EMISSION FACTOR DOCUMENTATION FOR AP-42 SECTION 11.18 (Formerly 8.16)
Mineral Wool Manufacturing

1. INTRODUCTION

The document Compilation of Air Pollutant Emission 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 preparation of AP-42 Section 8.16, Mineral Wool Manufacturing.

This background report consists of five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the mineral wool 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 mineral wool production operations. Section 3 is a review of emission data collection and laboratory 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 pollutant emission factor development. It includes a review of specific data sets and the results of data analyses. Section 5 presents AP-42 Section 8.16, Mineral Wool Manufacturing.

2. INDUSTRY DESCRIPTION[1,2]

Mineral wool often is defined as any fibrous glassy substance made from minerals (typically natural rock materials such as basalt or diabase) or mineral products such as slag and glass. Because glass wool production is covered separately in AP-42 (Section 8.11), this section deals only with the production of mineral wool from natural rock and slags such as iron blast furnace slag, the primary material, and copper, lead, and phosphate slags. These materials are processed into insulation and other fibrous building materials that are used for structural strength and fire resistance. Generally, these products take one of four forms: "blowing" wool or "pouring" wool, which is put into the structural spaces of buildings; batts, which may be covered with a vapor barrier of paper or foil and are shaped to fit between the structural members of buildings; industrial and commercial products such as high-density fiber felts and blankets, which are used for insulating boilers, ovens, pipes, refrigerators, and other process equipment; and bulk fiber, which is used as a raw material in manufacturing other products, such as ceiling tile, wall board, spray-on insulation, cement, and mortar.

Mineral wool manufacturing facilities are included in Standard Industrial Classification (SIC) Code 3296, mineral wool. This SIC code also includes the production of glass wool insulation products, but those facilities engaged in manufacturing textile glass fibers are included in SIC Code 3229. The six digit source category code (SCC) for mineral wool manufacturing is 3-05-017.

2.1 CHARACTERIZATION OF THE INDUSTRY[1,3,4]

Because the U.S. Department of Commerce aggregates the mineral wool manufacturing industry, as defined in this document, into a single SIC category with glass wool manufacturing, industry statistics are difficult to obtain. The available U. S. Government publications do not present information on rock and slag wool production, nor was such information found in the open literature. The most recent data related strictly to rock and slag wool production appear to be those generated by EPA in 1980. However, 1993 data concerning only the number and location of mineral wool facilities is also available. These data form the basis for the discussion below.

As of March, 1993, approximately 18 mineral wool manufacturing facilities are operating in the United States. Table 2-1 lists the number of facilities by State. In 1980, approximately 26 mineral wool manufacturing facilities were operating in the United States. These 26 facilities were estimated to have shipped about 2.7×10^5 megagrams (Mg) (3.0×10^5 tons) of structural mineral wool insulation products with a value of about $100 million during 1980. A growth rate of less than 2 percent per year was projected at that time.

PROCESS DESCRIPTION[1,5,6]

Most mineral wool produced in the United States today is produced from slag or a mixture of slag and rock. Most of the slag used by the industry is generated by integrated iron and steel plants as a blast furnace byproduct from pig iron production. Other sources of slag include the copper, lead, and phosphate industries. The production process has three primary components--molten mineral generation in the cupola, fiber formation and collection, and final product formation. Figure 2-1 illustrates the mineral wool manufacturing process.

The first step in the process involves melting the mineral feed. The raw material (slag and rock) is loaded into a cupola in alternating layers with coke at weight ratios of about 5 to 6 parts mineral to 1 part coke. As the coke is ignited and burned, the mineral charge is heated to the molten

TABLE 2-1. DISTRIBUTION OF MINERAL WOOL MANUFACTURING FACILITIES[4]

State	No. of facilities
Alabama	4
Illinois	1
Indiana	4
Minnesota	1
North Carolina	1
Ohio	1
Pennsylvania	2
Tennessee	1
Texas	1
Washington	1
Wisconsin	1

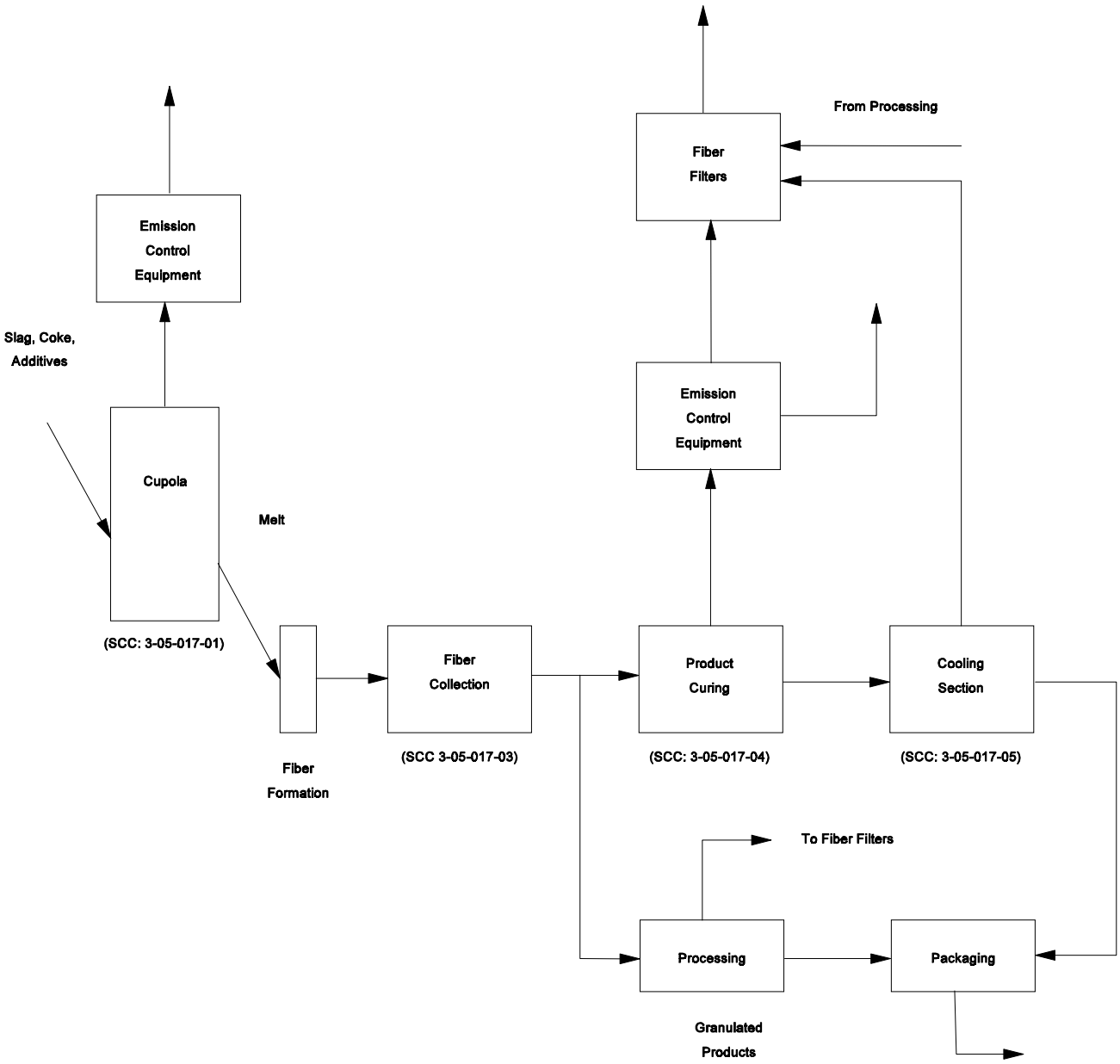

Figure 2-1. Mineral wool manufacturing process flow diagram.

state at a temperature of 1300° to 1650°C (2400° to 3000°F). Combustion air is supplied through tuyeres located near the bottom of the furnace. Process modifications at some plants include oxygen enrichment and the use of natural gas auxiliary burners to reduce coke consumption. One facility also reported using an aluminum flux byproduct to reduce coke consumption.

The molten mineral charge exits the bottom of the cupola in a water-cooled trough and falls onto a fiberization device. Most of the mineral wool produced in the United States is made by variations of two fiberization methods. The Powell process uses groups of rotors revolving at a high rate of speed to form the fibers. Molten material is distributed in a thin film on the surfaces of the rotors and then is thrown off by centrifugal force. As the material leaves the surface, small globules develop and form long, fibrous tails as they travel horizontally. Air or steam may be blown around the rotors to assist in fiberizing the material. A second fiberization method, the Downey process, uses a spinning concave rotor with air or steam attenuation. Molten material is distributed over the surface of the rotor, from which it flows up and over the edge and is captured by a high-velocity stream of air or steam.

During the spinning process, not all globules that develop are converted into fiber. The nonfiberized globules that remain are referred to as "shot." In raw mineral wool, as much as half of the mass of the product may consist of shot. Shot is usually separated from the wool by gravity immediately following fiberization.

Depending on the desired product, various chemical agents may be applied to the newly formed fiber immediately following the rotor. In almost all cases, an oil is applied to suppress dust and, to some degree, anneal the fiber. This oil can be either a proprietary product or a medium-weight fuel or lubricating oil. If the fiber is intended for use as loose wool or bulk products, no further chemical treatment is necessary. If the mineral wool product is required to have structural rigidity, as in batts and industrial felt, a binding agent is applied with or in place of the oil treatment. This binder is typically a phenol-formaldehyde resin that requires curing at elevated temperatures. Both the oil and the binder are applied by atomizing the liquids and spraying the agents to coat the airborne fiber.

After formation and chemical treatment, the fiber is collected in a blowchamber. Resin- and/or oil-coated fibers are drawn down on a wire mesh conveyor by fans located beneath the collector. The speed of the conveyor is set so that a wool blanket of desired thickness can be obtained.

Mineral wool containing the binding agent is carried by conveyor to a curing oven, where the wool blanket is compressed to the appropriate density and the binder is baked. Hot air, at a temperature of 150° to 320°C (300° to 600°F), is forced through the blanket until the binder has set. Curing time and temperature depend on the type of binder used and the mass rate through the oven. A cooling section follows the oven, where blowers force air at ambient temperatures through the wool blanket.

To make batts and industrial felt products, the cooled wool blanket is cut longitudinally and transversely to the desired size. Some insulation products are then covered with a vapor barrier of aluminum foil or asphalt-coated kraft paper on one side and untreated paper on the other side. The cutters, vapor barrier applicators, and conveyors are sometimes referred to collectively as a batt machine. Those products that do not require a vapor barrier, such as industrial felt and some residential insulation batts, can be packed for shipment immediately after cutting.

Loose wool products consist primarily of blowing wool and bulk fiber. For these products, no binding agent is applied, and the curing oven is eliminated. For granulated wool products, the fiber blanket leaving the blowchamber is fed to a shredder and pelletizer. The pelletizer forms small, 1-inch-diameter pellets and separates shot from the wool. A bagging operation completes the processes. For other loose wool products, fiber can be transported directly from the blowchamber to a baler or bagger for packaging.

2.3 EMISSIONS[1,4]

The sources of emissions in the mineral wool manufacturing industry are the cupola; binder storage, mixing, and application; the blow chamber; the curing oven; the mineral wool cooler; materials handling and bagging operations; and wastewater treatment and storage. With the exception of lead, the industry emits the full range of criteria pollutants. Also, depending on the particular types of slag and binding agents used, the facilities may emit both metallic and organic hazardous air pollutants (HAP's). However, with the exception of hydrogen sulfide (H_2S), no HAP data were obtained during this review.

The primary source of emissions in the mineral wool manufacturing process is the cupola. It is a significant source of particulate matter (PM) emissions and is likely to be a source of PM less than 10 micrometers in diameter (PM-10) emissions, although no particle size data are available. The cupola is also a potential source of HAP metal emissions attributable to the coke and slags used in the furnace. Coke combustion in the furnace produces carbon monoxide (CO), carbon dioxide (CO_2), and nitrogen oxide (NO_x) emissions. Finally, because coke and blast furnace slags contain sulfur, the cupola is also a source of sulfur dioxide (SO_2) and H_2S emissions.

The blowchamber is a source of PM (and probably PM-10) emissions. Also, the annealing oils and binders used in the process can lead to volatile organic compound (VOC) emissions from the process. Other sources of VOC emissions include batt application, the curing oven, and wastewater storage and treatment. Finally, fugitive PM emissions can be generated during cooling, handling, and bagging operations.

2.4 CONTROL TECHNOLOGY[1]

Mineral wool manufacturers use a variety of air pollution control techniques, but most are directed toward PM control with minimal control of other pollutants. The industry has given greatest attention to cupola PM control, with two-thirds of the cupolas in operation having fabric filter control systems. Some cupola exhausts are controlled by wet scrubbers and electrostatic precipitators (ESP's); cyclones are also used for cupola PM control either alone or in combination with other control devices. About half of the blow chambers in the industry also have some level of PM control, with the predominant control device being low-energy wet scrubbers. Wire mesh filters also are often used to control PM emissions from blow chambers. Cyclones and fabric filters have been used to a limited degree on blow chambers. Finally, afterburners have been used to control VOC emissions from blow chambers and curing ovens and CO emissions from cupolas. Table 2-2 provides a summary of the extent of control in the industry as of 1980.

TABLE 2-2. SUMMARY OF AIR POLLUTION CONTROLS OPERATING IN THE U.S. MINERAL WOOL INDUSTRY

Process source	Total	Number of process sources controlled by indicated devices						
		Fabric Filters	ESP	Wet scrubbers	Cyclones	After-burners	Other	None
Cupolas[a]	53	35	2	3	20	2	2[b]	3
Blowchambers[c]	46	2	0	21	3	2	0	21[d]
Curing ovens	15	1	0	0	0	6	0	8
Coolers	6	0	0	0	0	1	0	5

[a]Two cupolas are controlled with fabric filters followed by direct-flame afterburners; two cupolas are controlled by wet scrubbers followed by ESP's; seven cupolas are controlled by cyclones followed by fabric filters; and one cupola is controlled by a cyclone followed by a wet scrubber.
[b]Carbon monoxide control system is operating on two cupolas with a fabric filter in one plant.
[c]Three blowchambers use two control devices in series; two plants use afterburners plus wet scrubbers, and one plant has cyclones plus a fabric filter.
[d]Includes nine units reported to use wire mesh filters.

REFERENCES FOR SECTION 2

1. Source Category Survey: Mineral Wool Manufacturing Industry, EPA-450/3-80-016. U. S. Environmental Protection Agency, Research Triangle Park, NC, March 1980.

2. The Facts on Rocks and Slag Wool, Pub. No. N 020, North American Insulation Manufacturers Association, Alexandria, VA, Undated.

3. ICF Corporation, Supply Response to Residential Insulation Retrofit Demand, Report to the Federal Energy Administration, Contract No. P-14-77-5438-0, Washington, D.C., June 1977.

4. Personal communication between M. Johnson, U. S. Environmental Protection Agency, Research Triangle Park, NC, and D. Bullock, Midwest Research Institute, Cary, NC, March 22, 1993.

5. Personal communication between F. May, U.S.G. Corporation, Chicago, Illinois, and R. Marinshaw, Midwest Research Institute, Cary, NC, June 5, 1992.

6. Memorandum from K. Schuster, N.C. Department of Environmental Management, to M. Aldridge, American Rockwool, April 25, 1988.

3. GENERAL DATA REVIEW AND ANALYSIS

3.1 LITERATURE SEARCH AND SCREENING[1]

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 VOC/PM Speciation Data Base Management System (SPECIATE) data bases 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.

The Minerals Yearbook and Census of Manufactures were reviewed for information on the industry, including number of plants, plant location, and annual production capacities. However, because the data from these sources could not be disaggregated for mineral wool manufacturing, this information was obtained from the Source Category Survey Report. 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 (TSAR) data base was conducted to identify test reports for sources within the mineral wool 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. 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 mineral wool industry. In addition, representative trade associations, including the North American Insulation Manufacturers Association (NAIMA), were contacted for assistance in obtaining information about the industry and emissions.

To screen out unusable test reports, documents, and information from which emission factors could not be developed, the following general criteria were used:

1. Emission 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 (e.g., one-page reports were generally rejected).

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 to which 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 are 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 using 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 upon 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 REVISION OF SECTION NARRATIVE[1]

Section 8.16, Mineral Wool Manufacturing, was last revised in 1972. The narrative provided in that version was quite limited, and the discussion of emissions and emission controls provided almost no information. Consequently, the narrative was completely rewritten for this version. The draft section, which is based primarily on information presented in the Source Category Survey Report and in test reports reviewed as a part of this study, contains an expanded discussion of the process, emissions, and emission controls and provides a process flow diagram.

4.2 POLLUTANT EMISSION FACTOR DEVELOPMENT

In addition to a review of the data available in the background file for Section 8.16, this evaluation included an examination of the emission data contained in the Source Category Survey Report and reviews of nine emission test reports. All tests described in these nine reports were conducted by facilities to demonstrate compliance with State or local regulations. The tests documented in References 8, 9, and 10 were conducted at the same facility. However, no process data were provided for these tests. In addition, the two stacks that were sampled served several emission sources, including cupolas, fugitive dust collection systems, a curing oven, and pipe manufacturing machines. (Based on exhaust gas flow rates provided, the cupolas accounted for 5 to 8 percent of the total flow exiting the stacks.) For these reasons, these three references were not used to develop emission factors.

The remainder of this section is divided into five parts. First the data presented in the Source Category Survey Report are discussed. Then the six test reports that contain sufficient data for emission factor development are discussed individually. Emission factors for mineral wool manufacturing included in the XATEF and SPECIATE data bases were also reviewed, and a discussion of these emission factors is presented. Then a discussion of the review of the existing test data in the AP-42 background file is presented. Finally, the results of the data review and analysis are presented.

4.2.1 Review of Source Category Survey Data (Reference 1)

As part of a review of the mineral wool manufacturing industry to assess the need for a new source performance standard, EPA compiled a substantial amount of emission data from State and local agencies. Because the data were only presented in summary form, their quality cannot be evaluated. Consequently, they cannot be averaged with other available test data to obtain emission factors. In view of these limitations, the emission factors developed from these data were deemed to be useful for order of magnitude estimates only and are rated E. Table 4-1 summarizes the information on uncontrolled emission factors for mineral wool cupolas. For each pollutant, the table shows the number of tests reviewed during the study and a range and average emission factor. Table 4-2 summarizes uncontrolled PM emission factor information for blow chambers. Finally, one test on a cupola in San Bernadino County, California, generated particle size data that were obtained with an Andersen cascade impactor. These data are presented in Table 4-3.

TABLE 4-1. SUMMARY OF SOURCE CATEGORY SURVEY EMISSION FACTOR DATA FOR UNCONTROLLED MINERAL WOOL CUPOLAS

		Emission factor			
		kg/Mg feed		lb/ton feed	
Pollutant	No. of tests	Range	Average	Range	Average
PM	3	2.3-6.8	5.3	4.6-13.7	10.6
SO_2	10	ND	5.3	ND	10.6
H_2S	3	ND	1.5	ND	3.0
CO	9	3-156	78	6-312	156
NO_x	6	0.1-1.9	0.8	0.2-3.7	1.6

ND = No data available.

TABLE 4-2. SUMMARY OF SOURCE CATEGORY SURVEY EMISSION FACTOR DATA FOR UNCONTROLLED MINERAL WOOL BLOW CHAMBERS

		Emission factor			
		kg/Mg feed		lb/ton feed	
Source	No. of tests	Range	Average	Range	Average
PM	2	0.7 -0.9	0.8	1.4-1.8	1.6
VOC's	2	ND	0.2	ND	0.4

TABLE 4-3. SOURCE CATEGORY PARTICLE SIZE DATA FOR UNCONTROLLED MINERAL WOOL CUPOLAS

Particle size range, µm	Percent by weight
+30	5.6
9.2-30	0.1
5.5-9.2	0.5
3.3-5.5	1.0
2.0-3.3	5.0
1.0-2.0	67.8
0.2-1	20.0

4.2.2 Review of Specific Data Sets

4.2.2.1 Reference 2. This test was sponsored by the facility in 1988 to demonstrate that SO_2 emissions from the Nos. 1 and 2 cupolas were in compliance with State requirements. While the primary purpose of the test was to measure SO_2 levels, sufficient data were obtained from the associated Method 2 and 3 tests to calculate CO and CO_2 emission factors. The SO_2 measurements were made with a Standard EPA Method 8 train; sulfur trioxide (SO_3) measurements also were obtained from this train. Volumetric flow rates were obtained via EPA Method 2, and CO and CO_2 concentrations were obtained from Orsat measurements per EPA Method 3.

The process information contained in the test report was quite sparse. In fact, the only data that were available in the test report were process rate data sheets, which were contained in an appendix. Subsequently, the State agency supplied a process flow diagram for the facility. The information contained in the process flow diagram and in the process data appendix indicated that emissions from each cupola were controlled by a fabric filter, but no design or operating data on the system are available. During the tests, cupola No. 1 fired a mixture of coke (~15 percent) and slag (~85 percent), while cupola No. 2 fired a mixture of coke (~15 percent), slag (~80 percent), and ore (~5 percent).

The data are rated A for CO, CO_2, and SO_2 because standard methodology was used, no problems were reported, and all results were fully documented. Unlike these gaseous pollutants (CO, CO_2, and SO_2), which generally are not controlled by fabric filters, SO_3 is emitted as PM, and, thus, would be controlled by a fabric filter. Because the report did not include adequate information on the design and operation of the fabric filter, the SO_3 data are rated B.

4.2.2.2 Reference 3. This test program was sponsored by the facility in January 1981 to demonstrate that PM emissions from the cupola complied with State emission limits. The PM measurements were made on each operation at the outlet to an air pollution control device using EPA Method 5. Fyrite was used to quantify CO_2 emissions. Three runs were completed on the blow chamber; four runs were conducted on the cupola, but one was declared invalid because of sampling equipment problems. The results from that run were not reported.

The process information contained in the test report was limited to process data sheets contained in the appendix. However, the State agency provided flow diagrams indicating that the cupola was controlled by a fabric filter and the blowchamber was controlled by a wire mesh filter. No other information is available on the process.

The PM test data from this report are rated B. Tests were conducted with standard EPA methods, and no problems were reported. However, the process information contained in the report was insufficient to characterize the processes or control systems adequately. The CO_2 data are rated C due to the relative inaccuracy of the Fyrite analysis.

4.2.2.3 Reference 4. This test program was sponsored in June 1979 by the facility to demonstrate that the PM emissions from cupolas Nos. 1, 2, and 3 complied with State emission limits. Some data also were collected on organic emissions from the blow chamber. The sampling train used to collect the hydrocarbons included a heated glass probe with glass wool plug to collect the PM, followed by two tubes filled with activated charcoal. The samples were analyzed by placing carbon disulfide in the activated carbon tubes for 24 hours, then filtering and evaporating the liquid to dryness at room temperature. However, it is likely that a significant amount of sample was lost in the

evaporation step. For that reason, the test method used was not considered to be acceptable for AP-42 emission factor development, and the results are not included in this review. The PM tests were conducted with EPA Methods 1 through 5, and no problems were noted. Fyrite was used to quantify CO_2 emissions.

The process information for the cupolas is limited to a process flow diagram supplied by the State agency and process data sheets contained in the report appendix. The process diagrams indicate that each cupola is equipped with a fabric filter. During the tests, the process data indicated that the cupola was fired with a blend of coke (~10.5 percent), shale (~6.4 percent), slag (probably blast furnace slag) (~62.3 percent), and phosphate slag (~20.8 percent). Some process data were supplied on the blow chamber operation, but they were insufficient to determine the basis for the process weights associated with these operations.

The PM test data are rated B. Tests were conducted with standard EPA methods and no problems were reported. However, the process information was inadequate to warrant a higher rating. The CO_2 data are rated C due to the relative inaccuracy of Fyrite analysis.

4.2.2.4 Reference 5. This facility-sponsored test was conducted to demonstrate that the PM emissions from the batt curing oven complied with State emission limits. Five test runs were conducted using EPA Methods 1 through 5. Run 1 was discarded because of a failed posttest leak check, and Run 2 was discontinued because of a process malfunction, leaving three valid runs. The report does not provide process or emission data for the two discarded runs. Fyrite was used to quantify CO_2 emissions.

The process information in the report is quite limited. The introduction does note that emissions are directed through an ESP, but no other process description is provided. Operational data are presented in Chapter IV of the report. However, these data are difficult to read, and the raw data could not be clearly related to the process weights presented in summary tables. The process weights appear to be in units of batt produced, but the exact basis for the process weights could not be confirmed from the raw data.

The test data from this report are rated C. Tests were conducted with standard EPA methods, and no problems were reported. However, the process information contained in the report was insufficient to characterize the processes or control systems adequately. Also, the basis for the process rates given in summary tables is unclear.

4.2.2.5 Reference 6. This test program was conducted by the facility to measure emissions of PM, SO_2, and fluorides. The tests were designed to evaluate the effect of substituting an

aluminum smelting cell byproduct material (SPL) for coke on a pound-per-pound carbon basis. The typical charge compositions for the different test conditions are shown below.

AVERAGE CHARGE MAKEUP

Charge (1 lb)	Condition A	Condition B	Condition D
SPL	0	210	450
Lime	0	0	50
Coke	385	260	140
Duquesne slag	1,300	1,300	1,300
Trap rock	1,100	1,100	1,100
Steel slag	400	400	400
Tennessee slag	400	400	400
Avg. No. charges/hr	3.5	3.4	3.0

The test design for this program was somewhat unusual. The facility operates two cupolas, each with its own spark arrestor and fabric filter. The exhaust from the fabric filters is combined and ducted to the atmosphere through a common stack. The sampling was conducted in this common stack. Sampling for fluorides was conducted using Alcoa Method 4075A (which was approved by the State and EPA) in conjunction with EPA Methods 1 through 4. Particulate matter emissions were obtained from a cellulose thimble in the front half of the Method 4075A. This procedure provides results that are comparable to EPA Method 5 front half results but are less accurate for emissions that include significant levels of condensible PM. However, for the reported stack gas temperatures, which ranged from 34° to 44°C (93° to 111°F), the condensible PM fraction should be negligible. Therefore, the filterable PM results should be relatively accurate for AP-42 emission factor development with a one-step quality down-rating. The SO_2 samples were obtained with a glass-bulb technique that is purported to be similar to EPA Method 15 procedures. The concentration of SO_2 was measured with a gas chromatograph/flame photometric detector. Although the test method appears to be acceptable, there is inadequate information to evaluate the validity of the analytical method used or to demonstrate that this method is equivalent to EPA Method 6 or 8. Consequently, the SO_2 data are rated D. Fyrite was used to quantify CO_2 emissions.

The test data for fluorides are rated A. Reference or equivalent methods were used, no problems were reported, and results were fully documented. The PM data were rated B because the method used is somewhat less reliable than EPA Method 5. The SO_2 data were rated D because a nonstandard method was used and no information was presented on its reliability, accuracy, precision, or equivalence to other methods. The CO_2 data are rated C due to the relative inaccuracy of Fyrite analysis.

4.2.2.6 Reference 7. This test program was sponsored by the facility to demonstrate that PM, SO_2, and fluoride emissions from the cupola were in compliance with State requirements. The

tests were conducted in the common stack for the two cupolas as described in Reference 6 above. Tests were conducted with two different charge conditions as shown below.

CHARGE MAKEUP

Baseline		710 lb/hr SPL	
Charge	lb	Charge	lb
Coke	385-400	Coke	260
SPL	0	SPL	225
Duquesne slag	1,300	Duquesne slag	1,300
Trap rock	1,100	Trap rock	1,100
Lime	50	Lime	50
Steel	400	Steel	400
Tennessee slag	400	Tennessee slag	400

Three test runs were completed for the baseline conditions, and four were completed for the SPL runs. Standard EPA methods were used for PM (Methods 1 through 5) and SO_2 (Method 6). An Alcoa method (Method 4075A) that was approved by the State and EPA was used for fluorides. Fyrite was used to quantify CO_2 emissions.

The PM, SO_2, and fluoride test data from this report are rated A. Standard methods or acceptable equivalents were used, no problems were reported, and the test report fully documented results. The CO_2 data are rated C due to the relative inaccuracy of Fyrite analysis.

4.2.3 Review of XATEF and SPECIATE Data Base Emission Factors

The XATEF data base does not contain emission factors for mineral wool manufacturing.

The SPECIATE data base contains emission factors for emissions from mineral wool furnaces, curing ovens, and coolers. However, all of the emission factors are based on surrogate profiles. Consequently, they will not be used in the revised AP-42 section.

4.2.4 Review of Test Data in AP-42 Background Files

The current version of AP-42 contains uncontrolled PM emission factors for the cupola, reverberatory furnace, blow chamber, curing oven, and cooler and an uncontrolled SO_2 emission factor for the cupola. A review of the background file indicated that these emission factors are based on averaging a limited quantity of emission data that were reported in an early (1967) version of AP-40 (Reference 11). In addition, Reference 11 includes emission data on uncontrolled emissions of SO_3 and CO from cupolas; SO_2 and aldehydes from blow chambers; SO_2, nitrogen dioxide (NO_2), and aldehydes from curing ovens; and SO_2 and aldehydes from coolers. This reference reported average rather than run-specific test results, and the test methods were not documented. Given these limitations, the emission factors developed from these data were deemed to be useful for order of magnitude estimates only. The emission factors developed from these data are rated E, with the

exception of the emission factors for aldehydes. Because the lack of documentation on the aldehyde emission tests and the fact that a reliable method for testing aldehydes was not available at the time of these tests, the aldehyde emission results are highly suspect and are unrated.

4.2.5 Results of Data Analysis

For mineral wool manufacturing cupolas, the test reports and documents described above provided sufficient data to develop emission factors for uncontrolled and controlled filterable PM emissions; uncontrolled CO, CO_2, SO_2, H_2S, and NO_x emissions; uncontrolled and controlled SO_3 emissions; and controlled fluoride emissions. For reverberatory furnaces, an uncontrolled filterable PM emission factor was developed. For mineral wool batt curing ovens, emission factors were developed for uncontrolled and controlled filterable PM emissions and for uncontrolled SO_2 and N_2O emissions. For mineral wool blow chambers, emission factors were developed for uncontrolled and controlled filterable PM emissions and for uncontrolled SO_2 and CO_2 emissions. Finally, for mineral wool coolers, emission factors were developed for filterable PM and SO_2 emissions. The data used in the analysis are summarized in Tables 4-4 and 4-5. Table 4-6 summarizes the emission factors developed from data found in AP-40 (Reference 11). The final emission factors that were incorporated into the revised AP-42 section and their ratings are tabulated in Table 4-7. The paragraphs below describe how the emission factors were calculated and summarize the rationale for the ratings.

The filterable PM emission factor for cupola emissions was developed by averaging the data in the source category survey report (Reference 1) and AP-40 Reference 11. When compared to the fabric-filter-controlled data from References 3, 4, 6, and 7, the uncontrolled PM data indicate a control efficiency of 99 percent. Thus, although the emission factor is based on secondary references, the uncontrolled data are consistent with the controlled data from primary references. Because the emission factor is based on secondary data, it is rated E.

The emission factors included in the revised AP-42 section on mineral wool manufacturing for uncontrolled CO and CO_2 emissions from cupolas were developed from Reference 2. Emission factors for CO_2 emissions from cupolas also were developed from References 3, 4, 6, and 7. The Reference 2 data are rated A and indicated an emission factor of 125 kg/Mg (250 lb/ton), and the data from the other four references are rated C and average 205 kg/Mg (410 lb/ton). However, emission factors developed from C-rated data can only be rated E. For that reason, the emission factor for CO_2 emissions from cupolas developed from Reference 2 was used.

Although the CO and CO_2 emissions were measured downstream from a fabric filter, these emission factors are considered to be uncontrolled because fabric filters are not expected to affect CO and CO_2 emissions. These emission factors are rated D, because they are based on A- and B-rated data from only one plant.

For SO_2 emissions from cupolas, A- or B-rated data are available for three operating units--cupola Nos. 1 and 2 at Facility A and the combined stream at Facility C under different operating conditions. Examination of the data shows the data to fall in a reasonably narrow range. Consequently, the emission factor was obtained by simply averaging the four A- and B-rated test data. This emission factor is rated D because of the limited number of tests and facilities used.

Uncontrolled emission factors for SO_3, H_2S, and NO_x emissions from cupolas were developed from secondary references (References 1 and 11). The uncontrolled SO_3 emission factor for cupolas, which was developed from Reference 11, indicates a fabric filter control efficiency of 98 percent when

TABLE 4-4. SUMMARY OF EMISSION TEST DATA FOR MINERAL WOOL MANUFACTURING CUPOLAS

Facility	Source ID	APCD	Pollutant	No. of runs	Data rating	Emission factor, kg/Mg (lb/ton) feed		Ref.
						Range	Average	
A	Cupola No. 1 (slag)	FF	CO	3	A	130-140 (260-280)	130 (260)	2
			SO_2	3	A	2.5-3.8 (5.1-7.6)	3.1 (6.2)	2
			CO_2	3	A	230-270 (470-550)	250 (510)	2
			SO_3	3	B	0.0085-0.43 (0.017-0.86)	0.15 (0.30)	2
	Cupola No. 2 (slag/ore)	FF	CO	3	A	120-130 (230-260)	120 (250)	2
			SO_2	3	A	3.3-3.8 (6.5-7.6)	3.4 (6.9)	2
			CO_2	3	A	250-310 (490-620)	270 (540)	2
			SO_3	3	B	0.0010-0.0050 (0.0040-0.010)	0.0034 (0.0067)	2
B	Cupola No. 4 (slag)	FF	PM	3	B	0.0020-0.049 (0.0041-0.098)	0.025 (0.050)	3
		None	CO_2	3	C	310-350 (610-690)	330 (650)	3
	Cupola No. 1	FF	PM	3	B	0.015-0.072 (0.030-0.14)	0.041 (0.082)	4
		None	CO_2	3	C	150-290 (290-580)	220 (430)	4
	Cupola No. 2	FF	PM	3	B	0.016-0.053 (0.033-0.11)	0.032 (0.065)	4
		None	CO_2	3	C	110-200 (210-390)	150 (290)	4
	Cupola No. 3 (slag, shale, phosphate slag)	FF	PM	3	B	0.037-0.073 (0.073-0.15)	0.050 (0.099)	4
		None	CO_2	3	C	200-250 (390-500)	230 (450)	4
C	Cond. 1[a]	FF	PM	3	B	0.035-0.057 (0.069-0.11)	0.049 (0.098)	6
			SO_2	3	D	3.7-4.5 (7.4-8.9)	4.2 (8.3)	6
			Fluorides	3	A	0.016-0.036 (0.031-0.072)	0.029 (0.058)	6
		None	CO_2	3	C	160-170 (320-330)	170 (330)	6
	Cond. 2	None	PM	4	B	0.019-0.095 (0.038-0.19)	0.074 (0.15)	6
			SO_2	4	D	1.9-4.1 (3.8-8.1)	3.8 (7.6)	6
			Fluorides	4	A	0.059-0.49 (0.19-0.98)	0.32 (0.63)	6
		None	CO_2	4	C	100-180 (200-360)	120 (240)	6
	Cond. 3	None	PM	2	B	0.076-0.079 (0.15-0.16)	0.18 (0.37)	6
			SO_2	2	D	2.0-2.9 (4.1-5.8)	2.5 (5.0)	6
			Fluorides	2	A	0.19-0.26 (0.37-0.51)	0.22 (0.44)	6
		None	CO_2	2	C	110-170 (220-340)	140 (280)	6
C	Cond. 1[a]	FF	PM	3	A	0.061-1.1 (0.12-2.2)	0.084 (0.17)	7
			SO_2	3	A	5.0-6.5 (10-13)	5.5 (11.0)	7
			Fluorides	3	A	0.0073-0.011 (0.015-0.021)	0.0085 (0.017)	7
		None	CO_2	3	C	240-260 (480-510)	250 (500)	7
	Cond. 2	None	PM	4	A	0.12-0.17 (0.24-0.33)	0.14 (0.28)	7
			SO_2	4	A	3.7-4.5 (7.5-9.0)	4.1 (8.2)	7
			Fluorides	4	A	0.026-0.036 (0.052-0.073)	0.032 (0.064)	7
		None	CO_2	3	C	230-240 (460-480)	240 (470)	7

[a]Refer to Section 4.2.2.5 for composition of charge material.

TABLE 4-5. SUMMARY OF EMISSION TEST DATA FOR MINERAL WOOL MANUFACTURING CURING AND BLOWING

Facility	Source ID	APCD	Pollutant	No. of runs	Data rating	Emission factor, kg/Mg (lb/ton) feed		Ref.
						Range	Average	
B	Batt curing oven	ESP	PM	3	C	0.23-0.60 (0.46-1.2)	0.36 (0.72)	5
		None	CO_2	3	C	60-110 (110-220)	80 (160)	5
B	Blow chamber	Wire mesh filter	PM	3	B	0.30-5.9 (0.59-1.2)	0.45 (0.91)	3

TABLE 4-6. SUMMARY OF UNCONTROLLED EMISSION FACTORS DEVELOPED FROM AP-40[11,a]

Process	Pollutant	No. of tests	Range		Average	
			kg/Mg	lb/ton	kg/Mg	lb/ton
Cupola	PM (filterable)	3	8.0-14	16-28	11	22
	SO_2	1			5.6	11
	SO_3	1			3.2	6.3
	CO	1			45	91
Reverberatory furnace	PM (filterable)	1			2.4	4.8
Blow chamber	PM (filterable)	4	2.0-28	4.0-56	8.6	17
	SO_2	1			0.43	0.87
	aldehydes[b]	1			0.43	0.86
Curing oven	PM (filterable)	5	0.74-2.9	1.5-5.9	1.8	3.6
	SO_2	1			0.58	1.2
	aldehydes[b]	2	0.37-0.63	0.73-1.3	0.50	1.00
	NO_2	2	0.043-0.12	0.086-0.23	0.079	0.16
Cooler	PM (filterable)	4	0.21-2.8	0.43-5.5	1.2	2.4
	SO_2	1			0.034	0.068
	aldehydes[b]	1			0.021	0.042

[a]All emission factors rated E except where indicated.
[b]Emission factors are unrated.

TABLE 4-7. MINERAL WOOL MANUFACTURING EMISSION FACTORS

Source	Control	Pollutant	Emission factor		Rating	Ref. No.
			kg/Mg	lb/ton		
Cupola[a]	Uncontrolled	Filterable PM	8.2	16	E	1, 11
		CO	125	250	D	2
		CO_2	260	520	D	2
		SO_2	4.0	8.0	D	2,7
		SO_3	3.2	6.3	E	11
		H_2S	1.5	3.0	E	1
		NO_2	0.8	1.6	E	1
	Fabric filter	Filterable PM	0.051	0.10	D	2,3,4,6,7
		SO_3	0.077	0.15	E	2
		Fluorides[b]	0.019	0.038	D	7
		Fluorides[c]	0.19	0.38	D	6
Reverberatory Furnace	Uncontrolled	Filterable PM	2.4	4.8	E	11
Batt curing oven[d]	Uncontrolled	Filterable PM	1.8	3.6	E	11
		SO_2	0.58	1.2	E	11
		NO_2	0.079	0.16	E	11
		CO_2	80	160	E	5
	ESP	Filterable PM	0.36	0.72	D	5
Blow chamber[e]	Uncontrolled	Filterable PM	6.0	12	E	1,11
		SO_2	0.43	0.87	E	11
	Wire mesh filter	Filterable PM	0.45	0.91	D	3
Cooler	Uncontrolled	Filterable PM	1.2	2.4	E	11
		SO_2	0.034	0.068	E	11

[a]Activity level is total feed-charged.
[b]Only coke was used as fuel.
[c]Fuel was a combination of coke and aluminum smelting byproducts.
[d]Activity level is mass of product.
[e]Activity level is mass of molten mineral feed.

compared to the data in Reference 2. For that reason, the uncontrolled SO_3 emission factor also appears to be reasonable. The uncontrolled emission factors for H_2S and NO_x also were developed from Reference 1. However, there are no controlled data to which these emission factors can be compared.

The controlled filterable PM emission factor for cupolas was obtained by averaging the average of the data from five tests at Facility C with the data from tests on the four cupolas at Facility B. Again, the emission factor is rated D because it is based on a very limited quantity of data. The remaining emission factors developed for mineral wool cupolas are for controlled SO_3 and fluoride emissions. The SO_3 emission factor is based on two B-rated tests at the same facility (Reference 2) and is rated D. Fluoride emission factors for two types of fuel were developed from one test each and are also rated D.

The emission factors for controlled filterable PM emissions from batt curing ovens and blow chambers were developed from References 5 and 3, respectively. These emission factors are each rated D, because they are based on a single emission test. All other emission factors for mineral wool manufacturing are based on secondary references and are rated E.

The uncontrolled filterable PM emission factor for blow chambers is based on an average of the data in References 1 and 11. This emission factor, when compared to the wire mesh filter-controlled emission factor developed from Reference 3, indicates a control efficiency of 93 percent, which seems reasonable. Also, a comparison of the uncontrolled (based on secondary data) and ESP-controlled PM emission factors for curing ovens indicates a control efficiency of 80 percent, which also appears to be reasonable. There are no other data with which the other emission factors developed from secondary data can be compared. However, they are considered to be useful for order-of-magnitude estimates and have been included in the revised AP-42 section.

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