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Environmental Protection Technology Series

INDUSTRIAL PROCESS PROFILES FOR ENVIRONMENTAL USE: Chapter 25. Primary Aluminum Industry

Industrial Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
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INDUSTRIAL PROCESS PROFILES

FOR ENVIRONMENTAL USE

CHAPTER 25

PRIMARY ALUMINUM INDUSTRY

by

Terry Parsons
Radian Corporation
Austin, Texas 78766

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Project Officer
Alfred B. Craig
Metals and Inorganic Chemicals Branch
Industrial Environmental Research Laboratory
Cincinnati, Ohio 45268

INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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TABLE OF CONTENTS

CHAPTER 25

LIST OF FIGURES

CHAPTER 25

LIST OF TABLES

CHAPTER 25

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PRIMARY ALUMINUM INDUSTRY

INDUSTRY DESCRIPTION

The primary aluminum industry as defined for this study consists of processing bauxite ore to produce alumina and occasionally aluminum hydroxide and processing alumina to produce aluminum. The manufacture of other aluminum chemical compounds is not considered a part of this industry, since only two companies that produce primary aluminum also produce a few aluminum based chemicals. (See Company-Product listing in Appendix A).

The two main industry segments consist of bauxite processing to alumina and alumina processing to aluminum. They are not usually performed at the same site, since they are distinct and separate processes. A third industry segment, electrode preparation, is accomplished at the aluminum production site. Production of aluminum from recycled scrap aluminum and the production of many other aluminum based chemicals are not considered parts of this industry. These industries utilize different raw materials and include mainly companies and/or divisions which do not produce aluminum from alumina.

This study describes the processes which form each of three segments. Flow sheets are provided for each segment which show the processes and the materials entering and leaving each process and the emission points.

Approximately 7.6 billion kg (8.4 million tons) of alumina were produced in this country in 1972, including 0.27 billion kg (0.3 million tons) in the Virgin Islands, from processing about 15.4 billion kg (17 million tons) of bauxite.[1] Approximately 11 percent of this bauxite was mined in this country, and the balance was imported mainly from Jamaica and Surinam.[2] The primary aluminum industry utilized about 94 percent of this alumina to make aluminum. Bauxite is processed to alumina by five companies at nine sites (one in the Virgin Islands). Plants range in capacity from 0.32 to 1.22 billion kg (0.350 to 1.380 million tons) per year.[2] Limited growth of bauxite processing plants in this country is expected.

Production of alumina compounds such as aluminum hydroxide and sodium aluminate amounts to approximately 0.36 billion kg (0.4 million tons) per year.

Aluminum is produced by 13 companies at 32 locations, but three companies produce most (87 percent) of the alumina and 65 percent of the aluminum in the U.S.[3,4] The basic process used for producing raw aluminum metal in all plants in the U.S. consists of the electrolytic dissociation of alumina (Al_2O_3) dissolved in a molten bath of cryolite (Na_3AlF_6). Oxygen released in this process reacts with the carbon anode to form carbon dioxide and some carbon monoxide. The molten aluminum settles to the bottom of the cell, directly above the cathode. The three types of cells or pots used to accomplish this reaction are the prebake cell and the vertical and horizontal Stud Soderberg designs. These cells all operate under the same principle, but they differ in anode configuration. The prebake design is used in about 70 percent of total production.[3]

Individual aluminum plants range in size from 31.7 to 254 million kg (35,000 to 280,000 tons) per year capacity. Total capacity is about 4.445 billion kg (4.9 million tons) per year. The industry operates at about 85 percent of capacity and employs approximately 146,600 people under Standard Industrial Classification Code 3334.[5] Aluminum currently sells for approximately $0.39 per pound,[6] yielding a total value of approximately $3.8 billion based on 1973 production rates.

Aluminum plants are generally not located near large population centers and are always located near sources of relatively low-cost electrical power. Approximately 70 percent of the aluminum manufacturing capacity is located in areas with a population density of less then 80 people per square mile.[3,7] The environmental effects from aluminum production on livestock and vegetation are very significant due to the potentially high fluoride emissions. Alumina plants are located near mining areas in Arkansas and in port cities along the Gulf of Mexico and tend to be in more populated areas.

Aluminum production is projected to grow at a rate of about 5.2 percent per year until 1980, based on a demand growth of 7.5 percent.[3,7] The excess in demand over growth will be made up by an increased operating ratio, by the gradual disposal of the GSA stockpile, and by construction of new plants.

The promulgation of emission standards by EPA is not expected to limit industry growth significantly. Increased electrical power costs will, however, cause secondary (recycled) aluminum to compete more economically with primary aluminum for some markets.

A number of aluminum reduction plants produce their own electricity by fuel combustion and/or hydroelectrically.

Raw Materials

Bauxite, of which approximately 87 percent is imported, is the raw material for alumina production. This material is composed mainly of metallic oxides with aluminum oxide comprising from 20 to 60 percent of the ore as mined.[8] Domestic ores tend to be leaner in alumina content as shown by data in Appendix B. Heavy metals are not usually found in this ore. The major environmental problems associated with bauxite mining and shipping are caused by fugitive dust and water runoff.

Alumina and carbon (petroleum coke) are the major constituents used for making aluminum as shown in Table 1. Calcined petroleum coke, pitch,

Table 1. RAW MATERIALS REQUIRED TO PRODUCE ALUMINUM[8]

Material	Amount, % by weight of aluminum products
Sulfur	1-5
Alumina (Al_2O_3)	190
Cryolite (Na_3AlF_6)	3-5
Aluminum fluoride (AlF_3)	3-5
Fluorspar (CaF_2)	0.3
Anode	
Petroleum Coke	49 (Prebake) 45 (Soderberg)
Pitch Binder	12.7 (Prebake) 16.7 (Soderberg)
Cathode (carbon)	2

and some anthracite are used to make anodes and cathodes for the aluminum reduction process.

Products

Alumina and aluminum metal are the primary products of the industry. Much smaller amounts of aluminum hydroxide, sodium aluminate, and aluminum fluoride are also made by a few plants. The alumina is used largely in the aluminum smelting industry, and the aluminum is used for manufactured products.

Companies

The primary product of most aluminum companies is aluminum metal cast in a variety of rough shapes such as sheets, billets, and wire.

Table 2 lists the aluminum plants in this country, their approximate capacities, and the type of cell used. Table 3 lists the alumina plants, their locations, and their capacity in 1971.

Environmental Impact

Waste sludge (red mud) is the primary pollution problem associated with bauxite processing. For each kilogram of alumina product, two kilograms of bauxite must be processed. Atmospheric emissions of particulate are caused by raw material and product handling, by calcining the hydrated alumina in a rotary furnace, and by sintering of the mud when required. Table 4 quantifies and characterizes liquid waste streams from U.S. bauxite refineries.

Atmospheric emissions of coke dust from crushing and screening operations occur in the electrode manufacturing process. Volatile hydrocarbons from the paste and binder mixing operations also occur. When prebaked electrodes are manufactured, atmospheric emissions of fluoride, hydrocarbons, and sulfur oxides also occur. The fluoride compounds come from the recycled anode scrap material from the aluminum smelting operation. Emissions of SO_x and total fluorides amount to between 0.35 to 1.0 and 0.15 to 0.75 percent of aluminum produced, respectively.[8]

Primary aluminum reduction mainly causes atmospheric emissions of particulate and gaseous fluorides. Emissions vary with the type of reduction cell and with the type of hooding and control device utilized. Approximately 20 to 30 grams of fluoride are evolved per kilogram of aluminum (40 to 60 pounds/ton), with the gaseous fluorides accounting for up to about 60 percent of the total emissions.[3,7] On the average about 25 to 30 percent of this emission escapes to the atmosphere from the cell. Total particulate (including solid fluoride) emissions from the cell have not been well quantified, but amount to approximately 45 grams/kg of product (90 pounds per ton).[7]

Table 2. PRIMARY ALUMINUM PLANT LOCATIONS AND CAPACITY[3,4]

	Capacity[a]	Anode type		
		Soderberg		Pre-baked
		Vertical	Horiz.	
Aluminum Company of America				
Alcoa, Tennessee	265	X		X
Badin, North Carolina	115			X
Massena, New York	130			X
Point Comfort, Texas	184	X		
Rockdale, Texas	280			X
Vancouver, Washington	100			X
Warrick, Indiana	225			X
Wenatchee, Washington	175			X
Anaconda Aluminum Company				
Columbia Falls, Montana	180	X		
Sebree, Kentucky	120			X
Consolidated Aluminum Corp.				
New Johnsonville, Tennessee	140			X
Lake Charles, Louisiana	35			X
Eastalco Aluminum Company				
Frederick, Maryland	87			X
Martin-Marietta Aluminum Inc.				
The Dalles, Oregon	91	X		
Goldendale, Washington	110	X		
Intalco Aluminum Co.				
Ferndale, Washington	265			X
Kaiser Aluminum and Chem. Corp.				
Chalmette, Louisiana	260		X	
Mead, Washington	206			X
Ravenswood, West Virginia	163			X
Tacoma, Washington	81		X	
National-Southwire Aluminum Co.				
Hawesville, Kentucky	180			X
North West Aluminum Co.				
Astoria, Oregon	68			
Noranda Aluminum, Inc.				
New Madrid, Missouri	70			X
Ormet Corporation				
Hannibal, Ohio	250			X
Revere Copper and Brass, Inc.				
Scottsboro, Alabama	112			X
Reynolds Metals Co.				
Arkadelphia, Arkansas	63		X	X
Jones Mills, Arkansas	122			X
Listerhill, Alabama	221		X	
Longview, Washington	190		X	
Massena, New York	128		X	
Corpus Christi, Texas	111		X	
Troutdale, Oregon	140			X
Total - 32 plants	4868			

[a] Capacity is a variable value. Stated values are estimates expressed in 1000 short tons.

Table 3. ALUMINA PLANTS[2]

Company and location	Capacity[a]
Aluminum Company of America	
Bauxite, Arkansas	375
Mobile, Alabama	1,025
Point Comfort, Texas	1,350
Martin-Marietta Aluminum Inc.	
St. Croix, Virgin Islands	350
Kaiser Aluminum and Chemical Corp.	
Baton Rouge, Louisiana	1,025
Gramercy, Louisiana	800
Ormet Corp.	
Burnside, Louisiana	580
Reynolds Metals Co.	
Hurricane Creek, Arkansas	840
Corpus Christi, Texas	1,380
Total	7,725

[a] 1000 short tons per year. Capacity varies with bauxite feed.
0.906 metric tons = 1 short ton

Table 4. CHARACTERIZATION OF PRINCIPAL WASTE STREAMS FROM U.S. BAUXITE REFINERIES[10]

Waste	Quantity	Characterization
Red Mud	500-3600 T/D (dry basis) 1,000-7,200 T/D (wet, settled) 3,000-20,000 T/D (slurry at 18% solids)	15-20% solids 5-12 g/l soda 2-5 g/l aluminum pH - 12.5
Spent Cleaning Acid	Variable, 5-10 T/week intermittently discharged	Na_2SO_4, plus some free H_2SO_4 HCl or HAc may also be used pH - 0
Salts from salting - out evaporator	Variable-estimated up to several thousand kg/day	Na_2SO_4 - alkaline pH - 12.5
Barometric condenser, cooling water	Millions of liters/hr	Temp. rise of up to 15°C (25°F) may contain traces entrained alkali
Boiler and cooling tower blowdown	Variable-thousands of liters/day	Dilute alkaline solutions pH - 12.5
Water softener sludge	One to few T/D	Lime and suspended solids from intake water
Sanitary waste	375 liters/D/capita	B.O.D. 70 g(0.15 lb)/day/capita

An overall control efficiency of 70 to 80 percent for fluoride emissions is achieved by most plants. A primary control system vents the cell, and the pollutants captured in this system are reduced by about 95+ percent with wet scrubbers, electrostatic precipitators, or alumina coated fabric filters. The emissions that escape from the cell are vented through the cell building roof. A number of plants are now venting the entire cell room gases through low pressure drop baffled spray systems to reduce emissions.

Recovery of fluoride compounds from dry sorption systems employing fabric filters or from the scrubber sludges is practiced at some plants.

Sources of waste water from primary aluminum reduction include wet scrubbing, boiler blowdown, and cooling water. The reported volume of solid wastes resulting from water treatment in a number of plants was 15 to 30 kg per metric ton of aluminum produced.[9] These solid wastes are composed of cryolite, carbon, and calcium fluoride sludge. Spent carbon cathode pot linings are another source of solid waste. The estimated annual volume of such wastes produced is 1200 cubic meters (about one acre foot).[9] The Office of Solid Waste Management Programs is currently sponsoring an investigation of the wastes and disposal technologies for the primary metals industry which includes aluminum production. These results will be available in the near future.[11]

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(1) Saxton, J. C. and M. Kramer, EPA Findings on Solid Wastes from Industrial Chemicals, Chem. Eng., April 28, 1975, p. 107-111.

(2) Stamper, J. W., Aluminum, In: Minerals Yearbook, Vol. 1, U.S. Bureau of Mines, 1972.

(3) Crane, G. and B. A. Varner, Guidelines for State Emission Standards for Primary Aluminum Plant Fluorides - Draft, U.S. EPA, Office of Air Quality and Planning and Standards. Research Triangle Park, North Carolina.

(4) Chem. Sources - U.S.A., Directories Publishing Co. Inc., New Jersey, 1975.

(5) Characteristics of Population, Bureau of Census, 1970.

(6) Wall Street Journal, June 5, 1975.

(7) Air Pollution Control in the Primary Aluminum Industry, Singmaster and Breyer Co., EPA Publication 450/3-73-004A, pg. 4-11.

(8) Trace Pollutant Emissions from the Processing of Metallic Ores, EPA Publication 650/2-74-115, October 1974.

(9) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Primary Aluminum Smelting Subcategory of the Aluminum Segment of the Nonferrous Metals Manufacturing Point Source Category, EPA Publication 440/1-74-019-3, 1974.

(10) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Bauxite Refining Subcategory of the Aluminum Segment of the Nonferrous Metals Manufacturing Point Source Category. EPA Publication 440/1-74-019-C, 1974.

(11) Pierce, Alan, Office of Solid Waste Management Programs, EPA, Cincinnati, Ohio, personal communication, September, 1975.

INDUSTRY ANALYSIS

The environmental impact of the primary aluminum industry has received wide attention because of the atmospheric emissions of fluorides. Emission and processing data for the electrolytic reduction and electrode production segments of this industry have been fairly well defined in the recent EPA studies cited in references 3, 7, and 8 of the bibliography. Emission data on bauxite processing are, however, very sparse.

Information for this study was obtained from the literature and in-house experience in this industry. Descriptions of three industry segments are provided; namely bauxite processing to yield alumina, electrode production, and alumina reduction to aluminum. Separate process flow sheets are provided for each segment.

Bauxite Processing

This segment of the primary aluminum manufacturing industry includes those processes required to reduce bauxite ore to alumina. About 10 percent of the bauxite processed in this country is mined here; the balance is imported. About 90 to 95 percent of the bauxite is processed to alumina. Five process steps have been identified for this segment. As shown in Figure 1, three of these steps are involved in the direct production of alumina, and two alternate steps are involved in the processing of the waste sludge or red mud.

The major environmental problems associated with this industry segment are disposal of sludge and emission of particulates from the material handling and calcining operations. Bauxite processing is mainly performed near mining areas or ore receiving terminals.

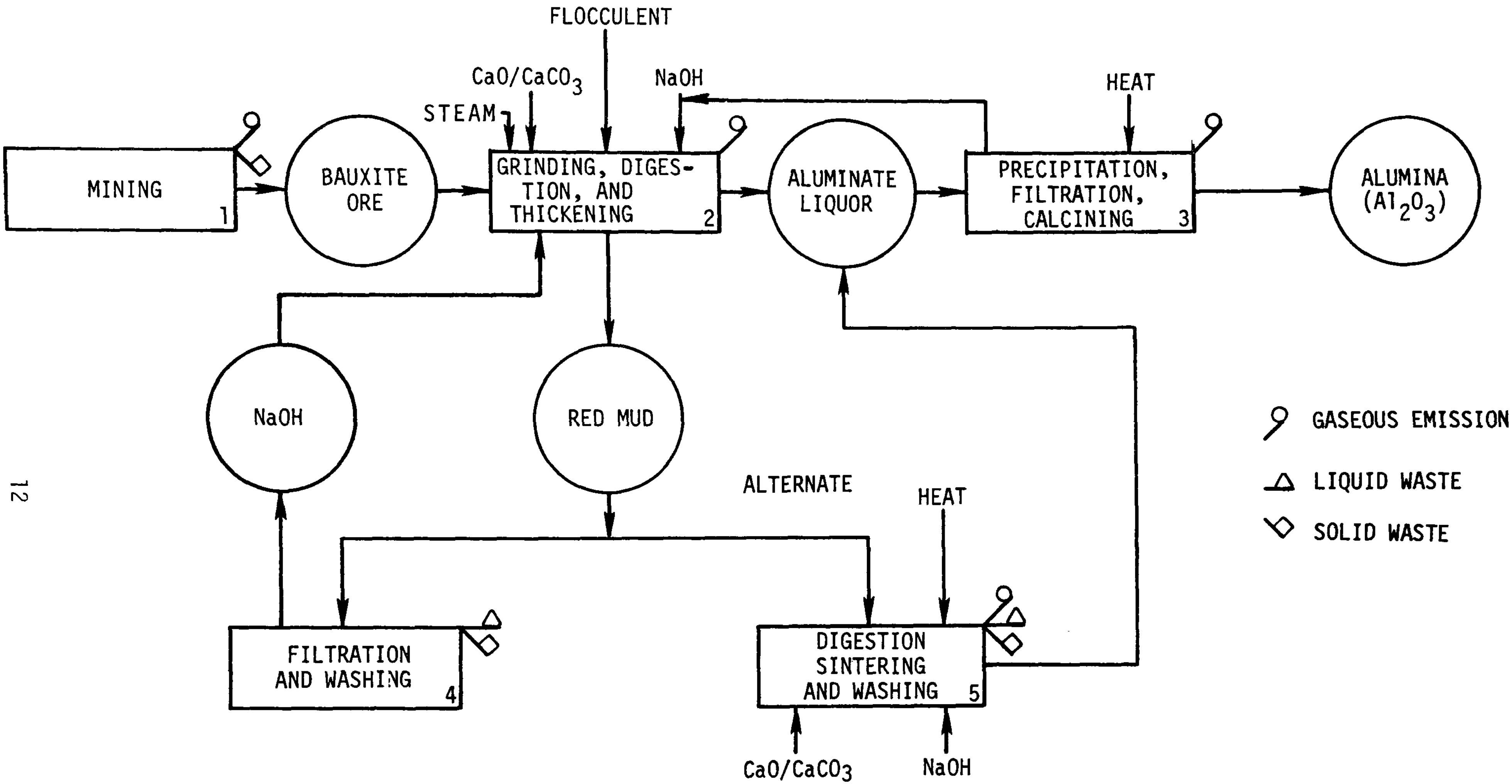

Figure 1. BAUXITE PROCESSING TO ALUMINA

Mining

1. Function - Mining is primarily accomplished by quarrying the ore in open pits. The ore is blasted loose and then shoveled via draglines, conveyors, and other heavy earth-moving equipment to transfer areas for shipping via rail and/or ship. Some bauxite contains up to 30 percent moisture and may be dried at 110°C before shipping.
2. Input Materials - Ore deposits, dynamite.
3. Operating Parameters - Open-pit mine.
4. Utilities - Fuel and water for drilling.
5. Waste Streams - Overburden, fugitive dust, and water runoff from mined areas.
6. EPA Source Classification Code - None exists.
7. References -

(1) Air Pollution Control in the Primary Aluminum Industry. Singmaster and Breyer Co., EPA Publication 450/3-73-004A.

(2) Crane, G. and B. A. Varner, Guidelines for State Emission Standards for Primary Aluminum Plant Fluorides - Draft, U.S. EPA, Office of Air Quality and Planning and Standards, Research Triangle Park, North Carolina.

Grinding, Digestion, and Thickening

1. Function - The raw ore is beneficiated by grinding to about 100 mesh, digested in caustic at elevated temperatures and pressures (Bayer digestor), and then filtered or thickened in the presence of flocculants. Lime may also be added to the digestor, depending on the ore's composition. These steps yield a sodium aluminate liquor and a waste stream of "red mud" which contains the impurities in the bauxite ore.

2. Input Materials - Bauxite Ore - The quantity of ore required varies from 1.3 to 3 times the amount of alumina obtained depending on the original alumina content. Typical ore analyses are provided in Appendix B. Caustic Solution - 2 moles of sodium hydroxide are required to stoichiometrically react with 1 mole of alumina. At a 30 percent excess, 1.5 kg of NaOH are required per kg of alumina. However most of this caustic is recycled and only a much smaller portion is required for make-up. Lime - Quantity varies with ore.

3. Operating Parameters - Grinding and mixing take place at ambient conditions. Digestion takes place at approximately 145°C and 4.2 kg/cm^2 (290°F and 60 psig).

4. Utilities - Water: Approximately 3.5 kg per kg of alumina. Steam is required to heat the digestor and electricity is required to drive pumps and fans.

5. Waste Streams - Red mud, a waste slurry, is the main waste stream from this process. Typical compositions of this stream are shown in Table 5. Depending on the type of bauxite processed, from 1/3 to 2 kg of red mud is produced for each kg of alumina product.[5] Uncontrolled atmospheric particulate emissions amount to approximately 0.003 kg per kg of bauxite processed (6 lb/ton).[4] Atmospheric emissions are usually well controlled.

Table 5. CHEMICAL ANALYSES OF RED MUDS[3]

Component	Weight percent		
	Surinam	Arkansas	Jamaica
Fe_2O_3	30-40	55-60	50-54
Al_2O_3	16-20	12-15	11-13
SiO_2	11-14	4-5	2.5-6
TiO_2	10-11	4-5	trace
CaO	5-6	5-10	6.5-8.5
Na_2O	6-8	2	1.5-5.0
Loss on ignition	10.7-11.4	5-10	10-13

6. EPA Source Classification Code - 3-03-000-01.

7. References -

(1) Air Pollution Control in the Primary Aluminum Industry, Singmaster and Breyer Co., EPA Publication 450/3-73-004A.

(2) Crane, G. and B. A. Varner, Guidelines for State Emission Standards for Primary Aluminum Plant Fluorides - Draft, U. S. EPA, Office of Air Quality and Planning and Standards, Research Triangle Park, North Carolina.

(3) Trace Pollutant Emission from the Processing of Metallic Ores, EPA Publication 650/2-74-115, October 1974.

(4) Vandergrift, A. E. et al., Particulate Pollutant Systems Study, Vol. 1, Mass Emissions, Midwest Research Institute, APTD 0743, May 1, 1971.

(5) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Bauxite Refining Subcategory of the Aluminum Segment of the Nonferrous Metals Manufacturing Point Source Category, EPA Publication 440/1-74-019-C, 1974.

Precipitation, Filtration, and Calcining

1. Function - The rich sodium aluminate (Na_2AlO_2) solution is hydrolyzed to aluminum hydroxide which is precipitated by cooling the solution. The precipitate is filtered and washed, and the wash solution and filtrate are concentrated and recycled. The aluminum hydroxide precipitate is calcined to alumina product in a rotary kiln or furnace.

2. Input Materials - The aluminate liquor from Process No. 2 is the only input material.

3. Operating Parameters - Precipitation is accomplished at approximately ambient conditions. Calcining occurs at about 1000°C (1800°F) in the presence of excess air.

4. Utilities - Oil or gas fuel for calcining; approximately 516 gm-cal/kg (3.7×10^6 BTU/ton of product).[a]

5. Waste Streams - Atmospheric emissions of particulate amounting to approximately 10 percent of the alumina product are evolved[4] (0.1 kg per kg of alumina or 200 lb/ton). Particulate control devices are utilized to reduce emissions. Water vapor is also emitted along with smaller amounts of combustion products.

6. EPA Source Classification Code - 3-03-000-01.

7. References -

(1) Air Pollution Control in the Primary Aluminum Industry, Singmaster and Breyer Co., EPA Publication 450/3-73-004A.

(2) Crane, G. and B. A. Varner, Guidelines for State Emission Standards for Primary Aluminum Plant Fluorides - Draft, U. S. EPA, Office of Air Quality and Planning and Standards, Research Triangle Park, North Carolina.

(3) Shreve, R. N., Chemical Process Industries, 3rd. Edition, McGraw-Hill Book Co., New York, 1967, pg. 353-354.

(4) Vandergrift, A. E. et al., Particulate Pollutant Systems Study, Vol. 1, Mass Emissions, Midwest Research Institute, APTD 0743, May 1, 1971.

[a] Estimate based on cement manufacture.

Red Mud Filtration and Washing

1. Function - The primary purpose of this step is to recover caustic and additional alumina compounds which can be recycled to the digestor in Process No. 2. This is accomplished by filtration and/or washing of the sludge. The filtrate (or wash liquor) is then concentrated and recycled.
2. Input Material - Red mud slurry from the thickener in Process No. 2.
3. Operating Parameters - Ambient conditions.
4. Utilities - Water and electricity for pumping.
5. Waste Streams - Approximately 1 kg of filter cake or washed sludge is dumped into tailings ponds per kg of alumina product.
6. EPA Source Classification Code - None
7. References -

(1) Air Pollution Control in the Primary Aluminum Industry, Singmaster and Breyer Co., EPA Publication 450/3-73-004A.

(2) Crane, G. and B. A. Varner, Guidelines for State Emission Standards for Primary Aluminum Plant Fluorides - Draft, U. S. EPA, Office of Air Quality and Planning and Standards, Research Triangle Park, North Carolina.

Red Mud Digestion and Sintering

1. Function - Additional processing of red mud from high silica (8% or more) bauxite is performed at some plants to recover alumina. The red mud is digested with caustic and lime or limestone and sintered to convert silica to calcium silicate (brown mud). The sintered material is reacted with water and filtered. The soluble sodium aluminate is recycled.
2. Input Materials - Red mud, caustic solution and lime or limestone are utilized.
3. Operating Parameters - The digestion is accomplished at approximately 145°C and 4.2 kg/cm^2 (290°F and 60 psig), similar to that in Process No. 2. Sintering is accomplished at 1100 to 1200°C.
4. Utilities - Gas and/or oil for the sintering step is required.
5. Waste Streams - Brown mud (calcium silicate) and other impurties in the bauxite occur as waste. On the order of 1 kg of mud is formed per kg of alumina. Brown mud has limited uses in cement manufacture.
6. EPA Source Classification Code - None
7. References -

(1) Air Pollution Control in the Primary Aluminum Industry, Singmaster and Breyer Co., EPA Publication 450/3-73-004A.

(2) Crane, G. and B. A. Varner, Guidelines for State Emission Standards for Primary Aluminum Plant Fluorides - Draft, U. S. EPA, Office of Air Quality and Planning and Standards, Research Triangle Park, North Carolina.

Electrode Preparation

The electrode preparation segment of the primary aluminum industry involves two processes to produce the anode and cathode electrodes used in the electrolytic reduction of alumina. Electrode preparation is usually performed near the alumina reduction process.

Figure 2 is a flow sheet of this segment of the industry. Particulate and fluoride emissions to the atmosphere are the primary environmental problems associated with this segment.

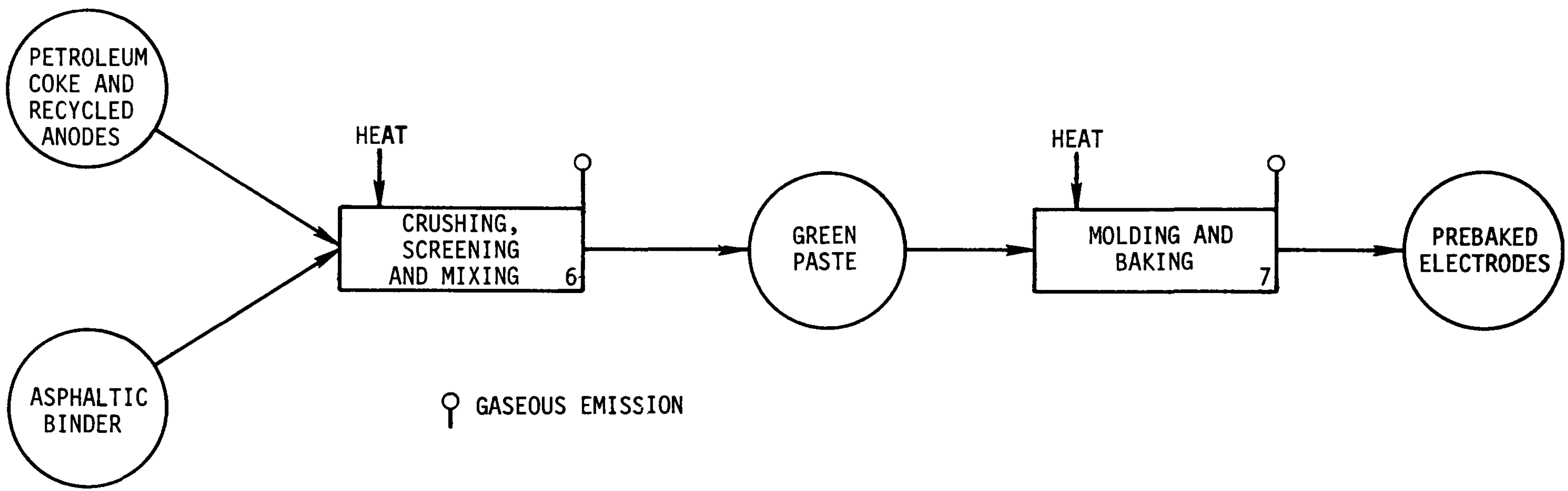

FIGURE 2. ELECTRODE PREPARATION

Crushing, Screening, and Mixing

1. Function - This process sizes and mixes the carbon in the form of petroleum coke, recycled scrap anode material, and asphaltic binder into a homogenous paste.
2. Input Materials - Raw material requirements are described in Table 6.

Table 6. INPUT MATERIALS FOR ELECTRODE PREPARATION (kg/kg ALUMINUM)

Anode Type	Petroleum Coke	Asphalt Pitch Binder	Total
Prebake anode	0.49	0.12	0.61
Paste (Soderberg)	0.45	0.17	0.62

3. Operating Parameters - Mixing of the ingredients takes place in jacketed heaters at 95°C (200°F) at atmospheric pressure.
4. Utilities - Electricity is required to power the ball and hammer mill grinders. Steam is used to heat the mixing chamber and asphalt binder.
5. Waste Streams - Particulate emissions occur from conveying, grinding and mixing transfer points. These sources are usually controlled to some extent. Volatile hydrocarbons from the binder are also vented. Quantitative emission data are not available.
6. EPA Source Classification Code - 3-03-001-04.
7. References -

(1) Air Pollution Control in the Primary Aluminum Industry, Singmaster and Breyer Co., EPA Publication 450/3-73-004A.

(2) Crane, G. and B. A. Varner, Guidelines for State Emission Standards for Primary Aluminum Plant Fluorides - Draft, U. S. EPA, Office of Air Quality and Planning and Standards, Research Triangle Park, North Carolina.

Molding and Baking

1. Function - This process is performed only when the prebaked anode cell system is used. The green paste is molded into the anode shape and then baked at elevated temperatures for about 40 hours to form a solid carbon electrode. In the Soderberg cell system the green paste is transferred directly to the electrolytic reduction cell and the molding and baking process is not required.
2. Input Materials - Green paste from Process No. 6.
3. Operating Parameters - Molding is accomplished by large presses. Baking is performed in sunken pits surrounded by interconnecting flues. The anode is slowly raised to its baking temperature of approximately 1200°C and held at that temperature for about 40 hours. The anode is then slowly cooled. The entire heating, baking, and cooling cycle requires about 28 days.
4. Utilities - Oil and/or gas.
5. Waste Streams - Broken and rejected anodes are recycled to Process No. 6. Atmospheric emissions occur as shown in Table 7.

Table 7. ATMOSPHERIC EMISSIONS FROM ANODE BAKING

Pollutant	Emissions, % of aluminum product[1,3]
Particulate	0.15 (0.1 to 0.5)
Hydrocarbons	0.025 to 0.075
Total fluorides	0.047 (0.015 to 0.075)
Sulfur	0.035 to 0.1

The fluorides occur almost entirely in the gaseous form.

6. EPA Source Classification Code - 3-03-001-05.
7. References-

(1) Air Pollution Control in the Primary Aluminum INdustry, Singmaster and Breyer Co., EPA Publication 450/3-73-004A.

(2) Crane, G. and B. A. Varner, Guidelines for State Emission Standards for Primary Aluminum Plant Fluorides - Draft, U. S. EPA, Office of Air Quality and Planning and Standards, Research Triangle Park, North Carolina.

(3) Compilation of Air Pollutant Emission Factors EPA Publication AP-40, 2nd edition, April 1973, pg. 7.1-5 and 7.1-6.

Aluminum Production

This industry segment includes the electrolytic reduction of alumina to aluminum (the Hall-Heroult process) and the casting and refining of the aluminum before it is shipped to other companies for rolling and casting. Figure 3 is a process flow sheet for this industry segment. It includes two processes; namely, the electrolytic reduction step, and the refining and casting steps.

Because of the extremely large electrical requirements, electrolytic reduction is always performed near sources of relatively inexpensive electricity. Atmospheric emissions of fluorides and the emissions resulting from fuel combustion required to generate the large electrical demand are the major environmental problems associated with this industry segment. Emission data are fairly well documented.

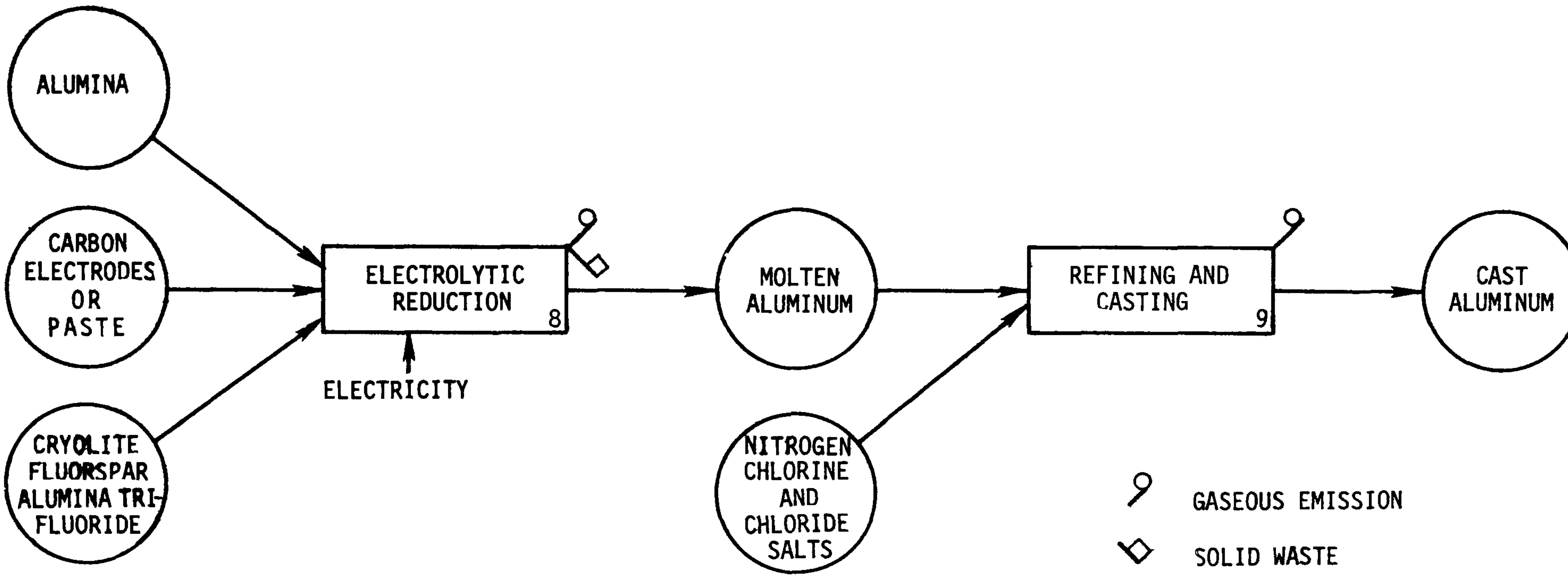

FIGURE 3. ELECTROLYTIC REDUCTION OF ALUMINA TO ALUMINUM

Electrolytic Reduction

1. Function - Alumina is reduced to aluminum electrically according to the following reaction $Al_2O_3 + 1\ 1/2C \rightarrow 2Al + 1\ 1/2\ CO_2$. This reduction is carried out in long rows of cells or pots made of carbon lined steel with carbon anodes suspended above the cell. The carbon lining serves as the cathode and the suspended carbon, the anode. Synthetic cryolite (Na_3AlF_6) serves as an electrolyte and solvent for the alumina. During the reduction process, the carbon anode is consumed and combines with oxygen to form CO and CO_2. The reduced heavier aluminum sinks to the bottom of the cell and is periodically tapped. Fresh alumina and cryolite are added periodically to the top of the melt.

2. Input Materials - The following raw materials are required per kg of aluminum product:

Alumina	1.9 kg
Carbon (electrodes)	0.62 kg
Cryolite	0.04 kg

3. Operating Parameters - The individual cells operate between 950 and 1000°C. This heat is generated by the flow of electricity between the two electrodes. A current of about 100,000 amps at 4.5 volts is typical. The cells are maintained at a slight negative pressure to reduce emissions into the cell room.

4. Utilties - 13.2 to 19.8 kWh/kg of aluminum (6 to 9 kWh per pound).

5. Waste Streams - Atmospheric emissions from the cell are described in Table 8. In addition, polynuclear hydrocarbons are generated from organic compounds in the electrodes. The SO_2 emissions originate from sulfur in the electrode materials.

Table 8. ATMOSPHERIC EMISSIONS FROM ELECTROLYTIC REDUCTION OF ALUMINA

Component	Average emission rate,[a] expressed as % of aluminum product
SO_2	3
Gaseous fluorides	1.2 (0.7 - 1.7)
Solid fluorides	1.0 (0.5 - 1.8)
Total particulate	4.6 (0.6 - 8.8)

[a]Based on Reference 3 and industry questionnaire data in Reference 1.

A wide variety of control devices are in use to reduce both particulate and gaseous emissions.

Particle size data from samples collected in the primary cell vent system are shown in Appendix C. These data show that 50 percent of the particles by weight are smaller than about 1 to 3 microns.

Solid waste in the form of prebaked anode butts is recycled to the electrode preparation plant.

6. EPA Source Classification Code -

Prebake type cell: 3-03-001-01

Horizontal stud Soderberg cell: 3-03-001-02

Vertical stud Soderberg cell: 3-03-001-03

7. References -

(1) Air Pollution Control in the Primary Aluminum Industry, Singmaster and Breyer Co., EPA Publication 450/3-73-004A.

(2) Crane, G. and B. A. Varner, Guidelines for State Emission Standards for Primary Aluminum Plant Fluorides - Draft, U. S. EPA, Office of Air Quality and Planning and Standards, Research Triangle Park, North Carolina.

(3) Compilation of Air Pollutant Emission Factors EPA Publication AP-40, 2nd edition, April 1973, pg. 7.1-5 and 7.1-6.

Refining and Casting

1. Function - Molten aluminum is tapped (siphoned) from the reduction cells into crucibles and transferred to gas-fired holding furnaces or cast in large sows for later remelt. Refining is accomplished by fluxing with gas or various salts to remove oxides and gas inclusions.
2. Input Materials - Raw molten aluminum; flux gases such as mixtures of chlorine and nitrogen or flux salts as hexachloroethane, aluminum chloride, or magnesium chloride are used.
3. Operating Parameters - Refining and casting occur at approximately 700°C and atmospheric pressure in gas-fired, hooded furnaces.
4. Utilities - Natural gas and/or electricity are required to maintain the aluminum in a molten state.
5. Waste Streams - Dross is skimmed from the bath and treated to recover any aluminum. Residual slag containing chloride flux salts is a solid waste which is usually sent to landfill. Emissions of aluminum chloride are evolved when gaseous chlorine is used for fluxing. Traces of gaseous fluorides may also be emitted.
6. EPA Source Classification Code - 3-03-001-99.
7. References -

(1) Air Pollution Control in the Primary Aluminum Industry, Singmaster and Breyer Co., EPA Publication 450/3-73-004A.

(2) Crane, G. and B. A. Varner, Guidelines for State Emission Standards for Primary Aluminum Plant Fluorides - Draft, U. S. EPA, Office of Air Quality and Planning and Standards, Research Triangle Park, North Carolina.

APPENDIX A

ALUMINUM COMPANY PRODUCT LISTING

Table A-1. ALUMINUM COMPANY PRODUCT LISTING[a]

Aluminum Co. of America

- Aluminum
- Alumina
- Alumina gel
- Aluminum fluoride and sodium aluminum fluoride
- Aluminum hydroxide
- Calcium cement
- Chlorine
- Gallium metal and salts
- Hydrofluoric acid
- Sodium hydroxide

Anaconda Aluminum Company,
Division of the Anaconda Company

- Aluminum

Consolidated Aluminum Corporation

- Aluminum

Eastalco Aluminum Company
(Subsidiary of Howmet Corporation)

- Aluminum

Gulf Coast Aluminum Corporation
(Division of Consolidated Aluminum Corp.)

- Aluminum

Intalco Aluminum Company

- Aluminum

Kaiser Aluminum & Chemical Corporation
Kaiser Aluminum Division

- Aluminum (Chemicals Div. makes alumina)
- Calcined coke

Martin Marietta Aluminum Inc.
(Formerly Harvey Aluminum Inc.)

- Aluminum
- Alumina (In Virgin Islands)

Table A-1 (Continued). ALUMINUM COMPANY PRODUCT LISTING[a]

National-Southwire Aluminum Company

Aluminum

Noranda

Aluminum

Northwest Aluminum Company

Aluminum

Ormet

Aluminum
Alumina

Revere Copper & Brass, Inc.

Aluminum

Reynolds Metals Company

Aluminum
Alumina
Aluminum hydroxide
Calcium fluoride
Pet. coke compounds
PVC
Sodium aluminate, sodium aluminum fluoride

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[a] Chemical Sources
1974 Directory of Chemical Producers SRI

APPENDIX B

CHEMICAL COMPOSITION OF BAUXITES

Table B-1. CHEMICAL COMPOSITION OF DOMESTIC BAUXITES (WEIGHT PERCENT)

	Arkansas	Oregon	Washington	Hawaii
Al_2O_3	40-60	35.0	38.8	25.9
SiO_2	1-20	6.7	6.6	4.7
Fe_2O_3	3-6	31.5	28.7	39.4
TiO_2	1-3	6.5	4.2	6.7
Loss on ignition	15.35	20.2	21.7	20-23

Table B-2. CHEMICAL COMPOSITION OF IMPORTED BAUXITES (WEIGHT PERCENT)

	Jamaica	Surinam	Guinea
Al_2O_3, total	49.0	59.8	58.6
SiO_2	0.8	3.8	4.9
Fe_2O_3	18.4	2.7	4.1
TiO_2	2.4	2.4	2.5
F	-	-	0.02
P_2O_5	0.7	0.06	-
V_2O_5	-	0.04	-
H_2O, combined	27.5	31.2	29.6
Al_2O_3, trihydrate	50-47	59.6	52.7
Al_2O_3, monohydrate	2-9	0.2	5.9

APPENDIX C

SIZE OF PARTICULATES FROM REDUCTION CELL VENT SYSTEM

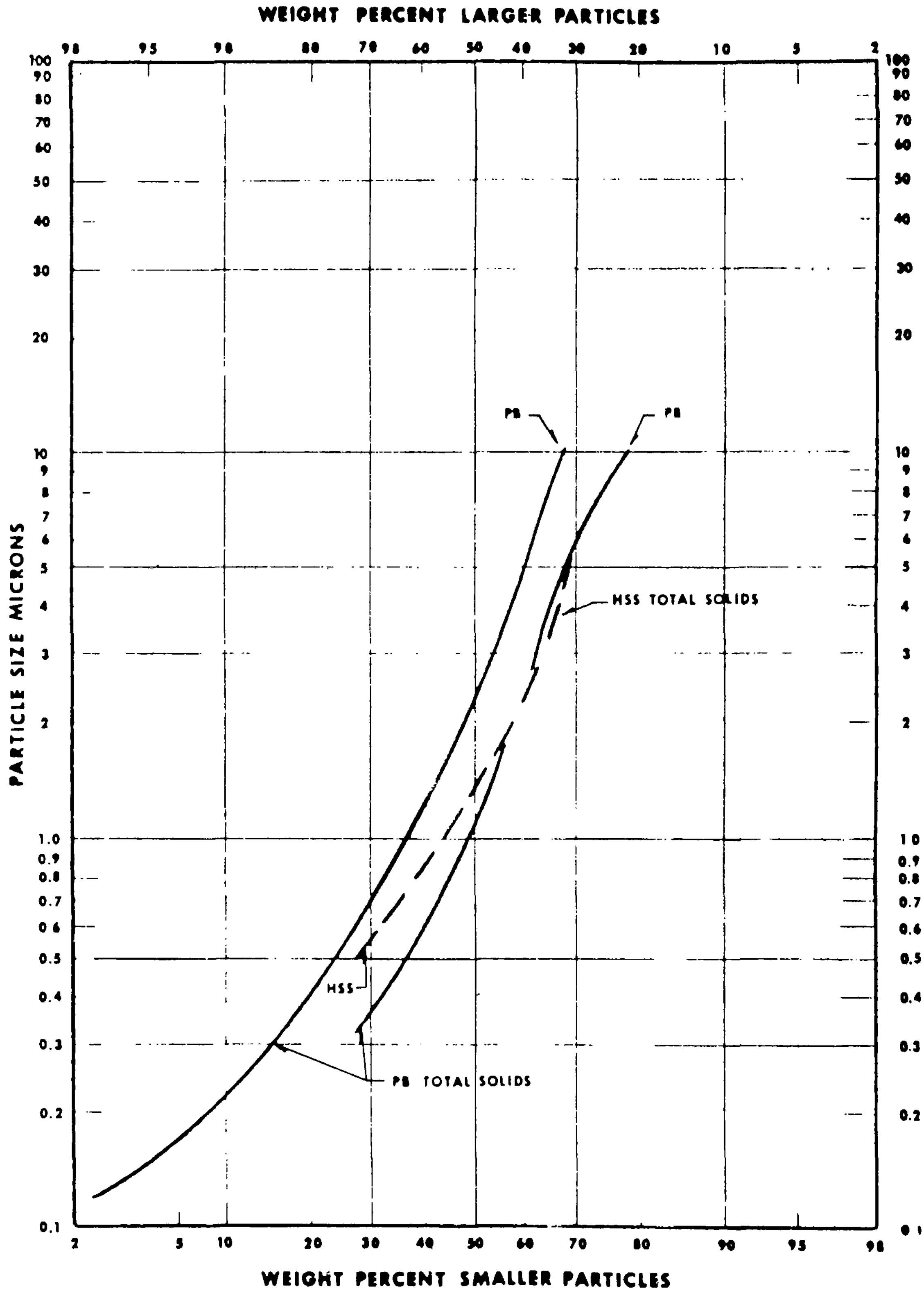

FIGURE C-1. PARTICLE SIZE WEIGHT DISTRIBUTION IN ALUMINA REDUCTION CELL POTLINE PRIMARY EFFLUENT[a]

Cell Design

PB - Prebake

HSS - Horizontal Stud Soderberg

[a]Source: Air Pollution Control in the Primary Aluminum Industry, Singmaster and Breyer Co., EPA Publication 450/3-73-004A.

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16. ABSTRACT

The catalog of Industrial Process Profiles for Environmental Use was developed as an aid in defining the environmental impacts of industrial activity in the United States. Entries for each industry are in consistent format and form separate chapters of the study.

The primary aluminum industry as defined for this study consists of processing bauxite ore to produce alumina and occasionally aluminum hydroxide and processing alumina to produce aluminum. The two main industry segments are bauxite processing to alumina and alumina processing to aluminum. These distinct and separate processes are not usually performed at the same site. A third industry segment electrode preparation is accomplished at the aluminum production site. Three industrial process flow sheets and nine process descriptions have been prepared to characterize the industry. Within each process description available data have been presented on input materials, operating parameters, utility requirements and waste streams. Data related to the subject matter including feedstock characteristics, and company/product listings are included as appendices.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Air Pollution Control	07B
Aluminum	Water Pollution Control	13B
Bauxite Ore	Solid Waste Control	11F
Alumina	Stationary Sources	
Aluminum Hydroxide	Nonferrous Metal Industry	
Reduction Electrodes	Aluminum Industry	
Process Description		

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