BACKGROUND REPORT

AP-42 SECTION 12.6

PRIMARY LEAD SMELTING AND REFINING

Prepared for

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TABLE OF CONTENTS

1.0 INTRODUCTION 1

2.0 INDUSTRY DESCRIPTION 2
2.1 GENERAL 2
2.2 PROCESS DESCRIPTION 2
2.3 EMISSIONS AND CONTROLS 5
2.4 REVIEW OF REFERENCES FOR CHAPTER 2.0 7
2.5 REFERENCES FOR CHAPTER 2.0 9

3.0 GENERAL EMISSION DATA REVIEW AND ANALYSIS PROCEDURES 10
3.1 LITERATURE SEARCH AND SCREENING 10
3.2 EMISSION DATA QUALITY RATING SYSTEM 11
3.3 EMISSION FACTOR QUALITY RATING SYSTEM 13
3.4 REFERENCES FOR CHAPTER 3.0 15

4.0 POLLUTANT EMISSION FACTOR DEVELOPMENT 16
4.1 CRITERIA POLLUTANT EMISSIONS DATA 16
4.2 NONCRITERIA POLLUTION EMISSION DATA 45
4.3 REVIEW OF SPECIFIC DATA SETS 46
4.4 DATA GAP ANALYSIS 59
4.5 REFERENCES FOR CHAPTER 4.0 60

LIST OF TABLES

TABLE 2.1-1: PRIMARY LEAD PROCESSING FACILITIES 2
TABLE 4.1-1 (METRIC): FILTERABLE PARTICULATE MATTER 19
TABLE 4.1-1 (ENGLISH): FILTERABLE PARTICULATE MATTER 22
TABLE 4.1-2 (METRIC): PM_{10} 25
TABLE 4.1-2 (ENGLISH): PM_{10} 28
TABLE 4.1-3 (METRIC): CONDENSIBLE PARTICULATE MATTER 31
TABLE 4.1-3 (ENGLISH): CONDENSIBLE PARTICULATE MATTER 34
TABLE 4.1-4 (METRIC): LEAD 38
TABLE 4.1-4 (ENGLISH): LEAD 41
TABLE 4.3-1 (METRIC): VOLUME SOURCE EMISSIONS FROM 1990 TESTS 52
TABLE 4.3-1 (ENGLISH): VOLUME SOURCE EMISSIONS FROM 1990 TESTS 53
TABLE 4.3-2: LEAD CONTENT OF OUTSIDE STORAGE PILES 55
TABLE 4.3-3 (METRIC): VOLUME SOURCE EMISSION RATES FROM 1976 TESTS 57
TABLE 4.3-3 (ENGLISH): VOLUME SOURCE EMISSION RATES FROM 1976 TESTS 58
TABLE 4.5-1: LIST OF CONVERSION FACTORS 61

LIST OF FIGURES

2.2-1: PROCESS FLOW FOR A TYPICAL LEAD PROCESSING FACILITY 3

1.0 INTRODUCTION

The document "Compilation of Air Pollutant Emission Factors" (AP-42) has been published by the U.S. Environmental Protection Agency (the EPA) since 1972. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. The AP-42 document is routinely updated by the EPA to respond to new emission factor needs of the EPA, state and local air pollution control agencies, 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 area-wide emissions;
2. Emission estimates for a specific facility; and
3. Evaluation of emissions relative to ambient air quality.

The purpose of this report is to provide background information for revisions to the emission factors and descriptions of the industry and its processes for AP-42 Section 12.6, *Primary Lead Smelting and Refining*.

Including the introduction (Chapter 1), this report contains four chapters. Chapter 2 gives a description of the primary lead smelting and refining industry. It includes a characterization of the industry, an overview of the various industrial processes associated with it, a description of emissions, and a description of the technology and techniques used to control emissions resulting from primary lead smelting and refining.

Chapter 3 is a review of emissions data collection and analysis procedures. It describes the literature search, the screening of quantitative emissions data reports, and the quality rating system for both emissions data and emission factors. Chapter 4 details criteria and noncriteria pollutant emission factor development. It includes the review of specific data sets and the results of data analysis. Particle size determination and particle size data analysis methodology are described.

2.0 INDUSTRY DESCRIPTION

2.1 GENERAL

Lead is found naturally as a sulfide ore containing small amounts of copper, iron, zinc, precious metals, and other trace elements. The lead in this ore, typically after being concentrated at or near the mine, is processed into metallurgical lead at four facilities in the U.S. The operator, location, and function of each of these facilities appear in Table 2.1-1. Demand for lead from these primary sources is expected to remain relatively stable in the early 1990s, due in large part to storage battery recycling programs being implemented by several states. Significant emissions of sulfur dioxide (SO_2), particulate matter, and especially lead have caused much attention to be focused on identifying, and quantifying emissions from, sources within these facilities.

TABLE 2.1-1: PRIMARY LEAD PROCESSING FACILITIES

Location	Corporation	Type
Herculaneum, Missouri	The Doe Run Co.	smelter/refinery
Glover, Missouri	ASARCO Incorporated	smelter/refinery
Omaha, Nebraska	ASARCO Incorporated	refinery
East Helena, Montana	ASARCO Incorporated	smelter

2.2 PROCESS DESCRIPTION

The processing of lead concentrate into metallurgical lead involves three major steps: sintering, reduction, and refining. A diagram of a typical facility, with particle and gaseous

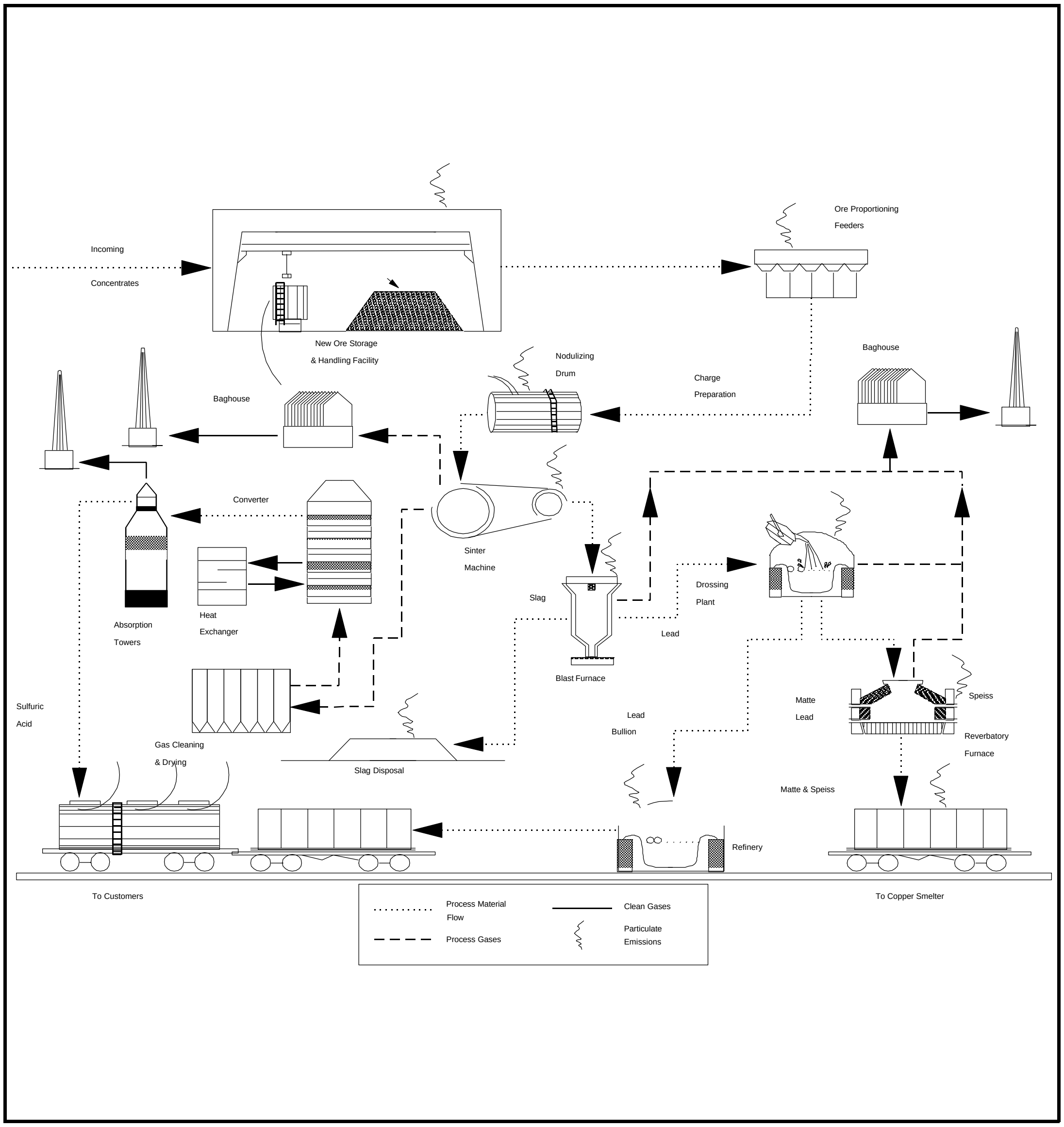

Figure 2.2-1. Process Flow for a Typical Lead Processing Facility.
(SCC = Source Classification Code)

emission sources indicated, is shown in Figure 2.2-1.

Sintering

The primary purpose of the sinter machine is the reduction of sulfur content of the feed material. This feed material typically consists of the following:

1) lead concentrates, including pyrite concentrates that are high in sulfur content, and concentrates that are high in impurities such as arsenic, antimony, and bismuth, as well as relatively pure high-lead concentrates;
2) lime rock and silica, incorporated in the feed to maintain a desired sulfur content;
3) high-lead content sludge by-products from other facilities; and
4) undersized sinter recycled from the roast exiting the sinter machine.

The undersized sinter return stream mixes with the other feed components, or green feed, as the two streams enter a rotary pelletizing drum. A water spray into the drum enhances the formation of nodules in which the sinter returns form a core rich in lead oxide and the green feed forms a coating rich in lead sulfide. The smaller nodules are separated out and conveyed through an ignition furnace, then covered with the remaining nodules on a moving grate and conveyed through the sinter machine, which is essentially a large oven. Excess air is forced upward through the grate, facilitating combustion, releasing SO_2 and oxidizing the lead sulfide to lead oxide. The "strong gas" from the front end of the sinter machine, containing 2.5 to 4 percent SO_2, is vented to gas cleaning equipment before possibly being piped to a sulfuric acid plant. Gases from the rear part of the sinter machine are recirculated up through the moving grate and are typically vented to a baghouse. That portion of the product which is undersized, usually due to insufficient desulfurization, is filtered out and recycled through the sinter; the remaining sinter roast is crushed before being transported to the blast furnace.

Reduction

The sinter roast is then conveyed to the blast furnace in charge cars along with coke, ores containing high amounts of precious metals, slags and byproducts dusts from other smelters, and byproduct dusts from baghouses and various other sources within the facility. Iron scrap is often added to the charge to aid heat distribution and to combine with the arsenic in the charge. The blast furnace process rate is controlled by the proportion of coke in the charge and by the air flow through the tuyeres in the floor of the furnace. The charge descends through the furnace shaft into the smelting zone, where it becomes molten, and is tapped into a series of settlers that allow the separation of lead from slag. The slag is allowed to cool before being stored, and the molten lead of roughly 85% purity is transported in pots to the dross building.

Refining

The drossing area consists of a variety of interconnected kettles, heated from below by natural gas combustion. The lead pots arriving from the blast furnace are poured into receiving kettles and allowed to cool to the point at which copper dross rises to the top and can be skimmed off and transferred to a reverberatory furnace. The remaining lead dross is transferred to a finishing kettle where such materials as wood chips, coke fines, and sulfur are added and mixed to facilitate further separation, and this sulfur dross is also skimmed off and transferred to the reverberatory furnace. To the drosses in the reverberatory furnace are added tetrahedrite ore (which is high in silver content but low in lead and may have been dried elsewhere within the facility) coke fines, and soda ash. When heated in the same fashion as the kettles, the dross in the reverberatory furnace separates into three layers: lead bullion settles to the bottom and is tapped back to the receiving kettles; matte (copper sulfide and other metal sulfides), which rises to the top; and speiss (high in arsenic and antimony content), the latter two of which are typically forwarded to copper smelters.

The third and final phase in the processing of lead ore to metallurgical lead, the refining of the bullion in cast iron kettles, occurs in five steps: 1) removal of antimony, tin and arsenic; 2) removal of precious metals by Parke's Process, in which zinc combines with gold and silver to form an insoluble intermetallic at operating temperatures; 3) vacuum removal of zinc; 4) removal of bismuth by the Betterson Process, in which calcium and magnesium are added to form an insoluble compound with the bismuth that is skimmed from the kettle; and 5) removal of remaining traces of metal impurities through the addition of sodium hydroxide (NaOH) and sodium nitrate ($NaNO_3$). The final refined lead, from 99.990 to 99.999 percent pure, is typically cast into 45 kilogram (100 pound) "pigs" for shipment.

2.3 EMISSIONS AND CONTROLS

Emissions of lead and particulate occur in varying amounts from nearly every process and process component within primary lead smelter/refineries, and SO_2 is also emitted from several sources. The lead and particulate emissions point, volume, and area sources may include:

1) the milling, dividing, and fire assaying of samples of incoming concentrates and high-grade ores;

2) fugitive emissions within the crushing mill area, including the loading and unloading of ores and concentrates from rail cars onto conveyors;
3) the ore crushers and associated transfer points, which may be controlled by baghouses;
4) fugitive emissions from the unloading, storage, and transfer of by-product dusts, high-grade ores, residues, coke, lime, silica, and any other materials stored in outdoor piles;
5) strong gases from the front end of the sinter machine, which are typically vented to a Cottrell electrostatic precipitator (ESP), one or more scrubbers, and a wet ESP for sulfuric acid mist elimination, but during shutdowns of the acid plant may bypass the Cottrell ESP;
6) weak gases from the back end of the sinter machine, which are high in lead dust content but typically pass through cyclones and a baghouse;
7) fugitive emissions from the sinter building, including leaks in the sinter machine and the sinter cake crusher;
8) gases exiting the top of the blast furnace, which are typically controlled with a baghouse;
9) fugitive emissions from the blast furnace, including leaks from the furnace covers and the bottoms of charge cars, dust from the charge car bottom dump during normal operation, and escaping gases when blow holes develop in the shaft and must be "shot" with explosives;
10) lead fumes from the molten lead and slag leaving the blast furnace area;
11) fugitive leaks from the tapping of the kettles and settlers;
12) the hauling and dumping of slag, at both the handling and cooling area and the slag storage pile;
13) the combustion of natural gas, as well as the creation of lead-containing fumes at the kettles and reverberatory furnace, all of which are typically vented to a baghouse at the drossing building;
14) fugitive emissions from the various pouring, pumping, skimming, cooling, and tapping operations with the drossing building;
15) the transporting, breaking, granulating, and storage of speiss and matte;
16) the loading, transferring, and drying of tetrahedrite ore, which is typically controlled with cyclones and a baghouse;

17) the periodic cleanout of the blast and reverberatory furnaces; and
18) dust caused by wind erosion and plant vehicular traffic, which are normally estimated with factors from Sections 11.2.6 and 11.2.7 of AP-42, but are addressed herein due to the high lead content of the dust at primary lead smelting and refining facilities.

2.4 REVIEW OF REFERENCES FOR CHAPTER 2.0

The following sources were contacted in order to obtain the most up-to-date information on process descriptions and emissions for this industry:

1) Lead Industries Association, Inc.
New York, NY

2) Missouri Department of Natural Resources
Division of Environmental Quality
Jefferson City, MO

3) Montana Department of Health and Environmental Services
Air Quality Bureau
Helena, MT

4) U.S. Environmental Protection Agency
Region VII
Air and Toxics Division
Kansas City, MO

5) U.S. Environmental Protection Agency
Air Quality Management Division
Research Triangle Park, NC

6) U.S. Department of the Interior
Bureau of Mines,
Washington, DC

No responses were received from sources 1 through 4. The material contained in the responses from sources 5 and 6 that was used to update AP-42 Section 12.6 is summarized below.

Reference 1: *Task 2 Summary Report: ASARCO East Helena Primary Lead Smelter - Revision and Verification of Lead Inventory Source List*

Reference 2: *Task 3 Summary Report: ASARCO East Helena Primary Lead Smelter - Emission Inventory Test Protocol*

Reference 3: *Task 5 Summary Report: ASARCO East Helena Primary Lead Smelter - Lead Emission Inventory*

A comprehensive lead emission inventory developed by North American Weather Consultants for the ASARCO primary lead smelter in East Helena, Montana was obtained from the Air Quality Management Division of the EPA (Source No. 5 above). This inventory, and the background information that accompanied it, included a detailed description of the facility and the industrial processes utilized; identification of each significant point, volume, and area emissions source in the facility; and the raw data and results associated with extensive emissions testing and ambient monitoring that occurred at the facility in September and October of 1990.

Reference 4: *"Lead," Mineral Commodities Summary 1992*

Reference 5: *"Lead," Minerals Yearbook 1992*

These documents reviewing the primary lead smelting and refining industry from a primarily commercial standpoint were received from the Bureau of Mines (Source No. 6). These documents are the basis for the industry profile provided in the revised AP-42 Section 12.6. The more detailed *Minerals Yearbook* also provided descriptions of the smelting and refining processes that were utilized in updating the section.

2.5 REFERENCES FOR CHAPTER 2

1. Task 2 Summary Report: ASARCO East Helena Primary Lead Smelter - Revision and Verification of Lead Inventory Source List, North American Weather Consultants, Salt Lake City, Utah, June 1990.

2. Task 3 Summary Report: ASARCO East Helena Primary Lead Smelter - Emission Inventory Test Protocol, North American Weather Consultants, Salt Lake City, Utah, June 1990.

3. Task 5 Summary Report: ASARCO East Helena Primary Lead Smelter - Lead Emission Inventory, Volume 1: Point Source Lead Emission Inventory, North American Weather Consultants, Salt Lake City, Utah, April 1991.

4. William Woodbury, "Lead," Mineral Commodities Summary 1992, U.S. Department of the Interior, Bureau of Mines, Washington, DC, 1992.

5. William Woodbury, "Lead," Minerals Yearbook 1989, U.S. Department of the Interior, Bureau of Mines, Washington, DC, 1990.

3.0 GENERAL EMISSION DATA REVIEW AND ANALYSIS PROCEDURES

3.1 LITERATURE SEARCH AND SCREENING

The first step of this investigation involved a search of available literature relating to the industrial processes and emissions of criteria and noncriteria pollutants associated with primary lead smelting and refining. This search included, but was not limited to, the following references:

1) AP-42 background files maintained by the Emission Factor and Methodologies Section. Two reports found in these files, neither of which was utilized in the development of emission factors for AP-42 Section 12.6, are summarized in Chapter 4 (References 7 and 8) of this background report.

2) Information in the *Air Facility Subsystems* (AFS) of the EPA *Aerometric Information Retrieval System* (AIRS). Only the ASARCO smelter/refinery in Glover, Missouri, had emissions data in the AFS, and all of these data were derived from calculations utilizing AP-42 emission factors for primary lead smelting and refining processes.

3) "Locating and Estimating" reports published by the Emission Factor and Methodologies Section. None of the pollutants for which these reports have been compiled is emitted from primary lead smelting and refining facilities, and thus no useful information was contained in these reports.

4) PM_{10} "gap filling" documents as listed below; none of these documents contained data of a quality suitable for development of emission factors for PM_{10}.

4a) "PM_{10} Emission Factor Listing Developed by Technology Transfer" (EPA-450/4-89-022).

4b) "Gap Filling PM_{10} Emission Factors for Selected Open Area Dust Sources" (EPA-450/88-003).

4c) "Generalized Particle Size Distributions for Use in Preparing Size Specific Particulate Emission Inventories" (EPA-450/4-86-013).

5) *Handbook of Emission Factors*, Parts I and II, Ministry of Health and Environmental Protection, The Netherlands, 1980/1983. No information concerning the primary lead smelting and refining industry is contained in this handbook.

6) The EPA *Clearinghouse for Inventories and Emission Factors* (CHIEF) and *National Air Toxics Information Clearinghouse* (NATICH). No emissions test data for the primary lead smelting and refining industry are contained in these databases.
7) The EPA databases, including but not limited to the *VOC/Particulate Matter* (PM) *Speciation Database Management System* (SPECIATE), the *Crosswalk/Air Toxic Emission Factor Data Base Management System* (XATEF). No emissions test data for the primary lead smelting and refining industry is contained in these databases.

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

1. Emissions data must be from a primary reference; i.e., 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.
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).

In cases where no primary emissions data were found for a particular process, and the previous AP-42 section utilized either secondary emissions data or data that could not be verified, these data were still used and the emission factor rating lowered. A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria. The final set of reference materials is reviewed in detail in Chapter 4.0 of this background report.

3.2 EMISSION DATA QUALITY RATING SYSTEM

As part of the of the emission data analysis, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data were always 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 (e.g., comparison of the EPA Method 5 front-half with the 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.

Data sets that were not excluded were assigned a quality rating. The rating system used was that specified by the OAQPS for the preparation of AP-42 sections. The data were rated as follows:

A

Multiple tests performed on the same source using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in the EPA reference test methods, although these methods were certainly 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. <u>Source operation</u>. 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. <u>Sampling procedures</u>. 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. Many variations can occur unnoticed and without warning during testing. Such variations can induce wide deviations in sampling results. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and are assigned 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 the 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

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. As in the A-rating, 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. As in the A-rating, 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.

3.4 REFERENCES FOR CHAPTER 3.0

1. Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections. U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711, April 1992. [Note: this document is currently being revised at the time of this printing.]

2. Compilation of Air Pollutant Emission Factors, Volume I: Stationary Sources. Supplement A, Appendix C.2, "Generalized Particle Size Distributions." U.S. Environmental Protection Agency, October 1986.

4.0 POLLUTANT EMISSION FACTOR DEVELOPMENT

4.1 CRITERIA POLLUTANT EMISSIONS DATA

Particulate Matter.

The principal air emissions from the processes associated with primary lead smelting and refining are particulate in nature. Emissions of particulate matter can be divided into three categories: filterable, organic condensible, and inorganic condensible. Filterable particulate matter is that which collects on the filter and in the sampling probe assembly of a particulate sampling train. When emissions testing is performed in accordance with EPA Reference Method 5, the filter and probe are maintained at approximately 120°C (248°F); materials that condense at a temperature lower than this will pass through the filter. Many emissions tests also quantify emissions of condensible particulate matter, typically that which condenses at or above 20°C (68°F). This condensible particulate matter is collected by passing the effluent gas through ice water-cooled impingers such that the gas exiting the last impinger is at a temperature less than 20°C. The preferred method for quantification of condensible particulate matter is EPA Reference Method 202. This method entails extraction of the organic portion of the condensible, or back-half, catch with methylene chloride, evaporation of the extract at room temperature, desiccation, and weighing. The inorganic portion of the back-half catch is evaporated at 105°C (221°F), desiccated, and weighed.

A further subset of emissions of particulate matter is PM_{10}, or particulate matter consisting of particles having an effective diameter of less than ten microns (µm). This PM_{10} can be filterable or condensible, organic or inorganic. While there is no single method which is universally accepted for the determination of particle size, EPA Reference Method 201A is preferred, and includes sampling procedures to be used with either a cascade impactor or a cyclone. Traditionally, cyclones and rotoclones have been used as a preseparator ahead of a cascade impactor to remove the larger particles. These devices are of the standard reverse-flow design whereby the flue gas enters the cyclone through a tangential inlet and forms a vortex flow pattern. Particles move outward toward the cyclone wall with a velocity that is determined by the geometry and flow rate in the cyclone and by their size. Large particles reach the wall and are collected. A series of cyclones with progressively decreasing cut-points can be used to obtain particle size distributions.

Cascade impactors used for the determination of particle size in process streams consist of a series of plates or stages containing either small holes or slits with the size of the openings decreasing from one plate to the next. In each stage of an impactor, the gas stream passes through the orifice or slit to form a jet directed toward an impaction plate. For each stage, there is a characteristic particle diameter that has a 50 percent probability of impaction. This characteristic diameter is called the cut-point (D50) of the stage. Typically, commercial instruments have six to eight impaction stages with a backup filter to collect those particles which are either too small to be collected by the last stage or which are re-entrained off the various impaction surfaces by the moving gas stream.

For the emissions testing performed on the ASARCO primary lead smelter in East Helena, Montana, from which the data appearing in Tables 4.1-1 through 4.1-4 below are derived, two particulate matter sampling trains were operated simultaneously at most sources tested. One of these was a conventional Method 5 sampling train (for filterable particulate matter) in combination with a Method 12 impinger train (for lead). The only modification to the method was the temperature of the sampling probe and filter, which were not heated for stacks characterized as dry and ambient (such as the crushing mill). The other sampling train was that specified by Method 201a, employing a cyclone as the particle sizing device, in combination with an impinger train which was analyzed for total condensible particulate (including organic and inorganic fractions) according to Method 202. It is important to note that the PM_{10} emission rates reported are for the front-half catch only; for total PM_{10}, the reported results from Methods 201a and 202 should be summed.

A detailed discussion of the report from which the data in Tables 4.1-1 through 4.1-4 are taken, including a description of each source tested and its typical hours of operation, can be found in Section 4.3 of this background report. Despite the fact that many of these emission tests are rated as high as "B," all of the emission factors presented in the revised AP-42 Section 12.6 derived from these data have been assigned a rating of "E" due to uncertainty as to their representativeness of the entire industry. Similarly, the emission factors copied directly from the previous version of the AP-42 Section 12.6 (October 1986) have been assigned a rating of "E" due to uncertainty as to their representativeness of the industry as it currently operates. Those factors in the latter category are presented on an uncontrolled basis, whereas the emission testing for which results were obtained and used in this AP-42 update did not allow for development of uncontrolled emission factors.

Emission factors for filterable particulate matter, total particulate matter, and PM_{10} are presented in the revised AP-42 Section 12.6 for the crushing mill; sinter machine weak gas; sinter building fugitive emissions; and blast furnace, dross reverberatory furnace, dross kettles, and dross building fugitive emissions. All of these emission factors are derived from testing performed as part of the comprehensive 1990 lead emission inventory on the ASARCO facility in East Helena, Montana.

TABLE 4.1-1 (METRIC UNITS)
FILTERABLE PARTICULATE MATTER

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
3P Copper matte crushing stack #1	B	5	1	100	0.2594	0.0102
			2	100	0.2485	0.0098
			Average	100	0.2539	0.0100
Control device: Baghouse						
4P Copper matte crushing stack #2	B	5	1	140	0.2232	0.0112
			2	140	0.1880	0.0094
			Average	140	0.2056	0.0103
Control device: Baghouse						
5P Copper matte crushing stack #3	B	5	1	140	0.0371	0.0019
			2	140	0.0951	0.0048
			Average	140	0.0661	0.0033
Control device: Baghouses						
Copper matte crushing-Total of tests on stacks 1-3	B	5	**Average**	127	0.5256	0.0226

[a] Units in megagrams per day.
[b] Units in kilograms per hour.
[c] Units in kilograms per megagram.

TABLE 4.1-1 (METRIC UNITS) (*continued*)
FILTERABLE PARTICULATE MATTER

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control devices: Baghouses						
6P Sinter feed Unloading & handling building	N/A	5	1	N/A	8.7105	N/A
			2	N/A	7.8422	N/A
			3	N/A	7.3702	N/A
			Average	N/A	7.9743	N/A
Control device: Baghouse						
7P Sinter machine weak gas	B	5	1	581	1.5038	0.0621
			2	581	0.9550	0.0394
			Average	581	1.2294	0.0508
Control devices: Cottrell ESP, 2 scrubbers, Wet ESP demister, Acid plant						
8P Sinter machine strong gas/ acid plant	N/A	5	1	N/A	1.1872	N/A
			2	N/A	0.2952	N/A
			Average	N/A	0.7412	N/A
Control device: None: routed through crushing mill baghouses 1 & 3 (points 3P, 5P) when mill not operating						
6V Sinter building fugitives	B	5	**Average**	23.9[d]	2.8330	0.1183
Control device: Baghouse						
9P Sinter storage & handling; matte breaking and blast furnace charge areas	N/A	5	1	N/A	0.1801	N/A
			2	N/A	0.2746	N/A
			3	N/A	0.1859	N/A
			Average	N/A	0.2135	N/A

[a] Units in megagrams per day, unless otherwise noted

[b] Units in kilograms per hour.

[c] Units in kilograms per megagram.

[d] Units in megagrams per hour.

TABLE 4.1-1 (METRIC UNITS) (*concluded*)
FILTERABLE PARTICULATE MATTER

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
10P Tetrahedrite dryer	C	5	1	25	0.1253	0.0050
			2	13	0.2307	0.0182
			Average	19	0.1780	0.0116
Control device: Baghouse						
16P Blast furnace, dross kettles, reverberatory furnace	C	5	1	384	3.0157	0.1886
			2	384	3.8025	0.2378
			Average	384	3.4091	0.2132
Control devices: None						
13V Dross plant/ bullion building	C	5	**Average**	351	6.2363	0.4264
Control device: Baghouse						
17P Acid dust bin	N/A	5	1	N/A	0.1228	N/A
			2	N/A	0.0805	N/A
			Average	N/A	0.1016	N/A

[a] Units in megagrams per day.
[b] Units in kilograms per hour.
[c] Units in kilograms per megagram.

TABLE 4.1-1 (ENGLISH UNITS)
FILTERABLE PARTICULATE MATTER

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
3P Copper matte crushing stack #1	B	5	1	110	0.5719	0.0204
			2	110	0.5480	0.0196
			Average	110	0.5600	0.0200
Control device: Baghouse						
4P Copper matte crushing stack #2	B	5	1	154	0.4922	0.0224
			2	154	0.4146	0.0188
			Average	154	0.4534	0.0206
Control device: Baghouse						
5P Copper matte crushing stack #3	B	5	1	154	0.0818	0.0037
			2	154	0.2096	0.0095
			Average	154	0.1457	0.0066
Control device: Baghouses						
Copper matte crushing Total of tests on stacks 1-3	B	5	**Average**	139	1.159	0.0452

[a] Units in tons per day.
[b] Units in pounds per hour.
[c] Units in pounds per ton.

TABLE 4.1-1 (ENGLISH UNITS) (*continued*)
FILTERABLE PARTICULATE MATTER

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
6P Sinter feed Unloading & handling building	N/A	5	1	N/A	19.2066	N/A
			2	N/A	17.2920	N/A
			3	N/A	16.2514	N/A
			Average	N/A	17.5833	N/A
Control device: Baghouse						
7P Sinter machine weak gas	B	5	1	641	3.3159	0.1241
			2	641	2.1059	0.0788
			Average	641	2.7109	0.1015
Control devices: Cottrell ESP, 2 scrubbers, Wet ESP demister, Acid plant						
8P Sinter machine strong gas/ acid plant	N/A	5	1	N/A	2.6177	N/A
			2	N/A	0.6509	N/A
			Average	N/A	1.6343	N/A
Control device: None: routed through crushing mill baghouses 1 & 3 (3P, 5P) when mill not operating						
6V Sinter building fugitive emissions	B	5	**Average**	26.4[d]	6.2467	0.2366
Control device: Baghouse						
9P Sinter storage & handling; matte breaking; blast furnace charge areas	N/A	5	1	N/A	0.3971	N/A
			2	N/A	0.6054	N/A
			3	N/A	0.4098	N/A
			Average	N/A	0.4708	N/A

[a] Units in tons per day, unless otherwise noted.
[b] Units in pounds per hour.
[c] Units in pounds per ton.
[d] Units in tons per hour.

TABLE 4.1-1 (ENGLISH UNITS) (*concluded*)
FILTERABLE PARTICULATE MATTER

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
10P Tetrahedrite dryer	C	5	1	28	0.2762	0.0099
			2	14	0.5086	0.0363
			Average	21	0.3924	0.0231
Control device: Baghouse						
16P Blast furnace, dross kettles, reverberatory furnace	C	5	1	423	6.6496	0.3772
			2	423	8.3845	0.4756
			Average	423	7.5171	0.4264
Control devices: None						
13V Dross plant/ bullion building fugitive emissions	C	5	**Average**	387	13.7510	0.8528
Control device: Baghouse						
17P Acid dust bin	N/A	5	1	N/A	0.2707	N/A
			2	N/A	0.1775	N/A
			Average	N/A	0.2241	N/A

[a] Units in tons per day.
[b] Units in pounds per hour.
[c] Units in pounds per ton.

TABLE 4.1-2 (METRIC UNITS)
PM$_{10}$

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
3P Copper matte crushing stack #1	B	201A	1	100	0.1732	0.0068
			2	100	0.1130	0.0045
			Average	100	0.1431	0.0057
Control device: Baghouse						
4P Copper matte crushing stack #2	B	201A	1	140	0.1861	0.0094
			2	140	0.1165	0.0059
			Average	140	0.1513	0.0076
Control device: Baghouse						
5P Copper matte crushing stack #3	B	201A	1	140	0.1028	0.0052
			2	140	0.0740	0.0037
			Average	140	0.0884	0.0045
Control device: Baghouses						
Copper matte crushing Total of tests on stacks 1-3	B	201A	**Average**	127	0.3828	0.0182

[a] Units in megagrams per day.
[b] Units in kilograms per hour.
[c] Units in kilograms per megagram.

TABLE 4.1-2 (METRIC UNITS) (*continued*)
PM$_{10}$

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
6P Sinter feed Unloading & handling building	N/A	201A	1	N/A	3.4869	N/A
			2	N/A	4.1572	N/A
			3	N/A	6.1113	N/A
			Average	N/A	4.5852	N/A
Control device: Baghouse						
7P Sinter machine weak gas	B	201A	1	581	1.2746	0.0526
			2	581	1.2432	0.0513
			Average	581	1.2589	0.0520
Control devices: Cottrell ESP, 2 scrubbers, Wet ESP demister, Acid plant						
8P Sinter machine strong gas/ acid plant	N/A	201A	1	N/A	0.5398	N/A
			2	N/A	0.3183	N/A
			Average	N/A	0.4290	N/A
Control device: None: routed through crushing mill baghouses 1 & 3 (3P, 5P) when mill not operating						
6V Sinter building fugitive emissions	B	201A	**Average**	23.9[d]	1.3974	0.0584

[a] Units in megagrams per day, unless otherwise noted.
[b] Units in kilograms per hour.
[c] Units in kilograms per megagram.
[d] Units in megagrams per hour.

TABLE 4.1-2 (METRIC UNITS) (*concluded*)
PM_{10}

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
10P Tetrahedrite dryer	C	201A	1	25	0.1660	0.0069
			2	13	0.4520	0.0186
			Average	19	0.3090	0.0128
Control device: Baghouse						
16P Blast furnace, dross kettles, reverberatory furnace	C	201A	1	384	6.4254	0.4018
			2	384	7.3696	0.4609
			Average	384	6.8975	0.4314
Control devices: None						
13V Dross plant/ bullion building fugitive emissions	C	201A	**Average**	351	1.4345	0.0981
Control device: Baghouse						
17P Acid dust bin	N/A	201A	1	N/A	0.0488	N/A
			2	N/A	0.0783	N/A
			Average	N/A	0.0635	N/A

[a] Units in megagrams per day.
[b] Units in kilograms per hour.
[c] Units in kilograms per megagram.

TABLE 4.1-2 (ENGLISH UNITS)
PM$_{10}$

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
3P Copper matte crushing stack #1	B	201A	1	110	0.3818	0.0136
			2	110	0.2492	0.0089
			Average	110	0.3155	0.0113
Control device: Baghouse						
4P Copper matte crushing stack #2	B	201A	1	154	0.4104	0.0187
			2	154	0.2568	0.0117
			Average	154	0.3336	0.0152
Control device: Baghouse						
5P Copper matte crushing stack #3	B	201A	1	154	0.2267	0.0103
			2	154	0.1632	0.0074
			Average	154	0.1950	0.0089
Control device: Baghouses						
Copper matte crushing Total of tests on stacks 1-3	B	201A	**Average**	139	0.8441	0.0363

[a] Units in tons per day.
[b] Units in pounds per hour.
[c] Units in pounds per ton.

TABLE 4.1-2 (ENGLISH UNITS) (*concluded*)
PM$_{10}$

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
6P Sinter feed Unloading & handling building	N/A	201A	1	N/A	7.6887	N/A
			2	N/A	9.1667	N/A
			3	N/A	13.4754	N/A
			Average	N/A	10.1103	N/A
Control device: Baghouse						
7P Sinter machine weak gas	B	201A	1	641	2.8106	0.1052
			2	641	2.7412	0.1026
			Average	641	2.7759	0.1039
Control devices: Cottrell ESP, 2 scrubbers, Wet ESP demister, Acid plant						
8P Sinter machine strong gas/ acid plant	N/A	201A	1	N/A	1.1903	N/A
			2	N/A	0.7018	N/A
			Average	N/A	0.9461	N/A
Control device: None: routed through crushing mill baghouses 1 & 3 (3P, 5P) when mill not operating						
6V Sinter building fugitive emissions	B	201A	**Average**	26.4[d]	3.0813	0.1167

[a] Units in tons per day, unless otherwise noted.
[b] Units in pounds per hour.
[c] Units in pounds per ton.
[d] Units in tons per hour.

TABLE 4.1-2 (ENGLISH UNITS) (*concluded*)
PM_{10}

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
10P Tetrahedrite dryer	C	201A	1	28	0.3661	0.0137
			2	14	0.9967	0.0372
			Average	21	0.6814	0.0255
Control device: Baghouse						
16P Blast furnace, dross kettles, reverberatory furnace	C	201A	1	423	14.1679	0.8036
			2	423	16.2499	0.9217
			Average	423	15.2089	0.8627
Control devices: None						
13V Dross plant/ bullion building fugitive emissions	C	201A	**Average**	387	3.1630	0.1962
Control device: Baghouse						
17P Acid dust bin	N/A	201A	1	N/A	0.1075	N/A
			2	N/A	0.1727	N/A
			Average	N/A	0.1401	N/A

[a] Units in tons per day.
[b] Units in pounds per hour.
[c] Units in pounds per ton.

TABLE 4.1-3 (METRIC UNITS)
CONDENSIBLE PARTICULATE MATTER

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
3P Copper matte crushing stack #1	B	202	1	100	0.2595	0.0102
			2	100	0.2262	0.0089
			Average	100	0.2429	0.0096
Control device: Baghouse						
4P Copper matte crushing stack #2	C	202	1	140	0.0938	0.0047
			2	140	0.3877	0.0195
			Average	140	0.2408	0.0121
Control device: Baghouse						
5P Copper matte crushing stack #3	B	202	1	140	0.1759	0.0088
			2	140	0.0739	0.0037
			Average	140	0.1249	0.0063
Control device: Baghouses						
Copper matte crushing Total of tests on stacks 1-3	C	202	**Average**	127	0.6086	0.0289

[a] Units in megagrams per day.
[b] Units in kilograms per hour.
[c] Units in kilograms per megagram.

TABLE 4.1-3 (METRIC UNITS) (*continued*)
CONDENSIBLE PARTICULATE MATTER

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
6P Sinter feed Unloading & handling building	N/A	202	1	N/A	0.4407	N/A
			2	N/A	0.0524	N/A
			3	N/A	0.0000	N/A
			Average	N/A	0.1644	N/A
Control device: Baghouse						
7P Sinter machine weak gas	B	202	1	581	15.1911	0.6268
			2	581	58.4445	2.4115
			Average	581	36.8178	1.5192
Control devices: Cottrell ESP, 2 scrubbers, Wet ESP demister, Acid plant						
8P Sinter machine strong gas/ acid plant	N/A	202	1	N/A	5.0615	N/A
			2	N/A	1.6629	N/A
			Average	N/A	3.3622	N/A
Control device: None: routed through crushing mill baghouses 1 & 3 (3P, 5P) when mill not operating						
6V Sinter building fugitive emissions	B	202	**Average**	23.9[d]	1.4709	0.0615

[a] Units in megagrams per day, unless otherwise noted.
[b] Units in kilograms per hour.
[c] Units in kilograms per megagram.
[d] Units in megagrams per hour.

TABLE 4.1-3 (METRIC UNITS) (*concluded*)
CONDENSIBLE PARTICULATE MATTER

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
10P Tetrahedrite dryer	C	202	1	25	0.4499	0.0186
			2	13	0.2216	0.0092
			Average	19	0.3358	0.0139
Control device: Baghouse						
16P Blast furnace, dross kettles, reverberatory furnace	C	202	1	384	22.3728	1.3991
			2	384	8.7600	0.5478
			Average	384	15.5664	0.9735
Control devices: None						
13V Dross plant/ bullion building fugitive emissions	C	202	**Average**	351	0.4781	0.0327
Control device: Baghouse						
17P Acid dust bin	C	202	1	N/A	0.0595	N/A
			2	N/A	0.1153	N/A
			Average	N/A	0.0874	N/A

[a] Units in megagrams per day.
[b] Units in kilograms per hour.
[c] Units in kilograms per megagram.

TABLE 4.1-3 (ENGLISH UNITS)
CONDENSIBLE PARTICULATE MATTER

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
3P Copper matte crushing stack #1	B	202	1	110	0.5722	0.0204
			2	110	0.4988	0.0178
			Average	110	0.5355	0.0191
Control device: Baghouse						
4P Copper matte crushing stack #2	C	202	1	154	0.2069	0.0094
			2	154	0.8549	0.0389
			Average	154	0.5309	0.0242
Control device: Baghouse						
5P Copper matte crushing stack #3	B	202	1	154	0.3879	0.0176
			2	154	0.1629	0.0074
			Average	154	0.2754	0.0125
Control device: Baghouses						
Copper matte crushing Total of tests on stacks 1-3	B	202	**Average**	139	1.342	0.0578

[a] Units in tons per day.
[b] Units in pounds per hour.
[c] Units in pounds per ton.

TABLE 4.1-3 (ENGLISH UNITS) (*continued*)
CONDENSIBLE PARTICULATE MATTER

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
6P Sinter feed Unloading & handling building	N/A	202	1	N/A	0.9718	N/A
			2	N/A	0.1157	N/A
			3	N/A	0.0000	N/A
			Average	N/A	0.3625	N/A
Control device: Baghouse						
7P Sinter machine weak gas	B	202	1	641	33.4964	1.2536
			2	641	128.8701	4.8230
			Average	641	81.1833	3.0383
Control devices: Cottrell ESP, 2 scrubbers, Wet ESP demister, Acid plant						
8P Sinter machine strong gas/ acid plant	N/A	202	1	N/A	11.1607	N/A
			2	N/A	3.6666	N/A
			Average	N/A	7.4137	N/A
Control device: None: routed through crushing mill baghouses 1 & 3 (3P, 5P) when mill not operating						
6V Sinter building fugitive emissions	B	202	**Average**	26.4[d]	3.2434	0.1229

[a] Units in tons per day, unless otherwise noted.
[b] Units in pounds per hour.
[c] Units in pounds per ton.
[d] Units in tons per hour.

TABLE 4.1-3 (ENGLISH UNITS) (*concluded*)
CONDENSIBLE PARTICULATE MATTER

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
10P Tetrahedrite dryer	C	202	1	28	0.9920	0.0371
			2	14	0.4887	0.0183
			Average	21	0.7404	0.0277
Control device: Baghouse						
16P Blast furnace, dross kettles, reverberatory furnace	C	202	1	423	49.3321	2.7982
			2	423	19.3159	1.0956
			Average	423	34.3240	1.9469
Control devices: None						
13V Dross plant/ bullion building fugitive emissions	C	202	**Average**	387	1.0543	0.0654
Control device: Baghouse						
17P Acid dust bin	C	202	1	N/A	0.1312	N/A
			2	N/A	0.2543	N/A
			Average	N/A	0.1928	N/A

[a] Units in tons per day.
[b] Units in pounds per hour.
[c] Units in pounds per ton.

Lead.

As would be expected due to the composition of the primary raw material, all intermediates, and the product associated with the primary lead smelting and refining industry, significant emissions of lead occur from nearly all processes associated with this industry. For the emissions testing performed on the ASARCO primary lead smelter in East Helena, Montana, in 1990, from which the data appearing in Table 4.1-4 below are derived, one of the sampling trains operated at each test point was a conventional Method 5 sampling train (for filterable particulate matter) in combination with a Method 12 impinger train (for lead). The only modification to the method was the temperature of the sampling probe and filter, which were not heated for stacks characterized as dry and ambient (such as the crushing mill).

A detailed discussion of the report from which the data in Table 4.1-4 are taken, including a description of each source tested and its typical hours of operation, can be found in Section 4.3 of this background report. Despite the fact that many of these emission tests are rated as high as "B," all of the emission factors presented in the revised AP-42 Section 12.6 derived from this data have been assigned a rating of "E" due to uncertainty as to their representativeness of the entire industry. Similarly, the emission factors copied directly from the previous version of the AP-42 Section 12.6 (October 1986) have been assigned a rating of "E" due to uncertainty as to their representativeness of the industry as it currently operates. Those factors in the latter category are presented on an uncontrolled basis, whereas the emission testing for which results were obtained and used in this AP-42 update did not allow for development of uncontrolled emission factors. This series of emissions tests was a part of a comprehensive lead emission inventory, which is described in detail in Section 4.3 of this background report.

Emission factors for lead are presented in the revised AP-42 Section 12.6 for the crushing mill; sinter machine weak gas; sinter building fugitive emissions; and blast furnace, dross reverberatory furnace, dross kettles, and dross building fugitive emissions. All of these emission factors are derived from testing performed as part of the comprehensive 1990 lead emission inventory on the ASARCO facility in East Helena, Montana.

TABLE 4.1-4 (METRIC UNITS)
LEAD

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
3P Copper matte crushing stack #1	B	12	1	100	0.0189	0.0008
			2	100	0.0143	0.0006
			Average	100	0.0166	0.0007
Control device: Baghouse						
4P Copper matte crushing stack #2	B	12	1	140	0.0070	0.0004
			2	140	0.0049	0.0003
			Average	140	0.0059	0.0003
Control device: Baghouse						
5P Copper matte crushing stack #3	B	12	1	140	0.0015	0.0001
			2	140	0.0010	0.0001
			Average	140	0.0012	0.0001
Control device: Baghouses						
Copper matte crushing Total of tests on stacks 1-3	B	12	**Average**	127	0.0238	0.0011

[a] Units in megagrams per day.
[b] Units in kilograms per hour.
[c] Units in kilograms per megagram.

TABLE 4.1-4 (METRIC UNITS) (*continued*)
LEAD

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
6P Sinter feed Unloading & handling building	N/A	12	1	N/A	1.9685	N/A
			2	N/A	1.7835	N/A
			3	N/A	1.6715	N/A
			Average	N/A	1.8078	N/A
Control device: Baghouse						
7P Sinter machine weak gas	B	12	1	581	0.1809	0.0075
			2	581	0.2748	0.0114
			Average	581	0.2279	0.0094
Control devices: Cottrell ESP, 2 scrubbers, Wet ESP demister, Acid plant						
8P Sinter machine strong gas/ acid plant	N/A	12	1	N/A	0.0106	N/A
			2	N/A	0.0083	N/A
			Average	N/A	0.0094	N/A
Control device: None: routed through crushing mill baghouses 1 & 3 (3P, 5P) when mill not operating						
6V Sinter building fugitive emissions	B	12	**Average**	23.9[d]	0.3774	0.0158
Control device: Baghouse						
9P Sinter storage & handling; matte breaking; blast furnace charge areas	N/A	12	1	N/A	0.0373	N/A
			2	N/A	0.0690	N/A
			3	N/A	0.0131	N/A
			Average	N/A	0.0398	N/A

[a] Units in megagrams per day, unless otherwise noted.
[b] Units in kilograms per hour.
[c] Units in kilograms per megagram.
[d] Units in megagrams per hour.

TABLE 4.1-4 (METRIC UNITS) (*concluded*)
LEAD

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
10P Tetrahedrite dryer	C	12	1	25	0.0069	0.0003
			2	13	0.0073	0.0003
			Average	19	0.0071	0.0003
Control device: Baghouse						
16P Blast furnace, dross kettles, reverberatory furnace	C	12	1	384	0.5171	0.0324
			2	384	0.5615	0.0351
			Average	384	0.5393	0.0337
Control devices: None						
13V Dross plant/ bullion building	C	12	**Average**	351	0.8608	0.0589
Control device: Baghouse						
17P Acid dust bin	N/A	12	1	N/A	0.0375	N/A
			2	N/A	0.0241	N/A
			Average	N/A	0.0308	N/A

[a] Units in megagrams per day.
[b] Units in kilograms per hour.
[c] Units in kilograms per megagram.

TABLE 4.1-4 (ENGLISH UNITS)
LEAD

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
3P Copper matte crushing stack #1	B	12	1	110	0.0416	0.0015
			2	110	0.0316	0.0011
			Average	110	0.0366	0.0013
Control device: Baghouse						
4P Copper matte crushing stack #2	B	12	1	154	0.0154	0.0007
			2	154	0.0108	0.0005
			Average	154	0.0131	0.0006
Control device: Baghouse						
5P Copper matte crushing stack #3	B	12	1	154	0.0032	0.0001
			2	154	0.0023	0.0001
			Average	154	0.0028	0.0001
Control device: Baghouses						
Copper matte crushing Total of tests on stacks 1-3	B	12	**Average**	139	0.0525	0.0023

[a] Units in tons per day.
[b] Units in pounds per hour.
[c] Units in pounds per ton.

TABLE 4.1-4 (ENGLISH UNITS) (*continued*)
LEAD

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouses						
6P Sinter feed Unloading & handling building	N/A	12	1	N/A	4.3406	N/A
			2	N/A	3.9237	N/A
			3	N/A	3.6856	N/A
			Average	N/A	3.9833	N/A
Control device: Baghouse						
7P Sinter machine weak gas	B	12	1	641	0.3989	0.0149
			2	641	0.6060	0.0227
			Average	641	0.5025	0.0188
Control devices: Cottrell ESP, 2 scrubbers, Wet ESP demister, Acid plant						
8P Sinter machine strong gas/ acid plant	N/A	12	1	N/A	0.0233	N/A
			2	N/A	0.0183	N/A
			Average	N/A	0.0208	N/A
Control device: None: routed through crushing mill baghouses 1 & 3 (3P, 5P) when mill not operating						
6V Sinter building fugitive emissions	B	12	**Average**	26.4[d]	0.8322	0.0315
Control device: Baghouse						
9P Sinter storage & handling; matte breaking; blast furnace charge areas	N/A	12	1	N/A	0.0822	N/A
			2	N/A	0.1522	N/A
			3	N/A	0.0288	N/A
			Average	N/A	0.0877	N/A

[a] Units in tons per day, unless otherwise noted.
[b] Units in pounds per hour.
[c] Units in pounds per ton.
[d] Units in tons per hour.

TABLE 4.1-4 (ENGLISH UNITS) (*concluded*)
LEAD

Process Tested, Source Test #	Test Rating	Test Method	Run #	Process Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse						
10P Tetrahedrite dryer	C	12	1	28	0.0152	0.0006
			2	14	0.0162	0.0006
			Average	21	0.0157	0.0006
Control device: Baghouse						
16P Blast furnace, dross kettles, reverberatory furnace	C	12	1	423	1.1401	0.0647
			2	423	1.2380	0.0702
			Average	423	1.1891	0.0674
Control devices: None						
13V Dross plant/ bullion building fugitive emissions	C	12	**Average**	387	1.8980	0.1177
Control device: Baghouse						
17P Acid dust bin	N/A	12	1	N/A	0.0827	N/A
			2	N/A	0.0531	N/A
			Average	N/A	0.0679	N/A

[a] Units in tons per day.
[b] Units in pounds per hour.
[c] Units in pounds per ton.

Sulfur dioxide.

Due to the sulfur content of lead concentrates in the green feed to the sinter (roughly 13 to 19 percent) and the heat at which the sinter machine and the blast furnace operate, significant emissions of sulfur dioxide are inherent to the lead smelting process. Most of this SO_2 is contained in the strong gas stream from the front of the sinter machine, and is routed through several control devices and a contact-process sulfuric acid production plant. Unfortunately, no primary emissions test data for sulfur dioxide were available for this update of AP-42 Section 12.6, and the emission factors in the previous version of AP-42 Section 12.6 (October 1986) could not be verified because the documents upon which they were reportedly based were not available for review. The emission factor for the blast furnace is copied directly from this previous section into the revision.

Nonmethane Organic Compounds.

No data on emissions of nonmethane organic compounds were found nor expected for the processes associated with the primary lead smelting and refining industry.

Nitrogen oxides.

No data on emissions of oxides of nitrogen were found directly from processes associated with the primary lead smelting and refining industry. It can be assumed that these compounds are emitted from in-process heating units such as dross kettles, but these units are outside the scope of AP-42 Section 12.6.

Carbon monoxide.

No data on emissions of carbon monoxide were found directly from processes associated with the primary lead smelting and refining industry. It can be assumed that this pollutant is emitted from in-process heating units such as dross kettles, but these units are outside the scope of AP-42 Section 12.6.

4.2 NONCRITERIA POLLUTION EMISSION DATA

Hazardous Air Pollutants.

Hazardous Air Pollutants (HAPs) are defined in the 1990 Clean Air Act Amendments. Included in this list are lead, arsenic, and other heavy metals entrained in the lead concentrates charged to the sinter machine. No quantitative emissions data suitable for use in emission factor development are available for any HAPs other than lead, the data for which are presented in Table 4.1-4 and in the review of data sets obtained for this AP-42 update in Section 4.3 below.

Global Warming Gases.

Pollutants such as methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O) have been found to contribute to overall global warming. No data on emissions of any of these pollutants were found directly from processes associated with the primary lead smelting and refining industry. It can be assumed that these pollutants (especially CO_2) are emitted from in-process heating units such as dross kettles, but these units are outside the scope of AP-42 Section 12.6.

Stratospheric Ozone-Depleting Gases.

Chlorofluorocarbons, halons, carbon tetrachloride, methyl chloroform, and hydrofluorocarbons have been found to contribute to stratospheric ozone depletion. Because none of these compounds are used in any of the processes associated with primary lead smelting and refining, no data on emissions of these pollutants were found nor expected.

4.3 REVIEW OF SPECIFIC DATA SETS

The emission factors presented in the revised AP-42 Section 12.6 are, for the purposes of this update, derived from two sources: a series of reports documenting results of a comprehensive 1990 lead inventory performed on the ASARCO primary lead smelter in East Helena, Montana, and the most recent revision (October 1986) of the AP-42 Section. The ASARCO inventory is documented in References 1-6 below. The original sources of emissions data that formed the basis for the emission factors in the previous Section 12.6 could not be obtained for this update, and are therefore not reviewed in this section. In cases where the ASARCO inventory did not yield data suitable for development of emission factors (see Section 4.1 of this background report for a discussion of the basis for each individual emission factor), emission factors from the previous AP-42 Section 12.6 were copied directly into the revised section.

Reference 1: *Task 2 Summary Report: ASARCO East Helena Primary Lead Smelter - Revision and Verification of Lead Inventory Source List* and

Reference 2: *Task 3 Summary Report: ASARCO East Helena Primary Lead Smelter - Emission Inventory Test Protocol*

These two reports were used in conjunction with the following four references to enable emissions data contained in the latter to be related to specific processes and equipment, and to be assigned a quality rating.

Reference 3: *Task 5 Summary Report: ASARCO East Helena Primary Lead Smelter - Lead Emission Inventory, Volume 1: Point Source Lead Emission Inventory*

This report is part of a comprehensive lead emission inventory conducted at a lead smelter in September and October 1990, and is the basis for the data contained in Tables 4.1-1 through 4.1-4 above as well as several of the emission factors in the revised AP-42 section on primary lead smelting and refining. Included in this report are data resulting from testing performed in order to quantify emissions of filterable and condensible particulate matter, PM_{10}, and lead. The sampling and analysis methodologies utilized for this testing are discussed under the "Particulate Matter" heading in Section 4.1 of this background report. The sources for which emission test results are documented in this report are discussed below.

Crushing mill [3P, 4P, 5P]. This mill is vented to three baghouses which exhaust through three separate stacks. These stacks were all tested, but not simultaneously. The process rate for each test is derived from monthly aggregate reports, and is not assumed to be highly accurate.

Sinter feed unloading and handling building [6P]. This building houses the unloading and handling of concentrates, by-product dusts and residues, coke breeze, rejects, lime, and silica. The building was constructed in 1990, and is ventilated so as to be under negative pressure relative to ambient even with windows and bay doors open. Operations take place in this building 24 hours per day, but no process rate during the period of testing was reported. The test results are not representative of normal, controlled emission rates because several bags in the three baghouses serving the building were found to be loose after testing. Three runs were performed on this test in order to meet operating permit conditions.

Sinter machine weak gas [7P]. These cleaned weak gases from the last one third of the sinter machine, which operates 24 hours per day, are vented to a baghouse.

Sinter machine strong gas and sulfuric acid contact plant [8P]. The strong gases from the front of the sinter machine are vented to the acid plant when it is operating, which is typically 21 hours per day; no process rate was available corresponding to testing on this source.

Sinter storage and handling, matte breaking, and blast furnace charge area [9P]. Various operations occur in this area 24 hours per day. The area is vented to a baghouse, but is poorly ventilated, and much of the particulate matter is emitted from the breaking floor building and blast furnace charge area. These areas and their emissions are addressed in the section below on building volume sources. Only the combination Method 5/12 sampling train was employed in testing this source.

Tetrahedrite dryer [10P]. This source, a converted coal dryer, is used to dry tetrahedrite concentrates from the Galena and Coeur mines which are high in silver content but contain only about three percent lead. Due to the intermittency of this process, the two test runs were run on separate days, and the second run lasted only 28 minutes and collected a sample volume of only 0.45 dry standard cubic meters (16 dry standard cubic feet). Additionally, the process rates during these tests are estimated, and are not assumed to be highly accurate.

Speiss granulating and handling. Only one test run was performed on this source, no documentation of the testing was found, and no process rate was reported. Emission rates of 8.3552 pounds per hour for filterable particulate matter and 1.1052 pounds per hour for lead were reported.

Blast furnace, blast furnace tapping, and drossing kettles [16P]. All of these sources, characterized by the molten lead and dross being processed in them, are vented to the same baghouse. The reported total emission rate from the stack to which this baghouse exhausts is biased low, because a portion of the emissions actually occur as building volume source emissions as described below under the headings for the tapping platform and the dross building.

Acid dust bin [17P]. The baghouse serving this bin exhausts only the pneumatic conveyor discharge point into the bin, and should be combined with the emissions from the acid dust bin building volume source to better represent total source emissions.

Reference 4: *Task 5 Summary Report: ASARCO East Helena Primary Lead Smelter - Lead Emission Inventory, Volume 2: Building Volume Source Lead Emission Inventory*

This report is part of a comprehensive lead emission inventory conducted at a lead smelter in September and October of 1990. Much of the data contained in the report is not suitable for use in developing emission factors, either because the sample collection methodologies do not conform to EPA Reference Methods or because no process data can be related directly to the emission rates. Two notable exceptions are the sinter building (source No. 6V) and the dross plant and bullion building (source No. 13V), both of which were tested for lead, filterable and condensible particulate, PM_{10}, and lead according to EPA Reference Methods 5, 202, 201a, and 12, respectively. The sinter building houses many operations that have the potential to emit or generate fugitive particulate and lead dust and fumes. These include the sinter machine, crushing tower, conveying system, and transfer points. At all times that the crushing mill is not operating, these sources are ducted to the crushing mill baghouses, and the inlets to these baghouses were sampled simultaneously to quantify the emissions. When the crushing mill is operating, emissions from equipment in the sinter building are released primarily from windows in the building. The emissions data for the aforementioned pollutants are summarized in the appropriate tables in Section 4.1.

The dross plant and bullion building are connected and interactive structures in which the lead pots are poured into kettles, the contents of the kettles are skimmed for dross several times, and the refined bullion is pumped into bullion molds to cool. The molten lead that exists throughout this process, especially during the charging and skimming operations that require removal of the kettle covers, results in significant fume emissions. The significance of these emissions justified the use of Method 14-type manifold systems to simultaneously collect the fumes exiting the buildings through two roof vents. The emissions data for the aforementioned pollutants are summarized in the appropriate tables in Section 4.1.

Emissions from the remaining building volume sources were quantified using anemometers and high volume samplers with glass fiber filters to measure flow rates and pollutant concentrations through such openings as windows, doorways, and roof vents. In all cases, the temperature of the gas sampled approximates ambient, and the calculated filterable particulate emission rate can be assumed to be equivalent to the total particulate matter emission rate (i.e., no condensible material is expected). These sampling methodologies do not provide data suitable for use in emission factor development, but the data are presented in Table 4.3-1 and described below as background information.

Crushing mill. This mill is used intermittently for size reduction of crude ores and plant by-products. During emissions testing, the mill was crushing copper matte 5.5 hours per day, three days per week at a rate of approximately 90 megagrams per day (100 tons per day). Sampling was performed 24 hours per day, and the emissions for the week are allocated to the operational hours of the mill in creating an emission factor.

Cottrell penthouse. The strong gases from the front end of the sinter machine, which are high in sulfur dioxide and lead content, are vented to a Cottrell electrostatic precipitator (ESP). Periodically, an imbalance occurs that results in the ESP being pressurized and these gases being blown out of the coverplates in the Cottrell penthouse. During emissions testing, the sinter machine was operating 21 hours per day, seven days per week. No process rate was available.

Breaking floor building. The breaking floor receives cooled and hardened matte and speiss from the reverberatory furnace and settlers from the blast furnace. These materials arrive in large chunks, and are broken by a large steel ball dropped by an overhead crane. During emissions testing, operations were taking place in this building eight hours per day, five days per week. No process rate was available.

Blast furnace charge building. Emissions from the charge area result from the handling, conveying, and dropping of sinter, coke, direct-feed ores, and assorted other materials charged to the blast furnace. During emissions testing, operations were taking place in this building 24 hours per day, seven days per week at a rate of 14.9 megagrams per hour (16.4 tons per hour).

Blast furnace feed floor. Bottom dump charge cars from the charge building deliver their load to the top level of the blast furnace, or the feed floor. During this dump, one section of the furnace cover must be removed. After some period of operation, often several weeks, blow holes develop which allow air to pass through the furnace without sufficient contact with the charge. These blow holes are alleviated through the use of dynamite deposited into the charge, which requires removal of the entire furnace cover. These two events, as well as slight leaks around the furnace covers during normal operation, account for the volume source emissions from the feed floor. During emissions testing, operations were taking place 24 hours per day, 7 days per week at a rate of 13.4 megagrams per hour (14.8 tons per hour). In addition, an average of 37 minutes per day were deemed "upset time," and an average emission rate of 0.0448 kg/minute of particulate and 0.0026 kg/minute of lead (0.0989 lbs/minute of particulate and 0.0057 lbs/minute of lead) was calculated for these upset periods.

Blast furnace tapping platform. The molten material tapped from the bottom of the blast furnace enters first a primary settler, followed by a lead pot and a secondary settler. Fumes from these vessels that are not captured by the blast furnace ventilation system are considered volume source emissions. During emissions testing, operations were taking place 24 hours per day, 7 days per week at a rate of 13.4 megagrams per hour (14.8 tons per hour).

Acid dust bin building. The particulate matter collected in the cyclones and ESP which serve the sinter machine and the baghouses which serve the sinter building is called acid dust. These dusts are transferred pneumatically and by a bucket elevator to the dust bin. During emissions testing, this transfer was taking place 24 hours per day, 7 days per week. No process rate was available.

TABLE 4.3-1 (METRIC UNITS)[a]
VOLUME SOURCE EMISSIONS FROM 1990 TESTS

Pollutant/ Plant	Volume Source	Particulate Matter kg/hr	kg/Mg	Lead kg/hr	kg/Mg	PM_{10} kg/hr	kg/Mg
ASARCO: East Helena, Montana	Crushing Mill	N/A	0.0115	N/A	0.0006	N/A	0.0042
	Breaking Floor Building	0.0835	N/A	0.0096	N/A	0.0306	N/A
	Blast Furnace Charge Building	0.0904	0.0061	0.0036	0.00024	0.0415	0.0028
	Blast Furnace Feed Floor	0.0439	0.0032	0.0027	0.00020	0.0262	0.0001
	Blast Furnace Tapping Platform	0.2121	0.0158	0.0364	0.0027	0.0369	0.0028
	Acid Dust Bin Building	0.0227	N/A	0.0065	N/A	0.0140	N/A

[a] Reference 4

TABLE 4.3-1 (ENGLISH UNITS)[a]
VOLUME SOURCE EMISSIONS FROM 1990 TESTS

Pollutant/ Plant	Volume Source	Particulate Matter lb/hr	Particulate Matter lb/ton	Lead lb/hr	Lead lb/ton	PM_{10} lb/hr	PM_{10} lb/ton
ASARCO: East Helena, Montana	Crushing Mill	N/A	0.0229	N/A	0.0012	N/A	0.0084
	Breaking Floor Building	0.1841	N/A	0.0212	N/A	0.0674	N/A
	Blast Furnace Charge Building	0.1994	0.0122	0.0080	0.00049	0.0915	0.0056
	Blast Furnace Feed Floor	0.0968	0.0065	0.0059	0.00040	0.0577	0.0002
	Blast Furnace Tapping Platform	0.4678	0.0315	0.0802	0.0054	0.0814	0.0055
	Acid Dust Bin Building	0.0501	N/A	0.0144	N/A	0.0140	N/A

[a] Reference 4

Reference 5: *Task 5 Summary Report: ASARCO East Helena Primary Lead Smelter - Lead Emission Inventory, Volume 3: Outside Material Handling Volume Source Lead Emission Inventory*

This report is part of a comprehensive lead emission inventory conducted at a lead smelter in September and October of 1990. Emission factors from Chapter 11 of AP-42 were used to estimate these emissions, and thus the data contained in this report are not suitable for further development of emission factors. Lead contents in the materials being handled were either estimated without documentation (as for concentrates being dumped into the direct-smelt bins) or taken from plant records (as for copper matte), and are not presented here.

Reference 6: *Task 5 Summary Report: ASARCO East Helena Primary Lead Smelter - Lead Emission Inventory, Volume 4: Area Source Lead Emission Inventory*

This report is part of a comprehensive lead emission inventory conducted at a lead smelter in September and October of 1990. The two categories of emission sources covered in this volume are windblown dust sources and vehicle traffic road dust sources. Emission factors from Chapter 11 of AP-42 were used to estimate these emissions, and thus the data contained in this report are not suitable for further development of emission factors. Analyses of various dust samples for lead content were performed, and the results are considered useful background information. Lead content in road dusts varied from 1.6 percent to 24.6 percent. Lead content in outside material storage piles appear in Table 4.3-2.

TABLE 4.3-2[a]
LEAD CONTENT OF OUTSIDE STORAGE PILES

Pile Name	Lead Content
Coke breeze	0.000077
Omaha matte	0.0461
Acid dust	0.2565
El Paso calcines	0.0106
Cruise Belmont	0.000114
Globe mix	0.01
Galena	0.0024
Coeur	0.000041
McCoy/Cove	0.02
Troy	0.0019
Republic/Blue Range	0.00083
Blue Range	0.0157
Amarillo sharp slag	0.0053
Sunshine residue	0.00037
Precious metals	0.00002
Sinter	0.0021
Hudson Bay dross	0.01
Belmont crude	0.000002
East Helena matte	0.00078
Plant clean-up	0.0314

[a] Reference 6

Reference 7: *Sample Fugitive Lead Emissions from Two Primary Lead Smelters, EPA-450/3-77-031*

This report details the methodologies used in, and the results from, sampling performed at the ASARCO smelters at East Helena, Montana, and Glover, Missouri. This sampling was performed under an EPA contract in order to quantify emissions from volume sources such as sinter buildings, blast furnace areas, dross kettle/reverberatory furnace buildings, and ore storage bins.

The sampling procedures upon which this report is based do not conform to EPA Reference Methods, due to the nature of the sources being tested. In all cases, the temperature of the gas sampled approximates ambient, and the calculated filterable particulate emission rate can be assumed to be equivalent to the total particulate matter emission rate (i.e., no condensible material is expected). Also, no process data are included in the report, precluding the use of the results in the development of emission factors. The data are useful in a qualitative sense, however, because they provide particle size distributions and concentrations of lead and arsenic in the particulate matter emitted from the volume sources sampled. For these reasons, the data are summarized in Table 4.3-3.

TABLE 4.3-3 (METRIC UNITS)[a]
VOLUME SOURCE EMISSION RATES FROM 1976 TESTS
(Units in kilograms per hour)

Pollutant\ Plant	Volume Source	Lead	Arsenic	PM_{10}	Particulate Matter
ASARCO: Glover, Missouri	Sinter Building	0.80	N/A	0.42	2.30
	Blast Furnace	1.19	N/A	N/A	2.33
	Ore Storage Bin	0.07	N/A	N/A	0.16
ASARCO: East Helena, Montana	Sinter Building	0.12	0.01	0.34	1.22
	Dross Building/ Reverberatory Furnace	1.26	0.57	1.21	5.66
	Blast Furnace Building	0.07	0.01	0.056	0.66

[a] Reference 7

TABLE 4.3-3 (ENGLISH UNITS)[a]
VOLUME SOURCE EMISSION RATES FROM 1976 TESTS

(Units in pounds per hour)

Pollutant\ Plant	Volume Source	Lead	Arsenic	PM_{10}	Particulate Matter
ASARCO: Glover, Missouri	Sinter Building	1.76	N/A	0.93	5.07
	Blast Furnace	2.62	N/A	N/A	5.13
	Ore Storage Bin	0.16	N/A	N/A	0.34
ASARCO: East Helena, Montana	Sinter Building	0.26	0.02	0.75	2.70
	Dross Building/ Reverberatory Furnace	2.78	1.26	2.67	12.5
	Blast Furnace Building	0.16	0.02	0.12	1.46

[a] Reference 7

Reference 8: *Inhalable Particulate Source Category Report for the Nonferrous Industry*

This report, which was the basis for the previous (1986) version of the AP-42 Section covering primary lead smelting and refining, presents and manipulates the results from several emissions tests performed in the early to mid-1970's but does not itself document any emissions testing. With the exception of fugitive lead emissions testing at two facilities in 1976 (details of which are provided in Reference 7 above), all of the tests from which data are derived for this report occurred prior to the January 1976 promulgation of New Source Performance Standards (NSPS) for sintering machines, blast furnaces, dross reverberatory furnaces, and converters (dross kettles) in primary lead smelters. Accordingly, these tests are not believed to represent emissions from this industry as it currently operates.

4.4 DATA GAP ANALYSIS

A significant data gap exists for emissions of all pollutants from the primary lead smelting and refining industry, insofar as current data were unavailable for the development of emission factors. Given that this industry is comprised of only four facilities, and that these facilities account for 26 percent of the total lead emissions reported to the Toxics Release Inventory Subsystem (TRIS) database maintained by the EPA, it is reasonable to assert that quantification of emissions from this industry is justifiable (Reference 9). The quantitative emissions data utilized for this update of AP-42 Section 12.6 are all derived from a single facility. No similar inventories for other primary lead processors could be obtained for this update of AP-42 Section 12.6.

4.5 REFERENCES FOR CHAPTER 4.0

1. Task 2 Summary Report: ASARCO East Helena Primary Lead Smelter - Revision and Verification of Lead Inventory Source List, North American Weather Consultants, Salt Lake City, Utah, June 1990.

2. Task 3 Summary Report: ASARCO East Helena Primary Lead Smelter - Emission Inventory Test Protocol, North American Weather Consultants, Salt Lake City, Utah, June 1990.

3. Task 5 Summary Report: ASARCO East Helena Primary Lead Smelter - Lead Emission Inventory, Volume 1: Point Source Lead Emission Inventory, North American Weather Consultants, Salt Lake City, Utah, April 1991.

4. Task 5 Summary Report: ASARCO East Helena Primary Lead Smelter - Lead Emission Inventory, Volume 2: Building Volume Source Lead Emission Inventory, North American Weather Consultants, Salt Lake City, Utah, April 1991.

5. Task 5 Summary Report: ASARCO East Helena Primary Lead Smelter - Lead Emission Inventory, Volume 3: Outside Material Handling Volume Source Lead Emission Inventory, North American Weather Consultants, Salt Lake City, Utah, April 1991.

6. Task 5 Summary Report: ASARCO East Helena Primary Lead Smelter - Lead Emission Inventory, Volume 4: Area Source Lead Emission Inventory, North American Weather Consultants, Salt Lake City, Utah, April 1991.

7. Sample Fugitive Lead Emissions from Two Primary Lead Smelters, EPA-450/3-77-031, U.S. Environmental Protection Agency, Research Triangle Park, NC, October 1977.

8. Inhalable Particulate Source Category Report for the Nonferrous Industry, EPA Contract 68-02-3156, Acurex Corporation, Energy & Environmental Division, Mountain View, CA, October 1985.

9. Memorandum from E. Hollins, Pacific Environmental Services, Inc., Mason, Ohio, to A. Pope, U.S. Environmental Protection Agency, Research Triangle Park, NC, June 1992.

TABLE 4.5-1

LIST OF CONVERSION FACTORS

Multiply:	**by:**	**To obtain:**
mg/dscm	4.37×10^{-4}	gr/dscf
m^2	10.764	ft^2
m^3	35.31	ft^3
m	3.281	ft
kg	2.205	lb
kPa	1.45×10^{-1}	psia
kg/Mg	2.0	lb/ton
Mg	1.1023	ton

Temperature conversion equations:

Fahrenheit to Celsius:

$$°C = \frac{(°F - 32)}{1.8}$$

Celsius to Fahrenheit:

$$°F = 1.8(°C) + 32$$