United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

EPA-450/3-86-010
September 1986

Air

EPA

Review of New Source Performance Standards for Primary Aluminum Reduction Plants

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NSPS

EPA-450/3-86-010

Review of New Source Performance Standards for Primary Aluminum Reduction Plants

Emission Standards and Engineering Division

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

September 1986

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1. SUMMARY

The new source performance standards (NSPS) for primary aluminum reduction plants were promulgated by the U.S. Environmental Protection Agency (EPA) on January 26, 1976, under Section 111 of the Clean Air Act. The standards apply to all aluminum reduction potlines and anode bake furnaces which commenced construction or modification after October 23, 1974. The NSPS limit emissions of gaseous and particulate fluorides, measured as total fluorides (TF).

The NSPS were amended on June 30, 1980, to permit TF to exceed previous limits, under certain circumstances. A requirement for monthly compliance tests was added at the same time.

The objective of this report is to document the review of the NSPS for primary aluminum reduction plants, and to assess the need for revision on the basis of developments that have occurred since the standard was promulgated. This review is required under Section 111(b) of the Clean Air Act, as amended. The following paragraphs summarize the findings of this review.

1.1 BEST DEMONSTRATED CONTROL TECHNOLOGY

The NSPS limit emissions of TF from primary aluminum reduction potlines and anode bake furnaces. No changes have occurred in the control techniques defined as best demonstrated technology (BDT) for these sources. For potlines, they are either wet scrubbers followed by wet electrostatic precipitators (ESP's) or dry scrubbers. For anode bake furnaces, they are either dry or wet scrubbers. However, all plants with potlines or anode bake furnaces subject to the NSPS have elected to use dry scrubbers for TF control, and all have demonstrated the capability to comply with the NSPS.

1.2 ECONOMIC CONSIDERATIONS AFFECTING THE NSPS

Information on the capital and annualized costs of dry scrubbers for controlling potlines and anode bake furnaces was supplied by plants subject to the NSPS. Additional cost data were extracted from a report published by the International Primary Aluminum Institute (IPAI). These data show that the installation of TF emission controls can either increase or decrease aluminum production costs.

The cost impacts of TF emission controls are reported by the IPAI to range from a credit of $11.60 to a cost of $10.65 for each ton of aluminum produced. Similar information on 3 domestic plants subject to the NSPS show net costs of $11.80 to $17.70 per ton of aluminum. Two of the NSPS plants utilize anode bake furnaces and those costs are included. The plants listed in the IPAI report did not include bake furnace control costs. For the 2 domestic plants having only anode bake furnaces subject to the NSPS, control costs are $3.60 and $4.45 per ton of aluminum produced.

Five new potlines and eight new anode bake furnaces have been placed in service since the NSPS was proposed. No potline or bake furnace construction has taken place in the U.S. in the last 4 years (1983-86), however, and forecasts indicate that none will be built in the next 5 to 10 years.

1.3 INDUSTRY TRENDS

No growth is expected in the domestic primary aluminum industry because of the relatively high cost of power in the United States. In fact, the domestic industry may well experience negative growth, with the less efficient plants, or those in high power cost areas, being closed down. Ten U.S. plants have closed in the last 5 years (1981-1985), at least six of them permanently, and most of the remainder are operating at reduced capacity. In December 1985, the domestic primary aluminum industry operated at 66 percent of capacity, after adjustment for permanent plant closures and capacity reductions. There are no known instances whereby an existing facility will become an affected facility through either modification or reconstruction.

1.4 OTHER FINDINGS

1.4.1 <u>Testing</u>

The principal issue raised by members of the primary aluminum industry is the monthly testing requirements for secondary (fugitive) potroom emissions.

There are no provisions in the standard for reducing the frequency of secondary potroom emissions tests. However, the General Provisions (§60.8(b)(4)) give to the Administrator, and subsequently to the States who have received delegation, the authority to reduce test frequency. Data from one well-controlled plant were used to develop formulae for determining the statistical probability of a random failure (assumes no known changes in the level of maintenance, in work practices, or in the frequency and thoroughness of potroom inspections).

1.4.2 Sulfur Dioxide Emissions

Sulfur dioxide (SO_2) emissions from primary aluminum reduction plants have increased since the NSPS were proposed due to an increase in the sulfur content of coke, and a shift to dry scrubbers for TF control.

2. INTRODUCTION

2.1 BACKGROUND INFORMATION

New source performance standards (NSPS) were promulgated for primary aluminum reduction plants on January 26, 1976, under Section 111 of the Clean Air Act.[1] The NSPS control emissions of gaseous and particulate fluorides, measured as total fluorides (TF), from aluminum reduction potlines and anode bake furnaces. They apply to all facilities constructed, modified, or reconstructed after October 23, 1974, the date of publication of the proposed regulations. Since fluoride is a designated pollutant1/, the States were required to develop companion standards for existing facilities. A document was, therefore, prepared to provide guidance to the States regarding probable fluoride emissions levels which could be expected from existing uncontrolled plants and the amounts of emission reduction which should be achievable at those plants. It was released in December 1979.[2]

Shortly after the NSPS was promulgated, petitions for review were filed by four U.S. aluminum companies. As a consequence, additional data were obtained and amendments to the NSPS were proposed on September 19, 1978. On June 30, 1980, the NSPS amendment was promulgated to permit TF emissions to exceed, under certain circumstances, the levels set initially.[3] A monthly monitoring requirement was added at the same time. This monitoring requirement has been waived by EPA for the primary fluoride control devices at some plants in favor of yearly tests. Measurement of secondary (fugitive) fluoride emissions from all new potrooms is, however, required on a monthly basis.

1/ A designated pollutant is one which is not included on a list published under Section 108(a) of the Act (National Ambient Air Quality Standards), but for which an NSPS has been established.

As was discussed in the background information document and the guidance document, effects of fluoride have been extensively documented.[4,5] Fluoride does not directly affect human health but can have deleterious effects on both plants and animals. It is, therefore, classified as a welfare pollutant.

2.2 SCOPE OF THE REVIEW

The Clean Air Act Amendments of 1977 require that the Administrator of EPA review and, if appropriate, revise established standards of performance for new stationary sources at least every 4 years.[6] The purpose of this report is to document this review and to assess the need for revision of the existing standards for primary aluminum reduction plants, based on developments that have occurred or are expected to occur within the aluminum industry. The information presented in this report was obtained from reference literature, discussions with industry representatives, trade organizations, process and control equipment vendors, EPA Regional Offices, and State and local agencies.

The review conducted to assess the current NSPS for primary aluminum reduction plants was limited to three areas of concern, as follows:

- technologies being used for compliance (process modifications, maintenance, work practices, housekeeping, capture and control equipment design, and process selection);
- enforcement and compliance experience; and
- State standards implemented as a result of the NSPS.

2.3 CURRENT STANDARDS

Federal NSPS for primary aluminum reduction plants regulate fluoride emissions from aluminum reduction potrooms and, if applicable, from anode bake furnaces. Other sources and pollutants are regulated by prevention of significant deterioration (PSD) or State regulations. The NSPS are summarized and discussed in Section 2.3.1 below, and the applicable regulations for those states with primary aluminum plants are reviewed in Section 2.3.2.

2.3.1 New Source Performance Standards

2.3.1.1 Summary of New Source Performance Standards. The original standards for primary aluminum plants (Table 2-1) were proposed on October 23, 1974, and promulgated on January 26, 1976.[7,8] They limited TF[2/] emissions from new, modified, or reconstructed potroom groups and (if applicable) anode bake furnaces in primary aluminum reduction plants to a total of 1 kilogram per megagram (kg/Mg) of aluminum produced (2.0 pounds per ton of aluminum produced [lb/TAP]).

The NSPS limit overall fluoride emissions from potrooms, and, therefore, require the measurement of both primary and secondary fluoride emissions. Primary emissions are those captured by the pot hoods while secondary emissions are fugitive emissions from the pot hoods and all emissions generated outside the pots. An example of the latter would be outgassing from a spent anode left beside the potline to cool.

Visible emissions regulations were set at the same time. They limit emissions from potroom groups to less than 10 percent opacity and those from anode bake plants to less than 20 percent opacity.

Amendments to the NSPS (Table 2-1) were proposed on September 19, 1978, and promulgated on June 30, 1980.[9,10] One major change was the addition of higher, never-to-be-exceeded (NTBE) limits for potrooms. These NTBE limits were added to allow for variability in fluoride emissions from the aluminum reduction process. Emissions which exceed the original NSPS but are below the NTBE limit are acceptable if the owner/operator can demonstrate that the appropriate control systems[3/] have been installed and are being operated and maintained in an exemplary fashion. The other major change was the addition of a monthly testing requirement.

2.3.1.2 Testing and Monitoring Requirements. Initial performance tests to verify compliance with the standards for primary aluminum reduction plants must be completed within 60 days after achieving full capacity

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[2/] The term "total fluoride" refers to elemental fluorine and all fluoride compounds (gaseous and particulate) which are measured by EPA reference methods 13A or 13B.

[3/] The control system includes the pot hoods, the ducting, and the primary control device.

TABLE 2-1

NEW SOURCE PERFORMANCE STANDARDS (NSPS)

FOR

PRIMARY ALUMINUM REDUCTION PLANTS[11,12]

Affected facility	Pollutant	NSPS emission limit[a]	Comments
Stud Soderberg potroom group (Vertical or horizontal)	Total Fluorides	1.0 kg TF/Mg Al (2.0 lb TF/ton Al)	Original standard
		1.3 kg TF/Mg Al (2.6 lb TF/ton Al)	NTBE limit, Amendment[b]
	Visible Emissions	<10% opacity	
Prebake plant potroom group (Center and side-worked)	Total Fluorides	0.95 kg TF/Mg Al (1.9 lb/ton Al)	Original standard
		1.25 kg TF/Mg Al (2.5 lb TF/ton Al)	NTBE limit, Amendment[b]
	Visible Emissions	<10% opacity	
Prebake plant anode bake plant	Total Fluorides	0.05 Kg TF/Mg Al equivalent (0.1 lb TF/ton Al)	
	Visible Emissions	<20% opacity	

[a] kg TF/Mg Al = Kilograms total fluoride per megagram aluminum produced
lb TF/ton Al = Pounds total fluoride per ton aluminum produced.

[b] Compliance to this never-to-be-exceeded (NTBE) limit is acceptable if owner/operator demonstrates that the proper control equipment was installed and that exemplary operation and maintenance procedures were used with respect to the emission control system.

operation, but not later than 180 days after initial start-up of the facility. This is a uniform requirement for all affected facilities under 40 CFR 60.8 (General Provisions). Following this initial testing, performance tests must be conducted at least once a month during the life of the facility to verify continued compliance. Less frequent testing of the anode bake plant or the primary control systems for the potrooms may be permitted, if the owner/operator can show that emissions have low variability during day-to-day operations. The monthly test requirement has been waived, in favor of annual testing, for the primary potline and anode bake furnace control systems at the three plants with center-worked prebake (CWPB) potlines subject to the NSPS. Measurement of secondary emissions from all NSPS potrooms is required on a monthly basis.

2.3.2 State Regulations

2.3.2.1 Fluorides. Of the 17 states that now have, or have had, operating primary aluminum plants, 14 have fluoride emissions regulations (Table 2-2). Thirteen limit fluoride emissions directly and one regulates atmospheric concentrations of fluorides. Another uses the PSD permitting route to limit fluoride emissions. Comparing the regulations listed in Table 2-2 with the recommended guidelines (Table 2-3) and the NSPS (Table 2-1), it can be seen that one State (Oregon) imposes limitations more stringent than the NSPS. Three other states have regulations comparable to the NSPS maximum, and four adopted the EPA guidelines.

2.3.2.2 Particulate Matter. All 17 states have standards for particulate matter (PM) (Table 2-4).

2.3.2.3 Visible Emissions. Thirteen of the 17 states have visible emission limits (Table 2-5).

2.3.2.4 Other State Regulations. Three states have sulfur dioxide (SO_2) regulations which are applicable to non-fuel burning sources in primary aluminum plants (Table 2-6). The Maryland limit of 500 parts

TABLE 2-2

STATE REGULATIONS FOR FLUORIDE EMISSIONS FROM EXISTING PRIMARY ALUMINUM PLANTS[13]

State	Affected facility[a]	Standard[b]	Comments
Alabama		None	
Arkansas	Potroom groups, all types	98.5% TF removal efficiency	Adopted EPA Guidelines
	VSS	80% capture efficiency	
	SWPB	80% " "	
	HSS	90% " "	
	CWPB	95% " "	
Indiana	Potroom groups and	90% capture efficiency	
	Anode bake furnace	95% TF removal efficiency	
Kentucky	Potroom groups with dry	1.9 lb TF/ton Al	
	scrubbers	1.9-2.5 lb TF/ton Al	If design, O&M exemplary
	Potroom groups with wet	3.25 lb F/hr from roof monitor	
	scrubbers	1.0 lb gas F/ton Al	Plant has exemption to 290 lb/hr SIP not yet approved by EPA
		0.01 gr/SCF	
Louisiana	Potroom groups, all types	98.5% TF removal efficiency	
	HSS	90% capture efficiency	Adopted EPA Guidelines
	PB	95% " "	
Maryland	Potroom group	2.5 lb TF/ton Al	
	Anode Bake Furnace	0.1 lb TF/ton Al equivalent	
Missouri	Potroom group and Anode bake furnace	2.5 lb TF/ton Al	Measurements made only at the primary control stack
Montana	SS Potroom group	2.6 lb TF/ton Al	
New York	SS Potroom group	4.3 lb TF/ton Al	
	PB Potroom group	4.2 lb TF/ton Al	
	Anode Bake Furnace	0.40 lb TF/ton Al equivalent	1 ton Anode production = 2 tons Aluminum
North Carolina	PB Plant	95% capture efficiency	
		98.5% TF removal efficiency	
Ohio		None	

TABLE 2-2 (CONCLUDED)

State	Affected facility	Standard	Comments
Oregon	Plant	1.3 lb TF/ton Al 1.0 lb TF/ton Al 12.5 tons F/month	Monthly average Annual average Total from all sources
South Carolina	PB Potroom Group	1.02 lb TF/ton Al 1.34 lb TF/ton Al	12 month running average Excursion (monthly average); PSD permit requirements
Tennessee	Potroom groups, all types CWPB SWPB	98.5% TF removal efficiency 95% capture efficiency 80% capture efficiency	
Texas		No fluoride emission limit	Apply air quality standards
Washington	Potroom groups, all types VSS SWPB HSS CWPB	95% TF removal efficiency 80% Fume capture efficiency 80% " " " 85% " " " 95% " " "	
W. Virginia	PB Potroom groups	90% fume capture efficiency 99% TF removal efficiency	

a/ VSS - Vertical stud Soderberg
HSS - Horizontal stud Soderberg
SWPB - Side-worked prebake
CWPB - Center-worked prebake
SS - Stud Soderberg
PB - Prebake

b/ TF - Total fluorides
lb TF/ton Al - Pounds total fluorides per ton aluminum produced
lb F/hr - Pounds fluoride per hour
gr/SCF - Grains (particulate) per standard cubic foot

TABLE 2-3

STATE GUIDELINES FOR CONTROL OF FLUORIDES FROM EXISTING PRIMARY ALUMINUM PLANTS[14]

Pot type[a]	Recommended control efficiencies			Expected fluoride emission range for potlines with recommended controls (lb TF/ton Al)[b]		
	Primary		Secondary removal			
	Collection	Removal		Primary emissions	Secondary emissions	Total emission
VSS	80	98.5	75	0.4 - 0.7	1.5 - 2.7	1.9 - 3.4
HSS	90	98.5	-	0.4 - 0.6	2.8 - 4.5	3.2 - 5.1
SWPB	80	98.5	75	0.4 - 0.6	1.9 - 2.7	2.3 - 3.3
CWPB	95	98.5	-	0.4 - 0.9	1.3 - 3.3	1.7 - 4.2

[a] VSS - Vertical stud Soderberg
HSS - Horizontal stud Soderberg
SWPB - Side-worked prebake
CWPB - Center-worked prebake
TF - Total fluorides
Al - Aluminum

[b] lb TF/ton Al = Pounds total fluorides per ton aluminum produced

TABLE 2-4
STATE REGULATIONS FOR PARTICULATE MATTER EMISSIONS FROM NEW PLANTS[15]

Particulate matter (PM) limit[a]	Prod.rate (tph)	Emission source	Number states	States applying[b]
$E = 4.10p^{0.67}$ $= 55.0p^{0.11} - 40$	$p<30$ $p>30$	Misc. Process Stacks	6	Indiana, Missouri, Montana, North Carolina, South Carolina, Ohio
$E = 3.59p^{0.62}$ $= 17.31p^{0.16}$	$p<30$ $p>30$	"	3	Alabama, Arkansas (option), Tennessee
$E = 0.24p^{0.67}$ $= 0.39p^{0.082} - 50$	$p<50$ $p>50$	"	1	New York
$E = 0.551p$	$p<0.05$	"	1	Ohio
$E = 0.048q^{0.62}$	----	"	1	Texas
E = 0.1% by wt.	>200	"	1	Indiana
0.03 gr/dscf	----	"	4	Indiana (non-attain.), Maryland (areas 3&4), Missouri, and New York
0.025-0.25 gr/dscf	----	"	1	Tennessee
7.0 lb/TAP 5.0 lb/TAP	---- ----	All sources	1	Oregon - monthly - annual
15 lb/TAP	----	Potroom groups	1	Washington
E = 6.2 lb/hr = 10.5 lb/hr = 21.2 lb/hr	15 25 >50	Misc. Process Stacks	1	West Virginia

b Several states have more than one type of standard.

a E = particulate matter emission limit, pounds per hour
p = production rate, tons per hour
q = air flow, actual cubic feet per minute
gr/dscf = grains per dry standard cubic foot
lb/TAP = pounds per ton aluminum produced
lb/hr = pounds per hour

TABLE 2-5

STATE REGULATIONS FOR VISIBLE EMISSIONS FROM NEW PLANTS[16]

Opacity limit (%)	Emission source	Number of states	States applying
0	Misc. Process Stacks	1	Md. (areas III & IV only)
10	Misc. Process Stacks	1	Ore.
	Pri. Alum. Potlines	1	Mont.
20	Misc. Process Stacks	11	Ala., Ark., Md., Mo., Mont., NY, NC, Ohio, Tex., Wash., and W.Va.
>20%	Misc. Process Stacks	1	Ind.

TABLE 2-6

STATE REGULATIONS FOR CONTROL OF SO_2, CO, NO_x, and HC FROM NON-FUEL BURNING SOURCES IN PRIMARY ALUMINUM PLANTS[17]

Pollutant[a]	Standard[b]	States applying
SO_2	60 lb/TAP	Washington
	500 ppm	Maryland (new plants)
	2000 ppm	Louisiana
CO	500 lb/day	Maryland
NO_x	None	
HC	None	

a SO_2 = Sulfur dioxide
CO = Carbon monoxide
NO_x = Nitrogen oxides
HC = Hydrocarbons

b lb/TAP = pounds per ton aluminum produced
ppm = parts per million

per million (ppm) could be restrictive for new stud Soderberg plants. The Washington standard of 60 lb SO_2/TAP limits the sulfur content of coke used in the anodes to about 3 percent.

One state (Maryland) has a carbon monoxide (CO) standard applicable to non-fuel burning sources in primary aluminum plants. For the one plant affected, this limit of 500 lb/day is roughly equivalent to 1 lb CO/TAP at full production.

There are no applicable State regulations for nitrogen oxides (NO_x) or hydrocarbons (HC).

2.3.3 PSD Regulations

Prevention of significant deterioration regulations apply to major sources of air pollutants subject to regulation under the Clean Air Act.[18,19] A primary aluminum reduction plant is classified as a major source if it emits, or has the potential to emit, 90.7 megagrams per year (Mg/yr) (100 tons/year) or more of a regulated air pollutant.[20] Pollutants emitted by primary aluminum plants which are regulated under the Act include: fluorides, SO_2, NO_x, PM, and CO. The preconstruction review and best available control technology (BACT) requirements of PSD apply to both new and modified plants.

Total fluoride emissions from two primary aluminum plants are controlled under PSD regulations. One is a new plant and one is an existing plant with a new potline. Determinations of BACT for those plants are listed in Table 2-7. Both impose considerably more stringent TF limits than does the NSPS. The PSD regulations also impose limits on SO_2 at three plants and PM at two plants. The SO_2 standard at one plant would require, in the absence of add-on SO_2 controls, the use of a very low sulfur coke (about 0.7 percent).

TABLE 2-7

BACT DETERMINATIONS FOR PLANTS SUBJECT TO PSD REGULATIONS[21]

Plant & location	Permit date	Source	Pollutants & allowable emissions[a/]		Comments
Alumax Goose Creek, S. Carolina	2/78	Potlines 1&2	TF	1.02 lb/TAP	12 month running average, excursion to 1.34 allowed
			SO_2	269 lb/hr/scrubber(P) 2.75 lb/hr/scrubber(S)	Sulfur contents of coke & pitch limited to 3.0% & 0.6%, respectively
			PM	5.92 lb/hr/scrubber(P) 9.07 lb/hr/scrubber(S)	
		Anode bake plant	TF	0.02 lb/TAP equivalent (0.04 lb/TAC)	
Commonwealth Goldendale, Washington	8/78	Potlines 1,2,3	TF	1.3 lb/TAP	To drop to 0.8 lb/TAP after one year
			SO_2	13.97 lb/TAP	Roughly equivalent to the use of 0.7% sulfur coke
			PM	4 lb/TAP	
Alcoa Wenatchee, Washington	2/82	Potlines 1,2,3	SO_2	46.0 lb/TAP	Sulfur content of coke limited to 3.0%

a/ TF = Total fluorides
SO_2 = Sulfur dioxide
PM = Particulate matter
(P) = Primary emissions
(S) = Secondary emissions
lb/TAP = Pounds/ton aluminum produced
lb/TAC = Pounds/ton anode consumed

2.4 REFERENCES FOR CHAPTER 2

1. U.S. Environmental Protection Agency. Standards of Performance for Primary Aluminum Reduction Plants. Title 40, Chapter I, Subchapter C, Part 60, Subpart S. Federal Register, Vol. 41, No. 17. Monday, January 26, 1976. Pages 3826-3830.

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

3. U.S. Environmental Protection Agency. Standards of Performance for New Stationary Sources: Primary Aluminum Plants; Amendments. 40 CFR Part 60, Subpart S. Federal Register, Vol. 45, No. 127. Monday, June 30, 1980. Pages 44202-44217.

4. U.S. Environmental Protection Agency. Background Information for Standards of Performance: Primary Aluminum Industry, Vol. 1. EPA 450/2-74-020a. October 1974. Pages xvii and xviii.

5. Reference 2, Chapter 12.

6. United States Congress. The Clean Air Act as amended August 1977. Serial No. 97-4, U.S. Government Printing Office. September 1981. Section 111(b)(1)(B). Page 31.

7. U.S. Environmental Protection Agency. Standards of Performance for New Stationary Sources, Proposed Rule for Primary Aluminum Plants. 40 CFR Part 60, Subpart S. Federal Register, Vol. 39, No. 206. Wednesday, October 23, 1974. Pages 37730-37741.

8. Reference 1.

9. U.S. Environmental Protection Agency. Standards of Performance for New Stationary Sources, Primary Aluminum Industry. 40 CFR Part 60, Subpart S. Federal Register, Vol. 43. No. 182. Tuesday, September 19, 1978. Pages 42186-42198.

10. Reference 3.

11. Reference 1.

12. Reference 3.

13. Memo from W.H. Maxwell, EPA:ISB, to Primary Aluminum Docket (A-86-07). September 18, 1986. State laws.

14. Reference 2, Table 8-4.

15. Reference 13.

16. Reference 13.

17. Reference 13.

18. U.S. Environmental Protection Agency. Prevention of Significant Deterioration of Air Quality. Title 40, Chapter I, Subchapter C, Part 51.24. Code of Federal Regulations. U.S. Government Printing Office. 1984. Pages 610-626.

19. Reference 18, Part 52.21, Pages 19-36.

20. Reference 18, Paragraph (b)(1)(i)(a), Page 611.

21. U.S. Environmental Protection Agency. Compilation of BACT/LAER Determinations, Revised. EPA-450/2-80-070. May 1980. Source Code 7.1.

3. THE PRIMARY ALUMINUM INDUSTRY

3.1 THE INDUSTRY

As of May 1986, the primary aluminum reduction industry consisted of 23 plants located in 14 states (Table 3-1). They are owned by 11 companies, many of which are multi-nationals and also operate plants in other countries. The types of reduction pots used in the individual plants, and their production capacities, are also shown in Table 3-1. Many of these plants periodically operate at reduced capacity and some have taken part of their capacity out of service permanently.

Industry growth has been negative in the United States in recent years with ten plants having shut down since 1978 (Table 3-2). These plant closings have not been offset by the new facilities noted in Chapter 5. At this time, there are no known plans by any company to construct primary aluminum reduction facilities in the United States.[1] The economics of aluminum production, particularly with regard to energy and labor costs, are not conducive to the expansion of primary aluminum production in the U.S.[2-4] In fact, further plant shut-downs or production cut-backs may result from these same economic considerations. In addition, there are no known plans whereby an existing facility will become an affected facility through either modification or reconstruction over the next 5 to 10 years.

3.2 PLANT DESCRIPTION

The major components of a primary aluminum reduction plant are:

- a storage area for raw materials and finished product
- one or more potlines where alumina feed material is reduced into aluminum
- a cast house in which the aluminum is reheated and purified, its characteristics are modified to meet various specifications, and it is cast into ingots

TABLE 3-1

LISTING OF OPERATING PRIMARY ALUMINUM PLANTS

IN THE UNITED STATES AND THEIR CAPACITIES - MAY 1986[5-7]

Plant name/location	Plant capacity (1,000 TAP/yr)[a]				
	By pot type[b]				Total
	CWPB	SWPB	VSS	HSS	
INDIANA					
Alcoa, Newburgh (Warrick)	298				298
KENTUCKY					
Nat'l. Southwire, Hawesville	190				190
Alcan, Sebree	180				180
MARYLAND					
Eastalco (Alumax), Frederick		176			176
MISSOURI					
Noranda, New Madrid	225				225
MONTANA					
Arco, Columbia Falls			180		180
NEW YORK					
Alcoa, Massena	226				226
Reynolds, Massena				126	126
NORTH CAROLINA					
Alcoa, Badin	127				127
OHIO					
Ormet, Hannibal	270				270
OREGON					
Reynolds, Troutdale	130				130
SOUTH CAROLINA					
Alumax, Goose Creek (Mount Holly)	200				200

TABLE 3-1 (concluded)

Plant name/location	Plant capacity (1,000 TAP/yr)[a]				
	By pot type[b]				Total
	CWPB	SWPB	VSS	HSS	
TENNESSEE					
Alcoa, Alcoa	220				220
Consolidated Aluminum, New Johnsonville		146			146
TEXAS					
Alcoa, Rockdale	342				342
WASHINGTON					
Intalco (Alumax), Ferndale		280			280
Kaiser, Mead (Spokane)	220				220
Kaiser, Tacoma				80	80
Alcoa, Vancouver	121				121
Alcoa, Wenatchee	226				226
Reynolds, Longview				210	210
Commonwealth, Goldendale			185		185
WEST VIRGINIA					
Kaiser, Ravenswood	164				164
Totals	3,139	602	365	416	4,522

a TAP/yr = Tons (Short) aluminum production/year (1 ton = 0.9 megagram)
b CWPB = Center-worked prebake
SWPB = Side-worked prebake
VSS = Vertical stud Soderberg
HSS = Horizontal stud Soderberg

TABLE 3-2

LISTING OF NON-OPERATING PRIMARY ALUMINUM PLANTS IN THE UNITED STATES AND THEIR CAPACITIES - MAY 1986[8-13]

Plant name/location	Plant capacity (1,000 TAP/yr)[a]				
	By pot type[b]				Total
	CWPB	SWPB	VSS	HSS	
ALABAMA					
Revere, Scottsboro		116			116[c]
Reynolds, Listerhill (Sheffield)				202	202[d]
ARKANSAS					
Reynolds, Arkadelphia	1	16		51	68[e]
Reynolds, Jones Mills	125				125[e]
LOUISIANA					
Kaiser, Chalmette			116		116[f]
Reynolds, Lake Charles		36			36[g]
OREGON					
Martin-Marietta, The Dalles			90		90[h]
TEXAS					
Alcoa, Palestine					16[i]
Alcoa, Point Comfort			185		185[j]
Reynolds, Corpus Christi (San Patricio)				114	114[k]
Totals	126	168	275	483	1,068

[a] TAP/yr = Tons (short) aluminum production/year (1 ton = 0.9 megagram)
[b] CWPB = Center-worked prebake
SWPB = Side-worked prebake
VSS = Vertical stud Soderberg
HSS = Horizontal stud Soderberg
[c] Operations indefinitely suspended in 1982. Company filed for Chapter 11 bankruptcy; seeking buyer for facility.
[d] Smelter shut down in 1985. Company announced permanent closure in 1986.
[e] Smelter shut down in 1985. Company announced permanent closure in 1985.
[f] Smelter shut down in 1983.
[g] Consolidated Aluminum announced permanent closing in 1981. Not restarted when purchased by Reynolds in 1983.
[h] Plant closed in 1984. Company seeking buyer for facility.
[i] Plant used an experimental chloride reduction process. Company wrote off investment in 1985.
[j] Smelter temporarily closed in 1978; shut down in 1980. Company announced permanent closing in 1982.
[k] Smelter shut down in 1981. Company announced permanent closing in 1984.

- a power source for the direct current (DC) voltage used in the reduction process
- maintenance and repair facilities
- an anode bake plant (optional) where the anodes used in some types of pots are prepared

A simplified diagram of a typical plant showing material flow patterns is provided as Figure 3-1. Figure 3-2 is a somewhat more detailed schematic showing many of the process operations performed in a typical plant.

An aluminum reduction potline is typically housed in one or two long, narrow buildings called potrooms (Figure 3-3). It usually consists of 150 to 200 aluminum reduction pots (cells). Aluminum reduction pots are shallow, rectangular vessels which may be lined up side-by-side or end-to-end in one or more rows down the center of the potroom. All of the pots in a potline are electrically connected, in series, with a typical DC voltage drop across each pot of 4 to 5 volts. The current flow through each pot may range from 40,000 to 280,000 amperes (150,000 amperes or more in newer designs). The pots are large heat sources, so the potrooms are ventilated to maintain reasonable working conditions and to ensure proper pot operation. Usually this ventialation air enters at the sides of a potroom and exits through roof vents (roof monitors).

Alumina and other raw materials are delivered to the plant by ship or railcar and stored. Alumina is transferred to the aluminum reduction pots as needed by airslide or crane-mounted hopper. Aluminum fluoride, sodium carbonate, and fluorspar are added to the pots manually or by hopper. Coke and pitch are mixed and either delivered to the bake plant for forming and baking, or transferred directly to the pots, depending on plant type.[1/] Periodically, the aluminum is removed from the pots by a process called "tapping" and transferred, still molten, to the cast house in crucibles or ladles. There, it is placed in holding furnaces or cast furnaces, alloying materials (iron, silicon, magnesium, and manganese) are added, and the aluminum alloy is fluxed with mixed gas or solid fluxes or with argon or chlorine to remove impurities. The purified alloy, still

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1/ The principal differences between primary aluminum plants are in the types of pots (cells) they use. Pot descriptions are presented in more detail in Section 3.5.

FIGURE 3-1

BLOCK DIAGRAM

PRIMARY ALUMINUM PLANT

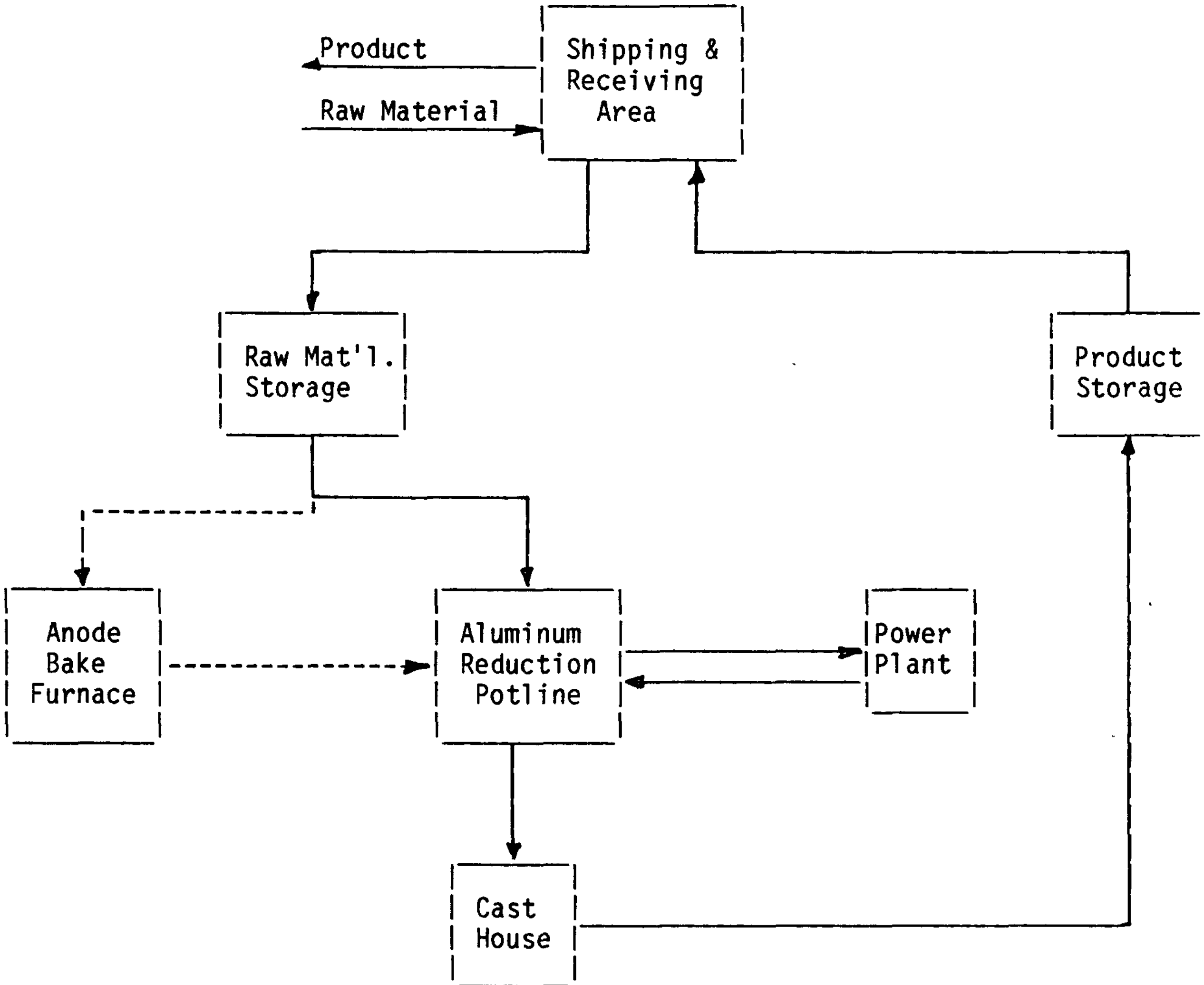
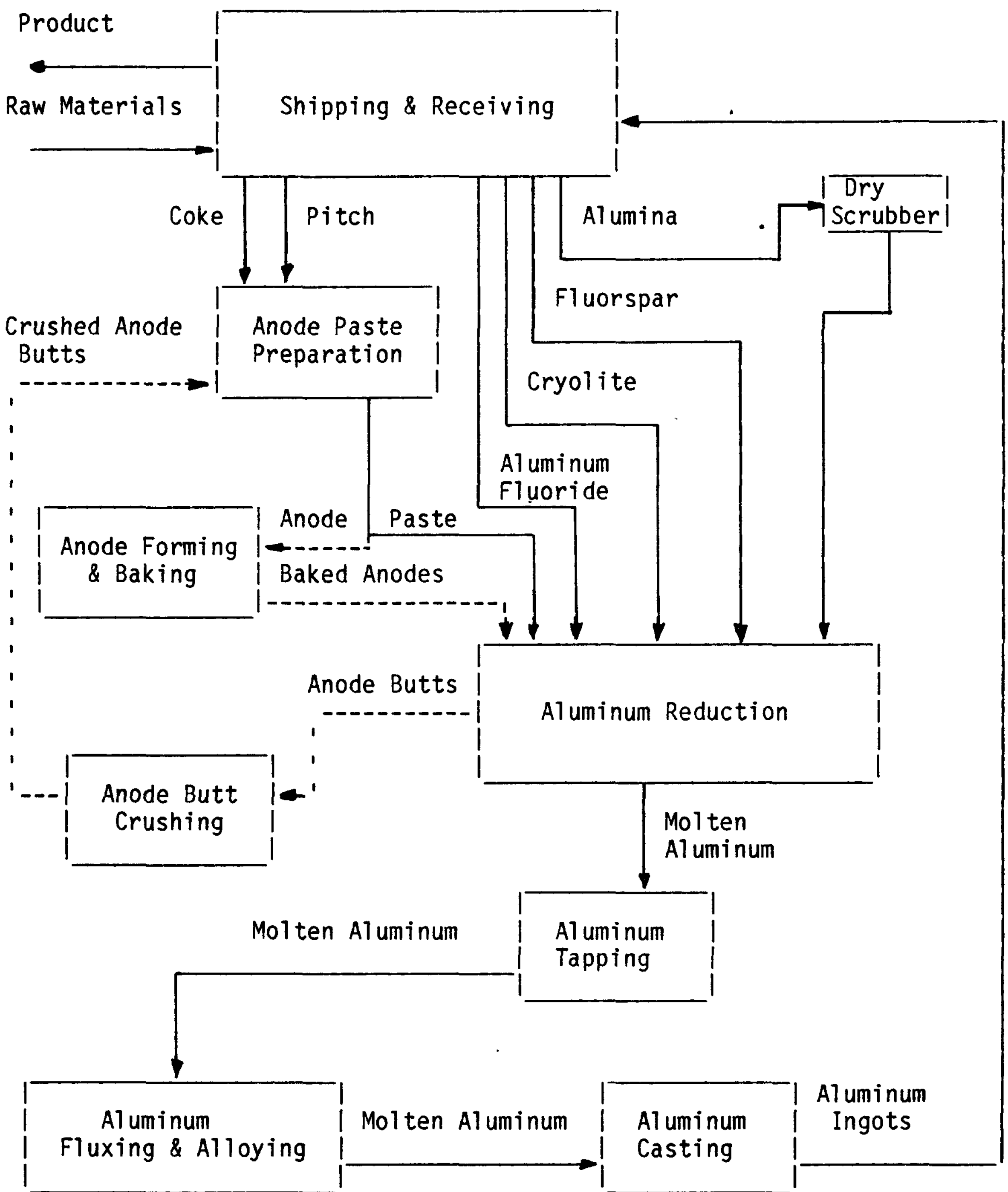


Figure 3-2

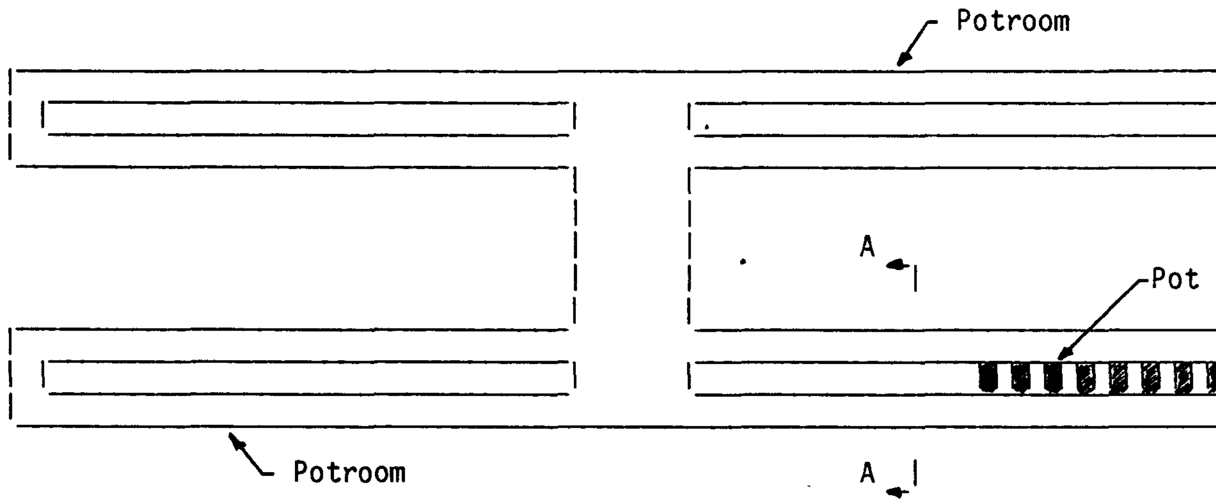
PROCESS OPERATIONS IN A PRIMARY ALUMINUM PLANT



Legend: Dotted lines (---) indicate operations performed only in a prebake plant

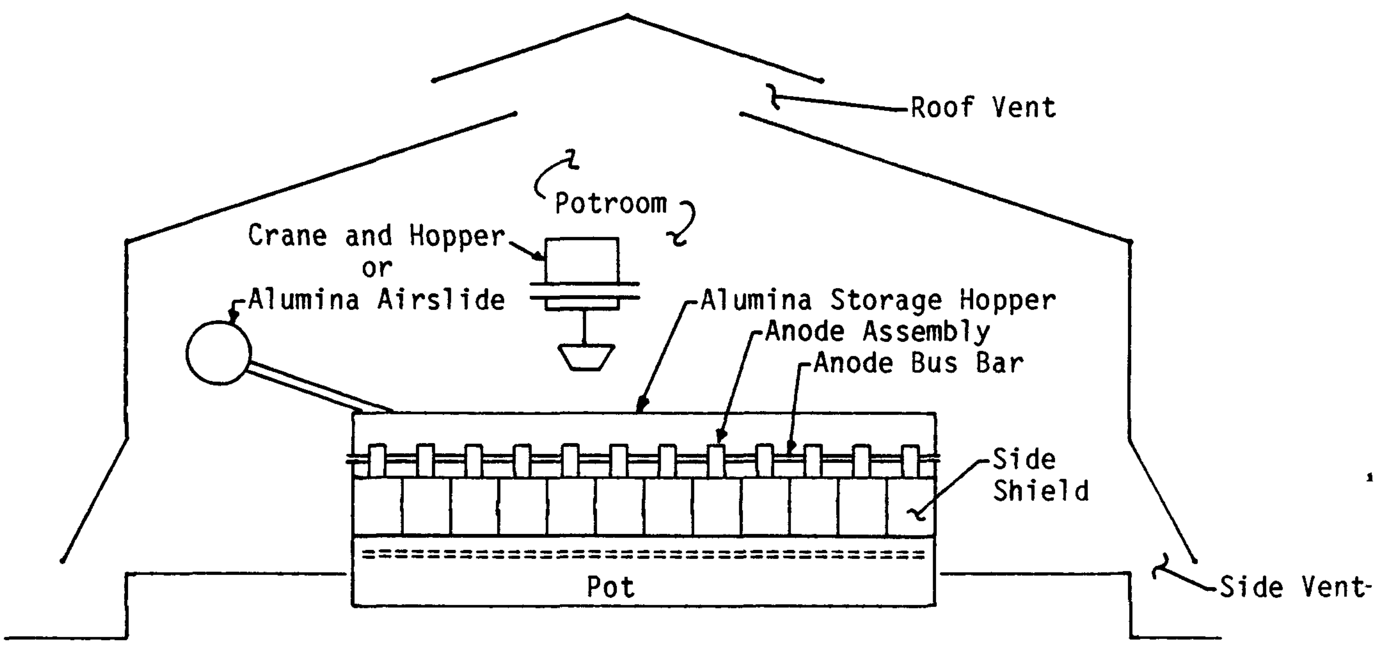
Figure 3-3

PLAN VIEW OF TYPICAL POTLINE



View A-A

Cross-Section of Potroom



molten, is then direct chilled, cast into ingots, billets, or slabs, or is poured into molds to set. After cooling, the aluminum ingots are transferred to storage or shipped.

3.3 PROCESS DESCRIPTION

From its inception in 1886, the primary aluminum industry in the United States has used the Hall-Heroult process to electrolytically reduce aluminum oxide (alumina) to aluminum.2/ Alumina, an intermediate product, is refined from bauxite ores using the Bayer process.

The reduction of alumina to aluminum is carried out in shallow rectangular pots, or cells. A pot consists of a shell supported by a pot cradle, lined with insulating material and having an electrically conductive bottom and sides made of carbon. It is filled with molten cryolite.3/ One or more carbon blocks are suspended above the pot and extend down into the cryolite bath (Figure 3-4).

A low voltage direct electric current is passed through the cryolite bath, which serves as an electrolyte and a solvent for the alumina, from the carbon blocks (anodes) to the molten aluminum on the bottom of the pot (cathode). Heat produced by resistance to this current flow keeps the cryolite molten and at a temperature of about 950°C (1740°F).4/ A crust is allowed to form over the cryolite in the pot. This crust contains alumina and cryolite. It helps reduce heat loss and protect the pot lining and is broken only to add fresh alumina or to allow the escape of generated gases.

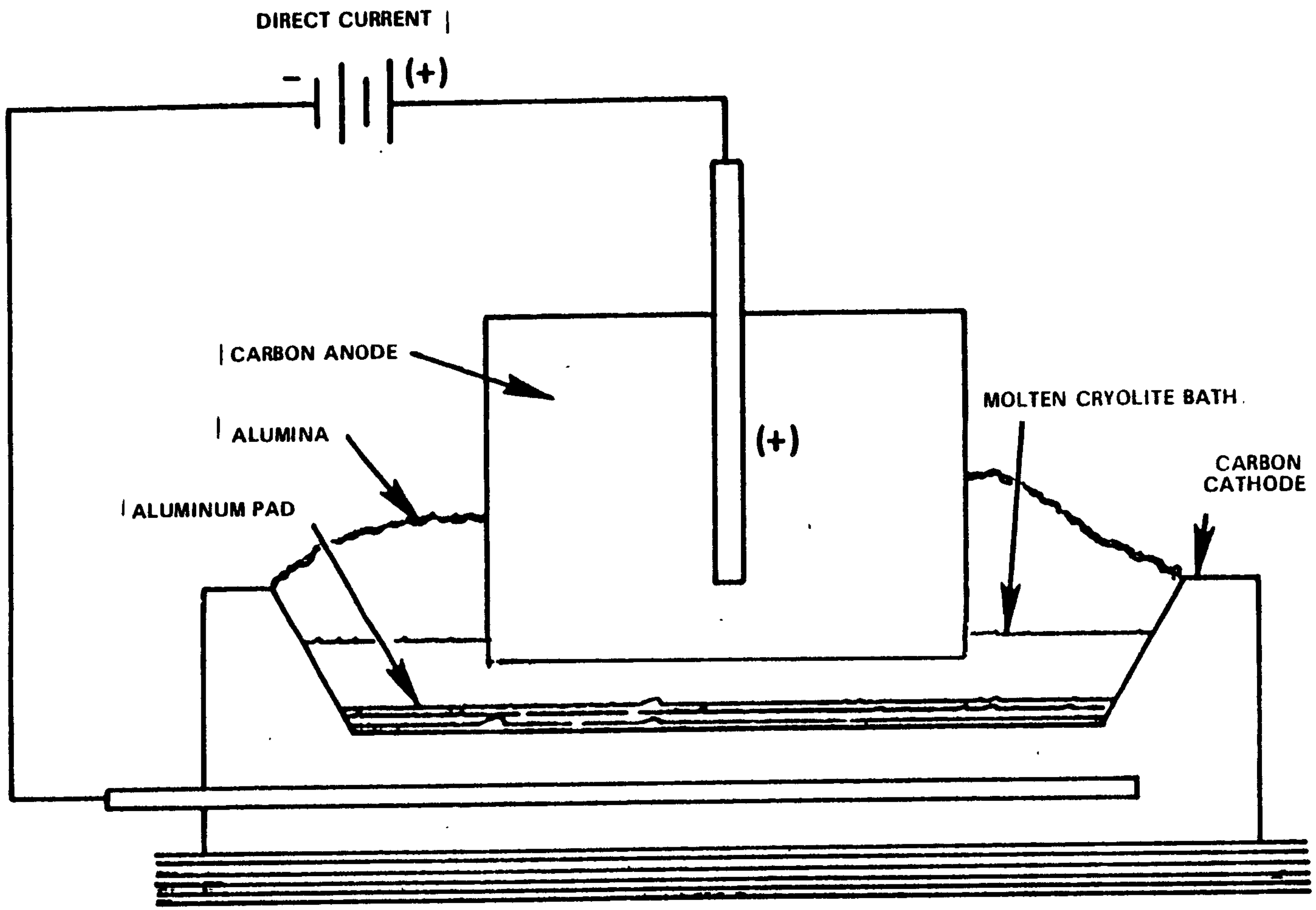
2/ One small, experimental plant in the United States used the aluminum chloride process.

3/ Cryolite is a double fluoride salt of sodium and aluminum (Na_3AlF_6). It is formed by the chemical mixing of two salts, sodium fluoride (NaF) and aluminum fluoride (AlF_3).

4/ Pure cryolite has a freezing temperature of about 1008°C (1846°F).

FIGURE 3-4

ALUMINUM REDUCTION POT



Alumina is periodically added to, and dissolves in, the molten cryolite bath. Cryolite, in its molten state, has the capability to dissolve up to 8 percent alumina.[14] The alumina then disassociates into its components; the molten aluminum settles to the bottom of the pot, and the oxygen migrates to the carbon anode. There, it reacts with the carbon, sulfur, and other impurities in the anode to form carbon dioxide (CO_2), carbon monoxide (CO), sulfur dioxide (SO_2), etc. The anodes are lowered as they are consumed, which occurs at the rate of about 0.23 kilogram (kg) (0.5 pounds [lb]) of carbon per 0.45 kg (1 lb) of aluminum produced.

The theoretical energy requirements for extracting aluminum from alumina are 20.3 megajoules per kilogram (MJ/kg) (2.56 kilowatt-hours/lb [kWh/lb]) of aluminum produced.[15] In practice, however, energy is required to bring the reactants up to temperature, is lost in the exhaust gases or through radiation into the potroom, and is removed from the pot when the molten aluminum is tapped. The increase in energy costs in recent years has fueled efforts to reduce energy losses, with some success. In the early 1970's, a modern pot consumed approximately 56 MJ/kg (7 kWh/lb) of aluminum produced, while more recent pot designs require only 48.4 MJ/kg (6.1 kwh/lb).[16-19] The newer pot operates at 185 kiloamperes (kA) and 4.1 volts.

3.3.1 Bath Ratio

Cryolite is added to the bath periodically to replenish material that is removed or consumed in normal operation, as is aluminum fluoride. The bath (weight) ratio of sodium fluoride to aluminum fluoride required to form a pure cryolite is 1.50. However, it has been found that adding excess aluminum fluoride to reduce the bath ratio increases pot current efficiency and lowers the freezing temperature of the bath, thus permitting lower pot operating temperatures. Bath ratios in use range from 1.05 to 1.50. Calcium fluoride, or fluorspar, may also be added to lower the melting point of the cryolite.

3.3.2 Tapping

The molten aluminum which collects in the bottom of the pot is periodically removed by "tapping". This involves the use of a ladle or crucible with a long snout, which is lowered through the cryolite bath into the layer of molten aluminum (Figure 3-5). Then, aspiration air is used to create a suction and the aluminum is sucked up into the ladle. The ladle is then moved to the next pot and the cycle is repeated. A tapping cycle takes about 5 minutes for a center-worked prebake (CWPB) pot, of which 1.5 to 2 minutes may be actual siphon time.[20] When full, the ladle may be transported directly to the cast house with the cover still in place. There, any cryolite that is accidentally siphoned is recovered as part of the dross skimmed from the surface. Alternatively, the cover may first be removed and placed on an empty ladle. In the latter case, any cryolite picked up with the aluminum quickly rises to the surface and freezes. The chunks of cryolite are scraped onto the potroom floor and the ladle with the still molten aluminum is routed to the cast house.

3.3.3 Anode Effects

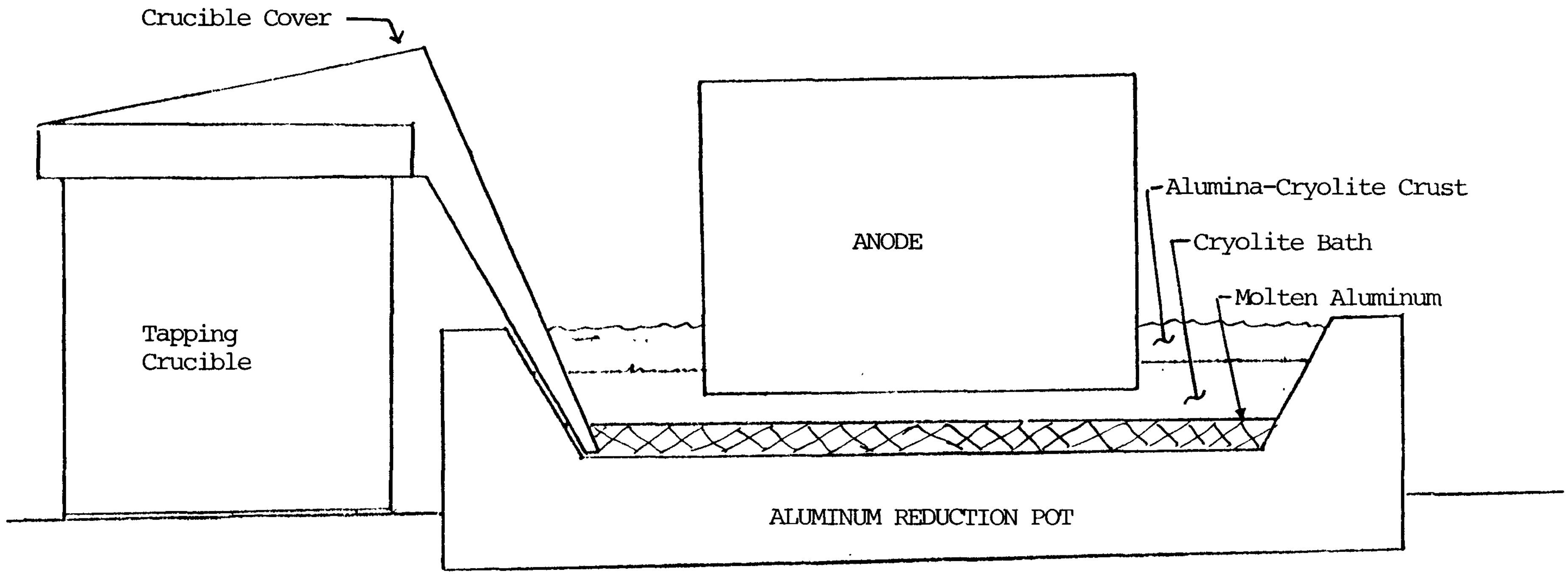
An anode effect can be caused by either a shortage or (rarely) an excess of alumina in the pot. It takes 2 to 5 minutes to correct either type of anode effect.[21] The cryolite bath normally contains 5 to 8 percent alumina at saturation.[22] If too much alumina is added to the pot bath, the excess does not dissolve. Instead, it settles to the bottom of the pot and increases resistance. This condition is corrected by shutting off the flow of alumina and rowelling (stirring) the pot with a steel rod to put the alumina in suspension where it can more readily dissolve.

FIGURE 3-5

TAPPING MOLTEN ALUMINUM

FROM

PRIMARY ALUMINUM REDUCTION POT



If insufficient alumina is added to the pot, a gas film forms on the surface of the anodes and creates a barrier to the flow of electrical current. The pot voltage then increases from 4 to 4.5 volts to 50 to 100 volts in seconds. This condition is corrected by adding alumina and changing the height of the anodes, or sticking a green wooden pole under one or more anodes and stirring (usually from an end door). For pots under computer control, this condition can usually be corrected without human intervention, by adding more alumina, by adjusting the height of the anode, or by shaking or swaying the anodes. If these actions are unsuccessful, the computer calls for assistance. A worker then sticks a green wood pole under one or more anodes and stirs to dissipate the gas layer. This can usually be accomplished from an end door, but sometimes one or more side shields must be removed.

Anode effects resulting from underfeeding are much less objectionable than those from overfeeding, so plants may purposely underfeed alumina--using the results as an analytical tool to determine when alumina is needed.[23] These plants either get one anode effect per day or they reduce the alumina feed.[24] Other facilities operate with less than one anode effect per week.[25]

3.4 TYPES OF PLANTS IN USE

Primary aluminum reduction plants are characterized by the type of reduction pots (cells) they contain. There are two major types: prebake and stud Soderberg. A majority of the primary aluminum plants in the U.S. currently use prebake technology (18 of 23, or 78 percent). Also, three of the four plants which have potlines subject to the new source performance standards (NSPS) use prebake pots.

The pots in prebake plants use multiple anodes which are formed and baked prior to use, while the stud Soderberg pots use a single, continuous anode which is shaped and baked in place. Each of these pot types has, in turn, two variations. The pots in prebake plants are classified as CWPB or side-worked prebake (SWPB), depending on where the pot working (crust breaking and alumina addition) takes place. Stud Soderberg pots, on the other hand, are differentiated by the positioning of the current-carrying studs in the anodes. They may be inserted vertically (VSS) or horizontally (HSS).

The anode bake plants which produce the anodes used in prebake pots are of two basic types. One is the ring furnace and the other the tunnel kiln.

3.5 ALUMINUM REDUCTION POTS

As noted above, primary aluminum reduction plants are characterized by the type of reduction pot (cell) they use. Each of these pot types is discussed in the following sections.

3.5.1 Center-Worked Prebake Pots

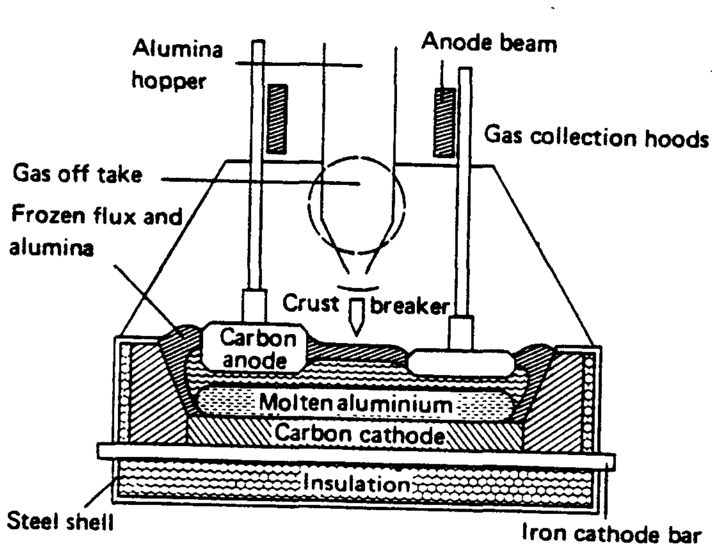
In the mid 1970's, 16 primary aluminum plants used CWPB pot technology. Two of these plants have since ceased operation while two have added new potlines. In addition, one new CWPB plant has been constructed. These 15 plants represent 65 percent of the total U.S. plants and 69 percent of domestic production capacity.

3.5.1.1 Design and Operation. A cross-sectional view of a CWPB pot is shown in Figure 3-6. Each CWPB pot may hold from 18 to 26 closely-spaced anode assemblies[5/] in two parallel rows running the length of the pot. Alumina is delivered to CWPB pots by a crane-mounted hopper or by air-slide and stored in hoppers located atop the pot superstructures. The hoppers run the full length of the pots, between the anode bus bars. The anode assemblies, which are suspended on these bus bars, are positioned close

5/ An anode assembly consists of an anode and a hanger. The hanger is positioned in a recess in the top of the anode after baking and molten iron is poured around it to hold it in place. The hanger serves both to support the anode and to transfer electricity from the bus bar to the anode.

FIGURE 3-6

CENTER-WORKED PREBAKE POT



to the sides of the pot to provide an area in the center for "pot working". All the anodes in a pot can be raised or lowered simultaneously by moving the anode bus bars, which have a vertical travel of 25 to 36 centimeters (cm) (10 to 14 inches [in.]).[26] Additionally, each anode assembly can be adjusted individually by releasing its latch and repositioning it on the bus bar. The anode assemblies are lowered as the carbon anodes are consumed. The spent anodes (butts) are replaced on a rotating basis, usually at the rate of about one per day for each pot.

The pot superstructure has a number of crustbreakers (punchers) mounted on the underside of each alumina hopper that serve a dual function. When activated, they extend down to punch holes in the crust over the molten cryolite. Then, as they retract, they release a metered amount of alumina into the holes. At the newer plants, the crust-breaking frequency of each pot and, thus, its alumina feed rate is monitored and controlled by computer. In this way, the frequency and severity of anode effects and other pot malfunctions can be minimized.

To prepare for tapping, an end door on the hood is opened and the crucible spout is inserted. After tapping, this operation is reversed.

3.5.1.2 Anode Replacement and Reclaiming. The anode replacement process usually takes 3 to 4 minutes.[27] To remove a spent anode assembly (anode butt), two to three side shields are removed and the crust around the anode is broken with a jackhammer. Then, the anode butt is clamped to a crane, the latches holding it to the bus bar are released, and the anode butt is extracted and placed on the potroom floor to cool. At some plants the spent anode assemblies are removed within 30 minutes and transferred to a holding area to cool. A fresh anode assembly is then clamped in place, after first removing any floating chunks of cryolite or anode which could prevent it from seating properly. Finally, a layer of recycled, crushed bath is spread over the top of the anode and the side shields are replaced.

After cooling, anode butts are cleaned, crushed, and recycled. First, jackhammers and brushes are used to remove most of the caked-on cryolite and alumina. This cryolite/alumina mix (typically about 25 percent alumina) is crushed and used to cover and insulate the fresh anodes. The hangers are then removed and refurbished and the butts are crushed and recycled to the green anode mix.[6/]

3.5.2 Side-Worked Prebake Pots

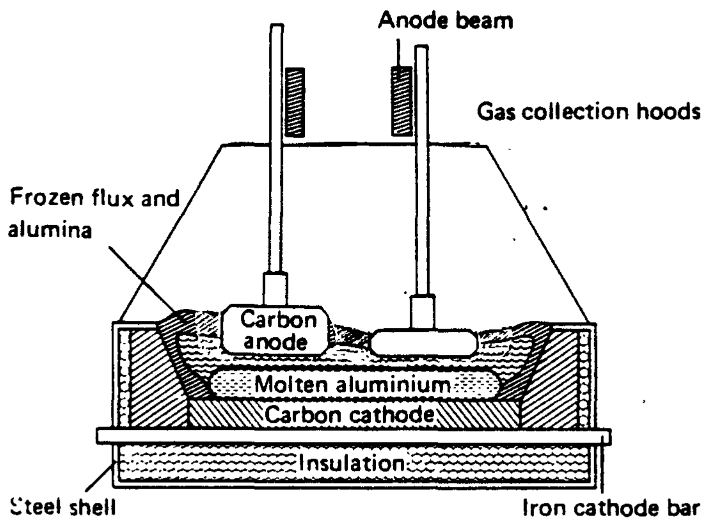
At the time the NSPS was proposed there were six plants in the United States with potlines using SWPB pots. Three of these plants have since ceased operations, leaving a total of three (13 percent of U.S. total and 13 percent of U.S. capacity). No SWPB potlines have been constructed since the NSPS was proposed in 1974.

A cross-sectional view of a SWPB pot is shown in Figure 3-7. Late model SWPB pots differ from CWPB pots in the placement of the anodes, the type of side-shield used, and the method of alumina addition. Alumina is added along the sides of the SWPB pot, rather than down the center as in a CWPB pot, so the two rows of anodes are set close together near the center-line of the pot. The side shields are two one-piece covers (one per side) which are hinged at the bottom and motor-driven. Alumina addition is typically accomplished using a gantry crane. This crane carries an alumina hopper and two jackhammers. On a predetermined cycle (usually 3 to 4 hours), the pot covers swing open and the gantry crane straddles the pot, one jackhammer per side. The crane moves the length of the pot and the jackhammers break the crust between the anodes and the sides of the pot. It then cycles up and down the pot, adding alumina until a wire positioned just behind the alumina spout provides a cut-off signal. The crane then rises, the covers swing closed, and the crane moves on to the next pot.

6/ About 25 percent of the carbon used in green anodes is recycled anode butts. This is the source of the fluoride emitted during anode baking.

FIGURE 3-7

SIDE-WORKED PREBAKE POT



3.5.3 Vertical Stud Soderberg Pots

Six primary aluminum plants utilized VSS pot technology at the time the NSPS was proposed (two of these plants also used prebake pots). Since then, the VSS potlines at two plants have ceased operation and one new VSS potline has been constructed at an existing plant. These plants constitute almost 9 percent of the domestic primary aluminum plants (2 of 23) and 8 percent of domestic capacity.

A cross-sectional view of a typical VSS pot is shown in Figure 3-8. It utilizes a single large anode. A green anode paste is periodically fed into the open top of a rectangular compartment, or casing, which serves to shape the anode. As the bottom face of the anode is consumed, the paste moves down inside this stationary casing, is compressed by the weight of the material above it, and is gradually hardened and baked by the heat of the pot.

Steel studs are positioned vertically in the green anode paste and move down with it. They are rigidly connected to the bus bar and form an electrical interface between the anode and the bus bar. Those studs which project the farthest down into the anode are disconnected from the bus and extracted, so that they will not become exposed to the bath at the bottom of the anode. At the same time, a fresh stud is inserted and clamped to the bus.

The green anode paste is composed of coke and a pitch binder. The in-place baking of the anode results in the release of sulfur oxides from the coke and hydrocarbon fumes and volatiles from the pitch binder. If not removed from the gas stream, the fumes and volatiles tend to condense in, and plug, control system hoods and ductwork.

Vertical stud Soderberg pots, because of their single anode, must be sideworked. That is, crust-breaking and alumina addition take place along the sides of the pots.

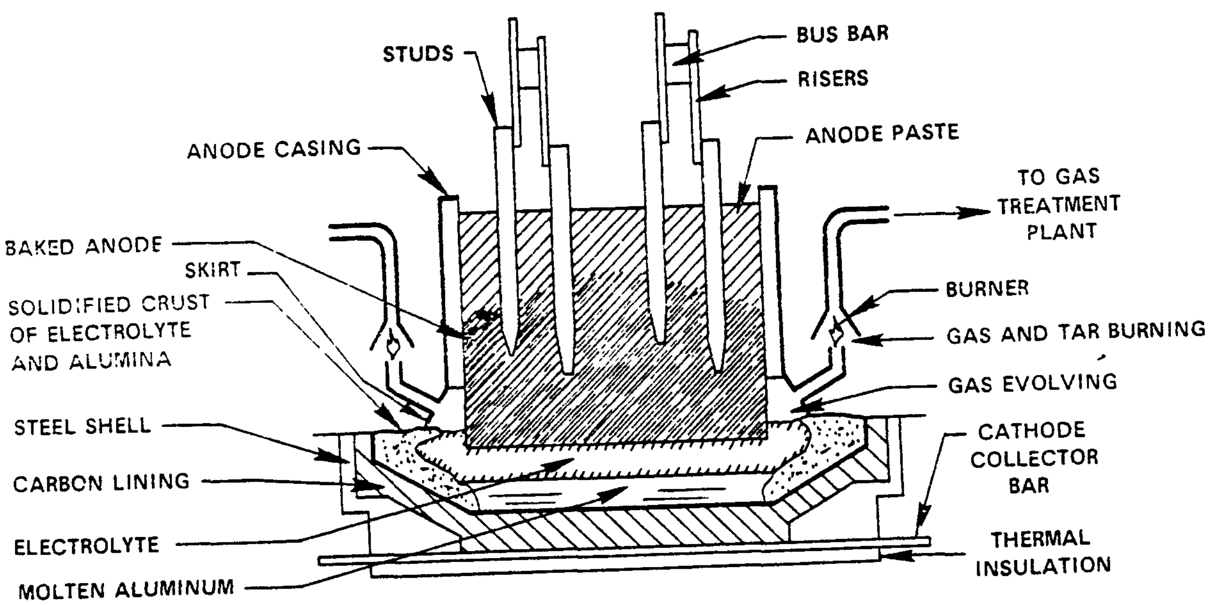


FIGURE 3-8

VERTICAL STUD SODERBERG POT

3.5.4 Horizontal Stud Soderberg Pots

The number of plants with HSS pots has declined from seven in the early 1970's, to three by May 1986. No new HSS potlines have been built. Although 13 percent of domestic plants use HSS pot technology (3 of 23), it accounts for only 9 percent of domestic capacity.

The HSS pot, like its VSS counterpart, utilizes a single, large, formed-in-place anode. The principle difference is the horizontal placement of the studs. A typical HSS pot is shown in cross-section in Figure 3-9. The anode casing is made of either steel or aluminum sheeting and removable steel channels. The anode and its casing are suspended over the pot and are moved downward as the anode is oxidized. The current-carrying studs are inserted horizontally into the anode through perforations in the steel channels at a point where the anode paste has not baked out. Electrical contact with the bus bar is through flexible connectors. When the lower channel reaches the bath, the flexible connectors are moved up to the next row of studs, the bottom row of studs is extracted, and the steel channel is removed.

3.6 ANODE BAKE FURNACES

Anode bake furnaces produce the anodes used in CWPB and SWPB pots. They are located in carbon plants, which also contain pitch storage, coke storage, green anode or paste production, and a rod shop. Two basic types of furnaces are used in the United States, the open top ring furnace and the tunnel kiln. A short description of each furnace type is provided in the following sections.

3.6.1 Ring Furnace

Essentially all of the anodes produced for prebake plants in the United States are baked in open-top ring furnaces. Since the advent of the NSPS, eight ring furnaces have been built for anode bake plants at five locations.

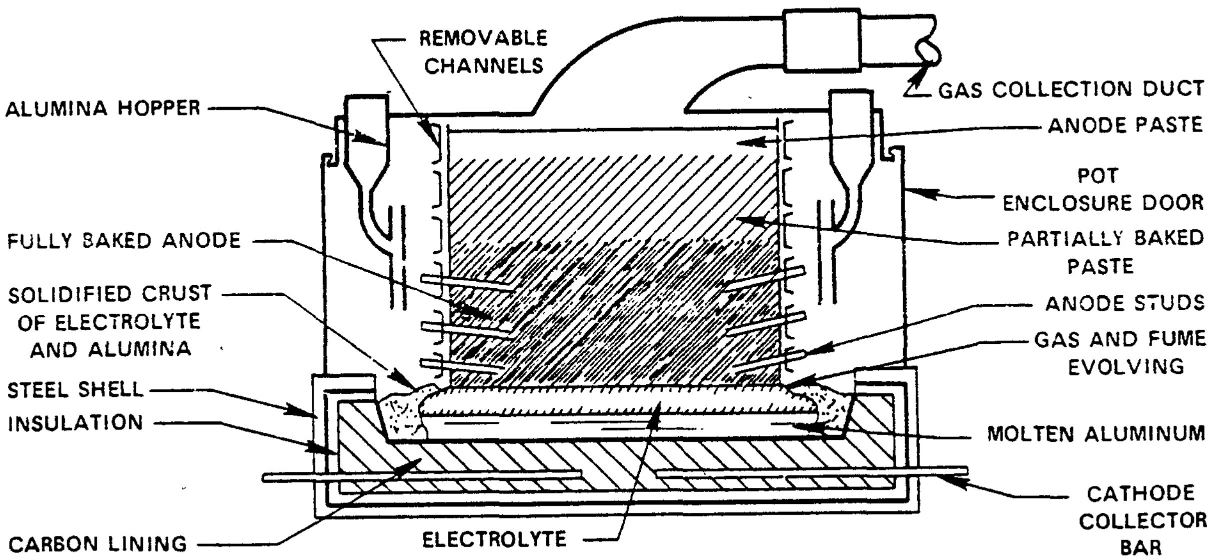


FIGURE 3-9

HORIZONTAL STUD SODERBERG POT

Ring furnaces vary greatly in size and production rate, but all have the same basic layout and operating parameters. Each ring furnace consists of a large number of indirectly fired sunken ovens, or pits, arranged in rows as shown in Figure 3-10. 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, and are surrounded by, a flue which 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 ring 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, as will be discussed in the following paragraphs, 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 0.9 meter (m) (3 feet [ft]) 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 with coke, petroleum coke, or some other insulating material to slightly above 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[7/] into the flue and around pits containing just-baked anodes. In the process, the air is heated and the anodes are cooled down. Usually,

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7/ Some furnaces do not have a forced draft air supply. In those cases all the draft is supplied by an exhaust fan.

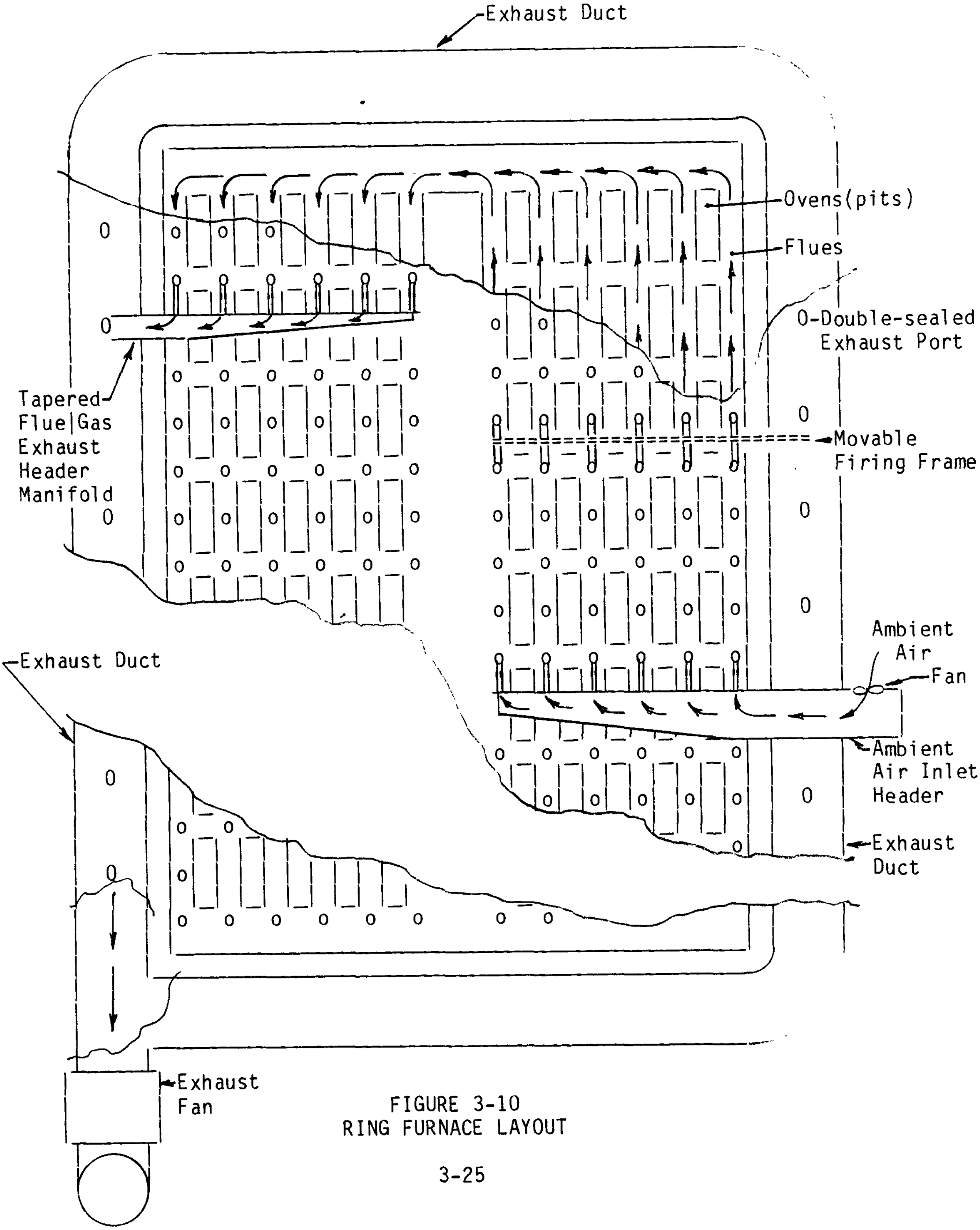

FIGURE 3-10
RING FURNACE LAYOUT

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.8/ There, natural gas or other fuel injected into the flue through movable firing frames is ignited by the high air temperature in the flue, increasing the flue gas temperature to 1225 to 1250°C (2237 to 2282°F). In the process, the anodes are heated to about 1150°C (2100°F), partly by the heat from the flues and partly by the calcining of the binder pitch in the anodes. One source reported that a substantial percentage of the total energy used in the baking process comes from the anode binder pitch.[28] Another source reported that the sulfur content of packing coke drops by 50 percent (from 4 to 2 percent) during the bake process.[29]

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 300°C (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 them into the large duct circling the furnace through one of the manholes located atop the duct. From these, the gases are routed to either a control system or to the atmosphere through a large exhaust fan.

8/ The negative pressure in the flue will be considerably higher in the firing zone if air is not supplied under forced draft.

3.6.2 Tunnel Kiln

Tunnel kilns are installed at only one plant in the United States. Twelve such kilns were installed at that plant between 1956 and 1974 but are currently being used only to provide "swing" capacity. There appears to be little potential for additional installations. Problems cited are:[30]

- Poor energy efficiency - heat requirements are greater than for a modern ring furnace;
- Poorer quality anodes - anodes are less dense than those baked in ring furnaces and so are more apt to crumble, break, or fracture during handling and have a lower life expectancy; and
- Anode quality is not consistent - those on the tops and sides of the stacks tend to be fired better than those in the center.

A kiln is a long, narrow, indirect-fired enclosure in which a controlled atmosphere is maintained to prevent oxidation of the anodes. Each kiln will hold either 44 or 54 railcars stacked with anodes (Figure 3-11). There is a vestibule or air lock at each end which is large enough for one car. Each vestibule has an inner and outer door, and an exhaust fan ducted to the atmosphere. The outer door will not open until the vestibule has been cleared of fumes which collect while the inner door is open.

3.7 PROCESS EMISSIONS

The principal emission points in a primary aluminum plant are the potrooms housing the aluminum reduction pots and, for prebake plants, the anode bake plant. Pollutants emitted include gaseous and particulate fluorides, other particulate matter (PM), and other gases. Non-fluoride PM emissions include alumina, carbon, hydrocarbon tars, and iron oxide (FeO_3). Gaseous non-fluorides include CO_2, CO, SO_2, hydrogen sulfide (H_2S), carbonyl sulfide (COS), carbon disulfide (CS_2), nitrogen oxides (NO_x), and water vapor.

Fluoride evolution from aluminum reduction pots and anode bake furnaces were quantified during EPA source tests conducted during development of the NSPS. These data are summarized here, as no additional data were found during this study.

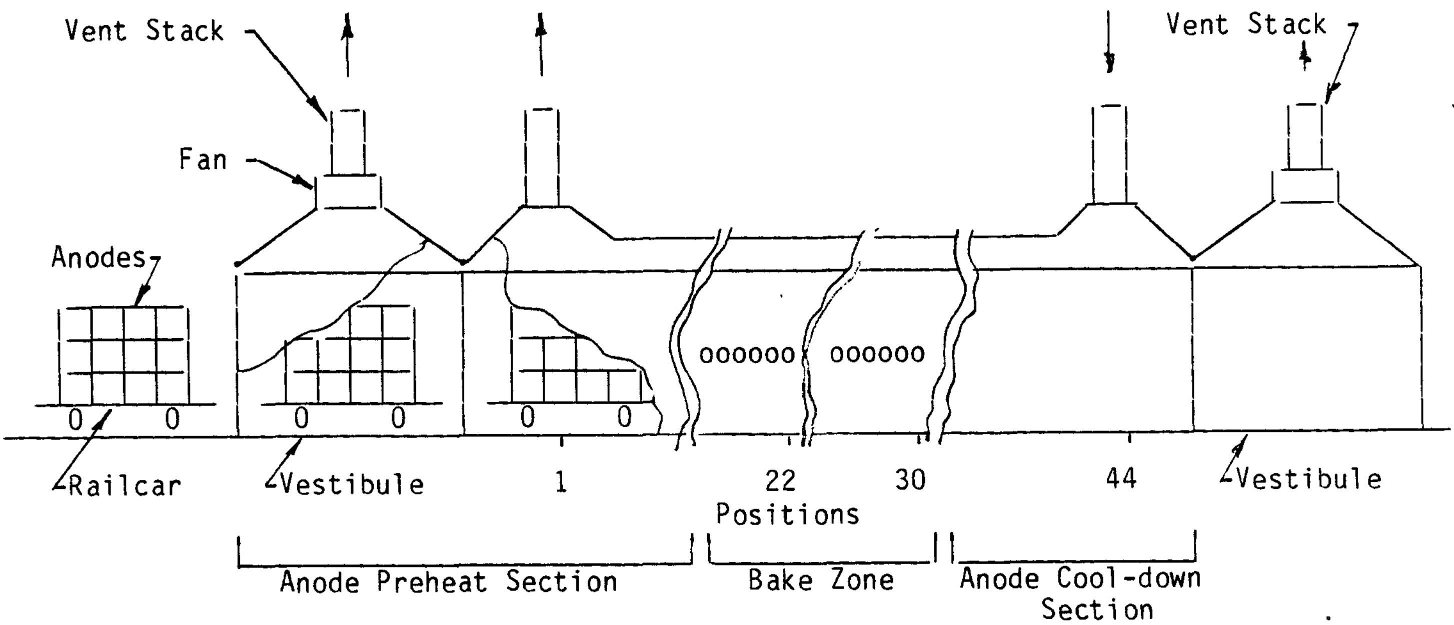

FIGURE 3-11

TUNNEL KILN

Side View of a Tunnel Kiln

The amount of SO_2 emitted during the production of primary aluminum is a function of the sulfur contents of the coke and pitch used in the anodes. Sulfur levels have been rising in recent years. In the early 1970's, a typical purchase specification for petroleum coke contained a 1.5 percent sulfur limit. By 1978, this limit had been driven up to 3.0 percent.[31,32] In 1985, sulfur contents of available cokes range from 2 to 7 percent with an average of about 3 percent.[33] One source has projected that the trend to increased sulfur in coke will continue until the sulfur limits in petroleum coke purchase specifications reach 4 to 6 percent.[34] Other sources, however, project that 3 percent sulfur petroleum coke will be available for the next 10 years.[35-37]

3.7.1 Total Fluorides

The NSPS limits emissions of total fluorides (TF), which includes both gaseous and particulate fluorides, from potrooms and anode bake furnaces. Gaseous fluorides present in potroom emissions during normal operation are reported to include hydrogen fluoride (HF) and silicon tetrafluoride (SiF_4). During an anode effect, fluorocarbons, principally carbon tetrafluoride (CF_4), and small amounts of hexafluoroethane (C_2F_6) are also known to be produced.[38] Particulate fluorides identified include cryolite (Na_3AlF_6), aluminum fluoride (AlF_3), calcium fluoride (CaF_2), and chiolite ($Na_5Al_3F_{14}$).

The ratio of gaseous to particulate fluorides in the TF emitted from uncontrolled potrooms varies with pot type and operating conditions. One study cited in a previous document reported that this ratio varied from 0.5 to 1.3.[39] Uncontrolled TF emissions from anode bake furnaces are believed to be mostly gases.

As previously noted, no data are available on TF evolution from any potrooms or anode bake furnaces subject to the NSPS. However data are available from other sources. Table 3-3 contains the results of tests conducted by EPA for the NSPS and guidance documents, plus more recent information supplied by manufacturers and users of primary aluminum

TABLE 3-3

AVAILABLE INFORMATION ON UNCONTROLLED EMISSIONS OF TOTAL FLUORIDES[43-46]

Data source	Document date	Pot type[a]	No. tests	TF emissions (lb TF/TAP)[b] Potline Range	Potline Avg.	Bake plant Range	Bake plant Avg.
BID	1974	CWPB	2	49.3-62.6	--	--	--
Guidance Doc.	1979	CWPB	--	25.7-65.6	40.8	0.4-1.6	0.86
IPAI Report	1985	CWPB	7	26.4-56.0	43.5	--	--
ALCOA[c]	1985	CWPB	--	65-70	--	--	--
BID	1974	VSS	2	39.3-47.3	--		
Guidance Doc.	1979	VSS	--	30.5-53.5	44.4		

[a] CWPB = Center-worked prebake pot
VSS = Vertical stud Soderberg pot

[b] lb TF/TAP = pounds total fluoride per ton aluminum produced.
(1 lb TF/TAP = 0.5 kilogram/megagram aluminum produced)

[c] ALCOA is a major primary aluminum reduction pot manufacturer. They produced all the pots used on the CWPB potlines subject to the NSPS.

reduction pots. Based on this information and the current trend to maximize efficiency by reducing bath ratio,[9/] current TF evolution rates are expected to be 33 kilograms per megagram (kg/Mg) (66 lb/ton) of aluminum produced and 25 kg/Mg (50 lb/ton), respectively, for CWPB and VSS potlines. There are no data available to either support or modify the estimated TF emission rate of 0.43 kg/Mg (0.86 lb/ton) of aluminum produced for anode bake furnaces.

3.7.2 Sulfur Dioxide

Little test data are available on SO_2 emissions from potlines or anode bake plants. It is generally recognized, however, that SO_2 is evolved from electrolytic pots in direct proportion to the anode consumption rate and the sulfur content of the anode materials. Bake plant SO_2 emissions correlate to anode weight loss during baking and to any change in sulfur content. At those anode bake plants where a lightly calcined coke is used for packing material, the packing coke is an additional source of SO_2.

Considering only the direct contribution of the anode materials, SO_2 emissions to the atmosphere are calculated to be 53 kg/Mg (106 lb/ton) of anode consumed.[47] This calculation is based on an anode composition of 85 percent coke and 15 percent pitch, where the coke and pitch have sulfur contents of 3 percent and 0.6 percent, respectively. For an anode consumption rate of 0.23 kg of anode per 0.45 kg (0.5 lb/lb) of aluminum produced, this correlates to 27 kg of SO_2 per megagram of aluminum produced (53 lb/ton). If the sulfur content of the coke were to increase to 5 percent, the SO_2 emissions would increase to 44 kg/Mg (87 lb/ton).

9/ Reducing the bath ratio of a pot tends to increase TF evolution.[40] Bath ratios of 1.30-1.45 were common in the 1970's.[41] Since then, however, large increases in the cost of power have forced plants to increase efficiency. One of the ways this was accomplished was to lower bath ratio. Some CWPB pots now operate at around 1.12 or 1.13 and the VSS pots at around 1.25. Pot operating efficiency may also be improved through the use of proprietory bake additives.[42]

A 90,700 Mg (100,000 ton) per year primary aluminum plant using a 3 percent sulfur coke will generate 2,400 Mg (2,650 tons) of SO_2 per year (274 kg SO_2/hr [605 lb/hr]). If the plant has HSS or VSS pots, all the SO_2 will be released by the potlines. For plants using CWPB or SWPB pots, the SO_2 emissions are split between the potlines and the anode bake furnaces. If it is assumed that 80 percent of the SO_2 emissions are released into the pots, then the SO_2 emissions distribution within the primary aluminum plant is 1,925 Mg/yr (2,120 tons/yr) SO_2 from the potlines and 480 Mg/yr (530 tons/yr) SO_2 from the anode bake furnaces.[48] (Another source indicates the split may be 95 percent from the potline and 5 percent from the anode bake furnace.[49])

Sulfur dioxide emissions from the packing coke used around the anode in the anode baking pits were not considered in these calculations because it is reused. However, it often has a higher initial sulfur content than anode coke and must be replenished periodically with makeup coke.[50] 10/

10/ Fugitive emissions during the loading and emptying of the pits account for some packing coke losses. Some coke also passes through cracks in the pit walls and is burned in the furnace flue.

3.8 REFERENCES FOR CHAPTER 3

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2. Letter and attachments from Dickie, R.C., Alumax of South Carolina, to Noble, E.A., EPA:ISB. April 16, 1986. Comments on draft document.

3. Letter and attachments from Tropea, L.C., Jr., Reynolds Aluminum, to Noble, E.A., EPA:ISB. May 9, 1986. Comments on draft document.

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10. Reference 3.

11. Reference 5.

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23. Memo from Noble, E.A., EPA:ISB, to Durkee, K.R., EPA:ISB. July 16, 1985. Report of May 1985 trip to Alumax of South Carolina, Goose Creek, South Carolina. Page 5.

24. Reference 20, Page 3.

25. Reference 3.

26. Reference 7, Page 4-14

27. Reference 7, Page 4-14.

28. Memo from Noble, E.A., EPA:ISB, to Durkee, K.R., EPA:ISB. November 26, 1985. Report of June 1985 trip to Aluminum Company of America, Newburgh, Indiana. Page 2.

29. Letter from Dickie, R.C., Alumax of South Carolina, to Farmer, J.R., EPA:ESED. August 27, 1985. Enclosure 1, Page 3.

30. Telecon. Boyt, J.S., Aluminum Company of America, with Noble, E.A., EPA:ISB. September 16, 1985. Information on tunnel kilns in use at Alcoa's Warrick plant.

31. International Primary Aluminum Institute. Review of the Petroleum Coke Situation and its Potential Impact on Sulfur Dioxide Emissions from Primary Aluminum Plants. December 1978.

32. Tropea, L.C. (Reynolds) and Atkins, P.R. (Alcoa). The Proper Perspective on Sulfur Dioxide Emissions from the Primary Aluminum Industry. (Presented at Air Pollution Control Association Meeting, Houston. June 25-30, 1978.) APCA Report #78-61.4. Pages 7 and 8.

33. Reference 23, Page 6.

34. Reference 31.

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36. Reference 2.

37. Letter and attachments from Boyt, J.S., Aluminum Company of America, to Noble, E.A., EPA:ISB. April 29, 1986. Comments on draft document.

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39. Reference 7, Page 5-14.

40. Reference 23, Page 4.

41. Reference 7, Page 4-4.

42. Reference 3.

43. U.S. Environmental Protection Agency. Background Information for Standards of Performance: Primary Aluminum Industry. Volume I: Proposed Standards. EPA 450/2-74-020a. October 1974. Pages 23, 36.

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45. International Primary Aluminum Institute. Fluoride Emissions Control: Updated Costs for New Aluminum Reduction Plants. February 1985. Chapter 3, Table 2.

46. Reference 28, Page 4.

47. Memo from Maxwell, W.H., EPA:ISB, to Primary Aluminum Docket (A-86-07). May 30, 1986. Green anode composition and calculated SO_2 emissions.

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4. EMISSION CONTROL TECHNOLOGY

The current new source performance standards (NSPS) limit all fluoride emissions from aluminum reduction potlines, not just those emissions which pass through the control device. Given the high efficiency of current primary control devices, the fluoride emissions released to the atmosphere consist mostly of emissions which bypass the primary control system. Thus, the pot hood, or enclosure, must prevent the emission of fluorides evolved within the pot. Also, fluoride evolution outside the pot must be kept to a minimum. The first is accomplished by utilizing the types of pots which can be tightly enclosed; by reducing the frequency, extent and duration of pot openings to an absolute minimum; and by developing a maintenance program to ensure that the integrity of the pot hoods does not deteriorate. The latter is achieved through operating procedures and by good housekeeping.

4.1 PRIMARY FLUORIDE CONTROL SYSTEMS

The primary control system for a potroom consists of the pot hood (or enclosure), necessary ducting, and a fluoride control device. For a bake furnace it includes the movable header(s) connecting the furnace flue to the exhaust duct, the exhaust duct, possibly an exhaust gas conditioning tower, and a fluoride control device.

The most common fluoride control device currently in use for both these applications is the dry scrubber. All plants subject to the NSPS utilize dry scrubbers. Wet scrubbers are also used at some plants.

4.1.1 Capture/Suppression

The effectiveness of a hood (or enclosure) depends not only on how much of the pot area it covers and how tightly it can be sealed, but also on how frequently it must be opened to perform process functions, the extent to which it must be opened, and the time it must stay open. Pot hooding, as discussed herein, includes those steps taken to minimize fluoride evolution from the pots, as well as those to maximize fume capture. Hoods for side-worked prebake (SWPB) pots and horizontal stud Soderberg (HSS) pots will not be discussed here, since neither type of potline has been built in the U.S. since proposal of the NSPS. They are, however, discussed in detail in the guidance document.[1]

4.1.1.1 Center-Worked Prebake Hoods. Center-worked prebake (CWPB) pots have a superstructure which supports the anode bus bars and the alumina storage hopper. Hoods are formed using curved metal side shields which extend from the outside edges of the pot sides to this superstructure (Figure 4-1). At each end of a 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 hanger. The shields and doors are removed and replaced manually. Together, the superstructure, side shields, and end pieces form an enclosure.

The fumes evolving from the pots are captured by enclosing the whole pot bath area; by sealing the pot enclosure to the maximum extent possible; by maintaining an airflow through the pot high enough to prevent fumes from escaping through apertures in the hood (such as between side shields) without entraining excessive alumina; and by minimizing the frequency, number, and duration of side shield and door removals. For CWPB pots, hood airflows have been optimized at around 1.89 cubic meters per second (m^3/s) (4,000 actual cubic feet per minute [acfm]). Some plants also increase airflow whenever the hood is opened by moving a damper set in the pot hood exhaust duct. Table 4-1 lists the airflows for individual pots at plants with NSPS potlines, for both normal and high flow conditions.

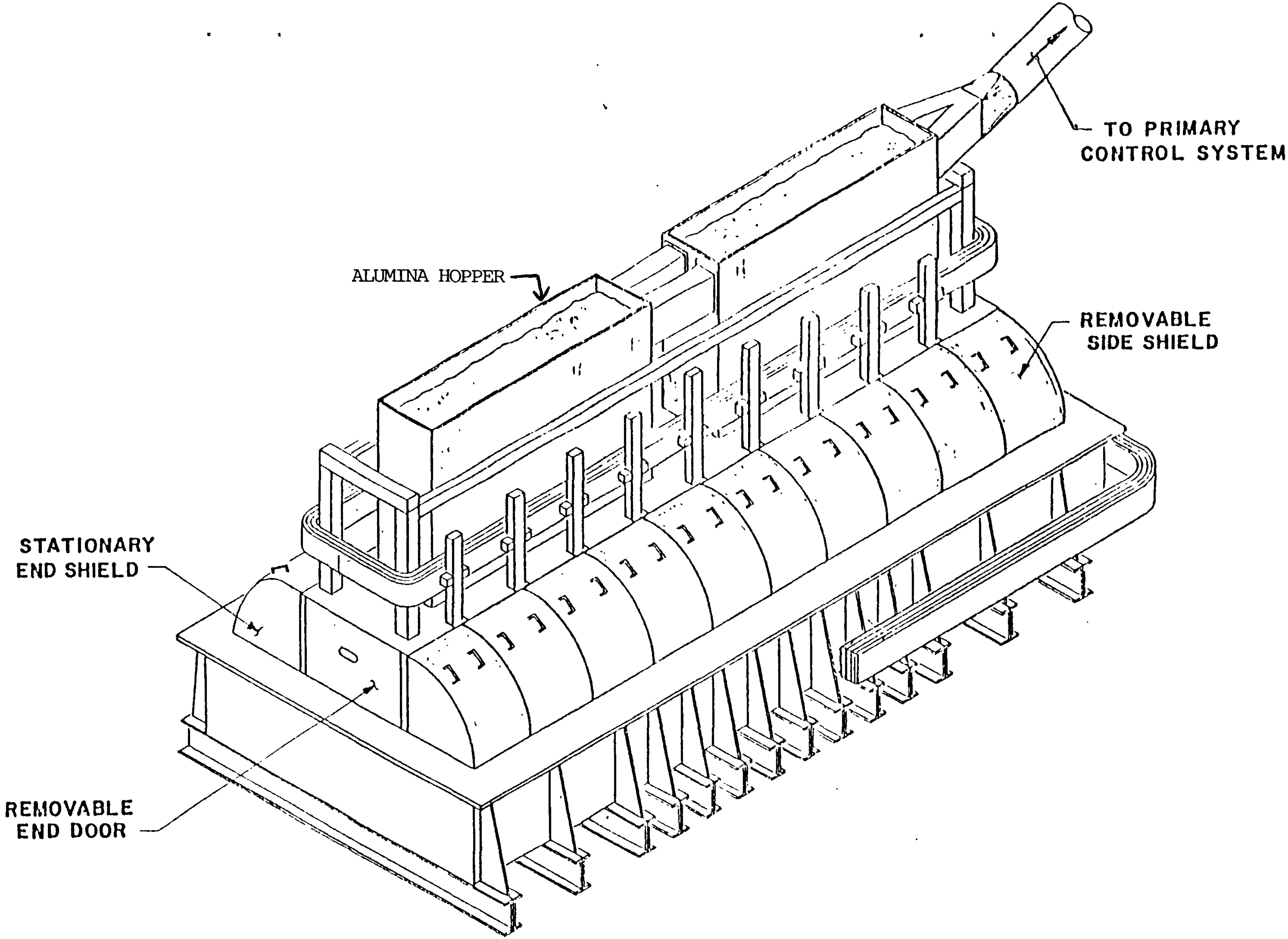


FIGURE 4-1

TYPICAL CENTER-WORKED PREBAKE POT HOODING

TABLE 4-1

AIRFLOWS TO INDIVIDUAL POTS AT PLANTS WITH POTLINES SUBJECT TO THE NSPS[2-5]

Plant code[a]	Pot type[b]	Pot airflows, m^3/s (acfm)[c] Normal	High flow[d]
A	CWPB	1.89 (4,000)	1.89 (4,000)
B	CWPB	1.89 (4,000)	1.89 (4,000)
C	CWPB	1.84 (3,900)	1.89 (4,000)
D	CWPB	1.77 (3,750)	2.64 (5,600)
E	VSS	0.26 (550)	0.26 (550)

a Plants are coded for simplicity. Information is non-confidential.

b CWPB = Center-worked prebake.

d m^3/s = cubic meters per second
acfm = actual cubic feet per minute.

d Airflow controlled by damper. At some plants, airflow is increased whenever hoods are opened.

The evolution of fluoride from CWPB pots is generally believed to have been reduced by using three to four crust breakers and point feeders located down the centerline of the pot to punch small holes in the crust and to drop alumina and bath additive into the bath through these openings. Older designs dumped enough alumina for several hours on the crust and then used a breaker bar to open the crust along the full length of the pot. The crust breakers operate more frequently than the breaker bars but open much smaller holes in the crust, so the potential for fluoride evolution is reduced.

However, one source believes that just the opposite may be true; that is, the use of point feeders over breaker bars may lead to increased fluoride evolution.[6] This is because more than one hole may now be open in the crust continuously, leading to more air being drawn in under the crust. A constant evolution of fluoride gases would then be permitted without the "crust scrubbing" effect of alumina sitting on the bath. In addition, the addition of cold, moist alumina directly onto the molten bath surface could lead to increased fluoride evolution through the hydrolysis of the moisture and the particulate fluoride.

The advent of computer control for many pot functions, while not a control panacea, has helped reduce the need to open the hood to correct overfeeding problems, to add bath additives, or to correct anode effects (see Section 3.3.3). Computer-controlled point feeders add precisely metered amounts of activated alumina directly into the bath, minimizing the potential for overfeeding and reducing the frequency and severity of anode effects. The computer can also correct most anode effects, by cycling the anodes up and down in the pot. Thus, side shields or end doors must be removed only to correct the serious anode effects, which occur relatively infrequently.

The degree to which hoods are opened and the time they remain open are, to some extent, at the discretion of the plant management (or plant operators). Side shields are removed primarily for anode replacement and to correct the occasional serious anode effect. End doors are opened for inspections, to measure the depth of the aluminum produced, and for tapping. Typically, at NSPS plants, only two to three side shields are removed to replace an anode. Usually, these side shields are replaced before those for the next anode change are removed.[7] Also, at NSPS plants, the time the end doors remain open is kept to a minimum and monitored frequently. During tapping, for example, one plant allows no more than three end doors to be open at a time.[8] While tapping is proceeding at one pot, the door to the preceding pot is closed and that to the following pot is opened. Also, the aspirator air used to draw the molten aluminum up into the ladle is vented into the door opening during tapping, thus minimizing fume escape through the opening.

4.1.1.2 Vertical Stud Soderberg Hoods. The hood of a vertical stud Soderberg (VSS) pot does not cover the total bath area. Rather, it forms a skirt around the anode, leaving the sides open for crust breaking and alumina addition (Figure 4-2). The hood captures most of the fumes evolving from the consumable anode, plus the fluoride emissions from that portion of the bath which it covers. Since the VSS hood area is much smaller than that for a CWPB hood, the optimum airflow is also much lower. The one VSS plant subject to the NSPS has selected an airflow of 0.26 m^3/s (550 acfm) (Table 4-1). The fumes from the anode are burned at the entrance to the exhaust duct to prevent carbon buildup in the ducts. Emissions from the bath area which is not covered by the hood are contained, except during pot working, by a crust of cryolite and alumina.

4.1.2 Primary Fluoride Removal

Either dry or wet scrubbers may be used for potroom primary control and for anode bake furnace control.[9] However, all plants subject to the NSPS have selected dry scrubbers for fluoride removal from both potlines and bake furnaces. These dry scrubbers are fully integrated into the feed material delivery process. They act as material handling equipment in the transfer of feed alumina from storage silos to the potlines. Most, if not all, of the alumina for the pots passes through the dry scrubbers at these plants.

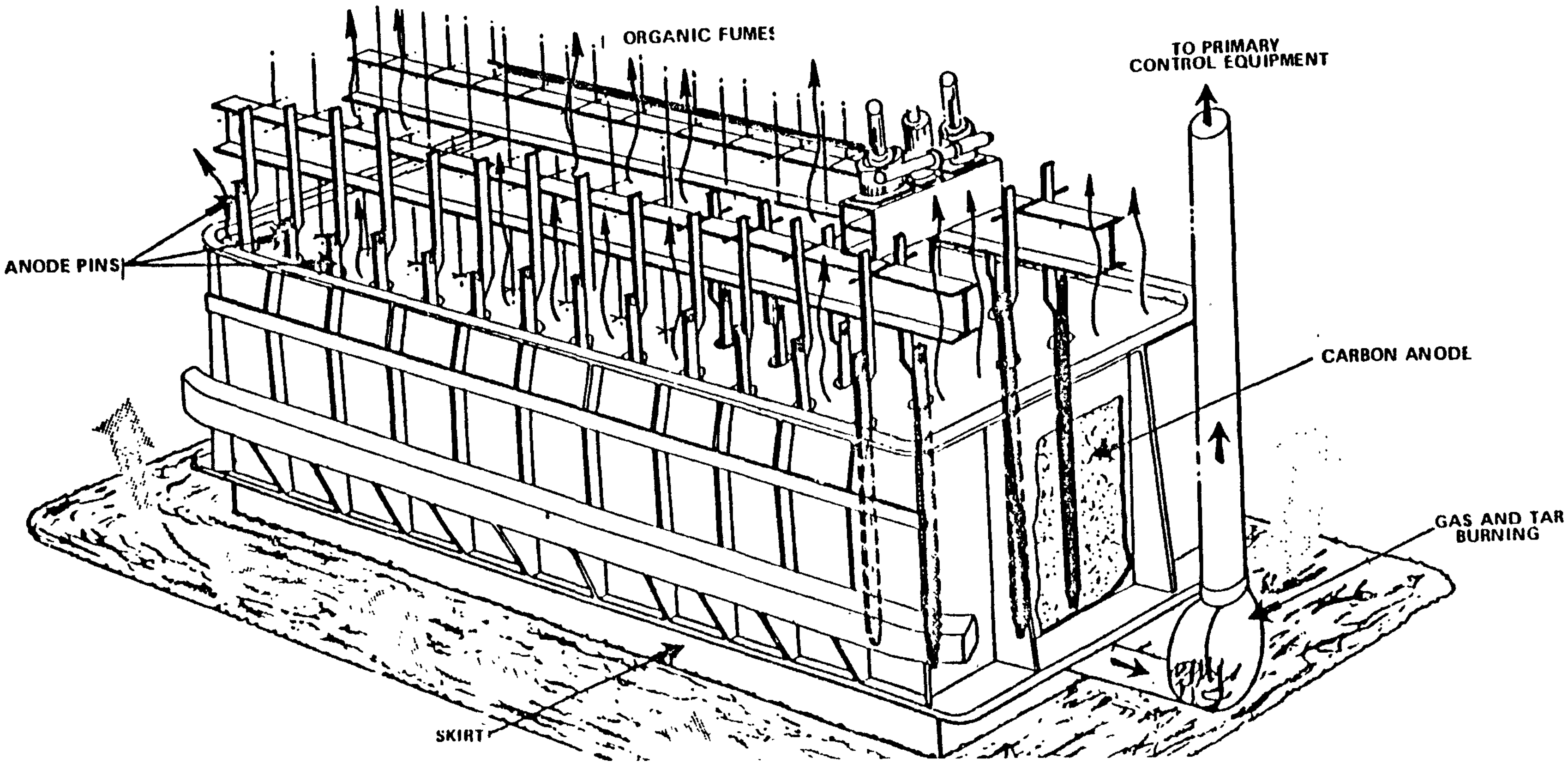


FIGURE 4-2 TYPICAL VERTICAL STUD SODERBERG POT HOODING

Two basic types of dry scrubbers are in use, the injected alumina and the fluidized bed. Cutaway views of these types are shown in Figures 4-3 and 4-4, respectively. Both introduce alumina feed material from the storage silos into the gas stream from the pots or furnace(s). There the alumina adsorbs total fluorides (TF) (i.e., gaseous and particulate fluorides) from the gas stream. Then, the gases pass through a baghouse where the alumina is removed and routed to the potline. Thus, much of the evolved fluoride is returned to the pots. A flow diagram of the dry scrubbing process is shown in Figure 4-5.

The inlet air to dry scrubbers used on anode bake furnaces must be cooled before entering the baghouse. This is accomplished with dilution air, with a water spray in a conditioning tower, or by injecting air or water directly into the fluid bed.[10] A cutaway view of a fluidized bed dry scrubber for a bake furnace, showing fume and water injection points, is shown in Figure 4-6.

4.2 SECONDARY FLUORIDE CONTROLS

Secondary controls include both add-on control units and the actions taken to suppress or eliminate the sources of emissions generated outside the pots.

Add-on potroom controls are not used at any new or existing CWPB plants. They are used at one plant with a new VSS potline and on some existing VSS and HSS potlines. Wet scrubbers are used in this application to control particulate and gaseous fluorides.

The wet scrubbers used for secondary fluoride control on potlines 1 and 2 at Plant E are configured as shown in Figure 4-7. Each potline has a scrubber (or mist eliminator) with five sections. Each section has five

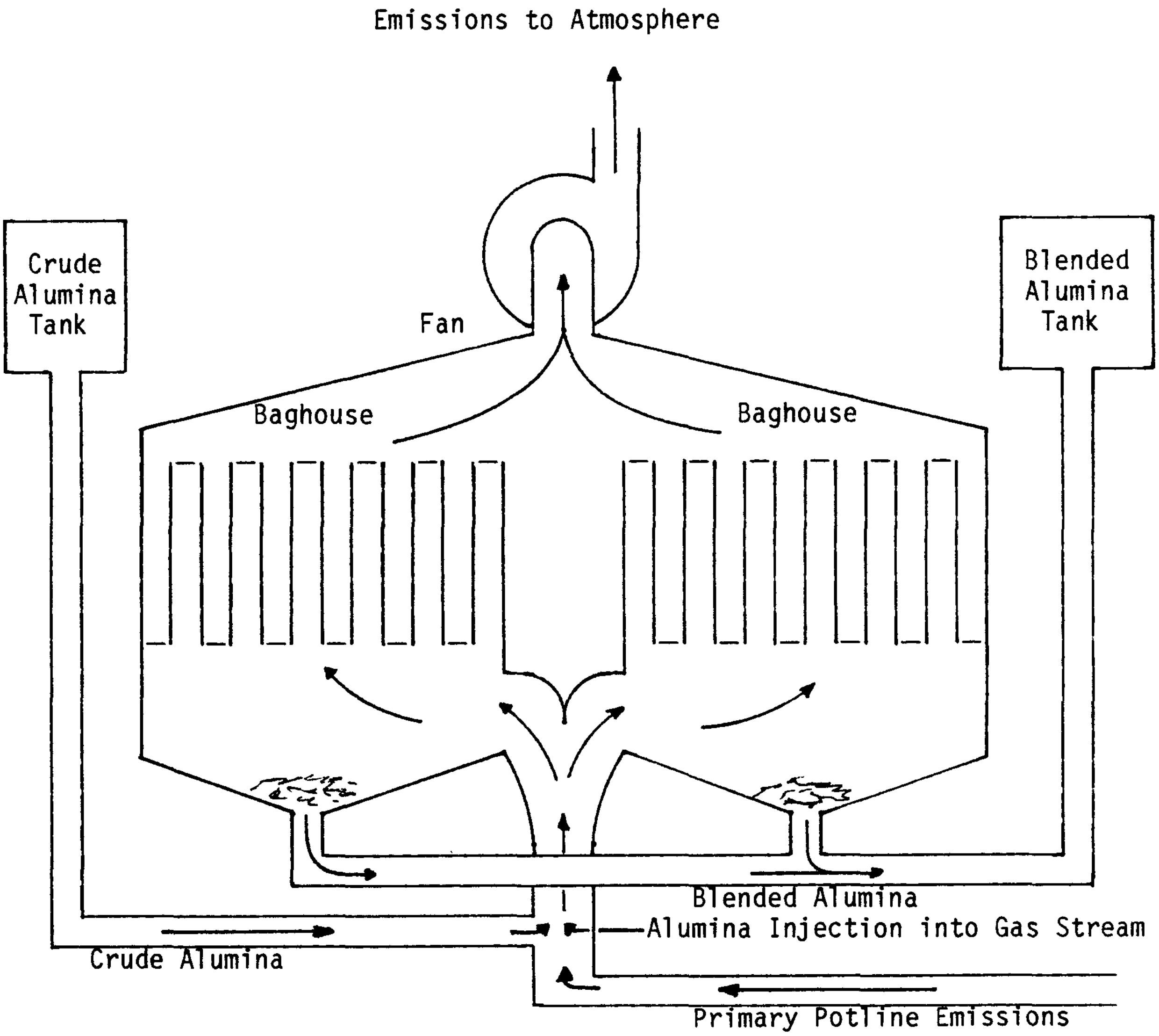


FIGURE 4-3

INJECTED ALUMINA DRY SCRUBBER

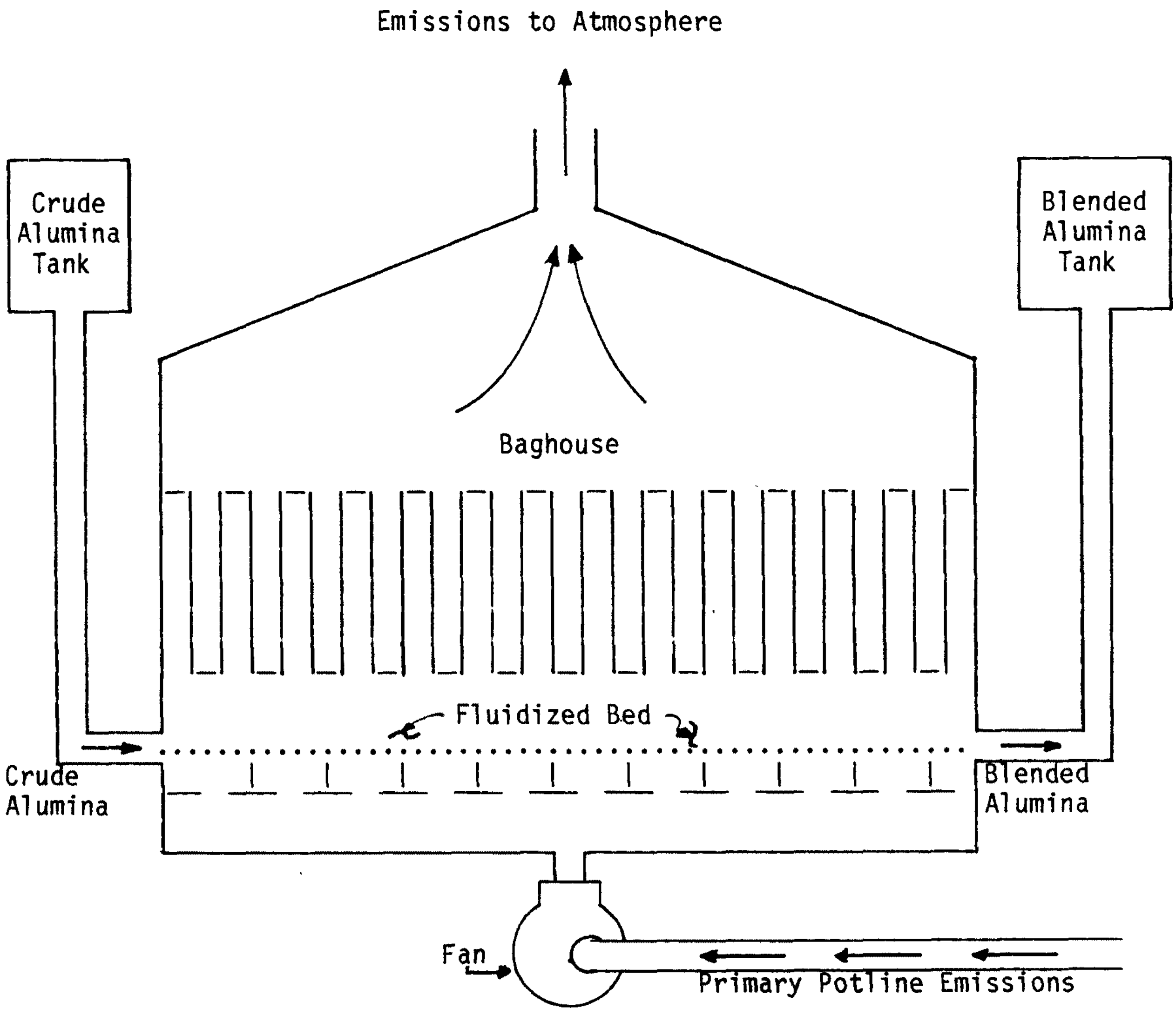


FIGURE 4-4

FLUIDIZED BED DRY SCRUBBER

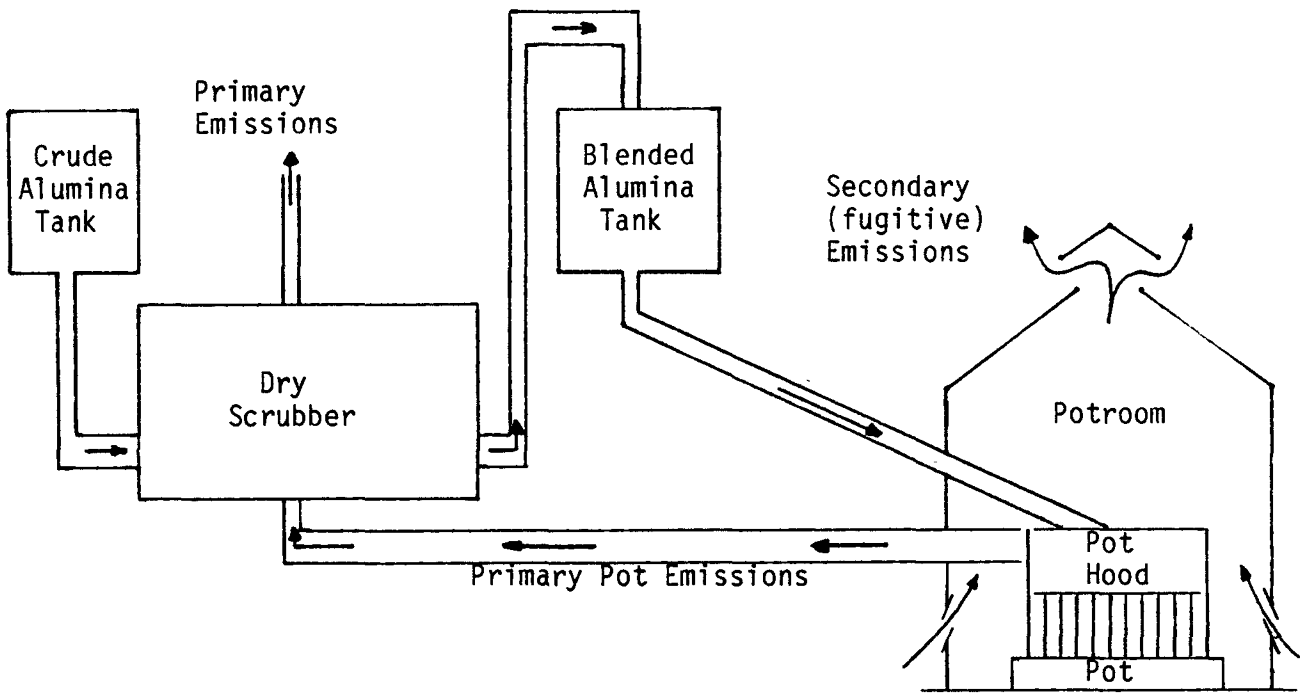


FIGURE 4-5

FLOW DIAGRAM OF THE DRY SCRUBBING PROCESS

FOR A PRIMARY ALUMINUM PLANT

FIGURE 4-6

FLUIDIZED BED DRY SCRUBBER

USED ON AN ANODE BAKE FURNACE EXHAUST

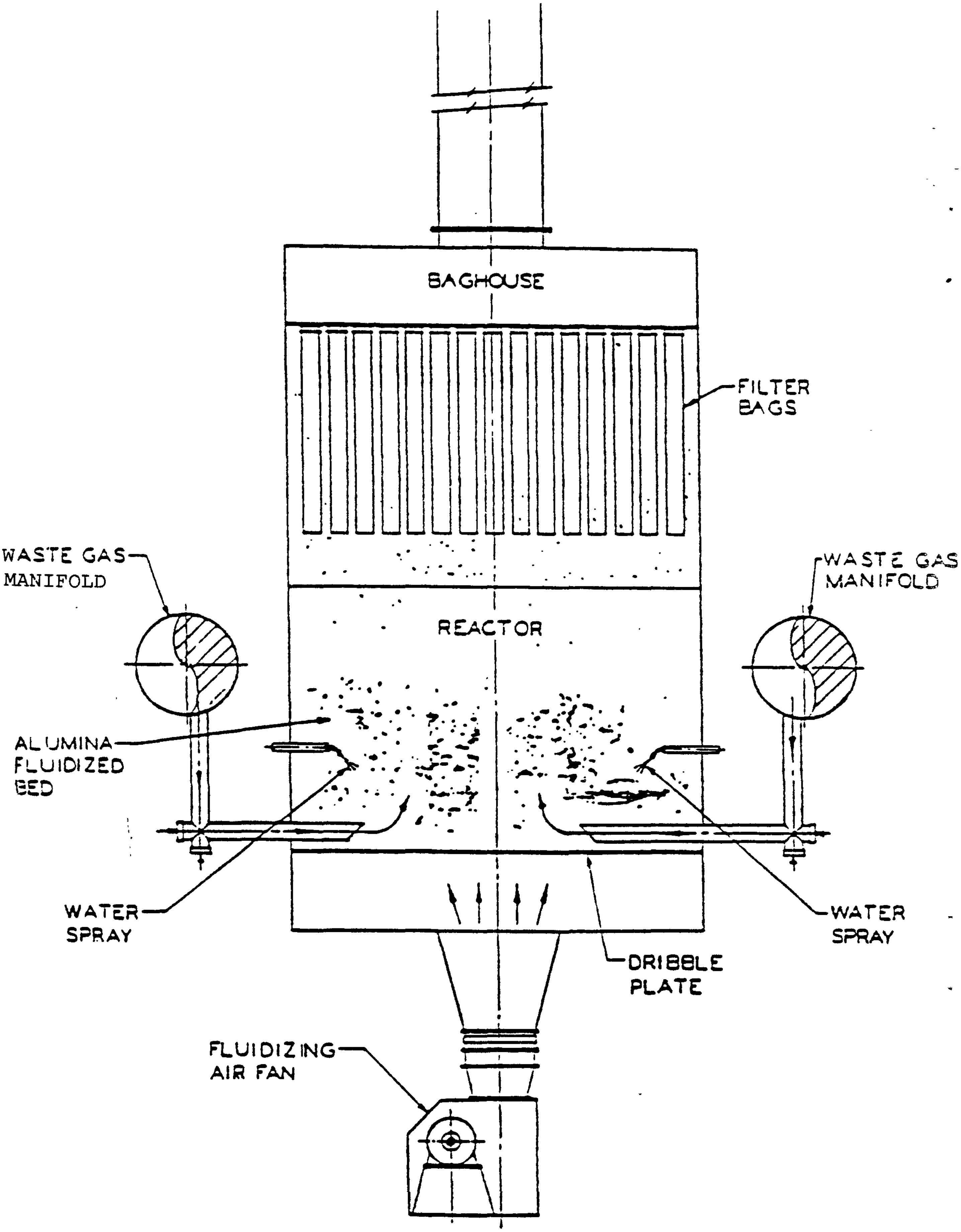
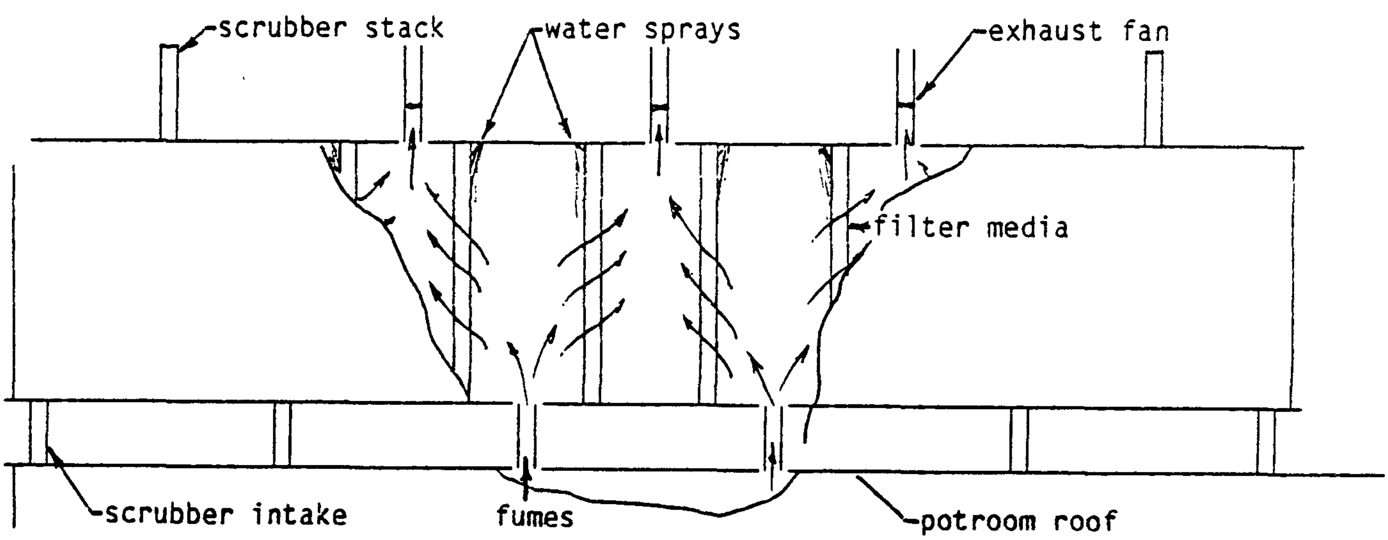


FIGURE 4-7

CROSS-SECTION OF WET SCRUBBER USED TO CONTROL SECONDARY EMISSIONS FROM PLANT E



stacks and six fume intake ducts, and each stack contains an exhaust fan. Fumes from the potroom roof area are drawn in through the intake ducts, sprayed with water, and captured on filter media. Fumes which escape the filter are drawn into the scrubber stacks and expelled to the atmosphere. The scrubber on line 3 operates in the same way, but is configured somewhat differently. It has 2 rooms, each with 14 fans. Total airflow through the line 1 and 2 scrubbers is 3,540 m^3/s (7.5 million acfm) each, while the line 3 scrubber has an airflow of 3,445 m^3/s (7.3 million acfm). All have negligible pressure drops.[11]

To minimize the release of activated alumina to potrooms when it is dumped from overhead conveyors into the alumina storage hoppers atop CWPB pots, most CWPB plants now use sandy alumina (a fairly coarse grade) to feed the pots. Also, some conveyer hoppers are equipped with baghouses to minimize particulate emissions during alumina transfer. One CWPB plant enclosed the pot hoppers and delivers the alumina by airslide.[12]

Most plants with NSPS potlines require good housekeeping. Small particles of alumina, solidified bath material, and crust tend to collect beside the pots during anode changes, etc., and, if not removed, can be picked up as dust and passed through the roof monitors. Also, a buildup of crust and bath material on the outer rim of the pot can prevent the side shields from seating properly, increasing fugitive emissions from the pots. One CWPB plant also makes it a point to remove hot anode butts from the potroom within 30 minutes.[13] They are carried to a storage area which is vented to the bake plant scrubber.

Plants with NSPS potlines and bake furnaces have instituted work practices designed to prevent the escape of fumes from the pots and to suppress emissions generated outside the pots. They also conduct periodic inspections to ensure that these practices are being followed. Figures 4-8 and 4-9 are inspection forms modelled after those used by some plants subject to the NSPS. Figure 4-8 is a form used to record the condition of a single pot, while Figure 4-9 is handy for summarizing and tabulating the condition of many pots and crucibles.

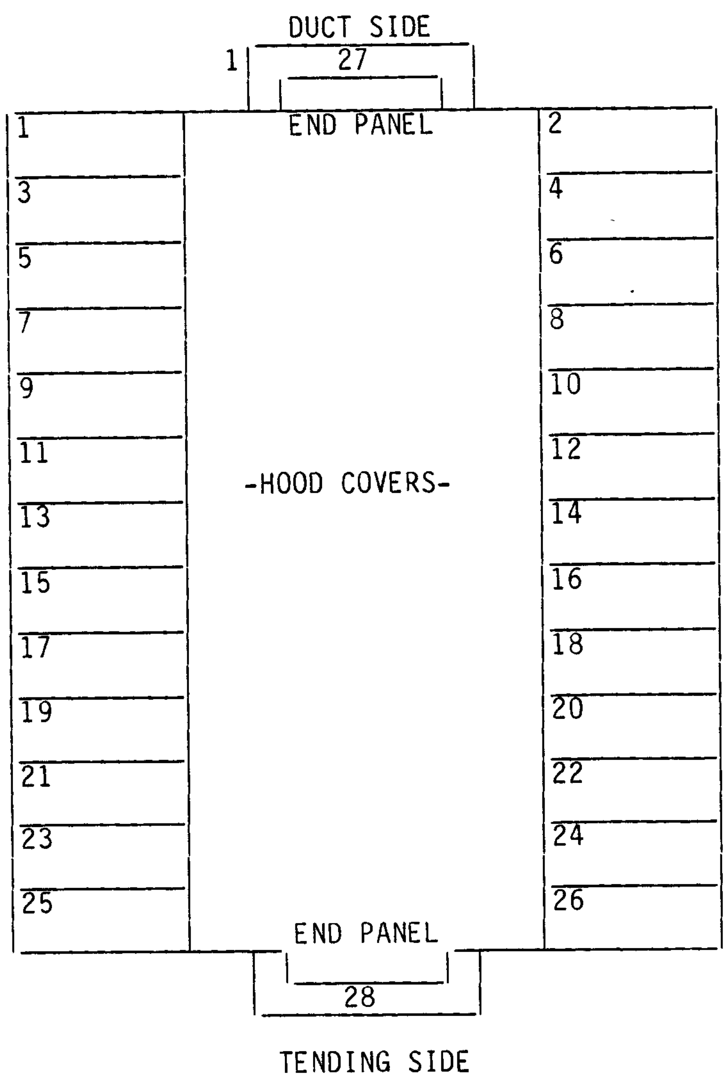
FIGURE 4-8

HOOD INSPECTION DATA SHEET[14]

Date____________________________

Potroom No._____________________

Pot No._________________________



Deficiency codes:
1. Bottom vent in or out
2. Damage to side of hood
3. Damage to top of hood
4. Hole burned in hood other than at step
5. Hole burned in hood step
6. Damaged end door

S Not sealed

0 Open not tending

OT Open tending

FIGURE 4-9

HOOD AND CRUCIBLE INSPECTION SUMMARY[15]

POT NO.	END DOORS OPEN	POOR SIDECOVER PLACEMENT	SIDECOVER PARTIALLY OPEN	HIGH DRAFT	SMOKING POT	BROKEN DAMPER ARM	LEAKING TRANSITE	CUT-OUT POTS NOT BLANKED OFF
1								
2								
3								
4								
5								
etc								

CRUCIBLE CONDITION				
CRUCE NO.	CRUCE ACCEPTABLE	DAMAGED FLEX PIPE	FLEX PIPE DISCONNECTED	FLEX PIPE MISSING
1				
2				
3				
4				
5				
etc				

4.3 PARTICULATE AND SULFUR DIOXIDE CONTROLS

Particulate matter (PM) emissions from potrooms and anode bake furnaces are controlled by the equipment and work practices used for TF control. No additional equipment has been installed at any NSPS plant solely to control PM from these sources. Other emission sources in primary aluminum plants do have controls specifically for PM, but these will not be addressed here.

As noted in Chapter 3, sulfur dioxide (SO_2) emissions are a function of the sulfur content of the coke and pitch used in the reduction pot anodes. Thus, SO_2 emissions can be controlled either by limiting the sulfur content of the coke and pitch used in the anodes, or by using add-on controls such as a wet scrubber.

Petroleum coke with a low sulfur content (e.g., less than 3 percent) can be purchased at a premium price for use in the anodes. Coke of this type is available under contract for periods up to 10 years.[16]

The dry scrubbers now employed for TF control at most primary aluminum plants have no long-term effect on SO_2 emissions. The SO_2 in the gas stream from a potroom is adsorbed onto the surface of the alumina cycled through the dry scrubber, along with the fluorides. It is then returned to the reduction pots with the feed alumina. There, the SO_2 is converted back to the vapor phase and returned to the scrubber, where the cycle is repeated. This continues until the SO_2 content of the gas stream exceeds the adsorption capability of the alumina. At that point, SO_2 is emitted from the dry scrubber at the same rate that it is evolved from the pot.[17] If the dry scrubber treats an anode furnace exhaust, the net effect is the same. The SO_2 emissions are merely redistributed, with the SO_2 captured by the anode furnace scrubber being emitted by the potroom scrubber.

Wet scrubbers have been installed for SO_2 control at one primary aluminum plant with VSS pots.[18] These scrubbers are located downstream of the dry scrubbers on the primary fluoride control system and use either sodium hydroxide or sodium carbonate as the scrubbing medium. The wet scrubbers used to control secondary TF also remove SO_2.

4.4 CONTROL SYSTEMS PERFORMANCE

Emissions test data have been received from plants known to have potlines and/or anode bake furnaces subject to the NSPS. This data base consists of one new CWPB plant, with two potlines and two anode bake furnaces; two existing CWPB plants, each with an NSPS potline and furnace; one VSS plant with a new potline; and two existing CWPB plants with anode bake furnaces subject to the NSPS. It should be noted that the emissions data provided by plant E are unusual in two respects. The data are for three lines, not one, and cannot reasonably be separated. All three lines have comparable primary and secondary control systems and all are required to meet the same emission limits, even though only line 3 is subject to the NSPS. Also, the plant normally performs only one test run per month on each line. Therefore, each monthly test is the average of three runs, as usual, but each run is on a different line.

4.4.1 Total Fluorides

All four plants with potrooms subject to the NSPS have demonstrated the capability for meeting the NSPS for TF, as have the five plants with anode bake furnaces (Table 4-2). The three plants with CWPB pots have average TF emissions between 0.43 and 0.64 kg/Mg (0.86 and 1.27 lb/ton) of aluminum produced.

TABLE 4-2

TOTAL FLUORIDE EMISSIONS FROM POTLINES AND ANODE BAKE FURNACES SUBJECT TO THE NSPS[19]

Plant code[a]	Plant type[b]	Emission source	Number monthly tests	Measured TF emissions (lb/TAP)[c] Range	Average	NSPS limit (lb/TAP)	Number exceed-ances
A	CWPB	Potroom	51	0.51-1.32	0.90	1.9	0
B	CWPB	"	48	0.36-1.46	0.86	"	0
C	CWPB	"	34	0.67-3.48	1.27	"	3[d]
D	CWPB	"	16	0.71-1.49	1.02	"	0
E	VSS	"	22	0.88-3.11	1.49	2.0	3[e]
F	CWPB	Furnace	20	0.003-0.113	0.017	0.1	1[f]
G	CWPB	"	16	0.001-0.043	0.008	"	0
H	CWPB	"	10	0.002-0.017	0.007	"	0
J	CWPB	"	10	0.003-0.056	0.014	"	0
K	CWPB	"	7	0.003-0.038	0.010	"	0

a Plants coded for simplicity.

b CWPB = center-worked prebake
VSS = vertical stud Soderberg

c Measured emissions of total fluorides (TF) includes both primary and secondary emissions. lb/TAP = pounds per ton aluminum produced (1 lb/TAP = 0.5 kilogram per megagram).

d Two failures occurred in same month, one on retest.

e Specific reason for failures not reported. Plant conducts one test run/line each month, so each reported test is the average for all three lines.

f Failure occurred in the first month test results reported.

The plant with VSS pots had average emissions which were somewhat higher, at 0.75 kg/Mg (1.49 lb/ton). The potlines at two plants have, however, exceeded the allowable emissions limit on occasion, as has the bake furnace at one plant.

It should be noted that the numbers presented in Table 4-2 include both primary and secondary TF emissions, as required by the NSPS. As mentioned earlier, TF emissions generated in the pots and captured by the pot hoods are called primary TF, while those which escape from (or are generated outside) the pot are classified as secondary TF. The split between primary and secondary TF emissions is shown in Table 4-3. As can be seen by comparing the data in this table, secondary TF emissions account for between 90 and 93 percent of total TF emissions to the atmosphere at both CWPB and VSS plants. This is significant, because it illustrates the importance of proper hood design and maintenance, and good work practices. In the absence of secondary TF controls, relatively small increases in emissions escaping the hoods can have dramatic impacts on emissions to the atmosphere. This effect is evident in Table 4-4, which tabulates the effect of changes in primary TF capture and control efficiencies on overall TF emissions for two TF evolution rates. It indicates, for example, that a drop of only 1 percent in capture efficiency can increase TF emissions to the atmosphere by 30 to 90 percent, depending on initial control efficiency. (Secondary emissions can also increase as a result of process changes that result in higher evolution rates, even through the hooding efficiencies remain the same.)

TABLE 4-3

TOTAL FLUORIDE EMISSIONS BY POTROOM GROUP AND TYPE[20]

Plant code[a]	Potroom group	Measured TF emissions (lb TF/TAP)[b]						
		Primary		Secondary		Total		Secondary
		Range	Avg.	Range	Avg.	Range	Avg.	%
A	1	0.02-0.26	0.09	0.44-1.15	0.77	0.51-1.28	0.88	
	2	0.02-0.08	0.05	0.57-1.29	0.87	0.59-1.32	0.91	
	1 & 2		0.07		0.82		0.90	91
B	1	0.02-0.16	0.07	0.41-1.12	0.73	0.36-1.17	0.79	
	2	0.04-.22	0.10	0.37-1.31	0.85	0.48-1.46	0.94	
	1 & 2		0.08		0.79		0.86	92
C	1 & 2	N/A[c]		0.50-3.41	1.18	0.67-3.48	1.27	93
D	1 & 2	0.04-0.13	0.07	0.35-1.40	0.92	0.71-1.49	1.02	90
E	1 - 3 (3 Lines)	0.01-0.64	0.13	0.86-3.01	1.36	0.88-3.11	1.49	91

a = Plant code same as Table 4-2. Coding is for simplicity.

b = lb TF/TAP = pounds total fluoride per ton aluminum produced.
(1 lb/TAP = 0.5 kilogram per megagram)

c = Not available.

TABLE 4-4

IMPACTS OF CHANGES IN PRIMARY TF CAPTURE AND REMOVAL EFFICIENCIES ON OVERALL TF EMISSIONS[21]

TF evolution from CWPB pots[a] (lb TF/TAP)	Hood capture efficiency (%)	Primary TF removal efficiency (%)	Overall TF control efficiency (%)	TF emissions to the atmosphere (lb TF/TAP)		
				Primary	Secondary	Total
66	99	99.9	98.9	0.065	0.660	0.725
		99.8	98.8	0.131	"	0.791
		99.6	98.6	0.261	"	0.921
	98	99.9	97.9	0.065	1.320	1.385
		99.8	97.8	0.129	"	1.449
		99.6	97.6	0.259	"	1.579
	97	99.9	96.9	0.066	1.980	2.046
		99.8	96.8	0.128	"	2.108
		99.6	96.6	0.256	"	2.236
	96	99.9	95.9	0.063	2.640	2.703
		99.8	95.8	0.127	"	2.767
		99.6	95.6	0.253	"	2.893
55	99	99.9	98.9	0.055	0.550	0.605
		99.8	98.8	0.110	"	0.660
		99.6	98.6	0.220	"	0.770
	98	99.9	97.9	0.054	1.100	1.154
		99.8	97.8	0.108	"	1.208
		99.6	97.6	0.216	"	1.316
	97	99.9	96.9	0.053	1.650	1.703
		99.8	96.8	0.107	"	1.757
		99.6	96.6	0.213	"	1.860
	96	99.9	95.9	0.053	2.200	2.273
		99.8	95.8	0.106	"	2.306
		99.6	95.6	0.211	"	2.411

[a] lb TF/TAP = pounds total fluoride per ton aluminum produced. (1 lb/TAP = 0.5 kilogram per megagram)

The capture efficiencies of the hooding systems and the TF removal capabilities of the primary control equipment cannot be determined for the NSPS plants because no data are available on uncontrolled fluoride evolution from the pots at those plants, nor on the magnitude of the emissions routed to their dry scrubbers. The average capture efficiency of a hood is a composite number which takes into account the effects of opening the hood for pot working, inspection, and tapping.

Primary TF emissions are controlled by dry scrubbers at all primary aluminum plants subject to the NSPS. Secondary TF emissions are not controlled at any CWPB plants, but are removed by wet scrubbers at the one VSS plant subject to the NSPS. Information provided by this plant on secondary TF control efficiencies (monthly averages) are summarized in Table 4-5. Their secondary wet scrubbers, which use a calcium additive and have negligible pressure drops, usually recovered over 68 percent of the secondary TF.

4.4.2 Particulate Matter

The control of PM from potlines and anode bake furnaces occurs as a side benefit of TF control. Data have been received on PM emissions from TF control devices on four potlines and three anode bake furnaces (Table 4-6). No data are available on uncontrolled primary PM emissions, so the effectiveness of dry scrubbers in controlling primary PM cannot be determined. One plant, however, provided information on the PM control efficiency of the wet scrubbers installed for secondary TF control. A summary of this information is presented in Table 4-5. The average monthly efficiency of these scrubbers in reducing PM was over 56 percent during the reporting period.

TABLE 4-5

EFFECTIVENESS OF SECONDARY WET SCRUBBERS AT PLANT E[11]

Pollutant	Pollutant Reduction (%)[a] Range	Average
Total Fluoride	56.26 - 80.94	68.73
Sulfur Dioxide	40.33 - 82.99	62.05[b]
Particulate Matter	35.05 - 72.72	56.93

a Monthly averages

b Inlet concentration averaged 1.0 ppmv (Reference 23).

TABLE 4-6

PARTICULATE EMISSIONS FROM PRIMARY ALUMINUM PLANTS USING DRY SCRUBBERS TO CONTROL FLUORIDE EMISSIONS[24]

				Emissions (lb PM/TAP)[c]								
				Primary			Secondary			Total		
Plant code[a]	Emission source[b]	Test year	No. monthly tests	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.	Avg
A	CWPB Potline, Subgroup											
	1	1984	1	--	--	0.018	--	--	0.576	--	--	0.594
	2	1984	1	--	--	0.057	--	--	0.542	--	--	0.599
B	CWPB Potline, Subgroup											
	1	1984	1	--	--	0.057	--	--	0.66	--	--	0.72
	2	1984	1	--	--	0.091	--	--	0.84	--	--	0.93
D	CWPB	1984	1	--	--	--	--	--	0.531	--	--	--
	Potline	1985	1	--	--	--	--	--	1.870	--	--	--
		all	2	--	--	--	--	--	1.200	--	--	--
E	VSS	1984	12	0.05	0.39	0.14	4.85	11.84	6.43	5.01	11.94	6.68
	Potlines	1985	10	0.04	0.29	0.14	2.94	6.30	5.03	3.12	6.36	5.17
	1&2	all	22	--	--	0.14	--	--	5.85	--	--	6.00
F	Anode Bake Furnace	1985	1	--	--	0.003	--	--	--	--	--	0.006
J	Anode	1984	5	0.102	0.223	0.169	--	--	--	0.102	0.223	0.169
	Bake	1985	6	0.176	2.034	0.603	--	--	--	0.176	2.034	0.603
	Furnace	all	11	--	--	0.405	--	--	--	--	--	0.405
K	Anode	1984	11	0.023	1.061	0.458	--	--	--	0.023	1.061	0.458
	Bake	1985	4	0.210	0.728	0.442	--	--	--	0.210	0.728	0.492
	Furnace	all	15	--	--	0.454	--	--	--	--	--	0.454

a Plant code same as Table 4-2. Coding is for simplicity.

b CWPB = Center-worked prebake
VSS = Vertical stud Soderberg

c lb PM/TAP = pounds particulate matter per ton aluminum produced.
(1 lb/TAP = 0.5 kilogram per megagram)

4.4.3 Sulfur Dioxide

The one plant with SO_2 controls (Plant E) reports SO_2 emissions averaging 3.6 kg/Mg (7.2 lb/ton) (Table 4-7).[25] This is equivalent to the use of coke with a sulfur content of 0.36 percent. In addition to listing total SO_2 emissions from the three VSS potlines at Plant E, Table 4-7 shows how this total is split between the primary and secondary control systems. It also shows the amount of variation experienced during the reporting period. This plant, which uses VSS pot technology, added SO_2 controls to meet a prevention of significant deterioration (PSD) limit of 6.99 kg SO_2/Mg (13.97 lb/ton). They control both primary and secondary SO_2. Lines 1 and 2 have a single sodium (wet) scrubber for primary SO_2 control, located downstream of the two dry scrubbers. The primary SO_2 control for Line 3 is provided by a sodium scrubber located downstream of the dry scrubber. Secondary SO_2 emissions from all three potlines are passed through calcium (wet) scrubbers which are provided primarily for TF control. Information provided by the plant and summarized in Table 4-5 indicates that these scrubbers generally remove about 62 percent of the secondary SO_2. However, the data provided by the plant are not adequate to determine SO_2 removal efficiencies of the primary SO_2 scrubbers, since the SO_2 content of the uncontrolled potroom primary exhaust gases was not measured and the sulfur content of the coke used at the plant during the test reporting period was not provided.

Data were also obtained on SO_2 emissions from two anode bake plants. These data are presented in Table 4-8. Average emissions range from 0.59 to 1.55 kg SO_2/Mg (1.18 to 3.10 lb/ton). Sulfur contents of the anode constituents ranged from 0.45 percent in the pitch to 2.0 percent for fresh coke at these two plants.

TABLE 4-7

SULFUR DIOXIDE EMISSIONS FROM A PRIMARY ALUMINUM PLANT USING WET SCRUBBERS FOR PRIMARY AND SECONDARY SULFUR DIOXIDE CONTROL[26]

Plant code[a]	Emission source[b]	Test year	No. monthly tests	Emissions (lb SO_2/TAP)[c] Primary			Secondary			Total		
				Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.	Avg
E	VSS	1984	12	1.09	11.71	3.49	2.12	7.43	3.52	3.21	14.87	7.02
	Potlines	1985	10	1.55	7.86	3.33	2.14	6.22	4.01	3.96	12.75	7.34
	1-3	all	22	1.09	11.71	3.42	2.12	7.43	3.73	3.21	14.87	7.17

a Plant code same as Table 4-2. Coding is for simplicity.

b VSS = vertical stud Soderberg. Data are for 3 potlines. Potlines 1 and 2 use same SO_2 scrubber.

c lb SO_2/TAP = pounds SO_2 per ton aluminum produced (1 lb/ton = 0.5 kilogram per megagram).

TABLE 4-8

SULFUR DIOXIDE EMISSIONS FROM ANODE BAKE PLANTS[27]

Plant code[a]	Emission source	Test year	No. monthly tests	Emissions (lb SO_2/TAE)[b] Total		
				Max.	Min.	Avg.
J[c]	Anode	1984	5	5.15	2.31	3.62
	Bake	1985	6	4.39	1.38	2.67
	Plant	all	11	5.15	1.38	3.10
K[d]	Anode	1984	10	1.63	0.39	1.07
	Bake	1985	4	1.74	1.23	1.46
	Plant	all	14	1.74	0.39	1.18

a Plant code same as Table 4-2. Coding is for simplicity.

b lb SO_2/TAE = pounds SO_2 per ton aluminum equivalent (1 lb/ton = 0.5 kilogram per megagram).

c Sulfur contents ranged from 0.45 percent for pitch to 1.95 percent for packing coke (Reference 28).

d Sulfur contents ranged from 0.60 percent for pitch to 2.0 percent for fresh coke (Reference 28).

4.5 REFERENCES FOR CHAPTER 4

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

2. Letter and attachments from Dickie, R.C., Alumax of South Carolina, to Farmer, J.R., EPA:ESED. August 27, 1985. Response to Section 114 information request.

3. Letter and attachments from Givens, H.L., Alcan, to Noble, E.A., EPA:ISB. September 26, 1985. Response to Section 114 information request.

4. Letter and attachments from Hurt, R.E., Noranda Aluminum, to Farmer, J.R., EPA:ESED. September 25, 1985. Response to Section 114 information request.

5. Letter and attachments from Casswell, S.J., Commonwealth Aluminum, to Farmer, J.R., EPA:ESED. September 6, 1985. Response to Section 114 information request.

6. Letter and attachment from Tropea, L.C., Jr., Reynolds Aluminum, to Noble, E.A., EPA:ISB. May 9, 1986. Comments on draft chapters.

7. Reference 4.

8. Reference 1.

9. Reference 1, Page 6-29.

10. Memo from Noble, E.A., EPA:ISB, to Durkee, K.R., EPA:ISB. September 4, 1985. Report of June 1985 trip to Noranda Aluminum, New Madrid, Mo.

11. Reference 5.

12. Reference 4. Attachment 1.

13. Reference 10, Page 3.

14. Reference 2.

15. Letter and attachments from Givins, H.L., Alcan, to Noble, E.A., EPA:ISB. Received June 28, 1985. Emissions data.

16. Letter and attachments from Dickie, R.C., Alumax of South Carolina, to Noble, E.A., EPA:ISB. April 16, 1986. Comments on draft chapters.

17. International Primary Aluminum Institute. Review of the Petroleum Coke Situation and Its Potential Impact on Sulfur Dioxide Emissions from Primary Aluminum Plants. December 1978.

18. Reference 5.

19. Memo and attachments from Maxwell, W.H., EPA:ISB, to Primary Aluminum Docket (A-86-07). June 18, 1986. Fluoride emissions from NSPS primary aluminum plants.

20. Reference 19.

21. Memo from Maxwell, W.H., to Primary Aluminum Docket (A-86-07). June 17, 1986. Impact of capture and removal efficiencies.

22. Memo and attachments from Maxwell, W.H., EPA:ISB, to Primary Aluminum Docket (A-86-07). June 17, 1986. Control device efficiencies.

23. Memo and attachments from Maxwell, W.H., EPA:ISB, to Primary Aluminum Docket (A-86-07). June 17, 1986. SO_2 emission concentration from Commonwealth Aluminum.

24. Memo and attachments from Maxwell, W.H., EPA:ISB, to Primary Aluminum Docket (A-86-07). June 17, 1986. Particulate and SO_2 emissions from NSPS primary aluminum plants.

25. Letter from Casswell, S.J., Commonwealth Aluminum, to Noble, E., EPA:ISB. November 21, 1985. Emissions data.

26. Reference 24.

27. Reference 24.

28. Letter and attachments from Boyt, J.S., Aluminum Company of America, to Farmer, J.R., EPA:ESED. October 7, 1985. Response to Section 114 information request.

5. COMPLIANCE STATUS OF PRIMARY ALUMINUM PLANTS

5.1 AFFECTED FACILITIES

Six plants have been built or have added aluminum reduction potlines or anode bake furnaces since the primary aluminum new source performance standards (NSPS) were proposed in 1974. Information on their locations and startup dates is presented in Table 5-1. The one new plant installed two center-work prebake (CWPB) potlines and two anode bake furnaces. Two plants replaced only their anode bake furnaces. The three existing plants which installed potlines utilized the same types of pots as were already in use on their existing potlines. Two of these were CWPB facilities and one was a vertical stud Soderburg (VSS) facility. Each of the CWPB plants also added an anode bake furnace at the same time.

5.2 EMISSIONS DATA

The NSPS limit emissions of total fluoride (TF) from potlines and bake furnaces. In addition, particulate and sulfur dioxide (SO_2) emissions are regulated by some states. The following sections present the available NSPS compliance emissions data, organized by pollutant.

5.2.1 Total Fluoride

The NSPS require monthly testing of primary TF emissions from anode bake furnaces and both primary and secondary TF emissions from aluminum reduction potrooms. However, the requirement for monthly testing of the primary control systems has been waived at three NSPS plants in favor of yearly tests and at one plant in favor of twice yearly tests.[1-3] In those cases, total TF emissions for potroom groups are calculated using the results of the last available test. Available data on TF emissions from potroom groups and anode bake furnaces are summarized on Table 5-2.

TABLE 5-1
LIST OF PRIMARY ALUMINUM
REDUCTION PLANTS SUBJECT
TO THE NSPS[4-8]

Plant name & location	NSPS Facility			Start up date(s)	Pot type[a]	NSPS potline capacity, tpy Al[b]	Total per plant, new and existing	
	Plant	Line	Bake furnace				Potlines	Bake furnace
Alumax of S. Carolina Mount Holly Plant Goose Creek, South Carolina	1	(2)	(2)	6/80	CWPB	100,000 X 2	2	2
Alcoa Warrick Plant Newburgh, Indiana	-	-	1	1/84	CWPB	--	6	1[c]
Alcan Aluminum Sebree Plant Henderson, Kentucky	-	1	1	6/79	CWPB	60,000	3	3
Noranda Aluminum Co. New Madrid, Missouri	-	1	1	7/83	CWPB	85,000	3	3
Commonwealth Aluminum Goldendale Plant Goldendale, Washington	-	1	-	3/82	VSS	65,000	3	-
Alcoa Rockdale Works Rockdale, Texas	-	-	3	12/77, 12/81, & 8/82	CWPB	--	8	4

a CWPB = Center-worked prebake
VSS = Vertical stud Soderberg

b TPY Al = tons per year aluminum (1 ton = 0.9 megagram)

c Plant also has 12 tunnel kilns, 4 of which would be used when operating at full capacity.

TABLE 5-2

FLUORIDE EMISSIONS FROM PRIMARY ALUMINUM PLANTS SUBJECT TO THE NSPS[9]

Plant code[a]	Plant type[b]	Emission source	Test period	No. tests	Emissions of total fluorides (lb TF/TAP)[c] Min.	Max.	Avg	No. exceed-ances
A	CWPB	Potline 1 Potroom						
		Group 1	1/81-3/85	51	0.51	1.28	0.88	0
		Group 2	1/81-3/85	51	0.59	1.32	0.91	0
B	CWPB	Potline 2 Potroom						
		Group 1	3/81-2/85	48	0.36	1.17	0.79	0
		Group 2	2/81-2/85	47	0.48	1.46	0.94	0
C	CWPB	Potline 3 Potroom Grps1&2	1/82-12/84[d]	34	0.67	3.48	1.27	3
D	CWPB	Potline 3 Potroom Grps1&2	3/84-6/85[e]	16	0.71	1.49	1.02	0
E	VSS	Potlines 1,2,&3	1/84-10/85	22	0.88	3.11	1.49	3
F	CWPB	Anode Bake Plt	8/81-5/85	20	0.003	0.113	0.017	1
G	CWPB	Anode Bake Plt	3/80-3/85	16	0.001	0.043	0.008	0
H	CWPB	Anode Bake Plt	3/84-1/85	10	0.002	0.017	0.007	0
J	CWPB	Anode Bake Plt	9/84-6/85	10	0.003	0.056	0.014	0
K	CWPB	Anode Bake Plt	9/84-4/85	7	0.003	0.038	0.010	0

a Plants are coded for simplicity
b CWPB = Center-worked prebake
VSS = Vertical stud Soderberg
c lb TF/TAP = pounds total fluoride per ton aluminum produced (1 lb/ton = 0.5 kilogram per megagram)
d Secondary TF data available from 9/79 to 5/85
e Secondary TF data available from 1/84 to 6/85

Table 5-2 is organized by plant and emission source (potroom group or furnace) and shows the test period, the total number of tests in the data base, the range of emissions reported in the test period, and the mean (or average) emission rate. It also indicates the number of times the NSPS has been exceeded during the reporting period. As can be seen, all the affected facilities (potroom groups and bake furnaces) have the capability to meet the NSPS, since average TF emissions are considerably below the NSPS. Average TF emissions for potroom groups range from 0.40 to 0.64 kilograms per megagram (kg/Mg) (0.79 to 1.27 lb/ton) aluminum produced for CWPB plants and are 0.75 kg/Mg (1.49 lb/ton) for the VSS plant, compared to their respective NSPS limits of 0.95 and 1.0 kg/Mg (1.9 and 2.0 lb/ton). Average anode bake plant emissions range from 0.004 to 0.009 kg/Mg (0.007 to 0.017 lb/ton) equivalent (NSPS limit is 0.05 kg/Mg [0.1 lb/ton]).

As indicated in Table 5-2, two of the five potlines subject to the NSPS reported TF emissions which exceeded the NSPS limits during the periods for which data are available. One of these used CWPB pots and the other VSS pots. The former reported 3 exceedances over a 3-year period (January 1982 to December 1984) and the latter recorded 3 in 20 months (January 1984 to August 1985). The dates of the exceedances and the reasons cited for their occurrence are provided on Table 5-3.

Tables 5-4 and 5-5 expand on the information provided in Table 5-2 by giving a calender year breakdown of that data. Most plants seem to show relatively little variation in emissions from year to year. Table 5-4 also indicates the relative contributions of primary and secondary sources to total potline emissions. The data show that 83 to 96 percent of total TF emissions are emitted through the roof monitors as secondary TF.

TABLE 5-3

RECORD OF REPORTED NSPS EXCEEDANCES WITH FAILURE RATIONALE[10-12]

Plant code[a]	Emission source[b]	Date of exceedance	Reported emission[c] (lb TF/TAP)	Emission limit (lb TF/TAP)	Comments
C	CWPB Potline 3	7/82	2.1	1.9/2.5	Exceeded original NSPS limit but not amended not-to-be-exceeded (NTBE) limit. Failure attributed to work practices and potroom conditions.
		7/82	2.07	1.9/2.5	Retest. Failed for same reason.
		10/83	3.38	1.9/2.5	Exceeded NTBE limit due to damper control malfunction. Retested at 1.20 after damper travel corrected.
E	VSS Potlines 1,2,&3	2/84	2.45	2.0/2.6	Exceeded original NSPS but not NTBE limit. Reason for exceedance not documented.
		5/84	2.15	2.0/2.6	Same as above.
		7/84	3.11	2.0/2.6	Exceeded NTBE limit. Reason not cited.
F	CWPB Anode Bake Plt	8/81	0.113	0.1	Exceeded NSPS in first month data reported. Reason not cited.

a Plant code same as Table 5-2. Coding is for simplicity.

b CWPB = Center-worked prebake
VSS = Vertical stud Soderberg

c lb TF/TAP = pounds total fluoride per ton aluminum produced
(1 lb/ton = 0.5 kilogram per megagram)

TABLE 5-4

EMISSIONS FROM POTLINES AT PRIMARY ALUMINUM PLANTS

WITH FLUORIDE CONTROLS[13]

Plant code[a]	Plant type[b]	Potroom group	Test year	No. Monthly tests [c] (Pri/Sec/Total)	Average TF (lb/TAP)[d]		Total TF (lb/TAP)		
					Primary	Sec.	Min.	Max.	Avg.
A	CWPB	1	1981	12/12/12	0.08	0.82	0.66	1.28	0.90
			1982	5/12/12	0.10	0.71	0.51	1.11	0.83
			1983	1/12/12	0.14	0.79	0.62	1.29	0.93
			1984	1/12/12	0.06	0.77	0.60	1.05	0.89
			1985	0/ 3/ 3	--	0.66	0.66	0.83	0.72
			all	19/51/51	0.09	0.77	0.51	1.28	0.88
		2	1981	12/12/12	0.05	0.89	0.69	1.32	0.94
			1982	5/12/12	0.03	0.85	0.59	1.15	0.89
			1983	1/12/12	0.05	0.86	0.73	1.08	0.90
			1984	1/12/12	0.06	0.87	0.80	1.06	0.93
			1985	0/ 3/ 3	--	0.87	0.76	1.11	0.93
			all	19/51/51	0.05	0.87	0.59	1.32	0.91
B	CWPB	1	1981	10/10/10	0.07	0.69	0.56	1.0	0.76
			1982	5/12/12	0.06	0.70	0.36	0.97	0.75
			1983	1/12/12	0.05	0.79	0.48	1.17	0.84
			1984	1/12/12	0.05	0.77	0.60	1.03	0.82
			1985	0/ 2/ 2	--	0.57	0.46	0.77	0.62
			all	17/48/48	0.07	0.73	0.36	1.17	0.79
		2	1981	10/10/9	0.13	0.99	0.79	1.46	1.01
			1982	5/12/12	0.08	0.85	0.54	1.30	0.95
			1983	1/12/12	0.04	0.80	0.48	1.22	0.89
			1984	1/12/12	0.08	0.85	0.64	1.35	0.90
			1985	0/ 2/ 2	--	0.53	0.50	0.72	0.61
			all	17/48/47	0.10	0.85	0.48	1.46	0.94
C	CWPB	1&2	1979	--/ 3/--	--	1.14	--	--	--
			1980	--/11/--	--	1.15	--	--	--
			1981	--/11/--	--	1.11	--	--	--
			1982	--/13/13	--	1.12	0.68	2.13	1.17
			1983	--/12/12	--	1.34	0.90	3.48	1.40
			1984	--/ 9/ 9	--	1.15	0.67	1.66	1.24
			1985	--/ 5/--	--	1.25	--	--	--
			all	--/64/34	--	1.18	0.67	3.48	1.27

TABLE 5-4 (concluded)

EMISSIONS FROM POTLINES AT PRIMARY ALUMINUM PLANTS

WITH FLUORIDE CONTROLS[13]

Plant code[a]	Plant type[b]	Potroom group	Test year	No. monthly tests [c] (Pri/Sec/Total)	Average TF (lb/TAP)[d]		Total TF (lb/TAP)		
					Primary	Sec.	Min.	Max.	Avg.
D	CWPB	1&2	1984	10/11/10	0.07	0.90	0.71	1.49	1.02
			1985	0/ 6/6	--	0.95	0.83	1.37	1.03
			all	9/17/16	0.07	0.92	0.71	1.49	1.02
E	VSS	1&2	1984	12/14/12	0.19	1.60	1.27	3.11	1.83
		(lines)	1985	10/10/10	0.05	1.04	0.88	1.37	1.09
		(1-3)	all	22/24/22	0.13	1.36	0.88	3.11	1.49

a Plant code same as Table 5-2. Coding is for simplicity.

b CWPB = Center-worked prebake
VSS = Vertical stud Soderberg

c Pri = primary
Sec = secondary

d All plants utilize dry scrubbers to control primary total fluorides (TF). Only one plant (Plant E) controls secondary emissions (using wet scrubbers).
lb/TAP = pounds per ton aluminum produced (1 lb/ton = 0.5 kilogram per megagram).

TABLE 5-5

EMISSIONS FROM ANODE BAKE FURNACES AT PRIMARY ALUMINUM PLANTS

WITH FLUORIDE CONTROLS[14]

Plant code[a]	Plant type[b]	Year	No. monthly tests	Emissions (lb TF/TAP)[c]		
				Minimum	Maximum	Average
F	CWPB	1981	5	0.010	0.113	0.043
		1982	12	0.003	0.040	0.009
		1983	1	--	--	0.011
		1984	1	--	--	0.006
		1985	1	--	--	0.003
		all	20	0.003	0.113	0.017
G	CWPB	1980	9	0.003	0.043	0.011
		1981	3	0.002	0.016	0.007
		1982	1	--	--	0.003
		1983	1	--	--	0.001
		1984	1	--	--	0.004
		1985	1	--	--	0.001
		all	16	0.001	0.043	0.008
H	CWPB	1983	1	--	--	0.011
		1984	9	0.002	0.017	0.006
		1985	1	--	--	0.006
		all	10	0.002	0.017	0.007
J	CWPB	1984	4	0.005	0.012	0.008
		1985	6	0.003	0.055	0.019
		all	10	0.003	0.056	0.014
K	CWPB	1984	3	0.003	0.004	0.003
		1985	4	0.005	0.038	0.016
		all	7	0.003	0.038	0.010

a Plant code same as Table 5-2. Coding is for simplicity.
b CWPB = center-worked prebake.
c All NSPS plants utilize dry scrubbers to control total fluorides (TF). lb/TF/TAP = pounds total fluorides per ton aluminum produced (1 lb/ton = 0.5 kilogram per megagram)

5.2.2 Visible Emissions

Visible emissions data were reported on one anode bake plant subject to the NSPS (Table 5-6).[15] The opacity readings were generally zero, but ranged up to 32 percent (6 minute average) on individual stacks.[1/] Readings on individual stacks met or exceeded 20 percent on 6 test runs. The NSPS limit is 20 percent. No reason was given for the high readings.

1/ The dry scrubber at this plant has 4 sections, each with 3 stacks (12 stacks total).

TABLE 5-6

VISIBLE EMISSIONS FROM ANODE BAKE FURNACE AT PLANT J[16]

Date	Reactor Stack 164 C-1			164 C-2			164 C-3			164 C-4		
	N	C	S	N	C	S	N	C	S	N	C	S
08/01/84	0.4	13.8	0	0	0	0				0	0	0
09/09/84				0	0	0	0	0	0	0	0	
08/24/84	0	0	0				0	0	0	0	0	0
08/27/84	0	0	1				0	0	0	0	0	0
09/26/84	0	0	0	0	0	0				0	0	0
09/28/84	0	0.4	0.4	0	0	0				0	0	0
10/2/84	0	0	0	0	0	0				0	0	0
10/10/84	0	0	0	0	0	0				0	0	0
10/11/84	0	0	0	0	0	0				0	0	0
10/12/84	0	0	0	0	0	0				0	0	0
11/6/84	0	0	0	0	0	0				2.2	2	2.2
11/7/84	0	0	0	0	0	0				1.2	1.67	1.2
11/9/84	0	0	0	0	0	0				0	0	0
12/3/84	0	0	0				0	0	0	0	0	0
12/6/84	0	0	0				0	0	0	0	0	0
12/7/84	0	0	0				0	0	0	0	0	0
01/08/85	0	0.4	0.2	0	0	0	0	0	0			
01/09/85	0	0	0	0	0	0	0	0	0			
01/10/85	0	2.2	2.2	0	0	0	0	0	0			
02/20/85	0	0	0	0	0	0	0	0	0			
02/21/85	0	0	0	0	0	0	0	0	0			
02/22/85	0	0	0	0	0	0	0	0	0			
02/26/85	0	0	0	0	0	0	0	0	0			
02/27/85	0	0	0.4	2	0	0	0	1.2	0			
02/28/85	0	0	0	0	0	0	0	0	0			
04/17/85	0	0	3.4	0	0	0				0	0	0.4
04/18/85	14.8	0	1.6	0	0	0				0	0	0
04/19/85	0	0	5.6	0	0	0				0	0	0
05/21/85				0	0	0	0	0	0	0	0	0
05/22/85				0	0	0	0	0	0	0	0	0
05/23/85				0.2	2.8	0.6	0	0.6	4	0	0	0
07/01/85	0	1	0	0	32	25				0	0	0
07/02/85	0	0	0	0	30	30				0	0	0
07/03/85	0	0	0	0	32	26				0	0	0

5.3 REFERENCES FOR CHAPTER 5

1. U.S. Environmental Protection Agency. Code of Federal Regulations. Title 40, Chapter I, Subchapter C, Part 60. Washington, D.C. Office of the Federal Register. June 30, 1980. Pages 44202-44217.

2. Letter and attchments from Hurt, R.E., Noranda Aluminum, to Noble, E., EPA:ISB. December 10, 1985. Information related to alternate test frequency.

3. Letter and attachments from Boyt, J.S., Aluminum Company of America, to Farmer, J.R., EPA:ESED. October 7, 1985. Response to Section 114 information request.

4. Letter and attachments from Dickie, R.C., Alumax of South Carolina, to Farmer, J.R., EPA:ESED. August 27, 1985. Response to Section 114 information request.

5. Reference 3.

6. Letter and attachments from Givens, H.L., Alcan, to Noble, E.A., EPA:ISB. September 26, 1985. Response to Section 114 information request.

7. Letter and attachments from Hurt, R.E., Noranda Aluminum, to Farmer, J.R., EPA:ESED. September 25, 1985. Response to Section 114 information request.

8. Letter and attachments from Casswell, S.J., Commonwealth Aluminum, to Farmer, J.R., EPA:ESED. September 6, 1985. Response to Section 114 information request.

9. Memo and attachments from Maxwell, W.H., EPA:ISB, to Primary Aluminum Docket (A-86-07). June 18, 1986. Fluoride emissions from NSPS primary aluminum plants.

10. Letter and attachments from Givens, H.L., Alcan, to Noble, E.A., EPA:ISB. Received June 28, 1985. Emission test data.

11. Letter and attachments from Casswell, S.J., Commonwealth Aluminum, to Noble, E., EPA:ISB. November 21, 1985. Emission test data.

12. Letter and attachment from Dickie, R.C., Alumax of South Carolina, to Noble, E., EPA:ISB. May 30, 1985. Emission test data.

13. Reference 9.

14. Reference 9.

15. Reference 3.

16. Reference 3.

6. COST ANALYSIS

Of the four types of primary aluminum reduction pots, only two types have been built in the years since the new source performance standards (NSPS) were promulgated. Those two are the center-worked prebake (CWPB) and the vertical stud Soderberg (VSS) pots. Industry sources advise that if any more primary aluminum plants are built they will contain potlines with CWPB pots. The one new VSS potline is unique in that it is the only one subject to the NSPS that has a sulfur dioxide (SO_2) scrubber.

The cost analysis will center on four areas. The first area will deal with the fluoride control costs for CWPB plants and will include both the potlines and the anode bake furnaces. The second area will cover fluoride control costs for a VSS plant and will include potline controls as well as controls for the fugitive fluorides leaving the building (primary and secondary controls). The third area will deal with the costs of SO_2 controls for the CWPB plants and the fourth with SO_2 controls for the VSS plants.

6.1 FLUORIDE CONTROLS

Only one level of fluoride emission control has been designated. Since no better technology has been developed, the dry alumina scrubber remains the best demonstrated technology for the control of total fluorides (TF). However, there is a difference in the level of control between the CWPB and the VSS units. The overall fluoride control efficiency for the CWPB potlines is assumed to be 98.5 percent, and that for the VSS potlines to be 89.6 percent based on information submitted by industry.

6.1.1 Costs for CWPB Fluoride Controls

Costs are drawn from two sources. The first source is a study of the cost for fluoride controls published in 1985 by the International Primary Aluminum Institute (IPAI).[1] The second source is information sent in from U. S. plants currently subject to the NSPS. The IPAI study covers the control costs for ten plants that are either new or recently retrofitted. Six of these are CWPB plants controlled by dry scrubbers which use fresh alumina as an adsorbing material.[1/] Fabric filters in the dry scrubbers collect the alumina which is then routed to the potline for use. Cost data for the six CWPB plants with dry scrubbers are shown in Table 6-1, along with the data from four NSPS installations. One other plant submitted data but a confidentiality request was made.

The IPAI costs are quoted in January 1981 dollars. These costs were escalated to August 1985 dollars using the Chemical Engineering Plant Index.[2,3] The IPAI data did not specify any anode bake furnace costs, so it was assumed that they were not included in the overall costs. The costs for the four NSPS installations have also been escalated to August 1985 dollars. Using an August 1985 price quotation of $1.047 per kilogram ($0.475 per pound) of aluminum from the Mineral Industries Surveys, the potential percentage increase in the price of aluminum resulting from the installation of controls was calculated and ranged from a credit of 1.3 percent (due to fluoride values recovered) to a positive 2.0 percent.[4]

Table 6-2 lists the fluoride control efficiency data and is presented to facilitate the cost effectiveness calculations shown in Table 6-3. Table 6-2 does not contain any emissions data for anode bake plants at the number-coded plants, since the IPAI document does not list bake plant emissions. Nor does it contain any emission information for the potlines at plants J and K, since only the anode bake plants at these facilities are subject to the NSPS.

The cost effectiveness in Table 6-3 varies from a negative $476 per megagram total fluoride ($476/Mg TF, $431/ton TF), to a positive $935/Mg ($848/ton) TF for the potlines. Cost effectiveness ratios for the anode bake plants vary from $9,400 to $11,500/Mg ($8,500 to $10,500/ton) TF. This might be attributable to an incorrect estimate of TF evolution from the furnace (no data are available on TF evolution rates at plants subject to the NSPS).

1/ One of the four exceptions is a side-worked prebake (SWPB) plant that was retrofitted to a CWPB unit. A second is a SWPB plant, unchanged. A third is a CWPB plant that utilizes electrostatic precitators before and after the dry scrubber to remove the fluoride laden alumina from the exhaust gases. The fourth utilizes a wet scrubber after the dry scrubber.

TABLE 6-1

COSTS OF DRY SCRUBBERS TO CONTROL TOTAL FLUORIDE EMISSIONS AT CENTER-WORKED PREBAKE PLANTS[5-11]

Plant code[a]	Capacity Mg Al/yr[b]	Control investment, $x10^6		Net annual TF control costs, $/Mg Al produced				
				Potlines		Furnace	Total cost	Cost as % of price[d]
		1/81$	8/85$	1/81$	8/85$[c]	8/85$	8/85$	
3	40,000	8.00	9.40	4.0	4.7	-[e]	4.7	0.4
4	60,000	7.75	9.11	<7.6>[f]	<8.9>	-	<8.9>	<0.8>
7	106,000	14.32	16.83	10.0	11.8	-	11.8	1.1
8	98,000	9.66	11.35	<7.8>	<9.2>	-	<9.2>	<0.9>
9	171,000	19.75	23.21	<10.9>	<12.8>	-	<12.8>	<1.2>
10	230,000	28.000	32.90	6.0	7.1	-	7.1	0.7
C/G	55,000	8.50[g]	12.67	-	-	-	13.0	1.2
D/H	77,000	44.48[h]	45.81	-	-	-	19.5[i]	1.9
J	311,000	3.54[j]	3.86	--	--	4.9	4.9	0.5
K	271,000	2.84[k]	2.95	--	--	4.0	4.0	0.4

a Arabic numerals represent plant designations from the IPAI report. Letters refer to designations of plants subject to the NSPS. coding is for simplicity.

b Mg Al/yr = megagram aluminum per year = 1.1 short tons Al/yr.

c IPAI potline costs in January 1981 dollars were updated to August 1985 using the Chemical Engineering Plant (CEP) Index (325.0/276.6 = 1.175)

d The U.S. Market price of aluminum, $0.475/lb or $950/ton ($1047/Mg), August 1985.

e Not reported or not applicable

f Credit

g CEP Index 1978 annual to August 1985 (325.0/218.8 = 1.49)

h CEP Index 1984 annual to August 1985 (325.0/322.7 = 1.01)

i CEP Index 1983 annual to August 1985 (325.0/316.9 = 1.03)

j CEP Index 1981 annual to August 1985 (325.0/297.0 = 1.09)

k CEP Index 1982 annual to August 1985 (325.0/314.0 = 1.04)

TABLE 6-2

EFFECTIVENESS OF TOTAL FLUORIDE CONTROL SYSTEMS AT CWPB PLANTS[12-19]

Plant name/ code[a]	Fluoride evolution kg/Mg of Al[b]		Overall fluoride removal efficiency, %		Fluoride removed, kg/Mg of Al		
	Potline	Furnace	Potline	Furnace	Potline	Furnace	Total
3	-[c]	-	-	-	-	-	-
4	25.0	-	95.8	-	23.95	-	23.95
7	13.2	-	95.6	-	12.62	-	12.62
8	28.0	-	96.6	-	27.05	-	27.05
9	28.0	-	96.0	-	26.88	-	26.88
10	27.8	-	97.3	-	27.05	-	27.05
C/G	33.0[d]	0.43[e]	98.1	99.1	32.37	0.426	32.80
D/H	33.0[d]	0.43[e]	98.5	99.2	32.51	0.427	32.94
J	-	0.43	-	98.4	-	0.423	0.423
K	-	0.43	-	98.8	-	0.425	0.425

a Arabic numerals represent plant designations from the IPAI report. Letters refer to designations of plants subject to the NSPS. Coding is for simplicity.

b kg/Mg of Al = kilograms per megagram of aluminum (1 kg/Mg = 2 pounds per ton).

c Not reported or not applicable.

d Estimated, based on review of available literature and information provided by the manufacturer. No data are available on TF emissions entering the primary control systems of potlines subject to the NSPS

e Estimated from the guidance document for primary aluminum reduction plants. No data are available on uncontrolled TF emissions from anode bake furnaces subject to the NSPS.

TABLE 6-3

COST-EFFECTIVENESS OF TOTAL FLUORIDE CONTROL SYSTEMS

Plant code[a]	Fluoride removal, kg/Mg of Al[b]			Removal costs, $/Mg of Al			Cost-effectiveness, $/Mg of TF ($/ton of TF)		
	Potline	Furnace	Total	Potline	Furnace	Total	Potline	Furnace	Total
3	-[c]	-	-	4.7	-	-	-	-	-
4	23.95	-	-	<8.9>[d]	-	-	<372> (<337>)	-	-
7	12.62	-	-	11.8	-	-	935 (848)	-	-
8	27.05	-	-	<9.2>	-	-	<340> (<308>)	-	-
9	26.88	-	-	<12.8>	-		<476> (<432>)	-	-
10	27.05	-	-	7.1	-	-	262 (238)	-	-
C/G	32.37	0.426	32.80	-	-	13.0	-	-	396(359)
D/H	32.48	0.427	32.91	-	-	19.5	-	-	592(537)
J	-	0.424	-	-	4.9	-	-	11,500 (10,500)	-
K	-	0.425	-	-	4.0	-	-	9,400 (8,500)	-

a Arabic numerals represent plant designations from the IPAI report. Letters refer to designations of plants subject to the NSPS. Coding is for simplicity.

b kg/Mg of Al = Kilograms per megagram of aluminum (1 kg/Mg = 2 pounds per ton).

c Not reported or not applicable.

d Credit.

6.1.2 Costs for VSS Fluoride Controls

Fluoride controls for a VSS plant are somewhat different from controls for a CWPB plant because the pots are more difficult to hood. One VSS potline has been installed since the NSPS was promulgated. This potline is equipped with primary controls consisting of a dry scrubber and a baghouse to collect fluoride emissions. Emissions which escape the primary hoods rise to the top of the potroom building and pass through a secondary scrubber consisting of screens that are continuously sprayed with a calcium solution. This secondary control system has a pressure drop of only about 25 pascals (0.1 inch of water). However, it removes over 65 percent of the TF present. It also removes about 62 percent of the SO_2 and 57 percent of the non-fluoride particulate. The resulting calcium fluoride/calcium sulfite sludge is flushed off of the screens and pumped to a lagoon for settling. Table 6-4 presents the capital investment and annualized costs for the VSS plant controls as reported by Plant E.[20] The total capital cost for TF and SO_2 controls is $233/Mg of annual capacity ($211/ton). The annualized costs are reduced by a large credit for fluorides captured by the dry scrubbers. With the plant operating at full capacity (161,000 Mg/yr, 177,600 tons/yr), the cost per Mg of aluminum produced is $14.99 ($13.60/ton). At the aluminum price of $1,047/Mg ($950/ton) used earlier, the $14.99/Mg ($13.60/ton) annualized control cost is 1.3 percent of the selling price. At 75 percent of capacity, the numbers are $19.99/Mg ($18.13/ton), and 1.7 percent, respectively.

6.2 SULFUR DIOXIDE CONTROLS

Two approaches are possible for the control of SO_2. The first is to limit the sulfur content of the anode constituents (the source of the SO_2). As noted in Chapter 2, three plants in two states are operating under prevention of significant deterioration (PSD) regulations limiting the sulfur content of their cokes to 3.0 percent in two cases and 0.7 percent in the other.[21] Plants not operating under PSD regulations also report using anode components with sulfur contents less than 3 percent.[22] Other sources indicate that cokes having a sulfur content of 3 percent or less will be available for the next 10 years.[23-25] As the practice of using less than 3 percent sulfur anodes is fairly widespread, no costs were developed for this method of SO_2 control.

TABLE 6-4

CAPITAL AND ANNUALIZED COSTS TO CONTROL TOTAL FLUORIDE AND SO_2 EMISSIONS FROM VSS PLANTS[26,27]
($000)

	Primary		Secondary		Total
	$ (yr)	$ (8/85)	$ (yr)	$(8/85)	$ (8/85)
Capital Costs					
Lines I & II	8,431(79)[a]	11,500	2,420(70)	6,300	17,800
Line III	7,341(80)	9,100	8,510(80)[b]	10,600	19,700
Annualized Costs	340(84)[c]	342	2,058(84)	2,072	2,414

a Chemical Engineering Plant Index Factors:

1979 Annual Index to August 1985: 325.0/238.7 = 1.36
1970 " " " " : 325.0/125.7 = 2.59
1980 " " " " : 325.0/261.2 = 1.24
1984 " " " " : 325.0/322.7 = 1.007

b Line III secondary scrubber costs include equipment to recycle the scrubbing medium for all three lines. Lines I and II originally utilized once-through scrubbing in their secondary scrubbers and the costs reflect that.

c Annualized costs of $5,963,000 less $5,873,000 recovery credits, plus $250,000 reporting costs

The second approach to SO_2 control is the use of add-on control technology (i.e., wet scrubbers). The use of CWPB versus VSS pots pose different problems for add-on SO_2 control. The CWPB plant uses much greater volumes of air to capture the pollutants from the pots (about 1.89 cubic meters per second [m^3/s], 4,000 actual cubic feet per minute [acfm]) compared to the 0.24 to 0.28 m^3/s (500 to 600 acfm) volume from VSS pots. For instance, a CWPB plant producing 90,700 Mg (100,000 tons) a year of primary aluminum and using coke with 3 percent sulfur will have a stack concentration of about 100 parts per million volume (ppmv) SO_2. On the other hand, a VSS plant producing 54,400 Mg (60,000 tons) a year of primary aluminum and using coke with 3 percent sulfur will have a stack concentration of about 350 ppmv of SO_2.

6.2.1 Costs for CWPB SO_2 Controls

The only add-on control in use on an NSPS potline is a spray tower on a VSS line. Therefore, estimating the costs of SO_2 controls when applied to CWPB potlines required several assumptions and cost data were lacking for some aspects of the analysis. Nevertheless, a rough cost analysis was performed to estimate the costs of this technology when transferred to a CWPB potline.[28-30] The resulting cost effectiveness values ranged from a credit up to a cost of $6,200/Mg ($5,645/ton).

Some of the assumptions made in performing the rough cost analysis include:

- coke of 3 percent sulfur content would become increasingly unavailable;
- SO_2 reductions of 65 to 85 percent would be achievable on CWPB pots using sodium-alkali scrubbers;
- costs from a prior document could be updated directly without considering any cost additions/deletions; and
- the use of a wet scrubber (spray tower) would be sufficient for fluoride and particulate control.

Further consideration of this analysis and comments received from the industry indicates that the resulting costs, and subsequent cost effectiveness values, are low.

6.2.2 Costs for VSS SO_2 Controls

Gases leaving the baghouse in the primary dry scrubber at Plant E are routed to a wet scrubber (spray tower) which captures the SO_2 in a sodium alkali spray. The cost analysis noted earlier also included VSS potlines.[31] However, the cost data submitted by industry did not allocate primary control costs between fluoride, controlled by the dry scrubber, and SO_2, controlled by a wet scrubber with a water treatment facility. In addition, the results of the analysis understate the costs of wastewater treatment and disposal, and, thus, the resulting control costs and cost effectiveness values are low.

6.3 REFERENCES FOR CHAPTER 6

1. Fluoride Emissions Control: Updated Costs for New Aluminum Reduction Plants. International Primary Aluminum Institute Environmental Committee Report. February 1985. Pages 6,7,11,16.

2. Economic Indicators. Chemical Engineering. 88(10):7. May 18, 1981.

3. Economic Indicators. Chemical Engineering. 92(25):7. December 9, 1985.

4. U.S. Department of the Interior, Bureau of Mines. Mineral Industry Surveys. Aluminum Industry in January 1985 through Aluminum Industry in April 1986, inclusive. Prepared in the Division of Nonferrous Metals. Dated April 9, 1985, through July 3, 1986.

5. Reference 1.

6. Reference 2.

7. Reference 3.

8. Reference 4.

9. Letter and attachments from Givens, H., Alcan, to Farmer, J.R., EPA:ESED. September 6, 1985. Response to Section 114 information request.

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12. Reference 1.

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14. Reference 10.

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16. U.S. Environmental Protection Agency. Background Information for Standards of Performance: Primary Aluminum Industry. Volume I: Proposed Standards. EPA-450/2-74-020a. October 1974. Pages 23 and 36.

17. U.S. Environmental Protection Agency. Primary Aluminum: Guidelines for Control of Fluoride Emissions from Existing Aluminum Plants. EPA-450/2-78-049b. December 1979. Table 3-1.

18. Memo from Noble, E.A., EPA:ISB, to Durkee, K.R., EPA:ISB. November 26, 1985. Report of June 1985 trip to Aluminum Company of America, Newburgh, Indiana. Page 4.

19. Memo and attachments from Maxwell, W.H., EPA:ISB, to Primary Aluminum Docket (A-86-07). June 18, 1986. Emission control effectiveness.

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21. U.S. Environmental Protection Agency. Compilation of BACT/LAER Determinations, Revised. EPA-450/2-80-070. May 1980. Source Code 7.1.

22. Memo from Maxwell, W.H., EPA:ISB, to Primary Aluminum Docket (A-86-07). May 30, 1986. Green anode composition and calculated SO_2 emissions.

23. Letter and attachments from Dickie, R.C., Alumax of South Carolina, to Noble, E.A., EPA:ISB. April 16, 1986. Comments on draft document.

24. Letter and attachments from Boyt, J.S., Aluminum Company of America, to Noble, E.A., EPA:ISB. April 29, 1986. Comments on draft document.

25. Letter and attachments from Goldman, J.H., The Aluminum Association, to Maxwell, W.H., EPA:ISB. May 21, 1986. Comments on draft document.

26. Reference 3.

27. Reference 20.

28. Memo and attachments from Maxwell, W.H., EPA:ISB, to Primary Aluminum Docket (A-86-07). June 19, 1986. Cost for add-on SO_2 control.

29. Singmaster and Breyer. Air Pollution Control in the Primary Aluminum Industry. EPA-450/3-73-004A. July 23, 1973. Pages 8-22 and 8-26.

30. Reference 3.

31. Reference 28.

7. ENFORCEMENT ASPECTS

7.1 COMMENTS

EPA Regional Offices, State agencies, the Aluminum Association, and companies subject to the new source performance standards (NSPS) were contacted to determine whether there were any problems with either enforcing the NSPS or complying with it.

Discussions with EPA offices and State agencies revealed no problems in enforcing the NSPS. Personnel at the plants contacted reported no problems in testing, monitoring, or recordkeeping (Table 7-1). One plant contact did suggest that alternate test methods be considered for secondary potroom testing.[1] He also claimed that the NSPS requirement for installing Method 14 sampling manifolds and stations is not interpreted consistently. He noted that his plant was required to install two sampling monitors and stations per potline, while other NSPS plants had to install only one. Another respondent noted that his plant is still operating under a consent decree (no operating permit has been issued). This plant is having difficulty in consistently achieving emission limits imposed for total fluorides, nonfluoride particulates, and sulfur dioxide.[2] Another commented about the high cost of testing and the time required to get waivers of the monthly testing requirements for primary control systems.[3]

7.2 SECONDARY EMISSION TESTING

Industry contacts have suggested that primary aluminum plants be allowed to petition for a reduction in the emission test schedule for secondary emissions from potrooms. As noted in Chapter 2, the 1980 amendment to the NSPS added a requirement for monthly compliance tests.[7] At the same time, provisions were made for establishing an alternative (less frequent) test schedule for primary potroom control systems and for anode bake plants. No provision was made for reducing the frequency of secondary potroom testing. However, Section 60.8(b)(4) of the General Provisions gives

TABLE 7-1

COMMENTS RECEIVED FROM PLANTS

WITH NSPS POTLINES OR ANODE BAKE FURNACES

Comment	Plant		
	Alcoa-Rockdale[4]	Alumax[5]	Commonwealth[6]
° NSPS unclear regarding the number of Method 14 sampling manifolds/stations required per potline (One plant required to install 2 per line, others needed only one)	-	x	-
° Excessive time required to conduct monthly testing of primary and secondary emissions	x	x	-
° Consider alternate test methods	-	x	-
° Consider reducing frequency of secondary tests	-	x	-
° Excessive time to get variance on monthly test requirement for primary control systems	x	x	-
° Excessive time required to get operating permit (still operating under consent decree)	-	-	x

to the Administrator, and subsequently to the States whose delegation requests have been approved, the authority to evaluate on a case-by-case basis whether a reduced test frequency is reasonable.[8]

There are two aspects to the question of whether a specific alternative test schedule should be made part of the standard for potroom secondary emissions. One is the possiblity that the normal variability of potroom emissions will result in periodic exceedances of the NSPS. The other is the very real possibility that plants granted a less stringent test schedule might cut back on maintenance activities and relax work practices. The first possibility can be quantified with an adequate data base; the second is more subjective.

Four years of data were evaluated from a plant which meets a State limitation of 0.51 kilograms total fluoride per megagram aluminum produced (kg/Mg) (1.02 pounds per ton [lb/ton]), much more stringent than the NSPS.[9] This plant is the only new "greenfield" plant subject to the NSPS. It uses sophisticated computer control techniques for potline operation and monitoring. The test results from this plant showed average TF emissions of 0.43 and 0.45 kg/Mg (0.86 and 0.90 lb/ton) (2 potlines). The data revealed that, if one assumes that plant operation and maintenance practices remain unchanged, the probability of exceeding the NSPS at this plant due to random variation alone is extremely remote (less than once every 100,000 years). The risk of an exceedance would be greater for plants with higher emissions or greater emissions variability. A procedure was developed for making similar assessments for other plants.

As noted earlier, the principal risk involved in reducing test frequency, aside from the possibility of a random failure, is that plants might take this opportunity to reduce their maintenance efforts and relax work practices. This risk might be reduced to a more acceptable level by mandating the development and use of work practices, housekeeping, and hood inspection programs to supplement less frequent testing. As noted in Chapter 4, informal inspection programs (which include hood inspections) have already been developed by some plants with NSPS potlines, to serve two purposes:

- to help in the allocation of maintenance dollars, and
- in the event of a test-failure, to support the claim of having a viable and continuing maintenance program.

The value of such programs cannot be determined with any certainty, because there has been no attempt to correlate such programs to the emission levels experienced.

States can use the statistical procedure developed to assess on a case-by-case basis the appropriateness of reduced secondary emission test frequency. The procedure documents the amount of test data needed to make an accurate assessment of the purely statistical probability of failure and the formulae to be used in making this assessment. Procedures for ensuring adequate operation and maintenance practices would need to be tailored to plant specific conditions.

7.3 NSPS INTERPRETATION

The affected facilities covered under the standards are each potroom group and each anode bake furnace. A potroom group can be an uncontrolled potroom, a potroom which is controlled by a single primary control device, or a group of potrooms or potroom segments ducted to a common primary control device. Typical potlines built since proposal of the standards have been housed in two potrooms. Each of these potrooms have been divided in half by crane- and traffic-ways. Thus, there are four potroom segments per potline. The typical ductwork configuration has taken the primary emissions from two of these segments to one primary control device, forming two potroom groups per potline. The NSPS, and Reference Method 14, also require one secondary emissions sampling manifold per potroom group. Under the typical configuration noted above, two secondary monitors would be required per potline.

It has been determined that interpretation and application of the NSPS is not consistent, at least with regard to the number of secondary monitoring stations required and the application of the NSPS emission limits, at prebake plants. The three NSPS prebake facilities are discussed below.

7.3.1 Plant 1

This plant has two potroom groups per potline as per the affected facility designation of the NSPS. Each primary control device is tested and the results reported separately. The plant also has one secondary emission monitoring system per potroom group, in accordance with the standards, and each is tested monthly.

7.3.2 Plant 2

This plant also has two potroom groups per potline. However, the two primary emission test values are added together to provide one primary value per potline. In addition, the plant only has one secondary monitoring system for the entire potline instead of the two specified by the NSPS. Data from this one secondary station are combined with the one primary emission value to determine compliance with the NSPS emission limit. That is, two primary emission tests results and one secondary emission test result are added to determine compliance with the NSPS limit. Thus in this case, the NSPS emission limit is applied to the entire potline, but with only one secondary emission value, rather than to the individual potroom groups.

7.3.3 Plant 3

This plant also has two potroom groups per potline. In addition, it has two secondary monitoring stations per potroom group instead of the one required. However, only one of the stations is used during the monthly test, instead of one per potroom group. It cannot be determined from the data submitted how these test results are combined, but it appears that this plant also is meeting the NSPS emission limit applied to the potline rather than to the potroom groups individually but with only one secondary monitor data value.

7.4 REFERENCES FOR CHAPTER 7

1. Letter and attachments from Dickie, R.C., Alumax of South Carolina, to Farmer, J.R., EPA:ESED. August 27, 1985. Response to Section 114 information request.

2. Letter and attachments from Casswell, S.J., Commonwealth Aluminum, to Farmer, J.R., EPA:ESED. September 6, 1985. Response to Section 114 information request.

3. Letter and attachments from Boyt, J.S., Aluminum Company of America, to Farmer, J.R., EPA:ESED. October 7, 1985. Response to Section 114 information request.

4. Reference 3.

5. Reference 1.

6. Reference 2.

7. U.S. Environmental Protection Agency. Standards of Performance for New Stationary Sources: Primary Aluminum Plants; Amendments. 40 CFR Part 60, Subpart S. Federal Register, Vol. 45, No. 127. Monday, June 30, 1980. Pages 44202-44217.

8. U.S. Environmental Protection Agency. Code of Federal Regulations. Title 40, Chapter I, Subchapter C, Part 60, Subpart A. Washington, D.C. Office of the Federal Register. July 1, 1984. pp 180-181.

9. U.S. Environmental Protection Agency. Primary Aluminum: Statistical Analysis of Potline Fluoride Emissions and Alternate Sampling Frequency. EPA-450/3-86-012. October 1986.

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16. ABSTRACT

As required by Section 111 (b) of the Clean Air Act, as amended, a four year review of the new source performance standards for primary aluminum reduction plants (40 CFR Subpart S) was conducted. This report presents a summary of the current standards, the status of current applicable control technology, and the ability of plants to meet the standards. No revision to the standards are recommended, but EPA should make available a procedure upon which a decision to reduce the frequency of secondary monitoring can be made.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air pollution Aluminum industry Fluorides Standards of performance Pollution control	Air Pollution Control	13B

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