cape Girardeau	10/12/83	1.25			1.25	1.25								B
SW Leamington	5/25/84							8.32	8.93	8.59	8.62			A R.M.O.
SW Victorville #2	2/85	0.043	0.052	0.062	0.052	0.06		5.26	4.70	3.14	4.36	6.13		A R.M.O.
	3/20/85	0.150	0.068	0.119	0.112			6.97	7.55	6.84	7.12			A R.M.O.
	2/24/87	0.028	0.032	0.037	0.032			7.04	6.50	5.72	6.41		5.18	A R.M.O.
	3/31/87	0.030	0.027	0.032	0.029			6.66	6.77	6.50	6.64			A R.M.O.

Where from not any where close

are we really using

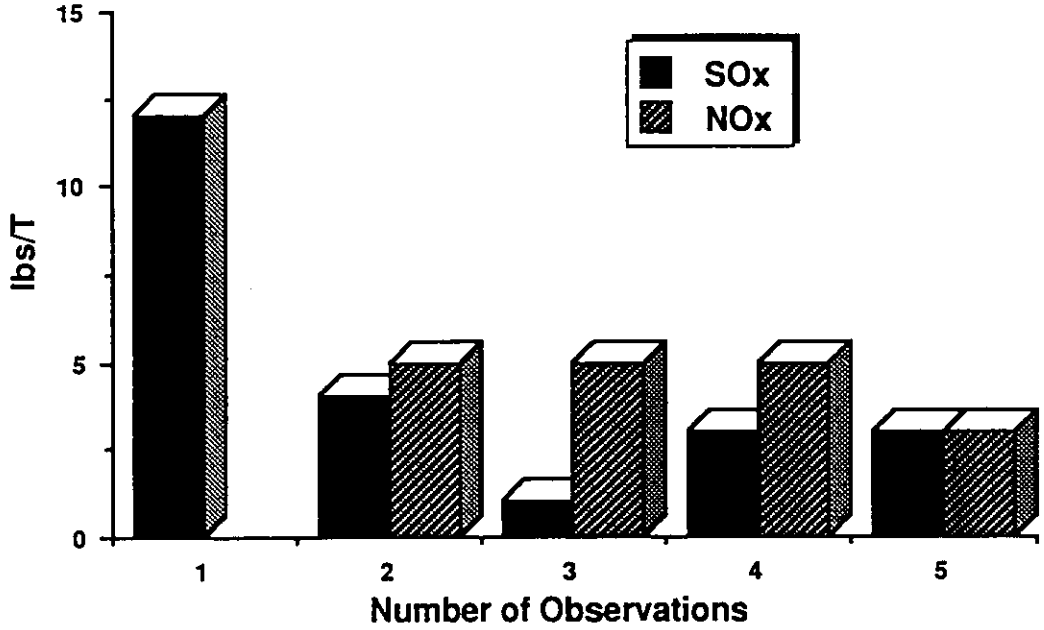


Figure 1: Distribution of all observations of SO_x and NO_x

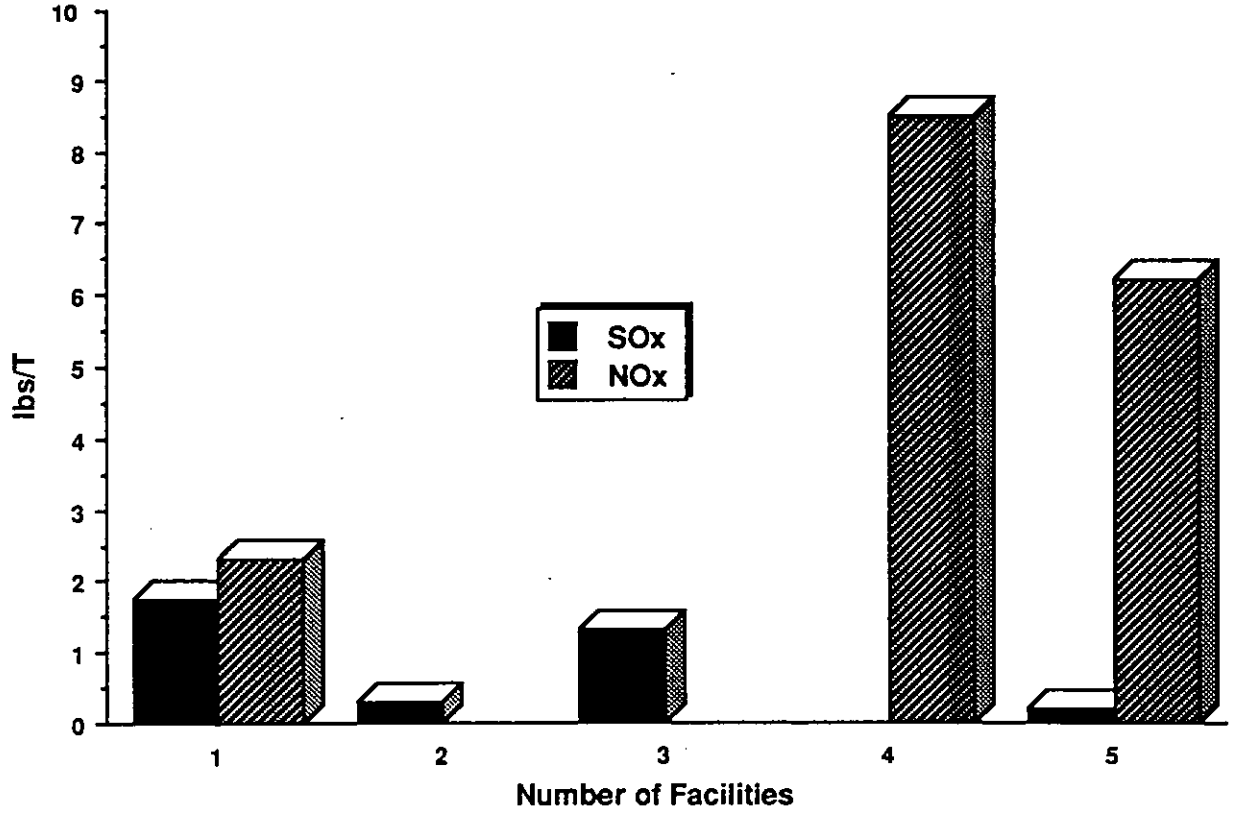


Figure 2: Dry process emissions of SO_x and NO_x

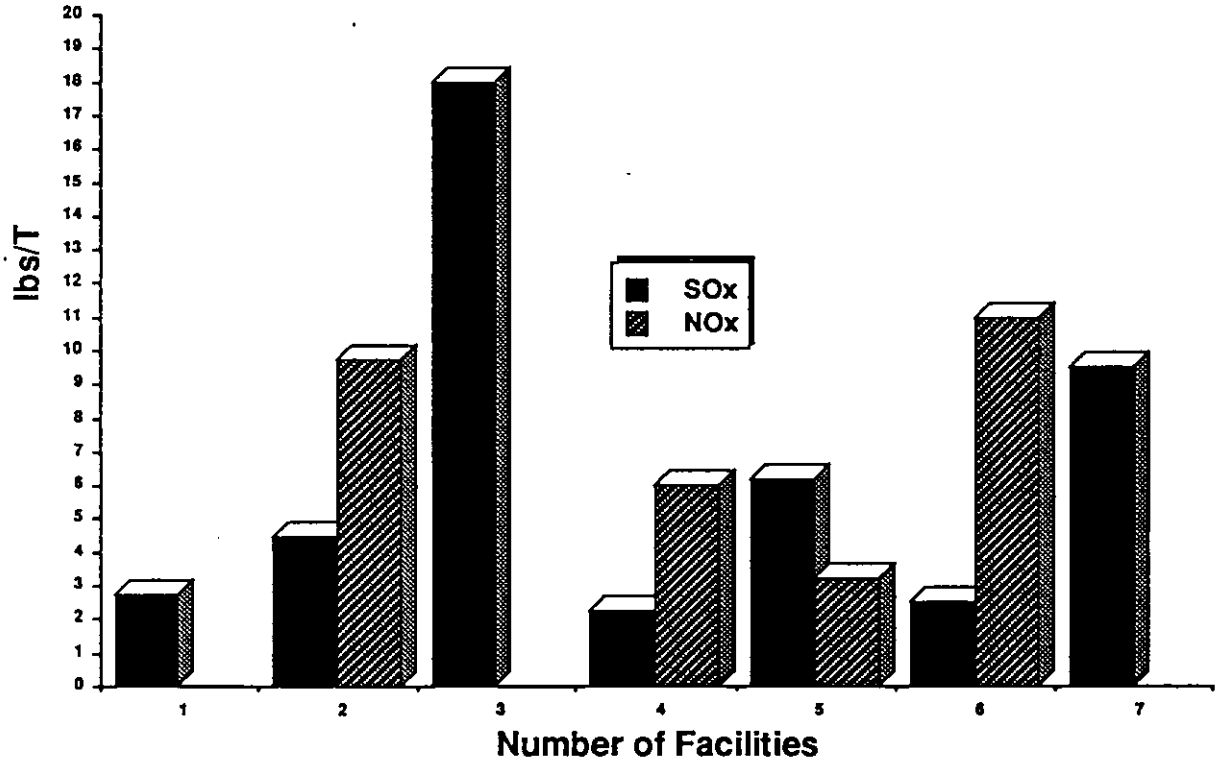


Figure 3: Wet process emissions of SO_x and NO_x

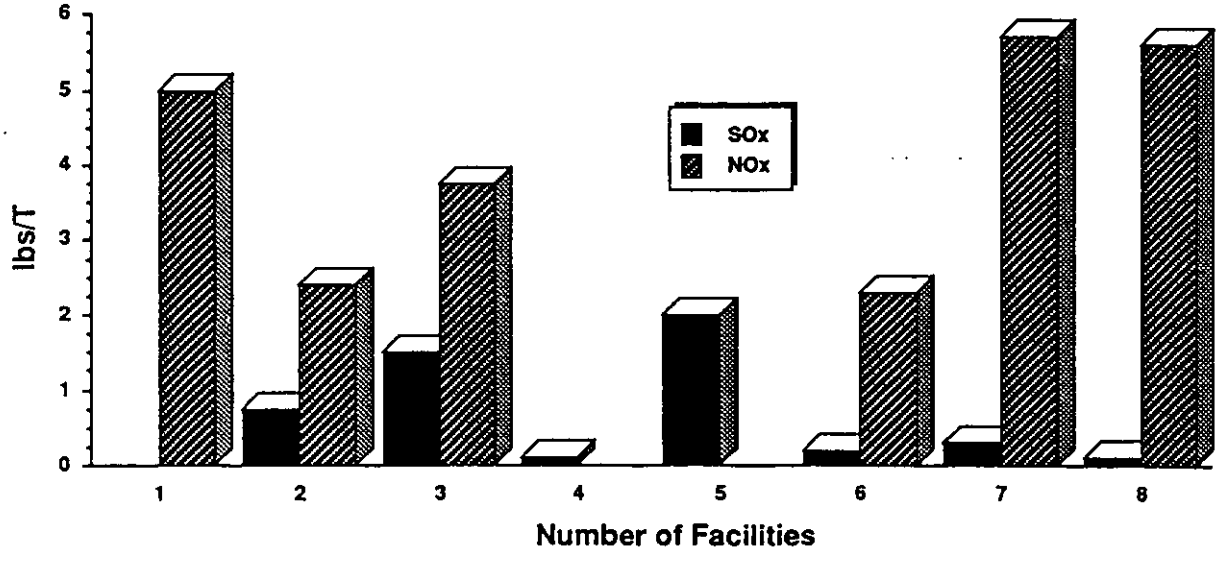


Figure 4: Preheater emissions of SO_x and NO_x

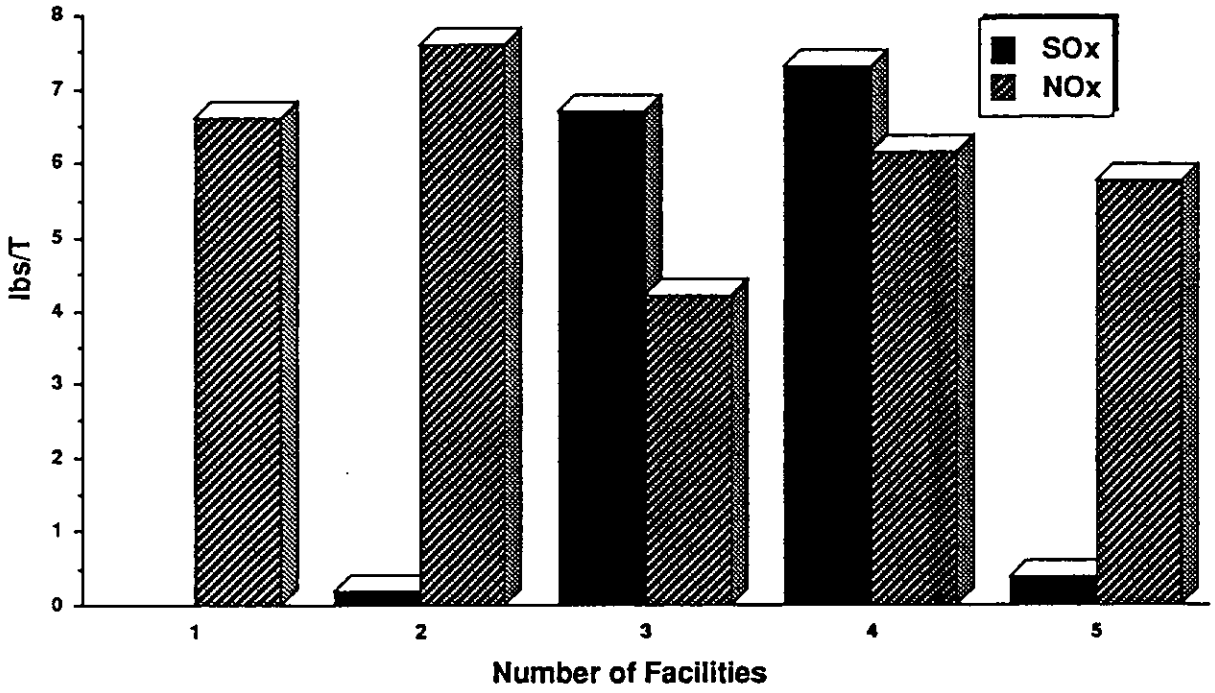


Figure 5: Precalciner emissions for SO_x and NO_x

TABLE II

SO_x AND NO_x EMISSION FACTOR CALCULATION

Process	SO_x lbs/T	NO_x lbs/T	Emission Factors lbs/T SO_x	Emission Factors lbs/T NO_x
Dry Process		6.65		
	0.18	7.8	Both "mean plus one"	
	6.72	4.25		
	7.25	6.16		
	0.4	5.89	7.5	7.4
Mean	3.64	6.15		
St Dev	2.132	2.015		
CV	106 %	21 %		
Wet Process	2.76			
	4.51	9.86		
	18.08			
	2.29	6.19	Both "mean plus one"	
	6.32	3.55		
	2.52	11.23		
	9.48		12.3	11.2
Mean	6.57	7.71		
St Dev	5.693	3.494		
CV	87 %	45 %		
Preheater		5.02		
	0.85	2.4	SO_x "mean plus two"	
	1.59	3.8	NO_x "mean plus one"	
	0.03			
	2.04			
	0.07	2.41	2.4	5.8
	0.09	5.78		
	0.01	5.64		
Mean	0.67	4.18		
St Dev	0.846	1.657		
CV	127 %	40 %		
Precalciner	1.71	2.38		
	0.32			
	1.25		SO_x "mean plus two"	
		8.62	NO_x "mean plus one"	
	0.06	6.13		
Mean	0.84	5.71		
St Dev	0.775-	3.141	2.4	8.9
CV	93 %	55 %		

St Dev = Standard Deviation
CV = Coefficient of variation; the standard deviation divided by the mean as a %.

1.3 RATIONAL FOR KILN SUBDIVISION

1.3.1 KILN FUEL

Prior to large price increases in fuel cost (mid 1970s and early 1980s) natural gas and oil were often used as fuel for cement kilns. But price increases in natural gas and oil quickly resulted in the cement industry converting almost exclusively to coal. When the Portland Cement Association polled the cement industry for source test data for the emission factor update, submissions from approximately 70 source tests since 1977 were preponderantly from kilns fueled with coal; one was from an oil fired kiln while two kilns were co-fueled with coal and waste derived fuel. Therefore, tests from coal fueled kilns only were used for estimation of emission factors herein.

1.3.2 KILN PROCESS CLASSIFICATION

Kilns were divided by manufacturing process because such classification generally reflects a division by amount of fuel used i.e., preheater and precalciner less than long dry and all less than wet process. Emission of NO_x are generally linearly correlated with fuel consumption (combustion NO_x rather than fuel or feed NO_x), while sulfur in SO_x is often derived from fuel rather than feed. So classification by a surrogate for fuel consumption is logical.

Further subdivision by dust control devices was not possible due to the small number of kilns in each original classification (by manufacturing process). Initial classification by dust control devices instead of manufacturing process would not be appropriate, as this would have resulted in combining manufacturing processes under dust control devices thereby loosing the natural classification by fuel consumption.

1.4 CRITERIA FOR RATING AND SELECTING DATA

1.4.1 CRITERIA FOR GRADING KILN DATA

Criteria for grading kiln data were derived in part from EPA's Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42. EPA's grading criteria were:

A. Tests performed by a sound methodology and reported in enough detail for adequate validation.
B. These tests are not necessarily EPA reference method tests, although such reference methods are certainly to be used as a guide.
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 only exclusion criteria relevant to data submission were:

(1) Fuel other than coal used during the test.
(2) Test series averages reported in units that cannot be converted to the selected reported units.

EPA recommended combining data of Grades A and B if there were not sufficient tests of Grade A to estimate emission factors; this recommendation was followed. Most source tests were Grade B which were combined with Grade A data for estimates of emission factors (See Table I).

While not specified as an exclusion criteria, widely varying replicate measurements were suggested as a basis for giving data a lower grade. Here, tests from the same kiln were excluded if replicates within the same test varied by more than 100% unless emissions were very low (average less than 2.0 lbs/T) and it tests within the same year varied by more than 500% unless information concerning a change in either fuel or raw fuel could explain the variation.

1.4.2 KILN DATA EXCLUSIONS

Data from two kilns were excluded from use in estimates of emission factors (Table I). Data from Oklahoma Cement in Pryor (Reference 6) was excluded as SO_2 emissions varied by more than 100% within the same test. Data from Gifford-Hill's #3 kiln at Midlothian (Reference 20) were excluded. NO_x replicates in 1978 varied by more than 100%; and repeated tests in 1985 for SO_2 varied by more than 500% for which there was no reasonable hypothesis.

All other data in Table I were employed in estimates of emission factors. Comments to the data provide information regarding specific use of source test data.

1.5 PROPOSED CEMENT KILN SO_x/NO_x EMISSION FACTORS (COAL FUEL ONLY)

Based on the data available and the criteria discussed in this document Table III is the paoposed emission factors.

Table III
Proposed Emission Factors

Kiln Type	SO_x lbs/T (kgs/MT)	NO_x lbs/T (kgs/MT)
Long Dry	7.5(1.3.1)	7.4(3.0)
Wet Process	12.3(5.1)	11.2(4.6)
Preheater	2.4(1.0)	5.8(2.4)
Precalciner	2.4(1.0)	8.9(3.7)

DATA REFERENCES

The references of the sources of data and comments regarding the data are supplied below.

I. DRY PROCESS

1. **CalMat Colton #s 1,2; letter from** David Cahn to Frank Noonan, EPA, NC, re: AP-42 Factors for Gaseous Emissions from Portland Cement Kilns, June 2, 1987; attached: data for Feb., Mar., April, 1987.
2. **Gifford-Hill, Riverside (Crestmore);** Gerald L. Young and John Croom, "Technical report on the demonstration of the feasibility of NOx emissions reduction at Riverside Cement Company, Crestmore Plant", January 13, 1986.
3. **Gifford-Hill, Riverside (Crestmore);** JC memo: "Crestmore SOx data reduction, Daily Averages from continuous monitor", no date.
4. **LaFarge, Alpena;** Clayton Environmental Consultants, Inc., "Emission study of the Cement Kiln 20 Baghouse Collector at Alpena Plant, Great Lakes Division LaFarge Corporation, Alpena, Michigan," proj.# 22105.00, March 8, 1989; and "Emission Testing of Dust Collectors on Kiln I at Lafarge Corporation, Paulding, Ohio," proj.# 23857.00.
5. **Lehigh, Waco;** Mullins Environmental Testing, Inc., "Source emissions survey Or Lehigh Portland Cement Co., Waco, Texas," File No. 83-69; August, 1983.
6. **Oklahoma Cement, Pryor,** Mullins Environmental Testing, Inc., "Source Emissions Survey of Oklahoma Cement Company Kiln Number 3 Stack, Pryor, Oklahoma," File No. 80-38, March, 1980.
7. **SW, Black Mt.;** Truesdail Labs., Inc., "Report: Sampling and Analysis for sulfur oxides (SOx), nitrogen oxides (NOx) and carbon monoxide (CO) in Kiln exhausts", (Victorville #5 & #8; Black Mt. #I); December 5, 1980. (SW Victorville, WET, repeated as 21. below)
8. **SW, Black Mt.;** letter from James Morgester, Air Resources Board, State of California, to Douglas MacIver, Southwestern Portland Cement Company, August 29, 1984. Following 3 reports attached:
9. **SW, Black Mt.;** "Summary of Source Test Results," July 25, 1984.
10. **SW, Black Mt.;** letter from G.W. Ogle to T.F. Knisley, July 20, 1984, Re: NOx Test - June 13, 1984. Attached report "Kiln exhaust at Black Mountain: SOx, NOx, CO emissions" July 12, 1984.
11. **SW, Black Mt.;** "Baghouse Exhaust at Black Mountain Kiln #1, Sulfur Oxides and Nitrogen oxides," August 10, 1984.

II. WET PROCESS

12. **Alpha, Cementon, NY;** Walter Hinkley, Energy & Resource Recovery Corp., "Baseline and solvent fuels stack emissions test," January 25-26, 1982.
13. **Lehigh, Cementon;** R.L. Baker, KVB, Inc., "Compliance Test Results, Particulate and Sulfur Oxide Emissions, Cementon Kiln, prepared for Lehigh Portland Cement Co., Cementon, NY," November 8-9, 1984.
14. **Lehigh, Waco;** Tenerx Corp., "Lehigh Portland Cement Co. White Kiln Coke Conversion (TACB permit no. C-9399) Emission Compliance Report (NOX, S02, particulates)," December 18, 1985.
15. **LS Florida, Miami (Pennsuco); letter** from Albert Townsend, LoneStar **Florida/ Pennsuco to Bill Arlington, South Florida Environmental Services, Inc.; attached,** "Compliance stack test, LS Florida/ Pennsuco, Inc. Report 387-S Kiln No. 3", July 15, 1981.
16. **LS, New Orleans;** Mullins Environmental Testing Co., Inc., "Source Emissions Survey of Lone Star Industries, Inc., New Orleans, Louisiana," File No. 81-107, November 10-13, 1981.
17. **LS, New Orleans;** Entropy Environmentalists, Inc., "Stationary Source Sampling Report, Lone Star Industries, Inc., New Orleans, Louisiana, Particulate and Sulfur Dioxide Emissions Compliance Testing, Kiln #1 & #2 Precipitators Outlet Stacks," May 20-21,25, 1 982.

18. **LS, New Orleans**; Entropy Environmentalists, Inc., "Stationary Source Sampling Report, Lone Star Industries, Inc., New Orleans, Louisiana, Pollutant Emissions Experimental Testing, Kiln #l & #2 Stacks," May 20-21,25-26, 1982.
19. **LS, New Orleans;** Mullins Environmental Testing Co., Inc., "Source Emissions Survey of Lone Star Industries, Inc., Kiln Number I Stack, New Orleans, Louisiana," File No. 84-39, March, 1984.
20. **Gifford-Hill, Midlothian, TX;** letter from Don Sinkular to QA, Inc. Dec. 18, 1989.
21. **St. Marys Peerless Cement, Detroit, MI;** letter from Gerald Young to John Croom. Dec. 13, 1989.
22. **SW Victorville;** Truesdail Labs., Inc., "Report: Sampling and Analysis for sulfur oxides (SOx), nitrogen oxides (NOx) and carbon monoxide (CO) in Kiln exhausts", (Victorville #5 & #8; Black Mt. #I); December 5, 1980.
23. **SW Victorville;** letter from Douglas MacIver, Southwestern Portland Cement Co., to Walter Mook, Air Pollution Control, CA, **re: NOx, SOx** and CO concentrations on Kilns No.'s 6, 7 and 9, August 22, 1980. (Attached report, Truesdail Laboratories, August 20, 1980)(see ref #7 above).

III. PREHEATER

24. **Ashgrove, Durkee;** letter from Richard Cooke, Ash Grove Cement West, Inc. to Frank Noonan, EPA, NC, May 13, 1987; attached l) Pit & Quarry, "Cement reports issue," July, 1980; and 2)Horizon Engineering, "NOx Emission Test Report, Ashgrove Cement West, Inc., Durkee, Oregon Cement Plant," September 15, 1985.
25. **Calaveras, Redding, CA;** letter from Stan Cramer, Calaveras Cement Co. to Frank Noonan, EPA, NC, re: AP-42 Factors for Gaseous Emissions from Portland Cement Plants, May 13, 1987.
26. **Lehigh, Buda, TX;** Mullins Environmental Testing Co., Inc., "Source Emissions Survey of Texas Cement Company, Buda, Texas," File No. 86-48, June, July, 1986.
27. **LS Davenport, CA;** L.A. Johnson, Chemecology Corporation, "Field Data Source Test, prepared for Lonestar Industries, Davenport, CA; regarding Particulate, NOx and SO_2 Emissions," May 13, 1982.
28. **LS Maryneal, TX;** letter from Billy Mullins, Mullins Environmental Testing Co., Inc. to Roy Blankenship, Lone Star Industries, Inc., July 29, 1980; attached report: Source Emissions Survey, June 20, 1980.
29. **SW Fairborn, OH;** Franklin Meadows, Pollution Control Science, Inc., "Determination of particulate and sulfur dioxide emissions from the kiln and alkali baghouse stacks, Southwestern Portland Cement Company, Fairborn, Ohio,: June 10,12, 1986.
30. **SW;** letter from Doug MacIver, Southwestern Portland Cement Co. to John Croom, October 23, 1989; attached reports, 29, 30, 31:
31. **SW Florida Mining #2; letter** from Matt Stone, Florida Mining & Materials to MacIver, re: Source Test Emissions, September 19, 1989; report on NOX, S02.
32. **SW Kosmosdale, KY;** "Source Test Summary, Kosmos, Louisville Kiln," June 6-8, 1989.
33. **SW Odessa, TX;** "Summary of source emissions surveys, Southwestern Portland Cement Co., Odessa. Texas Plant -Kiln #2 Stack," February, 1983.
34. **SW Odessa, TX;** letter from John Mummert, Southwestern Portland Cement Co. to Bill Stewart, Texas Air Control Board, re: Compliance test submittal for construction permit No. C-8411, April 14, 1983; attached report: Mullins Environmental Testing Co., Inc., "Source Emissions Survey of Southwestern Portland Cement Company Kiln number 2 stack, Odessa, Texas," File No. 83-09, February, 1983.

I V. PRECALCINER

35. **Ash Grove, Leamington, UT;** letter from Stephen Sheridan, Ash Grove Cement West, Inc. to John Croom, re: NOx testing at Leamington, Utah plant, January 15, 1980; attached report.

36. **CalMat, Mojave, CA;** letter from David Cahn, CalMat Co. to John Croom, rc: CEM emissions data summaries, Colton plant, December 18, 1989; attached report: Vernon McKnight, Pape & Steiner Environmental Services, "Mojave Plant (Kiln, Clinker Cooler, and Crusher Baghouses) Annual Compliance Test," May 15, 16 and 17, 1989.
37. **Marquette, Cape Girardeau;** Performance Testing & Consultants, Inc., "Source Emissions Compliance Test Report on the Kiln Stack, Marquette Cement Manufacturing Company, Cape Girardeau, Missouri," February, 1982.
38. **LS, Cape Girardeau;** B.W. Doyle and R.L. Baker, KVB, "Assessment of sulfur levels, Cape Girardeau, MO, prepared for Lone Star Industries," January, 1984.
39. **SW Leamington;** letter from Douglas MacIver of Southwestern Portland Cement Co. to Brent Bradford, Utah Air Conservation Committee, re: Leamington Cement Kiln, July 13, 1984; attached report: York Research Consultants, "Plant performance test program on the kiln and alkali bypass stacks at the Southwestern Cement Leamington, Utah Plant," June 21, 1984.
40. **SW Victorville #2;** Pape & Steiner Environmental Services, "Performance Guarantee Testing at Southwestern Portland Cement, February 5 through 8, 1985".
41. **SW Victorville #2;** Pape & Steiner Environmental Services, "Compliance Testing at Southwestern Portland Cement, March 18 through 21, 1985".
42. **SW Victorville #2;** Pape & Steiner Environmental Services, "Emission Tests on Quarry Plant #2 Kiln, February 24, 1987".
43. **SW Victorville #2;** Pape & Steiner Environmental Services, "Emission Tests on #2 Kiln Baghouse, March 32 and April 1, 1987".