BACKGROUND REPORT

AP-42 SECTION 12.1

PRIMARY ALUMINUM

Prepared for

U.S. Environmental Protection Agency
OAQPS/TSD/EIB
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AP-42 Background Report

TECHNICAL SUPPORT DIVISION

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

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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. AP-42 is routinely updated by the EPA to respond to new emission factor needs of the 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 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 from process information obtained from industry comment and test reports to support revision of the process description and/or emission factors for 12.1.

Including the introduction (Chapter 1), this report contains four chapters. Chapter 2 gives a description of the primary aluminum 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 primary aluminum production.

Chapter 3 is a review of emissions data collection and analysis procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. 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 when applicable.

2.0 INDUSTRY DESCRIPTION

2.1 GENERAL

Primary aluminum refers to aluminum produced directly from mined ore. The ore is refined and electrolytically reduced to elemental aluminum. There are 13 companies operating 23 primary aluminum reduction facilities in the U.S. In 1991, these facilities produced 4.1 million megagrams (4.5 million tons) of primary aluminum.

2.2 PROCESS DESCRIPTION

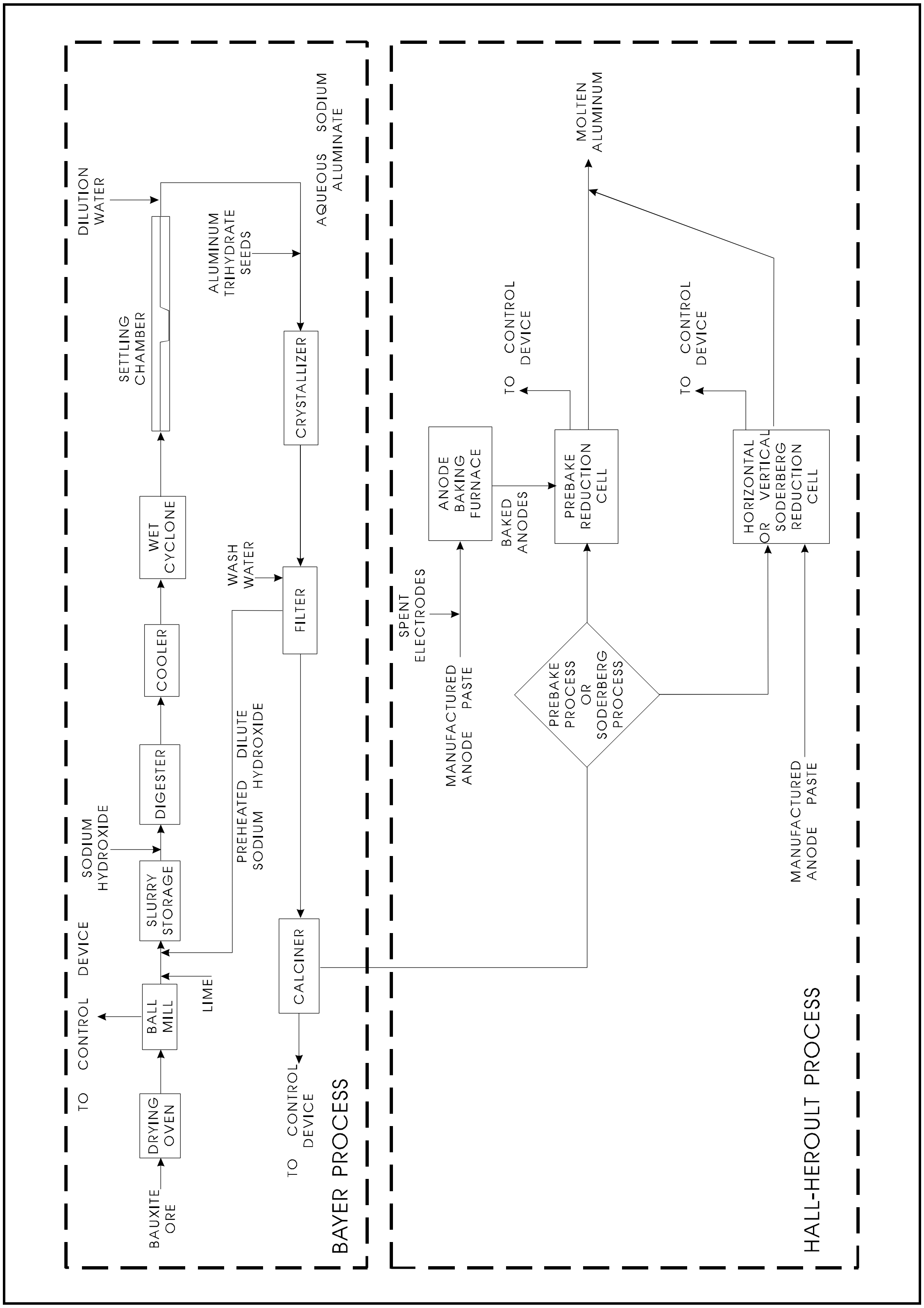

Figure 2.2-1 Schematic diagram of primary aluminum production process

Primary aluminum production is a two-step process that refines alumina and reduces alumina to aluminum metal. It starts with the mining of bauxite ore, a hydrated oxide of aluminum consisting of 36 to 56 percent alumina (Al_2O3_3) and lesser amounts of iron, silicon, and titanium. The Bayer process is used to refine bauxite into alumina. The Hall-Heroult process is used to reduce alumina to aluminum metal by electrolytic reduction. The refining (Bayer process) and the reduction (Hall-Heroult) process are seldom accomplished at the same facility. Details of both processes are discussed below. A schematic diagram of primary aluminum production is shown in Figure 2.2-1.

Bayer Process Description

In the Bayer process, crude bauxite ore is dried, ground in ball mills, and mixed with a preheated spent sodium hydroxide (NaOH) leaching solution. Lime (CaO) is added to the bauxite mixture to control phosphorus content and improve the solubility of alumina. The resulting slurry mixture is combined with fresh sodium hydroxide and pumped into pressurized digesters operated at 105°C to 290°C (221°F to 554°F). Digesters are large tanks that are operated at high temperatures and pressures 413 kPa to 6890 kPa (60 psi to 1,000 psi). After approximately five hours, the slurry contains sodium aluminate ($NaAl_2OH$) in solution and insoluble red mud. This is cooled to 100°C (212°F) and a flocculent, such as starch, is added to increase the settling rate of the red mud. It is then sent through either a gravity separator or a wet cyclone to remove course sand particles. The overflow from the settling tank contains the alumina in solution, which is further clarified by filtration prior to being pumped through a cooling tower. As the solution cools, it becomes supersaturated with sodium aluminate. Fine crystals of alumina trihydrate ($[Al_2O_3 \cdot 3H_2O]$) are seeded in the cooled solution, causing the alumina to precipitate out as alumina trihydrate. Washed and filtered, the alumina trihydrate is calcined to produce a crystalline form of alumina which is advantageous for the electrolysis process. The calcine is a course, sandy alumina that has not been fully calcined. This is done intentionally to improve the collection and recycling of fluoride emissions that occur during smelting operations.

Hall-Heroult Process

The Hall-Heroult process is used to produce aluminum metal by electrolytic reduction of alumina that takes place in shallow rectangular cells, or "pots," which are steel shells lined with carbon. Carbon electrodes extending into the pot serve as the anodes and the carbon lining as the cathode. Electrical resistance to the current passing between the electrodes generates heat that maintains the cell operating temperature. Molten cryolite (Na_3AlF_6) functions as both the electrolyte and the solvent for the alumina. The electrolytic reduction of Al_2O_3 by the carbon from the electrode occurs as follows:

$$2Al_2O_3 + 3C \rightarrow 4Al + 3CO_2 \tag{1}$$

The carbon required for this reaction comes from the electrode, which requires from 0.5 kg to 0.6 kg (1.1 to 1.3 lb) of carbon per kilogram (2.2 lb) of metal. Carbon anodes are continuously depleted by the reaction. In the electrolytic reduction of alumina, the carbon anodes are lowered into the cell and are consumed at a rate of about 2.57 cm (1 in) per day. In theory, only 0.33 kg (0.73 lb) of carbon is required per kg of aluminum. Furnace offgases contain and 10 to 50 percent carbon monoxide, accounting for the difference between theoretical and actual carbon consumption.

Molten cryolite functions as both the electrolyte and the solvent for the alumina. Pure cryolite has a melting temperature of 1010°C (1850 °F). The electrolyte contains fluorospar (CaF_2), some AlF_3, and lithium in some instances, which along with the dissolved alumina, reduces the melt temperature sufficiently to permit the cells to operate between 940 and 980°C (1725 and 1795°F).

Aluminum is deposited at the cathode, where it remains as molten metal below the surface of the cryolite bath. Aluminum metal is tapped every 24 to 48 hours beneath the cryolite cover using a vacuum siphon. The aluminum is then transferred to a reverberatory holding furnace where it is alloyed, fluxed and degassed to remove trace impurities. From the holding furnace, the aluminum is cast or transported in molten state to fabricating plants up to 300 miles away.

Three types of aluminum reduction cells are used in electrolytic reduction: prebaked anode cell (PB), horizontal stud Soderberg anode cell (HSS), and vertical stud Soderberg anode cell (VSS). Most of the aluminum produced in the U.S. is processed using the prebaked anode cell process.

All three aluminum cell configurations require a "paste" (petroleum coke mixed with a pitch binder). Paste preparation includes the crushing, grinding, and screening of coke and cleaned spent anodes (butts) and blending the coke with a pitch binder in a steam jacketed mixer. For Soderberg anodes, the thick paste mixture is added directly to the anode casings, which are baked in the aluminum reduction cell. In contrast, prebaked (green) anodes are produced and baked as an ancillary operation at a reduction plant.

During PB anode manufacturing, the paste mixture is molded into self supporting green anode blocks that are baked in a direct-fired ring furnace or a Reid Hammer furnace. Direct-fired ring furnaces use pitch and tars to isolate and seal off the green anode blocks from the atmosphere during a 28-day baking process. The Reid Hammer furnace, a European process, is extremely gas tight and indirectly heated. After baking, steel rods are inserted into the PB anode and sealed with molten iron. These rods become the electrical connections to the PB anode. Prebaked anode cells are preferred over Soderberg cells because they are electrically more efficient and emit fewer volatile organic compounds. Volatile organic vapors from the pitch paste are emitted during anode baking. In addition, PB cells are not constrained by operating requirements and cell design configurations, as are the Soderberg cells. Prebaked cells require less efficient emission control devices. A PB cell operation, however, does require a separate anode and rodding facility, not needed by HSS or VSS aluminum reduction cells. A better understanding of the magnetic fields generated during the electrolytic reduction in PB cells has recently resulted in the production and use of larger prebaked anodes, resulting in improved efficiency and lower aluminum production costs.

Even though HSS or VSS aluminum reduction facilities require less labor and operate continuously (no requirement to remove the anode), the less efficient emission collection devices require higher exhaust capture velocities. Higher capture velocities increases total air flow and emission dilution. This requires larger equipment and higher emission control capital investment for the same production rate by PB cells.

Although the prebake cell is the most common reduction cell used in the U.S., the HSS is used more frequently than the VSS cell. The HSS cell uses a "continuous" carbon anode. Green anode paste is periodically added at the top of the anode casing of the pot and is baked by the heat of the cell into a solid carbon mass, as the material moves down the casing. The cell casing is comprised of aluminum or steel sheeting, with a permanent steel skirt and perforated steel channels, through which electrode connections (studs) are inserted horizontally into the anode paste. During reduction, as the baking anode is consumed, the lower row of studs and the bottom channel are removed, and flexible electrical connectors are moved to a higher row of studs.

The VSS cell is similar to the HSS cell, except that the studs are mounted vertically in the anode paste. Vertical stud Soderberg cell construction prevents the installation of an integral gas collection device, and hoods are restricted to canopies or skirts at the base of the cells where the hot anodes enter the cell baths.

As discussed above, aluminum is periodically removed from the cells and transferred to a reverberatory holding furnace with other cell batches. The operation of aluminum reverberatory furnaces is discussed in detail in Section 12.8 of the AP-42 document. The molten aluminum is alloyed, fluxed and degassed to remove trace impurities. Primary aluminum generally contains less magnesium than recycled scrap aluminum refined by the secondary aluminum recovery industry. Therefore, primary aluminum emissions are generally lower than secondary aluminum emissions.

2.3 EMISSIONS AND CONTROLS

In bauxite grinding, hydrated aluminum oxide calcining, and materials handling operations, various dry dust collection devices (centrifugal collectors, multiple cyclones, or electrostatic precipitators and/or wet scrubbers) have been used. Large amounts of particulate are generated during the calcining of hydrated aluminum oxide, but the economic value of this dust leads to the use of extensive controls to reduce emissions to relatively small quantities.

Emissions from aluminum reduction processes are primarily gaseous hydrogen fluoride and particulate fluorides, alumina, carbon monoxide, carbon dioxide, volatile organics, and sulfur dioxide from the reduction cells. The source of fluoride emissions from reduction cells is the fluoride electrolyte, which contains cryolite ($Na_5Al_3F_{14}$), aluminum fluoride (AlF_3), and fluorospar (CaF_2). Particulate emissions from reduction cells include alumina and carbon from anode dusting, aluminum fluoride, calcium fluoride, cryolite and ferric oxide.

Emissions from reduction cells also include organics, carbon monoxide and sulfur oxides. These emission factors are not presented in this document due to lack of data. Small amounts of organics are released by PB pots, and larger amounts are emitted from HSS and VSS pots. In vertical cells, these organics are incinerated in integral gas burners. Sulfur oxides originate from sulfur in the anode coke and pitch.

Emissions from anode baking ovens include the products of fuel combustion; high boiling temperature organics from the cracking, distillation, and oxidation of paste binder pitch; sulfur dioxide from the sulfur in carbon paste, primarily from the petroleum coke; fluorides from recycled anode butts; and other particulate matter. Emission factors for these components are not included in this document due to insufficient data.

High molecular weight organics and other emissions from the anode paste are released from HSS and VSS cells. These emissions can be ducted to gas burners to be oxidized, or they can be collected and recycled or sold. If the heavy tars are not properly collected, they can cause plugging of exhaust ducts, fans and emission control equipment.

A variety of control devices have been used to remove emissions from reduction cells and anode baking furnaces. To control gaseous and particulate fluorides and particulate emissions, one or more types of wet scrubbers (spray tower and chambers, quench towers, floating beds, packed beds, venturi) have been applied to all three types of reduction cells and to anode baking furnaces. In addition, particulate control methods such as wet and dry electrostatic precipitators (ESP), multiple cyclones and dry alumina scrubbers (fluid bed, injected, and coated filter types) are used on all three cell types and with anode baking furnaces.

Recovery of fluorides is important as even small amounts of fluorides in the air can severely damage vegetation. Ingestion by animals causes severe health problems. In a material balance study of fluoride use in a potroom, it was found that approximately 65 pounds of an original 87 pounds of fluoride added to the pots were released as emissions.[13] Pot cathode linings absorb about 20 pounds, and 1.6 pounds adhere to anode butts. Approximately 54 pounds of fluoride are captured for recovery. Of that amount, only 16 pounds were returned to the pots, and about 34 pounds were in the scrubber water discharge. Collection efficiency of this older recovery system was found to be 83.4 percent. The fluoride adsorption system is becoming more prevalent and is used on all three cell types. This system uses a fluidized bed of alumina, which has a high affinity for fluoride, to capture gaseous and particulate fluorides. The pot offgases are passed through the crystalline form of alumina, which was generated using the Bayer process. A fabric filter is operated downstream from the fluidized bed to capture the alumina dust entrained in the exhaust gases passing through the fluidized bed. Both the alumina used in the fluidized bed and that captured by the fabric filter are used as feed stock for the reduction cells, thus effectively recycling the fluorides. Wet ESPs approach adsorption in particulate removal efficiency, but they must be coupled to a wet scrubber or coated baghouse to catch hydrogen fluoride.

Scrubber systems also remove a portion of the SO_2 emissions. These emissions could be reduced by wet scrubbing or by reducing the original quantity of sulfur in the coke and pitch, by calcining the coke prior to manufacturing anodes.

Molten aluminum may be batch treated in furnaces to remove gaseous impurities, and active metals such as sodium and magnesium. One process consists of adding a flux of chloride and fluoride salts and then bubbling chlorine gas, usually mixed with an inert gas, through the molten mixture. Chlorine reacts with the impurities to form hydrochloric acid, Al_20_3 and metal chloride emissions. A dross forms on the molten aluminum and is removed before casting.

Naphthalene and phenol have been found in small quantities during source tests at electrolytic reduction. Both are listed as hazardous air pollutants (HAPs).

Sources of fugitive particulate emissions in the primary aluminum industry are bauxite grinding, materials handling, anode baking, and the three types of reduction cells (see Table 2.3-1). These fugitive emissions have particulate size distributions similar to those presented in Table 2.3-2.

2.4 REVIEW OF REFERENCES

Pacific Environmental Services (PES) contacted the following sources to obtain the most up-to-date information on process descriptions and emissions for this industry:

1) ALCOA, Pittsburgh, PA.
2) U.S. EPA Region 6, Dallas, TX.
3) U.S. EPA Region 4, Atlanta, GA.
4) Noranda Aluminum, Inc., New Madrid, MO.
5) Reynolds Metal Company, Richmond, VA.
6) U.S. EPA Region 10, Seattle, WA.
7) The Aluminum Association, Washington, DC.

Responses to date have been process-related information and one source test summary document. The Aluminum Association (Source 7) brought attention to the European Reid-Hammer furnace in use in the U.S. The Reid-Hammer furnace is an airtight anode baking furnace with few emissions. Information about the Reid-Hammer furnace has been incorporated into the revised section.

Noranda Aluminum (Source 4) reviewed AP-42 Section 12.1 and pointed out that the section did not include a discussion of a digester used in the Bayer process. PES incorporated the purpose and use of digesters in the Bayer process description.

Reynolds Metal Company (Source 5) told PES that their review of AP-42 was being coordinated by the Aluminum Association.

ALCOA (Source 1) sent a source test information document relating chlorine emissions from a new experimental demagging system.

2.5 REFERENCES FOR CHAPTER 2.0

1. Engineering and Cost Effectiveness Study of Fluoride Emissions Control, Volume I, APTD-0945, U.S. Environmental Protection Agency, Research Triangle Park, NC, January 1972.

2. Air Pollution Control in the Primary Aluminum Industry, Volume I, EPA-450/3-73-004a, U.S. Environmental Protection Agency, Research Triangle Park, NC, July 1973.

3. Particulate Pollutant System Study, Volume I, APTD-0743, U.S. Environmental Protection Agency, Research Triangle Park, NC, May 1971.

4. Inhalable Particulate Source Category Report for the Nonferrous Industry, Contract No. 68-02-3159, Acurex Corporation, Mountain View, CA, October 1985.

5. Emissions from Wet Scrubbing System, Y-7730-E, York Research Corporation, Stamford, CT, May 1972.

6. Emissions from Primary Aluminum Smelting Plant, Y-7730-B, York Research Corporation, Stamford, CT, June 1972.

7. Emissions from the Wet Scrubber System, Y-7730-F, York Research Corporation, Stanford, CT, June 1972.

8. T.R. Hanna and M.J. Pilat, "Size Distribution of Particulates Emitted from a Horizontal Spike Soderberg Aluminum Reduction Cell," Journal of the Air Pollution Control Association, 22:533-5367, July 1972.

9. Background Information for Standards of Performance: Primary Aluminum Industry: Volume I, Proposed Standards, EPA-450/2-74-020a, U.S. Environmental Protection agency, Research Triangle Park, NC, October 1974.

10. Primary Aluminum: Guidelines for control of Fluoride Emissions from Existing Primary Aluminum Plants, EPA-450/2-78-049b, U.S. Environmental Protection Agency, Research Triangle Park, NC, December 1979.

11. Written communication from T.F. Albee, Reynolds Aluminum, Richmond, VA, to A.A. McQueen, U.S. Environmental Protection Agency, Research Triangle Park, NC, October 20, 1982.

12. Environmental Assessment: Primary Aluminum, Interim Report, U.S. Environmental Protection Agency, Cincinnati, OH, October 1978.

13. Shreve's Chemical Process Industries, 5th ed., McGraw-Hill, 1984.

3.0 GENERAL EMISSION DATA REVIEW AND ANALYSIS PROCEDURES

3.1 LITERATURE SEARCH AND SCREENING SOURCE TESTS

The first step in the investigative process involved a search of available literature relating to criteria and noncriteria pollutant emissions associated with primary aluminum. This search included the following references:

1) AP-42 background files maintained by the Emission Factor and Methodologies Section. This is the source of the six air tests that are in Chapter 4.
2) Files maintained by the Emission Standards Division. No files are available at this time.
3) "PM_{10} Emission Factor Listing Developed by Technology Transfer" (EPA-450/4-89-022). Reviewed but not used due to uncertain quality of data.
4) Background Information Documents for NSPS and NESHAPS. No emission source tests included in the documents reviewed.
5) Information in the *Air Facility Subsystems* (AFS) of the EPA *Aerometric Information Retrieval System* (AIRS). Three and a half boxes of computer printouts were reviewed. PES was unable to retrieve any useful information for this application.
6) Handbook of Emission Factors, Parts I and II, Ministry of Health and Environmental Protection, The Netherlands, 1980/1983. This information substantiated existing AP-42 Section information. No actual emission test data available.
7) The EPA *Clearinghouse for Inventories and Emission Factors* (CHIEF). CHIEF referenced emission source data as coming from AP-42. No new information was discovered.
8) The EPA databases, including *Speciation Database Management System* (SPECIATE), the *Crosswalk/Air Toxic Emission Factor Data Base Management System* (XATEF). Both of these database systems were reviewed without tangible benefits. SPECIATE provided some of the hazardous air pollutants (HAPs) discussed in Chapter 4.
9) A literature search was conducted at the Duke University Library, including a computer network search of the University of North Carolina and the North Carolina State University. In addition, the EPA Environmental Research Center library was visited in an attempt to obtain primary emission source tests for primary aluminum facilities.

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.
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

As part of Pacific Environmental Services' analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The importance of insuring that air emission reported in this document are accurate and properly reported requires stringent requirements be followed during data review and subsequent emission reporting. The following information is presented so the reader will have an thorough understanding of the emission factor ratings. This knowledge will help to establish the proper level of confidence in the published emission rates. 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 (i.e., 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 Rating

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 documents and methods were certainly used as a guide for the methodology actually used.

B Rating

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

C Rating

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

D Rating

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. <u>Sampling and process data</u>. 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 were given a lower rating.
4. <u>Analysis and calculations</u>. 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. AP-42, 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

Criteria pollutants consist of volatile organic compounds, lead, sulfur dioxide, nitrogen oxides, carbon monoxide, and total suspended particulate and PM_{10}. No new emission source tests have been made available for review. PES did review six source tests located in the U.S. EPA AP-42 background files. The results of that review are shown in Table 4.1-1. There was no source test information for volatile organic compounds, lead, sulfur dioxide, nitrogen oxides, or carbon monoxide. Although emission factors for these criteria pollutants cannot be determined, available information on each is discussed below.

Volatile Organic Compounds.

Volatile organic compounds are emitted during the production of prebaked anodes and from all three reduction cells (PB, HSS, and VSS) during the production of primary aluminum. No information was available to develop an emission factor for VOCs from these operations.

Lead.

No data on lead emissions were found for the primary aluminum process.

Sulfur Dioxide.

Coke and pitch are believed to be the main source of SO_2 during primary aluminum production. Table 2.3-1 includes a footnoted equation to estimate sulfur dioxide uncontrolled emissions from an anode baking furnace and a prebake (reduction) cell. The results are given an emission factor rating of "E." The derivation of these two equations is unknown.

Nitrogen Oxides.

No data on nitrogen oxide emissions were found for the primary aluminum process.

Carbon Monoxide.

Carbon monoxide has been found in the emissions from the reduction cells. No quantified data are available.

Total Suspended Particulate & PM$_{10}$.

PM$_{10}$ is a subset of total suspended particulate (TSP) and consists of particles having a diameter of less than ten microns (µm). There is no single method which is universally accepted for the determination of particle size. A number of different techniques can be used which measure the size of particles according to their basic physical properties. Since there is no "standard" method for particle size analysis, a certain degree of subjective evaluation was used to determine if a test series was performed using a sound methodology for particle sizing.

The following total suspended particulate table includes uncontrolled and controlled particulate emission factors developed from two "A" rated source tests (References 1 and 2) at primary aluminum production facilities. The first emission control system is a scrubber in series with an electrostatic precipitator. The second emission control systems has a scrubber. This information is not included in the revised section, as it represents data from two tests conducted at two facilities. The calculated emission factors may not be representative of the industry. Additional source tests should be conducted at other facilities to improve the emission factor validity. Total uncontrolled particulate in Table 4.1-1 has a range of emission factors 4.7 to 29.0 kg/Mg (9.3 to 59.4 lbs/ton). The uncontrolled emission factor for Reference 1 source test is 5.9 kg/Mg (11.8 lb/ton), while the uncontrolled emission factor for Reference 2 source test is 24.7 kg/Mg (49.3 lb/ton). The average emission factors for uncontrolled emissions from the two facilities represent a reduction of 17 to 42 percent of uncontrolled particulate emissions when compared to the AP-42, Section 12.1, October 1986 edition of Primary Aluminum. PES believes more uncontrolled particulate emission factors for other plants should be conbined with these new emission factors prior to changing the original 1986 uncontrolled particulate emission factors.

TABLE 4.1-1 (METRIC UNITS)
TOTAL PARTICULATE

Source Test #	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Uncontrolled						
1	A	5	1	3.14	14.65	4.67
			2	3.14	22.27	7.09
			3	3.16	18.59	5.89
			Average	3.15	18.50	5.86
Control device: Tandem Scrubber Electrostatic Precipitator						
1	A	5	1	3.14	0.57	0.18
			2	3.14	0.87	0.28
			3	3.16	1.12	0.36
			Average	3.15	0.85	0.27
Control device: Uncontrolled						
2	A	5	1	0.24	8.64	18.33
			2	0.24	12.25	25.98
			3	0.24	14.00	29.70
			Average	0.24	11.63	24.66
Control device: Scrubber						
2	A	5	1	0.24	0.207	0.44
			2	0.24	0.303	0.64
			3	0.24	0.298	0.63
			Average	0.24	0.269	0.57

[a] Units in Mg/hr.
[b] Units in kg/hr.
[c] Units in kg/Mg.

TABLE 4.1-1 (ENGLISH UNITS)
TOTAL PARTICULATE

Source Test #	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Uncontrolled						
1	A	5	1	3.46	32.3	9.34
			2	3.46	49.1	14.19
			3	3.48	41.0	11.78
			Average	3.47	40.8	11.77
Control device: Tandem Scrubber Electrostatic Precipitator						
1	A	5	1	3.46	1.26	0.36
			2	3.46	1.91	0.55
			3	3.48	2.46	0.71
			Average	3.47	1.88	0.54
Control device: Uncontrolled						
2	A	5	1	0.52	19.06	36.65
			2	0.52	27.02	51.96
			3	0.52	30.87	59.39
			Average	0.52	25.65	49.32
Control device: Scrubber						
2	A	5	1	0.52	0.456	0.88
			2	0.52	0.668	1.28
			3	0.52	0.657	1.26
			Average	0.52	0.594	1.14

[a] Units in tons/hr.
[b] Units in lb/hr.
[c] Units in lb/ton.

4.2 NONCRITERIA POLLUTANT EMISSIONS DATA

Hazardous Air Pollutants.

Hazardous Air Pollutants (HAPs) are defined in Title III of the 1990 Clean Air Act Amendments. Although no source tests listing HAP emission rates are available, the EPA SPECIATE database lists naphthalene and phenol, both HAPs, as being detected during two unspecified source tests. In addition, demagging with chlorine or fluorine results in the creation of hydrochloric acid vapor and hydrogen fluoride, both of which are listed as HAPs.

Global Warming Gases.

Pollutants such as methane, carbon dioxide, and N_2O have been found to contribute to overall global warming. Methane, nitrous oxide, and carbon dioxide emission rates were not available in the sic source tests reviewed. The percentage of carbon dioxide in the exhaust flow was measured for source testing purposes. The concentration of carbon dioxide in the stack gas being tested was measured in order to approximate the molecular weight of the stack gas. In the emissions test utilized in developing emission factors for primary aluminum, as with most emissions tests, this measurement is performed in such a way that its level of accuracy is less than that of the primary pollutants of interest. Unless the determination of CO_2 emission is a goal of the source test, the reported CO_2 emission comes from a grab sample and is expected to be within ±1/2 percent of total volume. This accuracy range precludes its use as reported CO_2 emissions for the primary aluminum process.

Ozone Depleting Gases.

Chlorofluorocarbons have been found to contribute to ozone depletion. No data on emissions of these pollutants were found for the primary aluminum process.

Fluoride gases.

Fluoride gas emission results from the use of fluorospar used in cryolite to reduce the melt temperature of cryolite. Table 4.2-1 provides uncontrolled and controlled fluoride emissions for two emission sources. The first source used a scrubber and electrostatic precipitator in tandem, while the second source used a scrubber as its sole control device. This information has not been added to the revised Section 12.1 of AP-42, as it represents 1972 testing using an unspecified but authorized EPA test of that time. A comparison of the uncontrolled emission factors from the two plants shows an unexplained ten-fold difference. More source testing is required to establish an emission factor for fluoride gas. This information was not included in the new section.

TABLE 4.2-1 (METRIC UNITS)
FLUORIDE

Source Test #	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Uncontrolled						
1	A	EPA[d]	1	3.14	7.10	2.27
			2	3.14	6.36	2.17
			3	3.16	7.91	2.51
			Average	3.15	7.12	2.32
Control device: Tandem Scrubber Electrostatic Precipitator						
1	A	EPA[d]	1	3.14	0.0013	4.0×10^{-4}
			2	3.14	0.0014	4.5×10^{-4}
			3	3.16	0.0007	2.0×10^{-4}
			Average	3.15	0.0011	3.5×10^{-4}
Control device: Uncontrolled						
2	A	EPA[d]	1	0.47	9.94	21.08
			2	0.47	13.18	27.95
			3	0.47	14.67	31.10
			Average	0.47	12.60	26.71
Control device: Scrubber						
2	A	EPA[d]	1	0.47	0.298	0.63
			2	0.47	0.392	0.83
			3	0.47	0.454	0.97
			Average	0.47	0.381	0.81

[a] Units in Mg/hr.
[b] Units in kg/hr.
[c] Units in kg/Mg.
[d] Unspecified 1972 EPA-approved method.

TABLE 4.2-1 (ENGLISH UNITS)
FLUORIDE

Source Test #	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Uncontrolled						
1	A	EPA[d]	1	3.46	15.66	4.53
			2	3.46	14.03	4.34
			3	3.48	17.44	5.01
			Average	3.47	15.71	4.63
Control device: Tandem Scrubber Electrostatic Precipitator						
1	A	EPA[d]	1	3.46	0.0028	0.0008
			2	3.46	0.0030	0.0009
			3	3.48	0.0015	0.0004
			Average	3.47	0.0024	0.0007
Control device: Uncontrolled						
2	A	EPA[d]	1	0.52	21.92	42.15
			2	0.52	29.07	55.90
			3	0.52	32.34	62.19
			Average	0.52	27.78	53.41
Control device: Scrubber						
2	A	EPA[d]	1	0.52	0.6569	1.26
			2	0.52	0.8646	1.66
			3	0.52	1.0010	1.93
			Average	0.52	0.841	1.62

[a] Units in tons/hr.
[b] Units in lb/hr.
[c] Units in lb/ton.
[d] Unspecified 1972 EPA-approved method.

4.3 REVIEW OF SPECIFIC DATA SETS

Controlled and uncontrolled emission factors for total particulate matter, gaseous fluoride and particulate fluoride are given in Table 4.3-1. Table 4.3-2 gives available data for size-specific particulate matter emissions for primary aluminum industry processes.

The emission information contained in Tables 4.3-1 and Table 4.3-2 remains unchanged from AP-42 Section 12.1, Primary Aluminum (October 1986). However, the emission factor rating for Table 4.3-1 has been changed from "A" to "E" because there are no references listed for the table. Table 4.3-2 is a compilation of three tables (12.2-3, 12.1-4, and 12.1-5) that had size-specific emission factors of "C," "D," and "D," respectively. These emission factors remain unchanged. Table 4.3-2 emission information was constructed from information listed in Reference 7, Inhalable Particulate Source Category Report for the Nonferrous Industry. Table 12.1-3 was derived from five "B"-rated emission tests in prebaked plants. Tables 12.1-4 and 12.1-5 have size-specific emission factors of "D" because the emission test results are based upon only one "B"-rated source test. The data in Table 12.1-4 may not be representative of the industry, and the size-specific data in Table 12.1-5 came from an old report that had a small amount of process information regarding particle size. Acurex, the author of Reference 7, determined the test ratings.

TABLE 4.3-1 (METRIC UNITS)
EMISSION FACTORS FOR PRIMARY ALUMINUM PRODUCTION PROCESSES[a,b]

All Emission Factors are in kg/Mg of Bauxite Produced
Ratings (A-E) Follow Each Factor

Operation	Total particulate[c]		Gaseous fluoride		Particulate fluoride		Reference
Bauxite grinding (in kg/Mg bauxite processed)							**(SCC 3-03-000-01)**
Uncontrolled	3.0	E	Neg		NA		1,3
Spray tower	0.9	E	Neg		NA		1,3
Floating bed scrubber	0.85	E	Neg		NA		1,3
Quench tower and spray screen	0.5	E	Neg		NA		1,3
Aluminum hydroxide calcining (in kg/Mg aluminum produced)							**(SCC-3-03-000-02)**
Uncontrolled[d]	100.0	E	Neg		NA		1,3
Spray tower	30.0	E	Neg		NA		1,3
Floating bed scrubber	28.0	E	Neg		NA		1,3
Quench tower	17.0	E	Neg		NA		1,3
ESP	2.0	E	Neg				1,3
Anode baking furnace (in kg/Mg of molten aluminum produced)							**(SCC-3-03-001-05)**
Uncontrolled	1.5	E	0.45	E	.05	E	2,10-11
Fugitive							
Spray tower	0.375	E	0.02	E	0.015	E	10
ESP	0.375	E	0.02	E	0.015	E	2
Dry aluminum scrubber	0.03	E	0.0045	E	0.001	E	2,10
Prebake cell (in kg/Mg of moltein aluminum produced)							**(SCC-03-0001-01)**
Uncontrolled	47.0	E	12.0	E	10.0	E	1-2,10-11
Fugitive	2.5	E	0.6	E	0.5	E	2,10
Emissions to collector	44.5	E	11.4	E	9.5	E	2
Multiple cyclones	9.8	E	11.4	E	2.1	E	2
Dry aluminum scrubber	0.9	E	0.1	E	0.2	E	2,10
Dry ESP plus spray tower	2.25	E	0.7	E	1.7	E	2,10
Spray tower	8.9	E	0.7	E	1.9	E	2
Floating bed scrubber	8.9	E	0.25	E	1.9	E	2
Coated bag filter dry scrubber	0.9	E	1.7	E	0.2	E	
Crossflow packed bed							2
Dry plus secondary scrubber	13.15	E	3.25	E	2.8	E	10
	0.35	E	0.2	E	0.15	E	10

TABLE 4.3-1 (METRIC UNITS)
EMISSION FACTORS FOR PRIMARY ALUMINUM PRODUCTION PROCESSES[a,b]

All Emission Factors are in kg/Mg of Bauxite Produced
Ratings (A-E) Follow Each Factor
(Concluded)

Operation	Total particulate[c]		Gaseous fluoride		Particulate fluoride		Reference
Vertical Soderberg stud cell (in kg/Mg of moltein aluminum produced)							**(SCC-03-0001-01)**
Uncontrolled	39.0	E	16.5	E	5.5	E	2,10
Fugitive	6.0	E	2.45	E	0.85	E	10
Emissions to collector	33.0	E	14.05	E	4.65	E	10
Spray tower	8.25	E	0.15	E	1.15	E	2
Venturi scrubber	1.3	E	0.15	E	0.2	E	2
Multiple cyclones	16.5	E	14.05	E	2.35	E	2
Dry alumina scrubber	0.65	E	0.15	E	0.1	E	2
Scrubber plus ESP plus spray screen and scrubber	3.85	E	0.75	E	0.65	E	2
Horizontal Soderberg stud cell (Mg in molten aluminum)							**(SCC 3-03-001-02)**
Uncontrolled	49.0	E	11.0	E	6.0	E	2,10
Fugitive	5.0	E	1.1	E	0.6	E	2,10
Emissions to collector	44.0	E	9.9	E	5.4	E	2,10
Spray tower	11.0	E	3.75	E	1.35	E	2,10
Floating bed scrubber	9.7	E	0.2	E	1.2	E	2
Scrubber plus wet ESP	0.9	E	0.1	E	0.1	E	2,10
Wet ESP	0.9	E	0.5	E	0.1	E	10
Dry alumina scrubber	0.9	E	0.2	E	0.1	E	10

Footnotes for Table 4.3-1 (Metric units)

[a] For bauxite grinding, expressed as kg/Mg of bauxite processed. For aluminum hydroxide calcining, expressed as kg/Mg of alumina produced. All other factors are Mg of molten aluminum product. ESP = Electrostatic precipitator, NA = Not Available, Neg = negligible.

[b] Sulfur dioxide may be estimated, with an Emission Factor Rating of E, by the following calculations.

Anode baking furnace, uncontrolled SO_2 emissions (excluding furnace fuel combustion emissions):

$$20(C)(S)(1-0.01\ K)\ \text{kg/Mg}$$

Prebake (reduction) cell, uncontrolled SO_2 emissions:

$$0.2(C)(S)(K)\ \text{kg/Mg}$$

Where: C = Anode consumption* during electrolysis, kg anode consumed/kg Al produced
S = % sulfur in anode before baking
K = % of total SO_2 emitted by prebake (reduction) cells.
* Anode consumption weight is weight of anode paste (coke + pitch) before baking.

[c] Includes particulate fluorides

[d] After multicyclone.

TABLE 4.3-1 (ENGLISH UNITS)
EMISSION FACTORS FOR PRIMARY ALUMINUM PRODUCTION PROCESSES[a,b]

All Emission Factors are in lb/ton of Bauxite Produced
Ratings (A-E) Follow Each Factor

Operation	Total particulate[c]		Gaseous fluoride		Particulate fluoride		Reference
Bauxite grinding (in lb/ton bauxite processed)							**(SCC 3-03-000-01)**
Uncontrolled	6.0	E	Neg				1,3
Spray tower	1.8	E	Neg				1,3
Floating bed scrubber	1.7	E	Neg				1,3
Quench tower and spray screen	1.0	E	Neg				1,3
Aluminum hydroxide calcining (in lb/ton produced)							**(SCC 3-03-000-02)**
Uncontrolled[d]	200.0	E	Neg				1,3
Spray tower	60.0	E	Neg				1,3
Floating bed scrubber	56.0	E	Neg				1,3
Quench tower	34.0	E	Neg				1,3
ESP	4.0	E	Neg				1,3
Anode baking furnace in lb/ton molten aluminum produced)							**(SCC 3-03-001-05)**
Uncontrolled	3.0	E	0.9	E	.01	E	2,10-11
Fugitive							
Spray tower	0.75	E	0.04	E	0.03	E	10
ESP	0.75	E	0.04	E	0.03	E	2
Dry aluminum scrubber	0.06	E	0.009	E	0.002	E	2,10
Prebake cell in lb/ton molten aluminum produced)							**(SCC 3-03-001-01)**
Uncontrolled	94.0	E	24.0	E	20.0	E	1-2,10-11
Fugitive	5.0	E	1.2	E	1.0	E	2,10
Emissions to collector	89.0	E	22.8	E	19.0	E	2
Multiple cyclones	19.6	E	22.8	E	4.2	E	2
Dry aluminum scrubber	1.8	E	0.2	E	0.4	E	2,10
Dry ESP plus spray tower	4.5	E	1.4	E	3.4	E	2,10
Spray tower	17.8	E	1.4	E	3.8	E	2
Floating bed scrubber	17.8	E	0.5	E	3.8	E	2
Coated bag filter dry scrubber	1.8	E	3.4	E	0.4	E	
Crossflow packed bed							2
Dry plus secondary scrubber	26.3	E	6.7	E	5.6	E	10
	0.7	E	0.4	E	0.3	E	10

TABLE 4.3-1 (ENGLISH UNITS)
EMISSION FACTORS FOR PRIMARY ALUMINUM PRODUCTION PROCESSES[a,b]

All Emission Factors are in lb/ton of Bauxite Produced
Ratings (A-E) Follow Each Factor
(Concluded)

Operation	Total particulate[c]		Gaseous fluoride		Particulate fluoride		Reference
Vertical Soderberg stud cell (in lb/ton molten aluminum produced)							**(SCC 3-03-001-03)**
Uncontrolled	78.0	E	33.	E	11.0	E	2,10
Fugitive	12.0	E	4.9	E	1.7	E	10
Emissions to collector	66.0	E	28.1	E	9.3	E	10
Spray tower	16.5	E	0.3	E	2.3	E	2
Venturi scrubber	2.6	E	0.3	E	0.4	E	2
Multiple cyclones	33.0	E	28.1	E	4.7	E	2
Dry alumina scrubber	1.3	E	0.3	E	0.2	E	2
Scrubber plus ESP plus spray screen and scrubber	7.7	E	1.5	E	1.3	E	2
Horizontal Soderberg stud cell (in lb/ton molten aluminum produced)							**(SCC 3-01-001-02)**
Uncontrolled	98.0	E	22.0	E	12.0	E	2,10
Fugitive	10.0	E	2.2	E	1.2	E	2,10
Emissions to collector	33.0	E	19.8	E	10.8	E	2,10
Spray tower	22.0	E	7.5	E	2.7	E	2,10
Floating bed scrubber	19.4	E	0.4	E	2.4	E	2
Scrubber plus wet ESP	1.8	E	0.2	E	0.2	E	2,10
Wet ESP	1.8	E	0.5	E	0.2	E	10
Dry alumina scrubber	1.8	E	0.4	E	0.2	E	10

Footnotes for Table 2.3-1 (English units)

[a] For bauxite grinding, expressed as lb/ton of bauxite processed. For aluminum hydroxide calcining, expressed as lb/ton of alumina produced. All other factors are ton of molten aluminum product.
ESP = Electrostatic precipitator, NA = Not Available, Neg = negligible.

[b] Sulfur dioxide may be estimated, with an Emission Factor Rating of E, by the following calculations.

Anode baking furnace, uncontrolled SO_2 emissions (excluding furnace fuel combustion emissions):

$$40(C)(S)(1-0.01\ K)\ \text{lb/ton}$$

Prebake (reduction) cell, uncontrolled SO_2 emissions:

$$0.4(C)(S)(K)\ \text{lb/ton}$$

Where: C = Anode consumption* during electrolysis, lb anode consumed/lb Al produced
S = % sulfur in anode before baking
K = % of total SO_2 emitted by prebake (reduction) cells.
* Anode consumption weight is weight of anode paste (coke + pitch) before baking.

[c] Includes particulate fluorides

[d] After multicyclone.

TABLE 4.3-2 (METRIC UNITS)
UNCONTROLLED EMISSION FACTORS AND PARTICLE SIZE DISTRIBUTION IN ALUMINUM PRODUCTION[a]

All Emission Factors are in kg/Mg of Aluminum Produced
Ratings (A-E) Follow Each Factor

Particle size[b] (µm)	Prebake Aluminum cells			HSS Aluminum Cells			VSS Reduction Cells		
	Cumulative mass (%) ≤ stated size	Cumulative emission factor		Cumulative mass (%) ≤ stated size	Cumulative emission factor		Cumulative mass (%) ≤ stated size	Cumulative emission factor	
0.625	13	0.33	C	8	0.40	D	26	12.7	D
1.25	18	0.46	C	13	0.65	D	32	15.7	D
2.5	28	0.70	C	17	0.85	D	40	19.6	D
5	43	1.08	C	23	1.15	D	50	25.5	D
10.	58	1.45	C	31	1.55	D	58	28.4	D
15	65	1.62	C	39	1.95	D	63	30.9	D
TOTAL:	100	2.5	C	100	5.0	D	100	49	D

[a] Reference 4.
[b] Expressed as equivalent aerodynamic particle diameter.

TABLE 4.3-2 (ENGLISH UNITS)
UNCONTROLLED EMISSION FACTORS AND PARTICLE SIZE DISTRIBUTION IN ALUMINUM PRODUCTION[a]

All Emission Factors are in lb/ton of Aluminum Produced
Ratings (A-E) Follow Each Factor

Particle size[b] (µm)	Prebake Aluminum cells			HSS Aluminum Cells			VSS Reduction Cells		
	Cumulative mass (%) ≤ stated size	Cumulative emission factor		Cumulative mass (%) ≤ stated size	Cumulative emission factor		Cumulative mass (%) ≤ stated size	Cumulative emission factor	
0.625	13	0.67	C	8	0.8	D	26	25.5	D
1.25	18	0.92	C	13	1.3	D	32	31.4	D
2.5	28	1.40	C	17	1.7	D	40	39.2	D
5	43	2.15	C	23	2.3	D	50	49.0	D
10.	58	2.90	C	31	3.1	D	58	56.8	D
15	65	3.23	C	39	3.9	D	63	61.7	D
TOTAL:	100	2.5	C	100	10.0	D	100	98	D

[a] Reference 4.
[b] Expressed as equivalent aerodynamic particle diameter.

Six source tests are a part of the EPA background files for AP-42 Section 12.1. The seventh source test was provided by ALCOA. Each of these source tests has been evaluated and rated by PES, including an explanation of any faults and omissions found in the test procedures, or reported data that are suspect.

Reference 1: Source Test: Primary Aluminum Smelting Plant (Special Emission Control System) at Aluminum Company of American, Wenatchee, Washington. Report No. y-7730-b, June 8, 1972.

This source test measures emissions from a primary aluminum production line. ALCOA installed a unique recirculation system that routes waste stream gases from production pots back through the pots prior to entering the pollution control system. This pollution control system consists of a scrubber in series with an electrostatic precipitator. Particulate and fluoride testing are rated as "A", while test results for SO_2 and NO_x are not credible and are not rated. Sulfur dioxide emission data indicates SO_2 is being produced in the scrubber, a process that does not appear to be feasible for a scrubber controlling primary aluminum emission. Nitrous oxide emission samples were to be neutralized at the test site, as required by the test method. However, that procedure was not followed, voiding the sample validity. Total uncontrolled and controlled particulate emissions are listed in Table 4.1-1. Uncontrolled and controlled fluorine emissions are listed in Table 4.2-1. These emission factors are not tabulated in the revised section because they represent a major reduction in uncontrolled particulate emissions when compared to the 1986 emission factor table for particulates.

Reference 2: Source Test: Emissions From the Wet Scrubber System at Harvey Aluminum, The Dalles, Oregon. Report No. Y-7730-F, June 7, 1972.

The goal of this source test is to measure particulate, fluorides, SO_2 and NO_x. The pollution control device is a scrubber. There is no recirculation of emissions into the production aluminum pots as in Reference 1. Only the particulate and fluoride emissions data are valid. Nitrous oxide samples were not recovered because the samples were not neutralized in the field as the procedure required. Sulfur dioxide testing on the inlet and outlet to the scrubber was not conducted concurrently, e.g., the inlet emission rate on day one is compared to the controlled emission taken on day two. In addition, the controlled emission rate of SO_2 increased by an order of magnitude over the uncontrolled emission rate. Controlled and uncontrolled particulate and emissions are tabulated in Tables 4.1-1 and 4.2-1. This information does not appear in the revised section because the new calculated emission factors are much lower than the 1986 published uncontrolled emission factor for particulates.

Reference 3: Source Test: Barmet Industries, Inc., Uhrichsville, Ohio. Contract No. 68-02-0240, February, 1975.

This compliance source test is for a dross aluminum recovery facility. The testing measures particulate emissions controlled by two scrubbers and one baghouse. The source test evaluates and compares controlled particulate emissions to allowable particulate emissions. This report lacks the field notes and Method 1 information necessary to properly rate the test. In addition, the efficiency of these pollution control devices were calculated to be much lower than standard scrubber and fabric filter removal efficiencies, further reducing confidence in the proper use of the required testing procedures. This source test is not rated as there is a lack of confidence in the order of magnitude of the emissions.

Reference 4: Source Test: Kaiser Aluminum and Chemical Company, Tacoma, Washington. September 1985.

This purpose of this source test was to measure emissions of toxic organic aromatic compounds from a primary pot line. A modified Method 5 was used to take controlled emissions samples from the exhaust stream after a fabric filter. In addition, fugitive emissions were sampled at the roof monitors. No production rates are reported in the source test, precluding an emission factor calculation. There are no field notes to establish the validity of Methods 1 through 5. This test is not rated due to the lack of information and inability of PES to establish an emission factor because there are no reported production rates.

Reference 5: Source Test: Emissions From Wet Scrubber System at Reynolds Metals, Inc., Troutdale, Oregon. May, 1972.

The purpose of this source test was to measure particulate, NO_x, SO_2, and Fluorides. Method 1 procedures were either not used, or the inlet sample ports were incorrectly positioned because of physical space limitations in the plant. No reason was reported as to why the inlet test port was installed in an air flow reduction duct fitting. There is confusion as to how many cells are producing emissions during the testing periods. The production process operating information indicates 16 cells are controlled at the inlet, and 30 cells are controlled at the outlet to the emission control system. Nothing is revealed in the narrative as to what this means. And finally, the data summary sheet indicates that more particulate exits the scrubber than enters it. This source test is not rated because the reported data is inaccurate and the process information prevents a conclusion concerning actual emissions.

Reference 6: Source Test: Testing of Abatement Equipment For Anode Baking Furnace, Aluminum Company of America, Rockdale, Texas. May 1979.

This source test was conducted to evaluate New Source Performance Standards at a new ALCOA anode baking furnace. The pollution control devices in tandem are parallel ALCOA 466 alumina reactors (primary abatement devices) and an ALCOA 466 regenerator. The reactors use alumina to absorb pollutants from the anode baking furnace. Reacted alumina goes to the regenerator and then to the pot room. Emissions were taken on both the reactors and regenerator and then summed. The source test reportedly used EPA Methods 1 through 5, and ALCOA's Method 4075A, which was approved for use by the EPA. The copy of this source test reviewed by PES has not field notes, isokinetic readings, sample rates, etc. Testing methodology also appears to be inadequate. For example, the probe was not heated during the collection of sample emissions. Even though this test cannot be rated, the uniqueness of the emissions from an anode baking furnace warrants repetition here for comparative use. This information is not used elsewhere in this document.

Total Fluoride	0.03 lbs/equivalent ton Al
Hydrogen Fluorides	0.02 lbs/equivalent ton Al
Total Suspended Particulate	0.41 lbs/equivalent ton Al
CO Concentration (Reactor Effluent)	0.03%
CO Concentration (Regenerator Effluent)	0.07%

Reference 7: Source Test: Chlorine Demagging Alcoa Warrick Operations, Warric County, Indiana. May 1989.

A total of 12 tests were conducted; 6 tests used 100 percent chlorine gas, and 6 tests used a mixture of 90 percent nitrogen and 10 percent chlorine gas. The gas mixtures were passed through a multi-orifice plate designed to limit the diameter of the gas bubbles being injected into the molten aluminum. Results of the tests indicate that the use of 100 percent chlorine gas resulted in an average emission of chlorine and chlorides of 9.9 percent of the total chlorine gas used. When the gas mixture consisted of 90 percent nitrogen and 10 percent chlorine, average emissions of chlorine and chlorides were found to be 23 percent of the total chlorine gas used. PES believes the reaction kinetics of 100 percent chlorine gas is greater than the reaction kinetics of the 10 percent chlorine gas, resulting in more conversion of chlorine gas into magnesium chloride (magnesium chloride is normally trapped in the dross), resulting in a lower percentage of emissions of chlorine and chlorides than the 90/10 percent gas mixture. A comparison of these chlorine/chloride emission rates with the published AP-42 chlorine emission factor of 50 percent emissions of total chlorine used in Section 12.8, Secondary Aluminum, indicates that chlorine and chloride emissions from recent demagging processes may be less than that reported in the current AP-42 revised section. This AP-42 emission rate was established from emission tests when demagging was accomplished using a carbon lance with liquid chlorine pumped through the lance into the aluminum.

The ALCOA information cannot be used to produce a chlorine demagging emission factor for several reasons. The sampling method was developed by the Texas Air Control Board. The Texas method was not described, so it is unknown how this method compares with U.S. EPA methods. The Texas method converts some chlorine into chlorides, so both chlorine and chlorides were summed when developing emission rates. ALCOA does not have documentation regarding the accuracy of the chlorine/chloride split provided by this method. In addition, the information is not complete enough to allow a test rating, precluding development of an emission factor.

4.4 DATA GAP ANALYSIS

The source tests and documentation used to generate existing emission factors are dated from the early 1970s. Since then, improvements in process control procedures, production equipment, and pollution control devices have been initiated by primary aluminum producers. Of primary interest are the fluoride and particulate emissions from modern aluminum pot lines using alumina fluidized bed and fabric filter control devices in tandem. A second priority should be chlorine emissions from primary aluminum processes, particularly those that use scrap aluminum in their primary aluminum operations. In 1987, the consumption of scrap aluminum by primary aluminum producers exceeded that used by the secondary aluminum industry. Chlorine emissions from demagging operations in smelting furnaces when chlorine gas is injected into an aluminum circulation pump discharge is not well-documented. Emission source tests should also be performed to improve and update emission factor ratings for current operations and control equipment listed in the emission tables for AP-42, Section 12.1, Primary Aluminum.

TABLE 4-4-1.

LIST OF CONVERSION FACTORS

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

Temperature conversion equations:

Fahrenheit to Celsius:

$$\frac{{}^\circ F - 32}{1.8} = {}^\circ C$$

Celsius to Fahrenheit:

$$(1.8\,{}^\circ C) + 32 = {}^\circ F$$

4.5 REFERENCES FOR CHAPTER 4.0

1. Source Test: Primary Aluminum Smelting Plant (Special Emission Control System) at Aluminum Company of American, Wenatchee, Washington. Report No. y-7730-b, June 8, 1972.

2. Source Test: Emissions From the Wet Scrubber System at Harvey Aluminum, The Dalles, Oregon. Report No. Y-7730-F, June 7, 1972.

3. Source Test: Barmet Industries, Inc., Uhrichsville, Ohio. Contract No. 68-02-0240, February, 1975.

4. Source Test: Kaiser Aluminum and Chemical Company, Tacoma, Washington. September 1985.

5. Source Test: Emissions From Wet Scrubber System at Reynolds Metals, Inc., Troutdale, Oregon. May, 1972.

6. Source Test: Testing of Abatement Equipment For Anode Baking Furnace, Aluminum Company of America, Rockdale, Texas. May 1979.

7. Source Test: Chlorine Demagging Alcoa Warrick Operations, Warrick County, Indiana. May 1989.