Primary Aluminum Industry: Technical Support Document for Proposed MACT Standards

U.S Environmental Protection Agency
Office of Air Quality Planning and Standards
Emission Standards Division
July 1996

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

The purpose of this technical support document is to provide a summary of the basic background information used in the development of maximum achievable control technology (MACT) standards for the primary aluminum industry. All references cited in this document are available in EPA's rulemaking docket for the primary aluminum source category. In addition, this document will be supplemented by technical memoranda to the docket to document those steps in the standards development process not covered here, such as the development of and rationale for subcategories, determination of the MACT floor and MACT, and the derivation of emission limits from the data presented in this document.

The balance of this chapter provides a summary of the statutory basis for MACT standards and the selection of the source category. Chapter 2 provides an overview of the industry, identifies plants, and describes the production operations. Emission control technologies and their performance are summarized in Chapter 3. Model plants are developed in Chapter 4 (for use in estimating potential impacts), and options for emission control and monitoring are discussed. Environmental and energy impacts are estimated for the model plants in Chapter 5. The estimated costs for emission control and monitoring are given in Chapter 6. Appendix A is a summary of key events leading to proposal, and Appendix B contains emissions data for individual compounds that comprise polycyclic organic matter (POM).

1.1 STATUTORY BASIS

Section 112 of the Clean Air Act as amended requires the development of national emission standards for hazardous air pollutants (NESHAP) for the control of hazardous air pollutants (HAP's) from both new and existing major or area sources. The statute requires the standard to reflect the maximum degree of reduction in emissions of HAP's that is achievable taking into consideration the cost of achieving the emission reduction, any nonair quality health and environmental reduction, and energy requirements. This level of control is commonly referred to as the maximum achievable control technology (MACT).

Emission reductions may be accomplished through application of measures, processes, methods, systems or techniques including, but not limited to: (1) reducing the volume of, or eliminating emissions of, such pollutants through process changes, substitution of materials, or other modifications, (2) enclosing systems or processes to eliminate emissions, (3) collecting, capturing, or treating such pollutants when released from a process, stack, storage or fugitive emissions point, (4) design, equipment, work practice, or operational standards (including requirements for operator training or certification) as provided in subsection (h), or (5) a combination of the above [section 112(d)(2)].

1.2 SELECTION OF SOURCE CATEGORY

Section 112 specifically directs the EPA to develop a list of all categories of all major and area sources as appropriate emitting one or more of the 189 HAP's listed in section 112(b). The EPA published an initial list of source categories on July 16, 1992 (57 FR 31576) and may amend the list at any time. A schedule for promulgation of standards for each source category was published on December 3, 1993 (58 FR 63941). Primary aluminum production is one of the 174 categories of sources listed. As defined in the EPA report, "Documentation for Developing the Initial Source Category List" (EPA-450/3-91-030), the category consists of plants engaged in producing primary aluminum by electrolytically reducing alumina, including but not limited to, the following process units: (1) carbon mix plants, (2) reduction plants, (3) anode bake plants, (4) holding furnaces in the casting area, (5) casting processes, and (6) refining processes. The listing was based on the Administrator's determination that primary aluminum plants may reasonably be anticipated to emit several of the 189 listed HAP's in sufficient quantity to be designated as major sources.

Typically, primary aluminum plants are components of larger facilities that prepare a variety of finished products. The source category does not include holding furnaces, casting, or refining processes because EPA has determined that emissions from these sources are more appropriately controlled under the source category for secondary aluminum, which is also a 7-year standard. MACT standards for secondary aluminum production are being developed separately and are not addressed in this document. The EPA schedule for promulgation of the Section 112 emission standards (58 FR 63941, December 3, 1993), requires MACT rules for the aluminum source category to be promulgated by November 15, 1997. If MACT standards for this source category are not promulgated by May 15, 1999 (18 months following the promulgation deadline), Section 112(j) of the Act requires States or local agencies with approved permit programs to issue permits or revise existing permits containing either an equivalent emission limitation or an alternative emission limitation for HAP control. Additional information is available in EPA's Guidelines for MACT Determinations under Section 112(j), (EPA 453/R-94-026, May 1994).

2.0 THE PRIMARY ALUMINUM INDUSTRY

This chapter presents an overview of the primary aluminum production industry and focuses on aluminum production, anode paste production, and anode baking processes. This chapter also presents a brief discussion of baseline regulations and baseline emissions for these processes.

2.1 INDUSTRY PROFILE

As of June 1994, the primary aluminum industry in the U.S. consisted of 23 plants located in 14 States (Table 2-1). They are owned by 11 companies, many of which also own and operate plants in other countries. The types of reduction processes used in the individual plants are also shown in Table 2-1.

2.2 GENERAL PLANT DESCRIPTION

The major components of a primary aluminum plant are:

- shipping and receiving areas for raw materials and finished product;
- one or more potlines where alumina (Al_2O_3) is reduced into aluminum in a cryolite (Na_3AlF_6) electrolytic bath;
- a cast house where the aluminum is reheated and purified, its characteristics are modified to meet various specifications, and it is cast into solid forms including ingots and billets, or transported in a molten state;
- a rectifier for converting alternating current (AC) voltage into the direct current (DC) voltage used in the reduction process;
- maintenance and repair facilities;
- an anode paste plant, where coke and pitch are mixed to form anode paste, briquettes, or green anodes; and
- an anode bake plant (located only at facilities using the prebake process).

TABLE 2-1. PRIMARY ALUMINUM PRODUCTION PLANTS IN THE U.S.[1]

State	Plant name and location	Type of plant
Indiana	Alcoa, Newburgh (Warrick)	Center-worked prebake
Kentucky	NSA, Hawesville	Center-worked prebake
	Alcan, Henderson	Center-worked prebake
Maryland	Eastalco, Frederick (Alumax)	Side-worked prebake
Missouri	Noranda, New Madrid	Center-worked prebake
Montana	Columbia Falls, Columbia Falls	Vertical stud Soderberg
New York	Alcoa, Massena	Center-worked prebake
	Reynolds, Massena	Horizontal stud Soderberg
North Carolina	Alcoa, Badin	Center-worked prebake
Ohio	Ormet, Hannibal	Center-worked prebake
Oregon	Reynolds, Troutdale	Center-worked prebake
	Northwest, The Dalles	Vertical stud Soderberg
South Carolina	Alumax, Goose Creek (Mount Holly)	Center-worked prebake
Tennessee	Alcoa, Alcoa	Center-worked prebake
Texas	Alcoa, Rockdale	Center-worked prebake
Washington	Intalco, Ferndale (Alumax)	Side-worked prebake
	Kaiser, Mead	Center-worked prebake
	Kaiser, Tacoma	Horizontal stud Soderberg
	Alcoa, Wenatchee	Center-worked prebake
	Reynolds, Longview	Horizontal stud Soderberg
	Columbia, Goldendale	Vertical stud Soderberg
	Vanalco, Vancouver	Center-worked prebake
West Virginia	Ravenswood, Ravenswood	Center-worked prebake

A simplified diagram of a typical Soderberg plant showing material flow patterns is provided in Figure 2-1. Similarly, Figure 2-2 shows a simplified schematic of the process operations performed in a typical prebake plant.

An aluminum reduction potline is typically housed in one or two long, narrow buildings called potrooms. A potline is made up of a series of electrically connected cells called aluminum reduction pots. The pots are shallow, rectangular vessels that may be lined up side-by-side or end-to-end in one or more rows down the center of the potroom. The pots are large heat sources; consequently, the potrooms are ventilated to maintain reasonable working conditions and to help with proper pot operation. Usually this ventilation air enters at the sides of a potroom and

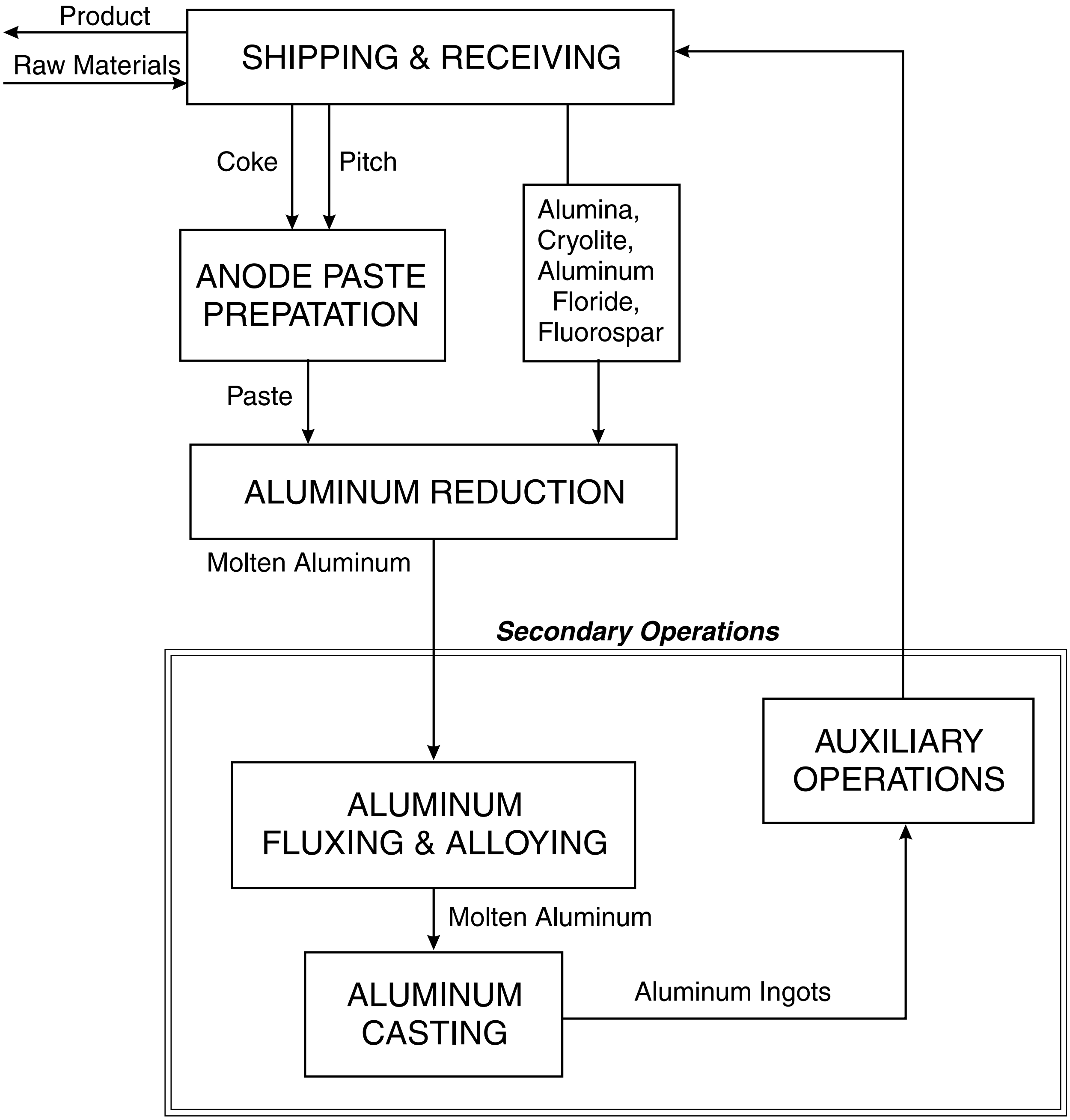

FIGURE 2-1. PROCESS FLOW DIAGRAM FOR A SODERBERG PLANT[2]

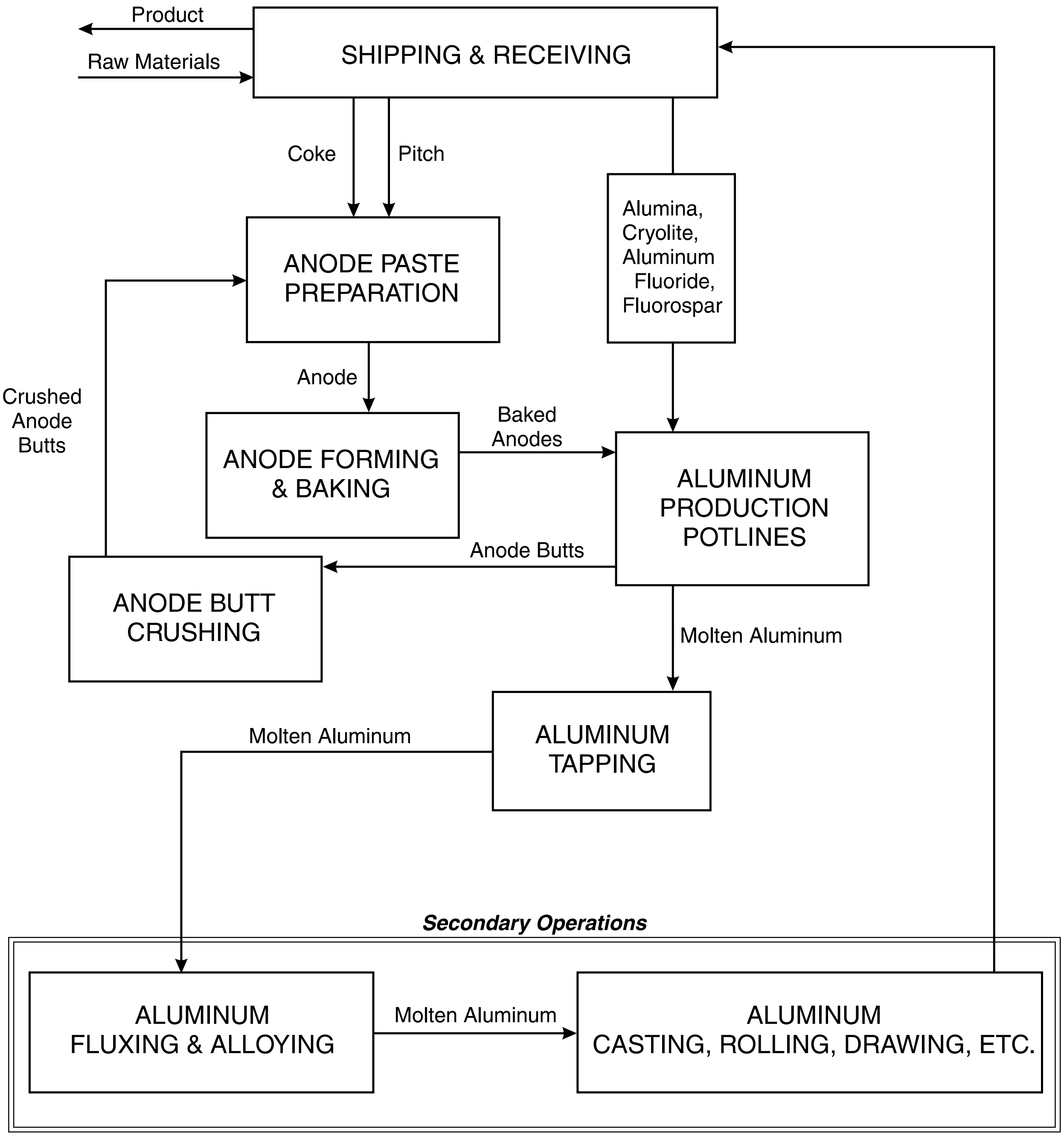

FIGURE 2-2. PROCESS FLOW DIAGRAM FOR A PREBAKE PLANT[3]

exits through roof vents (roof monitors). This ventilation is the major source of potroom fugitive emissions.

Raw materials (i.e., alumina, coke, and pitch) are delivered to the plant by ship or railcar and stored. Alumina is transferred to the dry alumina scrubbers by airslide as needed. Alumina is transferred to the aluminum reduction pots by air slides, ore trucks, or crane-mounted hoppers. Aluminum fluoride, sodium carbonate, and fluorspar are added to the pots manually, by hopper, or by automatic feeder. Coke, crushed recycled anodes, and pitch are mixed and formed into new anodes for baking in anode bake furnaces at prebake plants. In the case of Soderberg plants, coke and pitch are mixed and transferred directly to the pots in either paste or briquette form.

Periodically, the aluminum is removed from the pots by a process called "tapping" and transferred, still molten, to the cast house in crucibles. There it is placed in a holding furnace, alloyed with other materials (iron, silicon, magnesium, and manganese), and fluxed (generally with chlorine or argon) to remove impurities. The purified alloyed aluminum, still molten, is then direct chilled cast into ingots, billets, or slabs. Unalloyed molten aluminum is poured into "sow" molds to cool. After cooling, the aluminum products are transferred to storage or prepared for shipment.

2.3 TYPES OF PLANTS

Primary aluminum operations are differentiated by the type of anode used, the method by which the pot is worked, and the method by which the anode is introduced into the cell. There are two major types of processes: prebake and Soderberg. A majority of the primary aluminum plants in the U.S. currently use prebake technology (17 of 23 plants). Three of the four plants that have potlines subject to the new source performance standards (NSPS) use prebake pots.

The pots in prebake plants use multiple anodes that are formed and baked prior to consumption in the pots, while the Soderberg pots use a single, continuous anode that is shaped and baked in place directly in the pot. Each of these pot types has two variations. The pots in prebake plants are classified as center-worked prebake (CWPB) or side-worked prebake (SWPB), depending on where the pot working (crust breaking and alumina addition) takes place. Soderberg pots, on the other hand, are differentiated by the positioning of the current-carrying studs in the anodes, which may be inserted vertically or horizontally. The four basic types of primary aluminum reduction technology are:

1. Center-work prebake (CWPB)
2. Side-work prebake (SWPB)
3. Vertical stud Soderberg (VSS)
4. Horizontal stud Soderberg (HSS)

2.4 ALUMINUM REDUCTION[4]

Primary aluminum is produced by the reduction of alumina by electrolysis in a molten bath of natural or synthetic cryolite (Na_3AlF_6), which serves as an electrolyte and as a solvent for the alumina. The reduction cells or pots containing the bath are about 10 to 15 feet wide, 20 to 40 feet long, and about 3 to 4 feet deep, lined with carbon, and connected in electrical series of 100 to 240 cells to form a potline. From 800 to 3,000 pounds of aluminum metal are produced per day in each pot. The carbon lining is in contact with the molten aluminum metal and serves as the cathode. It usually must be replaced after 3 to 7 years. Figure 2-3 shows the components of a generic aluminum reduction pot.

Cryolite and aluminum fluoride are added to the electrolyte to maintain the desired ratio of sodium to aluminum fluoride and to replace fluorides lost from the cell in pot linings or through volatilization. The melting point of the bath is lowered by the addition of small quantities of fluorspar or, in some instances, lithium compounds. The carbon anode is consumed during the operation.

In the Soderberg method, a reinforced rectangular steel shell, approximately 3 to 5 feet high and open at the top and

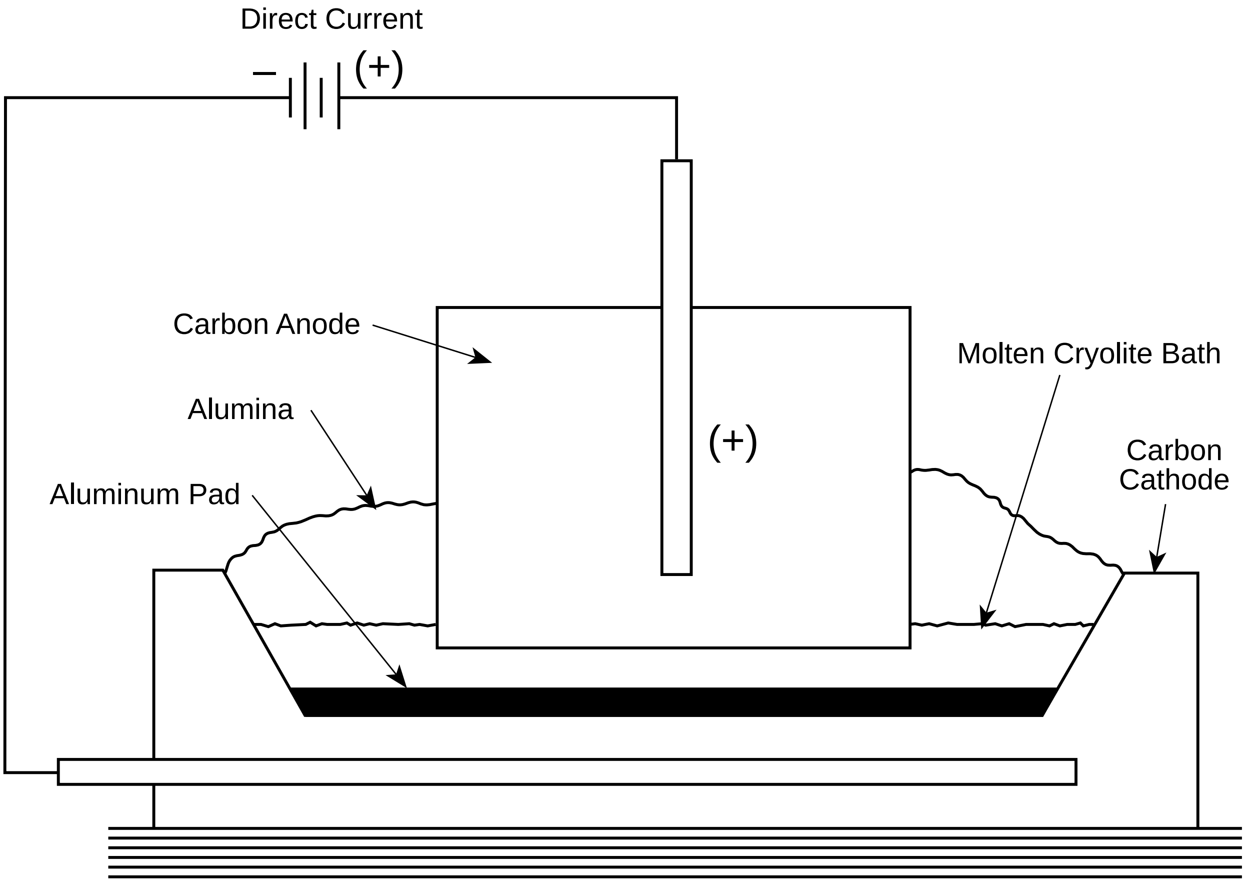

FIGURE 2-3. ALUMINUM REDUCTION POT[5]

bottom, is suspended above the pot. The carbon mass (coke and pitch) of paste or briquettes within the shell forms the anode and is added periodically as the anode is consumed. Current enters the anode through rows of pins inserted into the carbon mass either vertically (Figure 2-4) or horizontally (Figure 2-5). The heat of the bath and the heat resulting from the electrical resistance of the carbon bake the anode paste so that it becomes a hard monolithic mass from the surface of the electrolyte to a point approximately 20 inches above the bath. As the carbon anode is consumed and additional carbon descends through the rectangular steel shell and is consumed, the lowest pins are withdrawn and replaced at higher levels in the carbon mass. The optimum anode-cathode distance is maintained by raising or lowering the studs, which become baked into the lower part of the carbon block.

In the prebaked anode system, sets of 16 to 24 prebaked carbon blocks are used for the anode. The size of the blocks varies from plant to plant; typical blocks are about 20 inches wide, about 30 inches long, and 12 to 18 inches high. They weigh 400 to 600 pounds. Steel studs or rods, which suspend the block in the bath and conduct the current to the carbon, are sealed in the anode block by pouring molten iron around the rod and allowing it to solidify. The anode blocks are raised or lowered to maintain proper position with respect to the metal levels in the cell. When consumed, anode blocks are replaced.

There are two different types of prebake pots depending on the location of the anodes in the pot and where crust breaking and alumina addition take place. Center-worked prebake (CWPB) pots have anodes that are close to the sides of the pot with a space running down the middle of the pot where crust breaking and alumina addition take place (Figure 2-6). Side-worked prebake (SWPB) pots have anodes that are spaced down the center of the pot, and crust breaking and alumina addition take place on either side of the pot (Figure 2-7).

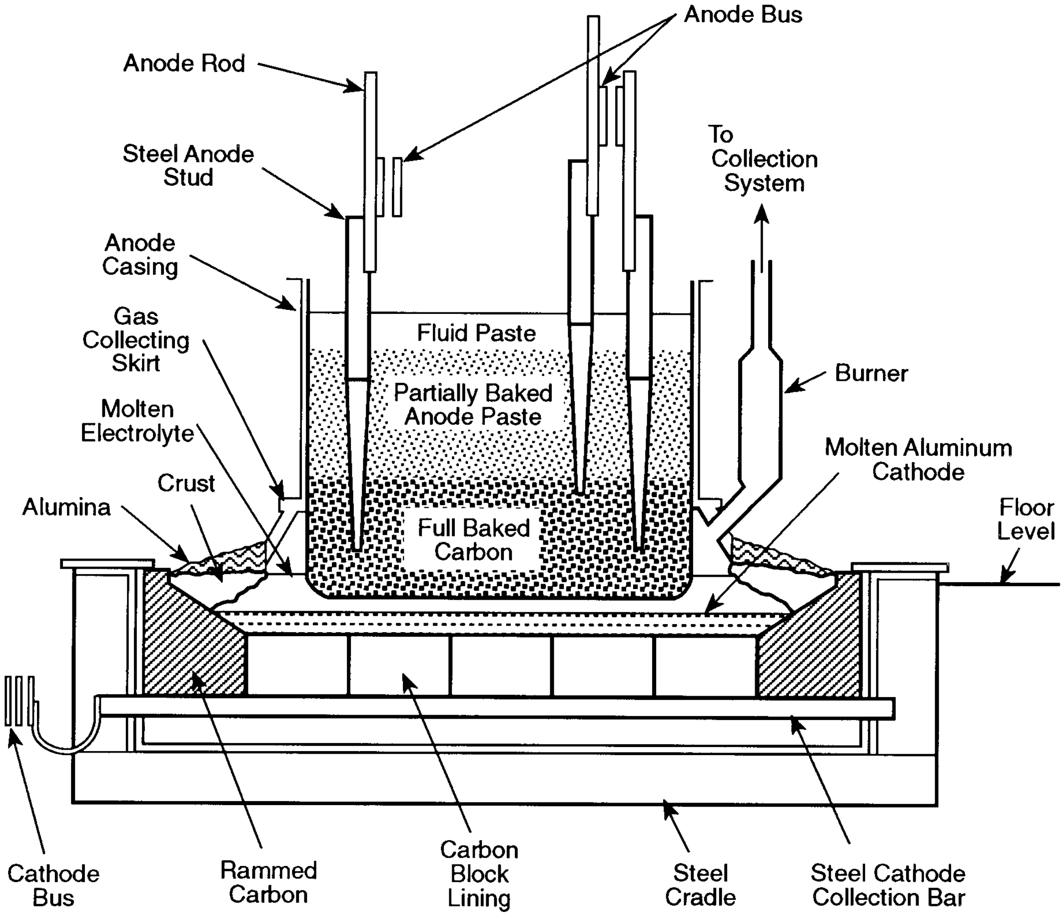

FIGURE 2-4. VERTICAL STUD SODERBERG CELL[6]

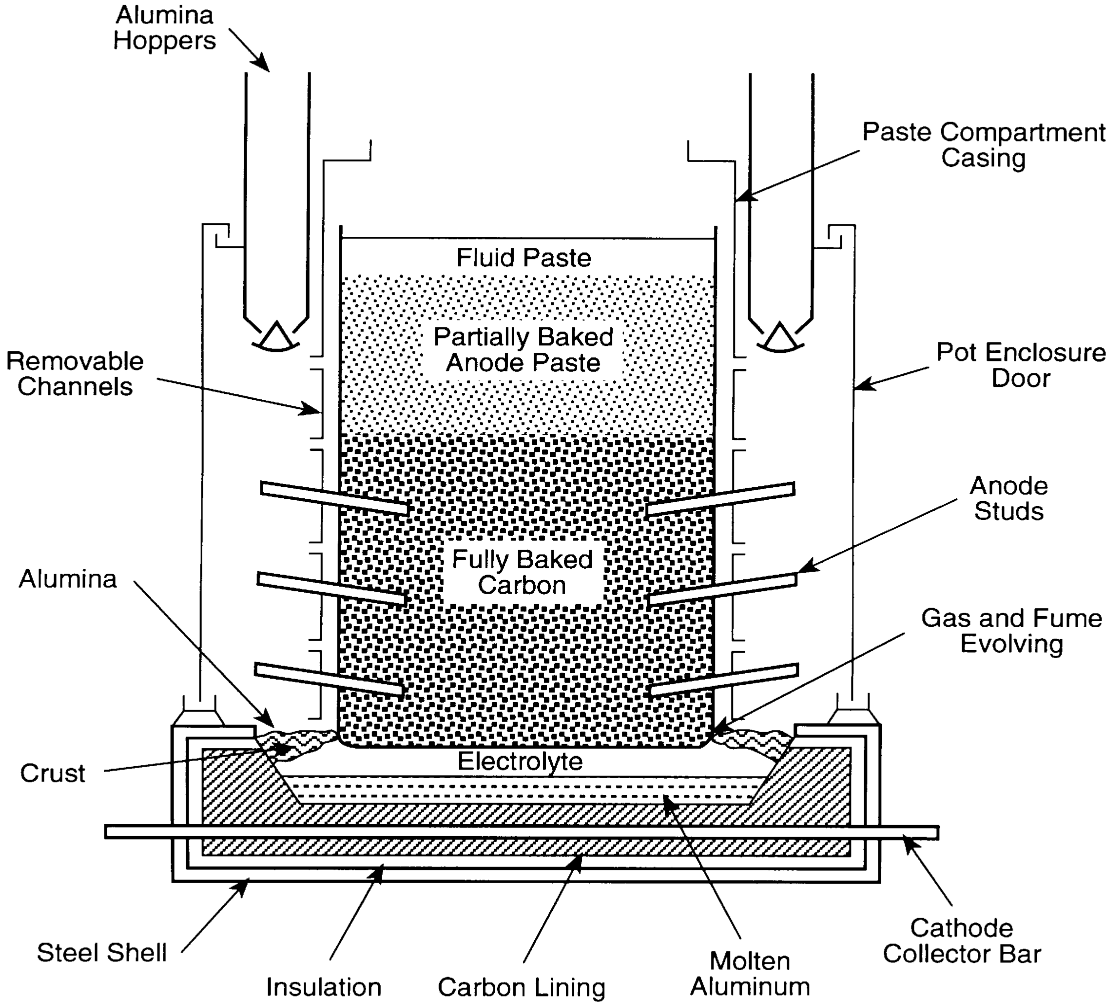

FIGURE 2-5. HORIZONTAL STUD SODERBERG CELL[7]

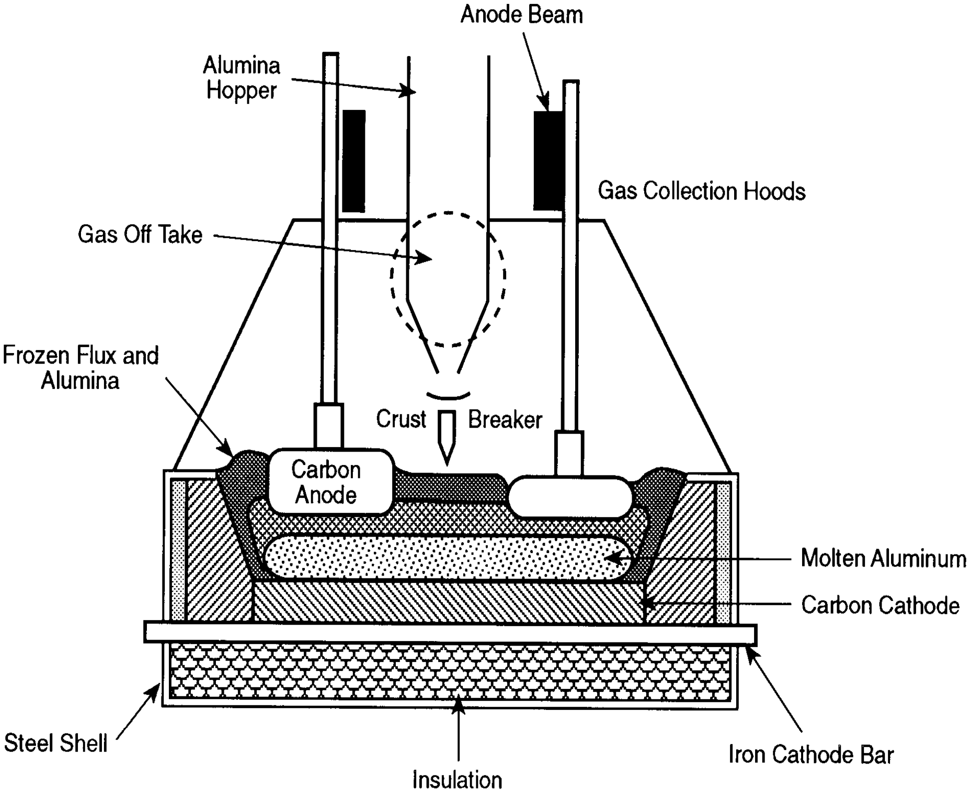

FIGURE 2-6. CENTER-WORKED PREBAKE CELL[8]

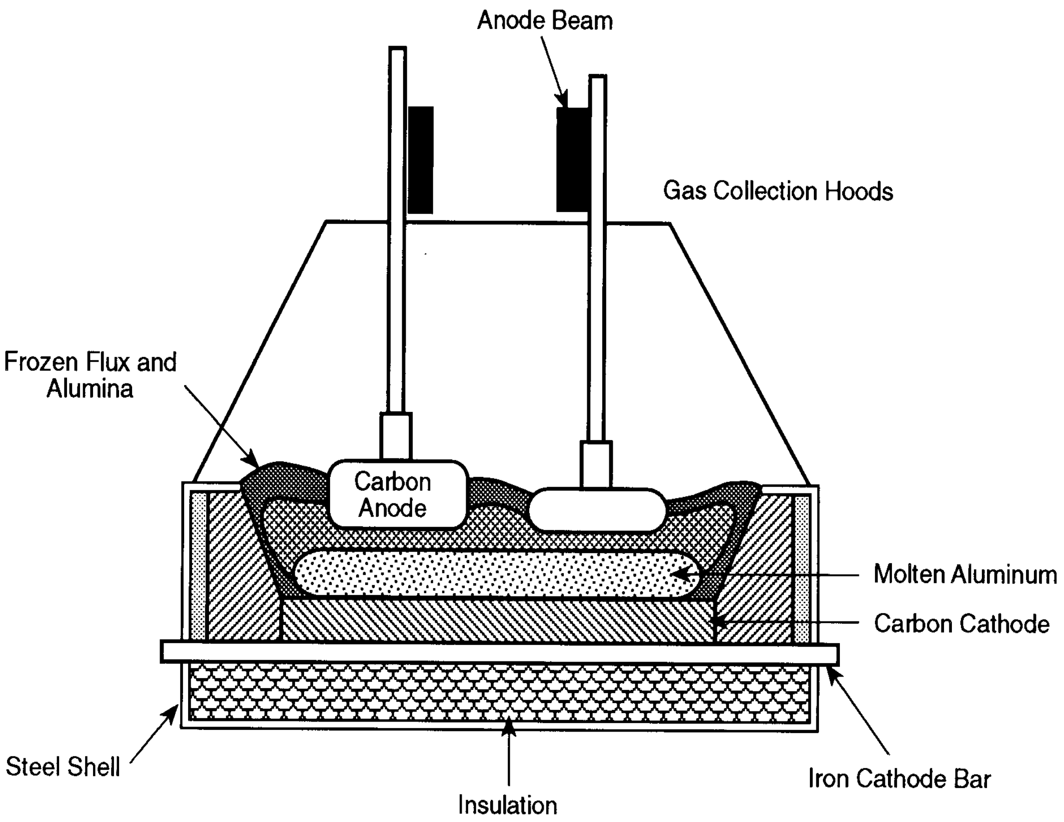

FIGURE 2-7. SIDE-WORKED PREBAKE CELL[9]

The Soderberg system, except for moving the steel pins, is a continuous method of feeding anode carbon. The prebake system results in better electrical efficiency in the reduction cell but requires separate anode production and rodding facilities that are not required in the Soderberg system. The prebake system permits efficient collection of the pot emissions for subsequent treatment to remove fluorides; the emissions from a Soderberg cell are difficult to collect, necessitating fluoride recovery from a larger volume of gas than that generated in prebake systems.

The molten bath or electrolyte may be as deep as 14 inches, but the anode is usually only 2 inches from the pad of molten aluminum collecting on the carbon cathode. Depending on pot chemistry and other factors, the optimum operating temperature is between 940°C and 985°C. At this temperature range, the alumina content of the bath ranges from 3 percent to 10 percent. When the alumina concentration drops to about 2 percent, the electrical resistance of the cell increases sharply, mainly because of a gas film that envelops the anode, and the voltage drop across the cell increases from about 5 volts to 30 to 40 volts. The phenomenon is known as the "anode effect," and as soon as it occurs, the bath crust on the reduction cell is broken and more alumina is added to the cell, returning it to normal operating condition.

Every 1 or 2 days the molten aluminum is removed from the bottom of the cell by a vacuum technique or by gravity siphoning. For siphoning, a "U"-shaped tube equipped with an aspirator is used to place the molten aluminum in the crucible. For vacuuming, the crucible is equipped with an air-tight lid and downward sloping tube. The crucible is placed under vacuum and the metal is sucked into the crucible (Figure 2-8). The molten metal is generally cast into various solid forms. Some metal is transported to customers in molten form.

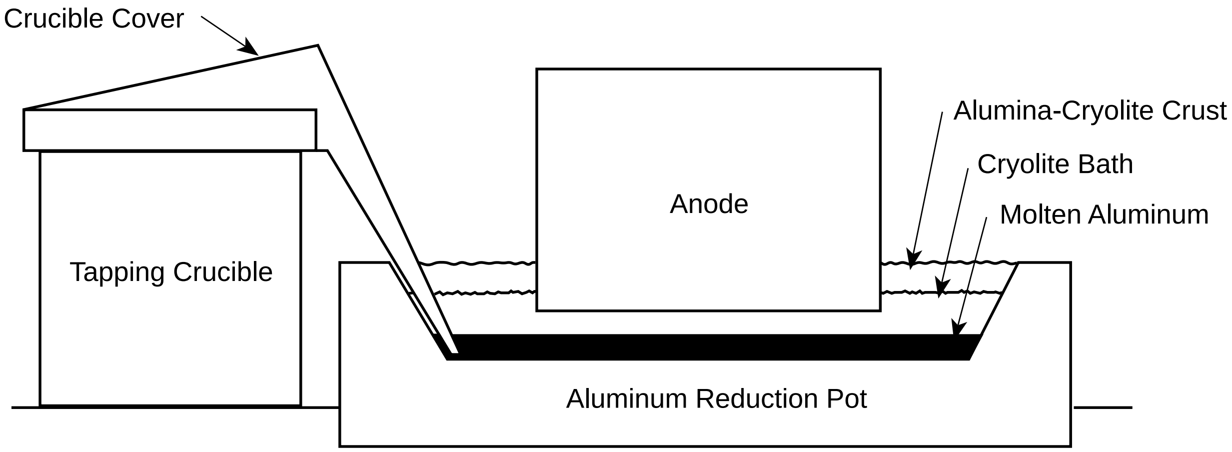

FIGURE 2-8. TAPPING MOLTEN ALUMINUM[10]

Using direct current, cells operate at 65,000 to over 200,000 amperes; the majority of plants have 80,000 to 100,000 ampere cells. Anode current densities range from 600 to 800 amperes per square foot. The voltage drop across a single cell is 3.9 to 5.0 volts; across a potline, it may be as high as 1,000 volts.

The larger cells require less labor per pound of aluminum produced, but special problems are encountered in cells designed to operate at 100,000 or more amperes. The larger currents cause powerful magnetic fields in the molten aluminum metal and the bath, resulting in violent agitation. This agitation causes aluminum to be dispersed in the bath, increasing the possibility of reversing the reduction reaction. Another detrimental effect is that the molten metal piles up toward the negative leads, causing a variation in the anode-cathode spacing. Moreover, localized effects may distort the carbon lining.

Production cells normally have current efficiencies ranging from 85 percent to 93 percent. Metal losses are principally caused by reoxidation of aluminum in the electrolyte and by physical loss of metal through vaporization from the bath or spillage. The resistance of the bath is sufficient to maintain the operating temperature. However, there are several ways heat energy is lost from the pot:

- by radiation;
- thermal conductance through electrode connections;
- exhaust gases and tapped metal; and
- electrodes removed from the cells.

To control pollution, fumes evolved from the cells during electrolysis are removed by a collection system followed by a dry scrubber (in most cases) where the fluorides are adsorbed by alumina that is subsequently recycled to the potlines. Wet scrubbers or electrostatic precipitators are used as the primary control device at a few plants (see Section 3).

2.5 PASTE PRODUCTION[11]

The anode paste plant is termed the "green mill" by the industry and may produce anode paste for Soderberg cells, cathode paste, or green pressed anodes to be baked for prebake cells. Carbon paste production consists of the following processes:

- crushing;
- grinding;
- screening and classifying;
- combining of carefully sized fractions with a pitch binder;
- mixing and forming.

Figure 2-9 shows a typical flowsheet for a Soderberg paste production plant and Figure 2-10 shows a typical flowsheet for the prebake paste and green anode production.

Solid raw materials (calcined petroleum coke, anthracite coal, and solid pitch, as required for various kinds of paste mixes) are received in bulk and transported to carbon plant storage. [Prior to processing in a reduction plant, green petroleum coke is calcined in a separate calcining or coke plant.] Wetting agent sprays are used in some green mills to reduce dusting conditions inherent in materials handling.

Material is reclaimed from storage by front-end loaders with enclosed cabs, airslide, or conveyors and fed to combinations of crushing equipment in closed circuit with vibrating screens followed by grinding units. Sized fractions of crushed and ground material are separated and stored in mix bins for make-up of paste composition. Cleaned reclaimed spent anodes and anode scrap from prebake plant operations are similarly crushed and sized for recycle to prebake anode preparation.

Dry solids are drawn from the sized mix bins in controlled proportions either in weighed batches for batch mixers or continuously for continuous mixers. Mixers are jacketed and heated with either steam or hot oil. For baked anode pastes the mixer feed contains either solid crushed coal tar pitch, which is

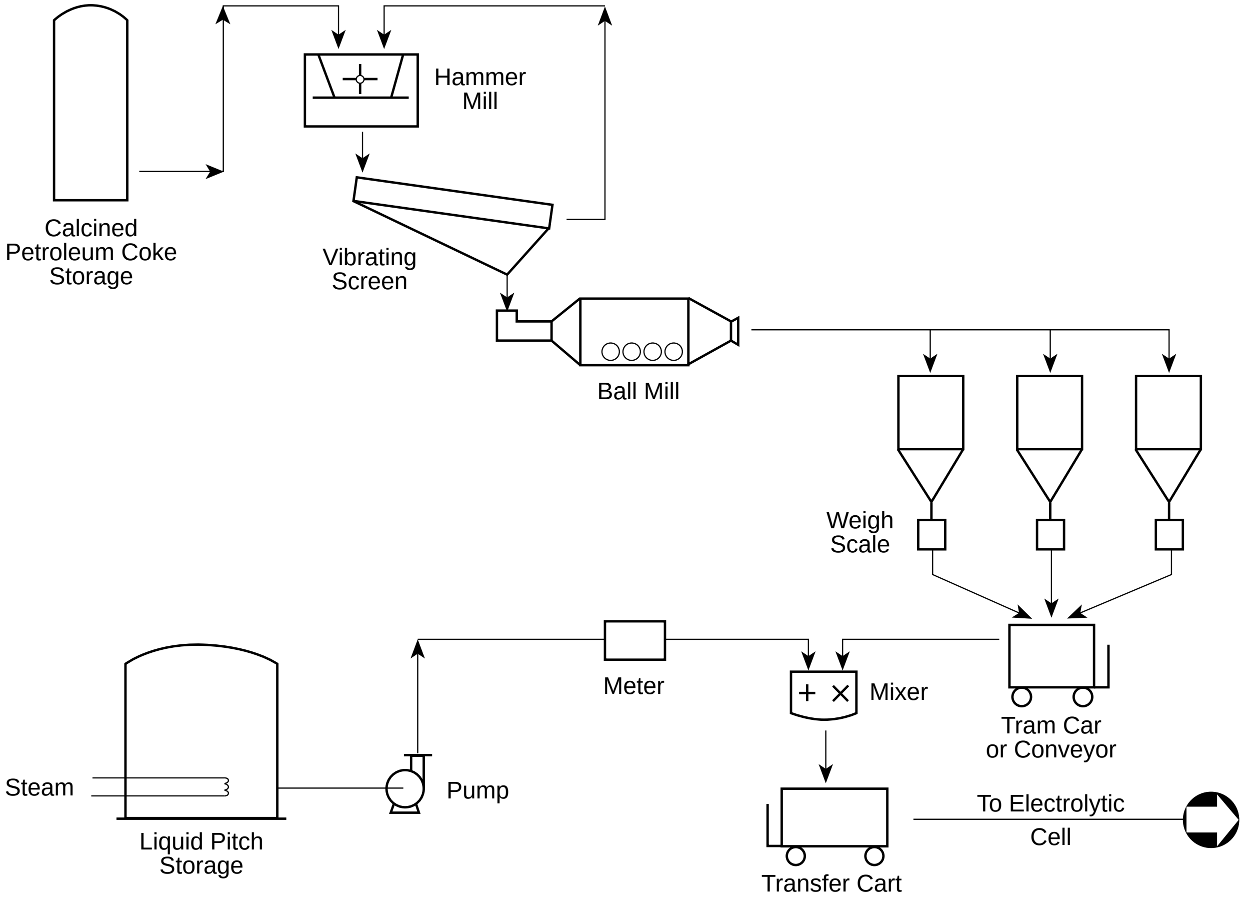

FIGURE 2-9. SCHEMATIC OF SODERBERG PASTE PLANT[12]

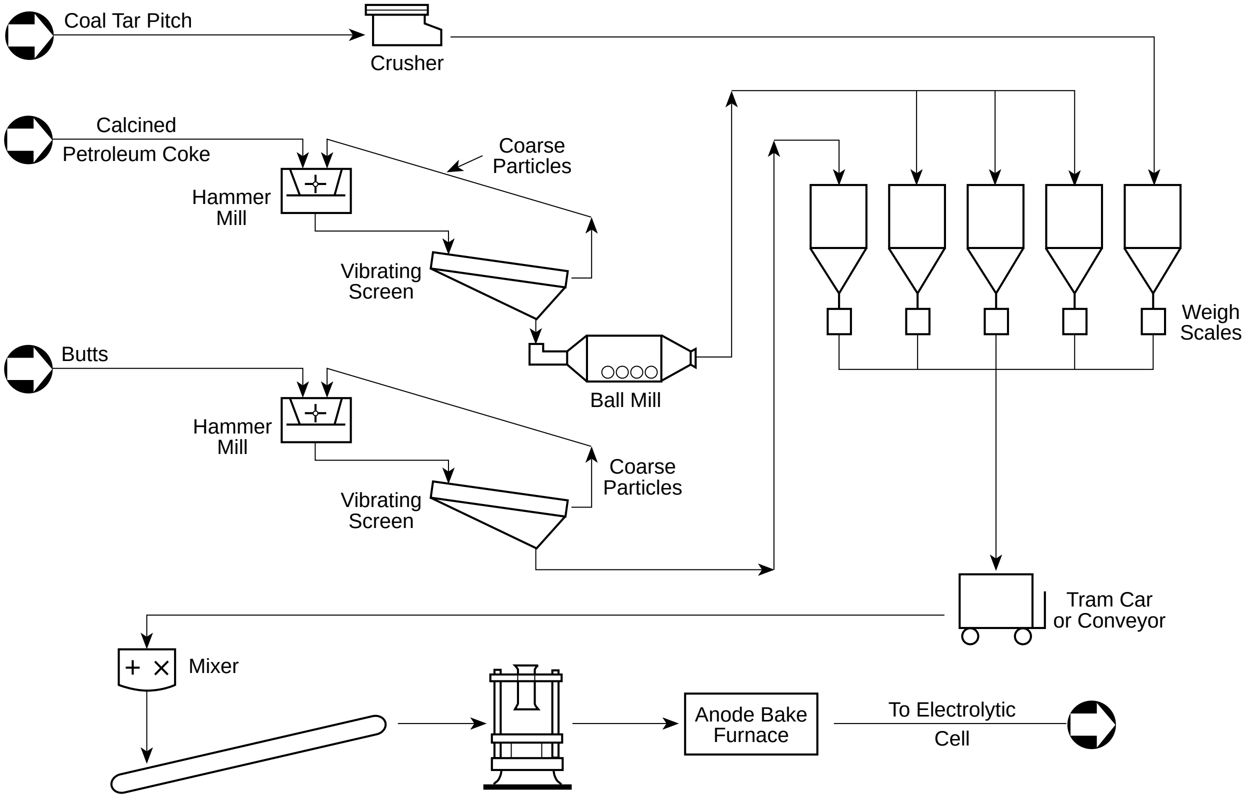

FIGURE 2-10. SCHEMATIC OF PREBAKE ANODE PREPARATION[13]

softened and blended in the mixers or hot liquid pitch to provide the paste binder.

For Soderberg paste, a liquid pitch is used and is metered to the mixers. The hot Soderberg paste is discharged directly from the batch mixers to transfer cars that convey it to the cell rooms for anode replenishment, or may be cooled and formed into briquettes. Briquettes are conveyed by conveyor belts, trucks, or front-end loaders. The prebake paste, less fluid than the Soderberg material, is transferred from the mixers to anode molds, in which the self-supporting green anode is formed by hydraulic or vibratory compaction.

2.6 ANODE BAKING[14]

Anode bake furnaces (used only at prebake plants) vary greatly in size and production rate, but all have the same basic layout and operating parameters. Figure 2-11 shows a typical ring furnace used for anode baking. Each furnace consists of a large number of indirectly fired sunken ovens or pits arranged in rows. The pits are open-topped and made of brick. Some of the spaces between the bricks are mortared, while others are intentionally left open. The pits sit in a flue which surrounds them. The flue is split down the middle by a wall. The wall is slightly shorter than the flue to permit the flue gases to pass from one side to the other at each end. A large pipe or duct circles the furnace and leads to an exhaust fan. Double-sealed manholes are spaced along the top of this duct, with at least one manhole per furnace section. Each one-half row of pits, from the center wall out, is called a section.

An operating furnace will have one or more "fires" operating continuously. A fire has three phases: preheat, bake, and cool-down. Each fire gradually traverses the length of the furnace on one side in a series of steps, one section per step. It then returns on the other side. Ahead of the fire(s), pits are filled with green anodes to within about 3 feet of the surface. Petroleum coke is then dumped into the pits from an overhead hopper and packed around the anodes. The anodes are then covered

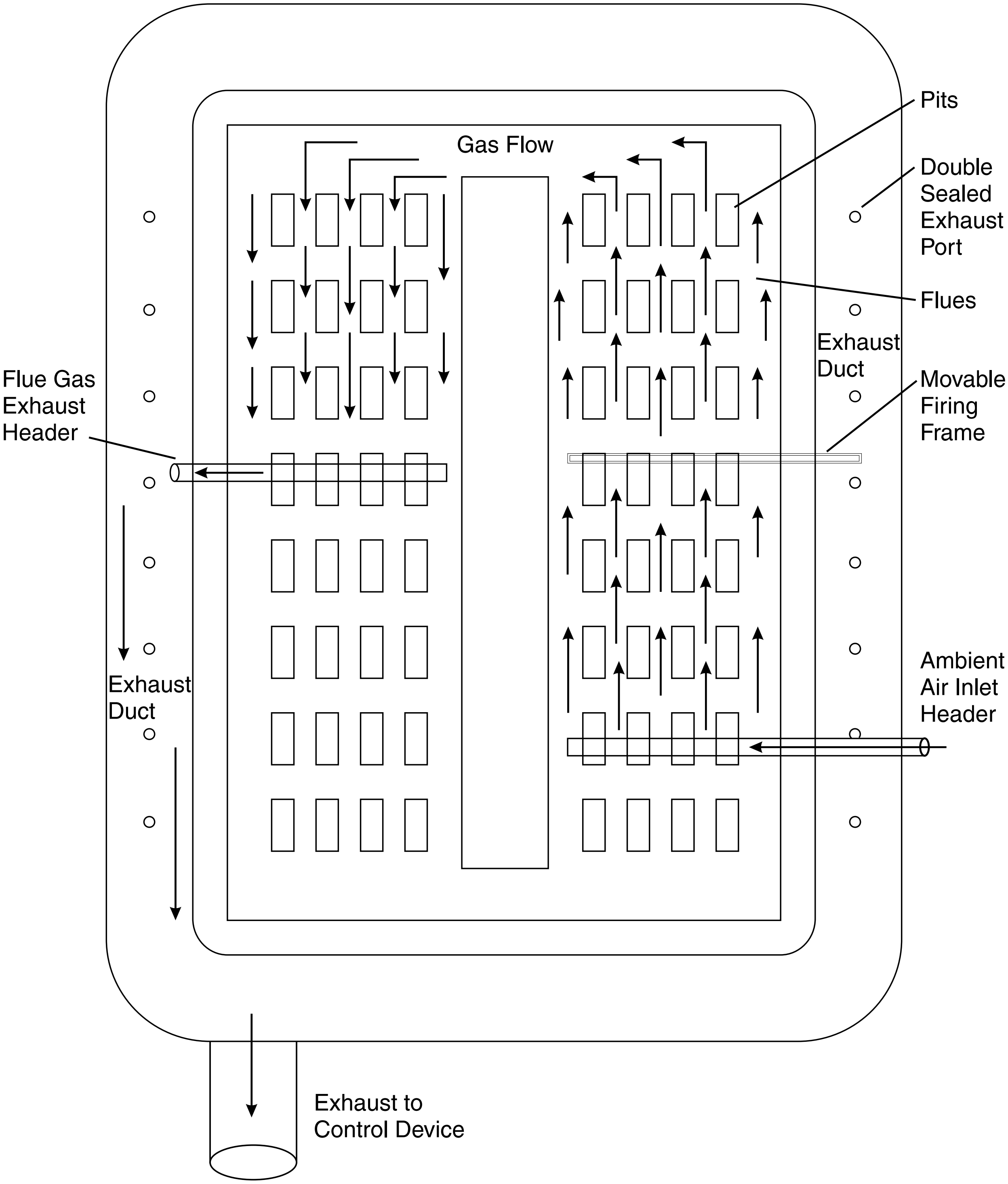

FIGURE 2-11. RING FURNACE LAYOUT[15]

with petroleum coke or some other insulating material to cover the tops of the pits. After the fire has passed by and the baked anodes have cooled, the packing coke is removed from the pits by vacuuming or other means, and reused. The baked anodes are then removed and necessary pit repairs are performed while the pits are empty. Both the coke placement and removal operations can be very dusty.

As previously noted, a "fire" (sometimes called a firing cycle) has three phases: preheat, bake, and cool-down. Ambient air is drawn or forced into the flue and around the pits containing just-baked anodes. In the process, the air is heated and the anodes are cooled down. Usually, the air preheat (anode cool-down) zone encompasses three to five sections. The preheated air then enters the firing zone (anode bake zone), usually under slightly negative pressure. There, natural gas or other fuel is injected into the flue through movable firing frames and ignited by the high air temperature in the flue, increasing the flue gas temperature to 2237 to 2282°F. In the process, the anodes are heated to about 2100°F, partly by the heat from the flues and partly by the calcining of the binder pitch in the anodes. A substantial percentage of the total energy used in the baking process comes from the anode binder pitch.

The flue gases leaving the anode bake zone pass around the pits in the anode preheat (flue gas cool-down) zone, transferring heat to the green anodes, and become progressively cooler as they approach the movable exhaust manifold. A typical exhaust temperature is about 570°F. The negative pressure in the flue also increases with proximity to the exhaust manifold. This pressure difference tends to draw fumes generated in the pits through cracks and seams in the pit walls and into the flues. There, if flue temperatures are adequate and there is sufficient oxygen, the fumes are incinerated. The movable exhaust manifold extracts the exhaust gases from the flue at the end of the last gas cool-down section through ports in its upper surface. It then vents the gases into the large duct circling the furnace through one of the manholes located atop the duct. The gases are then routed to either a control system or to the atmosphere through a large exhaust fan.

2.7 BASELINE EMISSIONS

A survey of aluminum plants indicated that hydrogen fluoride (HF) and polycyclic organic matter (POM) are the major hazardous air pollutants (HAPs) from primary aluminum production. Other HAP compounds that were reported include benzene, cyanide, metal compounds, phenol, toluene, and xylene.[16] HF is generated from the fluoride compounds (e.g., Na_3AlF_6) used in the production operation. POM and other organic compounds are introduced into the process primarily by the coal tar pitch.

2.7.1 Baseline Emission Limits

Current emission limits for potlines primarily address total fluoride (TF) from the primary control system and secondary emissions that generally escape through the roof. A New Source Performance Standard (NSPS) applies to facilities that commenced construction or modification after October 23, 1974 (Subpart S). The NSPS limits emissions of total fluorides to 1.9 lb/ton for prebake plants and 2.0 lb/ton for Soderbergs, except that higher limits of 2.5 and 2.6 lb/ton are allowed for prebake and Soderberg, respectively, if the owner or operator demonstrates that exemplary operation and maintenance were used with respect to the emissions control system. The opacity from any potroom group is limited to 10 percent. NSPS potlines include Alumax's two potlines in South Carolina, Noranda's Line 3 in Missouri, Alcan's Line 3 in Kentucky, and Columbia's Line 3 in Washington.

In addition, guidance was issued to the States in December 1979 under Section 111(d) of the Clean Air Act to adopt fluoride emission standards for existing plants.[17] Several States incorporated requirements for capture efficiency of the primary system and set standards for fluoride in the ambient air and in forage. Examples of State requirements specifically targeting total fluoride include limits of 3.5 lb/ton (monthly average) and 2.5 lb/ton (annual average) in Oregon, 2.6 lb/ton in Montana, 2.5 lb/ton in Maryland and Missouri, and 4.2 to 4.3 lb/ton in New York.[18] As part of their prevention of significant deterioration (PSD) permit, the three potlines at Columbia Aluminum in Goldendale, Washington must meet a plant-wide average of 2.0 lb/ton (monthly rolling average) and an annual average of 1.6 lb/ton.

The NSPS also applies to anode bake furnaces and limits TF to 0.1 lb/ton of aluminum equivalent and opacity to 20 percent. No States have TF limits for the anode bake furnace for existing facilities not subject to the NSPS.

2.7.2 Baseline Emissions

The details of the baseline emission estimates developed from model plants are given in Chapter 5. Baseline emissions from potlines at the 23 plants are estimated as 6,400 tons/year of total fluoride, which includes about 2,500 tons/year of gaseous fluoride. POM emissions are estimated as about 3,200 tons/year. Baseline emissions from anode bake furnaces are estimated as 700 tons/year of TF (most of this is gaseous fluoride) and 555 tons/year of POM. Paste production plants are estimated to emit about 150 tons/year of POM.

2.8 REFERENCES

1. Compiled from responses by each plant to Information Collection Requests issued under Section 114 of the Clean Air Act Amendments.

2. Review of New Source Performance Standards for Primary Aluminum Reduction Plants. EPA-450/3-86-010. September 1986. p. 3-7.

3. Reference 2, p. 3-7.

4. Plunkert, P.A.; Sehnke, E.D., "Aluminum, Bauxite, and Alumina", Annual Report, Department of the Interior, Bureau of Mines, 1991. pp. 6 and 7.

5. Reference 2, p. 3-10.

6. Air Pollution Control in the Primary Aluminum Industry, Volume I of II, Sections 1 through 10. EPA-450/3-73-004A. Singmaster & Breyer, New York, New York. July 23, 1973. p. 3-15.

7. Reference 6, p. 3-14.

8. Reference 2, p. 3-16.

9. Reference 2, p. 3-19.

10. Reference 2, p. 3-13.

11. Reference 6, pp. 3-16 to 3-18.

12. Reference 6, p. 3-19.

13. Reference 6, p. 3-20.

14. Reference 2, pp. 3-24 to 3-26.

15. Reference 2, p. 3-25.

16. Reference 1.

17. Primary Aluminum: Guidelines for Control of Fluoride Emissions from Existing Primary Aluminum Plants. U.S. Environmental Protection Agency. Report Number EPA-450/2-78-049b. December 1979. 343 p.

18. Reference 2, pp. 2-6, 2-7.

3.0 EMISSION CONTROL TECHNOLOGY

This chapter describes the emission control techniques used in the primary aluminum industry and the factors affecting emissions. The discussion focuses on the capture equipment (hooding), control devices, operating procedures, and work practices that are currently used to control both primary emissions and secondary (fugitive) emissions from aluminum production. Emission controls are also presented for paste mixing and anode baking operations. In addition, opportunities for pollution prevention are discussed.

Capture efficiency, control efficiency and levels of emissions are discussed in terms of total fluoride (TF) and gaseous fluoride (GF). There are approved EPA measurement methods for TF (e.g. Method 13 or approved alternatives); however, there is no EPA Method for GF. Measurements for TF are based on the fluoride in the particulate matter captured by the front-half filter plus fluoride captured in the back-half filters, which is primarily GF. Traditionally, the front-half catch has been referred to as particulate fluoride (PF) and the back-half (impinger) catch has been referred to as GF. Hydrogen fluoride (HF) is expected to be captured primarily in the impingers as GF.

There is uncertainty as to whether the impinger catch is a true measure of GF or HF. During the development of Method 13, EPA acknowledged difficulties in obtaining an accurate split between PF and GF; consequently, the method was developed and validated only for the measurement of TF (the sum of PF and GF). Difficulties include the adsorption of GF by alumina captured by the filter (where it is measured as PF) and fine particles passing through the filter to the impingers (where it is measured as GF). Consequently, TF data probably represent the most defensible measure of emission control performance as determined by validated EPA methods. References to GF in this document are made only to provide a "best" estimate or approximation of the HF portion of TF.

Emission measurements and control performance for polycyclic organic matter (POM) are prevented in terms of a surrogate measure based on methylene chloride extractables. This procedure extracts both the filter and impinger catches with methylene chloride and determines the amount of solid residue dissolved in the methylene chloride. Consequently, the surrogate measure is more appropriately called "methylene chloride soluble compounds" and is composed primarily of organic particulate matter. POM is extracted by methylene chloride, but the extract may also remove compounds that are not POM. Consequently, the emission results for methylene chloride extractables is not a direct measure of POM; however, the procedure provides a reasonable surrogate measure of POM.

3.1 ALUMINUM PRODUCTION

The control of primary emissions from the reduction cells, which are captured and controlled at each of the 23 plants, and fugitive emissions that generally escape through the roof monitor are interrelated. Actions that improve the capture efficiency of the primary systems, such as repair or replacement of damaged hooding, operating practices that reduce the number and duration of open cells, and work practices that minimize emissions can have a dramatic effect on total emissions from aluminum production. For example, a loss of only one percent in capture efficiency can increase total emissions by 30 to 90 percent, depending on the initial control efficiency.[1] Consequently, emission controls and performance are discussed collectively for primary and secondary emissions.

This section describes the hooding that is used for different types of production processes, the control devices used to remove the pollutants, and the combinations of work practices, equipment modifications, and operating practices that are an important part of the overall emission control program for both primary and secondary emissions.

3.1.1 Cell Hooding

The hooding used to capture emissions from the reduction cell cannot totally enclose the cell at all times because the cell must be opened periodically to add alumina ore and other raw materials, to replace anodes, to correct anode effects, and to remove molten aluminum ("tapping").[2] Hooding designs also depend on and vary with the cell designs with different considerations for Soderberg versus prebake and for side-worked versus center-worked cells. Within the Soderberg category, there are differences between the horizontal and vertical stud cells in hooding design, evacuation rates, and capture efficiency. Consequently, a brief discussion is provided for the different types of cells and the major design features of the hooding that is used for each type. Figure 3-1 provides a schematic for each type of reduction cell and illustrates some of the differences among the hooding for the various types of reduction cells.

3.1.1.1 Center-Worked Prebake (CWPB) Hoods. The hooding for CWPB cells has evolved and improved over the past 50 years as the technology changed from small, simple cells to large cells that are carefully controlled and automated. The most successful and effective hooding in use today is that used on the more modern center-worked cells. These cells have individual side shields that can be removed to expose only that section of the cell that must be "worked."[3] In some cases, the cells can be worked internally or from the end without removing the side shields.[4]

CWPB cells have a superstructure that supports the anode bus bars and the alumina storage hopper. Hoods are formed using curved metal side shields that extend from the outside edges of the pot sides to this super structure. At each end of the pot, the space between the pot and the hopper is closed and fitted with a door. Usually, there is one side shield per anode, and the side shield may be notched to fit tightly around the anode

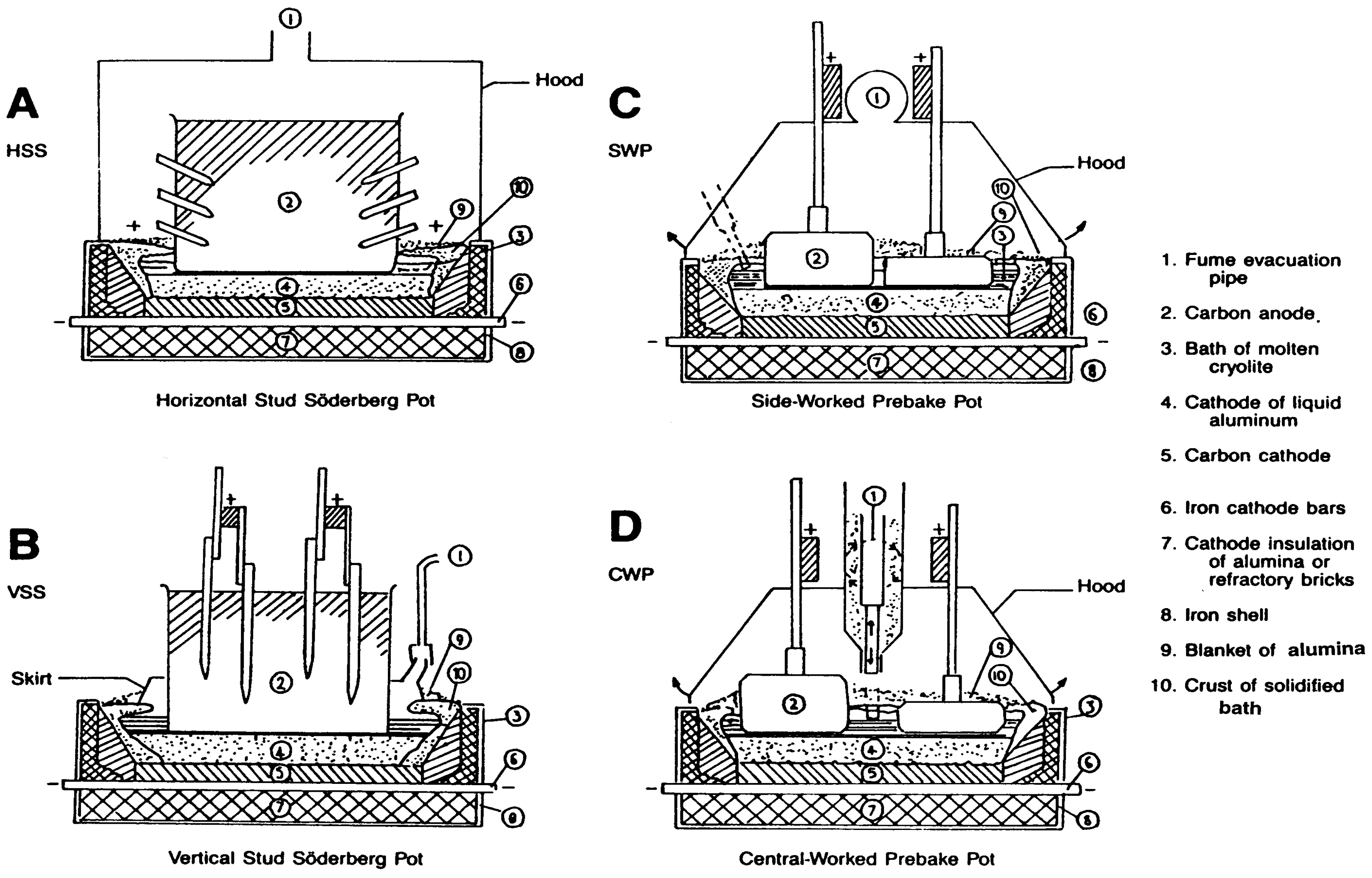

FIGURE 3-1. SCHEMATICS OF TYPES OF REDUCTION CELLS ("POTS")[5]

hanger. The shields and doors are removed and replaced manually. Together the superstructure, side shields, and end pieces form an enclosure.[6]

The fumes escaping from the pots are captured by enclosing the whole pot bath area and by sealing the pot enclosure to the maximum extent possible. The air flow through the pot must be high enough to prevent fumes from escaping through openings in the hood (such as between side shields) without entraining excessive alumina.[7] Plants with dual flow dampers and an adequate fan capacity have the ability to increase the evacuation rate on a cell when one or more of the side shields are removed. The increased evacuation rate increases the capture efficiency and reduces secondary emissions that escape from openings in the hood.[8]

Recent data from a survey of the industry showed evacuation rates ranged from about 3,000 to 4,900 ft^3/min per cell for the larger CWPB cells (i.e., those with amperages of 95,000 or more per potline). Six of ten plants with the larger CWPB cells reporting the data indicated they had the ability to increase the draft on a cell when needed; the high draft rate represented an increase of up to 50 percent over the normal rate. Data from three plants with the smaller and older CWPB cells (two plants were built in the 1940's) showed evacuation rates that ranged from 2,000 to 2250 ft^3/min per cell. Only one of these plants with the smaller cells indicated an ability to increase the evacuation rate (by a nominal 15 percent).[9]

The capture efficiency is improved (and secondary emissions are reduced) by minimizing the frequency, number, and duration of side shield and door removals (e.g., for removing anodes or correcting anode effects). When the cells are closed, tight seals are achieved by using tight-fitting end doors and side covers that fit snugly and align with each other.[10] A plant with small CWPB cells performed tests (using a helium tracer gas and their own method for evaluating capture efficiency) to evaluate the effect of gaps on capture efficiency. A capture efficiency of 97.5 percent was measured with all shields placed properly. Tests performed with the side shields misplaced (1- to 3-in gaps at the top and between shields) showed that the capture efficiency decreased to 76 percent.[11]

Capture efficiencies of 90 percent or more are possible for CWPB cells by using improved hooding.[12] A total of 14 CWPB plants reported capture efficiency information in the 1992 survey from sampling, measurements, or design data. The reported capture efficiency for nine plants with large CWPB cells ranged from 95 to 99 percent compared to a range of 90 to 95 percent for five plants with small CWPB cells.[13]

3.1.1.2 Side-Worked Prebake Hoods. Side-Worked Prebake (SWPB) cells must be worked manually along both sides with all of the side covers removed. Consequently, SWPB potlines are typically capable of achieving a primary collection efficiency of no higher than 85 percent.[14] However, one SWPB plant estimated a capture efficiency on the order of 90 to 95 percent in the 1991 survey. The two SWPB plants reported evacuation rates of 2,400 to 2,800 ft^3/min per cell, and neither plant indicated an ability to increase the air flow when side shields are removed.[15]

To work a SWPB cell in a potroom in a reasonable time period, all the side covers on the cell are normally removed while the cell is worked. For this reason, some SWPB plants have installed flat aluminum or steel hood doors that extend the full length of both sides of the cell. When closed, they form an angular gas collection skirt. They are opened by air cylinder or air motor to one or more open positions, depending on operating requirements. At each end of the cell, the doors seal against stationary wing panels that can be adjusted to minimize leakage. SWPB plants employing these hood designs have cells set into the floor rather than elevated. Heat-resistant cloth is installed around the door bottom and gravity seals the hood when the door is closed.[16]

3.1.1.3 Horizontal Stud Soderberg (HSS) Hoods. The hood doors on the HSS cell extend the full length of both sides of the cell, and working a side requires opening an entire door. Most draft systems cannot provide sufficient capture velocity to collect emissions efficiently under these circumstances.[17]

HSS potlines are capable of achieving total fluoride primary collection efficiencies of 85 to 95 percent.[18] Data from two HSS plants in the 1992 survey indicated capture efficiency from measurements of 74 to 90 percent. Evacuation rates were reported by only one plant and ranged from 2,500 to 2,750 ft^3/min with an ability to increase to 5,000 ft^3/min with dual flow dampers.[19]

As with CWPB potlines, the approach to improve capture efficiency involves tighter hood sealing and internal working with hood doors closed. Tighter sealing can be achieved by replacing manual with mechanically operated doors and by eliminating gaps on the top and the ends of the cell hooding enclosure.[20] A study conducted by one HSS plant showed that their capture efficiency was improved from 96.5 percent with all doors and shields closed to 98 percent by installing an improved door design. The capture efficiency with one side door open was 79 percent at the normal evacuation rate, and when the evacuation rate was doubled, the capture efficiency increased to 94 percent with one side door open.[21]

3.1.1.4 Vertical Stud Soderberg (VSS) Hoods. Figure 3-1 illustrates the hooding of a typical VSS cell. The hood skirt consists of an inverted U- or V-shaped channel that runs around the edge of the anode assembly at the bath level. The channel is formed by the anode and the outer anode casing. The channel serves as a duct to carry the evolved gases to integral gas burners. Hence, a substantial area of the cell surface is outside the hood skirt. This annular, exposed area is normally covered by a crust of cryolite and alumina, the latter adsorbing hydrogen fluoride. However, this crust is broken when the cell is worked, exposing the molten bath until the crust reforms or the bath is covered with alumina after the cell is worked. During the exposed period, large quantities of fluoride escape into the potroom roof.[22]

The permanent gas collecting skirt around the bottom of the anode that is sealed provides much lower evacuation rates than other processes, which results in less dilution. An advantage of the lower dilution rate is that the hydrocarbon concentration is high enough to support combustion in the gas burners, which are an integral part of the VSS design.[23] Evacuation rates at the two VSS plants ranged from 350 to 420 ft^3/min per cell, which is about an order of magnitude lower than the evacuation rates of other types of cells.[24] Unlike other cell designs, VSS cells do not benefit from attempts to increase evacuation rates because the cell working activities occur outside of the VSS cell skirt.

Primary collection efficiencies for VSS potlines are expected to vary from 75 to 92 percent.[25] Data from one of two VSS plants in the 1992 survey included a capture efficiency of 90 percent.[26]

3.1.2 Control Devices for Primary Emissions

Emissions collected by the cell hooding are routed to a control device for removal of gaseous and particulate emissions. The distribution of the types of control devices used for the 91 potlines at 23 existing plants is given in Table 3-1.

TABLE 3-1. SUMMARY OF PRIMARY CONTROLS AT EXISTING PLANTS[27]

Control device for primary system	Number of	
	Potlines	Plants[a]
Dry alumina scrubber - fluidized bed	40	12
Dry alumina scrubber - injection type	33	9
Wet scrubber and electrostatic precipitator	15	3
Wet scrubber only	3	1

[a] There are a total of 23 plants. Two plants use different types of controls for different potlines.

Table 3-1 indicates that dry alumina scrubbers are the most common control device and are used on 80 percent of the potlines in the U.S. Wet scrubbers and electrostatic precipitators (ESPs) are less common. The following sections will describe these control devices briefly and identify the most important parameters affecting performance.

3.1.2.1 Dry alumina scrubbers. The dry alumina scrubber system is composed of large central units that contact alumina ore with the off-gases from the reduction cell to adsorb gaseous pollutants. After contact with the alumina, the gases are sent to a baghouse (fabric filter) to remove the alumina and other particulate matter. During the last decade, dry scrubber systems have been used almost exclusively on new facilities for several reasons. The system uses alumina ore to adsorb gaseous fluoride (primarily hydrogen fluoride) and a baghouse to remove particulate fluoride. The ore is returned to the reduction cell; consequently, the process does not produce a pollution control residue, such as sludge, and it recovers fluoride for recycle back to the cell.[28] Data reported by individual companies showed that the removal efficiency for gaseous fluoride ranged from about 98 to 99.97 percent, with most plants reporting 99+ percent control.[29]

There are two basic types of dry scrubbers in use: one injects alumina into the gas stream and the other uses a fluidized bed of alumina. In the injected alumina type shown in Figure 3-2, the alumina is contacted with the gas in either long horizontal ducts, Venturi mixing systems, or in mixing chambers that have upward flow. The limited contact time in these systems makes it necessary to recirculate the alumina 2 to 6 times to provide for sufficient gas-solid contact for high removal efficiencies. Alumina can adsorb 4 to 6 percent of its weight in hydrogen fluoride.[30]

In the fluidized bed reactor shown in Figure 3-3, the gas-alumina contact occurs by passing the gas through an expanded bed of alumina, which fluidizes the bed. Outlet weirs are used in

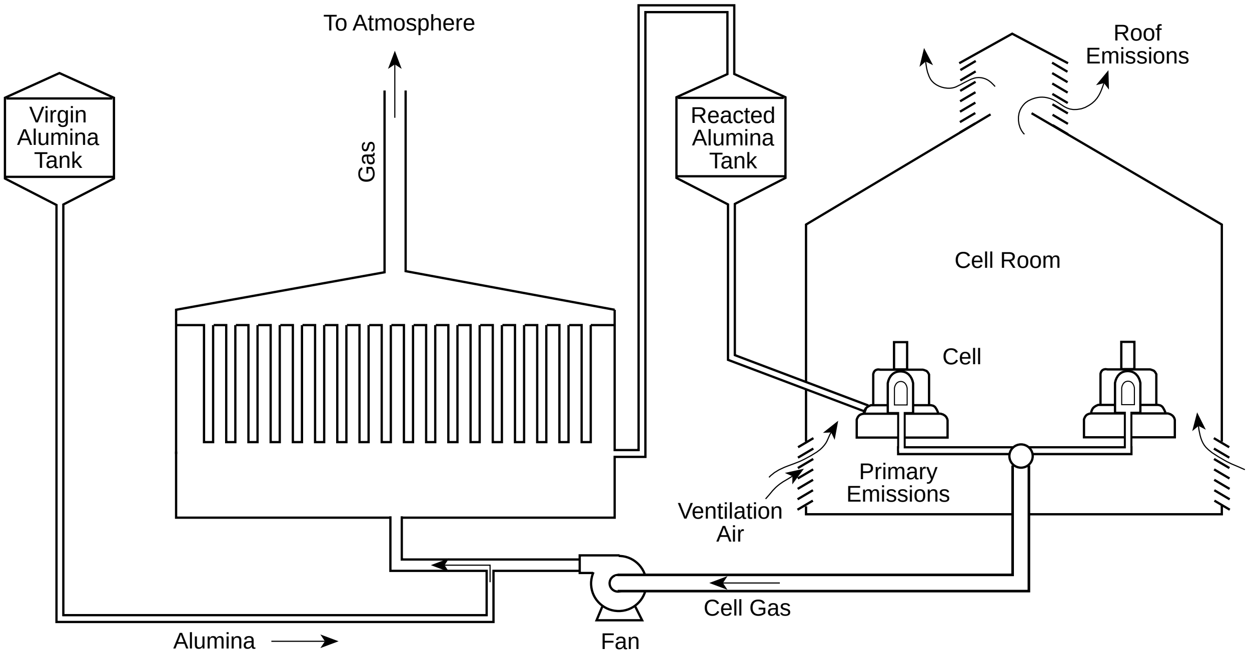

FIGURE 3-2. FLOW DIAGRAM FOR INJECTED ALUMINA DRY SCRUBBER[31]

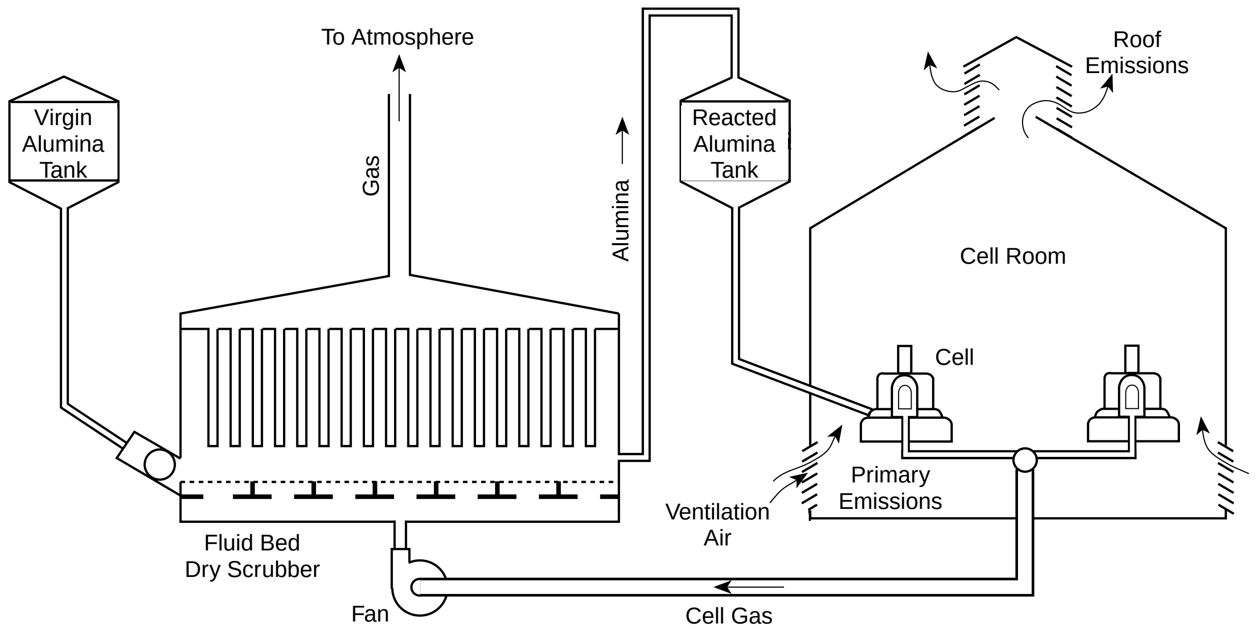

FIGURE 3-3. FLOW DIAGRAM FOR FLUIDIZED BED ALUMINA DRY SCRUBBER[32]

the reactor to allow fresh alumina to be added to the bed and to remove the reacted alumina. After passing through the fluidized bed only once, the reacted alumina is returned to the potline feed system as the raw material for the production process.[33]

Both types of dry scrubbers use baghouses to remove reacted alumina and other particulate matter from the gas. Baghouses are fabric filter collectors that achieve removal efficiencies of over 99 percent down to a particle size approaching 0.3 microns (in most applications).[34] Data from a 1992 survey of the industry indicated that polyester and acrylic materials were the most common choice of fabrics for baghouses. Air-to-cloth ratios ranged from about 2 to 5 ft^3/min per ft^2 of cloth. The most common types of bag cleaning reported were shaking, pulse jet, and reverse air.[35]

Important parameters affecting the efficiency of the alumina in adsorbing gaseous fluoride include the alumina flow rate, the degree of mixing between the alumina and the gas, and the retention time during which the contact occurs. Recirculating or reinjecting a portion of the alumina increases the probability of contact between the alumina particle and HF in the gas, which increases the efficiency of the scrubber.[36] The surface area, moisture content, and sodium content of the alumina also affect the adsorption of HF.[37] Additional details on the design and operation of dry alumina scrubbers can be found in References 38 and 39.[38,39] More information specific to the design and operation of baghouses is given in Reference 40.[40]

3.1.2.2 <u>Wet scrubbers and electrostatic precipitators</u>. Four of the 23 plants use wet scrubbers to control the primary emissions from the reduction cells, and three of these plants also use an electrostatic precipitator in series with the scrubber. These wet scrubbers operate at relatively low pressure drop; consequently, removal efficiencies are much lower than those observed for dry alumina scrubbers.[41] Wet scrubbers used ahead of ESPs serve to remove HF from the gas and to precondition the gas by raising its moisture content, which increases the removal efficiency of the ESP for particulate matter.[42] Wet scrubbers remove contaminants from the process, and unlike dry alumina scrubbers, do not return these contaminants to the cell. Consequently, plants using wet scrubbers can produce a higher purity aluminum.

Plant A uses a floating bed scrubber as its only primary control device. The scrubber operates at a pressure drop of about 3 inches of water with a liquid:gas ratio of 2 gal/1,000 ft^3/min. Soda ash is added to the scrubber water to increase alkalinity, which improves the removal of acid gases and permits greater recycling of the scrubber water. A removal efficiency for GF of 88.5 percent was reported from test data for this system.[43]

Plant B uses multicyclones to remove coarse particles, followed by a spray scrubber and a dry ESP to control emissions from the primary system. The scrubber operates at a pressure drop of 2 inches of water and a liquid:gas ratio of 20 gal/1,000 ft^3/min. No alkali is added to the scrubber water. The ESP is cleaned by rapping at 3-hour intervals, and the company reported a removal efficiency of 96 percent for particulate matter. The overall system was reported to have a removal efficiency of 93 percent for GF.[44]

Plant C also uses a combination of multicyclones, wet scrubbers, and ESPs to control emissions from the primary system. The scrubber is an impingement type and operates at a pressure drop of 0.5 to 2 inches of water and a liquid:gas ratio of 4 to 8 gal/1,000 ft^3/min. Quick lime is added to the scrubber water to improve absorption. Two of three types of ESPs are cleaned continuously by rapping, and the third is cleaned at 2-hour intervals. Based on sampling, this plant reported a removal efficiency of 90 percent for gaseous fluoride. The collection efficiency of the ESPs for particulate matter ranges from 66 to 98 percent.[45]

Plant D uses wet scrubbers and wet ESPs to control primary emissions. The wet scrubber is a cyclonic scrubber that operates at a pressure drop of 4 to 5 inches of water and a liquid:gas ratio of 5 gal/1,000 ft^3/min. The pH of the scrubber water is maintained at about 8.7. The company reported that the removal efficiency of this system for GF was unknown. The wet ESPs were reported to have a removal efficiency of 95 percent for particulate matter.[46]

Additional details on the use of wet scrubbers and ESPs for the control of primary system emissions from the production process can be found in Reference 47.[47]

3.1.2.3 **<u>Other controls.</u>** Two plants that use dry alumina scrubbers also use wet scrubbers for the gas exiting the baghouse. These scrubbers were installed to control SO_2 emissions, which are not controlled by the dry alumina system. Sodium hydroxide is added to the scrubber water to improve the removal of SO_2.[48] Although these scrubbers may provide some additional control of HF, the contribution to the overall control of HF is very small because of the highly-efficient dry alumina scrubber that precedes the wet scrubber.

3.1.3 <u>Control Devices for Secondary Emissions</u>

Secondary emissions are those fugitive emissions that escape capture by the primary control system for the cell. At most plants, these emissions escape through the roof monitor, and are controlled by operating, maintenance, and work practices, which are discussed in the next section. However, secondary emissions at four plants are controlled by wet roof scrubbers as discussed below.

The two plants using the side-worked prebake process have wet roof scrubbers that are a part of the original installation. Originally, these plants had no other controls for the primary system. However, after a primary collection and control system was installed, the wet roof scrubbers were maintained and continued to be used to further reduce emissions. These devices are impingement type scrubbers with very low pressure drops (e.g., on the order of 1 inch of water). The liquid:gas ratios for the two plants were reported as 0.12 and 2 gal/1,000 ft^3/min.

Alkali (sodium aluminate, sodium hydroxide) is added to improve the removal efficiency for acid gases such as HF. The control efficiencies for GF were reported to be 85 and 91 percent.[49]

The other two plants with wet roof scrubbers use the vertical stud Soderberg process. The scrubbers were part of the original installation at one plant, and they were retrofitted later at the second plant. These simple spray scrubbers use water containing sodium hydroxide to improve the removal of acid gases. The control efficiency for GF based on measurements was reported to be 60 percent at one plant and 90 percent at the other.[50]

Information from a vendor of control devices for the aluminum industry stated that wet roof scrubbers that would be installed today would likely continue to be low pressure drop scrubbers. The scrubbers are expected to have control efficiencies for HF and coarse dust on the order of 90 percent; however, the control efficiency for fine particles would be approximately 10 percent. The overall reduction of total fluorides, including both particulate and gaseous form, is expected to be in the range of 50 to 80 percent for wet roof scrubbers.[51]

3.1.4 Operating Procedures and Work Practices as Emission Controls

Operating procedures and work practices can have a direct effect on emissions control. Most of these efforts are directed toward improving the capture of emissions by the primary system and reducing fugitive emissions. The quantities and composition of potline emissions are strongly influenced by operating conditions such as the number, duration, and frequency of open cells; the ability to increase the draft on open cells; temperature; bath ratio; frequency of anode effects; changing of anodes; degree of automation; method of crust breaking; and housekeeping.

3.1.4.1 Suppression of anode effects. During an anode effect, the cell voltage differential rises from its normal 3.8-4.8 volts to 25-60 volts, and the line current is reduced by three- to five-thousand amperes. Anode effects are believed to occur when the alumina content of the both falls and a film of CF_4 gas collects under the anode, which causes a high electrical resistance. The net effect is that the power input to the cell increases more than tenfold. The power increase is converted into heat, which in turn raises the temperature of the cell electrolyte. At the higher cell temperature, fluorine evolution is increased. Depending on the promptness with which the cell operator reacts, an anode effect may last from one to fifteen minutes. Plants with mechanized crust breaking and cell feeding can reduce the amount of time that would be required to correct an anode effect manually.[52]

Replenishing the alumina content of the electrolyte before it falls below the concentration known to cause an anode effect can reduce the frequency of these events. In some cases, newer, more sophisticated computer controlled potlines may operate almost free from anode effects. Anode effects occur at a rate of one per week to one per day per pot at the better controlled plants.[53]

3.1.4.2 <u>Bath temperature and bath ratio</u>. The higher the bath temperature, the more the bath salts will vaporize and become part of the cell emissions. Normal operating temperatures for cells with a bath ratio (i.e., the ratio of sodium fluoride to aluminum fluoride) of approximately 1.40 are between 970°C and 980°C. Because this low operating temperature is near the freezing point of the electrolyte, cell operators must pay close attention to the potroom cells to prevent the cell from becoming too cold. A cold cell is corrected by increasing the cell voltage and allowing the electrolyte to increase in temperature. Abnormal or "sick" cells operate at temperatures in excess of 1000°C and sometimes do not crust over. When these conditions occur, the high temperature molten electrolyte is exposed to the air, and there is a large increase in fluorine in the gases from the cell. Although it is desirable to operate cells at the lowest possible temperature to minimize fluorine emissions, it requires the supervision of trained, conscientious cell operators and/or computer control.[54]

Reducing the bath ratio tends to increase the evolution of fluoride from the bath. Bath ratios of 1.30 to 1.45 were common in the 1970's. However, since then plants have made efforts to increase efficiency to decrease power consumption and costs by lowering the bath ratio.[55] Data from the 1992 survey of plants showed that the bath ratio ranged from 1.05 to 1.41 and the bath temperature ranged from 942°C to 965°C.[56]

Operating conditions that destroy the ability of the bath to crust over and carry a cover of alumina may result in a net increase in cell emissions. The alumina cover prevents the escape of fluoride from the molten bath.[57]

3.1.4.3 Mechanization and Computer Control. Mechanization of crust breaking and cell feeding allows the cell operators time to maintain close watch over the operating cells and to control them within narrow temperature ranges. The overall effect is lower average operating cell temperature, fewer and briefer anode effects, and a reduction in the fluorine content of cell gases compared to normal manual cell operation. Computer control has helped to reduce the need to open the hood to correct overfeeding problems, to add bath additives, or to correct anode effects, which in turn has reduced the quantity of emissions that escape capture.[58]

Full mechanization of reduction cells makes it possible to apply computer control that incorporates frequent scanning of operating variables on each cell and triggers automatic corrective action for any variation that is outside set operating limits. Such control makes it possible for all cells in a potline to be operated at the lowest practical temperature and with fewer upsets caused by anode effects. Cell feeding and crust breaking operations can be cycled in response to the needs of individual cells, and the number of abnormally operating cells usually associated with manual potline operation can be reduced. Variations in the cell operations that stem from individual work practices among cell operators are virtually eliminated by mechanization and computer control.[59]

3.1.4.4 Hood Maintenance and Operation. The present design of reduction cells, regardless of how well enclosed or shielded they may be, do not achieve 100 percent hooding efficiency because the shields need to be opened for cell working, for anode replacement (for the prebake process), and for metal tapping. In order to contribute significantly to improved pollution control, operators of primary aluminum facilities must pay careful attention to the design and construction of hoods and strictly insist that potroom operators keep shields in good repair and that they open or remove them no more than necessary.[60] The number of hoods or shields that are open, the degree to which they are open, and the duration directly affect capture efficiency and the quantity of secondary emissions that eventually escape through the roof. These factors are to some extent directly under the control of the plant management or plant operator. Side shields or end doors are opened for anode replacement, correcting anode effects, inspections, measuring the depth of aluminum, and tapping. Many plants limit the number of side shields and end doors that may be open at any given time. In addition, some plants vent the aspiration air used to draw the molten aluminum into the ladle back into the primary collection hood, thus minimizing emissions from tapping.[61]

Some potlines are provided with the means of increasing the air flow into the primary collection system at individual cells when hoods need to be opened. This contributes to higher collection efficiency and reduces secondary emissions. The use of this technique is discussed in Section 3.1.1 (Cell Hooding) for the different types of processes.

3.1.4.5 Work practices. Several plants have developed formal procedures and work practices to control emissions. These programs include limits on the number of cells that can be open at any one time, periodic inspections of hooding and work practices, and repair or replacement of damaged hooding.

The State of Washington has established formal inspection programs at one plant and requires periodic inspection of the hoods and their condition, recording this information, and reporting the results to the State agency. The information is also used by plant management to take corrective actions to reduce emissions. At the small CWPB plant, the inspector records the condition of each side, quarter, and end shield and whether it is misplaced, damaged, dropped, or missing. The inspector also notes if emissions are observed from stacks or from fugitive sources, if baghouse tops are leaking, any other leaks (e.g., air slides, feeders, dischargers), and if the baghouse pressure drop is within specifications.[62] At a VSS plant, the inspection includes the hood skirt (if it is smoking, red hot, or needs to be replaced), the burner (open door, smoking, obstructed), and open cells.[63]

Examples of work practices programs were obtained from the 1992 survey of the industry, and several examples are given below.[64]

Plant A:

- Vent exhaust from tapping back into the cell
- Clean anodes at central location with dust collection
- Extinguish anode effects within 30 seconds using computer (keeping hoods and doors closed)
- Feed alumina with computer control and keep hoods and doors closed
- Clean floors, inspect shields, and straighten as necessary each shift
- When setting anodes, no more than 3 shields per cell may be removed on 3 consecutive cells
- No more than 3 end doors may removed during tapping.

Plant B:

- Place open cells on high draft
- Frequent manual sweeping of cell deck plates, floors
- Larger passages cleaned with mobile sweepers 3 times per day
- Daily inspection of shields and end doors, with daily repair or replacement if damaged
- Independent checks of the cell's exhaust velocity
- Limit of 3 cells with 3 shields removed at any one time

Plant C:

- Place open cells on high draft
- Main traffic aisles and area around pots swept daily
- Two persons (80 hours per week) are assigned to hood repair
- Hoods are inspected every 4 weeks, and repairs made on line or damaged hoods replaced

3.2 CONTROL DEVICES FOR ANODE BAKING

Anode bake furnaces are used at prebake plants to produce the carbon anode used in center-worked and side-worked prebake cells. The pollutants emitted from the bake furnace include polycyclic organic matter (POM) and other hydrocarbons that evolve from heating and carbonizing the paste binder pitch in ring furnaces.[65] The pitch contains polycyclic organic matter that is recovered as tar from the by-product coking process, and the tar is refined to produce a 40 to 60 percent bottoms fraction of heavy organics with very high boiling points. Fluorides also evolve from the furnace and originate from residual bath materials that adhere to anode "butts" that are recycled to the anode production process. (Anode butts are the portion of the original anode that remains after its useful life has been depleted in the reduction cell; they are replaced with new anodes on a regular schedule.) Because of residual moisture and the elevated temperatures in the furnace (combustion temperatures around 1300°C), most of the fluoride that is evolved is HF (on the order of 95 percent of the total fluoride).[66]

The most common device used to control emissions of HF and POMs from anode bake furnaces is a dry alumina scrubber system similar to that described for control of primary emissions from the cell. Twelve of the 17 prebake plants use alumina ore to adsorb gaseous pollutants followed by a baghouse for the removal of particulate matter. Dry alumina scrubber systems provide higher levels of emission control than the other systems because of the dual mechanism of removal and the higher efficiency of baghouses for particles. The distribution of types of control devices is given in Table 3-2.[67]

TABLE 3-2. SUMMARY OF ANODE BAKE FURNACE CONTROL DEVICES[68]

Control device	Number of plants
Dry alumina scrubber - fluidized bed	7
Dry alumina scrubber - injection type	5
Wet scrubber and electrostatic precipitator	1
Electrostatic precipitator only	1
No control device	3

The organic vapors that evolve from the anodes as they are baking are pulled into the hot flue gas system where they can be burned at a temperature of about 1,300°C. The degree of destruction of these organic compounds depends on an adequate supply of oxygen, sufficient temperature and residence time, and adequate mixing.[69, 70]

The emission control systems in use are designed to remove fluorides (including HF) and tar, which contains POMs. The removal of tar is influenced by the exhaust gas temperature because of its condensation temperature. For example, the concentration of uncondensed tar in the gas, measured by toluene extraction, decreases from 700 mg/Nm^3 at 212°F to less than 50 mg/Nm^3 at 122°F.[71]

The 1992 survey of plants indicated that the gas temperature entering the dry scrubber system ranged from 209°F to 360°F. The flow rate of alumina for three plants of different sizes included 0.6 t/hr for a fluidized bed and a gas flow of 45,000 acfm, 3 t/hr for dry injection and a gas flow of 88,500 acfm, and 1.25 t/hr for a fluidized bed and a gas flow of 240,000 acfm. The most common types of material used in the baghouse were woven acrylic and polyester felt. The most common bag cleaning methods were pulse jet and reverse air, and these installations had air-to-cloth ratios (acfm/ft^2) of 3 to 5. A few plants used a shaker cleaning procedure with air-to-cloth ratios of 1.4 to 1.6.[72]

One plant uses a wet scrubber and wet ESP to control emissions from the anode bake furnace. The scrubber operates at a pressure drop of 3.5 inches of water and a liquid-to-gas ratio of 2.3 gal/1,000 acfm. The gas enters the wet ESP at about 110°F.[73]

Several factors affect the emissions from the anode bake furnace. Combustion conditions in the flues (temperature, oxygen content, residence time, mixing) affect the quantity of hydrocarbons entering the control device. The degree to which recycled anodes are cleaned of bath materials that contain fluorides affects the evolution of HF from the furnace. For example, careful cleaning of the recycled anodes instead of simply knocking off residual bath solids was reported to reduce total uncontrolled fluorides from the furnace from 1.6 to 0.4 lb/ton.[74]

3.3 CONTROL DEVICES FOR ANODE PASTE PRODUCTION

The carbon plant (also called the "green mill") is a materials handling and mixing operation in which coal tar pitch, petroleum coke, and recycled anode butts (for prebake plants only) are combined to form "green" (unbaked) anode paste or briquettes. These raw materials are crushed and sized before mixing, and many plants have control devices for nuisance dust generated in this operation. The focus for control of HAPs are those generated during the processes involving mixing of the components, transfer, and anode forming (e.g., in a molding press). Many plants have hoods or other types of pickup points within the green mill to collect emissions of organic vapors from these operations and route them to a control device.

The most common type of control device currently used for paste mixing is a baghouse; however, the most effective control for emissions of organic compounds from this operation is a dry coke scrubber. The dry coke scrubber uses petroleum coke as an adsorbent material for the organics, and a baghouse is used to remove coke fines and any particulate matter generated by this process.[75] The types of controls currently in use at the 23 plants are summarized in Table 3-3.

TABLE 3-3. SUMMARY OF PASTE MIXING CONTROL DEVICES[76]

Control device	Number of plants
Dry coke scrubber	5
Dry alumina scrubber	7
Wet scrubber	2
High efficiency air filter	2
Electrostatic precipitator	1
No control device	5

The dry coke scrubbers include both injection type and fluidized bed. The rate of coke usage was reported by three plants and ranged from 0.5 to 1.5 t/hr for gas flows of 17,000 to 50,000 acfm. The most common features of the baghouses associated with the dry scrubber are the use of pulse cleaning, air-to-cloth ratios of 3 to 5 acfm/ft^2, and polyester felt or acrylic fabric.[77]

Emission testing for polycyclic organic matter (POM) was performed at a plant with continuous paste mixers[78] and at a plant with batch mixers.[79] The POM control efficiency ranged from 95 to 99 percent for the two control devices used at the continuous paste mixing operation compared to a control efficiency of 90 percent at the plant using batch mixers. Factors that may explain the variations in control efficiency between batch and continuous paste processes are: (1) differences in operation that allow the continuous process to maintain a lower evacuation rate (less dilution), (2) a higher coke rate relative to the volume of gas treated, and (3) a higher POM inlet concentration.

3.4 POLLUTION PREVENTION OPPORTUNITIES

The work practices, equipment maintenance, and equipment improvements discussed in this chapter all represent the opportunity to prevent the escape of secondary emissions. Because secondary emissions are the major contributor to total plant emissions, most plants are expected to use these techniques to improve emission control.

Another opportunity is to establish specifications for fines for the alumina ore. Plants prefer to have a relatively low level of fines (e.g., no more than 5 to 12 percent less than 325 mesh) because the fines more easily become airborne or entrained, which increases emissions. Some plants have reported alumina shipments with as much as 50 percent less than 325 mesh, and stated that increases in emissions were due (at least in part) to the fines. The problem is compounded at VSS plants because the fines tend to flow (i.e., they are very fluid), and the alumina cover around the VSS cell is much more difficult to maintain.

Future opportunities may become available if a substitute is found for the coal tar pitch that is used as a binder to make anodes. This pitch is the major source of polycyclic organic matter (POM) emitted from Soderberg potlines, and any reduction in the POM content of the binder should result in lower levels of POM emissions.

3.5 REFERENCES

1. Review of New Source Performance Standards for Primary Aluminum Reduction Plants. U.S. Environmental Protection Agency. Report No. EPA-450/3-86-010. September 1986. p. 4-20.

2. Air Pollution Control in the Primary Aluminum Industry. Singmaster and Breyer. Report No. EPA-450/3-73-004A. July 1973. p. 5-3.

3. Atkins, P.R. External Problems and Measures for Their Control: Fluorides, Coal Tar Pitch Volatiles, SO_x, NO_x, Dust, etc. In: Multi-regional Training Workshop on Environmental Management of Aluminum Smelters. United Nations Environment Programme/International Primary Aluminum Institute. December 8-9, 1986. p. 100.

4. Primary Aluminum: Guidelines for Control of Fluoride Emissions from Existing Primary Aluminum Plants. U.S. Environmental Protection Agency. Report No. EPA-450/2-78-049b. December 1979. p. 6-2.

5. Lallement, Yves. Environmental Impact of Aluminum Smelters. In: Multi-regional Training Workshop on Environmental Management of Aluminum Smelters. United Nations Environment

Programme/International Primary Aluminum Institute. December 8-9, 1986. p. 71.

6. Reference 1, p. 4-2.

7. Reference 2.

8. Reference 1, p. 4-2.

9. Memorandum from Ours, K., Research Triangle Institute, to docket. July 1994. Summary of responses to 1992 Section 114 information collection request from the primary aluminum industry. Table entitled "Primary Aluminum Potlines." 5 p.

10. Reference 4, p. 6-4.

11. Memorandum from Sawatzky, M., Kaiser Aluminum, to Ted Mix, Washington Department of Ecology. November 3, 1993. Enclosing final report on cell hooding efficiency evaluation. 4 p.

12. Reference 4, p. 6-4.

13. Memorandum from Ours, K., Research Triangle Institute, to docket. July 1994. Summary of responses to 1992 Section 114 information collection request from the primary aluminum industry. Table entitled "Potline Information." 3 p.

14. Reference 4, p. 6-4.

15. Reference 9, 5 p.

16. Reference 4, p. 6-5.

17. Reference 4, p. 6-6.

18. Reference 4, p. 6-6.

19. Reference 9, 5 p.

20. Reference 4, p. 6-6.

21. Memorandum from Scultz, R.C., Kaiser Aluminum, to Merley McCall, Washington Department of Ecology. August 28, 1992. Cell hooding efficiency evaluation. 5 p.

22. Reference 4, p. 6-8.

23. Reference 3, p. 5-7.

24. Reference 9, 5 p.

25. Reference 4, p. 6-10.

26. Reference 13, 3 p.

27. Reference 13, 3 p.

28. Reference 3, p. 100.

29. Reference 13, p. 3

30. Reference 3, p. 100.

31. Reference 4, p. 6-33.

32. Reference 4, p. 6-31.

33. Reference 3, p. 101.

34. Handbook: Control Technologies for Hazardous Air Pollutants. U.S. Environmental Protection Agency. Report No. EPA-625/6-86-014. September 1986. p.80.

35. Memorandum from Ours, K., Research Triangle Institute, to docket. July 1994. Summary of responses to 1992 Section 114 information collection request from the primary aluminum industry. Table entitled "Aluminum Smelting Control Parameters." 14 p.

36. Reference 3, p. 8.

37. Wedde, G. Emission Control Technologies. ABB Environmental, ABB Flakt Systems for the Primary Aluminum Industry. Oslo, Norway. 1990. p.8.

38. Reference 2, p. 5-24 to 5-29.

39. Reference 4, p. 6-29 to 6-34.

40. Reference 34, p. 80-87.

41. Reference 35, 14 p.

42. Reference 2, p. 5-32.

43. Reference 13, 3 p.

44. Reference 13, 3 p.

45. Reference 13, 3 p.

46. Reference 13, 3 p.

47. Reference 2, p. 5-29 to 5-59.

48. Reference 35, 14 p.

49. Reference 13, 3 p.

50. Reference 13, 3 p.

51. Reference 37, p. 11.

52. Reference 2, p. 5-2, 5-3.

53. Reference 2, p. 5-2, 5-3.

54. Reference 2, p. 5-2.

55. Reference 1, p. 3-31.

56. Reference 9, 5 p.

57. Reference 2, p. 5-3.

58. Reference 1, p. 4-5.

59. Reference 1, p. 4-5.

60. Reference 2, p. 5-3.

61. Reference 1, p. 4-5, 4-6.

62. Forms received from Ted Mix, Washington Department of Ecology entitled: "Potroom Survey Summary for Kaiser Aluminum, Mead Works." November 1992. 2 p.

63. Memorandum from Wooster, W.E., Columbia Aluminum Corporation, to Ted Mix, Washington Department of Ecology. March 2, 1994. Cell Line Inspection Sheets and Cell Line Work Practice Environmental Procedures. 5 p.

64. Memorandum from Ours, K., Research Triangle Institute, to docket. July 1994. Summary of responses to 1992 Section 114 information collection request from the primary aluminum industry. Table entitled "Work Practices." 5 p.

65. Reference 37, p. 14.

66. Reference 4, p. 5-26.

67. Reference 13, 3 p.

68. Memorandum from Ours, K., Research Triangle Institute, to docket. July 1994. Summary of responses to 1992 Section

114 information collection request from the primary aluminum industry. Table entitled "Anode Baking Control Parameters." 6 p.

69. Reference 1, p. 4-11.

70. Reference 4, p. 3-26.

71. Reference 37, p. 15.

72. Reference 68, 6 p.

73. Reference 68, 6 p.

74. Reference 4, p. 5-26.

75. Memorandum from Ours, K., Research Triangle Institute, to docket. July 1994. Summary of responses to 1992 Section 114 information collection request from the primary aluminum industry. Table entitled "Paste Mixing and Anode Forming Control Parameters." 5 p.

76. Reference 75, 5 p.

77. Reference 75, 5 p.

78. Emissions Measurements Test Report - Northwest Aluminum Company. Prepared by Entropy, Inc. June 1994. 77 p.

79. Kaiser Aluminum and Chemical Corporation Method 5/POM and 13B Testing - Mead, Washington - March 15-24, 1994. Prepared by AmTest Air Quality, Inc. November 9, 1994. pp. 1 to 99.

4.0 MODEL PROCESSES WITH OPTIONS FOR EMISSION CONTROL AND MONITORING

This chapter describes the model processes that were developed to analyze the environmental, cost, and economic impacts of various control options on the primary aluminum industry. The model processes represent the major production processes in the industry (aluminum production, paste production, and anode baking) and their emission control technologies.

Control options for new and existing sources are also presented and are based on the emission control technologies described in detail in Chapter 3. In addition, options for monitoring are provided in this chapter.

4.1 MODEL PROCESSES

Detailed model processes were developed to represent the different types of production units, control devices, and production rates found at existing primary aluminum plants. The type of production process is important in the estimates of impacts because it affects the composition and quantity of emissions, as well as the choice of control device and how it is designed and operated. The model process characterization of emission control devices provides insight into the current level of control (the baseline) and the impacts of improved control. Variations in production rates for the model processes are important to obtain representative estimates of emissions and to account for economies of scale in the cost analysis.

The major sources of information used to characterize the industry were responses to information collection requests.[1] The information on the types of processes and emission controls for each plant are summarized in Table 4-1. Details were also developed for the model processes to describe typical gas flow rates, temperatures, and other factors for potential use in the analysis of impacts. These parameters are documented in a technical note to the docket[2] and are not repeated here. The following sections provide a brief explanation of the development

TABLE 4-1. SUMMARY OF INFORMATION USED TO DEVELOP MODEL PROCESSES[3]

Plant identification	Plant type	Paste production	Anode baking	Aluminum production	
				Primary control	Secondary control
Alcan Aluminum Corp., Henderson, KY	CWPB	baghouse (coke hopper, mixer)	dry alumina fluidized bed scrubber	alumina fluidized bed scrubber	work practices
Alcoa, Alcoa, TN	CWPB	baghouse (coke unloading, crusher, mixer)	none	alumina fluidized bed scrubber	work practices
Alcoa, Badin, NC	CWPB	baghouse (ball mill, conveyors)	none	alumina fluidized bed	work practices
Alcoa, Massena, NY	CWPB	baghouse (butt crusher, coke storage, aggregate blender, coke crusher, sizing, classifiers, storage discharge, mixers)	dry alumina injection scrubber	alumina fluidized bed dry scrubber	work practices
Alcoa, Newburg, IN	CWPB	baghouse (crusher, ball mill, mixer)	dry alumina fluidized bed scrubber	4 alumina fluidized bed scrubbers 2 alumina dry injection scrubbers	work practices
Alcoa, Rockdale, TX	CWPB	baghouse (butt crushing, heater, crusher, mixer, former)	dry alumina injection scrubber	multicyclone, wet scrubber, ESP; wet scrubber, ESP; fluidized bed dry injection	work practices
Alcoa, Wenatchee, WA	CWPB	baghouse (fugitive emissions)	dry alumina fluidized bed scrubber	alumina fluidized bed scrubber	work practices
Alumax, Goose Creek, SC	CWPB	coke dry scrubber, baghouse (ball mill, coke conveyors)	dry alumina injection scrubber	alumina dry injection scrubber	work practices
Columbia Aluminum Corp., Goldendale, WA	VSS	HEAF (ball mill, heater, mixer), baghouse (unloading and storage, heater, ball mill)	not applicable (na)	dry alumina injection and NaOH venturi scrubber	wet roof scrubbers, work practices
Columbia Falls Aluminum Co., MT	VSS	wet scrubber (pitch transfer, heater, mixer, extruder)	na	fluidized bed alumina dry scrubber	work practices
Eastalco, Frederick, MD	SWPB	coke dry scrubber (ball mill, heater, mixer, press), baghouse (butt crushing, cathode paste mixer)	dry alumina injection scrubber	dry alumina injection scrubber	wet roof scrubbers, work practices
Intalco, Ferndale, WA	SWPB	dry alumina scrubber (heater, mixer, anode former), baghouse (butt crusher)	dry alumina injection scrubber	dry alumina injection scrubber	wet roof scrubbers, work practices
Kaiser Aluminum, Mead, WA	CWPB	coke dry scrubber (mixer, conveyors, former), baghouse (crusher, heater), dry ESP (ball mill)	dry alumina injection plus fluidized bed scrubber	alumina dry injection, fluidized bed scrubber	work practices
Kaiser Aluminum, Tacoma, WA	HSS	HEAF (anode and cathode mixers), baghouses (unloading, storage, and crusher)	na	alumina fluidized bed with dry injection	work practices
Noranda Aluminum, Inc. New Madrid, MO	CWPB	baghouse (butt crusher, crusher, mixer)	dry alumina fluidized bed scrubber	dry alumina fluidized bed scrubber	work practices

(continued)

TABLE 4-1. (Continued)

Plant identification	Plant type	Paste production	Anode baking	Aluminum production	
				Primary control	Secondary control
Northwest Aluminum Co., The Dalles, OR	VSS	coke injected dry scrubber (ball mill, heater, mixer)	na	dry alumina injection and wet scrubbers	wet roof scrubbers, work practices
NSA, Hawesville, KY	CWPB	baghouse (conveyors, ball mill, crusher)	none	multiple cyclones, wet scrubbers, ESP	work practices
Ormet Corp., Hannibal, OH	CWPB	baghouse (coke sizing, ball mill)	induced draft/ESP	alumina dry injection scrubber	work practices
Ravenswood, Aluminum Corp., WV	CWPB	baghouse (ball mill, crusher, mixer, conveyors)	ring furnaces- dry alumina fluidized bed scrubber cranes- hoods/ baghouse anode cleaning- canopy hood/ baghouse	alumina fluidized bed scrubber	work practices
Reynolds, Longview, WA	HSS	venturi scrubber (mixer), baghouse (sizing, crushing, cathode prep)	na	wet prescrubbers and wet ESP	work practices
Reynolds , Massena, NY	HSS	coke dry scrubber (heater, mixer), baghouse (crusher)	na	wet scrubber (SO_2 control)	work practices
Reynolds, Troutdale, OR	CWPB	baghouse (ball mill, mixer belt [not mixer])	flues/ wet ESP	alumina dry injection scrubber	work practices
Vanalco Inc., Vancouver, WA	CWPB	dry ESP (mixer, grinder, ball mill, conveyor)	dry alumina fluidized bed scrubber	alumina fluidized bed scrubber	work practices

Plant types:

CWPB = center-work prebake
HSS = horizontal stud Soderberg
SWPB = side-work prebake
VSS = vertical stud Soderberg
ESP = electrostatic precipitator
HEAF = high efficiency air filter
na = not applicable

of the model processes and present the most important parameters that will be used to evaluate control options.

4.1.1 Aluminum Production

The primary aluminum industry in the United States is currently made up of 91 potlines located at 23 plants. There are 64 center-work prebake (CWPB) potlines at 15 plants, 5 side-work prebake (SWPB) potlines at 2 plants, 12 horizontal stud Soderberg

(HSS) potlines at 3 plants, and 10 vertical stud Soderberg (VSS) potlines at 3 plants (see Table 4-1). The average production rate for these plants is about 200,000 tons per year with a range of about 78,000 to 360,000 tons per year.[4]

Model potlines for aluminum production were developed by first dividing the industry into the four different types of potlines (CWPB, SWPB, HSS, and VSS). Next, each potline type was divided into categories by the type of primary and secondary emission control device that is used. The final step was to develop a model potline to represent groups of potlines with similar production rates based on the range found in the industry. This approach resulted in 13 model potlines to represent the 91 potlines at primary aluminum plants.

A brief description of each of the model processes is given in Table 4-2 along with the number of actual potlines in the industry that are represented by each model. Additional details on the parameters used to develop the model processes and the range of values found for the various plants are given in a technical note to the docket.[5]

4.1.2 Paste Production

Model processes for anode paste production were also developed from technical information that was submitted by the industry to the EPA in information collection requests.[6] Because the paste production process and operating parameters are similar at all plants, separate model processes were required only to represent the different types of control devices used. Table 4-3 summarizes each of the six model processes for anode paste production and shows the number of facilities represented by each model.

4.1.3 Anode Baking

The anode baking process only takes place at prebake facilities and is similar at all such facilities; consequently, model processes were required only to represent differences in the types of emission control devices used and the range of production rates at actual facilities. Table 4-4 summarizes the

TABLE 4-2. MODEL PROCESSES FOR ALUMINUM PRODUCTION

Model	Type of potline	Control device(s)	Production (tons/year)	Number of potlines represented
1	SWPB	Dry alumina scrubbers for primary control and wet roof scrubbers for fugitive control.	100,000	5
2	CWPB	Dry alumina scrubbers for primary control.	28,000	26
3	CWPB	Dry alumina scrubbers for primary control.	60,000	20
4	CWPB	Dry alumina scrubbers for primary control.	100,000	8
5	CWPB	Multicyclones, wet scrubbers, and ESP for primary control.	46,000	8
6	CWPB	Wet scrubbers and ESP for primary control.	40,500	1
7	VSS	Dry alumina scrubbers followed by wet scrubbers for primary control and wet roof scrubbers for fugitive control.	50,000	5
8	VSS	Dry alumina scrubbers for primary control.	37,000	5
9	HSS	Dry alumina scrubbers for primary control.	20,000	2
10	HSS	Dry alumina scrubbers for primary control.	39,000	1
11	HSS	Wet scrubber for primary control.	45,600	3
12	HSS	Wet prescrubbers and wet ESP for primary control.	26,000	3
13	HSS	Wet prescrubbers and wet ESP for primary control.	51,000	3

Plant types:

CWPB = center-work prebake
HSS = horizontal stud Soderberg
SWPB = side-work prebake
VSS = vertical stud Soderberg
ESP = electrostatic precipitator

TABLE 4-3. MODEL PROCESSES FOR PASTE PRODUCTION

Model	Control device	Paste production (tons/year)	Number of plants represented
1	Dry coke scrubber	98,000	5
2	Dry alumina scrubber	162,000	1
3	Baghouse	137,000	12
4	High efficiency air filter (HEAF)	64,000	2
5	Wet scrubber	109,000	2
6	Electrostatic precipitator	79,800	1

TABLE 4-4. ANODE BAKING MODEL PROCESSES

Model	Control device	Anode production (tons/year)	Number plants represented
1	Dry alumina scrubber	98,500	8
2	Dry alumina scrubber	160,500	4
3	Electrostatic precipitator	133,000	2
4	No emission controls	112,000	3

four model processes that were developed to represent the differences among anode baking processes at existing plants.

4.2 CONTROL OPTIONS FOR EXISTING PLANTS

4.2.1 Aluminum Production

The emission control options for aluminum production include both upgrading the primary control system and reducing secondary or fugitive emissions that generally escape through the roof monitor. These two emission sources associated with potlines are interrelated by the fact that a small increase in the capture efficiency of the primary control system will result in a large decrease in secondary emissions.[7] Secondary emissions account for over 90 of the total fluoride emissions from the production operation at most aluminum plants.[8]

4.2.1.1 Primary Control.

All of the aluminum plants have primary emission control systems on their potlines. The primary control system for a potroom consists of the pot hood, necessary ducting, and a primary air pollution control device or a series of devices designed primarily to remove hydrogen fluoride gas, particulate matter containing fluoride, polycyclic organic matter (POM), other particulate matter, and in some cases, sulfur dioxide.

The most common and most effective control device for fluoride emissions currently in use is the dry alumina scrubber with a baghouse. When it is operating properly, the alumina scrubber/baghouse has a control efficiency for total fluoride in excess of 99 percent;[9] consequently, there are few opportunities to upgrade this control device or to reduce significantly primary emissions.

Two of the plants with dry alumina scrubbers for primary control also have wet scrubbers in series with the dry scrubbers (see Northwest Aluminum and Columbia Aluminum in Table 4-1). These plants are represented by Model Process 7 in Table 4-2. The wet scrubbers following the alumina scrubbers/baghouse were installed primarily to control sulfur dioxide emissions. They provide little additional reduction in the mass of fluoride emissions because of the high efficiency of the alumina scrubber/baghouse. Consequently, the installation of wet scrubbers in series with existing dry alumina scrubbers will not be considered as an option for improved primary control in this analysis.

There are 18 potlines (at 4 plants) among the total of 91 potlines that are not controlled by dry alumina scrubbers. These plants use multiple cyclones, electrostatic precipitators, wet scrubbers, or some combination of these devices for primary control. The control efficiency of these devices, as discussed in Chapter 3, is on the order of 88 to 90 percent for fluoride. The four plants are identified in Table 4-1, and the

18 potlines are represented by Model Processes 5, 6, 11, 12, and 13 in Table 4-2.

The focus of control options to improve the primary emission control system will be on the model processes (representing 18 potlines) that do not have alumina scrubbers/baghouse controls. For the purpose of identifying control options for MACT for hazardous air pollutants, controls for SO_2 (e.g., wet scrubbers) are not considered. The control option chosen for analysis for the primary system is to **replace the existing wet systems for primary control with a dry alumina scrubber/baghouse system.**

This option reflects the additional emission control achieved by most of the existing plants that have already installed dry alumina scrubbers. This control device captures fluorides and enables the facility to return the fluoride back to the production process (i.e., there is no pollution control residue, and valuable fluorides are recovered).

The control option for the primary system is applied to the model processes in Table 4-5. Several other options were considered; however, they were not included for analysis because they do not achieve the very high control efficiency of dry alumina scrubbers and have operating costs that are on the same order of magnitude. For example, in recent years 19 plants have either replaced wet systems with the dry alumina scrubber, or in cases of no primary control, have chosen to install dry alumina scrubbers instead of other types of control devices that achieve lower control efficiencies. Consequently, replacing the existing wet control systems with devices other than an alumina scrubber/baghouse or adding another device in series with the existing system was not considered because of lower control efficiency and comparable or higher costs. Similarly, splitting the uncontrolled primary emissions and directing part of the flow to the existing control device and the other part to a new, more efficient control device does not offer advantages over

TABLE 4-5. CONTROL TECHNOLOGY FOR PRIMARY EMISSIONS

Model	Type of potline	Existing control	Control option
1	SWPB	Dry alumina scrubbers	None
2	CWPB		
3	CWPB		
4	CWPB		
5	CWPB	Multicyclones, wet scrubbers, ESP	Dry alumina scrubbers
6	CWPB	Wet scrubbers, ESP	
7	VSS	Dry alumina scrubbers followed by wet SO_2 scrubbers	None
8	VSS	Dry alumina scrubbers	
9	HSS		
10	HSS		
11	HSS	Wet scrubber	Dry alumina scrubbers
12	HSS	Wet scrubbers and wet ESP	
13	HSS		

Plant types:

CWPB = center-work prebake
HSS = horizontal stud Soderberg
SWPB = side-work prebake
VSS = vertical stud Soderberg
ESP = electrostatic precipitator

replacement with the dry alumina scrubber. Again in this case, the overall control efficiency would be lower than that of a dry alumina scrubber, and in addition, economy of scale would be lost in installing a smaller, more efficient control for only a part of the primary emissions.

4.2.1.2 Secondary Control.

The control option for secondary emissions includes improved work practices, operation, and equipment maintenance procedures. As discussed in detail in Chapter 3, numerous activities involving work practices, equipment condition, and operation of the cell affect the capture efficiency of the primary system, which in turn directly affect the quantity of secondary emissions escaping capture. Most plants have work practice programs, inspection procedures, and maintenance programs for the repair or replacement of damaged hoods and seals. However, the performance demonstrated at the best-controlled plants indicates that many plants have the capability of improving their control program for secondary emissions by increasing the capture of the primary system. The improved or enhanced program for secondary emissions includes optimizing work practices and following written procedures; inspections to assess equipment condition and adherence to work practices; and repair of hoods, seals, and other parts of the primary collection system as needed. This control option is applied to the model processes in Table 4-6.

4.2.2 Anode Paste Production

The major hazardous air pollutant of interest from anode paste production is polycyclic organic matter (POM), and the dry coke scrubber with a baghouse was judged to be the best control device for POM from the paste production process.[10] Coke is the dry scrubbing material of choice for this process because it can be returned directly to the paste production operation. The dry coke serves as a condensation point for organic compounds, and the baghouse removes coke fines as well as POM in the form of fine particulate matter. There are five plants that use a dry coke scrubber/baghouse for air pollution control on their paste production processes. The other plants use baghouses alone (primarily for dust control), high efficiency air filters (HEAF), wet scrubbers, an electrostatic precipitator (ESP), or a dry alumina scrubber to control emissions from paste production. One plant, Intalco, ducts its paste plant fumes to the flue that carries exhaust gases from the anode bake oven to the bake oven scrubber.

One control option was developed for paste production. The option would be to install dry coke scrubbers to replace the existing controls on plants without dry coke scrubbers. The dry coke scrubber includes the use of a dry scrubbing medium (coke) as well as a baghouse; consequently, it is more efficient than a baghouse or air filter alone. In addition, the coke scrubber/baghouse is also more efficient than wet scrubbers or ESPs. The control option is applied to the model processes in Table 4-7.

TABLE 4-6. CONTROL OPTION FOR SECONDARY EMISSIONS

Model	Type of potline	Existing control	Control option
1	SWPB	Wet roof scrubbers, work practices, inspection, maintenance, operation, etc.	For all: improved or enhanced work practices, inspection, maintenance, operation, etc.
2	CWPB	Work practices, inspection, maintenance, operation, etc.	
3	CWPB		
4	CWPB		
5	CWPB		
6	CWPB		
7	VSS	Wet roof scrubbers, work practices, inspection, maintenance, operation, etc.	
8	VSS	Work practices, inspection, maintenance, operation, etc.	
9	HSS		
10	HSS		
11	HSS		
12	HSS		
13	HSS		

Plant types:

CWPB = center-work prebake
HSS = horizontal stud Soderberg
SWPB = side-work prebake
VSS = vertical stud Soderberg

TABLE 4-7. CONTROL TECHNOLOGY FOR PASTE PRODUCTION

Model	Existing control device	Control option
1	Dry coke scrubber	None
2	Dry alumina scrubber	Replace with dry coke scrubber
3	Baghouse	
4	High Efficiency Air Filter (HEAF)	
5	Wet scrubber	
6	Electrostatic precipitator	

4.2.3 Anode Baking

The dry alumina scrubber/baghouse has also been demonstrated as the most effective device currently used for the control of emissions of both fluorides and POM from the anode bake furnaces.[11] There are 12 prebake plants in the industry that use dry alumina scrubbers as the control for anode baking. There are two prebake plants that use ESPs as control devices, and the three remaining prebake plants have no emission controls on their bake furnaces.

The control option developed for the bake furnaces without any controls is to install a dry alumina scrubber. This option is applied to the model processes in Table 4-8.

TABLE 4-8. CONTROL TECHNOLOGY FOR ANODE BAKING

Model	Existing control device	Control option
1	Dry alumina scrubber	None
2	Dry alumina scrubber	
3	Electrostatic precipitator	Replace with dry alumina scrubber
4	No emission controls	Install a dry alumina scrubber

4.3 CONTROL OPTIONS FOR NEW SOURCES

Control options for new sources are based on the emission control that is achieved by the best controlled similar source. The control option for new sources for primary emissions from the reduction cell is based on the well-demonstrated and effective dry alumina scrubber. For the control of secondary emissions, the demonstrated controls are work practice programs, inspection procedures, and maintenance programs for the repair or replacement of damaged hoods and seals. The dry coke scrubber was identified as the best control for paste production, and the dry alumina scrubber was determined to be the best control for the anode bake furnace. These control options for new sources are summarized in Table 4-9.

TABLE 4-9. CONTROL TECHNOLOGY FOR NEW SOURCES

Source	Control Technology
Primary system	Dry alumina scrubber
Secondary system	Improved maintenance, operation, equipment repair, etc.
Paste production	Dry coke scrubber
Anode baking	Dry alumina scrubber

4.4 MONITORING OPTIONS

The purposes of monitoring include determining compliance with emission limits; assessing the functioning of emission control equipment on a continuing basis; assessing the performance of work practices, operating procedures, and equipment maintenance or repair on emissions; and providing information for prompt corrective actions when the control device malfunctions or when operating practices increase emissions.

Options for monitoring are discussed in the following sections and will be considered for emissions from potlines (primary and secondary), paste mixing, and the anode bake furnace. The focus is on those techniques, surrogates, or other parameters that can be used to assess the emission control performance for hydrogen fluoride (HF) and POM. The options discussed in this section are presented in tabular form and evaluated in Chapter 6.

4.4.1 Continuous Emission Monitoring

The major HAPs of interest from the primary aluminum industry include HF and POM. Currently, there is no known CEM for POM; however, devices are available for continuously monitoring HF. One device is based on infrared absorption and was developed and used by Hydro Aluminum (a Norwegian company).[12] Alcoa Aluminum has developed two continuous monitors of HF: one is the Alcoa Gaseous Fluoride Analyzer, which uses a scrubbing medium and analysis by fluoride electrode, and the other is a device based on ion mobility spectrometry.

These devices can be used to monitor both primary and secondary HF emissions from potlines, as well as HF emissions from other sources. The Hydro Aluminum system can be used to measure secondary emissions by monitoring the emissions at a location above the potlines. The Alcoa device monitors secondary emissions by making measurements in the stack associated with an EPA Method 14 sampling manifold. The CEM options for monitoring include an HF CEM for secondary emissions from potlines, primary emissions from potlines, and emissions from the anode bake furnace.

There are no approved EPA methods for HF CEMs, and no procedures have been formally adopted to address quality control and quality assurance, including calibration. The use of these devices would likely require approval on a case-by-case basis based on demonstrated correlations with other methods.

4.4.2 Periodic Monitoring (manual sampling)

Most plants currently perform emission tests as often as once to three times per month for such pollutants as particulate matter, total fluorides, and gaseous fluoride. There is currently very little sampling and analysis performed regularly for POM.

There are established EPA sampling procedures and methods for determination of total fluorides from aluminum potlines (EPA Methods 13 and 14). The analysis adds particulate fluoride captured in the front half filter to gaseous fluoride from the back-half impingers to determine total fluoride. The Alcan "cassette" sampler has also been approved by EPA for use at one plant in lieu of the EPA Method 14 manifold. In addition, a method has been developed to provide a surrogate measure of POM emissions for the primary aluminum source category (Modified Method 5). This method uses a gravimetric determination of methylene chloride extractables from both the front and back halves of the sampling train. Methylene chloride extracts that portion of the particulate matter that is POM; however, it is a surrogate because it also extracts some material that is not POM.

The options for manual sampling include sampling at different frequencies (e.g., weekly, monthly, quarterly, annually) for TF and POM. Additional options include manual sampling for each potline or sampling one potline to represent a group of similar potlines. These manual sampling options are applicable to primary and secondary emissions from potlines, the anode bake furnace, and the paste production plant. Currently, several plants perform monthly sampling of individual potlines or representative potlines as a result of State regulations or the NSPS.

4.4.3 Parametric Monitoring

Parametric monitoring is also an option and includes the monitoring of certain parameters associated with the production process, the emission control device, or both to ensure that the emission control equipment is operating properly. The choice of the parameters depends upon the process and control device, and the parameters must be relatable to emission control performance. The parameters and acceptable ranges for normal operation are developed from design specifications, historical operating experience, and observation of these parameters during emission tests. These parameters may be monitored on a more frequent basis than periodic manual sampling and may be used to supplement the manual sampling to ensure continuing emission control performance.

For a dry alumina scrubber, parameters such as the alumina flow rate, air flow rate, pressure drop, inlet gas temperature, etc. could be monitored. For a wet scrubber and secondary emissions, examples of possible monitoring parameters include the scrubbing liquor flow rate, the pressure drop across the scrubber, and air flow. For wet electrostatic precipitators, example parameters include voltage and amperage. These parameters are given as examples, and all of these parameters do not necessarily need to be monitored to ensure the control device is working properly. For secondary (fugitive) emissions, the parametric monitoring could include inspections to observe work practices; the condition of hoods and shields; the number of shields removed, the frequency of removal, and the duration. Other types of inspections include visual observations of opacity and periodic inspection of fabric filters for tears or gaps.

4.4.4 Other Monitoring Options

Other possible monitoring options were considered but not included for analysis because they are not direct measures of emissions. For example, several plants conduct ambient monitoring for fluoride, and some measure the fluoride uptake in vegetation around the facility. These analyses are affected by several factors beyond the production operation, such as meteorological conditions and contributions from other sources. In addition, these options are not directly and quickly relatable to emissions or the performance of the emission control equipment. Consequently, these options were not considered to be applicable for monitoring.

4.5 REFERENCES

1. Compiled from responses by each plant in the industry to Information Collection Requests issued under Section 114 of the Clean Air Act Amendments.
2. Memorandum from Ours, K.D., Research Triangle Institute, to W.S. Fruh, EPA/ISB. October 15, 1993. Model Processes for the Primary Aluminum Production Industry.
3. Reference 1.
4. Reference 1.
5. Reference 2.
6. Reference 1.
7. Review of New Source Performance Standards for Primary Aluminum Reduction Plants. U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards. Research Triangle Park, N.C. EPA-450/3-86-010. September 1986. p. 4-22.
8. Reference 7, p. 4-20.
9. Reference 7.
10. Emissions Measurement Test Report - Northwest Aluminum Company. Prepared by Entropy, Inc. June 1994. 77 p.
11. Washington Department of Ecology and Kaiser Aluminum and Chemical Corporation Method 5/POM and 13B Testing - Anode Bake Furnace - Mead, Washington - May 2-5, 1994. Prepared by AmTest Air Quality, Inc. December 12, 1994. pp. 1 through 33.
12. Memorandum from Ours, K.D., Research Triangle Institute, to W.S. Fruh, EPA/ISB. April 29, 1994. Summary of Meeting with Hydro Aluminum Representatives. 4 pp.

5.0 ENVIRONMENTAL AND ENERGY IMPACTS OF CONTROL OPTIONS

This chapter presents estimates of the air, water, solid waste, and energy impacts from the control of emissions from aluminum production, anode bake furnaces, and paste production.

5.1 AIR POLLUTION IMPACTS

Estimates of the air emission impacts are developed from the emission control performance data in the Basis and Purpose Document (in the rulemaking docket). Emission reductions are based on the difference between current (baseline) emissions and the estimated average emissions that will be achieved by each type of plant.

5.1.1 Aluminum Production

The control options for aluminum production include installing dry alumina scrubbers on those plants that do not have them and using improved operation and maintenance for control of secondary emissions.

Most of the reported data for emission control performance are based on emissions of total fluoride (TF), which includes hydrogen fluoride (gaseous form) and particulate fluoride. The baseline TF emission estimates are based on data supplied by the Aluminum Association for most of the plants.[1] These data were assigned to the model plants and used to estimate both model plant and nationwide emissions. The level of control that has been achieved by the control option is given in the Basis and Purpose Document. The average emission level after control and the basis used for the estimate are given in Table 5-1.

Estimates are given for several types of production processes. "CWPB1" represents the larger and more modern center-worked prebake plants. "CWPB2" represents the older and smaller center-worked prebake plants (e.g., World War II vintage). CWPB3 represents those center-worked prebake potlines that produce high purity aluminum and have wet scrubbers as the primary control device. "HSS" identifies the horizontal stud Soderberg process, and "SWPB" stands for the side-worked prebake process. "VSS1" is

TABLE 5-1. MACT EMISSION FACTORS FOR POTLINES[a]

Type[b]	Emissions (lb/ton)			Basis
	Total fluoride	Gaseous fluoride	Polycyclic organic matter	
CWPB1	1.1	0.4	0.3	Noranda Line 3
CWPB2	2.1	0.9	1.1	Kaiser-Mead Line 1
CWPB3	2.0	0.8	1.0	Estimate
HSS	2.0	0.8	2.6	Kaiser-Tacoma Line 4
SWPB	1.0	0.2	0.3	Intalco Line C, except POM based on CWPB1
VSS1	1.3	0.2	0.4	Columbia-Goldendale Line 1
VSS2	2.1	0.9	0.6	Columbia Falls, except POM based on Columbia-Goldendale

[a] These emission factors are approximations of the average level of emissions on a nationwide basis for the MACT level of control. Emissions may vary significantly from potline to potline based on site-specific differences.

[b] **CWPB1** = modern, large center-worked prebake potlines; **CWPB2** = center-worked prebake potlines characterized by smaller cells of older construction, more frequent anode changes than modern cells; **CWPB3** = center-worked prebake potlines that produce high purity aluminum and have wet scrubbers for the primary control system; **HSS** = horizontal stud Soderberg; **SWPB** = side-worked prebake; **VSS1** = vertical stud Soderberg with roof scrubbers and no freezing problems; **VSS2** = vertical stud Soderberg in cold climate.

the vertical stud Soderberg process with roof scrubbers and no significant freezing problems that affect their operation. "VSS2" represents vertical stud Soderberg processes that operate in cold climates, which limits the utility of wet roof scrubbers.

Emissions of gaseous fluoride (GF) and polycyclic organic matter (POM) are approximated from the ratio of GF and POM to TF from the emission testing summarized in Table 5-1 and the emission estimates for total fluoride. A ratio of GF to TF of 0.4 was applied to all CWPB plants, HSS plants, and the VSS2 plant without roof scrubbers. A ratio of 0.2 was applied to those plants with wet roof scrubbers (SWPB and VSS1). For POM, a ratio of 0.3 was used for CWPB1 and SWPB; 0.5 for CWPB2 and CWPB3; 0.3 for VSS1 and VSS2; and 1.3 for HSS.

The emission factors and ratios are applied to the model plants in Tables 5-2 and 5-3 to estimate emissions for each of the models and then summed across all model plants to estimate nationwide emissions. These estimates are approximations of total nationwide emissions based on ratios of pollutants for a few plants. Site-specific differences among plants can result in significant uncertainty in the estimates for a given potline. Consequently, the estimates of total nationwide emissions are expected to be unbiased, but the results for a single model plant may not be representative of an actual plant.

5.1.2 Anode Baking

The control option for anode baking is to retrofit dry alumina scrubbers to those model plants that do not have them. Emission factors for uncontrolled furnaces and those controlled by dry alumina scrubbers were derived from the testing summarized in Chapter 3 and Appendix B. For those plants with wet electrostatic precipitators as control devices, the control efficiency was assumed to be 95 percent for TF and GF and 80 percent for POM. The midrange and range of emission factors for the anode bake furnace are given in Table 5-4. The midrange of the emission factors is applied to the model plants in Table 5-5 to estimate model plant and nationwide emissions. These estimates are uncertain because they are based on limited test data for POM from bake furnace.

5.1.3 Paste Production

The emissions of POM from paste production are based on the two tests summarized in Appendix B. These plants use dry coke scrubbers to control the organic fume and vapor from paste mixers

TABLE 5-2. TOTAL FLUORIDE EMISSION ESTIMATES FOR THE MODEL PLANTS

Model Plant	Aluminum Production Rate (Tons/ Year)	Plant Type	Current TF Emission Rate (lb/ton)	Baseline TF Emissions (ton/year)	Average TF Emission Achieved (lb/ton)	TF Emissions After Control (ton/year)	Annual TF Emissions Reduction (ton/year)
1	300,000	CWPB2	3.0	450	2.1	315	135
2	220,000	CWPB1	1.1	121	1.1	121	0
3	224,000	CWPB2	2.1	235	2.1	235	0
4	184,000	CWPB3	5.3	488	2.0	184	304
5	200,000	CWPB1	0.8	83	0.8	83	0
6	180,000	CWPB1	1.3	117	1.1	99	18
7	140,000	CWPB2	2.0	140	2.0	140	0
8	140,000	CWPB2	4.7	329	2.1	147	182
9	112,000	CWPB2	3.5	196	2.1	118	78
10A	224,500	CWPB2	8.5	954	2.1	236	718
10B	180,000	CWPB2	3.0	270	2.1	189	81
11	200,000	CWPB1	4.3	430	1.1	110	320
12	300,000	CWPB1	5.3	795	1.1	165	630
13	120,000	CWPB1	2.1	126	1.1	66	60
14	100,000	CWPB1	2.1	105	1.1	55	50
15	300,000	CWPB1	2.1	315	1.1	165	150
16	300,000	SWPB	1.0	150	1.0	150	0
17	200,000	SWPB	1.0	100	1.0	100	0
18	231,000	HSS	2.5	289	2.0	231	58
19	137,000	HSS	4.0	274	2.0	137	137
20	79,000	HSS	2.0	79	2.0	79	0
21	185,000	VSS	2.1	194	2.1	194	0
22	150,000	VSS	1.5	113	1.3	98	15
23	100,000	VSS	0.7	37	0.7	37	0
	Totals			6,389		3,453	2,936
						Percent Reduction in TF Emissions =	46

TABLE 5-3. EMISSION ESTIMATES OF GF AND POM FOR THE MODEL PLANTS

Model Plant	Plant Type	Ratio of GF to TF	Baseline GF Emissions (tons/year)	Controlled GF Emissions (tons/year)	Ratio of POM to TF	Baseline POM Emissions (tons/year)	Controlled POM Emissions (tons/year)
1	CWPB2	0.4	180	126	0.5	225	158
2	CWPB1	0.4	48	48	0.3	36	36
3	CWPB2	0.4	94	94	0.5	118	118
4	CWPB3	0.4	195	74	0.5	244	92
5	CWPB1	0.4	33	33	0.3	25	25
6	CWPB1	0.4	47	40	0.3	35	30
7	CWPB2	0.4	56	56	0.5	70	70
8	CWPB2	0.4	132	59	0.5	165	74
9	CWPB2	0.4	78	47	0.5	98	59
10A	CWPB2	0.4	382	94	0.5	477	118
10B	CWPB2	0.4	108	76	0.5	135	95
11	CWPB1	0.4	172	44	0.3	129	33
12	CWPB1	0.4	318	66	0.3	239	50
13	CWPB1	0.4	50	26	0.3	38	20
14	CWPB1	0.4	42	22	0.3	32	17
15	CWPB1	0.4	126	66	0.3	95	50
16	SWPB	0.2	30	30	0.3	45	45
17	SWPB	0.2	20	20	0.3	30	30
18	HSS	0.4	116	92	1.3	376	300
19	HSS	0.4	110	55	1.3	356	178
20	HSS	0.4	32	32	1.3	103	103
21	VSS2	0.4	78	78	0.3	58	58
22	VSS1	0.2	23	20	0.3	34	29
23	VSS1	0.2	7	7	0.3	11	11
	Totals		2476	1305		3172	1796
			Percent Reduction in GF Emissions	47		Percent Reduction in POM Emissions	43

TABLE 5-4. EMISSION FACTORS FOR THE ANODE BAKE FURNACE

Control	Emission factors (lb/ton anode)		
	Total fluoride	Gaseous fluoride	Polycyclic organic matter
Uncontrolled	3.0 (2.4 - 3.6)	3.0 (2.4 - 3.5)	2.0 (1.1 - 2.8)
Alumina scrubber	0.02 (0.014 - 0.028)	0.01 (0.001 - 0.02)	0.09 (0.024 - 0.16)
Electrostatic precipitator	0.15	0.15	0.4

and other operations in the paste plant where the pitch is heated, which releases POM. The emission factors from these test are summarized in Table 5-6.

For paste plants controlled by dry alumina scrubbers, a control efficiency of 90 percent was used (e.g., similar to that observed for the dry alumina scrubber on the primary control system at Kaiser-Tacoma). There were no data on the level of control provided by wet scrubbers or high efficiency air filters (HEAF); consequently, these devices were assumed to obtain about 80 percent control of POM.

Many plants reported the use of hoods and other enclosures for the capture of dust from material handling in the paste plant. These dust emissions are usually routed to a baghouse for control. The focus of these estimates is on POM emissions, which originate from heated pitch, such as in the paste mixers and conveyors prior to cooling. The POM emission estimates for the paste production model plants and nationwide totals are given in Table 5-7. As with other sources, the estimates of POM emissions are uncertain because they are based on a very limited set of emissions test data.

5.2 WATER POLLUTION

Four plants use wet scrubbers in their primary control system, and the control option is based on replacing the existing wet systems with dry alumina scrubbers. However, the current wet

TABLE 5-5. EMISSION ESTIMATES FOR ANODE BAKE FURNACE MODEL PLANTS

Model Plant	Model Plant Anode Production (tons/year)	Control Device	Baseline TF Emissions (tons/year)	Baseline GF Emissions (tons/year)	Baseline POM Emissions (tons/year)	Controlled TF Emissions (tons/year)	Controlled GF Emissions (tons/year)	Controlled POM Emissions (tons/year)
1	133,000	ESP	10.0	10.0	26.6	1.3	0.7	6.0
2A	54,000	dry alumina fluidized bed	0.5	0.3	2.4	0.5	0.3	2.4
2B	106,500	none	160	160	107	1.1	0.5	4.8
3	160,500	dry alumina injection plus fluidized bed	1.6	0.8	7.2	1.6	0.8	7.2
4	112,000	none	168	168	112	1.1	0.6	5.0
5	98,500	dry alumina injection scrubber	1.0	0.5	4.4	1.0	0.5	4.4
6	98,500	dry alumina fluidized bed scrubber	1.0	0.5	4.4	1.0	0.5	4.4
7	133,000	wet ESP	10.0	10.0	26.6	1.3	0.7	6.0
8	98,500	dry alumina fluidized bed scrubber	1.0	0.5	4.4	1.0	0.5	4.4
9	98,500	dry alumina fluidized bed scrubber	1.0	0.5	4.4	1.0	0.5	4.4
10	160,500	dry alumina injection scrubber	1.6	0.8	7.2	1.6	0.8	7.2
11	112,000	none	168	168	112	1.1	0.6	5.0
12	98,500	dry alumina fluidized bed scrubber	1.0	0.5	4.4	1.0	0.5	4.4
13	112,000	none	168	168	112	1.1	0.6	5.0
14	98,500	dry alumina injection scrubber	1.0	0.5	4.4	1.0	0.5	4.4
15	98,500	dry alumina fluidized bed scrubber	1.0	0.5	4.4	1.0	0.5	4.4
16	160,500	dry alumina injection scrubber	1.6	0.8	7.2	1.6	0.8	7.2
17	98,500	dry alumina injection scrubber	1.0	0.5	4.4	1.0	0.5	4.4
	Totals		697	690	555	20	10	91
					Percent Reduction	97	99	84

TABLE 5-6. EMISSION FACTORS FOR PASTE PRODUCTION

Control	POM emission factors (lb/ton paste)
Uncontrolled	0.25 (0.24 - 0.25)
Coke scrubber	0.012 (0.001 - 0.023)
Alumina scrubber	0.025
Other controls (wet scrubbers, HEAF)	0.050

system controls SO_2, whereas the dry scrubber will not. This analysis assumes that existing requirements for SO_2 control will remain in effect, and these plants will continue to use wet SO_2 scrubbers following the dry alumina scrubber. Consequently, no significant decrease is expected in the quantity of wastewater generated if these plants install dry alumina scrubbers.

Wastewater quality could be improved from a decrease in the quantity of fluorides and solids discharged with the wastewater because most of the fluorides and particulate matter will be recovered by the dry scrubber before the gas enters the wet scrubber. For a wet primary control system, about 3.4 lb fluorides/ton Al and 0.25 lb total suspended solids/ton Al are estimated to be discharged with the wastewater. Data for Plant 19 were provided by the Aluminum Association.[2] Table 5-8 presents the estimated decrease in water pollution from the installation of dry alumina scrubbers on those model plants that have wet scrubbers as primary control.

None of the other control options is expected to have a significant effect on water pollution.

5.3 SOLID WASTE

Solid waste generated from control of air emissions in the primary aluminum industry is a direct result of wet air emission control devices (e.g., wet scrubbers, wet electrostatic precipitators) and the accompanying wastewater treatment. Dry alumina scrubbing techniques do not generate any solid wastes

TABLE 5-7. EMISSION ESTIMATES FOR PASTE PRODUCTION MODEL PLANTS

Model Plant	Paste Production (tons/year)	Control Device (mixer)	Baseline POM Emissions (lb/ton)	Baseline POM Emissions (tons/year)	Controlled POM Emissions (tons/year)	Annual POM Emissions Reduction (tons/year)
1	137,000		0.25	17.1	0.82	16.3
2	137,000		0.25	17.1	0.82	16.3
3	98,000	coke dry scrubber	0.012	0.6	0.59	0.0
4	137,000		0.25	17.1	0.82	16.3
5	98,000	coke dry scrubber	0.012	0.6	0.59	0.0
6	137,000	baghouse	0.05	3.4	0.82	2.6
7	137,000		0.25	17.1	0.82	16.3
8	79,830	dry ESP	0.25	10.0	0.48	9.5
9	137,000	baghouse	0.05	3.4	0.82	2.6
10	137,000	baghouse	0.05	3.4	0.82	2.6
11	137,000	baghouse	0.05	3.4	0.82	2.6
12	137,000		0.25	17.1	0.82	16.3
13	137,000		0.25	17.1	0.82	16.3
14	137,000	baghouse	0.05	3.4	0.82	2.6
15	137,000	baghouse	0.05	3.4	0.82	2.6
16	162,000	dry alumina scrubber	0.025	2.0	0.97	1.1
17	98,000	dry coke scrubber	0.012	0.6	0.59	0.0
18	109,000	wet scrubber	0.05	2.7	0.65	2.1
19	98,000	dry coke scrubber	0.012	0.6	0.59	0.0
20	64,445	HEAF	0.05	1.6	0.39	1.2
21	109,000	wet scrubber	0.05	2.7	0.65	2.1
22	64,445	HEAF	0.05	1.6	0.39	1.2
23	98,000	dry coke scrubber	0.012	0.6	0.59	0.0
	Totals			147	16	131
					Percent reduction	89

TABLE 5-8. ESTIMATED REDUCTIONS OF FLUORIDES AND SUSPENDED SOLIDS IN WATER DISCHARGES FOR THE MODEL PLANTS

Model plant	Production rate (tons/year)	Fluorides (tons/year)	Suspended solids (tons/year)
4	184,000	310	23
10	224,500	380	28
18	231,000	390	29
19	137,000	230	17
	Total	1,310	97

because all captured solids are returned to the process.[3] Table 5-9 presents solid waste generation rates for the various emissions control systems for aluminum production.

From Table 5-9, wet scrubbers and wet ESPs generate 120 to 154 lb/ton Al of solid waste[4], which results in a solid waste generation rate of 6,000 to 15,000 tons per year for model plants that range roughly in size from 100,000 to 200,000 t/yr. Because all the captured solids are returned to the process with dry alumina scrubbing, the use of this technology has the potential to reduce solid waste generation by 6,000 to 15,000 t/yr for a typical plant.

None of the other control options has a significant impact on the generation of solid waste.

TABLE 5-9. SOLID WASTE GENERATION FOR VARIOUS FLUORIDE EMISSIONS CONTROL SYSTEMS[5]

Fluoride emission control system	Solid waste generation (lb/ton Al)
Primary dry scrubbing	0*
Primary wet scrubbing	154
Secondary wet scrubbing	160
Primary wet scrubbing with lime treatment	120
Secondary wet scrubbing with lime treatment	40
Primary wet electrostatic precipitator with lime treatment	150
Primary wet electrostatic precipitator	154

* Does not include disposal of bags used in dry scrubber, which is a very low quantity relative to the other sources of solid waste.

5.4 ENERGY

Table 5-10 presents a summary of the energy requirements for air emission control systems associated with aluminum production.

Model Plant 19 has a wet scrubber for primary control. From Table 5-10, this model plant currently uses about 78 kwh/ton Al to operate the control device. If the model plant is retrofitted with a dry alumina scrubber and keeps the wet scrubber, the total energy consumption is estimated as 287 kwh/ton (211 + 76).

Model Plant 18 has a wet scrubber and a wet ESP for primary control. From Table 5-10, the model plant is estimated to use 163 kwh/ton (76 + 87) to operate the controls. If the model plant is retrofitted with a dry alumina scrubber and keeps the wet scrubber, the total energy consumption would be 287 kwh/ton (211 + 76).

Model Plant 10 has a wet scrubber and a dry ESP for primary control. From Table 5-10, the model plant currently uses about 165 kwh/ton (78 + 87) to operate the controls. If the model

TABLE 5-10. ELECTRICAL ENERGY REQUIREMENTS FOR PRIMARY ALUMINUM FLUORIDE EMISSIONS CONTROL[6]

Fluoride control system	Average electrical energy requirements (kwh/ton Al)
Dry scrubbing	211
Primary wet scrubbing	78
Secondary wet scrubbing	357
Primary wet scrubbing with lime water treatment	76
Secondary wet scrubbing with lime water treatment	300
Electrostatic precipitator incremental power when used in series with another primary control device	87
Primary venturi scrubbing	600
Primary multicyclone	75
Primary wet electrostatic precipitator with lime water treatment.	100

plant is retrofitted with a dry alumina scrubber and keeps the wet scrubber, the total energy consumption would be 287 kwh/ton.

Model Plant 4 has a wet scrubber and a wet ESP for primary control. From Table 5-10, the model plant currently uses 163 kwh/ton (76 + 87) to operate the controls. If the model plant is retrofitted with a dry alumina scrubber and keeps the wet scrubber, the total energy consumption would be 287 kwh/ton.

The total increase in energy consumption for the four model plants is estimated as 579 kwh/ton Al or an average of 145 kwh/ton. The electrical consumption to produce aluminum is estimated as 6 to 7 kwh/lb Al or 12,000 to 14,000 kwh/ton Al.[7] Consequently, an increase of 145 kwh/ton is a very small increase in overall energy consumption.

There will be no significant effect on energy consumption for anode baking and paste production when an existing control device is replaced with a dry alumina scrubber for anode baking or a dry coke scrubber for paste production. However, energy consumption will increase when these control devices are installed at those plants that have no controls.

Using model potline productions and model potline gas flow rates, the average gas flow per ton of aluminum produced is calculated to be 9.5 cfm/ton Al. Dividing the energy consumption of a dry alumina scrubber (211 kwh/ton Al) by the average gas flow per ton aluminum produced gives about 22 kwh/cfm. There are three model plants for anode baking that do not have emission controls. Based on a flow rate of 197,000 cfm, the increase in energy consumption to control the anode bake furnace is estimated as 4.3 million kwh per plant for the three plants or about 19 kwh/ton Al (based on a model plant capacity of 112,000 tons of anode per year and 0.5 lb anode to produce a lb of Al).

5.5 REFERENCES

1. Data submitted by the Aluminum Association: "Total Fluoride Emission Assessment." Covers the period from January 1989 through December 1992. 57 p.

2. Memorandum from Strieter, R., Aluminum Association, to S. Fruh, EPA. May 1, 1995. Transmitting comments on the Draft Technical Support Document. p. 18

3. Primary Aluminum: Guidelines for Control of Fluoride Emissions from Existing Primary Aluminum Plants. U.S. Environmental Protection Agency. Report No. EPA-450/2-78-049b. December 1979. p. 9-26

4. Reference 3. p. 9-27

5. Reference 3. p. 9-27

6. Reference 3. p. 9-33

7. Review of New Source Performance Standards for Primary Aluminum Reduction Plants. U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards. Research Triangle Park, N.C. EPA-450/3-86-010. September 1986. p. 3-11.

6.0 COSTS FOR EMISSION CONTROLS AND MONITORING

This chapter discusses the methods used to estimate capital and operating costs for the emission control technologies for the model facilities developed in Chapter 4. The terms used in this chapter include the one-time **installed capital cost** of equipment and the following annual costs: **indirect operating cost** (estimated as 4 percent of capital), **direct operating cost**, and **capital recovery** (based on a 20-year life and an interest rate of 7 percent). There are three indirect operating costs factored from the capital cost: property taxes, insurance, and administrative charges. For simplicity, the three items are combined into a single 4-percent factor, which is the standard value used in OAQPS cost analyses.[1] **Total annualized cost** is the sum of direct and indirect operating costs plus the annualized cost of capital.

6.1 EMISSION CONTROL COSTS FOR ALUMINUM PRODUCTION

The control costs for aluminum production include the installation of dry alumina scrubbers at one of the four plants that use wet control systems for the primary collection system. The other plants indicated that the existing primary control system would probably be upgraded to achieve improved control.

The plants with wet primary control systems produce a premium quality of aluminum that has fewer impurities than that produced at plants using the dry scrubbing process. The impurities are removed with the pollution control sludge that is generated, whereas the dry scrubbing process returns the impurities to the reduction cell with the alumina used in the scrubber. Consequently, these plants are investigating other control alternatives that would allow them to keep their market for high purity aluminum and also enable them to meet the MACT level of emission control.

The costs for control of secondary (roof) emissions include the capital cost of upgrading or replacing equipment that improves the capture efficiency of the primary system. In addition, costs are also incurred from work practices that require the proper operation, maintenance, inspection, and repair of equipment.

6.1.1 Capital Cost for the Primary Control System

The primary air emission control system for the potline consists of the following major components:

- Cell hooding system.
- Collection ductwork from cells to the dry scrubbers.
- A battery of dry scrubbers using removable sections of bags (fabric filters) mounted in a structural steel housing.
- The clean air ductwork and fans that provide the energy for moving air from the cells for discharge to the atmosphere.
- Aluminum storage and transfer system.

The pollutants are removed by a dry scrubbing process that injects dry alumina into the gas stream to adsorb the gaseous fluoride. The alumina, particulate fluoride, and other particulate matter are then collected on the bag filters. Fresh alumina is continually withdrawn from a storage silo and transported to the dry scrubbers by air slides. The fluorinated alumina collected in the baghouses is returned to the cells. The cleaned gases are released to the atmosphere through a stack.

Construction costs for a dry scrubber system were obtained from a document prepared for the Bureau of Mines, U.S. Department of the Interior.[2] A cost function (regression equation) provided an estimate of the direct construction cost as a function of aluminum production capacity. The costs in 1984 dollars were indexed to 1994 dollars using the Marshall and Swift Cost Index.[3]

The direct construction costs for the primary air pollution control system for aluminum potlines were provided by the following cost relationship for aluminum plants ranging in capacity from 100,000 to 300,000 tons per year:

$$\text{Direct Construction Cost} = [156.39(X)]1.256$$

where X is aluminum production in tons per year.

The costs are subdivided into the following components:

Labor	20 percent
Material	18 percent
Equipment Usage	3 percent
Equipment	59 percent

[Note: There may be site-specific variability in these costs depending on the type of potline and additional expenses from dismantling an existing wet primary control system. The estimate does not include these retrofit costs or the cost of other equipment that may be installed at the same time, such as SO_2 scrubbers.]

6.1.2 Operating Cost for the Primary Control System

The direct operating costs were estimated by averaging the operating costs for the control devices in the control options that were reported by the industry in survey responses.[4] The operating costs reported by industry were converted into 1994 dollars.[5] The average direct operating cost for the dry alumina scrubber was estimated as $12.06 per ton of aluminum.

Some plants currently have wet scrubbing air pollution control systems that are very effective in controlling pollutants other than HAPs (i.e., criteria pollutants such as SO_2 and particulate matter). Because dry alumina scrubbers are not effective in controlling SO_2, these facilities may be required by their respective States to maintain their current level of SO_2 control. Therefore, this analysis assumes that any operating costs associated with installing a dry alumina scrubber will be incurred in addition to the operating costs of the current wet emission control systems.

6.1.3 Costs For Control of Secondary Emissions

Work practices, equipment modifications, and repairs represent a control option to reduce fugitive emissions from aluminum production. An attempt has been made to define the general level of expenditures that the model plants are likely to incur to improve the capture and control of secondary (fugitive) emissions. Plants that have potlines that define MACT or already perform better than MACT will obviously not incur additional emission control costs to meet the standard (additional monitoring, reporting, and record keeping costs are addressed separately in Section 6.4). Other plants with hooding in poor condition may experience significant costs to replace or improve the hooding and doors and to improve work practices.

In general, the estimates in this section assume that the plants with the highest levels of emissions are those most likely to incur the highest costs. The current level of control of the various plants was determined as described in Chapter 5, and the data from the actual plants were assigned to the appropriate model plants. The emission control data for total fluoride were used and include the 1989-1992 data that were compiled and submitted by the Aluminum Association[6] and more recent data supplied in a report from Kaiser, Ravenswood, and Reynolds.[7]

A questionnaire was submitted to the industry that was designed to collect information on costs related to work practices and operating procedures that would reduce fugitive emissions from the aluminum production process. The information that was submitted was used to determine a range of cost estimates that was applied to the model plants. Unfortunately, very few plants responded with the requested information, in some cases because of uncertainty as to what might be required for each potline.

6.1.3.1 Potlines Likely to Incur "High" Costs

One facility estimated a capital cost of $5.7 million to upgrade equipment to meet a performance level on the order of 3.5 lb TF/ton or less.[8] The capital cost items included redesign and alignment of quarter shields; seals for the superstructure legs, crust breaker cylinder, anode buss jack, and end shields; additional new shields; upgrading the scrubber; modifications to the ore bucket; and a new cleaning station for the vacuum crucible, which was the major component at $4.3 million. Their reported average annual production rate is about 113,000 tons per year. This results in a capital cost of $50 per ton for the improvements.

Another plant reported that a total of $4.4 million had been spent to improve their emission control of total fluoride from about 5.0 to 3.0 lb/ton.[9] This plant has a capacity of about 220,000 tons per year, which yields an estimate of about $20/ton.

A plant using the horizontal stud Soderberg process estimated a capital cost of $19 to $24 million for their facility to meet a performance level in the range of 2.3 to 3.0 lb TF/ton.[10] The capital costs include improvements to the hoods and superstructure for all cells (at $2,000 per cell), computer controls to limit the number of times cells doors are opened and to operate new point feeder systems ($11 to 15 million), and a new alumina transfer system ($7 to 8 million). This plant's modernization program should result in improved production operations and lower production costs as well as better control of emissions. It is not clear that all of these capital costs would be attributable to the MACT standard, and even if they were, a credit would be realized in lower operating costs. However, for the purpose of this analysis, these costs were assigned to a model plant to represent this facility or a facility that could require major capital improvements.

Similarly, the cost estimates provided by the other two plants were assigned to appropriate model plants to represent their potential expenditures. In addition, the midrange value of $35/ton capital cost from these two plants was used to estimate the capital cost for control of secondary emissions from those model plants that are expected to have to improve emission control by 1.0 lb/ton or more of total fluoride.

Operating costs for these facilities were estimated from information supplied by one plant, which estimated an increased operating and maintenance cost of $1.2 million.[11] This cost includes $67,000/yr for maintaining seals, $589,000/yr for increased shield audits, and $561,000/yr for increased maintenance. Using their average production rate of 113,000 tons per year yields a cost factor of $10.60 per ton. This cost was applied to a model plant to represent the actual plant and was also assigned to those model plants expected to require the greatest emission reductions.

6.1.3.2 Potlines Likely to Incur "Medium" Costs

The next group of model plants is expected to incur more modest capital costs because they have better current emission control performance than those discussed above. An engineering judgement was made that these plants would require improvements to their hooding and seals to attain the MACT floor level of control.

One facility estimated a capital cost of about $2200 per pot for redesigned shields, increased audits, improved maintenance and housekeeping, upgrading a scrubber, and modifying the ore bucket.[12] Another plant estimated improved hooding and seals would cost about $2000 per pot.[13] The average is $2100 per pot or about $11 per ton of aluminum. This cost is used to estimate the capital cost for model plants that would most likely incur a mid-range cost to reduce fugitive emissions.

Another facility estimated they spend about $22,000 per year in manpower costs for a complete system of daily audits, reporting of deficiencies, a protocol for ensuring deficiencies are corrected within specified time frames, and recordkeeping.[14] Their production rate is 200,000 tons per year, which yields a cost factor of about $0.11 per ton. This cost was used to estimate operating costs for the model plants in this "medium" category.

6.1.3.3 Potlines Likely to Incur "Low" Costs

This group is expected to obtain improved control of a few tenths of a lb TF/ton primarily by improved inspections, work practices and maintenance without any significant capital costs. For this group, a cost of $0.11/ton (from the previous section) was used to estimate the operating cost for a nominal improvement in control.

6.1.4 Summary of Cost Estimates for Potline Emission Control

The cost functions developed in the previous sections were applied to the model plants based on the emission control performance associated with each model. The cost estimates for control of primary and secondary emissions from aluminum production are summarized in Table 6-1 and the totals (summed across all model plants) represent the estimated nationwide costs. The nationwide capital cost is estimated as $177 million ($107 million for replacing primary control systems) and a total annualized cost of about $38 million per year. These cost estimates do not reflect the possibility that owners or operators may find or develop ways to meet the MACT performance standard that are less costly than the assumptions presented here.

6.2 COST ESTIMATES FOR PASTE PRODUCTION EMISSION CONTROLS

The control technology for paste mixing and anode forming is to duct the emissions (organic fume or POM) to a dry scrubbing process that uses a dry coke injected scrubber to adsorb polycyclic organic matter (POM). Fresh coke is continually injected into the air stream and collected on bag filters. The used coke is then returned to the paste mixing process. The cleaned gases are released to the atmosphere through a stack. There may be some differences in the capital and operating costs for continuous versus batch mixers. However, there were insufficient data to determine if these differences have a significant effect on control costs.

The total capital cost of a dry coke scrubber is the sum of the purchased cost and the installation cost. The control device costs were submitted by the industry[15] and were converted into 1994 dollars.[16] These costs were then used to determine the cost per ton of annual paste production, which was then plotted against the anode paste production rate. A curvi-linear

TABLE 6-1. ESTIMATED COST OF CONTROL OPTIONS FOR SMELTING

Model Plant	Aluminum Production Rate (tons/year)	Capital Cost for Dry Alumina Scrubber for Smelting	Capital Recovery Cost (7%, 20 years)	Indirect Operating Cost (4%)	Direct Operating Cost	Current TF Emission Rate (lb/ton)	Estimated Work Practice and Equipment Cost Range (0-none, L-low, M-medium, H-high)	Capital Cost to Upgrade Equipment (i.e., hooding, shields, ore feeders etc.)	Capital Recovery Cost to Upgrade Equipment (7%, 20 years)	Annual Work Practice, Operating, and Maintenance Cost	Total Annualized Cost
1	300,000	$0	$0	$0	$0	3.0	M	$3,300,000	$310,000	$33,000	$340,000
2	220,000	$0	$0	$0	$0	1.1	0	$0	$0	$0	$0
3	224,000	$0	$0	$0	$0	2.1	0	$0	$0	$0	$0
4	184,000	$0	$0	$0	$0	5.3	*	$7,100,000	$670,000	$1,950,000	$2,620,000
5	200,000	$0	$0	$0	$0	0.8	0	$0	$0	$0	$0
6	180,000	$0	$0	$0	$0	1.3	L	$0	$0	$19,800	$20,000
7	140,000	$0	$0	$0	$0	2.0	0	$0	$0	$0	$0
8	140,000	$0	$0	$0	$0	4.7	H	$4,900,000	$460,000	$1,480,000	$1,940,000
9	112,000	$0	$0	$0	$0	3.5	**	$5,700,000	$540,000	$1,200,000	$1,740,000
10	224,500	$0	$0	$0	$0	8.5	*	$12,650,000	$1,190,000	$2,380,000	$3,570,000
	180,000	$0	$0	$0	$0	3.0	M	$1,980,000	$190,000	$19,800	$210,000
11	200,000	$0	$0	$0	$0	4.3	M	$2,200,000	$210,000	$22,000	$230,000
12	300,000	$0	$0	$0	$0	5.3	H	$10,500,000	$990,000	$3,180,000	$4,170,000
13	120,000	$0	$0	$0	$0	2.1	M	$1,320,000	$120,000	$13,200	$130,000
14	100,000	$0	$0	$0	$0	2.1	M	$1,100,000	$100,000	$11,000	$110,000
15	300,000	$0	$0	$0	$0	2.1	M	$3,300,000	$310,000	$33,000	$340,000
16	300,000	$0	$0	$0	$0	1.0	0	$0	$0	$0	$0
17	200,000	$0	$0	$0	$0	1.0	0	$0	$0	$0	$0
18	231,000	$0	$0	$0	$0	2.5	***	$21,500,000	$2,030,000	$25,410	$2,060,000
19	137,000	$26,910,000	$2,540,000	$1,080,000	$1,650,000	4.0	M	$1,510,000	$140,000	$20,000	$5,430,000
20	79,000	$0	$0	$0	$0	2.0	0	$0	$0	$0	$0
21	185,000	$0	$0	$0	$0	2.1	0	$0	$0	$0	$0
22	150,000	$0	$0	$0	$0	1.5	0	$0	$0	$0	$0
23	100,000	$0	$0	$0	$0	0.7	0	$0	$0	$0	$0
	Totals	$26,910,000	$2,540,000	$1,080,000	$1,650,000			$77,060,000	$7,260,000	$10,390,000	$22,910,000

* Capital cost from plant estimate, annual cost of $10.60/ton.

** Both capital and operating cost from plant estimate.

***Capital cost from plant estimate, annual cost of $0.11/ton.

H = capital $35/ton, operating $10.60/ton; M = capital $11/ton, operating $0.11/ton; L = no capital,operating $0.11/ton.

regression analysis was performed to obtain the following cost function:

$$Y = (X^{-1.051})(2.62)10^{6}$$

where Y = total direct capital cost per ton of paste ($/ton)
X = annual production rate (tons/year), and
coefficient of determination (R^2) = 0.8847.

The direct operating costs were estimated by averaging the operating costs for the dry coke scrubbers that were reported by the industry in survey responses.[17] The operating cost reported by the industry were converted into 1994 dollars[18] and resulted in an annual direct operating cost of $1.16/ton of paste. Indirect operating costs were included at a rate of 4 percent of the capital cost.

The cost estimates for paste production are summarized in Table 6-2. The costs assume that all plants without a dry coke scrubber for the control of POM emissions from paste production (18 of 23 plants) must install one. However, some plants may be able to meet the MACT performance standard with dry alumina scrubbers or other control devices, or they may be able to utilize many of the components of their existing system. In these cases, the actual costs that will be incurred would be less than those provided in the table. The total capital cost is estimated as $26 million and the total annualized cost is estimated as $5.7 million per year.

6.3 COST FOR ANODE BAKING EMISSION CONTROLS

A dry alumina scrubber system similar to that used for the aluminum production process removes fluoride, POM, and fine particulate matter from the anode baking furnace exhaust gases. The system consists of a dry alumina fluidized bed scrubber, a baghouse (fabric filters), and the associated duct work and fans to collect and move the gases from the anode bake furnace. The scrubber adsorbs fluorides and POM, which are removed with other particulate matter in the baghouse. The spent alumina is then

TABLE 6-2. ESTIMATED COST OF CONTROLS FOR PASTE PRODUCTION

Model Plant	Paste Production Rate (tons/year)	Coke Scrubber Capital Cost Function ($/ton)	Capital Cost of Coke scrubber	Direct Operating Cost ($1.16/ton)	Total Annualized Cost ($/yr)
1	137,000	$10.50	$1,440,000	$159,000	$353,000
2	137,000	$10.50	$1,440,000	$159,000	$353,000
3	98,000	$0.00	$0	$0	$0
4	137,000	$10.50	$1,440,000	$159,000	$353,000
5	98,000	$0.00	$0	$0	$0
6	137,000	$10.50	$1,440,000	$159,000	$353,000
7	137,000	$10.50	$1,440,000	$159,000	$353,000
8	79,830	$18.50	$1,480,000	$93,000	$292,000
9	137,000	$10.50	$1,440,000	$159,000	$353,000
10	137,000	$10.50	$1,440,000	$159,000	$353,000
11	137,000	$10.50	$1,440,000	$159,000	$353,000
12	137,000	$10.50	$1,440,000	$159,000	$353,000
13	137,000	$10.50	$1,440,000	$159,000	$353,000
14	137,000	$10.50	$1,440,000	$159,000	$353,000
15	137,000	$10.50	$1,440,000	$159,000	$353,000
16	162,000	$8.80	$1,430,000	$188,000	$380,000
17	98,000	$0.00	$0	$0	$0
18	109,000	$13.30	$1,450,000	$126,000	$321,000
19	98,000	$0.00	$0	$0	$0
20	64,445	$23.10	$1,490,000	$75,000	$275,000
21	109,000	$13.30	$1,450,000	$126,000	$321,000
22	64,445	$23.10	$1,490,000	$75,000	$275,000
23	98,000	$0.00	$0	$0	$0
	Totals		$26,070,000	$2,591,000	$6,100,000

A zero cost is shown for plants that already have a dry coke scrubber.

Total annual cost includes direct and indirect operating plus capital recovery.

recycled to the potlines and the cleaned gases are released to the atmosphere through a stack.

The cost function for a dry scrubber system for the anode bake furnace was obtained from a document prepared for the Bureau of Mines, U.S. Department of the Interior.[19] The costs in 1984 dollars were converted to 1994 dollars using the Marshall and Swift Cost Index.[20]

The original cost function included the direct construction costs of emission control equipment for the entire carbon plant and included the following three major components:

- 7 fabric filters (1 for the coke receiving area, 1 for the pitch melting and anode forming areas, and 5 for the anode rodding area.);
- 2 fume scrubbers for the anode former and mixer;
- 1 dry alumina scrubber system for the anode baking furnace exhaust gases.

The capital cost of this entire system is given by the following equation:

$$[522{,}540(X)^{0.171}]1.256 = \text{total capital cost}$$

where X is aluminum production in tons per year.

The total capital investment for the 7 fabric filter dust collectors in the carbon plant was estimated using the OAQPS cost manual.[21] The typical gross cloth area for fabric filters in the carbon plant was determined to be about 1,500 ft^2 from data submitted by plants in response to information collection requests. The total gross cloth area for all 7 baghouses was estimated as 5,250 ft^2. Using the procedure outlined in the cost manual, this gross cloth area results in a total capital cost of $300,000 (1994 dollars) for the baghouses, which includes the structure, fabric filters, and auxiliary equipment. The cost of the 7 baghouses and the cost associated with the dry coke scrubbers (presented in Section 6.1.2) are subtracted from the cost function for control of the entire carbon plant. After subtracting these costs, the balance represents the cost for the dry alumina scrubber, which is the air emission control system for the anode bake furnace.

The following equation is the resulting cost function for control of the anode bake furnace for aluminum plants ranging in capacity from 100,000 to 300,000 tons per year:

$$= [522{,}540(X)^{0.171}]1.256-(300{,}000)-(\text{cost of dry coke scrubber})$$

where X is aluminum production in tons per year.

The costs are subdivided into the following components:

Labor	25 percent
Material	14 percent
Equipment Usage	4 percent
Equipment	57 percent.

The direct operating costs were estimated by averaging the operating costs for dry alumina scrubbers that were reported by the industry in survey responses.[22] The operating costs reported by industry were converted into 1994 dollars[23] and resulted in an operating cost of $4.81/ton of anode. Indirect operating costs were included at a rate of 4 percent of the capital cost.

The cost estimates for the anode bake furnace are summarized in Table 6-3. The costs assume that all plants without a dry alumina scrubber (5 of 17 total) must install one. The total capital cost is estimated as $17 million and the total annualized cost is estimated as $5.2 million per year.

TABLE 6-3. ESTIMATED COST OF CONTROLS FOR ANODE BAKE FURNACES

Model Plant	Anode Production Rate (tons/year)	Aluminum Production Rate (tons/year)	Capital Cost of Dry Alumina Scrubber	Direct Operating Cost ($/year)	Total Annualized Cost ($/year)
1	133,000	300,000	$3,930,000	$640,000	$1,168,000
2A	107,000	150,000	$3,300,000	$515,000	$959,000
4	112,000	184,000	$3,480,000	$539,000	$1,007,000
7	133,000	140,000	$3,240,000	$640,000	$1,075,000
11	112,000	200,000	$3,550,000	$539,000	$1,016,000
13	112,000	120,000	$3,110,000	$539,000	$957,000
	Totals		$20,610,000	$3,412,000	$6,182,000

Model 2A has one furnace with a dry alumina scrubber and two without.

All models not listed already have dry alumina scrubbers.

Total annual cost = indirect and direct operating plus capital recovery.

6.4 MONITORING COSTS

This section provides the unit costs for various monitoring techniques and describes the basic information and assumptions that are used to estimate the costs on a nationwide basis. The estimates presented here represent a range of potential costs because the rule is expected to provide flexibility in the choice of techniques for monitoring. Actual costs may be lower than the estimates presented here because the rule is also expected to contain provisions for reduced sampling frequency and for less expensive monitoring options for similar potlines.

These monitoring cost estimates represent the additional monitoring burden that will be imposed by the MACT standard (i.e., the incremental cost attributable to the rule). The estimates do **not** include the costs already being incurred by many plants as a result of existing regulations. These estimates do not include the cost of reporting and recordkeeping that will be associated with the final rule. Estimates of the combined costs of monitoring, reporting, and recordkeeping associated with the rule can be found in the rulemaking docket in the Office of Management and Budget's (OMB's) Form SF-83 and Supporting Statement.

The basic components of the monitoring costs and the approach are discussed below:

1. Technical labor hours are estimated to cost \$33/h. Management hours are estimated as 5 percent of the technical labor hours at \$49/h, and clerical hours are estimated as 10 percent of the technical hours at \$15/h. The overall cost per technical labor hour, including management and clerical costs, is \$37/h.[24]

2. The cost of 3 8-h runs of Method 13 or Method 315 is estimated as \$3,700 (100 h at \$37/h). Three 24-h runs for secondary emission measurements are estimated as \$7,400 (200 h at \$37/h). For more automated systems such as the HF continuous emission monitor (CEM) and Alcan cassette, the labor cost is estimated as \$1,500 per test (40 h per test at \$37/h).

3. The installed capital costs for major equipment items include $200,000 for a Method 14 manifold[a], $92,000 for an Alcan cassette sampling system[25], and $100,000[b] for an HF CEM.[26] For continuous monitoring of parameters, assume the instrumentation is in place for items such as flow rate and pressure drop (i.e., no significant capital cost).

4. **Primary control system**: For manual sampling of each potline's primary emission control system for TF using Method 13, about 31 of the nationwide total of 91 potlines are already sampled on a regular basis. Assume that the remaining 60 lines will require a 3-run test (8 hours each) with options of testing monthly, quarterly, and annually.

   For POM emissions, all 22 Soderberg potlines must be sampled. Assume that 8-h runs by Method 315 would be required with options of testing monthly, quarterly, and annually.

5. **Secondary system**: For the manual sampling of each potline's secondary TF emissions, we estimate that about 60 new Method 14 manifolds would be required. However, the rule is expected to accommodate alternative sampling procedures for similar potlines; consequently, each potline would not require a Method 14 manifold. To account for the alternative sampling procedures, assume that 12 new Method 14 manifolds must be installed, Alcan cassettes will be used on 24 potlines, and the HF CEM will be used on 24 potlines. Evaluate sampling options of monthly, quarterly, and annually. The 10 potlines with wet roof scrubbers already sample routinely for TF and will incur no additional cost.

   For POM emissions, assume all 22 Soderberg potlines must sample secondary emissions. Evaluate options of monthly, quarterly, and annual sampling.

6. **Bake furnaces:** Assume that all bake furnaces (36 total) must be sampled for TF and POM using 3 8-h runs. Evaluate options of monthly, quarterly, and annual sampling.

7. For capital recovery, assume an equipment lifetime of 15 years and a 7-percent interest rate for the CEM and 20 years at 7 percent for the Method 14 manifold (capital recovery factors of 0.1098 and 0.0944 for 15 and 20 years, respectively).

---

[a] Chosen from the midrange of $150,000 to $250,000 each.

[b] Includes $20,000 for installation.

The information listed above is used in Table 6-4 to estimate the nationwide costs for options for monitoring at at different frequencies. These estimates can be combined into different scenarios to estimate different combinations of cost. Examples are given below:

Scenario	Testing option	Total annual cost ($/yr)
1	Monthly sampling for all points	11,500,000
2	Quarterly sampling for all points	4,300,000
3	Annual sampling for all points	1,600,000
4	Monthly sampling for TF secondary emissions, quarterly sampling for POM secondary emissions, and annual sampling of all control devices (primary system and bake furnace)[c]	3,800,000

As discussed earlier, several assumptions were required to estimate monitoring costs because the proposed rule is expected to provide flexibility. Monitoring costs could be lower than estimated if plants qualify for a reduced sampling frequency based on low day-to-day variability. Costs could be higher for plants with multiple stacks for the primary control device if they are all sampled annually. In addition, one plant submitted information that indicated the cost of the Method 14 manifold and associated equipment was higher than the estimate of $200,000 used in this analysis. Consequently, site-specific factors and monitoring options will affect the monitoring costs incurred by a given plant.

---

[c] At the time this document was prepared (January 1996), this scenario best represented what is anticipated to be required by the proposed rule. However, the final cost estimates for monitoring, reporting, and recordkeeping for the proposed rule will be documented in OMB's Form SF-83 and Supporting Statement, which are included in the rulemaking docket.

TABLE 6-4. NATIONWIDE COST ESTIMATES FOR VARIOUS MONITORING OPTIONS

Emission point	Pollutant	Option	Capital cost ($ millions)	Operating cost ($ thousands/yr)	Total annual cost ($ thousands/yr)[a]
Potline primary emission control system	TF[b]	Monthly	--	2,700	2,700
		Quarterly	--	890	890
		Annually	--	220	220
	POM[c]	Monthly	--	980	980
		Quarterly	--	330	330
		Annually	--	81	81
Potline secondary emissions	TF[d]	Monthly	7.0[e]	1,900	2,600
		Quarterly		640	1,400
		Annually		160	890
	POM[f]	Monthly	--	2,000	2,000
		Quarterly	--	650	650
		Annually	--	160	160
Bake furnace control system	TF[g]	Monthly	--	1,600	1,600
		Quarterly	--	530	530
		Annually	--	130	130
	POM[g]	Monthly	--	1,600	1,600
		Quarterly	--	530	530
		Annually	--	130	130

Note: Footnotes are on the next page.

TABLE 6-4. NATIONWIDE COST ESTIMATES FOR VARIOUS MONITORING OPTIONS (continued)

Footnotes:

[a] Operating cost plus capital recovery cost.

[b] Sampling costs are based on $3,700/test for 60 potlines with 12, 4, and 1 test(s) per year (i.e., options for monthly, quarterly, and annual sampling).

[c] Sampling costs are based on $3,700/test for 22 Soderberg potlines with 12, 4, and 1 test(s) per year.

[d] Sampling costs are based on $7,400/test for 12 potlines (Methods 13 and 14) and $1,500/test (Alcan cassettes and HF CEMs) for 48 potlines with 12, 4, and 1 test(s) per year.

[e] Includes 12 Method 14 manifolds ($200,000 each), 24 Alcan cassette systems ($92,000 each), and 24 HF CEMs ($100,000 each).

[f] Sampling costs are based on $7,400/test for 22 Soderberg potlines with 12, 4, and 1 test(s) per year.

6.5 REFERENCES

1. Turner, J. H., A. S. Viner (Research Triangle Institute). OAQPS Control Costs Manual. J. D. McKenna (ETS, Inc.) Roanoke, VA. R. E. Jenkins, W. E. Vatavuk. Prepared for U.S. Environmental Protection Agency. Standards Development Branch, OAQPS. Research Triangle Park, NC. Publication No. EPA 450/3-90-006. January 1990. Chapter 5.

2. Raymond Kaiser Engineers, Inc. Capital and Operating Cost Estimating System Handbook for Aluminum Smelter Facilities. Prepared for Bureau of Mines, United States Department of the Interior. Denver, CO. August 1985. 196 pp.

3. Marshall & Swift Equipment Cost Index. Chemical Engineering Magazine.

4. Compiled from responses by each plant in the industry to Information Collection Requests issued under Section 114 of the Clean Air Act Amendments.

5. Reference 3.

6. Data provided by the Aluminum Association covering the period January 1989 through December 1992.

7. Development of Clean Air Act Amendments 112(d), Proposal for Setting Standards for Horizontal Stud Soderberg and

Centerwork Prebake-2 Subcategories, Prepared by: Kaiser Aluminum, Ravenswood Aluminum, Reynolds Metal Company, July 27, 1994.

8. Letter from Logan, R.L., Ravenswood Aluminum Corporation, to Fruh, W.S., EPA/ISB. July 26, 1994. Response to request for assistance from the aluminum industry in regard to costs of achieving emission reductions.

9. Submittal from NSA entitled "Fluoride Emissions Reductions and High Purity History." January 1995. 6 p.

10. Letter from Tanchuk, M.F., Reynolds Metal Company, to Fruh, W.S., EPA/ISB. June 6, 1994. Response to request for assistance from the aluminum industry in regard to costs of achieving emission reductions.

11. Reference 8.

12. Reference 8.

13. Reference 10.

14. Letter from Givens, H.L., Alcan Ingot, to Durkee, K., EPA/ISB. June 21, 1994. Response to request for assistance from the aluminum industry in regard to costs of achieving emission reductions.

15. Reference 4.

16. Reference 3.

17. Reference 4.

18. Reference 3.

19. Reference 2.

20. Reference 3.

21. Reference 1.

22. Reference 4.

23. Reference 3.

24. ESD Regulatory Procedures Manual. U.S. Environmental Protection Agency. Vol. X, Sec. 2.4. October 1990. p.5.

25. Letter from Givens, H.L., Alcan Aluminum Association, to M. Branscome, RTI. February 14, 1995. Transmitting Alcan

Cassette Method and Cost Estimates. 29 p.

26. Memorandum from Griggin, J.W., Norsk Hydro, to S. Fruh, EPA. HF Monitoring System. January 17, 1995. 8 p.

APPENDIX A
EVOLUTION OF PROPOSED STANDARD

January 1992	Formed project team and conducted initial meeting with industry representatives
March 1992	Conducted literature search and review of literature
May 1992	Summarized State and local regulations
June 1992	Mailed generic information collection request to the industry
July 1992	Initial list of source categories published (57 FR 31576)
December 1992	Compiled information from generic information collection request
December 1992	Mailed detailed follow-up information collection request to the industry
March 1993	Compiled and summarized responses from detailed follow-up information collection request
April 1993	Met with EPA Work Group
August 1993	Emission tests conducted at Northwest Aluminum
September 1993	Developed preliminary industry profile
January 1994	Started MACT Partnership process
March 1994	Conference call with the States and other interested parties to explain MACT partnership process
March 1994	Emission tests conducted at Kaiser, Mead, WA
March 1994	Emission tests conducted at Kaiser, Tacoma, WA
May 1994	Emission tests conducted at Kaiser, Mead bake furnace
July 1994	Conducted presumptive MACT meeting with State partners

September 1994	Emission tests conducted at Noranda, New Madrid, MO
September 1994	Conducted tests at Alcoa's Warrick, IN plant to evaluate continuous emission monitors
October 1994	Additional POM emission tests conducted at Kaiser, Tacoma
October 1994	Presentation and discussion of HF CEM by Hydro Aluminum at Columbia Falls aluminum, MT
December 1994	Emission tests conducted at Columbia, Goldendale, WA
January 1995	Conducted meeting with State partners, Aluminum Association, and compliance personnel to discuss enhanced monitoring
February 1995	Mailed draft Technical Support Document for review
April, May 1995	Meetings and discussions with State partners and The Aluminum Association
July 1995	Public meeting with EPA, State partners, industry, and environmental groups
August 1995	EPA Work Group meeting
September 1995	Meeting with The Aluminum Association; EPA Work Group meeting
November 1995	Prepared Work Group closure package
December 1995	EPA Work Group closure
July 1996	Completed OMB review
August 1996	Proposal

APPENDIX B

SUMMARY OF EMISSION TEST DATA FOR POM SPECIES

[NOTE: This appendix summarizes emission test data for POM species. The data used to determine the MACT floor and MACT level of control are given in the Basis and Purpose Document in the rulemaking docket (Docket Number A-92-60).]

The testing for POM included the use of a surrogate measure based on extracting the front and back half catches of a modified Method 5 sampling train with methylene chloride. The compounds extracted by the methylene chloride include the POM species of interest as well as some other compounds. In addition, the individual POM species typically found in the pitch were quantified.

Table B-1 summarizes the results for individual POMs from the primary system at two Soderberg plants. The dry alumina scrubber at Northwest Aluminum (vertical stud Soderberg) was much more efficient for POM control than the scrubber at the horizontal stud Soderberg plant. Two possible explanations are a much lower air-to-cloth ratio at the VSS plant, and in addition, the VSS process uses a burner in the exhaust prior to the scrubber, which may have assisted in the destruction of POM.

Table B-2 contains the primary system results for the two prebake plants. Most of the individual species were not detected or were present below the quantitation limit. The POM extractables were also near the levels found from the analysis of blanks and contained less then 1 percent of the targeted POM species. These factors suggest that the POM species expected from the pitch were generally not present at the prebake plants, or were present in much smaller quantities than the levels found at Soderbergs. These results, when coupled with the anode bake furnace results discussed later, suggest that the POMs introduced with the pitch are driven off, destroyed, or captured at the anode bake furnace, and few are left to be emitted from the prebake reduction cell.

TABLE B-1. POM COMPOUND DATA FOR THE PRIMARY CONTROL SYSTEM--SODERBERGS

COMPOUND	PRIMARY SYSTEM RESULTS: DRY ALUMINA SCRUBBER (LB/TON)				
	NORTHWEST ALUMINUM[1]			KAISER-TACOMA[2]	
	INLET	OUTLET	WS OUTLET	INLET	OUTLET
ACENAPHTHENE	4.3E-03 *	5.7E-06	6.5E-06	2.2E-02	1.0E-03
ACENAPHTHYLENE	2.5E-03 *	3.4E-06	3.7E-06	4.0E-03	1.0E-04
ANTHRACENE	1.2E-02	3.0E-06	3.6E-06	1.7E-01	4.0E-03
BENZO(A)ANTHRACENE	8.7E-02	9.4E-06	6.6E-06	3.1E-01	4.0E-04
BENZO(A)PYRENE	5.7E-02	4.2E-06	4.8E-06	1.4E-01	1.0E-04
BENZO(B)FLUORANTHENE	2.0E-01	1.2E-05	1.0E-05	3.8E-01	3.0E-04
BENZO(E)PYRENE	9.5E-02	4.6E-06	4.8E-06		
BENZO(G,H,I)PERYLENE	7.5E-02	4.7E-06	5.3E-06	3.6E-01	1.0E-04
BENZO(K)FLUORANTHENE	1.1E-01	4.4E-06	4.9E-06	1.2E-01	1.0E-04
CARBAZOLE				7.8E-02	1.0E-03
2-CHLORONAPHTHALENE	4.3E-03 *	5.5E-06	9.2E-06	2.0E-04*	4.0E-05*
CHRYSENE	2.2E-01	2.0E-05	2.7E-05	5.5E-01	1.0E-03
DIBENZO(A,H)ANTHRACENE	1.9E-02	4.5E-06	5.0E-06	2.4E-02	4.0E-05 *
FLUORANTHENE	3.1E-01	2.8E-04	1.1E-04	1.4E+00	3.5E-02
FLUORENE	7.7E-03	1.1E-05	6.8E-06	8.3E-02	2.9E-02
INDENO(1,2,3-CD)PYRENE	5.2E-02	4.4E-06	4.7E-06	6.7E-02	1.0E-04
2-METHYLNAPHTHALENE	4.0E-03 *	4.5E-06	5.7E-06	7.0E-03	1.0E-03
NAPHTHALENE	2.6E-03 *	2.7E-05	4.6E-05	2.0E-03	2.0E-04
PERYLENE	1.2E-02	4.2E-06	4.8E-06		
PHENANTHRENE	1.9E-01	3.0E-04	1.2E-04	1.5E+00	3.2E-01
PYRENE	2.5E-01	1.4E-04	1.8E-05	1.2E+00	2.8E-02
RETENE				2.0E-04*	4.0E-05*
TOTAL SPECIES (lb/t)	1.7	8.5E-04	4.1E-04	6.4	0.42
POM EXTRACTABLES (lb/t)	6.15	0.01	0.01	15.4	1.60
PERCENT POM SPECIES	28.0	8.5	3.8	41.4	26.5

Notes:

* These compounds were not detected; the number represents the estimated quantitation limit.

"Total species" is the sum of the emissions of the POM compounds, including the quantitation limit as a worst case for those that could not be quantified. "POM extractables" is the surrogate measure for POM determined by the amount of emissions extractable by methylene chloride. "Percent POM species" is the percent of the methylene chloride extractables that could be accounted for by the sum of individual POM species.

Northwest Aluminum has a wet SO_2 scrubber following the dry alumina scrubber (results under "WS Outlet").

TABLE B-2. POM COMPOUND DATA FOR THE PRIMARY CONTROL SYSTEM--PREBAKE

COMPOUND	PRIMARY SYSTEM RESULTS: DRY ALUMINA SCRUBBER (LB/TON)			
	NORANDA[3]		KAISER-MEAD[4]	
	INLET	OUTLET	INLET	OUTLET
ACENAPHTHENE	2.6E-05*	2.0E-05*	1.0E-04*	2.0E-05*
ACENAPHTHYLENE	2.6E-05*	2.0E-05*	1.0E-04*	2.0E-05*
ANTHRACENE	2.6E-05*	2.0E-05*	1.0E-04*	1.0E-05
BENZO(A)ANTHRACENE	2.6E-05*	3.8E-05	1.0E-04	1.0E-04
BENZO(A)PYRENE	2.6E-05*	2.0E-05*	5.0E-05	1.0E-05
BENZO(B)FLUORANTHENE	2.6E-05*	2.6E-05*	1.0E-03	1.0E-04
BENZO(G,H,I)PERYLENE	2.6E-05*	2.0E-05*	1.0E-04	2.0E-05*
BENZO(K)FLUORANTHENE	2.6E-05*	2.0E-05*	2.0E-04	3.0E-05
CARBAZOLE	2.6E-05*	2.0E-05*	1.0E-04*	3.0E-05*
2-CHLORONAPHTHALENE	2.6E-05*	2.0E-05*	1.0E-04*	2.0E-05*
CHRYSENE	5.7E-05	8.2E-05	2.0E-03	3.0E-04
DIBENZO(A,H)ANTHRACENE	2.6E-05*	2.0E-05*	1.0E-04	1.0E-05*
FLUORANTHENE	1.8E-04	4.7E-05	2.0E-03	3.0E-04
FLUORENE	2.6E-05*	2.0E-05*	3.0E-05	3.0E-05
INDENO(1,2,3-CD)PYRENE	2.6E-05*	2.0E-05*	1.0E-04	2.0E-05*
2-METHYLNAPHTHALENE	2.6E-05*	2.0E-05*	1.0E-04	5.0E-05
NAPHTHALENE	2.6E-05*	2.0E-05*	1.0E-04	3.0E-05
PHENANTHRENE	1.7E-04	3.9E-05	1.0E-03	5.0E-04
PYRENE	5.1E-05	4.1E-05	2.0E-04	3.0E-04
RETENE	2.6E-05*	2.0E-05*	1.0E-04*	2.0E-05
TOTAL SPECIES (lb/t)	<8.7E-04	<5.5E-04	<7.7E-03	<1.9E-03
POM EXTRACTABLES (lb/t)	0.24	0.21	0.67	0.46
PERCENT POM SPECIES	<0.4	<0.3	<1.1	<0.4

* These compounds were not detected; the number represents the estimated quantitation limit.

"Total species" is the sum of the emissions of the POM compounds, including the quantitation limit as a worst case for those that could not be quantified. "POM extractables" is the surrogate measure determined by the amount of emissions extractable by methylene chloride. "Percent POM species" is the percent of the methylene chloride extractables that could be accounted for by the sum of individual POM species.

The results for secondary (roof) emissions given in Table B-3 also show that the individual POM species are not present (or were not detected) from the prebake plants (Noranda and Kaiser-Mead). In addition, the methylene chloride extractables were not measuring the POMs of interest with again less than 1 percent of the species appearing in the total. For both of the Soderbergs, much higher quantities of the POM species and methylene chloride extractables were found.

The paste plant results in Table B-4 show that the POM species were present and that they contributed significantly to the total methylene chloride extractables (30 to 55 percent). The testing of the baghouse used for fugitive dust emissions at Northwest Aluminum showed much lower levels of POM than those from the fume collection system. Most of the POM fume from the paste plant was routed to the dry coke scrubber, which controlled over 99 percent of the POM emissions.

The results for two anode bake furnaces are given in Table B-5. The table indicates that the dry alumina scrubber controls POM emissions (in addition to fluoride emissions). The methylene chloride extractables contained a high percentage of the individual POM species (22 to 57 percent).

TABLE B-3. POM COMPOUND DATA FOR SECONDARY (ROOF) EMISSIONS

COMPOUND	SECONDARY EMISSIONS: ROOF DATA (lb/ton)					
	NW ALUMINUM[5]		KAISER-TACOMA[6]		NORANDA[7]	MEAD[8]
	INLET	OUTLET	LINE 2	LINE 4	LINE 3	LINE 1
ACENAPHTHENE	3.4E-03	1.3E-03	1.0E-04	2.0E-04*	7.7E-05*	1.0E-04*
ACENAPHTHYLENE	2.2E-03*	1.0E-03*	1.0E-04*	2.0E-04*	7.7E-05*	1.0E-04*
ANTHRACENE	4.5E-02	1.9E-02	3.0E-03	1.0E-03	7.7E-05*	1.0E-04*
BENZO(A)ANTHRACENE	4.9E-02	2.3E-02	1.2E-02	8.0E-03	7.7E-05*	3.0E-05*
BENZO(A)PYRENE	2.6E-02	1.2E-02	4.0E-03	2.0E-03	7.7E-05*	1.0E-04*
BENZO(B)FLUORANTHENE	6.0E-02	3.0E-02	1.3E-02	1.0E-02	7.7E-05*	1.0E-04
BENZO(E)PYRENE	2.6E-02	1.3E-02				
BENZO(G,H,I)PERYLENE	1.7E-02	8.5E-03	3.0E-03	2.0E-03	7.7E-05*	1.0E-05
BENZO(K)FLUORANTHENE	1.7E-02	8.4E-03	4.0E-03	3.0E-03	7.7E-05*	3.0E-05
CARBAZOLE			3.0E-03	2.0E-03	9.6E-05	4.0E-05
2-CHLORONAPHTHALENE	3.8E-03*	1.8E-03*	1.0E-04*	2.0E-04*	7.7E-05*	1.0E-04*
CHRYSENE	8.1E-02	4.0E-02	2.7E-02	2.4E-02	7.7E-05*	3.0E-04
DIBENZO(A,H)ANTHRACENE	3.0E-03*	3.0E-03	1.0E-03	1.0E-03	7.7E-05*	1.0E-04*
FLUORANTHENE	2.6E-01	1.2E-01	5.1E-02	4.2E-02	7.7E-05*	3.0E-03
FLUORENE	1.4E-02	4.7E-03	3.0E-04	1.0E-04	7.7E-05*	4.0E-05
INDENO(1,2,3-CD)PYRENE	1.4E-02	6.6E-03	3.0E-03	2.0E-03	7.7E-05*	2.0E-05
2-METHYLNAPHTHALENE	3.6E-03*	1.7E-03*	1.0E-04*	2.0E-04*	7.7E-05*	2.0E-04
NAPHTHALENE	2.3E-03*	1.1E-03*	1.0E-04*	2.0E-04*	7.7E-05*	1.0E-04
PERYLENE	6.9E-03	3.1E-03				
PHENANTHRENE	2.7E-01	1.2E-01	2.2E-02	1.3E-02	7.7E-05*	1.0E-03
PYRENE	1.9E-01	9.3E-02	4.3E-02	3.2E-02	7.7E-05*	1.0E-03
RETENE			1.0E-04*	2.0E-04*	7.7E-05*	1.0E-04*
TOTAL SPECIES (lb/t)	1.1	0.51	0.19	0.14	<1.6E-03	<6.6E-03
POM EXTRACTABLES (lb/t)	3.65	1.80	1.71	1.97	0.11	0.67
PERCENT POM SPECIES	30.1	28.4	11.1	7.3	<1.4	<1.0

* These compounds were not detected; the number represents the estimated quantitation limit.

Northwest Aluminum has wet roof scrubbers; consequently, both inlet and outlet measurements are given for the scrubbers.

TABLE B-4. POM COMPOUND DATA FOR PASTE PRODUCTION (lb/ton paste)

COMPOUND	NW ALUMINUM PASTE PLANT[9]				MEAD PASTE PLANT[10]	
	COKE SCRUBBER		BAGHOUSE		DRY COKE SCRUBBER	
	INLET	OUTLET	INLET	OUTLET	INLET	OUTLET
ACENAPHTHENE	7.0E-03	3.2E-05	1.0E-04	4.1E-07	5.0E-03	2.0E-03
ACENAPHTHYLENE	8.1E-05*	6.9E-07*	3.8E-06*	2.2E-07	2.0E-05	2.0E-05
ANTHRACENE	2.6E-03	9.4E-06	2.2E-05	2.8E-07	5.0E-03	5.0E-04
BENZO(A)ANTHRACENE	3.3E-03	1.0E-06	4.3E-06	1.2E-06	1.0E-03	3.0E-05
BENZO(A)PYRENE	1.6E-03	6.2E-07	3.6E-06*	1.1E-06	2.0E-03	1.0E-06
BENZO(B)FLUORANTHENE	2.6E-03	9.4E-07	3.4E-06*	2.2E-06	2.0E-03	2.0E-06
BENZO(E)PYRENE	9.1E-04	5.1E-07	2.9E-06*	1.0E-06		
BENZO(G,H,I)PERYLENE	3.8E-04	5.9E-07*	3.2E-06*	8.7E-07	1.0E-03	2.0E-07
BENZO(K)FLUORANTHENE	8.1E-04	5.9E-07	3.6E-06*	7.5E-07	1.0E-03	1.0E-06
CARBAZOLE					1.0E-03	1.0E-04
2-CHLORONAPHTHALENE	1.4E-04*	1.2E-06*	6.9E-06*	3.7E-07	5.0E-06*	4.8E-07*
CHRYSENE	3.7E-03	1.6E-06	6.1E-06	1.8E-06	2.0E-03	2.0E-05
DIBENZO(A,H)ANTHRACENE	1.1E-04*	6.9E-07*	3.8E-06*	4.1E-07	2.0E-04*	3.6E-07
FLUORANTHENE	1.4E-02	5.1E-05	8.1E-05	2.3E-06	1.1E-02	1.0E-03
FLUORENE	2.3E-03	1.2E-05	2.6E-05	3.5E-07	6.0E-03	2.0E-03
INDENO(1,2,3-CD)PYRENE	4.3E-04	5.3E-07*	3.1E-06*	9.4E-07	1.0E-03	2.9E-07
2-METHYLNAPHTHALENE	1.6E-04	1.9E-06	1.6E-05	4.5E-07	1.0E-04	1.0E-05
NAPHTHALENE	1.1E-04	6.9E-06	3.3E-05	5.7E-07	2.0E-05	2.0E-06
PERYLENE	4.2E-04	6.9E-07*	3.9E-06*	4.7E-07		
PHENANTHRENE	1.5E-02	1.1E-04	2.0E-04	1.2E-06	2.6E-02	3.0E-03
PYRENE	1.1E-02	3.2E-05	5.7E-05	2.1E-06	7.0E-03	4.0E-04
RETENE					5.0E-06*	4.8E-07*
TOTAL SPECIES (lb/t)	6.7E-02	2.6E-04	5.8E-04	1.9E-05	7.1E-02	9.1E-03
POM EXTRACTABLES (lb/t)	0.22	4.7E-04	0.030	6.9E-04	0.235	0.023
PERCENT POM SPECIES	30.6	55.2	1.9	2.8	30.4	39.5

* These compounds were not detected; the number represents the estimated quantitation limit.

TABLE B-5. POM COMPOUND DATA FOR ANODE BAKE FURNACE (lb/ton of anode)

COMPOUND	**NORANDA[11]**		**MEAD[12]**	
	DRY ALUMINA SCRUBBER		**DRY ALUMINA SCRUBBER**	
	INLET	**OUTLET**	**INLET**	**OUTLET**
ACENAPHTHENE	1.4E-04	3.8E-06*	2.0E-03	1.0E-05
ACENAPHTHYLENE	1.8E-03	3.8E-06*	5.0E-03	2.0E-05
ANTHRACENE	7.2E-03	5.8E-05	2.8E-02	3.0E-06*
BENZO(A)ANTHRACENE	1.9E-02	1.5E-05	6.6E-02	1.0E-04
BENZO(A)PYRENE	4.6E-03	1.6E-05	3.7E-02	1.0E-04
BENZO(B)FLUORANTHENE	2.4E-02	8.4E-05	1.0E-01	1.0E-03
BENZO(G,H,I)PERYLENE	3.8E-03	2.0E-05	1.9E-02	1.0E-03
BENZO(K)FLUORANTHENE	2.2E-03	2.4E-05	3.4E-02	2.0E-04
CARBAZOLE	5.45-03	2.2E-05		
2-CHLORONAPHTHALENE	1.5E-04*	3.8E-06*	2.0E-04*	3.0E-06*
CHRYSENE	3.8E-02	1.2E-04	1.1E-01	1.0E-03
DIBENZO(A,H)ANTHRACENE	1.4E-03	7.2E-06	6.0E-03	1.0E-04
FLUORANTHENE	7.2E-02	1.5E-03	1.9E-01	6.0E-03
FLUORENE	1.3E-03	8.8E-05	8.0E-03	1.0E-03
INDENO(1,2,3-CD)PYRENE	4.2E-03	2.4E-05	2.1E-02	4.0E-04
2-METHYLNAPHTHALENE	3.6E-04	3.8E-06*	1.0E-03	2.0E-05
NAPHTHALENE	4.8E-04	7.8E-06	1.0E-03	2.0E-05
PHENANTHRENE	6.8E-02	5.8E-03	1.3E-01	2.4E-02
PYRENE	4.8E-02	3.6E-04	1.3E-01	1.0E-03
RETENE	1.5E-04*	3.8E-06*		
TOTAL SPECIES (lb/t)	0.30	0.0082	0.91	0.036
POM EXTRACTABLES (lb/t)	0.53	0.012	2.76	0.161
PERCENT POM SPECIES	56.6	68.3	32.9	22.4

* These compounds were not detected; the number represents the estimated quantitation limit.

The reported results for Noranda were in lb/ton aluminum and were multiplied by two to express as lb/ton of anode.

REFERENCES

1. Emissions Measurement Test Report - Northwest Aluminum Company. Prepared by Entropy, Inc. June 1994. 77 p.

2. Kaiser Aluminum and Chemical Corporation Method 5/POM and 13B Testing - Tacoma, Washington - March 1-8, 1994. Prepared by AmTest Air Quality, Inc. July 29, 1994. pp. 1 through 47. [Also draft test data for October 1994.]

3. Noranda Aluminum Inc. Method 5/POM and 13B Testing - New Madrid, Missouri - September 14-20, 1994. Prepared by AmTest Air Quality, Inc. January 10, 1994. pp. 1 through 62.

4. Kaiser Aluminum and Chemical Corporation Method 5/POM and 13B Testing - Mead, Washington - March 15-24, 1994. Prepared by AmTest Air Quality, Inc. November 9, 1994. pp. 1 through 99.

5. Reference 1.

6. Reference 2.

7. Reference 3.

8. Reference 4.

9. Reference 1.

10. Reference 4.

11. Reference 3.

12. Washington Department of Ecology and Kaiser Aluminum and Chemical Corporation Method 5/POM and 13B Testing - Anode Bake Furnace- Mead, Washington - May 2-5, 1994. Prepared by AmTest Air Quality, Inc. December 12, 1994. pp. 1 through 33.