AP42 Section: **11.7 Ceramic Products Manufacturing**

Title: **Comments**

1993

MMEI: Copy

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

Mr. Robert Eagan
American Ceramic Society
757 Brooksedge Plaza Drive
Westerville, Ohio 43081-2821

Dear Mr. Eagan:

As you may 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 8 of AP-42 addresses the mineral products industry and is one of the chapters being updated. Enclosed is a copy of the draft Section 8.5, Refractory Manufacturing, and the corresponding background report for the section. We would appreciate it if you or one of your associates would review the enclosed draft AP-42 section and background report and would send us your comments. It would also be helpful if you could distribute copies of the enclosed section and background report to members of your association for their review. Unfortunately, we are on a very tight schedule, and it is important that we have all comments by April 28, 1993.

The emission factors presented in AP-42 generally are based upon results from validated tests or other emission evaluations that are similar to EPA reference test methods. As a result, revisions to the emission factors presented in AP-42 sections must be supported by equivalent documentation. If you disagree with any emission factors presented in the enclosed AP-42 section or have additional supporting documentation, we would appreciate your providing either a copy of the documentation or information on how we can obtain copies of the supporting documentation.

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

OAQPS/TSD/EIB/:RMYERS, rm 455B, 4201 Bldg, 541-5407, MD-14
(MRI/RMcKinshaw/LKaufman/677-0249/03/24/93)

IDENTICAL LETTER SENT TO THE FOLLOWING ADDRESSEE:

Mr. Charles G. Marvin
Refractories Institute
Suite 326, 500 Wood Street
Pittsburgh, Pennsylvania 15222
Mr. Marvin
8.5, Refractory Manufacturing
April 28, 1993

Enclosure 1

EMISSION FACTOR DOCUMENTATION FOR AP-42 SECTION 8.5
Refractory Manufacturing

1. INTRODUCTION

The document "Compilation of Air Pollutant Emissions Factors" (AP-42) has been published by the U.S. Environmental Protection Agency (EPA) since 1972. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. AP-42 is routinely updated by EPA to respond to new emission factor needs of EPA, State and local air pollution control programs, and industry.

An emission factor relates the quantity (weight) of pollutants emitted to a unit of activity of the source. The uses for the emission factors reported in AP-42 include:

1. Estimates of areawide emissions;

2. Estimates of emissions for a specific facility; and

3. Evaluation of emissions relative to ambient air quality.

The purpose of this report is to provide background information from test reports and other information to support revision of AP-42 Section 8.5, Refractory Manufacturing.

This background report consists of five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the refractory manufacturing industry. It includes a characterization of the industry, an overview of the different process types, a description of emissions, and a description of the technology used to control emissions resulting from refractory manufacturing. Section 3 is a review of emissions data collection and analysis procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. Section 4 details revisions to the existing AP-42 section narrative and the development of pollutant emission factors. It includes the review of specific data sets and the results of data analysis. Section 5 presents the draft AP-42 Section 8.5, Refractory Manufacturing.

2. INDUSTRY DESCRIPTION[1]

Refractories are materials that provide linings for high-temperature furnaces and other processing units. Refractories must be able to withstand physical wear, high temperatures (above 538°C [1000°F]), and corrosion by chemical agents. There are two general classifications of refractories: clay (Standard Industrial Classification [SIC] Code 3255) and nonclay (SIC Code 3297). The six-digit source classification code (SCC) for refractory manufacturing is 305005.

Clay refractories are produced from fireclay (hydrous silicates of aluminum) and high alumina (57 to 87.5 percent). Other clay minerals used in the production of refractories include kaolin, bentonite, ball clay, and common clay. Nonclay refractories are produced from a composition of alumina (<87.5 percent), mullite, chromite, magnesite, silica, silicon carbide, zircon, and other nonclays.

Refractories are produced in two basic forms: preshaped objects and unformed compositions in granulated or plastic forms. The preformed products are called bricks and shapes. These products are used to form the walls, arches, and floor tiles of various high-temperature process equipment. Unformed compositions include mortars, gunning mixes, castables (refractory concretes), ramming mixes, and plastics. These products are then cured to form a monolithic, internal structure after application.

2.1 CHARACTERIZATION OF THE INDUSTRY[2]

There are a total of approximately 280 refractory manufacturing plants operating in the United States. This total is divided more or less equally between clay and nonclay refractory plants. Refractory materials are produced in 37 States, and the leading producers are Ohio and Pennsylvania. Table 2-1 lists the number of plants by State for the largest producers of refractory materials. The largest producers of fire clay, which is the most widely used raw material for refractory manufacturing, are Missouri, Ohio, and Alabama. Total annual shipments of refractory materials in the United States is approximately $2 billion.

TABLE 2-1. LARGEST REFRACTORY MATERIALS PRODUCING STATES[2]

State	No. of refractory plants	
	Clay (SIC Code 3255)	Nonclay (SIC Code 3297)
Alabama	8	--
California	10	6
Georgia	5	4
Illinois	7	7
Indiana	--	7
Kentucky	--	6
Maryland	4	--
Michigan	--	7
Missouri	9	3
New York	--	3
New Jersey	--	7
North Carolina	--	2
Ohio	27	24
Pennsylvania	30	22
Texas	7	--
West Virginia	--	3

2.2 PROCESS DESCRIPTION[1,3]

Refractory manufacturing involves four processes: raw material processing, forming, firing, and final processing. Raw material processing consists of crushing and grinding raw materials, followed by size classification and calcining and drying the raw materials, if necessary. Certain types of refractory products may omit some of these processes. Figure 2-1 illustrates the refractory manufacturing process.

Forming consists of mixing the raw materials and forming them into the desired shapes. This process frequently occurs under wet or moist conditions. Firing involves heating the refractory material to high temperatures in a periodic (batch) or continuous tunnel kiln to form the ceramic bond that gives the product its refractory properties. The final processing stage involves milling, grinding, and sandblasting of the finished product. This step allows the product to maintain the correct shape and size after thermal expansion has occurred. Final processing may also include, for certain products, impregnating the product with tar and pitch, and final packaging.

Two other types of refractory processes also warrant discussion. The first is production of fused products. This process involves using an electric arc furnace to melt the refractory raw materials, then pouring the melted materials into sand molds for forming. Another type of refractory process is ceramic fiber production. In this process, calcined kaolin is melted in an electric arc furnace. The melted material is then fiberized in a blowchamber with a centrifuge device, or the molten clay is dropped into an air jet and is immediately blown into fine strands. After the blowchamber, the ceramic fiber may then be conveyed to an oven for curing, which adds structural rigidity to the fibers. During the curing process, oils are used to lubricate the fibers and the machinery used to handle and form the fibers. The production of ceramic fiber for refractory material is very similar to the production of mineral wool.

2.3 EMISSIONS[3-8]

The primary pollutant of concern that is emitted in refractory manufacturing is particulate matter (PM). Particulate matter emissions occur during milling and grinding of the raw materials, firing of the brick kiln, tar and pitch operations, and finishing of the refractories (grinding, milling, and sandblasting). The greatest emissions of PM are from brick firing kilns and electric arc furnaces.

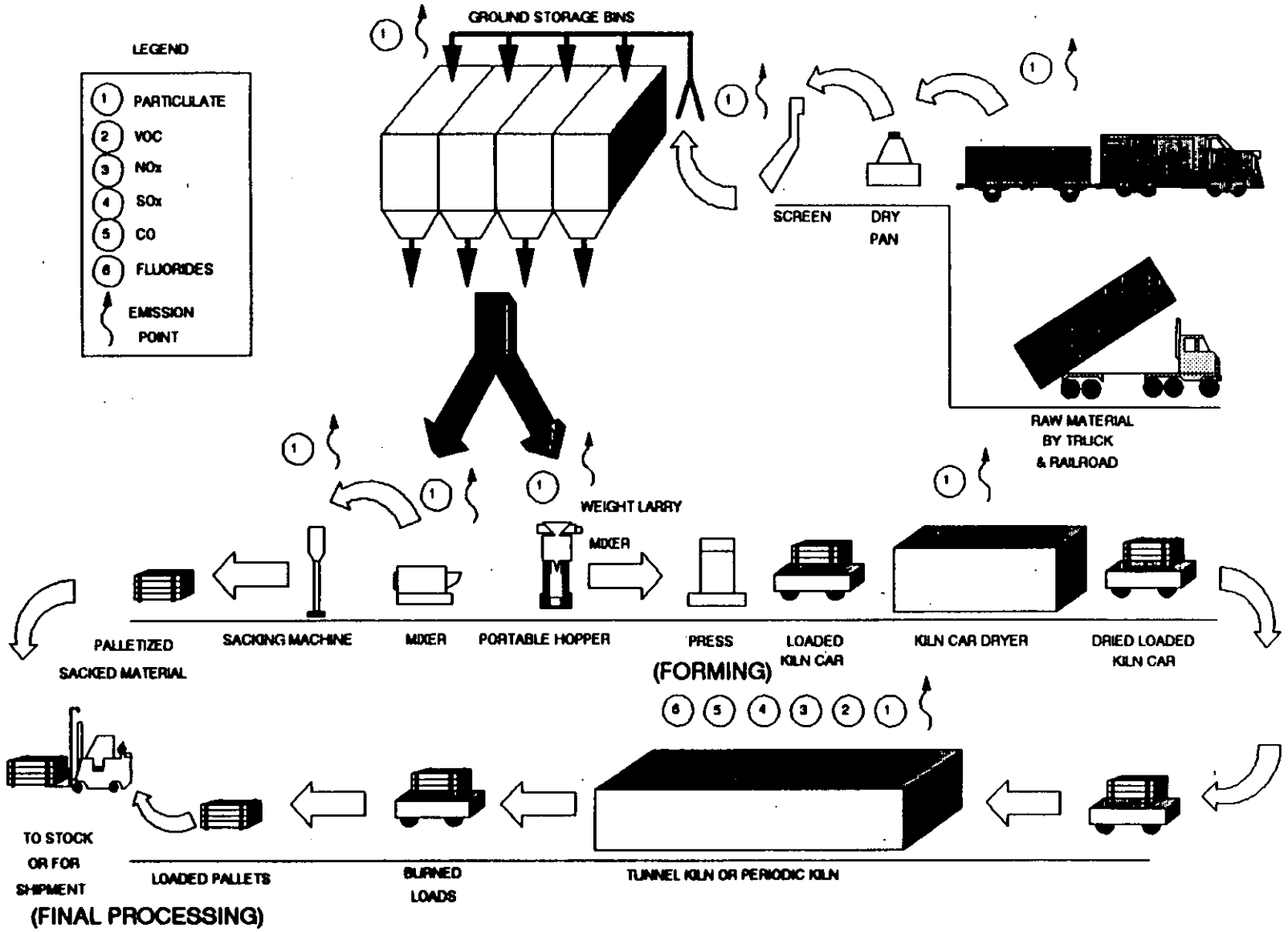

Figure 2-1. Refractory manufacturing process flow diagram.

Pollutants emitted as a result of combustion in the calcining and kilning processes include sulfur oxides (SO_x), nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compounds (VOC's). Volatile organic compounds are also emitted by tar and pitch operations. The emission of SO_x is also a function of the sulfur content of certain clays and the plaster added to refractory materials to induce brick setting. Fluoride emissions occur during the kilning process and are a result of fluorides in the raw materials.

Chromium is used in several types of nonclay refractories, including chrome-magnesite (chromite-magnesite), magnesia-chrome, and chrome-alumina. Chromium compounds are emitted from the ore crushing and grinding, material drying and storage, and brick firing and finishing processes used in producing these types of refractories. In addition, a number of elements in trace concentrations, including aluminum, beryllium, lead, mercury, manganese, nickel, titanium, vanadium, and zinc are emitted in trace amounts by drying, calcining, and firing operations of all types of refractory materials.

2.4 CONTROL TECHNOLOGY[3-8]

Emissions from crushing and grinding operations generally are controlled with fabric filters. Product recovery cyclones followed by wet scrubbers are used on calciners and dryers to control PM emissions from these sources.

Particulate matter emissions from kilns generally are not controlled. However, at least one refractory manufacturer currently uses a multiple-stage scrubber to control kiln emissions. Particulate matter emissions from electric arc furnaces generally are controlled with fabric filters. Particulate matter removal of 87 percent and fluoride removal of greater than 99 percent have been reported at one facility that uses an ionizing wet scrubber.

Volatile organic compounds emitted from tar and pitch operations generally are controlled by incineration, when inorganic particulates are not significant. Based on destruction of organic aerosols, a control efficiency in excess of 95 percent can be achieved using incinerators.

Emissions of PM from the ceramic fiber process also are controlled with fabric filters, and the efficiency is similar to that found in the fused cast refractory process. To control blowchamber emissions, a fabric filter is used to remove small pieces of fine threads that are formed in the fiberization stage. The efficiency of fabric filters in similar control devices exceeds 99 percent. Small particles of ceramic fiber are broken off or separated during the handling and forming of the fiber blankets in the curing oven. An oil is used in this process, and higher molecular weight organics are emitted. These emissions are controlled using a fabric filter followed by incineration. An overall efficiency in excess of 95 percent is expected for this type of control.

REFERENCES FOR SECTION 2

1. Refractories, The Refractories Institute, Pittsburgh, PA, 1987.

2. 1987 Census of Manufactures, U.S. Department of Commerce, Washington D.C., May 1990.

3. Source Category Survey: Refractory Industry, EPA-450/3-80-006, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1980.

4. Locating and Estimating Air Emissions from Sources of Chromium, EPA-450/4-84-007g, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1985.

5. Calciners and Dryers Emission Test Report, North American Refractories Company, Farber, Missouri, EMB Report 84-CDR-14, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1984.

6. Emission Test Report: Plant A, Confidential Business Information Files, Document No. C-7-12, ESD Project No. 81/08, U.S. Environmental Protection Agency, Research Triangle Park, NC.

7. Calciners and Dryers Emission Test Report, A. P. Green Company, Mexico, Missouri, EMB Report 83-CDR-1, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, October 1983.

8. Chromium Screening Study Test Report, Harbison-Walker Refractories, Baltimore, Maryland, EMB Report 85-CHM-12, U.S. Environmental Protection Agency, Research Triangle Park, NC, June 1985.

3. GENERAL DATA REVIEW AND ANALYSIS

3.1 LITERATURE SEARCH AND SCREENING

Data for this investigation were obtained from a number of sources within the Office of Air Quality Planning and Standards (OAQPS) and from outside organizations. The AP-42 Background Files located in the Emission Inventory Branch (EIB) were reviewed for information on the industry, processes, and emissions. The Crosswalk/Air Toxic Emission Factor Data Base Management System (XATEF) and the VOC/PM Speciation Data Base Management System (SPECIATE) were searched by SCC code for identification of the potential pollutants emitted and emission factors for those pollutants. A general search of the Air CHIEF CD-ROM also was conducted to supplement the information from these two data bases.

Information on the industry, including number of plants, plant location, and annual production capacities were obtained from the Minerals Yearbook, Census of Minerals, and Census of Manufacturers. The Aerometric Information Retrieval System (AIRS) data base also was searched for data on the number of plants, plant location, and estimated annual emissions of criteria pollutants.

A number of sources of information were investigated specifically for emission test reports and data. A search of the Test Method Storage and Retrieval System (TSAR) data base was conducted to identify test reports for sources within the refractory manufacturing industry. Copies of these test reports were obtained from the files of the Emission Measurement Branch (EMB). The EPA library was searched for additional test reports. A list of plants that have been tested within the past 5 years was compiled from the AIRS data base. Using this information and information obtained on plant location from the Minerals Yearbook, Census of Minerals, and Census of Manufacturers, State and Regional offices were contacted about the availability of test reports. However, the information obtained from these offices was limited. Publications lists from the Office of Research and Development (ORD) and Control Technology Center (CTC) were also searched for reports on emissions from the refractory manufacturing industry. In addition, the Refractories Institute was contacted for assistance in obtaining information about the industry and emissions.

To reduce the amount of literature collected to a final group of references from which emission factors could be developed, the following general criteria were used:

1. Emissions data must be from a primary reference:

   a. Source testing must be from a referenced study that does not reiterate information from previous studies.

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

2. The referenced study must contain test results based on more than one test run.

3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions.

A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria.

3.2 EMISSION DATA QUALITY RATING SYSTEM[1]

As part of the analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data were excluded from consideration:

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

2. Test series representing incompatible test methods (i.e., comparison of EPA Method 5 front half with EPA Method 5 front and back half);

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; and

5. Test series in which it is not clear whether the emissions were measured before or after the control device.

Test data sets that were not excluded were assigned a quality rating. The rating system used was that specified by EIB for preparing AP-42 sections. The data were rated as follows:

A--Multiple tests that were performed on the same source using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in EPA reference test methods, although these methods were used as a guide for the methodology actually used.

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

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

D--Tests that were 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 acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of the extent such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in the report, and any variations in the sampling and process operation are noted. 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 (if any) specified by EPA 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.

3.3 EMISSION FACTOR QUALITY RATING SYSTEM[1]

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

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 so that variability within the source category population may be minimized.

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. The source category is specific enough so that variability within the source category population may be minimized.

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. In addition, the source category is specific enough so that variability within the source category population may be minimized.

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 noted in the emission factor table.

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 noted.

The use of these criteria is somewhat subjective and depends to an extent on the individual reviewer. Details of the rating of each candidate emission factor are provided in Chapter 4 of this report.

REFERENCES FOR SECTION 3

1. Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections (Draft), Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC. March 6, 1992.

4. AP-42 SECTION DEVELOPMENT

4.1 REVISIONS TO SECTION NARRATIVE

The draft AP-42 section described in this report replaces Section 8.5, Castable Refractories, in the current version of AP-42. The existing section, which was last revised in 1972, addresses castable refractory manufacturing only and does not describe other types of refractory manufacturing processes and emissions. In addition, the quality of the data, upon which the existing section was based, is suspect. The draft section, which is based on more recent information, addresses several types of refractory manufacturing and provides a description of the industry and a process flow diagram.

4.2 POLLUTANT EMISSION FACTOR DEVELOPMENT

In addition to reviewing the data available in the background file for Section 8.5, a total of eight emission test reports were documented and reviewed in the process of revising the section on refractory manufacturing. Three of the tests (References 1, 2, and 3) were conducted as part of the emission test program for developing a new source performance standard (NSPS) for calciners and dryers in mineral processing industries. These tests were sponsored by EPA. Reference 4 documents a test conducted by EPA as part of the chromium screening study to identify significant sources of chromium emissions. The other four test reports reviewed were industry-sponsored compliance tests (References 5 through 8). All four of the industry-sponsored tests were rejected from consideration in developing emission factors. The emissions test documented in Reference 5 was conducted at the same facility as the test documented in Reference 1. However, the data from Reference 5 was not considered for emission factor development because of anisokinetic conditions during testing. The emission test documented in Reference 6 was conducted at the same facility as the test documented in Reference 2. However, Reference 6 does not include process rate data and the test was conducted at sources other than those documented in Reference 2. References 7 and 8 lack adequate documentation of process rates for emission factor development. The four emission tests from which emission factors were developed are described below. Emission factors for refractory manufacturing included in the XATEF and SPECIATE data bases were also reviewed. A discussion of these

emission factors is also presented. Finally, a discussion of the review of the existing test data in the AP-42 background file is presented.

4.2.1 Review of Specific Data Sets

4.2.1.1 Reference 1. This test report included measurements of filterable PM, particle size distribution, and carbon dioxide (CO_2) on a rotary dryer and was sponsored by EPA as part of the emission test program for the development of the proposed NSPS for calciners and dryers. Emission rates were measured for two types of fire clay used in refractory manufacturing--flint clay (Reference 1a) and plastic clay (Reference 1b). A Method 5 sampling train was used for measuring the PM, and cascade impactors were used for quantifying the particle size distribution. The CO_2 emissions were measured using Method 3A (instrument analyzer).

Emissions from the dryer were controlled by means of a cyclone (for product recovery) followed by a wet scrubber in series. The wet scrubber operated with a pressure drop of 2.7 to 3.2 kilopascals (kPa) (11 to 13 inches of water [in. w.c.]). Three runs were conducted on each of the two clays. Uncontrolled emissions and controlled emissions, at both the cyclone and scrubber outlets, were measured. In addition, a trace element analysis of the PM catch was performed for each of the two clays. Analysis of the plastic clay and flint clay samples identified aluminum, beryllium, calcium, chromium, iron, lead, mercury, magnesium, manganese, nickel, titanium, vanadium, and zinc.

A rating of A was assigned to both sets of PM, particle size distribution, and CO_2 data. The reports included adequate detail, the methodology appeared to be sound, and no problems were reported. The trace element data were not rated due to the fact that only one run was analyzed.

4.2.1.2 Reference 2. This test included measurements of filterable PM, particle size distribution, sulfur dioxide (SO_2), and NO_x on a coal-fired rotary calciner and was sponsored by EPA as part of the emission test program for the development of the proposed NSPS for calciners and dryers. A Method 5 sampling train was used for measuring the PM, and cascade impactors were used for quantifying the particle size distribution. Sulfur dioxide and NO_x emissions were measured in accordance with EPA Reference Methods 6 and 7, respectively.

Emissions from the calciner were controlled by means of a multiclone (for product recovery) followed by a venturi scrubber in series. The scrubber operated at a pressure drop of 4.5 kPa (18 in. w.c.). Three runs were conducted. For PM and particle size distribution, uncontrolled emissions and controlled emissions at both the cyclone and scrubber outlets were measured. Sulfur dioxide and NO_x emissions were measured at the scrubber outlet only. In addition, a trace element analysis of the PM catch for one run was performed. The analysis indicated trace amounts of aluminum, beryllium, calcium, chromium, iron, lead, mercury, magnesium, manganese, nickel, titanium, vanadium, and zinc.

A rating of A was assigned to the PM, SO_2, and NO_x test data. The reports included adequate detail, the methodology appeared to be sound, and no problems were reported. The trace element data were not rated due to the fact that only one run was analyzed.

4.2.1.3 Reference 3. This test included measurements of filterable PM and particle size distribution on a rotary calciner and was sponsored by EPA as part of the emission test program for the development of the proposed NSPS for calciners and dryers. A Method 5 sampling train was used for measuring the PM, and cascade impactors were used for quantifying the particle size distribution.

Emissions from the calciner were controlled by means of a multiclone (for product recovery) followed by a venturi scrubber in series. The scrubber operated at a pressure loss of 6 to 6.7 kPa (24 to 27 in. w.c.). A total of three runs were conducted. For PM and particle size distribution, uncontrolled emissions at the calciner outlet and controlled emissions at the scrubber outlet were measured. In addition, a trace element analysis of the PM catch was performed. The analysis identified calcium, chromium, iron, nickel, silicon, zinc, aluminum, magnesium, lead, mercury, and fluorine in the sample. However, because the run number for the trace element analysis was not identified in the report, it was not possible to develop emission factors from the data.

A rating of A was assigned to the test data. The reports included adequate detail. Although some changes were made in the number of sampling points and sampling time after the first run, the methodology appeared to be sound, and no problems were reported.

4.2.1.4 Reference 4. This test report documented measurements of filterable PM, hexavalent chromium (Cr^{+6}), and total chromium emissions from a refractory rotary dryer and tunnel kiln. The particle size distributions of the dryer and kiln emissions also were measured. The plant uses magnesite and chromite ores to manufacture chromite-magnesite refractory brick. The chromite content of the material processed varied from 14.5 to 46.3 percent. The test was sponsored by EPA as part of the screening study for industrial sources of chromium emissions.

A Method 5 sampling train (front half only) was used to measure filterable PM emissions. The Method 5 filter catch was analyzed for Cr^{+6} using the diphenylcarbazide colorimetric method and for total chromium using neutron activation analysis. Particle size distribution was measured using cascade impactors with a preseparator.

Both uncontrolled and controlled (cyclone followed by a fabric filter) dryer PM emissions were sampled. However, because the controlled emissions included the dryer exhaust and the emissions from five material handling points, the emission factors developed from the controlled data are of limited use. Four test runs were conducted at both the cyclone inlet and fabric filter outlet. Three test runs of uncontrolled filterable PM emissions from a tunnel kiln also were conducted. In addition, four particle size distribution runs were conducted on the dryer exhaust and fabric filter outlet, and three particle size distribution runs were conducted on the kiln exhaust.

The PM and particle size distribution data are rated A. The data are presented in adequate detail and a sound methodology was used. The Cr^{+6} and total chromium data are rated C due to the fact that the methods used were still under development at the time of the test.

4.2.2 Review of XATEF and SPECIATE Data Base Emission Factors

The only emission factors for refractory manufacturing included in the XATEF data base are for chromium emissions from chromite-magnesite brick and chromic oxide brick production. The source of these emission factors traces back to a 1973 document (EPA-450/3-74-012), which references the 1972 version of AP-42. Because there is no further documentation of these emission factors in the AP-42 background files, the original source of these data could not be identified. Therefore, these emission factors do not satisfy the minimum criteria for inclusion in AP-42.

The SPECIATE data base includes a number of emission factors for refractory manufacturing. However, the emission factors are based on speciation profiles for average mineral products industry sources, and therefore do not satisfy the minimum criteria for inclusion in AP-42.

4.2.3 Review of Test Data in AP-42 Background File

The current version of Section 8.5 includes particulate emission factors for drying, crushing, electric arc melting, curing, and molding castable refractories. The emission factors are based on unpublished data from three stack tests that were conducted at a plant in Kentucky in 1967 and 1969. The background file contains estimates of annual emissions from the same facility for 1968 but does not contain any of the test data upon which the emission factors were based. Because of the lack of documentation and the fact that the tests predate the development of EPA reference methods, the test method and representativeness of the data are highly suspect. Therefore, the emission factors based on these data cannot be considered to be representative of the refractory manufacturing industry, so they were deleted from the section.

4.2.4 Results of Data Analysis

Emission factors were developed for three types of refractory manufacturing sources: rotary dryers, rotary calciners, and tunnel kilns. The majority of these emission factors were developed for the processing of fire clay. However, emission factors also were developed for the processing of chromite-magnesite ore.

For rotary dryers, emission factors were developed for emissions of filterable PM, filterable PM-10, CO_2, and several trace elements, including aluminum, beryllium, calcium, chromium, iron, lead, magnesium, manganese, mercury, nickel, titanium, vanadium, and zinc. These factors were developed from test data on two types of fire clay. In addition, rotary dryer emission factors for the drying of chromite-magnesite ore were developed for filterable PM, filterable PM-10, hexavalent chromium, and total chromium. Particle size distribution for emissions from the drying of both fire clay and chromite-magnesite ore also were developed from the data. For the drying of fire clay, Table 4-1 summarizes the test data on emissions of filterable PM, filterable PM-10, and CO_2, and Table 4-2 summarizes the data on trace element emissions. Although separate data are presented in

TABLE 4-1. SUMMARY OF TEST DATA FOR REFRACTORY MANUFACTURING ROTARY DRYERS

Type of control	Pollutant	No. of test runs	Data rating	Emission factor		Ref. No.
				range, kg/Mg (lb/ton)	average, kg/Mg (lb/ton)	
none	filterable PM	3	A	17-53 (34-105)	32 (63)	1a
none	filterable PM	3	A	29-38 (58-77)	34 (67)	1b
cyclone	filterable PM	3	A	2.7-13 (5.4-25)	6 (12)	1a
cyclone	filterable PM	3	A	2.8-6.9 (5.7-14)	5.1 (10.1)	1b
cyclone/ scrubber	filterable PM	3	A	0.034-0.104 (0.067-0.21)	0.062 (0.124)	1a
cyclone/ scrubber	filterable PM	3	A	0.024-0.064 (0.048-0.13)	0.043 (0.085)	1b
none	filterable PM-10	3	A	0.7-20 (1.4-41)	17 (33)	1a
none	filterable PM-10	2	A	2.6-5.8 (5.2-12)	4.2 (8.3)	1b
cyclone	filterable PM-10	2	A	1.2-2.0 (2.5-4.0)	1.6 (3.2)	1a
cyclone	filterable PM-10	2	A	0.96-2.3 (1.9-4.5)	1.6 (3.2)	1b
none	CO_2	3	A	11-18 (21-36)	13 (26)	1a
none	CO_2	3	A	7.1-13 (14-25)	9.7 (19)	1b
cyclone	CO_2	3	A	15-26 (30-52)	19 (37)	1a
cyclone	CO_2	3	A	11-17 (22-34)	14 (28)	1b
cyclone/ scrubber	CO_2	3	A	13-33 (26-67)	20 (40)	1a
cyclone/ scrubber	CO_2	3	A	12-17 (23-35)	14 (29)	1b

TABLE 4-2. SUMMARY OF TRACE ELEMENT EMISSION DATA FOR ROTARY DRYERS[a]

Reference 1a

Pollutant	Uncontrolled		Cyclone		Cyclone + scrubber	
	Emission factor		Emission factor		Emission factor	
	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
aluminum	1.1	2.2	0.14	0.27	0.0044	0.0088
beryllium	$1.2x10^{-5}$	$2.3x10^{-5}$	b	b	b	b
calcium	0.011	0.022	0.0018	0.0036	0.00070	0.0014
chromium	0.0031	0.0063	0.00023	0.00046	$1.4x10^{-5}$	$2.9x10^{-5}$
iron	0.12	0.24	0.018	0.037	0.00068	0.0014
lead	0.00056	0.0011	0.00010	0.00020	$7.4x10^{-6}$	$1.5x10^{-5}$
magnesium	0.020	0.040	0.0024	0.0048	0.00016	0.00033
manganese	0.00087	0.0017	b	b	$5.2x10^{-6}$	$1.0x10^{-5}$
mercury	$6.0x10^{-6}$	$1.2x10^{-5}$	$2.2x10^{-6}$	$4.4x10^{-6}$	$6.5x10^{-7}$	$1.3x10^{-6}$
nickel	0.0063	0.013	0.00013	0.00027	$9.1x10^{-6}$	$1.8x10^{-5}$
titanium	0.0015	0.0030	0.00044	0.00088	0.00011	0.00021
vanadium	0.0011	0.0023	0.00017	0.00034	$9.1x10^{-6}$	$1.8x10^{-5}$
zinc	0.0058	0.012	0.00012	0.00025	$2.5x10^{-5}$	$4.9x10^{-5}$

Reference 1b

Pollutant	Uncontrolled		Cyclone		Cyclone + scrubber	
	Emission factor		Emission factor		Emission factor	
	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
aluminum	2.4	4.7	0.40	0.79	0.0037	0.0075
beryllium	$8.2x10^{-5}$	0.00016	$1.1x10^{-5}$	$2.2x10^{-5}$	b	b
calcium	0.072	0.14	0.011	0.023	0.0014	0.0028
chromium	0.0055	0.011	0.00098	0.0020	$9.7x10^{-6}$	$1.9x10^{-5}$
iron	0.19	0.39	0.029	0.058	0.00039	0.00078
lead	0.00092	0.0018	0.00015	0.00031	$5.8x10^{-6}$	$1.2x10^{-5}$
magnesium	0.0084	0.017	0.0077	0.015	0.00045	0.00090
manganese	b	b	b	b	$3.2x10^{-6}$	$6.4x10^{-6}$
mercury	$2.0x10^{-5}$	$4.0x10^{-5}$	$4.5x10^{-6}$	$9.0x10^{-6}$	$6.4x10^{-7}$	1.3e-$x10^{-6}$
nickel	0.0029	0.0057	0.00073	0.0015	$1.1x10^{-5}$	$2.3x10^{-5}$
titanium	0.0025	0.0051	0.00060	0.0012	5.9-$x10^{-5}$	0.00012
vanadium	0.0036	0.0073	0.00063	0.0013	$5.6x10^{-6}$	$1.1x10^{-5}$
zinc	0.0021	0.0042	0.00026	0.00052	$3.0x10^{-5}$	$6.1x10^{-5}$

[a]Based on 1 run; data are not rated.
[b]Below detection limit.

TABLE 4-2 (continued)

Average of 1a and 1b

Pollutant	Uncontrolled		Cyclone		Cyclone + scrubber	
	Emission factor		Emission factor		Emission factor	
	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
aluminum	1.7	3.5	0.27	0.53	0.0041	0.0081
beryllium	4.7×10^{-5}	9.3×10^{-5}	1.1×10^{-5}	2.2×10^{-5}	b	b
calcium	0.041	0.083	0.0066	0.013	0.0011	0.0021
chromium	0.0043	0.0087	0.00061	0.0012	1.2×10^{-5}	2.4×10^{-5}
iron	0.16	0.32	0.024	0.047	0.00053	0.0011
lead	0.00074	0.0015	0.00013	0.00025	6.6×10^{-6}	1.3×10^{-5}
magnesium	0.014	0.028	0.0051	0.010	0.00031	0.00061
manganese	0.00087	0.0017	b	b	4.2×10^{-6}	8.2×10^{-6}
mercury	1.3×10^{-5}	2.6×10^{-5}	3.3×10^{-5}	6.7×10^{-6}	6.5×10^{-7}	1.3×10^{-6}
nickel	0.0046	0.0092	0.00043	0.00087	1.0×10^{-5}	2.0×10^{-5}
titanium	0.0020	0.0040	0.00052	0.0010	8.3×10^{-5}	0.00017
vanadium	0.0024	0.0048	0.00040	0.00080	7.4×10^{-6}	1.5×10^{-5}
zinc	0.0039	0.0079	0.00019	0.00038	2.8×10^{-5}	5.5×10^{-5}

[a]Based on 1 run; data are not rated.
[b]Below detection limit.

Table 4-1 for CO_2 emissions from uncontrolled and controlled rotary dryers all the data is considered to be uncontrolled, because the control devices used (cyclones and scrubber) achieve only incidental control of CO_2 emissions. Table 4-3 summarizes the test data on emissions of filterable PM, filterable PM-10, hexavalent chromium, and total chromium from the drying of chromite-magnesite ore. Table 4-4 summarizes the particle size distribution data for the drying of fire clay, and Table 4-5 summarizes the particle size distribution data for the drying of chromite-magnesite ore.

For rotary calciners, emission factors were developed for emissions of filterable PM, filterable PM-10, CO_2, SO_2, NO_x, and several trace elements, including aluminum, beryllium, calcium, chromium, iron, lead, magnesium, manganese, mercury, nickel, titanium, vanadium, and zinc. These factors were developed from test data on the calcining of fire clay. Particle size distribution for emissions from calcining fire clay also was developed from the data. For calcining fire clay, Table 4-6 summarizes the test data on emissions of filterable PM, filterable PM-10, SO_2, NO_x, and CO_2, and Table 4-7 summarizes the data on trace element emissions. Although separate data are presented in Table 4-6 for CO_2 emissions from uncontrolled and controlled rotary calciners, all the data is considered to be uncontrolled, because the control devices used (multiclones and scrubber) achieve only incidental control of CO_2 emissions. Table 4-8 summarizes the particle size distribution data for the calcining of fire clay.

For tunnel kilns, emission factors were developed for filterable PM, filterable PM-10, hexavalent chromium, and total chromium emissions from the firing of chromite-magnesite ore. Particle size distribution for emissions from the tunnel kilns firing chromite-magnesite ore also were developed from the data. Table 4-3 summarizes the test data for emissions from tunnel kilns, and Table 4-5 summarizes the particle size distribution data for tunnel kiln emissions.

Although the emission factors discussed above for filterable PM, filterable PM-10, CO_2, SO_2, and NO_x, are developed from A-rated test data, each of these factors is based on only one or two emission tests. Because of the relatively large number of refractory manufacturing plants (280), it is likely that the emission factors are not representative of the industry. For this reason, these emission factors are all assigned a quality rating of D. The emission factors developed for hexavalent chromium and total chromium emissions are developed from C-rated data. For this reason, these emission factors are rated E.

TABLE 4-3. SUMMARY OF TEST DATA FOR REFRACTORY MANUFACTURING FOR CHROMITE/MAGNESITE ORE ROTARY DRYERS AND TUNNEL KILNS

Process	Type of control	Pollutant	No. of test runs	Data rating	Emission factor		Ref. No.
					range, kg/Mg Cr_2O_3 (lb/ton Cr_2O_3)	average, kg/Mg Cr_2O_3 (lb/ton Cr_2O_3)	
rotary dryer	none	filterable PM	4	A	0.45 to 1.36 (0.90 to 2.71)	0.83 1.7	4
	cyclone/ fabric filter	filterable PM	4	A	0.11 to 0.21 (0.22 to 0.43)	0.15 0.30	4
	none	filterable PM-10	4	A	--	0.20 (0.41)	4
	none	hexavalent chromium	4	C	$1.3x10^{-6}$ to $4.2x10^{-6}$ ($2.6x10^{-6}$ to $8.3x10^{-6}$)	$2.5x10^{-6}$ ($5.0x10^{-6}$)	4
	cyclone/ fabric filter	hexavalent chromium	4	C	$9.9x10^{-7}$ to $2.6x10^{-6}$ ($2.0x10^{-6}$ to $5.3x10^{-6}$)	$1.6x10^{-6}$ ($3.2x10^{-6}$)	4
	none	total chromium	4	C	0.0094 to 0.077 (0.019 to 0.15)	0.037 (0.073)	4
	cyclone/ fabric filter	total chromium	4	C	0.0018 to 0.012 (0.0035 to 0.024)	0.0062 (0.012)	4
tunnel kiln	none	filterable PM	3	A	0.26 to 0.55 (0.51 to 1.1)	0.41 (0.82)	4
	none	filterable PM-10	3	A	--	0.34 (0.69)	4
	none	hexavalent chromium	3	A	0.00013 to 0.00016 (0.00025 to 0.00031)	0.00015 (0.00029)	4
	none	total chromium	3	A	0.0017 to 0.0031 (0.0033 to 0.0062)	0.0023 (0.0046)	4

TABLE 4-4. SUMMARY OF PARTICLE SIZE DATA FOR EMISSIONS FROM REFRACTORY ROTARY DRYERS

Reference 1a

Diameter, micrometers	Uncontrolled			Controlled (cyclone)		
	Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor	
		kg/Mg	lb/ton		kg/Mg	lb/ton
2.5	3	0.9	1.9	13	0.79	1.6
6.0	14	4.4	8.8	32	1.9	3.9
10.0	36	11	23	53	3.2	6.4
15.0	50	16	32	71	4.3	8.6
20.0	66	21	42	78	4.7	9.4

Reference 1b

Diameter, micrometers	Uncontrolled			Controlled (cyclone)		
	Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor	
		kg/Mg	lb/ton		kg/Mg	lb/ton
2.5	2	0.7	1.3	14	0.71	1.4
6.0	6	2.0	4.0	29	1.5	2.9
10.0	12	4.0	8.0	38	1.9	3.8
15.0	24	8.0	16	48	2.4	4.8
20.0	36	12	24	57	2.9	5.8

Average

Diameter, micrometers	Uncontrolled			Controlled (cyclone)		
	Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor	
		kg/Mg	lb/ton		kg/Mg	lb/ton
2.5	3	0.81	1.6	14%	0.75	1.5
6.0	10	3.2	6.4	31%	1.7	3.4
10.0	24	7.7	15	46%	2.6	5.1
15.0	37	12	24	60%	3.4	6.7
20.0	51	16	33	68%	3.8	7.6

TABLE 4-5. SUMMARY OF PARTICLE SIZE DATA FOR CHROMITE-MAGNESITE ORE: ROTARY DRYER AND TUNNEL KILN[4]

Uncontrolled rotary dryer

Diameter, micrometers	Filterable PM			Hexavalent chromium			Total chromium		
	Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor	
		kg/Mg	lb/ton		kg/Mg	lb/ton		kg/Mg	lb/ton
1	1.2	0.010	0.020	3.5	8.8×10^{-8}	1.8×10^{-7}	0.8	1.5×10^{-4}	3.0×10^{-4}
5	13	0.11	0.22	39	9.8×10^{-7}	2.0×10^{-6}	9	0.0017	0.0033
10	24	0.20	0.41	64	1.6×10^{-6}	3.2×10^{-6}	19	0.0035	0.0070

Uncontrolled tunnel kiln

Diameter, micrometers	Filterable PM			Hexavalent chromium			Total chromium		
	Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor	
		kg/Mg	lb/ton		kg/Mg	lb/ton		kg/Mg	lb/ton
1	71	0.29	0.58	71	5.3×10^{-5}	0.00011	84	0.0010	0.0019
5	78	0.32	0.64	81	6.1×10^{-5}	0.00012	91	0.0010	0.0021
10	84	0.34	0.69	84	6.3×10^{-5}	0.00013	93	0.0011	0.0021

TABLE 4-6. SUMMARY OF TEST DATA FOR REFRACTORY MANUFACTURING: ROTARY CALCINERS

Type of control	Pollutant	No. of test runs	Data rating	Emission factor		Ref. No.
				range, kg/Mg (lb/ton)	average, kg/Mg (lb/ton)	
none	PM	3	A	60-73 (120-145)	66 (132)	2
none	PM	3	A	49-65 (99-130)	57 (113)	3
multiclone	PM	3	A	30-32 (60-63)	31 (61)	2
multiclone/ scrubber	PM	3	A	0.25-0.27 (0.49-0.54)	0.26 (0.51)	2
multiclone/ scrubber	PM	3	A	0.032-0.070 (0.064-0.14)	0.045 (0.090)	3
none	PM-10	3	A	10-18 (20-35)	15 (30)	3
multiclone/ scrubber	PM-10	3	A	0.021-0.042 (0.042-0.084)	0.030 (0.060)	3
none	CO_2	3	A	360-410 (710-810)	380 (760)	2
none	CO_2	3	A	290-310 (570-622)	300 (600)	3
multiclone	CO_2	3	A	330-360 (660-720)	340 (680)	2
multiclone/ scrubber	CO_2	3	A	270-280 (530-560)	270 (550)	2
multiclone/ scrubber	CO_2	3	A	210-230 (420-460)	220 (440)	3
multiclone/ scrubber	SO_2	3	A	3.7-3.9 (7.4-7.8)	3.8 (7.6)	2
multiclone/ scrubber	NO_x	3	A	0.75-0.96 (1.5-1.9)	0.87 (1.7)	2

TABLE 4-7. SUMMARY OF TRACE ELEMENT DATA FOR ROTARY CALCINERS[a]

Pollutant	Uncontrolled		Multiclone		Multiclone + scrubber	
	Emission factor		Emission factor		Emission factor	
	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
aluminum	3.4	6.9	1.2	2.4	0.011	0.021
beryllium	8.0×10^{-5}	0.00016	8.0×10^{-5}	0.00016	b	b
calcium	0.080	0.16	0.055	0.11	0.0027	0.0054
chromium	0.0070	0.014	0.0018	0.0037	2.6×10^{-5}	5.2×10^{-5}
iron	0.31	0.62	0.19	0.37	0.0011	0.0023
lead	0.0019	0.0038	0.0012	0.0025	3.6×10^{-5}	7.1×10^{-5}
magnesium	0.024	0.049	0.021	0.041	0.00028	0.00057
manganese	0.00072	0.0014	0.00032	0.00064	b	b
mercury	0.00014	0.00028	5.1×10^{-5}	0.00010	3.9×10^{-6}	7.8×10^{-6}
nickel	0.0049	0.0098	0.0018	0.0036	3.6×10^{-5}	7.2×10^{-5}
titanium	0.041	0.081	0.025	0.050	0.00035	0.00070
vanadium	0.0049	0.0099	0.0032	0.0065	7.2×10^{-5}	0.00014
zinc	0.020	0.039	0.0017	0.0034	8.7×10^{-5}	0.00017

[a]Reference 2; based on 1 run; data are not rated.
[b]Below detection limit.

TABLE 4-8. SUMMARY OF PARTICLE SIZE DATA FOR EMISSIONS FROM ROTARY CALCINERS[3]

Diameter (microns)	Uncontrolled			Controlled (multiclone/scrubber)		
	Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor	
		kg/Mg	lb/ton		kg/Mg	lb/ton
1.0	0.8	0.43	0.86	31	0.014	0.028
1.25	1.1	0.63	1.3	43	0.019	0.038
2.5	2.7	1.5	3.0	46	0.021	0.041
6.0	11	6.4	13	55	0.025	0.050
10.0	25	14	28	69	0.031	0.063
15.0	38	22	43	81	0.036	0.073
20.0	52	29	59	91	0.041	0.082

Table 4-9 summarizes the emission factors developed for emissions of filterable PM, filterable PM-10, CO_2, SO_2, and NO_x from the processing of fire clay; Table 4-10 summarizes the emission factors developed for trace element emissions from the processing of fire clay; and Table 4-11 summarizes the emission factors developed for emissions of filterable PM, filterable PM-10, hexavalent chromium, and total chromium from the processing of chromite-magnesite ore. The emission factors presented in Tables 4-4, 4-5, 4-8, 4-9, and 4-11 are incorporated in the draft AP-42 Section 8.5, Refractory Manufacturing. Because the trace element emission factors are based on unrated data, these emission factors have not been incorporated in the revised AP-42 Section 8.5. As discussed above, the emission factors in the current version of Section 8.5 of AP-42 are highly suspect, and, therefore, have been deleted from the revised section.

REFERENCES FOR SECTION 4

1. Calciners and Dryers Emission Test Report, North American Refractories Company, Farber, Missouri, EMB Report 84-CDR-14, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1984.

2. Emission Test Report: Plant A, Confidential Business Information Files, Document No. C-7-12, ESD Project No. 81/08, U.S. Environmental Protection Agency, Research Triangle Park, NC.

3. Calciners and Dryers Emission Test Report, A. P. Green Company, Mexico, Missouri, EMB Report 83-CDR-1, U.S. Environmental Protection Agency, Research Triangle Park, NC, October 1983.

4. Chromium Screening Study Test Report, Harbison-Walker Refractories, Baltimore, Maryland, EMB Report 85-CHM-12, U.S. Environmental Protection Agency, Research Triangle Park, NC, June 1985.

5. Emission Test Report: North American Refractories Company, Farber, Missouri, Confidential Business Information Files, Document No. C-10-6, ESD Project No. 81/08, U.S. Environmental Protection Agency, Research Triangle Park, NC.

6. Emission Test Report: Plant A, Confidential Business Information Files, Document No. C-7-12, ESD Project No. 81/08, U.S. Environmental Protection Agency, Research Triangle Park, NC.

7. Particulate Emissions Testing of the Rotary Kiln Cooler Stack, Harbison-Walker Refractories, Fulton, Missouri, Environmental Triple S Company, St. Louis, MO, December 1975.

8. Report of the Particulate Emissions Testing of the Rotary Kiln Stack, Harbison-Walker Refractories, Fulton, Missouri, Environmental Triple S Company, St. Louis, MO, September 1974.

TABLE 4-9. SUMMARY OF EMISSION FACTORS DEVELOPED FOR REFRACTORY MANUFACTURING: FILTERABLE PM, FILTERABLE PM-10, CO_2, SO_2, AND NO_x

Process	Type of control	Pollutant	No. of tests	Average emission factor, kg/Mg (lb/ton)	Emission factor rating	References
rotary dryer	none	filterable PM	2	33 (65)	D	1
rotary dryer	cyclone	filterable PM	2	5.6 (11)	D	1
rotary dryer	cyclone/ scrubber	filterable PM	2	0.052 (0.11)	D	1
rotary dryer	none	filterable PM-10	2	10 (21)	D	1
rotary dryer	cyclone	filterable PM-10	2	1.6 (3.2)	D	1
rotary dryer	none	CO2	6	15 (30)	D	1
rotary calciner	none	filterable PM	2	61 (120)	D	2, 3
rotary calciner	multiclone	filterable PM	1	31 (61)	D	2
rotary calciner	multiclone/ scrubber	filterable PM	2	0.15 (0.30)	D	2, 3
rotary calciner	none	filterable PM-10	1	15 (30)	D	3
rotary calciner	multiclone/ scrubber	filterable PM-10	1	0.030 (0.060)	D	3
rotary calciner	none	CO_2	5	310 (620)	D	2, 3
rotary calciner	multiclone/ scrubber	SO_2	1	3.8 (7.6)	D	2
rotary calciner	multiclone/ scrubber	NO_x	1	0.87 (1.7)	D	2

TABLE 4-10. SUMMARY OF EMISSION FACTORS DEVELOPED FOR REFRACTORY MANUFACTURING: TRACE ELEMENTS

Process	Type of control	Pollutant	No. of Tests	Average emission factor		References
				kg/Mg	lb/ton	
Rotary dryer	none	aluminum	2	1.7	3.5	1a, 1b
		berylium	2	4.7×10^{-5}	9.3×10^{-5}	1a, 1b
		calcium	2	0.041	0.083	1a, 1b
		chromium	2	0.0043	0.0087	1a, 1b
		iron	2	0.16	0.32	1a, 1b
		lead	2	0.00074	0.0015	1a, 1b
		magnesium	2	0.014	0.028	1a, 1b
		manganese	2	0.00087	0.0017	1a, 1b
		mercury	2	1.3×10^{-5}	2.6×10^{-5}	1a, 1b
		nickel	2	0.0046	0.0092	1a, 1b
		titanium	2	0.0020	0.0040	1a, 1b
		vanadium	2	0.0024	0.0048	1a, 1b
		zinc	2	0.0039	0.0079	1a, 1b
	cyclone	aluminum	2	0.27	0.53	1a, 1b
		berylium	2	1.1×10^{-5}	2.2×10^{-5}	1a, 1b
		calcium	2	0.0066	0.013	1a, 1b
		chromium	2	0.00061	0.0012	1a, 1b
		iron	2	0.024	0.047	1a, 1b
		lead	2	0.00013	0.00025	1a, 1b
		magnesium	2	0.0051	0.010	1a, 1b
		mercury	2	3.3×10^{-6}	6.7×10^{-6}	1a, 1b
		nickel	2	0.00043	0.00087	1a, 1b
		titanium	2	0.00052	0.0010	1a, 1b
		vanadium	2	0.00040	0.00080	1a, 1b
		zinc	2	0.00019	0.00038	1a, 1b

TABLE 4-10. (continued)

Process	Type of control	Pollutant	No. of Tests	Average emission factor		References
				kg/Mg	lb/ton	
Rotary dryer	none	aluminum	2	1.7	3.5	1a, 1b
rotary dryer (continued)	cyclone + scrubber	aluminum	2	0.0041	0.0081	1a, 1b
		calcium	2	0.0011	0.0021	1a, 1b
		chromium	2	1.2×10^{-5}	2.4×10^{-5}	1a, 1b
		iron	2	0.00053	0.0011	1a, 1b
		lead	2	6.6×10^{-6}	1.3×10^{-5}	1a, 1b
		magnesium	2	0.00031	0.00061	1a, 1b
		manganese	2	4.2×10^{-6}	8.2×10^{-6}	1a, 1b
		mercury	2	6.5×10^{-7}	1.3×10^{-6}	1a, 1b
		nickel	2	1.0×10^{-5}	2.0×10^{-5}	1a, 1b
		titanium	2	8.3×10^{-5}	0.00017	1a, 1b
		vanadium	2	7.4×10^{-6}	1.5×10^{-5}	1a, 1b
		zinc	2	2.8×10^{-5}	5.5×10^{-5}	1a, 1b
rotary calciner	none	aluminum	1	3.4	6.9	2
		berylium	1	8.0×10^{-5}	0.00016	2
		calcium	1	0.080	0.16	2
		chromium	1	0.0070	0.014	2
		iron	1	0.31	0.62	2
		lead	1	0.0019	0.0038	2
		magnesium	1	0.024	0.049	2
		manganese	1	0.00072	0.0014	2
		mercury	1	0.00014	0.00028	2
		nickel	1	0.0049	0.0098	2
		titanium	1	0.041	0.081	2
		vanadium	1	0.0049	0.0099	2
		zinc	1	0.020	0.039	2

TABLE 4-10. (continued)

Process	Type of control	Pollutant	No. of Tests	Average emission factor		References
				kg/Mg	lb/ton	
Rotary dryer	none	aluminum	2	1.7	3.5	1a, 1b
rotary calciner (continued)	multiclone	aluminum	1	1.2	2.4	2
		berylium	1	8.0×10^{-5}	0.00016	2
		calcium	1	0.055	0.11	2
		chromium	1	0.0018	0.0037	2
		iron	1	0.19	0.37	2
		lead	1	0.0012	0.0025	2
		magnesium	1	0.021	0.041	2
		manganese	1	0.00032	0.00064	2
		mercury	1	5.1×10^{-5}	0.00010	2
		nickel	1	0.0018	0.0036	2
		titanium	1	0.025	0.050	2
		vanadium	1	0.0032	0.0065	2
		zinc	1	0.0017	0.0034	2
	multiclone + scrubber	aluminum	1	0.011	0.021	2
		calcium	1	0.0027	0.0054	2
		chromium	1	2.6×10^{-5}	5.2×10^{-5}	2
		iron	1	0.0011	0.0023	2
		lead	1	3.6×10^{-5}	7.1×10^{-5}	2
		magnesium	1	0.00028	0.00057	2
		mercury	1	3.9×10^{-6}	7.8×10^{-6}	2
		nickel	1	3.6×10^{-5}	7.2×10^{-5}	2
		titanium	1	0.00035	0.00070	2
		vanadium	1	7.2×10^{-5}	0.00014	2
		zinc	1	8.7×10^{-5}	0.00017	2

[a]Emission factors are not rated.

TABLE 4-11. SUMMARY OF EMISSION FACTORS DEVELOPED FOR REFRACTORY MANUFACTURING: CHROMITE/MAGNESITE ORE

Process	Type of control	Pollutant	No. of tests	Average emission factor, kg/Mg Cr_2O_3 (lb/ton Cr_2O_3)	Emission factor rating	Ref. No.
rotary dryer	none	filterable PM	1	0.83 (1.7)	D	4
		filterable PM-10	1	0.20 (0.41)	D	4
		hexavalent chromium	1	$2.5x10^{-6}$ ($5.0x10^{-6}$)	E	4
		total chromium	1	0.037 (0.073)	E	4
tunnel kiln	none	filterable PM-10	1	0.41 (0.82)	D	4
		filterable PM-10	1	0.34 (0.69)	D	4
		hexavalent chromium	1	0.00015 (0.00029)	E	4
		total chromium	1	0.0023 (0.0046)	E	4

8.5 REFRACTORY MANUFACTURING

8.5.1 Process Description[1,2]

Refractories are materials that provide linings for high-temperature furnaces and other processing units. Refractories must be able to withstand physical wear, high temperatures (above 538°C [1000°F]), and corrosion by chemical agents. There are two general classifications of refractories: clay (Standard Industrial Classification [SIC] Code 3255) and nonclay (SIC Code 3297). The six-digit source classification code (SCC) for refractory manufacturing is 305005. Clay refractories are produced from fireclay (hydrous silicates of aluminum) and high alumina (57 to 87.5 percent). Other clay minerals used in the production of refractories include kaolin, bentonite, ball clay, and common clay. Nonclay refractories are produced from a composition of alumina (<87.5 percent), mullite, chromite, magnesite, silica, silicon carbide, zircon, and other nonclays.

Refractories are produced in two basic forms: preshaped objects and unformed compositions in granulated or plastic forms. The preformed products are called bricks and shapes. These products are used to form the walls, arches, and floor tiles of various high-temperature process equipment. Unformed compositions include mortars, gunning mixes, castables (refractory concretes), ramming mixes, and plastics. These products are then cured to form a monolithic, internal structure after application.

Refractory manufacturing involves four processes: raw material processing, forming, firing, and final processing. Raw material processing consists of crushing and grinding raw materials, followed by size classification and calcining and drying the raw materials, if necessary. Certain types of refractory products may omit some of these processes. Figure 8.5-1 illustrates the refractory manufacturing process.

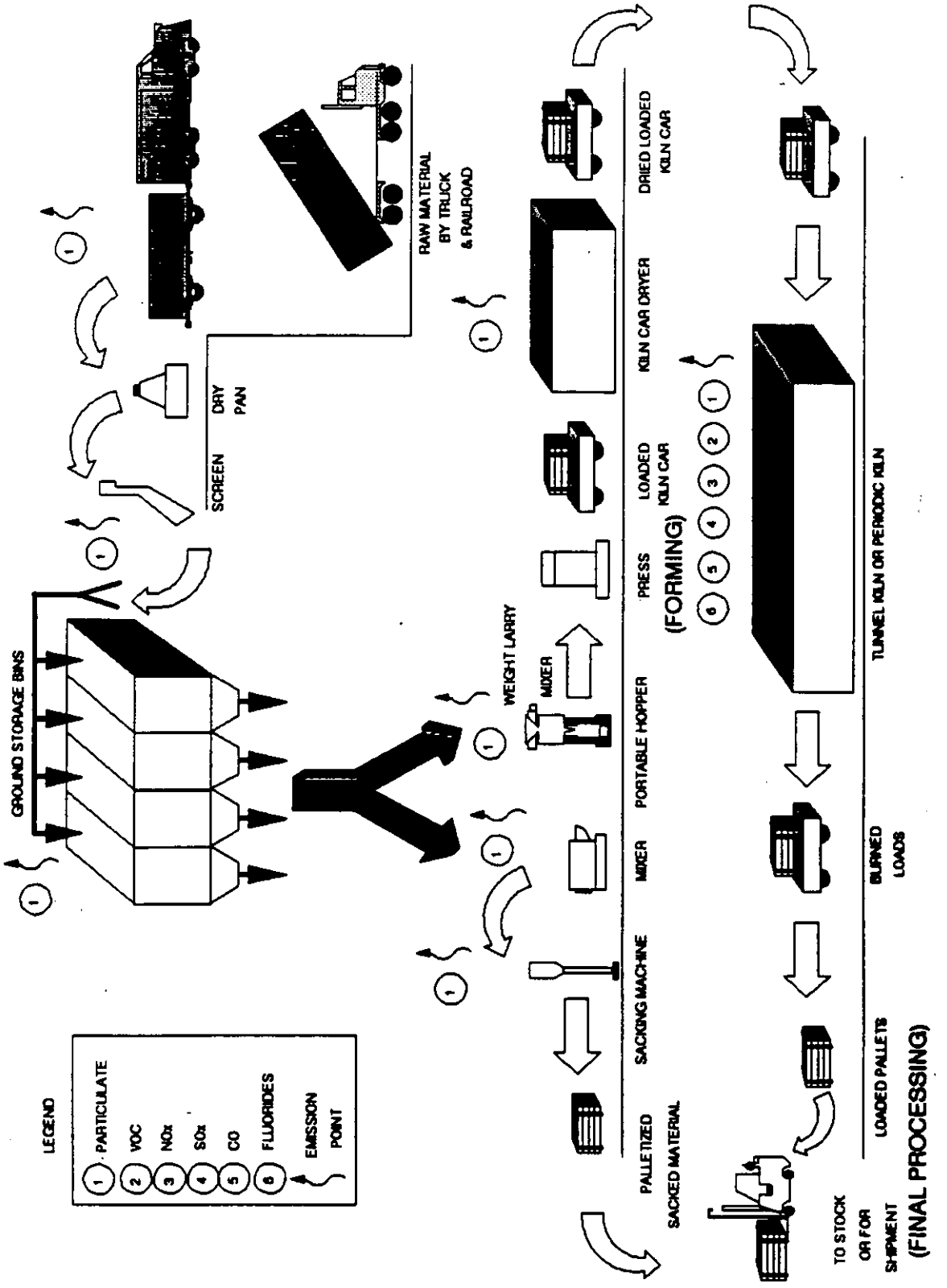

Figure 8.5-1. Refractory manufacturing process flow diagram.

Forming consists of mixing the raw materials and forming them into the desired shapes. This process frequently occurs under wet or moist conditions. Firing involves heating the refractory material to high temperatures in a periodic (batch) or continuous tunnel kiln to form the ceramic bond that gives the product its refractory properties. The final processing stage involves milling, grinding, and sandblasting of the finished product. This step allows the product to maintain the correct shape and size after thermal expansion has occurred. Final processing may also include, for certain products, impregnating the product with tar and pitch and final packaging.

Two other types of refractory processes also warrant discussion. The first is production of fused products. This process involves using an electric arc furnace to melt the refractory raw materials, then pouring the melted materials into sand molds for forming. Another type of refractory process is ceramic fiber production. In this process, calcined kaolin is melted in an electric arc furnace. The melted material is then fiberized in a blowchamber with a centrifuge device, or the molten clay is dropped into an air jet and is immediately blown into fine strands. After the blowchamber, the ceramic fiber may then be conveyed to an oven for curing, which adds structural rigidity to the fibers. During the curing process, oils are used to lubricate the fibers and the machinery used to handle and form the fibers. The production of ceramic fiber for refractory material is very similar to the production of mineral wool.

8.5.2 Emissions and Controls[2-6]

The primary pollutant of concern that is emitted in refractory manufacturing is particulate matter (PM). Particulate matter emissions occur during milling and grinding of the raw materials, firing of the brick kiln, tar and pitch operations, and finishing of the refractories (grinding, milling, and sandblasting).

Emissions from crushing and grinding operations generally are controlled with fabric filters. Product recovery cyclones followed by wet scrubbers are used on calciners and dryers to control PM emissions from these sources. Emission factors for filterable PM and PM-10 emissions from rotary dryers and calciners processing fire clay are presented in Table 8.5-1. Size-specific emission factors for filterable particulate emissions from rotary dryers and calciners processing fire clay are presented in Table 8.5-2.

TABLE 8.5-1 (METRIC UNITS)
EMISSION FACTORS FOR REFRACTORY MANUFACTURING[a]

All Emission Factors in Kg/Mg of Raw Material Feed
Ratings (A-E) Follow Each Emission Factor

Process (SCC)	Filterable[b]			
	PM		PM-10	
Rotary dryer[c] (30500501)	33	D	10	D
Rotary dryer with cyclone[c] (30500501)	5.6	D	1.6	D
Rotary dryer with cyclone and wet scrubber[c] (30500501)	0.052	D	d	D
Rotary calciner (305005__)	61[e]	D	15[f]	D
Rotary calciner with multiclone (305005__)	31[g]	D	d	
Rotary calciner with multiclone and wet scrubber (305005__)	0.15[e]	D	0.030[f]	D

[a]Emission factors represent uncontrolled emissions unless otherwise noted.
[b]Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. PM-10 values are based on cascade impaction particle size distribution.
[c]Reference 3.
[d]No data available.
[e]References 4, 5.
[f]Reference 5.
[g]Reference 4.

TABLE 8.5-1 (ENGLISH UNITS)
EMISSION FACTORS FOR REFRACTORY MANUFACTURING[a]

All Emission Factors in Kg/Mg of Raw Material Feed
Ratings (A-E) Follow Each Emission Factor

Process (SCC)	Filterable[b]			
	PM		PM-10	
Rotary dryer[c] (30500501)	65	D	21	D
Rotary dryer with cyclone[c] (30500501)	11	D	3.2	D
Rotary dryer with cyclone and wet scrubber[c] (30500501)	0.11	D	d	D
Rotary calciner (305005__)	120[e]	D	30[f]	D
Rotary calciner with multiclone (305005__)	61[g]	D	d	
Rotary calciner with multiclone and wet scrubber (305005__)	0.30[e]	D	0.060[f]	D

[a]Emission factors represent uncontrolled emissions unless otherwise noted.
[b]Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. PM-10 values are based on cascade impaction particle size distribution.
[c]Reference 3.
[d]No data available.
[e]References 4, 5.
[f]Reference 5.
[g]Reference 4.

TABLE 8.5-2. SIZE-SPECIFIC EMISSION FACTORS FOR REFRACTORY MANUFACTURING[a]

All emission factors in units of kg/Mg (lb/ton) of feed.

EMISSION FACTOR RATING: D

Rotary Dryers[b]

Diameter (microns)	Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor	
		kg/Mg	lb/ton		kg/Mg	lb/ton
2.5	2.5	0.81	1.6	14	0.75	1.5
6.0	10	3.2	6.4	31	1.7	3.4
10.0	24	7.7	15	46	2.6	5.1
15.0	37	12	24	60	3.4	6.7
20.0	51	16	33	68	3.8	7.6

EMISSION FACTOR RATING: D

Rotary Calciners[c]

Diameter	Uncontrolled			Controlled (cyclone/scrubber)		
	Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor	
		kg/Mg	lb/ton		kg/Mg	lb/ton
1.0	0.76	0.43	0.86	31	0.014	0.028
1.25	1.1	0.63	1.3	43	0.019	0.038
2.5	2.7	1.5	3.0	46	0.021	0.041
6.0	11	6.4	13	55	0.025	0.050
10.0	25	14	28	69	0.031	0.063
15.0	38	22	43	81	0.036	0.073
20.0	52	29	59	91	0.041	0.082

[a]Particle size distribution and size-specific emission factors for filterable PM only.
[b]Reference 3.
[c]Reference 5.

The primary sources of PM emissions of PM are brick firing kilns and electric arc furnaces. Particulate matter emissions from kilns generally are not controlled. However, at least one refractory manufacturer currently uses a multiple-stage scrubber to control kiln emissions. Particulate matter emissions from electric arc furnaces generally are controlled by a baghouse. Particulate removal of 87 percent and fluoride removal of greater than 99 percent have been reported at one facility which uses an ionizing wet scrubber.

Pollutants emitted as a result of combustion in the calcining and kilning processes include sulfur oxides (SO_x), nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), and volatile organic compounds (VOC's). The emission of SO_x is also a function of the sulfur content of certain clays and the plaster added to refractory materials to induce brick setting. Fluoride emissions occur during the kilning process and are a result of fluorides in the raw materials. Table 8.5-3 summarizes the emission factors for SO_x, NO_x, and CO_2 emissions from rotary dryers and calciners processing fire clay.

Volatile organic compounds emitted from tar and pitch operations generally are controlled by incineration, when inorganic particulates are not significant. Based on destruction of organic aerosols a control efficiency in excess of 95 percent can be achieved using incinerators.

Chromium is used in several types of nonclay refractories, including chrome-magnesite, (chromite-magnesite), magnesia-chrome, and chrome-alumina. Chromium compounds are emitted from the ore crushing, grinding, material drying and storage, and brick firing and finishing processes used in producing these types of refractories. Table 8.5-4 presents emission factors for emissions of filterable PM, filterable PM-10, hexavalent chromium, and total chromium from the drying and firing of chromite-magnesite ore. The emission factors are presented in units of kilograms of pollutant emitted per megagram of chromite ore processed (kg/Mg CrO_3) (pounds per ton of chromite ore processed [lb/ton CrO_3]). Size-specific emission factors and particle size distribution for the drying and firing of chromite-magnesite ore are summarized in Table 8.5-5.

A number of elements in trace concentrations including aluminum, beryllium, calcium, chromium, iron, lead, mercury, magnesium, manganese, nickel, titanium, vanadium, and zinc also are emitted in trace amounts by the drying, calcining, and firing operations of all types of refractory

TABLE 8.5-3 (METRIC UNITS)
EMISSION FACTORS FOR REFRACTORY MANUFACTURING[a]

All Emission Factors in lb/ton of Raw Material Feed
Ratings (A-E) Follow Each Emission Factor

Process (SCC)	SO_x		NO_x		CO_2	
Rotary dryer (30500501)	b		b		15[c]	D
Rotary calciner (305005__)	b		b		310[b]	D
Rotary calciner with multiclone and wet scrubber (305005__)	3.8[e]	D	0.87[e]	D	b	

[a]Emission factors represent uncontrolled emissions unless otherwise noted.
[b]No data available.
[c]Reference 3.
[d]Reference 4, 5.
[e]Reference 4.

TABLE 8.5-3 (ENGLISH UNITS)
EMISSION FACTORS FOR REFRACTORY MANUFACTURING[a]

All Emission Factors in lb/ton of Raw Material Feed
Ratings (A-E) Follow Each Emission Factor

Process (SCC)	SO_x		NO_x		CO_2	
Rotary dryer (30500501)	b		b		30[c]	D
Rotary calciner (305005__)	b		b		620(d)	D
Rotary calciner with multiclone and wet scrubber (305005__)	7.6[e]	D	1.7[e]	D	b	

[a]Emission factors represent uncontrolled emissions unless otherwise noted.
[b]No data available.
[c]Reference 3.
[d]Reference 4, 5.
[e]Reference 4.

TABLE 8.5-4 (METRIC UNITS)
EMISSION FACTORS FOR REFRACTORY MANUFACTURING: CHROMITE-MAGNESITE ORE[a]

All Emission Factors in Lb/Ton of Chromite Ore Processed
Ratings (A-E) Follow Each Emission Factor

Process (SCC)	Filterable[b]				Chromium			
	PM		PM-10		hexavalent		total	
Rotary dryer (30500501)	0.83	D	0.20	D	2.5×10^{-6}	E	0.037	E
Tunnel kiln (305005__)	0.41	D	0.34	D	0.00015	E	0.0023	E

[a]Reference 6. Emission factors represent uncontrolled emissions.
[b]Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. PM-10 values are based on cascade impaction particle size distribution.

TABLE 8.5-4 (ENGLISH UNITS)
EMISSION FACTORS FOR REFRACTORY MANUFACTURING: CHROMITE-MAGNESITE ORE[a]

All Emission Factors in Lb/Ton of Chromite Ore Processed
Ratings (A-E) Follow Each Emission Factor

Process (SCC)	Filterable[b]				Chromium			
	PM		PM-10		hexavalent		total	
Rotary dryer (30500501)	1.7	D	0.41	D	5.0×10^{-6}	E	0.073	E
Tunnel kiln (305005__)	0.82	D	0.69	D	0.00029	E	0.0046	E

[a]Reference 6. Emission factors represent uncontrolled emissions.
[b]Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. PM-10 values are based on cascade impaction particle size distribution.

TABLE 8.5-5 (METRIC UNITS)
SIZE-SPECIFIC EMISSION FACTORS FOR REFRACTORY MANUFACTURING: CHROMITE-MAGNESITE ORE DRYING AND FIRING[a]

All emission factors in lb/ton of chromite ore processed.
Ratings (A-E) follow each factor.
Uncontrolled rotary dryer

	Filterable PM			Hexavalent chromium			Total chromium		
Diameter, micrometers	Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor	
		kg/Mg	Rating		kg/Mg	Rating		kg/Mg	Rating
1	1.2	0.010	D	3.5	8.8×10^{-8}	E	0.8	1.5×10^{-5}	E
5	13	0.11	D	39	9.8×10^{-7}	E	9	0.0017	E
10	24	0.20	D	64	1.6×10^{-6}	E	19	0.0035	E

Uncontrolled tunnel kiln

	Filterable PM			Hexavalent chromium			Total chromium		
Diameter, micrometers	Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor	
		kg/Mg	Rating		kg/Mg	Rating		kg/Mg	Rating
1	71	0.29	D	71	5.3×10^{-5}	E	84	0.0010	E
5	78	0.32	D	81	6.1×10^{-5}	E	91	0.0010	E
10	84	0.34	D	84	6.3×10^{-5}	E	93	0.0011	E

[a]Reference 4. Particle size distribution and size-specific emission factors for filterable PM only.

TABLE 8.5-5 (ENGLISH UNITS)
SIZE-SPECIFIC EMISSION FACTORS FOR REFRACTORY MANUFACTURING: CHROMITE-MAGNESITE ORE DRYING AND FIRING[a]

All emission factors in lb/ton of chromite ore processed.
Ratings (A-E) follow each factor.
Uncontrolled rotary dryer

Diameter, micrometers	Filterable PM			Hexavalent chromium			Total chromium		
	Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor	
		lb/ton	Rating		lb/ton	lb/ton		lb/ton	Rating
1	1.2	0.020	D	3.5	1.8×10^{-7}	E	0.8	3.0×10^{-4}	E
5	13	0.22	D	39	2.0×10^{-6}	E	9	0.0033	E
10	24	0.41	D	64	3.2×10^{-6}	E	19	0.0070	E

Uncontrolled tunnel kiln

Diameter, micrometers	Filterable PM			Hexavalent chromium			Total chromium		
	Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor	
		lb/ton	Rating		lb/ton	Rating		lb/ton	Rating
1	71	0.58	D	71	0.00011	E	84	0.0019	E
5	78	0.64	D	81	0.00012	E	91	0.0021	E
10	84	0.69	D	84	0.00013	E	93	0.0021	E

[a]Reference 4. Particle size distribution and size-specific emission factors for filterable PM only.

materials. However, data are inadequate to develop emission factors for these elements.

Emissions of PM from electric arc furnaces used to produce fused cast refractory material are controlled with baghouses. The efficiency of the fabric filters often exceeds 99.5 percent. Emissions of PM from the ceramic fiber process also are controlled with fabric filters, and the efficiency is similar to that found in the fused cast refractory process. To control blowchamber emissions, a fabric filter is used to remove small pieces of fine threads that are formed in the fiberization stage. The efficiency of fabric filters in similar control devices exceeds 99 percent. Small particles of ceramic fiber are broken off or separated during the handling and forming of the fiber blankets in the curing oven. An oil is used in this process, and higher molecular weight organics are emitted. These emissions are controlled using a fabric filter followed by incineration. An overall efficiency in excess of 95 percent is expected for this type of control.

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Enclosure 2

DRAFT AP-42 SECTION 8.5

8.5 REFRACTORY MANUFACTURING

8.5.1 Process Description[1,2]

Refractories are materials that provide linings for high-temperature furnaces and other processing units. Refractories must be able to withstand physical wear, high temperatures (above 538°C [1000°F]), and corrosion by chemical agents. There are two general classifications of refractories: clay (Standard Industrial Classification [SIC] Code 3255) and nonclay (SIC Code 3297). The six-digit source classification code (SCC) for refractory manufacturing is 305005. Clay refractories are produced from fireclay (hydrous silicates of aluminum) and high alumina (57 to 87.5 percent). Other clay minerals used in the production of refractories include kaolin, bentonite, ball clay, and common clay. Nonclay refractories are produced from a composition of alumina (<87.5 percent), mullite, chromite, magnesite, silica, silicon carbide, zircon, and other nonclays.

Refractories are produced in two basic forms: preshaped objects and unformed compositions in granulated or plastic forms. The preformed products are called bricks and shapes. These products are used to form the walls, arches, and floor tiles of various high-temperature process equipment. Unformed compositions include mortars, gunning mixes, castables (refractory concretes), ramming mixes, and plastics. These products are then cured to form a monolithic, internal structure after application.

Refractory manufacturing involves four processes: raw material processing, forming, firing, and final processing. Raw material processing consists of crushing and grinding raw materials, followed by size classification and calcining and drying the raw materials, if necessary. Certain types of refractory products may omit some of these processes. Figure 8.5-1 illustrates the refractory manufacturing process.

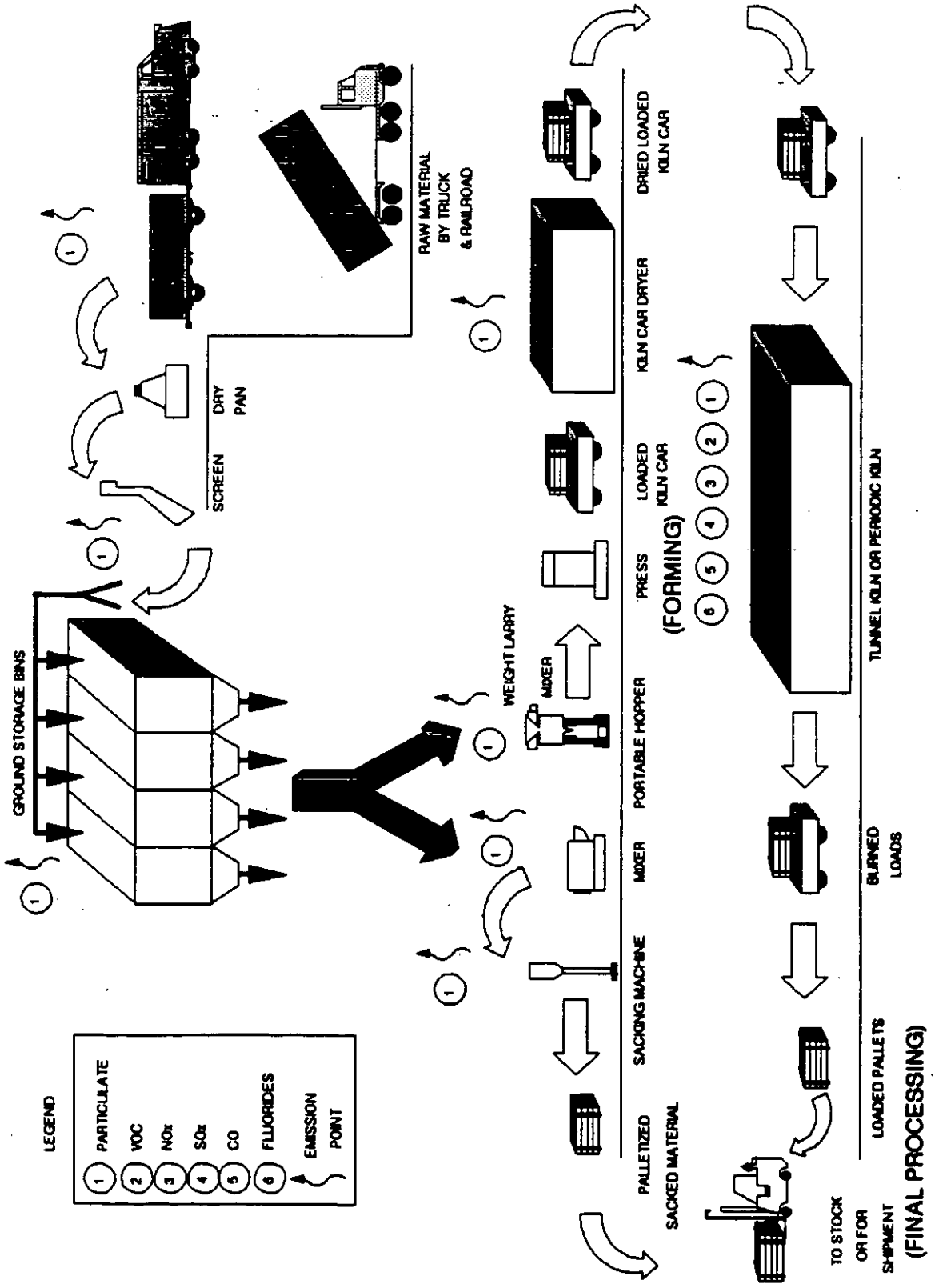

Figure 8.5-1. Refractory manufacturing process flow diagram.

Forming consists of mixing the raw materials and forming them into the desired shapes. This process frequently occurs under wet or moist conditions. Firing involves heating the refractory material to high temperatures in a periodic (batch) or continuous tunnel kiln to form the ceramic bond that gives the product its refractory properties. The final processing stage involves milling, grinding, and sandblasting of the finished product. This step allows the product to maintain the correct shape and size after thermal expansion has occurred. Final processing may also include, for certain products, impregnating the product with tar and pitch and final packaging.

Two other types of refractory processes also warrant discussion. The first is production of fused products. This process involves using an electric arc furnace to melt the refractory raw materials, then pouring the melted materials into sand molds for forming. Another type of refractory process is ceramic fiber production. In this process, calcined kaolin is melted in an electric arc furnace. The melted material is then fiberized in a blowchamber with a centrifuge device, or the molten clay is dropped into an air jet and is immediately blown into fine strands. After the blowchamber, the ceramic fiber may then be conveyed to an oven for curing, which adds structural rigidity to the fibers. During the curing process, oils are used to lubricate the fibers and the machinery used to handle and form the fibers. The production of ceramic fiber for refractory material is very similar to the production of mineral wool.

8.5.2 Emissions and Controls[2-6]

The primary pollutant of concern that is emitted in refractory manufacturing is particulate matter (PM). Particulate matter emissions occur during milling and grinding of the raw materials, firing of the brick kiln, tar and pitch operations, and finishing of the refractories (grinding, milling, and sandblasting).

Emissions from crushing and grinding operations generally are controlled with fabric filters. Product recovery cyclones followed by wet scrubbers are used on calciners and dryers to control PM emissions from these sources. Emission factors for filterable PM and PM-10 emissions from rotary dryers and calciners processing fire clay are presented in Table 8.5-1. Size-specific emission factors for filterable particulate emissions from rotary dryers and calciners processing fire clay are presented in Table 8.5-2.

TABLE 8.5-1 (METRIC UNITS)
EMISSION FACTORS FOR REFRACTORY MANUFACTURING[a]

All Emission Factors in Kg/Mg of Raw Material Feed
Ratings (A-E) Follow Each Emission Factor

Process (SCC)	Filterable[b]			
	PM		PM-10	
Rotary dryer[c] (30500501)	33	D	10	D
Rotary dryer with cyclone[c] (30500501)	5.6	D	1.6	D
Rotary dryer with cyclone and wet scrubber[c] (30500501)	0.052	D	d	D
Rotary calciner (305005__)	61[e]	D	15[f]	D
Rotary calciner with multiclone (305005__)	31[g]	D	d	
Rotary calciner with multiclone and wet scrubber (305005__)	0.15[e]	D	0.030[f]	D

[a]Emission factors represent uncontrolled emissions unless otherwise noted.
[b]Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. PM-10 values are based on cascade impaction particle size distribution.
[c]Reference 3.
[d]No data available.
[e]References 4, 5.
[f]Reference 5.
[g]Reference 4.

TABLE 8.5-1 (ENGLISH UNITS)
EMISSION FACTORS FOR REFRACTORY MANUFACTURING[a]

All Emission Factors in Kg/Mg of Raw Material Feed
Ratings (A-E) Follow Each Emission Factor

Process (SCC)	Filterable[b]			
	PM		PM-10	
Rotary dryer[c] (30500501)	65	D	21	D
Rotary dryer with cyclone[c] (30500501)	11	D	3.2	D
Rotary dryer with cyclone and wet scrubber[c] (30500501)	0.11	D	d	D
Rotary calciner (305005__)	120[e]	D	30[f]	D
Rotary calciner with multiclone (305005__)	61[g]	D	d	
Rotary calciner with multiclone and wet scrubber (305005__)	0.30[e]	D	0.060[f]	D

[a]Emission factors represent uncontrolled emissions unless otherwise noted.
[b]Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. PM-10 values are based on cascade impaction particle size distribution.
[c]Reference 3.
[d]No data available.
[e]References 4, 5.
[f]Reference 5.
[g]Reference 4.

TABLE 8.5-2. SIZE-SPECIFIC EMISSION FACTORS FOR REFRACTORY MANUFACTURING[a]

All emission factors in units of kg/Mg (lb/ton) of feed.

EMISSION FACTOR RATING: D

Rotary Dryers[b]

Diameter (microns)	Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor	
		kg/Mg	lb/ton		kg/Mg	lb/ton
2.5	2.5	0.81	1.6	14	0.75	1.5
6.0	10	3.2	6.4	31	1.7	3.4
10.0	24	7.7	15	46	2.6	5.1
15.0	37	12	24	60	3.4	6.7
20.0	51	16	33	68	3.8	7.6

EMISSION FACTOR RATING: D

Rotary Calciners[c]

Diameter	Uncontrolled			Controlled (cyclone/scrubber)		
	Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor	
		kg/Mg	lb/ton		kg/Mg	lb/ton
1.0	0.76	0.43	0.86	31	0.014	0.028
1.25	1.1	0.63	1.3	43	0.019	0.038
2.5	2.7	1.5	3.0	46	0.021	0.041
6.0	11	6.4	13	55	0.025	0.050
10.0	25	14	28	69	0.031	0.063
15.0	38	22	43	81	0.036	0.073
20.0	52	29	59	91	0.041	0.082

[a]Particle size distribution and size-specific emission factors for filterable PM only.
[b]Reference 3.
[c]Reference 5.

The primary sources of PM emissions of PM are brick firing kilns and electric arc furnaces. Particulate matter emissions from kilns generally are not controlled. However, at least one refractory manufacturer currently uses a multiple-stage scrubber to control kiln emissions. Particulate matter emissions from electric arc furnaces generally are controlled by a baghouse. Particulate removal of 87 percent and fluoride removal of greater than 99 percent have been reported at one facility which uses an ionizing wet scrubber.

Pollutants emitted as a result of combustion in the calcining and kilning processes include sulfur oxides (SO_x), nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), and volatile organic compounds (VOC's). The emission of SO_x is also a function of the sulfur content of certain clays and the plaster added to refractory materials to induce brick setting. Fluoride emissions occur during the kilning process and are a result of fluorides in the raw materials. Table 8.5-3 summarizes the emission factors for SO_x, NO_x, and CO_2 emissions from rotary dryers and calciners processing fire clay.

Volatile organic compounds emitted from tar and pitch operations generally are controlled by incineration, when inorganic particulates are not significant. Based on destruction of organic aerosols a control efficiency in excess of 95 percent can be achieved using incinerators.

Chromium is used in several types of nonclay refractories, including chrome-magnesite, (chromite-magnesite), magnesia-chrome, and chrome-alumina. Chromium compounds are emitted from the ore crushing, grinding, material drying and storage, and brick firing and finishing processes used in producing these types of refractories. Table 8.5-4 presents emission factors for emissions of filterable PM, filterable PM-10, hexavalent chromium, and total chromium from the drying and firing of chromite-magnesite ore. The emission factors are presented in units of kilograms of pollutant emitted per megagram of chromite ore processed (kg/Mg CrO_3) (pounds per ton of chromite ore processed [lb/ton CrO_3]). Size-specific emission factors and particle size distribution for the drying and firing of chromite-magnesite ore are summarized in Table 8.5-5.

A number of elements in trace concentrations including aluminum, beryllium, calcium, chromium, iron, lead, mercury, magnesium, manganese, nickel, titanium, vanadium, and zinc also are emitted in trace amounts by the drying, calcining, and firing operations of all types of refractory

TABLE 8.5-3 (METRIC UNITS)
EMISSION FACTORS FOR REFRACTORY MANUFACTURING[a]

All Emission Factors in lb/ton of Raw Material Feed
Ratings (A-E) Follow Each Emission Factor

Process (SCC)	SO_x		NO_x		CO_2	
Rotary dryer (30500501)	b		b		15[c]	D
Rotary calciner (305005__)	b		b		310[b]	D
Rotary calciner with multiclone and wet scrubber (305005__)	3.8[e]	D	0.87[e]	D	b	

[a]Emission factors represent uncontrolled emissions unless otherwise noted.
[b]No data available.
[c]Reference 3.
[d]Reference 4, 5.
[e]Reference 4.

TABLE 8.5-3 (ENGLISH UNITS)
EMISSION FACTORS FOR REFRACTORY MANUFACTURING[a]

All Emission Factors in lb/ton of Raw Material Feed
Ratings (A-E) Follow Each Emission Factor

Process (SCC)	SO_x		NO_x		CO_2	
Rotary dryer (30500501)	b		b		30[c]	D
Rotary calciner (305005__)	b		b		620(d)	D
Rotary calciner with multiclone and wet scrubber (305005__)	7.6[e]	D	1.7[e]	D	b	

[a]Emission factors represent uncontrolled emissions unless otherwise noted.
[b]No data available.
[c]Reference 3.
[d]Reference 4, 5.
[e]Reference 4.

TABLE 8.5-4 (METRIC UNITS)
EMISSION FACTORS FOR REFRACTORY MANUFACTURING: CHROMITE-MAGNESITE ORE[a]

All Emission Factors in Lb/Ton of Chromite Ore Processed
Ratings (A-E) Follow Each Emission Factor

Process (SCC)	Filterable[b]				Chromium			
	PM		PM-10		hexavalent		total	
Rotary dryer (30500501)	0.83	D	0.20	D	2.5×10^{-6}	E	0.037	E
Tunnel kiln (305005__)	0.41	D	0.34	D	0.00015	E	0.0023	E

[a]Reference 6. Emission factors represent uncontrolled emissions.
[b]Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. PM-10 values are based on cascade impaction particle size distribution.

TABLE 8.5-4 (ENGLISH UNITS)
EMISSION FACTORS FOR REFRACTORY MANUFACTURING: CHROMITE-MAGNESITE ORE[a]

All Emission Factors in Lb/Ton of Chromite Ore Processed
Ratings (A-E) Follow Each Emission Factor

Process (SCC)	Filterable[b]				Chromium			
	PM		PM-10		hexavalent		total	
Rotary dryer (30500501)	1.7	D	0.41	D	5.0×10^{-6}	E	0.073	E
Tunnel kiln (305005__)	0.82	D	0.69	D	0.00029	E	0.0046	E

[a]Reference 6. Emission factors represent uncontrolled emissions.
[b]Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. PM-10 values are based on cascade impaction particle size distribution.

TABLE 8.5-5 (METRIC UNITS)
SIZE-SPECIFIC EMISSION FACTORS FOR REFRACTORY MANUFACTURING: CHROMITE-MAGNESITE ORE DRYING AND FIRING[a]

All emission factors in lb/ton of chromite ore processed.
Ratings (A-E) follow each factor.
Uncontrolled rotary dryer

	Filterable PM			Hexavalent chromium			Total chromium		
Diameter, micrometers	Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor	
		kg/Mg	Rating		kg/Mg	Rating		kg/Mg	Rating
1	1.2	0.010	D	3.5	8.8×10^{-8}	E	0.8	1.5×10^{-5}	E
5	13	0.11	D	39	9.8×10^{-7}	E	9	0.0017	E
10	24	0.20	D	64	1.6×10^{-6}	E	19	0.0035	E

Uncontrolled tunnel kiln

	Filterable PM			Hexavalent chromium			Total chromium		
Diameter, micrometers	Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor	
		kg/Mg	Rating		kg/Mg	Rating		kg/Mg	Rating
1	71	0.29	D	71	5.3×10^{-5}	E	84	0.0010	E
5	78	0.32	D	81	6.1×10^{-5}	E	91	0.0010	E
10	84	0.34	D	84	6.3×10^{-5}	E	93	0.0011	E

[a]Reference 4. Particle size distribution and size-specific emission factors for filterable PM only.

TABLE 8.5-5 (ENGLISH UNITS)
SIZE-SPECIFIC EMISSION FACTORS FOR REFRACTORY MANUFACTURING: CHROMITE-MAGNESITE ORE DRYING AND FIRING[a]

All emission factors in lb/ton of chromite ore processed.
Ratings (A-E) follow each factor.
Uncontrolled rotary dryer

	Filterable PM			Hexavalent chromium			Total chromium		
Diameter, micrometers	Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor	
		lb/ton	Rating		lb/ton	lb/ton		lb/ton	Rating
1	1.2	0.020	D	3.5	1.8×10^{-7}	E	0.8	3.0×10^{-4}	E
5	13	0.22	D	39	2.0×10^{-6}	E	9	0.0033	E
10	24	0.41	D	64	3.2×10^{-6}	E	19	0.0070	E

Uncontrolled tunnel kiln

	Filterable PM			Hexavalent chromium			Total chromium		
Diameter, micrometers	Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor		Cumulative % less than diameter	Emission factor	
		lb/ton	Rating		lb/ton	Rating		lb/ton	Rating
1	71	0.58	D	71	0.00011	E	84	0.0019	E
5	78	0.64	D	81	0.00012	E	91	0.0021	E
10	84	0.69	D	84	0.00013	E	93	0.0021	E

[a]Reference 4. Particle size distribution and size-specific emission factors for filterable PM only.

materials. However, data are inadequate to develop emission factors for these elements.

Emissions of PM from electric arc furnaces used to produce fused cast refractory material are controlled with baghouses. The efficiency of the fabric filters often exceeds 99.5 percent. Emissions of PM from the ceramic fiber process also are controlled with fabric filters, and the efficiency is similar to that found in the fused cast refractory process. To control blowchamber emissions, a fabric filter is used to remove small pieces of fine threads that are formed in the fiberization stage. The efficiency of fabric filters in similar control devices exceeds 99 percent. Small particles of ceramic fiber are broken off or separated during the handling and forming of the fiber blankets in the curing oven. An oil is used in this process, and higher molecular weight organics are emitted. These emissions are controlled using a fabric filter followed by incineration. An overall efficiency in excess of 95 percent is expected for this type of control.

REFERENCES FOR SECTION 8.5

1. Refractories. The Refractories Institute. Pittsburgh, PA. 1987.

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3. Calciners and Dryers Emission Test Report, North American Refractories Company, Farber, Missouri, EMB Report 84-CDR-14, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1984.

4. Emission Test Report: Plant A, Confidential Business Information Files, Document No. C-7-12, ESD Project No. 81/08, U.S. Environmental Protection Agency, Research Triangle Park, NC.

5. Calciners and Dryers Emission Test Report, A. P. Green Company, Mexico, Missouri, EMB Report 83-CDR-1, U.S. Environmental Protection Agency, Research Triangle Park, NC, October 1983.

6. Chromium Screening Study Test Report, Harbison-Walker Refractories, Baltimore, Maryland, EMB Report 85-CHM-12, U.S. Environmental Protection Agency, Research Triangle Park, NC, June 1985.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

Do not prepare this one to Marvin. We have to wait another week or so on this

Rick - save for future use. Rose Marie

Mr. Charles G. Marvin
Refractories Institute
Suite 326, 500 Wood Street
Pittsburgh, Pennsylvania 15222

Dear Mr. Marvin:

As you may 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 8.5, Refractory Manufacturing, and the corresponding background report for the section. We would appreciate it if you or one of your associates would review the enclosed draft AP-42 section and background report and would send us your comments. It would also be helpful if you could distribute copies of the enclosed section and background report to members of your association for their review. Unfortunately, we are on a very tight schedule, and it is important that we have all comments by February 15, 1993.

The emission factors presented in AP-42 generally are based upon results from validated tests or other emission evaluations that are similar to EPA reference test methods. As a result, revisions to the emission factors presented in AP-42 sections must be supported by equivalent documentation. If you disagree with any emission factors presented in the enclosed AP-42 section or have additional supporting documentation, we would appreciate your providing either a copy of the documentation or information on how we can obtain copies of the supporting documentation.

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

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

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