BART DETERMINATION FOR ALCOA INTALCO WORKS
FERNDALE, WASHINGTON

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TABLE OF CONTENTS

1.0 INTRODUCTION 1-1

2.0 IDENTIFICATION OF BART-ELIGIBLE UNITS AT INTALCO 2-1

3.0 BART-ELIGIBLE EMISSION UNIT GROUP DESCRIPTION 3-1
3.1 PRIMARY ALUMINUM REDUCTION PROCESS DESCRIPTION 3-1
3.1.1 EXISTING POTLINE EMISSIONS CONTROL 3-2
3.1.2 ANODE BAKE FURNACE EMISSIONS CONTROL 3-2
3.1.3 ALUMINUM HOLDING FURNACE EMISSIONS CONTROL 3-3

4.0 BASELINE CONDITIONS AND VISIBILITY IMPACTS FOR BART-ELIGIBLE UNITS 4-1
4.1 CALPUFF MODEL AND BASELINE EMISSION INPUTS 4-1
4.2 SCREENING-LEVEL MODELING ANALYSIS 4-1
4.3 REFINED MODELING ANALYSIS 4-2

5.0 BART ANALYSIS FOR BART-ELIGIBLE EMISSION UNITS 5-1
5.1 AVAILABLE AND TECHNICALLY FEASIBLE EMISSION CONTROL OPTIONS 5-1
5.1.1 POTLINE EMISSIONS AND EXISTING CONTROLS 5-1
5.1.2 ANODE BAKE FURNACE EMISSIONS AND EXISTING CONTROLS 5-1
5.1.3 POTENTIALLY APPLICABLE BART CONTROL OPTIONS FOR SO_2 5-2
5.1.4 POTENTIALLY APPLICABLE BART CONTROL OPTIONS FOR PM 5-12
5.1.5 POTENTIALLY APPLICABLE BART CONTROL OPTIONS FOR NO_X 5-13
5.1.6 SUMMARY OF TECHNICALLY FEASIBLE BART CONTROL OPTIONS 5-15
5.2 CONTROL EFFECTIVENESS OF FEASIBLE OPTIONS 5-17
5.2.1 SO_2 WET SCRUBBING 5-17
5.2.2 SO_2 POLLUTION PREVENTION 5-18
5.2.3 ANODE BAKE FURNACE ADVANCED FIRING SYSTEM 5-18
5.2.4 ANODE BAKE FURNACE LOTOX™ SYSTEM 5-18
5.3 EVALUATION OF COSTS AND OTHER IMPACTS 5-18
5.3.1 COST IMPACTS FOR FEASIBLE CONTROLS 5-18
5.3.2 ENERGY IMPACTS 5-21
5.3.3 GREENHOUSE GAS GENERATION 5-21
5.3.4 NON-AIR QUALITY ENVIRONMENTAL IMPACTS 5-21
5.3.5 REMAINING USEFUL LIFE 5-22
5.4 EVALUATE VISIBILITY IMPACTS 5-22

6.0 DETERMINATION OF BART 6-1
6.1 ALUMINUM POTLINES 6-1
6.2 ANODE BAKE FURNACE 6-1
6.3 ALUMINUM HOLDING FURNACES 6-2
6.4 MATERIAL HANDLING AND TRANSFER OPERATIONS 6-2

TABLES

3-1	Primary Aluminum Reduction Emission Units
4-1	Source Input Data for Baseline Modeling – Point Sources
4-2	Source Input Data for Baseline Modeling – Line Sources
4-3	Source Input Data for Baseline Modeling – Area Sources
4-4	Source Input Data for Baseline Modeling – Volume Sources
4-5	Screening Baseline Visibility Modeling Results
4-6	Refined Baseline Visibility Modeling Results
4-7	Culpability Analysis for Refined Baseline Visibility Modeling Results in Olympic National Park
5-1	RBLC Database Search Results for Primary Aluminum Facilities
5-2	Post Control SO_2 Emission Rates
5-3	Summary of Impacts Analysis for SO_2 Control Scenarios
5-4	Source Input Data for Post Control SO_2 Modeling
5-5	Post Control SO_2 Visibility Modeling Results

FIGURES

5-1	Wet Scrubber Process Flow Diagram

APPENDICES

A	BART Modeling Results
B	Business Confidential Information
C	Pre-Feasibility Report
D	Wet Scrubber Economic and Energy Impact
E	Greenhouse Gas Emission Calculations

ACRONYMS

acfm	actual cubic feet per minute
AWMA	Air and Waste Management Association
BACT	Best Available Control Technology
BART	Best Available Retrofit Technology
CAA	Clean Air Act
CFR	Code of Federal Regulations
DNR	Department of Natural Resources
dv	deciview
ELG	Effluent Limitations Guidelines
ESP	Electrostatic Precipitator
FGD	Flue Gas Desulfurization
Intalco	Alcoa Intalco Works
LAER	Lowest Achievable Emissions Rate
lb/day	pounds per day
LSFO	Limestone Slurry Forced Oxidation
LSNO	Limestone Slurry Natural Oxidation
MW	Megawatt
NESHAP	National Emission Standards for Hazardous Air Pollutants
NO_x	Nitrogen Oxides
PAH	Polycyclic Aromatic Hydrocarbons
PM	Particulate Matter
$PM_{2.5}$	Particulate Matter less than 2.5 micrometers in diameter
PM_{10}	Particulate Matter less than 10 micrometers in diameter
ppm	parts per million
ppmv	parts per million by volume
RACT	Reasonably Available Control Technology
RBLC	RACT/BACT/LAER Clearinghouse
SCR	Selective Catalytic Reduction
SEPA	State Environmental Protection Act
SNCR	Selective Non-Catalytic Reduction
SO_2	Sulfur Dioxide
USEPA	United States Environmental Protection Agency

EXECUTIVE SUMMARY

The Clean Air Act (CAA) requires the protection of visibility in 156 scenic areas across the United States. Under CAA Section 169A(b)(2)(A), states must require certain existing stationary sources to install Best Available Retrofit Technology (BART). Alcoa, Inc. – Intalco Works (Intalco) is a "BART-eligible" source. A BART determination is required because Intalco emits air pollutants that may reasonably be anticipated to contribute to impairment of visibility in a Class I area.

The BART analysis contained herein lists the individual BART-eligible emission units and evaluates visibility impacts, control option feasibility, cost effectiveness and visibility improvement. The BART evaluation was completed according to guidance provided in 40 Code of Federal Regulations (CFR) 51, Appendix Y and the Washington, Oregon, and Idaho BART modeling protocol[1].

A baseline Class I area visibility impact analysis was performed on 100 BART-eligible emission units at Intalco using the CALPUFF model as recommended by the modeling protocol. These sources include three potlines, the anode bake furnace, 12 aluminum holding furnaces, various material handling and transfer operations, natural gas, diesel and propane combustion sources, and other small miscellaneous sources.

The modeled or projected 98th percentile visibility impacts for the entire facility exceed the 0.5 deciview (dv) contribution threshold in five Class I areas: Alpine Lakes Wilderness Area, Glacier Peak Wilderness Area, Mount Rainier National Park, North Cascades National Park, and Olympic National Park. The highest modeled facility-wide impact is 1.527 deciviews (dv) in the Olympic National Park (ONP). The modeled visibility impacts are primarily from the potlines, with a small amount from the anode bake furnace. Other sources contribute negligible amounts to the total as described further below.

The highest modeled or projected 98th percentile visibility impact of the potlines is approximately 1.44 dv in the ONP. The projected impacts in the other, more distant, Class I areas are lower. More than 98% of the projected impact from the potlines is attributable to emissions from the potroom primary control devices, with the remainder from the existing potroom roof scrubbers. More than 96% of the potroom primary control device impact is from emissions of sulfur dioxide (SO_2).

[1] *Modeling Protocol for Washington, Oregon, and Idaho: Protocol for the Application of the CALPUFF Modeling System Pursuant to the Best Available Retrofit Technology (BART) Regulation.* www.deq.state.or.us/aq/haze/docs/bartprotocol. October 11, 2006.

Results from the BART analysis for potroom emissions determined that BART for potline SO_2 emissions is a pollution prevention limit of 3% sulfur in the calcined petroleum coke used to manufacture anodes (i.e., coke). BART for other pollutants emitted from the potlines [particulate matter (PM) and nitrogen oxides (NO_x)] was determined to be the existing level of emission control.

The highest modeled or projected 98th percentile visibility impact from the anode bake furnace is approximately 0.053 dv in ONP, with lower projected impacts in other Class I areas. More than 40% of the anode bake furnace impact (0.02 dv) is from SO_2 emissions and 55% of the impact (0.03 dv) is from NO_x. The analysis of control options for the anode bake furnace determined that BART for bake furnace SO_2 emissions is a pollution prevention limit of 3% sulfur in the coke. BART for other pollutants emitted from the anode bake furnace (NO_x and PM) was determined to be the existing level of emission control.

Additional BART-eligible emission units at the Intalco facility include aluminum holding furnaces, various material handling and transfer operations, natural gas, diesel, and propane combustion, and other small miscellaneous sources that support the primary aluminum ore reduction process. The combined projected impacts from all remaining BART-eligible emission units (sources other than the potlines and anode bake furnace) are less than 0.05 dv in ONP, with lower projected impacts in other Class I areas. Considering the minimal contribution to visibility impairment (less than 0.05 dv) and the existing level of emissions control, these emission sources were excluded from further engineering analysis and BART was determined to be no further emissions control for these sources.

1.0 INTRODUCTION

The Clean Air Act (CAA) requires the protection of visibility in 156 scenic areas across the United States. Under CAA Section 169A(b)(2)(A), states must require certain existing stationary sources to install Best Available Retrofit Technology (BART). A "BART-eligible" source is one that is contained in the 26 identified source categories that has the potential to emit greater than or equal to 250 tons per year of any air pollutant and was put in place during the 15-year interval between August 7, 1962, and August 7, 1977. BART is required when any source meeting this definition emits any air pollutant that may reasonably be anticipated to cause or contribute to any impairment of visibility in any Class I area.

2.0 IDENTIFICATION OF BART-ELIGIBLE UNITS AT INTALCO

Alcoa, Inc. – Intalco Works (Intalco) operates emission units that fall within the categories of primary aluminum ore reduction plants, one of the 26 identified source categories to which BART is applicable. The Intalco facility was originally constructed in 1965, and began operation in 1966. Therefore, the facility's emission units were in existence on August 7, 1977, but were not in operation before August 7, 1962. The facility has the potential to emit greater than or equal to 250 tons/year of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter (PM), all of which have been classified as visibility impairing pollutants. As such, the Intalco facility is defined as a BART-eligible source. All emission units at Intalco, with the exception of one remelt furnace, were constructed between August 7, 1962 and August 7, 1977 and are, therefore, BART-eligible.

3.0 BART-ELIGIBLE EMISSION UNIT GROUP DESCRIPTION

3.1 PRIMARY ALUMINUM REDUCTION PROCESS DESCRIPTION

Intalco's primary aluminum reduction operations include three potlines, an electrode manufacturing operation, consisting of a paste production operation and a green anode baking furnace, and miscellaneous material handling operations.

The potline operation manufactures metallic aluminum by the electrolytic reduction of alumina in side-worked prebake cells. Direct electrical current, passing between anodes and the cathode, electrolytically reduces the alumina to metallic aluminum and oxygen. Molten aluminum is deposited and accumulates over time at the cathode beneath a layer of molten cryolite bath. Periodically the molten aluminum is siphoned from beneath the cryolite bath and processed to achieve specific metal properties or is retained as pure aluminum. The produced aluminum is solidified into intermediate or final products.

Anodes are manufactured in an ancillary on-site paste production plant. Calcined petroleum coke used to manufacture anodes (i.e., coke) is crushed and sized, anode butt material is crushed and sized, and both are mixed together with pitch and formed into self-supporting carbonaceous blocks called "green anodes." The green anodes are then cured and baked in furnaces before being used in the side-worked prebake aluminum reduction process.

Table 3-1 presents the individual emission units that are included in the primary aluminum reduction emission unit group and that were identified as BART-eligible emission units. Potlines A, B, and C emit SO_2 and PM, and the anode bake furnace emits lesser amounts of SO_2, NO_x, and PM. These emission units are already equipped with sophisticated emission control equipment for PM, so the BART determination for these emission units focuses primarily on potential reductions for SO_2 and NO_x.

The remaining emission units identified in Table 3-1 include aluminum holding furnaces, various material handling and transfer operations, natural gas, diesel, and propane combustion, and other small miscellaneous sources that support the potlines and anode bake furnace. Aside from the natural gas combustion products, emissions from most of the support operations consist of relatively small amounts of PM that are controlled by fabric filter type control devices. Fabric filters effectively remove more than 99% of particulate emissions and, based on the control technology review, represent the best available control for these types of material handling and transfer operations. The natural-gas fired units at Intalco emit very little PM. Given the relatively low level of emissions, the fact that fabric filters represent the best available control, and the minimal impacts of these sources on visibility, these emission units were excluded from

further BART engineering analysis. BART for these support operations was determined to be the existing level of control.

3.1.1 Existing Potline Emissions Control

The potlines at Intalco consist of six potroom groups [i.e., "…a group of potroom segments ducted to a common control system" (40 Code of Federal Regulations 60.191)] of electrolytic reduction cells connected in series that produce molten aluminum. There are two potroom groups per potline. Each potroom is comprised of 120 reduction cells (or pots) with 18 anodes per cell. All pots at Intalco are hooded to control emissions. Emissions captured by the hoods are drawn through primary control systems, which consist of dry alumina injection systems with baghouses for the control of PM and fluoride emissions. A small fraction of the pot emissions escape capture by the hoods and are released inside the potrooms. These secondary emissions are drawn through a secondary control system which consists of wet roof scrubbers that control PM and fluoride emissions.

Each of Intalco's primary control system centers consists of multi-compartment baghouse cells. Either reverse pulse or reverse flow is used in cleaning the fabric filters of the baghouse cells. The multiple compartment design allows for maintenance and troubleshooting of individual cells while the baghouse center is still operating. The PM control efficiency of the primary control system is estimated to be 97.7% based on measured emissions.

Fugitive potroom emissions from primary aluminum smelters are typically not controlled. However, Intalco operates a secondary pollution control system on each of its potlines to abate fugitive emissions. The secondary control system consists of 159 wet roof scrubbers for the three potlines. Each wet roof scrubber treats approximately 10,000 actual cubic feet per minute (acfm) of potroom air. The wet roof scrubbers become inoperable and must be shutdown during any sustained periods of below-freezing temperatures in order to avoid permanent damage from freezing. These shutdowns occur only in the winter months, and occur infrequently. For the last four operating years, shutdowns due to cold temperatures have averaged less than six or seven days per year. The PM control efficiency of the secondary control system is estimated to be approximately 82%.

3.1.2 Anode Bake Furnace Emissions Control

Products of natural gas combustion, products of combustion from volatiles liberated during the baking of green anodes, and other emissions typically associated with anode baking are exhausted to a dry alumina scrubbing system. The baking furnace emission control equipment conditions the exhaust gases prior to alumina being injected. Fabric filtration modules located downstream of the alumina injection reduce PM emissions by as much as 99%.

3.1.3 Aluminum Holding Furnace Emissions Control

The 12 holding furnaces at Intalco vary in size. The largest of these furnaces has a natural gas rated burner capacity of 22 MMBtu/hr. There are no emission controls associated with the aluminum furnaces at Intalco.

4.0 BASELINE CONDITIONS AND VISIBILITY IMPACTS FOR BART-ELIGIBLE UNITS

CALPUFF modeling was performed to evaluate the cumulative visibility impacts of BART-eligible emission units at Intalco, and to compare the relative contribution of individual emission units to the total visibility impact. All modeling performed in association with this BART determination was done by TRC Environmental Corporation following the WDOE's BART modeling protocol[2]. The complete Intalco BART modeling report is contained in **Appendix A**.

4.1 CALPUFF MODEL AND BASELINE EMISSION INPUTS

CALPUFF and its meteorological model CALMET are designed to handle the complexities posed by complex terrain, long source receptor distances, chemical transformation and deposition, and other issues related to Class I impacts. The USEPA adopted the CALPUFF modeling system as a guideline model for source-receptor distances greater than 50 km and for use on a case-by-case basis in complex flow situations for shorter distances (Federal Register, April 15, 2003). CALPUFF was recommended for Class I impact assessments by the Federal Land Managers Workgroup in 2000 and the Interagency Workgroup on Air Quality Modeling in 1998. CALPUFF is recommended by USEPA (Federal Register, July 6, 2005) and the State of Washington[3] for BART analyses.

Tables 4-1, 4-2, 4-3, and 4-4 present the baseline modeling source input data for point sources, line sources, area sources, and volume sources, respectively, that were used in the CALPUFF model to forecast the visibility impacts. In accordance with Section IV of 40 CFR 51 Appendix Y and the BART modeling protocol for Washington, Oregon, and Idaho, baseline emission rates used in the model were based on 24-hour average actual emissions from the highest emitting day.

4.2 SCREENING-LEVEL MODELING ANALYSIS

Screening runs were performed for 2003 through 2005 using the 4-km resolution CALMET meteorological data set prepared by Geomatrix for Washington, Oregon, and Idaho. Eight Class I areas (Mount Adams Wilderness Area, North Cascades National Park, Goat Rock Wilderness Area, Pasayten Wilderness Area, Glacier Peak National Park, Alpine Lakes Wilderness Area, Olympic National Park, and Mount Rainier National Park) were included in the screening level visibility modeling.

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[2] *Modeling Protocol for Washington, Oregon, and Idaho: Protocol for the Application of the CALPUFF Modeling System Pursuant to the Best Available Retrofit Technology (BART) Regulation.* www.deq.state.or.us/aq/haze/docs/bartprotocol.pdf. October 11, 2006.

[3] Ibid.

The screening level analysis results are presented in Table 4-5. These results project visibility impacts within Mount Adams Wilderness Area of less than 0.5 dv, indicating that Intalco does not contribute to visibility impairment in the Mount Adams Wilderness Area. A refined, 1-km visibility impact analysis was subsequently performed on the remaining seven Class I areas.

4.3 REFINED MODELING ANALYSIS

Table 4-6 presents the modeled 98th percentile total source visibility impacts (reported as deciviews) for 2003, 2004, and 2005 in the seven Class I areas identified in the screening modeling analysis as having visibility impacts greater than 0.5 dv. Refined modeled visibility impacts exceed the contribution threshold limit of 0.5 dv at Alpine Lakes Wilderness Area, Glacier Peak Wilderness Area, Mount Rainier National Park, North Cascades National Park, and Olympic National Park. Refined modeled visibility impacts at the Goat Rock and Pasayten Wilderness Areas were below the 0.5 dv contribution threshold. The highest predicted visibility impacts were in Olympic National Park.

Table 4-7 presents a culpability analysis for Olympic National Park. Individual emission unit visibility impacts in Olympic National Park were used to identify which emission units were forecasted to have the most impact on visibility impairment. The modeled or projected 98th percentile visibility impact from the combined potline emissions for the maximum year is approximately 1.44 dv in Olympic National Park. More than 98% of this projected impact from the potlines is attributable to emissions from the potroom primary control devices, with the remainder from the potroom wet roof scrubbers. More than 96% of the potroom primary control device impact is from emissions of SO_2. The modeled or projected 98th percentile visibility impact for the maximum year from the anode bake furnace was 0.053 dv in Olympic National Park. More than 40% of the anode bake furnace impact is attributable to SO_2 emissions and approximately 55% of the impact is from NO_x emissions. The total projected impacts from the remainder of the facility's BART-eligible sources for the maximum year are 0.049 dv in Olympic National Park.

For all emission units other than the potlines and anode bake furnace, the refined modeling results in Table 4-7 show a combined total visibility impact that is less than 0.05 dv. The combined impact of these emission units is less than 10% of the facility-wide contribution threshold level of 0.5 dv for BART applicability established for Washington[4]. Reduction in emissions from these units would not result in significant visibility improvement in any of the Class I areas. For example, the modeled visibility impact from all 12 aluminum holding furnaces (casthouse stacks in Table 4-7) was 0.004 dv at ONP. The use of added controls for these

[4] *Modeling Protocol for Washington, Oregon, and Idaho: Protocol for the Application of the CALPUFF Modeling System Pursuant to the Best Available Retrofit Technology (BART) Regulation.* October 11, 2006. www.deq.state.or.us/aq/haze/docs/bartprotocol.pdf

furnaces would provide a negligible visibility improvement at ONP, as well as the other Class I areas.

Based on results from the baseline modeling, the scope of the BART control analysis and engineering cost calculations were focused on the potlines and anode bake furnace.

5.0 BART ANALYSIS FOR BART-ELIGIBLE EMISSION UNITS

The results of the refined CALPUFF modeling show that Intalco's potline reactors and anode bake furnace contribute to visibility impairment in five Class I areas. The BART analysis completed for these emission sources is described in this section. The analysis included a review of available and technically feasible retrofit technologies (Steps 1 and 2), determination of control effectiveness for feasible options (Step 3), evaluation of cost and secondary impacts for feasible alternatives (Step 4), and analysis of impacts and visibility improvements (Step 5).

5.1 AVAILABLE AND TECHNICALLY FEASIBLE EMISSION CONTROL OPTIONS

Steps 1 and 2 of the BART analysis are to identify available emission control options and to evaluate the technical feasibility of these control technologies. Control options for the potline reactors and anode bake furnace are described separately in the following sections.

5.1.1 Potline Emissions and Existing Controls

Aluminum is manufactured in large electrolytic reduction cells called pots. Aluminum is produced from alumina in the pot as current is passed from a carbon anode to carbon blocks on the pot wall, which serve as the cathode. The anodes are made from pitch and coke. The major pollutants emitted from the cells are PM, hydrogen fluoride, SO_2, and carbon monoxide. PM includes particulate fluoride, carbon dust, and alumina. SO_2 comes from the sulfur in the components used to make the anodes. NO_x emissions are minimal since there is no external fuel or combustion zone and there are no large sources of nitrogen in the raw materials.

Emissions from the pots are collected by close capture hoods over each pot. The hoods enclose the pot as tightly as possible to collect off-gases, but sections may be removed to allow anodes to be changed. The off-gases are collected into manifolds that combine the gases from the individual pots. The temperature of the exhaust gases entering the control equipment is typically 150 to 300°F[5]. The combined gases are routed to a dry alumina scrubber. The potline primary control systems for Intalco's three potlines consist of dry scrubbers using alumina injection with fabric filtration for PM control. The system at Intalco is large, treating approximately 1,815,000 acfm of 180°F exhaust gases.

5.1.2 Anode Bake Furnace Emissions and Existing Controls

The anode bake furnace structure is a series of interconnected refractory flues connected to side main exhaust manifolds. The furnace is fueled with natural gas. Exhaust gases are routed so that

[5] Air and Waste Management Association (AWMA). 2000. *Air Pollution Engineering Manual*, Second Edition.

flue gases preheat the next section to be fired. Flue gases from the anode bake furnace contain PM, hydrogen fluoride, SO_2, carbon monoxide, and hydrocarbons.

The bake furnace control device used at Intalco is similar to the potline primary control system, consisting of dry alumina injection with fabric filtration. The bake oven gas stream is conditioned by a water spray to reduce the inlet temperature before it enters the scrubber. Fresh and recycled alumina are injected into the gas stream, gaseous fluoride and POM are adsorbed onto the alumina surface, and fabric filters on top of the reactor compartments collect entrained particulate matter present in the gas stream. The system at Intalco treats approximately 216,000 acfm of 205°F exhaust gases.

5.1.3 Potentially Applicable BART Control Options for SO_2

Sulfur in the anodes is oxidized, releasing SO_2 from the potlines as the anodes are consumed. SO_2 is also released from the anode bake furnace as pitch used to help form the anodes is oxidized during the baking process. Options for controlling SO_2 include both add-on controls and pollution prevention.

5.1.3.1 Add-on Emission Controls

Absorption and adsorption have been used for the control of SO_2 emissions from numerous power utility and industrial processes. As a result many commercialized control technologies have been used for SO_2 control. However, the practical application of these controls systems to the potline reactors and anode bake furnace is limited by the very low inlet SO_2 levels, in the range of 100 parts per million by volume (ppmv), and the expected range of gas conditions, including temperature, oxygen content, humidity, SO_2/O_2 ratio, and gas impurities.

Eight different SO_2 control options were considered as having potential practical application as part of the BART analysis. Two of these technologies have been applied to the control of SO_2 emissions at aluminum smelters. Six of the control options use wet scrubbing and two use dry scrubbing technology. The eight potentially applicable control options are:

- Limestone slurry scrubbing with forced oxidation
- Limestone slurry scrubbing with natural oxidation
- Conventional lime wet scrubbing
- Seawater scrubbing
- Dual alkali sodium/lime scrubbing (dilute mode)
- Conventional sodium scrubbing

- Dry injection
- Semi-dry scrubbing

5.1.3.1.1 Wet Scrubbing

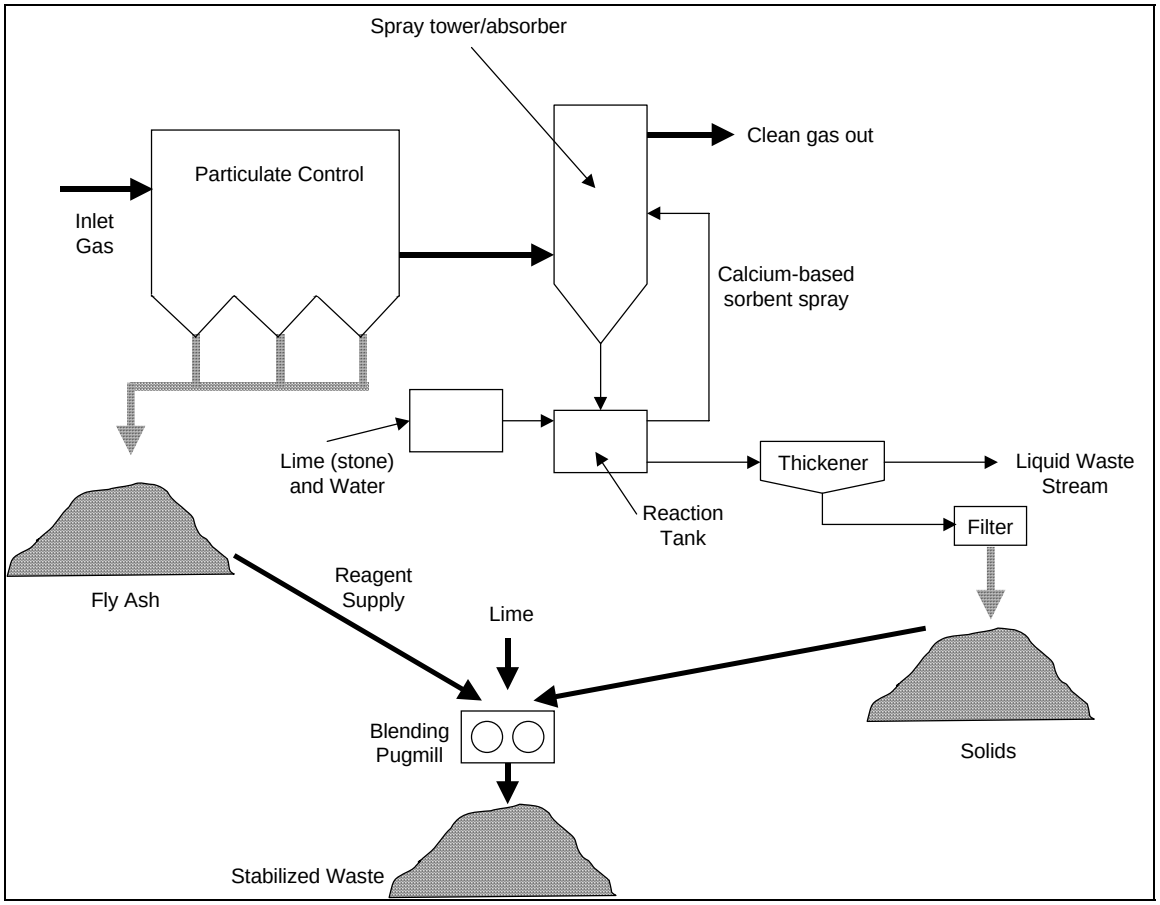
The primary development of SO_2 control technology occurred because of the need to control emissions from the coal-fired, electric utility power industry[6]. The large volumetric size of the potroom exhaust (approximately 1,815,000 acfm) would require a system similar to those used in the electric utility power industry.

The typical temperature range for wet scrubbers is 300 to 700°F. For utility combustion units, wet scrubbing systems have been installed on systems as large as 1,500 megawatts (MW). Sodium compounds, lime, or limestone can be used. However, the high solubility of sodium complicates disposal of waste and wastewater. The typical sorbent material is lime or limestone. Lime is generally easier to manage on-site but is significantly more costly. Wet limestone scrubbing has a high capital and operating cost due to the handling of liquid reagent and waste, but is the preferred process for coal-fired utility power plants due to the low cost of limestone and high removal efficiencies. Typical removal efficiencies for wet scrubbers are between 80 and 95%. Approximately 85% of the flue gas desulfurization (FGD) systems installed in the United States are wet scrubber systems[7].

In wet scrubbers, the waste gas enters a large vessel (spray tower or absorber), where it is sprayed with water slurry. The calcium in the slurry reacts with SO_2 to form $CaSO_3$. A portion of the slurry from the reaction tank is pumped into the thickener, where the solids settle before going to a filter for final dewatering to about 50% solids. Figure 5-1 is a simplified process flow diagram of a conventional wet scrubber.

[6] AWMA. 2000. *Air Pollution Engineering Manual*, Second Edition.
[7] USEPA. 2003. "Air Pollution Control Technology Fact Sheet – Flue Gas Desulfurization." EPA-452/F-03-034. August 8.

Figure 5-1. Wet scrubber process flow diagram



In the utility industry, the $CaSO_3$ waste product is usually mixed with fly ash (approximately 1:1) and fixative lime (approximately 5%) and typically disposed of in landfills. Alternately, the forced oxidation process oxidizes the spent slurry to gypsum. Gypsum crystals dewater more efficiently and reduce the size of waste handling equipment. Depending on quality and demand, the gypsum may be commercially sold, eliminating the need for landfilling the waste product.

"Mist eliminators" installed at the spray tower outlet or downstream ductwork remove droplets from the gas. In some power plant installations, the gas is reheated to avoid corrosion downstream. Many scrubbers have gas bypassing capability, which can be used for gas reheating. If the wet scrubber is downstream of a high-efficiency particulate removal device [fabric filter or electrostatic precipitator (ESP)], the particulate concentration may be higher leaving the scrubber than entering due to the solids in mist droplets that are carried out of the scrubber.

Some disadvantages of using wet scrubbing techniques in many applications are the requirement to treat wastewater, the need to construct components from expensive alloys to resist corrosion, and much higher energy usage. A practical issue associated with a wet scrubber system is the complexity of the system. The space required for a wet system is substantial (i.e., large footprint), the systems require more maintenance due to their complexity, and more personnel are required for their operation.

5.1.3.1.1.1 Limestone Slurry Forced Oxidation

Limestone slurry forced oxidation (LSFO) is used extensively in the utility FGD market. The raw material is finely ground limestone. There are a number of suppliers of LSFO technology. The most commonly used equipment is an open, multi-level, countercurrent spray tower scrubber equipped with spray nozzles to inject the limestone slurry droplets into the gas stream. Liquor is collected at the bottom of the tower and sparged with air to oxidize the calcium sulfite to calcium sulfate to enhance the settling properties of the calcium sulfate. Recirculation pumps circulate the scrubbing liquor to the spray nozzles. SO_2 removal efficiencies of 90% have been achieved. The bleed from the scrubber is sent to a dewatering system to remove excess moisture. For an aluminum smelter, the process will produce either solid gypsum waste or commercial-grade gypsum suitable for reuse as a cement additive if a cement production facility is available and willing to accept the material. Only a very small purge or blowdown stream is required.

LSFO was determined to be a technically feasible retrofit control option for the potroom reactor and the anode baking exhausts even though it is not ideally suited for scrubbing SO_2 concentrations that are less than or equal to 105 ppm.

5.1.3.1.1.2 Limestone Slurry Natural Oxidation

Limestone slurry natural oxidation (LSNO) is very similar to LSFO. The major difference is the absence of an oxidation stage. The gypsum/calcium sulfite product is essentially a waste product with limited possibilities of use for agricultural purposes.

5.1.3.1.1.3 Conventional Lime Wet Scrubbing

Conventional lime wet scrubbing is also similar to LSFO except that the raw material is hydrated lime or quick lime that is either slaked on-site or purchased in the slaked form. The system typically uses forced oxidation, although natural oxidation is possible. The process will produce either solid gypsum waste or

commercial-grade gypsum suitable for reuse as a cement additive if a cement production facility is available and willing to accept the material.

5.1.3.1.1.4 Seawater Scrubbing

Seawater scrubbing is a method for controlling SO_2 emissions in which seawater is used to absorb SO_2 in exhaust gases. Seawater is slightly alkaline (with a pH of approximately 8). SO_2 has a high solubility in seawater. Absorbed SO_2 is subsequently oxidized to sulfates by the use of aeration and the pH is adjusted by the addition of additional seawater.

There are three main steps in this process: absorption, oxidation, and neutralization. Seawater is passed countercurrent through the gaseous exhaust stream, typically using a spray column in the aluminum industry. SO_2 preferentially dissolves in the seawater. Removal efficiencies of 85% to 95% have been measured in practice. The clean exhaust gas is de-misted prior to release to the atmosphere. The acidified seawater is then passed to an oxidation basin in which air is blown through the effluent. The additional oxygen ensures that the dissolved SO_2 is converted to sulfates. Finally, additional fresh seawater is added to adjust the pH back up to neutral (or slightly alkaline) and the seawater is discharged back into the ocean.

The effluent from this process will typically have a temperature increase of about 1°C and will have a change in sulfate concentration of approximately 2-5% above background[8,9]. Scrubbing of the potline emissions also adds fluoride and trace amounts of polycyclic aromatic hydrocarbons (PAHs) to the effluent seawater. No additional chemicals are required and there is normally no solid waste generated for disposal as the effluent is typically discharged directly to the sea. The pH of the effluent can be adjusted to within the original range in the neutralization step of the process.

The volume of seawater required varies with exhaust flowrate and SO_2 loading in the gaseous exhaust stream. Based on a review of specifications for existing potline seawater scrubbing systems, the volumetric flowrate of seawater needed for proper operation of a seawater scrubber at Intalco would be approximately 2.2 million gallons of seawater per hour.

[8] Information from the ALSTOM Seawater FGD – Environmental Impact website (www.environment.power.alstom.com/home/power/seawater_fgd/environmental_impact.htm)

[9] Kwawaji, Akili D., et. al. 2005. "Seawater Scrubbing for the Removal of Sulfur Dioxide in a Steam Turbine Power Plant". Proceeding of the PWR2005 ASME Power Conference. April 5-7. Chicago, IL.

A global review of feasible control technologies identified seawater scrubbing as having been installed at seven aluminum smelters, none of which are in the United States[10]. Even though this technology has been identified as a control technology in operation at six primary aluminum ore reduction plants in Norway and one primary aluminum ore reduction plant in Sweden[11], there are two reasons why this technology is not feasible at Intalco.

1) The Administrator of USEPA has issued environmental regulations establishing effluent limitations guidelines (ELGs) pursuant to section 304(b) of the Clean Water Act for facilities producing primary metals from ore concentrates and recovering secondary metals from recycled wastes. The ELGs are for facilities that discharge or may discharge pollutants to waters of the United States or which introduce or may introduce pollutants into a publicly owned treatment works. Seawater scrubbers installed to abate SO_2 and other visibility impairing pollutants from the Intalco's BART eligible potline emission units would be subject to the ELGs for "Potline SO_2 Emissions Wet Air Pollution Control."[12] A seawater scrubber installed downstream of the alumina dry scrubbers at Intalco would remove both fluoride and SO_2 from the dry scrubber exhaust. The amount of fluoride absorbed into the seawater would exceed the ELG, requiring treatment of the seawater to remove fluoride before it could be discharged back into the sea. For example with three potlines operational, approximately 159 lb/day of fluoride would be absorbed by the seawater and the applicable ELG would be 59.5 lb/day (monthly average). Removal of potline fluoride from the seawater scrubber effluent may be feasible, but would also require precipitation of many other naturally occurring salts in the seawater (chlorides, sulfates, other fluorides, etc.), resulting in the unnecessary generation of large amounts of sludge for land disposal. Seawater scrubbing is, therefore, not a viable alternative for smelters in the United States, especially when compared with other scrubbing technologies that use fresh water and require treatment/disposal for only those salts present in the potline exhaust.

2) In addition to the regulatory restrictions and economic viability issues discussed above, a seawater scrubber is infeasible for BART compliance due to permitting obstacles. The Washington State Environmental Policy Act (SEPA), Chapter 43.21C RCW was enacted in 1971, and it provides the framework for agencies to consider the environmental consequences of a proposal before taking

[10] The HATCH Group. 2006. *"Analysis of Options for BART Compliance"*. April 18. Page 4.
[11] Ibid. Page 9.
[12] 40 CFR 421.23(n)

action. It also gives agencies the ability to condition or deny proposals due to adverse impacts identified as likely to occur as a result of a proposal. The portion of Puget Sound where seawater would be withdrawn and discharged for an Intalco seawater scrubber has been included as part of the Cherry Point Aquatic Reserve that was established in 2000. The Aquatic Reserves Program is part of the Washington Department of Natural Resources (DNR) efforts to promote preservation, restoration, and enhancement of state-owned aquatic sites that benefit the health of native aquatic habitat and species in the state. The aquatic reserves established by DNR are aquatic lands of special educational or scientific interest, or lands of special environmental importance. The construction of intake and/or discharge structures within the Cherry Point Aquatic Reserve would require an impact analysis, assessment, and DNR authorization of any environmental impacts associated with a seawater scrubbing system. Since seven years have already passed since Cherry Point was designated as an aquatic reserve and the initial SEPA evaluation has yet to be completed, the time required to complete an analysis of the environmental impacts associated with a seawater scrubbing system and obtain the requisite authorizations for a system that withdraws seawater from and discharges scrubber liquor into the Cherry Point Aquatic Reserve would render this technology infeasible for BART compliance.

5.1.3.1.1.5 Dual Alkali Sodium/Lime Scrubbing (Dilute Mode)

Dual alkali sodium/lime scrubbing (dilute mode) uses a caustic sodium solution in the scrubber tower. A portion of the scrubbing liquid is discharged to a neutralization stage where lime slurry is used to regenerate the caustic, which is returned to the scrubber. The bleed from the scrubber is sent to a dewatering system to produce a gypsum byproduct. The process will produce either solid gypsum waste or commercial-grade gypsum suitable for reuse as a cement additive. It should be noted, however, that dual alkali sodium/lime scrubbing (dilute mode) is not currently marketed by major FGD vendors because the system is too complicated and expensive.

5.1.3.1.1.6 Conventional Sodium Scrubbing

Globally, conventional sodium scrubbing has been installed in at least 12 aluminum smelters. An alkaline solution of either soda ash or sodium hydroxide is pumped into the scrubbing tower and recirculated through a network of spray nozzles. Atomized droplets contact the up-flowing gas containing SO_2. Where this technology has been deployed, the liquid effluent containing dissolved salts, including sodium and fluorides, has been discharged into a large receiving stream or an open body of water without treatment.

5.1.3.1.2 Dry Scrubbing

5.1.3.1.2.1 Dry Injection

In dry injection, a reactive alkaline powder is injected into a furnace, ductwork, or a dry reactor. Typical removal efficiencies with calcium adsorbents are 50 to 60% and up to 80% with sodium base adsorbents. However, as with wet scrubbing, disposal of waste using sodium adsorbents must consider their high solubility in water compared to those from calcium adsorbents. The temperature range over which scrubbing has been used is 300 to 1,800°F; the minimum temperature is 300 to 350°F. Dry systems are rarely used and according to USEPA only 3% of FGD systems installed in the United States are dry systems[13]. The dry waste material is removed using particulate control devices such a fabric filter or an ESP.

Dry scrubbing downstream of the potline reactors and anode bake furnace fabric filters is not technically feasible because of the low temperatures (less than or equal to 205°F) and low SO_2 concentrations (less than or equal to 105 ppm).

5.1.3.1.2.2 Semi-Dry Scrubbing (Spray Dryer)

Semi-dry scrubbing is more commonly referred to as spray drying. Calcium hydroxide slurry (lime mixed with water) is introduced into a spray dryer tower. Sodium compounds can be used, but as with the dry scrubber, the high solubility of the sodium-based waste products in water complicates disposal of the waste. The slurry is atomized and injected into a reactor with the exhaust gases, where droplets react with SO_2 as the liquid evaporates. This system is categorized as a semi-dry system because the end product of the SO_2 conversion reaction is a dry material. The dry waste product is collected in the bottom of the spray dryer reactor and a fabric filter or ESP downstream of the spray dryer removes the $CaSO_3$, $CaSO_4$, and unreacted lime. This air pollution control system uses water for evaporative cooling and for the SO_2 reaction. It operates in a temperature range of 300 to 350°F because the temperature of the gases must be high enough to evaporate the water portion of the slurry. Approximately 12% of the FGD systems installed in the United States are spray dry systems[14] with typical SO_2 removal efficiencies in the range of 80 to 90%. Unlike a wet scrubbing system there is no liquid blow-down stream from the dry system and the collected solids are typically landfilled.

[13] USEPA. 2003. "Air Pollution Control Technology Fact Sheet – Flue Gas Desulfurization." EPA-452/F-03-034. August 8.
[14] Ibid.

Spray dry scrubbing downstream of the potline reactors and anode bake furnace fabric filters is not technically feasible because of the low temperatures (less than or equal to 205°F) and low SO_2 concentrations (less than or equal to 105 ppm).

5.1.3.2 Pollution Prevention

The guidelines for BART determinations under the Regional Haze Rule recommend consideration of pollution prevention options in addition to add-on controls. The primary opportunity for pollution prevention in the smelting process to minimize SO_2 emissions is through limitations on the sulfur content in the incoming coke. Coke is a major raw material used in the manufacture of green anodes. Green anodes are subsequently baked in a furnace prior to their use in the smelting process.

Intalco's Title V operating permit currently has a number of operational limits that cap allowable emissions of SO_2 from the facility, including: a net potline aluminum production limit of 307,000 ton/yr; a daily potline SO_2 limit of 37,780 pounds per day (lb/day); limits on sulfur in coke and pitch at 3.0% and 0.6%, respectively; and a carbon consumption limit of 0.425 pounds of carbon per pound of aluminum produced.

During the BART process, Intalco evaluated the current levels of sulfur in coke used by other aluminum smelters to determine whether a pollution prevention option using lower sulfur content coke would be a feasible BART option. This analysis indicated that certain smelters currently utilize coke with sulfur contents as low as 2%. Given that sulfur contents lower than the current Intalco specification are utilized, Intalco undertook a low sulfur coke availability analysis to determine whether coke at levels below 3% would be available beyond 2013 when BART controls requirements are anticipated. Confidential research information belonging to the market analysts assisting with the coke availability analysis is included in **Appendix B**. The primary conclusions from this analysis indicate that:

- Coke is a byproduct of the oil refining process. The sulfur content of the world's crude oil supply has been and will continue increasing in sulfur content. Those refiners with coking capacity are minimizing their raw material costs by maximizing use of high sulfur crude oils and oil sands to the optimal extent for their overall refinery design. The result will be a continuing increase in the sulfur content of available coke.
- Coke is a relatively small, low revenue component of the refinery's product profile. As such, the aluminum industry has little influence in controlling the quantity, quality, and price of the coke produced by refineries.

- Anode grade (or anode quality) coke is a small subset of the total coke produced world-wide. Growth in the aluminum industry has increased the demand for the limited quantities of anode grade coke and has driven prices for coke to unprecedented levels. Refining higher sulfur crude oils and oil sands further shrinks this small subset of anode grade coke.
- Prices for coke nearly doubled from 1994 to 2006.
- The increased global growth in aluminum production will continue to outpace the production of coke.
- Primary aluminum production is expected to grow at the rate of 3 to 4% annually, resulting in a commensurate growth in demand for anode grade coke.
- Coke providers are blending imported, high cost, lower sulfur coke with domestically sourced coke in attempts to meet the current specification requirements for coke.
- Removal or reduction of the sulfur content of the coke once it has been received is not feasible.
- Aluminum smelters are experimenting with alternative cokes and technologies that are outside of the traditional specifications to ensure continued aluminum production in the face of the changing characteristics of this key raw material.
- The deterioration in coke quality and the tightness of supply is expected to continue for the foreseeable future.
- The increased demand for coke will force the aluminum industry to accept lower quality coke with higher sulfur contents.

Based on the market and availability analysis of the future coke supply, Intalco determined that it is infeasible to consider coke at sulfur contents below 3% as a BART pollution prevention option because a supply of coke with sulfur contents below 3% cannot be ensured beyond 2013 when BART control requirements are anticipated. These same market pressures are expected to force facilities currently using coke with sulfur contents below 3% to begin using higher sulfur content coke in the future. Although coke at sulfur contents below 3% is considered infeasible due to availability concerns, a pollution prevention option that maintains Intalco's current sulfur in coke limit of 3% is considered technically viable or feasible, assuming that sufficient imported lower sulfur coke remains available to allow blending to 3% sulfur content beyond 2013.

5.1.3.3 Feasible Control Options from RBLC Database

A review of USEPA's RACT/BACT/LAER Clearinghouse (RBLC) database was also completed to determine which control technologies or techniques have been utilized by primary aluminum ore reduction plants. The results from the RBLC database search are summarized in Table 5-1.

The data in the RBLC database support the approach of limiting raw material sulfur content as a control option for the potlines and the anode bake furnace. Many facilities have limited sulfur content in coke to limit SO_2 emissions. Two facilities have limits of 3% sulfur content in coke and one has a 2.95% sulfur content limit. One facility is shown in the RBLC to have a wet scrubber to control SO_2 emissions; however, an investigation revealed that the wet scrubber was not required as part of a best available control technology (BACT) determination and that the facility currently does not operate a wet scrubber to control SO_2 emissions. That facility's current Title V permit for "Potline 5" simply limits coke sulfur content to 3% and coal tar pitch sulfur to 0.8%.

Dry alumina scrubbers (with fabric filters) are the controls that have been considered BACT for PM.

5.1.4 Potentially Applicable BART Control Options for PM

Potentially applicable PM emission controls are discussed in the following sections.

5.1.4.1 Fabric Filters

Fabric filters generally provide high collection efficiencies for both coarse and fine (submicron) particles. They are relatively insensitive to fluctuations in gas stream conditions. Efficiency is relatively unaffected by large changes in inlet dust loadings. Filter outlet air is very clean[15]. Collected material is dry, which usually simplifies processing or disposal. Fabric filters are currently applied for controlling PM emissions from the potrooms and the anode bake furnace at Intalco.

5.1.4.2 Electrostatic Precipitators

ESPs are capable of very high removal efficiencies for large and small particles[16]. They offer control efficiencies that are comparable to fabric filters. Because of their modular design, ESPs, like fabric filters, can be applied to a wide range of system sizes. The operating parameters that influence ESP performance include fly ash mass loading, particle size distribution, fly ash electrical resistivity, and precipitator voltage and current.

[15] USEPA. 2003. "Air Pollution Control Technology Fact Sheet – Fabric Filter." EPA-452/F-03-025. August 7.
[16] USEPA. 2003. "Air Pollution Control Technology Fact Sheet – Dry Electrostatic Precipitator." EPA-452/F-03-028. August 7.

Dusts with high resistivities are not well-suited for collection in dry ESPs because the particles are not easily charged. This also affects the ash layers on the collecting electrodes. An ESP is technically feasible for control of PM from the potrooms and the anode bake furnace at Intalco.

5.1.4.3 Cyclones, Inertial Separators, and Wet Scrubbers

Cyclones and inertial separators are used for collection of medium-sized and coarse particles. Wet scrubbers generally remove large particles but can remove small particles with the use of high pressure drops. However, none of these devices are as effective at removing small and submicron particles as fabric filters and ESPs[17].

5.1.5 Potentially Applicable BART Control Options for NO_x

Potentially applicable NO_x emission controls include combustion controls and post-combustion controls.

5.1.5.1 Combustion Controls

The concentration of NO_x in the potroom reactor exhaust is extremely low (less than 1 ppm) because there is no external fuel or combustion zone and there are no large sources of nitrogen in the raw materials. Traditional methods of preventing NO_x formation using staged combustion or low NO_x burners are not applicable to the potlines at Intalco.

NO_x emissions from anode baking depend on operating practices and burner controls. The traditional methods of preventing NO_x formation using staged combustion or low NO_x burners are not applicable because of the unique configuration of an anode baking ring furnace, with fuel injected at several points in narrow flues. However, advanced firing systems that measure and regulate fuel flow precisely using a computerized control system may reduce NO_x emissions by reducing total fuel usage. Prevention of NO_x formation using advanced firing control is technically feasible for the anode bake furnace at Intalco.

5.1.5.2 Post-Combustion Controls

Selective non-catalytic reduction (SNCR), selective catalytic reduction (SCR), and low temperature oxidation (LoTOx) controls are discussed in this section.

5.1.5.2.1 Selective Non-Catalytic Reduction

SNCR is an add-on technique that involves injecting ammonia or urea into a specific temperature zone in a furnace or boiler. The ammonia or urea reacts with NO_x in the gas to produce nitrogen and water. SNCR typically provides a NO_x reduction of 30 to 50%.

The effectiveness of SNCR depends on the temperature where reagents are injected, mixing of the reagent in the gas, residence time of the reagent within the required temperature window, and the ratio of reagent to NO_x. The required temperature window is 1,600 to 2,100°F. Typical uncontrolled NO_x levels where this technology has been applied vary from 200 to 400 ppm. SNCR is less effective at lower levels of uncontrolled NO_x[18].

The temperature (approximately 200°F) and NO_x concentration (less than 1 ppm) of the potroom emission exhaust are outside the levels where SNCR could be used. Thus, SNCR is not technically feasible for the potlines at Intalco.

The temperature of the anode baking emission exhaust (300 to 450°F) is below the temperature where SNCR could be used. Downstream of the reactor where tar vapors are removed, the temperature is approximately 200°F, which is also below the appropriate range. In addition, the NO_x concentration (less than 20 ppm) is below the level where SNCR could be used. Thus, SNCR is not technically feasible for the anode bake furnace at Intalco.

5.1.5.2.2 Selective Catalytic Reduction

SCR is an add-on technique similar to SNCR that involves injecting ammonia into flue gas in the presence of a metal-based catalyst to convert NO_x emissions to elemental nitrogen and water. The catalyst allows SCR systems to operate at much lower temperatures than SNCR; typical temperatures for SCR are 500 to 800°F, compared with 1,600 to 2,100°F for SNCR. The optimum temperature range is 700 to 750°F[19]. SCR is capable of NO_x reduction efficiencies in the range of 70 to 90% and can be used with NO_x concentrations as low as 20 ppm. However, higher NO_x levels result in increased performance[20].

The temperature of the potroom emission exhaust (approximately 200°F) and NO_x concentration (less than 1 ppm) of the potroom emission exhaust are outside the levels where SCR could be used. Thus, SCR is not technically feasible for the potlines at Intalco.

The temperature of the anode baking emission exhaust (300 to 450°F) is below the temperature where SCR could be used. Downstream of the reactor where tar vapors are

[17] AWMA. 2000. *Air Pollution Engineering Manual*, Second Edition.
[18] USEPA. 2003. "Air Pollution Control Technology Fact Sheet – Selective Non-Catalytic Reduction." EPA-452/F-03-031. August 8.
[19] USEPA. 2002. *EPA Air Pollution Control Cost Manual*, Sixth Edition. EPA/452/B-02-001. January.
[20] USEPA. 2003. "Air Pollution Control Technology Fact Sheet – Selective Catalytic Reduction." EPA-452/F-03-032. August 8.

removed, the temperature is approximately 200°F, which is also below the appropriate range. In addition, the NO_x concentration (less than 20 ppm) is below the level where SCR could be used. Thus, SCR is not technically feasible for the anode bake furnace at Intalco.

5.1.5.2.3 Low-temperature Oxidation Technology (LoTOx™)

The LoTOx™ system is the patented technology of BOC Gases. In this NO_x removal system, ozone is injected into the exhaust gas stream in order to oxidize insoluble NO_x to soluble nitrogen compounds, including N_2O_5. N_2O_5 is highly soluble and reacts with moisture in the gas stream to form nitric acid. A scrubber is required downstream of the LoTOx™ system to remove the nitric acid formed by the reaction of N_2O_5 and moisture in the gas stream. The ozone is typically generated on site and on demand. Since LoTOx™ is a low temperature system it does not require heat input and the low operating temperature (150 to 250°F) allows for stable and consistent control even with variations in flow, load, and NO_x concentrations[21].

Use of the LoTOx™ system has not been demonstrated at an aluminum plant. Research indicates that application of the LoTOx™ technology has been limited to a sulfuric acid regeneration plant, a lead smelting reverbatory furnace, a stainless steel plant, a coal-fired electric generation unit, and two fluidized-bed catalytic cracking units (FCCU) at refineries[22,23]. Reported NO_x removal efficiencies for the LoTOx™ system are on the order of 90% to 95%.

The temperature of the anode baking emission exhaust (approximately 200°F) is within the temperature range where LoTOx™ could be used. Although this technology has not been demonstrated on an anode bake furnace, low-temperature oxidation technology may be technically feasible for reducing anode bake furnace NO_x emissions.

5.1.6 Summary of Technically Feasible BART Control Options

5.1.6.1 Feasible BART Control Options for SO_2

Two technically feasible options were identified for controlling SO_2 emissions from the potlines and anode bake furnace:

- Adding a wet scrubber to the potline and/or anode bake furnace exhausts, and

[21] BOC Process Gas Solutions. 2001. *Low Temperature Oxidation System Demonstration at RSR Quemetco, Inc., City of Industry, California.* June 28. (www.arb.ca.gov/research/icat/projects/boc.pdf)
[22] USEPA. 2005. "Using Non-Thermal Plasma to Control Air Pollutants". EPA-456/R-05-001. February. www.epa.gov/ttn/catc/dir1/fnonthrm.pdf,
[23] USEPA RACT/BACT/LAER Clearinghouse (RBLC) database.

- A pollution prevention option limiting the sulfur content in the coke used to produce anodes to 3.0%.

These two options were evaluated further as part of the BART determination analysis.

5.1.6.2 Feasible BART Control Options for PM

Cyclones, inertial separators, wet scrubbers, ESPs, and fabric filters are all technically feasible for controlling potroom PM emissions. However, ESPs and fabric filters are superior devices for controlling fine PM.

Fabric filtration with dry alumina scrubbing has been widely used in the primary aluminum industry. Most smelters constructed within the past 20 years have used dry alumina scrubbing with fabric filters to control emissions from potlines. A few plants use control systems consisting of ESPs to collect PM followed by spray towers to scrub gaseous fluoride. Wet systems have many disadvantages, such as corrosion by hydrofluoric acid, scaling, and the requirement to treat wastewater. ESPs and wet systems are no longer installed on new smelters[24].

Dry scrubbers are widely used on anode bake furnaces because they provide effective removal of hydrocarbons, fluorides, and PM. Wet systems have the same disadvantages for anode bake furnaces as for potlines: corrosion by hydrofluoric acid, scaling, and the requirement to treat wastewater. Dry scrubbers with fabric filters are a superior choice for anode bake furnaces.

Given that fabric filters are already used for PM control and that these high-efficiency devices are superior or equal to other feasible control options, no further analysis of PM controls was performed.

5.1.6.3 Feasible BART Control Options for NO_x

Since there is no external fuel or combustion zone in the smelting cells, there are no technically feasible pre-combustion NO_x controls. Likewise, there are no technically feasible add-on controls because of the temperature of the potroom exhaust (approximately 200°F) and low NO_x concentration (less than 1 ppm).

Advanced firing systems may prevent NO_x formation by reducing natural gas usage and are technically feasible for the anode bake furnace. Add-on SCR and SNCR controls are not feasible at the furnace exhaust because of the temperature (less than 450°F) and presence of tar vapor. SCR and SNCR are not feasible downstream of the reactor because of the temperature (approximately 200°F) and low NO_x concentration (less than

[24] Air and Waste Management Association (AWMA). 2000. *Air Pollution Engineering Manual*, Second Edition.

20 ppm). The use of low temperature oxidation (LoTOx™) may be a viable option for reducing NO_x emissions if a wet scrubber were installed on the bake furnace for SO_2 control.

The option for reducing NO_x formation through advanced firing systems for the anode bake furnace was evaluated further as part of the BART determination analysis. Further consideration was also given to the potential use of low temperature oxidation (LoTOx™).

5.2 CONTROL EFFECTIVENESS OF FEASIBLE OPTIONS

Step 3 of the BART analysis is to evaluate the control effectiveness of the technically feasible control technologies.

5.2.1 SO_2 Wet Scrubbing

A wet scrubber was identified as a technically feasible add-on pollution control option to reduce SO_2 from the potline reactors. Typical removal efficiencies are 80 to 95%. Capital cost estimates and control efficiencies for wet scrubbers at Intalco were developed by scaling costs from two vendor quotes obtained for the installation of LSFO scrubbing technology at Alcoa's facility in Alcoa, Tennessee. Each of the vendors that provided proposals for the Tennessee facility indicated that a 95% SO_2 removal was technically feasible. Accordingly, an SO_2 removal efficiency of 95% was used in the Intalco BART analysis for the wet scrubber control option.

Mist droplets will be a component of the gas stream emitted from the scrubber. Solids in the droplets will become airborne PM when the water in the droplets evaporates. The PM concentration in the outlet of the wet scrubber was predicted to be 20 mg/Nm^3 by one of the vendors. This compares to a concentration of 10 mg/Nm^3 currently emitted from the existing potline control system. Consequently, the wet scrubber option would cause a collateral increase in PM from the potlines.

A wet scrubber was also identified as a technically feasible add-on pollution control option for the anode bake furnace since it has an SO_2 concentration and a temperature similar to the potline reactor exhaust. However, the anode bake furnace is a smaller source than the potlines because of the lower exhaust gas flow rate (1,950,000 acfm versus 202,500 acfm). A separate vendor cost proposal was not obtained for the anode bake furnace, but an SO_2 removal efficiency of 95% is assumed to be feasible. Wet scrubber costs for the anode bake furnace were also scaled from the LSFO potline wet scrubber vendor quotes.

Table 5-2 summarizes the SO_2, NO_x, and PM emission levels under the control scenarios considered for BART. The emissions represent the combined total emissions from the primary and secondary potline control systems and the anode bake furnace for each scenario. Control scenario #1 is the addition of a wet scrubber to the potline reactors. Control scenario #2 is the addition of a wet scrubber to the anode bake furnace. The current potential emissions with 3.0% sulfur coke are also listed. The emissions reductions achievable for each of the scenarios were compared to current potential emissions.

5.2.2 SO_2 Pollution Prevention

The pollution prevention option represents a 3.0% sulfur limit in the coke used to produce anodes. This option reflects the current sulfur limit in Intalco's Title V operating permit.

5.2.3 Anode Bake Furnace Advanced Firing System

NO_x emissions from the anode bake furnace could be reduced by incorporating an advanced firing system. Total gas usage is projected to be reduced by 20%, which would result in a corresponding 20% reduction in NO_x emissions, or approximately 27 tons/year.

5.2.4 Anode Bake Furnace LoTOx™ System

NO_x emissions from the anode bake furnace could potentially be reduced by using the LoTOx™ system for post-combustion control. This technology has a control efficiency of 90% for NO_x emissions when combined with wet scrubbing, resulting in a potential reduction in NO_x emissions of approximately 122 tons/year.

5.3 Evaluation of Costs and Other Impacts

Step 4 of the BART analysis involves evaluation of cost and other impacts, including energy impacts, greenhouse gas generation, non-air quality environmental impacts, and remaining useful life. Costs of control, energy impacts, greenhouse gas generation impacts, non-air quality environmental impacts, and remaining useful life are evaluated in this section.

5.3.1 Cost Impacts for Feasible Controls

5.3.1.1 Wet Scrubbers

The exhaust gases from each potline are routed to dry alumina reactors. Potline gases currently exhaust to atmosphere from stacks above the fabric filters in each of the six baghouse scrubbing centers, which are located in courtyards between the potrooms.

Wet scrubber costs for Intalco were estimated based on cost quotes received by Alcoa from two flue gas desulphurization equipment vendors. The cost quotes were originally provided as part of the BART analysis for Alcoa's Tennessee Operations in Alcoa, TN.

Both vendors provided cost proposals for wet scrubbing systems based on limestone forced oxidation (LSFO) SO_2 scrubbers. Lime- or sodium-based scrubbers could also be used for potlines, but lime and sodium are less desirable reagents considering that these reagents are much more expensive. An advantage of the limestone forced oxidation process is that the spent slurry is oxidized to gypsum, which dewaters more efficiently, resulting in less waste materials requiring disposal. Thus, an LFSO scrubber was determined to be the most appropriate control device for the cost analysis. The vendor proposals are provided in **Appendix B.** These proposals contain confidential business information and are, therefore, labeled as confidential.

Neither of the two vendors provided a comprehensive installed cost estimate. Both preliminary designs were based on a central scrubbing center as the least cost approach, where exhaust from all dry scrubbing systems would be ducted to a centralized scrubbing system. Both design estimates were based on systems that would provide 100% availability of emissions control on each day of the year, given that potlines cannot be easily shutdown and restarted for control system outages.

One vendor provided an estimate of the scrubber equipment only. The other provided an "indicative price," with an installed cost assumed equal to the equipment cost. Important retrofit considerations for installing a potline wet scrubbing system include: (1) that gases must be collected from multiple individual baghouse stacks, (2) the system must simultaneously maintain balanced flow from multiple potline control devices, and (3) the system installation would require transport of new components through narrow passages in the existing potline. Coordination of the equipment delivery and the daily work schedule of the potline operation would also affect the control system installation. One of the vendors recognized the complexity of this project, pointing out in their proposal that an extensive engineering effort was needed because of space limitations, access limitations, uncertainty as to laydown areas, and uncertainty of ductwork and supports. These retrofit issues would apply equally to both the Alcoa, TN facility and Intalco.

The vendor cost proposals for the Tennessee facility were based on a total scrubber exit gas volume of approximately 1,580,000 acfm at 101°F compared to a design exit gas volume of approximately 1,950,000 acfm at 98°F for Intalco. Vendor equipment cost proposals for the Alcoa, TN facility therefore had to be adjusted to account for differences in exhaust gas volume and other design parameters.

Hatch, an engineering firm contracted by Alcoa, prepared a pre-feasibility report for Intalco in which equipment costs provided by one of the vendors for the Alcoa, TN facility were scaled or adjusted to estimate LSFO equipment costs for Intalco. The procedure used by Hatch adjusted equipment cost estimates using appropriate exponential

factors for equipment type (reagent feed, SO_2 removal, gas handling, etc.), along with differences in system exhaust gas volume, limestone consumption, and gypsum by-product generation. ENVIRON used the cost adjustment approach developed by Hatch to prepare an average equipment cost based on both vendor quotations. The equipment cost scaling procedures are outlined in the Hatch report in **Appendix C** and ENVIRON's parallel calculations based on the average of the two vendor quotes are provided in **Appendix D**.

The average scrubber equipment cost was used with factors from the *EPA Air Pollution Cost Control Manual*[25] to determine installation costs and total capital costs. Operating costs were calculated based on utility and raw material requirements provided by Hatch, along with unit cost information provided by Intalco and other cost assumptions from the *EPA Air Pollution Cost Control Manual*. Complete cost calculations and assumptions are provided in **Appendix D**.

Separate vendor cost quotes were not obtained for installing a wet SO_2 scrubbing system on the anode bake furnace. Instead, the potline SO_2 scrubber equipment costs were scaled to estimate Intalco anode bake control equipment costs using the same approach discussed above for the potlines. The anode bake wet scrubber design was based on a scrubber exhaust gas volume of 202,500 acfm at 98°F. The vendor equipment costs were adjusted using exponential factors that account for differences in exhaust gas volume, limestone consumption, and gypsum by-product generation.

Table 5-3 summarizes the cost of installing and operating an LSFO wet scrubber on the Intalco potlines and anode bake furnace to remove 95% of the SO_2. The capital and total annualized costs for a potline wet scrubber are high at approximately $234.5 million and $46.8 million per year, respectively. The wet scrubber cost effectiveness is also high at $7,500 per ton of SO_2 removed.

The estimated installed capital cost to add a wet scrubber to remove 95% of the SO_2 from the anode bake furnace exhaust would be approximately $29.5 million with an annualized cost of $6.3 million per year. The wet scrubber cost effectiveness is also high at $36,400 per ton of SO_2 removed.

5.3.1.2 Coke Sulfur Limit

Intalco is currently able to obtain coke with 3.0% sulfur without incurring significant additional cost. However, as low sulfur coke becomes more difficult to procure, the cost will increase. Additional information regarding low sulfur coke availability is included in **Appendix B**.

[25] USEPA. 2000. *EPA Air Pollution Cost Control Manual*, Sixth Edition. EPA-452/B-02-001. January 2002 (and updates).

5.3.1.3 Anode Bake Furnace LoTOx™ System

Cost data for the LoTOx™ system is not readily available. However, as demonstrated above for the control of SO_2 emissions from the anode bake furnace, the cost of the downstream scrubber required for the use of the LoTOx™ system would make this option cost prohibitive. NO_x emissions are lower than SO_2 emissions for the anode bake furnace, so the cost per ton values for NO_x would be even higher than for SO_2.

5.3.2 Energy Impacts

A wet scrubber removes SO_2 by forcing the exhaust gas through a spray tower or absorber where it contacts water droplets that contain the unreacted lime or limestone. Energy is required to overcome the resistance of the scrubber components as well as falling water droplets. A substantial amount of energy would be associated with fans to move the potline and anode bake furnace exhaust streams through scrubbers. Other energy is required for the slurry pumps, instrumentation, and miscellaneous items (e.g., lighting). The total energy required[26] would be approximately 7,400 kilowatt-hours (kWh)/hr for the potline scrubber and 750 kWh/hr for the anode bake furnace scrubber. As listed in Table 5-3, this is equivalent to 64,824,000 kWh of electricity per year for the potline scrubber. A wet scrubber on the anode bake furnace would add 6,570,000 kWh per year.

5.3.3 Greenhouse Gas Generation

Greenhouse gases (GHGs) are gaseous compounds that are known to provide a warming effect to the atmosphere. The predominant GHG is carbon dioxide (CO_2). Other GHGs include nitrous oxide and methane. The proposed SO_2 control devices will increase overall emissions of GHGs via three mechanisms: (1) as a byproduct of the reaction chemistry in the scrubbers, (2) as indirect emissions from the generation of electricity required to power the scrubbing systems, and (3) as direct emissions from vehicle travel for the additional personnel that will be required at the facility to maintain and operate the scrubbing systems. The details of the GHG emission calculations for each of these mechanisms are presented in the **Appendix E**.

The total GHGs (in carbon dioxide equivalents) generated by the implementation of the proposed scrubbing system for the potline fumes was estimated to be 96,441 pounds per day, or 17,597 tons per year. The total GHGs (in carbon dioxide equivalents) generated by the implementation of the proposed scrubbing system for the anode baking furnace was estimated to be 7,298 pounds per day, or 1,330 tons per year.

5.3.4 Non-Air Quality Environmental Impacts

Both of the wet scrubber proposals were based on the LSFO process. This process oxidizes the spent slurry to gypsum, which may be landfilled or commercially sold. There is no way to know

at this time whether the gypsum would have commercial value or whether there would be any demand for it. Therefore, it must be assumed that 27,130 tons of waste from a potline wet scrubber and 639.5 tons of waste from an anode bake furnace wet scrubber would be landfilled each year.

It is estimated that 182.5 million gallons of water will be required annually to operate the potline wet scrubber at a cost of approximately $97,000. This will significantly impact the community infrastructure in that this will increase Intalco's daily water demand by approximately 9%[27].

It is also estimated that a total of approximately 71.4 million kWh would be needed to operate the potline and anode bake furnace scrubbers annually. This would impact power demand in the community and would also have an environmental impact due to power production equivalent to adding approximately 6,700 new households in the community[28].

5.3.5 Remaining Useful Life

The Intalco smelter has been in operation since 1966 and remains a critical component of Alcoa's aluminum production in the United States. The facility intends to be in operation throughout the period of the Regional Haze Program.

5.4 EVALUATE VISIBILITY IMPACTS

Step 5 of the BART analysis involves evaluation of visibility impacts. More specifically, this is an evaluation of the potential improvement in visibility resulting from application of feasible pollution prevention/add-on control options. Refined CALPUFF modeling was performed for two control scenarios: one with wet SO_2 scrubbing applied to the potline and one with wet SO_2 scrubbing applied to the anode bake furnace. This modeling was accomplished according to State of Washington's BART modeling protocol[29]. In general, this modeling was the same as the baseline modeling except stack data and emission data associated with the application of the feasible add-on controls were used as model inputs. Table 5-4 presents the post-control modeling source input data that were used in the CALPUFF model to forecast visibility impacts for the two control options.

Table 5-5 presents the results of modeling with the two scrubber SO_2 control scenarios along with baseline impacts. As shown in Table 5-5, the addition of a potline wet scrubber reduced

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[26] Hatch. 2007. *SO_2 Scrubbing for the INTALCO Primary Aluminum Smelter: Pre-Feasibility Report.* July 26.

[27] Based on average facility incoming water flow rates for 1998 through 2000, the three most recent years the facility was at full production.

[28] Calculated based on 2001 average energy usage per household for the United States as reported by the Department of Energy (http://www.eia.doe.gov/emeu/reps/enduse/er01_us_tab1.html).

[29] *Modeling Protocol for Washington, Oregon, and Idaho: Protocol for the Application of the CALPUFF Modeling System Pursuant to the Best Available Retrofit Technology (BART) Regulation.* October 11, 2006. www.deq.state.or.us/aq/haze/docs/bartprotocol.pdf

modeled visibility impacts in all five Class I areas to between approximately 0.1 and 0.35 dv for the three years modeled. For example, the baseline modeling results indicate that the highest 98th percentile visibility impact from Intalco's BART-eligible sources at Olympic National Park with 3% sulfur in the coke was 1.527 dv. The post-control modeling results indicate that the highest 98th percentile visibility impact from Intalco's BART-eligible sources at Olympic National Park with wet scrubbers installed on the potlines was 0.355 dv in 2003. This represents a 1.17 dv reduction in total facility visibility impacts at Olympic National Park with the addition of wet scrubbers on the potlines.

The modeled visibility improvements shown in Table 5-5 from adding a wet scrubber at the anode bake furnace are minimal, with improvements ranging from approximately 0.004 to 0.024 dv compared to the baseline conditions. For example, the post-control modeling results for the anode bake furnace indicate a highest 98th percentile visibility impact of 1.503 dv compared to the baseline value of 1.527 dv in 2003. This represents less than a 2% reduction in total facility visibility impacts at Olympic National Park with the addition of wet scrubbers on the anode bake furnace.

For NO_x, the use of an advanced firing system or LoTOx^{TM} technology for the anode bake furnace would also result in minimal improvements in visibility. The baseline visibility modeling indicated that the highest 98th percentile visibility impact due to anode bake furnace NO_x emissions was approximately 0.03 dv (55% of 0.053 dv). Therefore, a 20% reduction in NO_x emissions from the anode bake furnace with the use of an advanced firing system would reduce Intalco's total visibility impacts by approximately 0.006 dv and a 90% reduction with the use of LoTOx^{TM} would reduce the impacts by approximately 0.027 dv. Based on the minimal change in visibility forecast resulting from the installation of an advanced firing system or use of LoTOx^{TM}, it was determined that neither of these technologies represents reasonably effective BART control technologies for the anode bake furnace.

6.0 DETERMINATION OF BART

6.1 ALUMINUM POTLINES

For potline SO_2 emissions, BART was determined to be the current level of control, which is a pollution prevention limit of 3% sulfur in the coke used to manufacture anodes. A pollution prevention limit based on coke sulfur contents below 3% was determined by Intalco to be infeasible as BART for 2013 and beyond based on a market and availability analysis for future coke supply. Use of wet scrubbing technology to reduce potline SO_2 emissions was rejected as BART due to excessive costs: total cost effectiveness of $7,500 per ton of SO_2 removed and capital and total annualized costs of $234.5 million and $46.8 million per year, respectively. A potline wet scrubber would also have substantial secondary impacts, including increased energy usage of 64,824,000 kWh of electricity per year, added water consumption of 183 million gallons per year, and solid waste generation of 27,000 tons per year.

For PM emissions, BART was determined to be the current level of control, which is the use of baghouses to control PM emissions from the alumina dry scrubbers and wet roof scrubbers to control secondary PM emissions from the potroom roofs.

There are no feasible technologies for control of NO_x from the potlines; thus, BART for NO_x was determined to be no controls.

6.2 ANODE BAKE FURNACE

A pollution prevention limit of 3% sulfur in the coke was also determined to be BART for anode bake furnace SO_2 emissions. The cost of wet scrubbing to reduce SO_2 emissions would be excessive at $36,400 per ton of SO_2 removed while providing minimal visibility improvement.

The existing level of control (based on baghouses on the alumina dry scrubbers) was determined to be BART for PM emissions.

BART for anode bake furnace NO_x emissions was determined to be no controls. The use of an advanced firing system for reduced energy use was rejected as BART because the technology would result in negligible visibility improvement. Similarly, the use of LoTOx^{TM} was rejected as BART because the cost of the technology would be excessive and result in negligible visibility improvement.

6.3 ALUMINUM HOLDING FURNACES

BART for the aluminum holding furnaces was determined to be no controls. The use of additional controls was rejected as BART because any visibility improvement would be negligible.

6.4 MATERIAL HANDLING AND TRANSFER OPERATIONS

PM emissions from the BART-eligible material handling and transfer operations are all controlled using fabric filter technology. This existing level of emissions control was determined to be BART for these material handling and transfer operations.

TABLES

Table 3-1
Primary Aluminum Reduction Emission Units
Alcoa Intalco Works
Ferndale, Washington

Process Number	Emission Unit ID	Emission Unit Description	Visibility Impairing Pollutants	Existing Pollution Controls	Modeling Source Type
5	181-186	Potline primary emission control system stacks	PM, SO_x	Reactor/ Fabric Filter	Point
5	22-180	Potline secondary emission control system stacks	PM, SO_x	Roof Water Scrubbers	Line
3	187	Anode bake furnace	PM, SO_x, NO_x	Reactor/ Fabric Filter	Point
6	4, 5, 7, 8, 10, 11, 13, 14, 16-19	Aluminum holding furnaces	PM	Fabric Filter	Point
2	188	Paste plant baghouse stack	PM	Fabric Filter	Point
2	189	Phase A ball mill baghouse stack	PM	Fabric Filter	Point
2	191	Phase B ball mill baghouse stack	PM	Fabric Filter	Point
7	195	Primary WTP kiln wet scrubber	PM	Wet Scrubber	Point
4	198	Rod shop (west) baghouse stack	PM	Fabric Filter	Point
4	199	Rod shop (east) baghouse stack	PM	Fabric Filter	Point
7	208	Ladle cleaning baghouse stack	PM	Fabric Filter	Point
7	209	Autogenous mill baghouse stack	PM	Fabric Filter	Point
7	210	TAC station baghouse stack	PM	Fabric Filter	Point
6	217	Remelt furnace stack	PM		Point
2	232	Butts baghouse stack	PM	Fabric Filter	Point
4	260	Aluminum spray cyclone stack	PM		Point
4	312	Rod shop induction furnace (east) stack	PM		Point
4	313	Rod shop induction furnace (west) stack	PM		Point
2	316	Pitch fume treatment system	PM		Point
3	251	Anode bake building monitor roof	PM		Volume
3	252	Anode block hole blower	PM		Volume
4	257A	Rod shop crust recovery discharge to trucks from bins #1 and #2	PM		Volume
4	257B	Rod shop crust recovery discharge to trucks from bins #1 and #2	PM		Volume
4	259A	Rod shop carbon recovery discharge to trucks from bins #1 and #2	PM		Volume
4	259B	Rod shop carbon recovery discharge to trucks from bins #1 and #2	PM		Volume
7	280	Annex cathode assembly area roof vents	PM		Volume
7	282	Annex ramming paste area roof vents	PM		Volume
1	239	Paved road vehicle dust emissions	PM		Area
1	241	Facility-wide natural gas combustion	PM, SO_x, NO_x		Area
7	273	Alumina ore handling fugitive dust	PM		Area
1	233	General welding	PM		Volume (combined)
1	240	Fugitive dust from loading and dumping waste	PM		Volume (combined)
1	242	Plant-wide propane combustion emissions	PM, SO_x, NO_x		Volume (combined)
2	190	Phase "A" mixer fugitives	PM		Volume (combined)
2	192	Phase "B" mixer fugitives	PM		Volume (combined)
2	193	KVS ball mill baghouse stack	PM	Fabric Filter	Volume (combined)
2	194	Pet coke baghouse stack	PM	Fabric Filter	Volume (combined)
2	243	Paste plant roof vents	PM, SO_x, NO_x		Volume (combined)
2	244	Phase "A" paste cooling conveyor fugitives	PM		Volume (combined)
2	245	Phase "B" paste cooling conveyor fugitives	PM		Volume (combined)
2	248	Scrap paste storage bins	PM		Volume (combined)
2	249	Paste plant vacuum system baghouse stack	PM	Fabric Filter	Volume (combined)
3	250	Packing coke silo vent	PM		Volume (combined)
4	253	Rod shop roof vents (north)	PM		Volume (combined)
4	254	Rod shop roof vents (south)	PM		Volume (combined)
4	255	Hot anode butts transport	PM		Volume (combined)
4	256A,B	Rod shop crust recovery discharge to storage bins #1 and #2	PM		Volume (combined)
4	258A,B	Rod shop carbon recovery discharge to storage bins #1 and #2	PM		Volume (combined)
4	263	Cooling of cast iron dross sows outside rod shop	PM		Volume (combined)

Table 3-1
Primary Aluminum Reduction Emission Units
Alcoa Intalco Works
Ferndale, Washington

Process Number	Emission Unit ID	Emission Unit Description	Visibility Impairing Pollutants	Existing Pollution Controls	Modeling Source Type
5	238	Auxiliary diesel generators	PM, SO_x, NO_x		Volume (combined)
6	3, 6, 9, 12, 15	Casting pit steam exhaust stacks	PM		Volume (combined)
6	21	Pigger cooling conveyor exhaust stack	PM		Volume (combined)
6	220a, 220b, 221a, 221b	MHD holding furnaces	PM		Volume (combined)
6	266	Casthouse monitor roof	PM		Volume (combined)
6	269	Pigger aluminum furnace door exhaust hood	PM		Volume (combined)
6	315	Dross/silicon storage baghouse	PM	Fabric Filter	Volume (combined)
7	196	Primary WTP reclaimed storage silo baghouse stack	PM	Fabric Filter	Volume (combined)
7	206	Pangborn baghouse stack	PM	Fabric Filter	Volume (combined)
7	207	Annex paste plant baghouse stack	PM	Fabric Filter	Volume (combined)
7	211	Alumina ore silo #1 baghouse stack	PM	Fabric Filter	Volume (combined)
7	212	Alumina ore silo #2 baghouse stack	PM	Fabric Filter	Volume (combined)
7	213	Alumina ore silo #3 baghouse stack	PM	Fabric Filter	Volume (combined)
7	214	Alumina ore silo #4 railcar unloader baghouse stack	PM	Fabric Filter	Volume (combined)
7	215	Alumina ore pier-head transfer point baghouse stack	PM	Fabric Filter	Volume (combined)
7	216	Alumina ore ship unloading baghouse stack	PM	Fabric Filter	Volume (combined)
7	226	Aluminum fluoride silo baghouse stack	PM	Fabric Filter	Volume (combined)
7	228	Covered annex bunkers for crust and digout	PM		Volume (combined)
7	229	Brick crushing facility baghouse stack	PM	Fabric Filter	Volume (combined)
7	274	Alumina silo #4 truck loader baghouse stack	PM	Fabric Filter	Volume (combined)
7	275	Aluminum fluoride/anthracite railcar unloading fugitive dust	PM		Volume (combined)
7	276	Coke unloading and transfer fugitive dust	PM		Volume (combined)
7	281	Annex ramming paste area roof vents	PM		Volume (combined)
7	284	Annex west pitch melter stack	PM		Volume (combined)
7	285	Annex east pitch melter stack	PM		Volume (combined)
7	286	Annex ramming paste mixer stack	PM		Volume (combined)
7	287	Autogenous mill silo baghouse stack	PM	Fabric Filter	Volume (combined)
7	293	Baghouse hopper unloading	PM		Volume (combined)
7	295	Landfill - solid waste	PM		Volume (combined)
7	296	Landfill - RCRA waste	PM		Volume (combined)
7	306	Alumina ore ship unloader clamshell	PM		Volume (combined)
8	222	Paint shop shot blaster baghouse stack	PM	Fabric Filter	Volume (combined)

Table 4-1
Source Input Data for Baseline Modeling - Point Sources
Alcoa Intalco Works
Ferndale, Washington

Source Description	LCC Coordinate X (km)	LCC Coordinate Y (km)	Stack Height (m)	Base Elevation (m)	Effective Stack Diameter (m)	Exit Velocity (m/s)	Flow Rate (m^3/s)	Exit Temperature (°K)	PM_{10} Emission Rate (g/s)	Filterable $PM_{2.5}$ Emission Rate (g/s)	Condensable $PM_{2.5}$ Emission Rate (g/s)	SO_2 Emission Rate (g/s)	NO_x Emission Rate (g/s)
DSA1	-120.536	-14.914	19.8	65.4	3.733	12.98	142.1	363.7	1.81	0.097	1.48	37.41	
DSA2	-120.466	-15.150	19.8	63.9	3.733	13.05	142.8	363.7	1.81	0.097	1.48	37.41	
DSB3	-120.691	-14.958	17.9	62.2	5.957	5.17	144.1	353.1	1.81	0.097	1.48	37.41	
DSB4	-120.621	-15.195	17.9	61.4	5.957	5.17	144.1	353.1	1.81	0.097	1.48	37.41	
DSC5	-120.840	-15.000	17.9	59.7	5.723	4.90	126.0	355.1	1.81	0.097	1.48	37.41	
DSC6	-120.770	-15.238	17.9	59.0	5.723	4.79	123.2	355.1	1.81	0.097	1.48	37.41	
BAKEOVEN	-121.011	-15.391	25.5	57.5	2.129	12.98	46.2	369.4	0.35	0.15	0.15	5.22	3.91
CAST1-6	-120.392	-15.061	26.9	66.1	2.365	5.69	25.0	433.0	0.33	0.079	0.13		
CAST7-8	-120.415	-14.965	23.2	66.1	1.365	5.69	8.3	433.0	0.11	0.026	0.045		
CAST9-10	-120.422	-14.960	18.4	66.1	1.365	5.69	8.3	433.0	0.11	0.026	0.045		
CAST11-12	-120.433	-14.922	23.2	66.1	1.365	5.69	8.3	433.0	0.11	0.026	0.045		
188	-120.933	-15.393	36.1	58.5	1.462	5.34	9.0	Ambient	0.010	0.010			
189	-120.919	-15.088	36.1	58.5	1.287	3.63	4.7	Ambient	0.090	0.090			
191	-120.940	-15.395	36.1	58.5	1.287	3.63	4.7	Ambient	0.090	0.090			
195	-120.553	-15.394	17.7	63.1	0.61	4.29	1.3	343.0	0.080	0.080			
198	-120.957	-15.122	13.3	58.5	1.219	20.23	23.6	Ambient	0.24	0.24			
199	-120.953	-15.121	13.3	58.5	1.219	20.23	23.6	Ambient	0.24	0.24			
208	-121.006	-15.002	5.0	58.5	1.828	2.53	6.6	Ambient	0.076	0.076			
209	-121.095	-14.985	15.7	74.4	0.914	36.19	23.7	Ambient	0.43	0.43			
210	-120.400	-15.282	9.4	65.2	0.762	3.11	1.4	395.0	0.00018	0.00018			
217	-120.360	-15.210	23.2	77	1.365	5.69	8.3	433.0	0.026	0.0035	0.0070		
232	-120.931	-15.423	6.6	58.2	0.61	29.12	8.5	Ambient	0.097	0.097			
260	-120.925	-15.134	11	59.1	0.26	1.46	0.08	Ambient	0.025	0.025			
312	-120.922	-15.099	13.7	58.5	0.49	1.59	0.30	370.0	0.11	0.11			
313	-120.941	-15.104	13.7	58.5	0.49	1.59	0.30	370.0	0.11	0.11			
316	-120.858	-15.400	22.86	57.96	1.372	15.9	23.5	302.9	0.30	0.30			

Table 4-2
Source Input Data for Baseline Modeling - Line Sources
Alcoa Intalco Works
Ferndale, Washington

Roof Scrubber Water On Conditions

Source Description	LCC Coordinate Begin X (km)	LCC Coordinate Begin Y (km)	LCC Coordinate End X (km)	LCC Coordinate End Y (km)	Release Height (m)	Base Elevation (m)	Line Source Width (m)	Exit Velocity (m/s)	Flow Rate (m^3/s)	Buoyancy Parameter (m^4/s^3)	PM_{10} Emission Rate (g/s)	Filterable $PM_{2.5}$ Emission Rate (g/s)	Condensable $PM_{2.5}$ Emission Rate (g/s)	SO_2 Emission Rate (g/s)	NO_x Emission Rate (g/s)
WSLINEA1	-120.532	-14.845	-120.422	-15.219	16.40	65.4	4.24	3.920	55.32	410.22	2.30	0.87	0.83	1.97	0.00
WSLINEA2	-120.606	-14.867	-120.496	-15.241	16.40	64.1	4.24	3.920	55.32	410.22	2.30	0.87	0.83	1.97	0.00
WSLINEB1	-120.681	-14.892	-120.571	-15.266	16.40	62.9	4.24	3.990	56.30	417.52	2.30	0.87	0.83	1.97	0.00
WSLINEB2	-120.755	-14.914	-120.645	-15.288	16.40	61.7	4.24	3.990	56.30	417.52	2.30	0.87	0.83	1.97	0.00
WSLINEC1	-120.828	-14.936	-120.719	-15.309	16.40	60.5	4.24	3.904	55.08	408.49	2.30	0.87	0.83	1.97	0.00
WSLINEC2	-120.903	-14.958	-120.793	-15.332	16.40	59.3	4.24	3.904	55.08	408.49	2.30	0.87	0.83	1.97	0.00

Roof Scrubber Water Off Conditions

Source Description	LCC Coordinate Begin X (km)	LCC Coordinate Begin Y (km)	LCC Coordinate End X (km)	LCC Coordinate End Y (km)	Release Height (m)	Base Elevation (m)	Line Source Width (m)	Exit Velocity (m/s)	Flow Rate (m^3/s)	Buoyancy Parameter (m^4/s^3)	PM_{10} Emission Rate (g/s)	Filterable $PM_{2.5}$ Emission Rate (g/s)	Condensable $PM_{2.5}$ Emission Rate (g/s)	SO_2 Emission Rate (g/s)	NO_x Emission Rate (g/s)
WSLINEA1	-120.532	-14.845	-120.422	-15.219	16.40	65.4	4.24	3.920	55.32	860.33	11.94	4.48	4.29	1.97	0.00
WSLINEA2	-120.606	-14.867	-120.496	-15.241	16.40	64.1	4.24	3.920	55.32	860.33	11.94	4.48	4.29	1.97	0.00
WSLINEB1	-120.681	-14.892	-120.571	-15.266	16.40	62.9	4.24	3.990	56.30	875.62	11.94	4.48	4.29	1.97	0.00
WSLINEB2	-120.755	-14.914	-120.645	-15.288	16.40	61.7	4.24	3.990	56.30	875.62	11.94	4.48	4.29	1.97	0.00
WSLINEC1	-120.828	-14.936	-120.719	-15.309	16.40	60.5	4.24	3.904	55.08	856.70	11.94	4.48	4.29	1.97	0.00
WSLINEC2	-120.903	-14.958	-120.793	-15.332	16.40	59.3	4.24	3.904	55.08	856.70	11.94	4.48	4.29	1.97	0.00

Table 4-3
Source Input Data for Baseline Modeling - Area Sources
Alcoa Intalco Works
Ferndale, Washington

Source ID	Source Description	Southwest Corner LCC Coordinate X (km)	Southwest Corner LCC Coordinate Y (km)	Release Height (m)	Initial σ_z (m)	Base Elevation (m)	Total Area (m^2)	PM_{10} Emission Rate ($g/s/m^2$)	Filterable $PM_{2.5}$ Emission Rate ($g/s/m^2$)	Condensable $PM_{2.5}$ Emission Rate ($g/s/m^2$)	SO_2 Emission Rate ($g/s/m^2$)	NO_x Emission Rate ($g/s/m^2$)
239	Fugitive dust from vehicle travel on paved roads	-120.536	-14.914	5	10	60	720,000	0.00000040	0.000000059	0	0	0
241	Facility-wide natural gas combustion (fugitive)	-120.466	-15.150	15	15	60	720,000	0.00000022	0.00000022	0	0.000000042	0.0000030
273	Alumina ore handling fugitive dust	-120.691	-14.958	15	15	60	720,000	0.000000053	0.0000000080	0	0	0

Table 4-4
Source Input Data for Baseline Modeling - Volume Sources
Alcoa Intalco Works
Ferndale, Washington

Source ID	Source Description	Reference LCC Coordinate X (km)	Reference LCC Coordinate Y (km)	Release Height (m)	Initial σ_y (m)	Initial σ_z (m)	Base Elevation (m)	PM_{10} Emission Rate (g/s)	Filterable $PM_{2.5}$ Emission Rate (g/s)	Condensable $PM_{2.5}$ Emission Rate (g/s)	SO_2 Emission Rate (g/s)	NO_x Emission Rate (g/s)
251	Anode bake building monitor roof	-120.982	-15.242	22	33.7	10.2	58.7	0.13	0.13	0.00	0.00	0.00
252	Anode block hole blower	-120.982	-14.242	22	33.7	10.2	58.7	0.12	0.12	0.00	0.00	0.00
257A	Rod shop crust recovery discharge to trucks from bins #1 and #2	-120.948	-15.123	4.6	1.07	1.07	58.5	0.0021	0.00032	0.00	0.00	0.00
257B	Rod shop crust recovery discharge to trucks from bins #1 and #2	-120.906	-15.112	4.6	1.07	1.07	58.5	0.0021	0.00032	0.00	0.00	0.00
259A	Rod shop carbon recovery discharge to trucks from bins #1 and #2	-120.948	-15.123	4.6	1.07	1.07	58.5	0.0030	0.00046	0.00	0.00	0.00
259B	Rod shop carbon recovery discharge to trucks from bins #1 and #2	-120.906	-15.112	4.6	1.07	1.07	58.5	0.0030	0.00046	0.00	0.00	0.00
280	Annex cathode assembly area roof vent	-120.983	-15.013	18.3	8.97	8.51	58.5	0.054	0.054	0.00	0.00	0.00
282	Annex ladle rebuild area rood vents	-120.952	-14.99	18.3	8.97	8.51	58.5	0.38	0.38	0.00	0.00	0.00
Others1	Other sources smaller than 0.1 g/s, combined (no SO_x or NO_x)	-120.665	-15.076	4.6	1.07	1.07	62.0	0.358	0.307	0.00	0.00	0.00
Others2	Other sources greater than 0.1 g/s, combined (no SO_x or NO_x)	-120.665	-15.076	4.6	1.07	1.07	62.0	0.849	0.7414	0.00	0.00	0.00
Others3	Other sources, combined (with SO_x or NO_x emissions)	-120.665	-15.076	4.6	1.07	1.07	62.0	0.1722	0.1676	0.00	0.1574	2.348

Table 4-5
Screening Baseline Visibility Modeling Results
Alcoa Intalco Works
Ferndale, Washington

Class I Area	2003		2004		2005	
	Modeled 98th Percentile (deciview)	Number of Days Exceeding 0.5 dv	Modeled 98th Percentile (deciview)	Number of Days Exceeding 0.5 dv	Modeled 98th Percentile (deciview)	Number of Days Exceeding 0.5 dv
Alpine Lakes Wilderness Area	**1.244**	36	**0.965**	37	**0.881**	23
Goat Rock Wilderness Area	0.500	8	**0.579**	10	0.317	3
Glacier Peak Wilderness Area	**1.161**	37	**1.156**	38	**0.736**	23
Mount Adams Wilderness Area	0.456	7	0.472	6	0.357	2
Mount Rainier National Park	**0.843**	22	**1.052**	26	**0.629**	15
North Cascades National Park	**1.376**	65	**1.395**	56	**1.138**	32
Olympic National Park	**2.363**	59	**1.858**	53	**2.136**	45
Pasayten Wilderness Area	**0.866**	30	**0.871**	33	**0.659**	13

Note:
Modeled visibility impacts that exceed the 0.5 dv contribution threshold are presented in bold in this table.

Table 4-6
Refined Baseline Visibility Modeling Results
Alcoa Intalco Works
Ferndale, Washington

Class I Area	2003		2004		2005	
	Modeled 98th Percentile (deciview)	Number of Days Exceeding 0.5 dv	Modeled 98th Percentile (deciview)	Number of Days Exceeding 0.5 dv	Modeled 98th Percentile (deciview)	Number of Days Exceeding 0.5 dv
Alpine Lakes Wilderness Area	**0.738**	24	**0.742**	18	**0.632**	9
Goat Rock Wilderness Area	0.332	4	0.287	5	0.194	0
Glacier Peak Wilderness Area	**0.916**	24	**0.769**	25	**0.552**	10
Mount Rainier National Park	**0.660**	11	**0.574**	9	0.414	3
North Cascades National Park	**0.936**	36	**0.986**	35	**0.693**	14
Olympic National Park	**1.527**	41	**1.369**	37	**1.225**	34
Pasayten Wilderness Area	0.448	6	0.469	6	0.412	2

Note:
Modeled visibility impacts that exceed the 0.5 dv contribution threshold are presented in bold in this table.

Table 4-7
Culpability Analysis for Refined Baseline Visibility Modeling Results in Olympic National Park
Alcoa Intalco Works
Ferndale, Washington

Year	Source Group	Modeled 98th Percentile (deciview)	Percentage of Species Contribution				
			SO_4	NO_3	Filterable $PM_{2.5}$	Coarse PM	Condensable PM
2003	**Total of all sources**	1.527	92.5%	3.0%	0.5%	0.5%	3.4%
	Potline primary emission controls	**1.414**	**96.6%**	0%	0.05%	0.3%	3.2%
	Potline secondary emission controls	0.026	67.6%	0%	5%	5.4%	21.6%
	Anode bake furnace	**0.048**	**59.4%**	**39.1%**	0%	0%	1.4%
	Casthouse stacks	0.002	0%	0%	0%	0%	66.7%
	All other stacks	0.003	0%	0%	80.0%	20.0%	0%
	All volume sources	0.022	6.3%	75.0%	12.5%	6.3%	0%
	All area sources	0.011	0%	93.8%	0%	0%	0%
2004	**Total of all sources**	1.369	80.8%	4.4%	1.7%	2.4%	10.6%
	Potline primary emission controls	**1.142**	**90.6%**	0%	0.12%	1.1%	8.2%
	Potline secondary emission controls	0.124	40.4%	0%	10.1%	11.8%	37.6%
	Anode bake furnace	**0.053**	**40.8%**	**55.3%**	1.3%	1.3%	2.6%
	Casthouse stacks	0.004	0%	0%	16.7%	16.7%	66.7%
	All other stacks	0.006	0%	0%	66.7%	33.3%	0%
	All volume sources	0.025	2.8%	69.4%	16.7%	11.1%	0%
	All area sources	0.014	0%	95.0%	5.0%	5.0%	0%
2005	**Total of all sources**	1.225	90.3%	2.5%	0.95%	0.89%	5.3%
	Potline primary emission controls	**1.080**	**95.7%**	0%	0%	0%	3.9%
	Potline secondary emission controls	0.079	61.5%	0%	7.3%	5.5%	26.6%
	Anode bake furnace	**0.039**	**62.3%**	**34.0%**	0%	0%	1.9%
	Casthouse stacks	0.001	0%	0%	0%	0%	100.0%
	All other stacks	0.003	0%	0%	75.0%	25.0%	0%
	All volume sources	0.016	4.5%	68.2%	13.6%	9.1%	0%
	All area sources	0.007	0%	90.0%	0%	0%	0%

Table 5-1
RBLC Database Search Results for Primary Aluminum Facilities
Alcoa Intalco Works
Ferndale, Washington

RBLC ID	Facility	Last Update	Process	Pollutant	Control Option	Percent Efficiency	Emission Limit
KY-0070	NSA - A Division of Southwire Company	03/02/2004	Potline 5	SO_2	Wet scrubber[1]	93%	25.51 lb/hr
SC-0037	Alumax of South Carolina	09/17/2002	Potroom Groups (4)	PM	Existing dry alumina scrubbers (fabric filter)		5.9 lb/hr
SC-0037	Alumax of South Carolina	09/17/2002	Potroom Groups (4)	SO_2	Limit maximum % sulfur of anode coke to 2.95%; limit maximum % sulfur of anode pitch to 1.2%		271 lb/hr
SC-0037	Alumax of South Carolina	09/17/2002	Anode Bake Plant	SO_2	No upgrade; limit maximum % sulfur of anode coke to 2.95%; limit maximum % sulfur of anode pitch to 1.2%		85.5 lb/hr
SC-0037	Alumax of South Carolina	09/17/2002	Anode Bake Plant	PM	No upgrade; limit sulfur content of raw materials		4.8 lb/hr
SC-0037	Alumax of South Carolina	09/17/2002	Anode Bake Plant	NO_x	No upgrade; limit sulfur content of raw materials		9 lb/hr
KY-0041	Arco Metals Co.	12/18/2001	Primary Aluminum Reduction Potline	PM	Baghouse, hooding for raw material handling	98%	0.02 gr/dscf
KY-0041	Arco Metals Co.	12/18/2001	Primary Aluminum Reduction Potline	SO_2	Fuel spec: low sulfur coke and pitch (calc. 3% sulfur)		388 lb/hr
OR-0002	Alumax Pacific Corp.	12/18/2001	Entire Plant	PM	Baghouse		5.4 lb/t (monthly ave.); 5.0 lb/ton (annual ave.)
OR-0002	Alumax Pacific Corp.	12/18/2001	Anode Coke	SO_2	Fuel spec: sulfur limit in coke		3% S in coke
WA-0003	Alcoa	12/18/2001	Potlines 1, 2, and 3	SO_2	Fuel spec: limit S content in coke, raw		3% S in coke
NC-0003	Alcoa	01/28/2002	Potline 3	PM	Fabric filter		26 lb/hr
NC-0003	Alcoa	01/28/2002	Potline 3	SO_2			321 lb/hr
NC-0003	Alcoa	01/28/2002	Anode Production	SO_2			13 lb/hr
NC-0003	Alcoa	01/28/2002	Anode Production	PM			9 lb/hr
MO-0036	Noranda Aluminum, Inc.	05/09/2006	Carbon Baking Furnace for Potline 3	PM_{10}			98.6 tons/yr
MO-0036	Noranda Aluminum, Inc.	05/09/2006	Potline 1	PM_{10}	Coated filter dry scrubber		56.76 tons/yr
MO-0036	Noranda Aluminum, Inc.	05/09/2006	Potline 3	PM_{10}	Coated filter dry scrubber		68.8 tons/yr

Note:
[1] This wet scrubber is not actually used or required by permit.

Table 5-2
Post Control Emission Rates[1]
Alcoa Intalco Works
Ferndale, Washington

Control Scenario	SO_2 Control Technology	SO_2		NO_x		$PM_{2.5}$		PM_{10}	
		Emissions (tons/yr)	% Reduction (Increase)[2]	Emissions (tons/yr)	% Reduction (Increase)[2]	Emissions (tons/yr)	% Reduction (Increase)[2]	Emissions (tons/yr)	% Reduction (Increase)[2]
1	LSFO Scrubber for Potlines	854	88	136	0	984	(42)	1,113	(28)
2	LSFO Scrubber for Anode Bake Furnace	6,904	2	136	0	747	(8)	921	(6)
Current Allowable Emissions	Operating Limit of 3% Sulfur in Coke	7,076		136		693		869	

Notes:

[1] Emission rates include the potline primary control system, the potline secondary control system emissions, and the anode bake furnace emissions.

[2] Compared with current potential emissions.

Table 5-3
Summary of the Impacts Analysis for SO_2 Control Scenarios
Alcoa Intalco Works
Ferndale, Washington

Control Scenario	Control Technology Evaluated	Controlled SO_2 Emission Rate[1] (tons/year)	SO_2 Emission Reductions[2] (tons/year)	Installed Capital Cost	Total Annualized Control Costs	Cost Effectiveness (per ton SO_2 removed)	Energy Impact (kW-hr/yr)	Collateral Increase in Other Pollutants	Non-Air Quality Environmental Impacts
1	LSFO Scrubber for Potlines	854	6,223	$234,531,049	$46,820,000	$7,500	64,824,000	291 tons/yr $PM_{2.5}$ 243 tons/yr PM_{10} 17,597 tons/yr GHG[3]	27,130 tons/year of solid waste disposal 182.5 million gallons/year makeup water
2	LSFO Scrubber for Anode Bake Furnace	6,904	172	$29,482,194	$6,277,000	$36,400	6,570,000	54 tons/yr $PM_{2.5}$ 52 tons/yr $PM_{2.5}$ 1,330 tons/yr GHG[3]	639.5 tons/year of solid waste disposal 12.8 million gallons/year makeup water
Current Allowable Emissions	Operating Limit of 3% Sulfur in Coke	7,076							

Notes:

[1] Emission rates include the potline primary control system, the potline secondary control system emissions, and the anode bake furnace emissions.

[2] Compared with current potential emissions.

[3] Greenhouse gas (GHG) emissions are presented as CO_2 equivalent emissions. The GHG emission calculations are presented in Appendix E.

Table 5-4
Source Input Data for Post Control SO_2 Modeling[1]
Alcoa Intalco Works
Ferndale, Washington

Control Scenario	SO_2 Control Technology	Source Description	LCC Coordinate X (km)	LCC Coordinate Y (km)	Stack Height (m)	Base Elevation (m)	Effective Stack Diameter (m)	Exit Velocity (m/s)	Exit Temperature (°K)	PM_{10} Emission Rate (g/s)	Filterable $PM_{2.5}$ Emission Rate (g/s)	Condensable $PM_{2.5}$ Emission Rate (g/s)	SO_2 Emission Rate (g/s)	NO_x Emission Rate (g/s)
1	LSFO Scrubber for Potlines	Potline Wet Scrubber[2]	-120.425	-15.316	38.1	59.0	8.1	18.3	310	0.00	17.8	0.00	11.22	0.00
2	LSFO Scrubber for Anode Bake Furnace	Anode Bake Furnace Wet Scrubber[3]	-121.018	-15.614	30.5	57.5	2.6	18.3	336	0.00	1.70	0.15	0.26	3.91

Notes:

[1] Source input data for all other sources are the same as listed in Table 4-1 through 4-4 for the baseline modeling.

[2] Potline wet scrubber source replaces sources DSA1, DSA2, DSB3, DSB4, DSC5, and DSC6 in Table 4-1 from the baseline modeling.

[3] Anode bake oven wet scrubber source replaces source BAKEOVEN in Table 4-1 from the baseline modeling.

Table 5-5
SO_2 Post Control Visibility Modeling Results
Alcoa Intalco Works
Ferndale, Washington

Control Scenario	SO_2 Control Technology Evaluated	Class I Area	2003		2004		2005	
			Modeled 98th Percentile (deciview)	Number of Days Exceeding 0.5 dv	Modeled 98th Percentile (deciview)	Number of Days Exceeding 0.5 dv	Modeled 98th Percentile (deciview)	Number of Days Exceeding 0.5 dv
1	LSFO Scrubber for Potlines	Alpine Lakes Wilderness Area	0.158	0	0.147	0	0.129	0
		Glacier Peak Wilderness Area	0.190	0	0.163	0	0.125	0
		Mount Rainier National Park	0.108	0	0.107	0	0.085	0
		North Cascades National Park	0.198	0	0.212	0	0.174	0
		Olympic National Park	0.355	2	0.303	1	0.325	1
2	LSFO Scrubber for Anode Bake Furnace	Alpine Lakes Wilderness Area	**0.723**	22	**0.729**	18	**0.621**	9
		Glacier Peak Wilderness Area	**0.901**	24	**0.752**	23	**0.546**	10
		Mount Rainier National Park	**0.648**	11	**0.565**	9	0.410	3
		North Cascades National Park	**0.921**	36	**0.974**	34	**0.684**	14
		Olympic National Park	**1.503**	41	**1.348**	37	**1.206**	33
Current Allowable Emissions	Operating Limit of 3% Sulfur in Coke	Alpine Lakes Wilderness Area	**0.738**	24	**0.742**	18	**0.632**	9
		Glacier Peak Wilderness Area	**0.916**	24	**0.769**	25	**0.552**	10
		Mount Rainier National Park	**0.660**	11	**0.574**	9	0.414	3
		North Cascades National Park	**0.936**	36	**0.986**	35	**0.693**	14
		Olympic National Park	**1.527**	41	**1.369**	37	**1.225**	34

Note:
Modeled visibility impacts that exceed the 0.5 dv contribution threshold are presented in bold in this table.

APPENDICES

APPENDIX A:

BART MODELING RESULTS

APPENDIX B:

BUSINESS CONFIDENTIAL INFORMATION

APPENDIX C:

PRE-FEASIBILITY REPORT

APPENDIX D:

WET SCRUBBER ECONOMIC AND ENERGY IMPACT

Scaling of Capital Equipment Costs Based on Vendor Proposals
Intalco Works
Ferndale, Washington

Scrubber Component	Fraction of Total Equipment Cost	Scaling Equation Exponent		Tennessee Potline Scrubber Equipment Costs			Intalco Scrubber Equipment Cost Estimates	
		Potlines	Anode Bake Furnace	Vendor Quote #1	Vendor Quote #2	Average	Potlines	Anode Bake Furnace
Reagent feed system	10%	0.33	0.80	$6,500,000	$8,200,000	$7,350,000	$7,894,009	$404,491
SO_2 removal system	35%	0.50	0.80	$22,750,000	$28,700,000	$25,725,000	$28,543,995	$4,666,407
Flue gas system	30%	0.50	0.80	$19,500,000	$24,600,000	$22,050,000	$24,466,281	$3,999,778
By-product handling system	10%	0.40	0.80	$6,500,000	$8,200,000	$7,350,000	$8,104,759	$403,121
General support equipment	15%	0.15	0.80	$9,750,000	$12,300,000	$11,025,000	$11,436,638	$568,845
TOTAL				**$65,000,000**	**$82,000,000**	**$73,500,000**	**$80,445,682**	**$10,042,642**

Captial Investment Cost Analysis for SO_2 Control Using a Wet Scrubber
Potlines
Intalco Works
Ferndale, Washington

	Value	Notes/References
Capital Investment Costs		
Direct Capital Costs (DCC)		
Purchased Equipment Costs (PEC)		
Adsorber vessels with internals	$80,445,682	Based on vendor quotations for Tennessee Alcoa smelter, adjusted for scrubber exhaust gas flow rate, limestone consumption, and gypsum generation per Pre-feasability Report (Hatch 2007)
Pumps	Included	
Limestone prep	Included	
Dewatering systems	Included	
Fans	Included	
Inlet ductwork	Included	
Stacks	Included	
Continuous Emission Monitoring system (2 stacks)	$80,000	
Subtotal (EC)	$80,525,682	
Instrumentation	$4,026,284	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (5% of EC; adjusted from 10% since basic instrumentation is included in proposal)
Sales tax	$5,234,169	State sales tax rate for Washington is 6.5%
Freight	$4,026,284	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (5% of EC)
Total Purchased Equipment Costs (PEC)	**$93,812,419**	
Direct Installation Costs (DIC)		
Foundations and supports	$11,257,490	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (12% of PEC)
Handling and erection	$75,049,936	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (80% of PEC; adjusted from 40% to account for retrofit of existing plant and onsite fabrication)
Electrical	$938,124	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (1% of PEC)
Piping	$28,143,726	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (30% of PEC)
Insulation	$938,124	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (1% of PEC)
Painting	$938,124	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (1% of PEC)
Total Direct Installation Costs (DIC)	**$117,265,524**	
Total Direct Capital Costs	**$211,077,944**	Sum of PEC and DIC
Indirect Capital Costs (ICC)		
Engineering	$4,690,621	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (5% of PEC; adjusted from 10% since vendor proposal includes an allowance for engineering)
Construction and field expenses	$9,381,242	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (10% of PEC)
Contractor fees	$4,690,621	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (5% of PEC; adjusted from 10% based on assumption that vendor will oversee scrubber installation)
Start-up	$938,124	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (1% of PEC)
Performance test	$938,124	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (1% of PEC)
Contingencies	$2,814,373	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (3% of PEC)
Total Indirect Capital Costs	**$23,453,105**	
Total Capital Investment Costs (TCIC)	**$234,531,049**	Sum of DCC and ICC

References:

Hatch. 2007. *SO_2 Scrubbing for the INTALCO Primary Aluminum Smelter: Pre-Feasibility Report* . July 26.
USEPA. 2002. *EPA Air Pollution Control Cost Manual* , Sixth Edition. EPA/452/B-02-001. January.

Operation and Maintenance Cost Analysis for SO_2 Control Using a Wet Scrubber
Potlines
Intalco Works
Ferndale, Washington

	Value	Units	Notes/References
Annual Operation and Maintenance Costs			
Direct Annual Costs (DAC)			
Operating labor			
Operator	$324,120		Assumes $37 per hour with one full-time operator, 3 shifts per day
Supervisor	$48,618		USEPA 2002, Section 5.2, Chapter 1, Table 1.4 (15% of operator costs)
Water	$96,725		
Water usage	500,000	gal/day	Pre-feasability Report (Hatch 2007)
Cost of water	$0.00053	$/gal	Intalco controller
Limestone	$470,052		
Limestone usage	14,244	tons/yr	Pre-feasability Report (Hatch 2007)
Cost of limestone	$33	$/ton	Assumes $28/ton for 8 mesh size limestone plus $5/ton for shipping by barge
Compressed air	$18,922		
Compressed air usage	150	scfm	Pre-feasability Report (Hatch 2007)
Cost of compressed air	$0.24	$/1000 scf	Average compressed air generation cost for industrial facilities (http://www1.eere.energy.gov/industry/bestpractices/pdfs/compressed_air1.pdf)
Gypsum disposal	$3,933,809		
Gypsum generation rate	6,194	lb/hr	Pre-feasability Report (Hatch 2007)
Cost of gypsum disposal	$145	$/ton	Non-hazardous waste disposal and transportation costs
Maintenance			
Labor	$673,920		Assumes $45 per hour with 4 full-time maintenance personnel, one shift per day, 5 days per week and 1 maintenance personnel for all other shifts
Material	$1,303,000		Cost for low sulfur boiler system with 1.7 macfm inlet/1.5 macfm outlet, which is smaller than the potline system with 2.2 macfm inlet/2.0 macfm outlet (Sargent & Lundy LLC 2003)
Electricity	$3,409,742		
Electricity usage	7,400	kWh/hr	Pre-feasability Report (Hatch 2007)
Electricity cost	$0.0526	$/kWh	Facility average power rate for 2007 (Intalco controller)
Total Direct Annual Costs	**$10,278,908**		
Indirect Annual Costs (IAC)			
Overhead	$1,409,795		USEPA 2002, Section 5.2, Chapter 1, Table 1.4 (60% of total labor and maintenance material costs)
General and administrative costs	$4,690,621		USEPA 2002, Section 5.2, Chapter 1, Table 1.4 (2% of TCIC)
Property tax	$2,345,310		USEPA 2002, Section 5.2, Chapter 1, Table 1.4 (1% of TCIC)
Insurance	$2,345,310		USEPA 2002, Section 5.2, Chapter 1, Table 1.4 (1% of TCIC)
Total Indirect Annual Costs	**$10,791,037**		Sum of PEC and DIC
Total Annual Operating and Maintenance Costs	**$21,069,945**		Sum of DAC and IAC

References:

Hatch. 2007. *SO_2 Scrubbing for the INTALCO Primary Aluminum Smelter: Pre-Feasibility Report*. July 26.
Sargent & Lundy LLC. 2003. *Wet Flue Gas Desulfurization Technology Evaluation*. Prepared for National Lime Association. January.
USEPA. 2002. *EPA Air Pollution Control Cost Manual*, Sixth Edition. EPA/452/B-02-001. January.

Installation of Wet Scrubber on Potline Exhaust

			Reference
Potline hooding capture efficiency	95%		
Total potline uncontrolled SO_x emission rate	37,780	lb/day	Total potline SO_x emission limit
Primary potline control system uncontrolled SO_x emission rate	35,891	lb/day	Calculated based on potline hooding capture efficiency
SO_x control efficiency	95%		
Controlled SO_x emission rate	1,795	lb/day	
Uncontrolled annual SO_x emissions	6,550	tpy	
Controlled annual SO_x emissions	328	tpy	
SO_x reduction	6,223	tpy	
Direct capital costs (DCC)	$211,077,944		
Indirect capital costs (ICC)	$ 23,453,105		
Total capital costs	**$234,531,049**		
Interest rate	7%		USEPA 2002, Section 1, Chapter 2.4.2
Period of annualization	15	years	Assumption
Capital recovery discount factor	0.11		USEPA 2002, Section 1, Chapter 2.4.4.4, Equation 2.8a
Annualized capital cost	**$ 25,750,000**		USEPA 2002, Section 1, Chapter 2.4.4.4, Equation 2.8
Operating labor costs	$ 324,120		
Supervisory labor costs	$ 48,618		
Maintenance labor costs	$ 673,920		
Maintenance material costs	$ 1,303,000		
Electricity costs	$ 3,409,742		
Water costs	$ 96,725		
Limestone costs	$ 470,052		
Compressed air costs	$ 18,922		
Gypsum disposal costs	$ 3,933,809		
Overhead	$ 1,409,795		
Property tax	$ 2,345,310		
Insurance	$ 2,345,310		
General and administrative costs	$ 4,690,621		
Total annual cost estimate	**$ 46,820,000**		
Cost of option per ton SO_x reduced	***$ 7,500***		

Captial Investment Cost Analysis for SO_2 Control Using a Wet Scrubber
Anode Bake Furnace
Intalco Works
Ferndale, Washington

	Value	Notes/References
Capital Investment Costs		
Direct Capital Costs (DCC)		
Purchased Equipment Costs (PEC)		
Adsorber vessels with internals	$10,042,642	Based on vendor quotations for Tennessee Alcoa smelter, adjusted for exhaust gas flow rate per Pre-feasability Report (Hatch 2007)
Pumps	Included	
Limestone prep	Included	
Dewatering systems	Included	
Fans	Included	
Inlet ductwork	Included	
Stacks	Included	
Continuous Emission Monitoring system (2 stacks)	$80,000	
Subtotal (EC)	$10,122,642	
Instrumentation	$506,132	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (5% of EC; adjusted from 10% since basic instrumentation is included in proposal)
Sales tax	$657,972	State sales tax rate for Washington is 6.5%
Freight	$506,132	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (5% of EC)
Total Purchased Equipment Costs (PEC)	**$11,792,878**	
Direct Installation Costs (DIC)		
Foundations and supports	$1,415,145	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (12% of PEC)
Handling and erection	$9,434,302	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (80% of PEC; adjusted from 40% to account for retrofit of existing plant and onsite fabrication)
Electrical	$117,929	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (1% of PEC)
Piping	$3,537,863	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (30% of PEC)
Insulation	$117,929	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (1% of PEC)
Painting	$117,929	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (1% of PEC)
Total Direct Installation Costs (DIC)	**$14,741,097**	
Total Direct Capital Costs	**$26,533,975**	Sum of PEC and DIC
Indirect Capital Costs (ICC)		
Engineering	$589,644	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (5% of PEC; adjusted from 10% since vendor proposal includes an allowance for engineering)
Construction and field expenses	$1,179,288	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (10% of PEC)
Contractor fees	$589,644	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (5% of PEC; adjusted from 10% based on assumption that vendor will oversee scrubber installation)
Start-up	$117,929	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (1% of PEC)
Performance test	$117,929	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (1% of PEC)
Contingencies	$353,786	USEPA 2002, Section 5.2, Chapter 1, Table 1.3 (3% of PEC)
Total Indirect Capital Costs	**$2,948,219**	
Total Capital Investment Costs (TCIC)	**$29,482,194**	Sum of DCC and ICC

References:

Hatch. 2007. *SO_2 Scrubbing for the INTALCO Primary Aluminum Smelter: Pre-Feasibility Report*. July 26.
USEPA. 2002. *EPA Air Pollution Control Cost Manual*, Sixth Edition. EPA/452/B-02-001. January.

Operation and Maintenance Cost Analysis for SO_2 Control Using a Wet Scrubber
Anode Bake Furnace
Intalco Works
Ferndale, Washington

	Value	Units	Notes/References
Annual Operation and Maintenance Costs			
Direct Annual Costs (DAC)			
Operating labor			
Operator	$324,120		Assumes $37 per hour with one full-time operator, 3 shifts per day
Supervisor	$48,618		USEPA 2002, Section 5.2, Chapter 1, Table 1.4 (15% of operator costs)
Water	$6,771		
Water usage	35,000	gal/day	Pre-feasability Report (Hatch 2007)
Cost of water	$0.00053	$/gal	Intalco controller
Limestone	$11,286		
Limestone usage	342	tons/yr	Pre-feasability Report (Hatch 2007)
Cost of limestone	$33	$/ton	Assumes $28/ton for 8 mesh size limestone plus $5/ton for shipping by barge
Compressed air	$6,307		
Compressed air usage	50	scfm	Pre-feasability Report (Hatch 2007)
Cost of compressed air	$0.24	$/1000 scf	Average compressed air generation cost for industrial facilities (http://www1.eere.energy.gov/industry/bestpractices/pdfs/compressed_air1.pdf)
Gypsum disposal	$92,725		
Gypsum generation rate	146	lb/hr	Pre-feasability Report (Hatch 2007)
Cost of gypsum disposal	$145	$/ton	Non-hazardous waste disposal and transportation costs
Maintenance			
Labor	$336,960		Assumes $45 per hour with 2 full-time maintenance personnel, one shift per day, 5 days per week and a half-time maintenance personnel equivalent for all other shifts
Material	$163,796		Calculated based on estimated maintenance material costs for potline scrubber and ratio of purchased equipment costs for the anode bake furnace and potline scrubbers
Electricity	$345,582		
Electricity usage	750	kWh/hr	Pre-feasability Report (Hatch 2007)
Electricity cost	$0.0526	$/kWh	Facility average power rate for 2007 (Intalco controller)
Total Direct Annual Costs	**$1,336,165**		
Indirect Annual Costs (IAC)			
Overhead	$524,097		USEPA 2002, Section 5.2, Chapter 1, Table 1.4 (60% of total labor and maintenance material costs)
General and administrative costs	$589,644		USEPA 2002, Section 5.2, Chapter 1, Table 1.4 (2% of TCIC)
Property tax	$294,822		USEPA 2002, Section 5.2, Chapter 1, Table 1.4 (1% of TCIC)
Insurance	$294,822		USEPA 2002, Section 5.2, Chapter 1, Table 1.4 (1% of TCIC)
Total Indirect Annual Costs	**$1,703,384**		Sum of PEC and DIC
Total Annual Operating and Maintenance Costs	**$3,039,549**		Sum of DAC and IAC

References:

Hatch. 2007. *SO_2 Scrubbing for the INTALCO Primary Aluminum Smelter: Pre-Feasibility Report*. July 26.

USEPA. 2002. *EPA Air Pollution Control Cost Manual*, Sixth Edition. EPA/452/B-02-001. January.

Installation of Wet Scrubber on Anode Bake Furnace Exhaust

			Reference
Uncontrolled SO_x emission rate	994	lb/day	
SO_x control efficiency	95%		
Controlled SO_x emission rate	50	lb/day	
Uncontrolled annual SO_x emissions	181	tpy	
Controlled annual SO_x emissions	9	tpy	
SO_x reduction	172	tpy	
Direct capital costs (DCC)	$ 26,533,975		
Indirect capital costs (ICC)	$ 2,948,219		
Total capital costs	**$ 29,482,194**		
Interest rate	7%		USEPA 2002, Section 1, Chapter 2.4.2
Period of annualization	15	years	Assumption
Capital recovery discount factor	0.11		USEPA 2002, Section 1, Chapter 2.4.4.4, Equation 2.8a
Annualized capital cost	**$ 3,237,000**		USEPA 2002, Section 1, Chapter 2.4.4.4, Equation 2.8
Operating labor costs	$ 324,120		
Supervisory labor costs	$ 48,618		
Maintenance labor costs	$ 336,960		
Maintenance material costs	$ 163,796		
Electricity costs	$ 345,582		
Water costs	$ 6,771		
Limestone costs	$ 11,286		
Compressed air costs	$ 6,307		
Gypsum disposal costs	$ 92,725		
Overhead	$ 524,097		
Property tax	$ 294,822		
Insurance	$ 294,822		
General and administrative costs	$ 589,644		
Total annual cost estimate	**$ 6,277,000**		
Cost of option per ton SO_x reduced	***$ 36,400***		

APPENDIX E:

GREENHOUSE GAS EMISSION CALCULATIONS

BART Determination
Alcoa Intalco Works
Ferndale, Washington
Greenhouse Gas Emission Calculations

Greenhouse gases (GHGs) are gaseous compounds that are considered to act as heat trapping constituents of the atmosphere. Although there are many gases that may trap heat in the atmosphere, there are six GHGs recognized by international and domestic regulations on climate change: carbon dioxide (CO_2), nitrous oxide (N_2O), methane, hydrofluorocarbons (HFCs), chlorinated fluorocarbons (CFCs), and sulfur hexafluoride. More than 80% of the global warming potential results from CO_2 emissions.

The proposed sulfur dioxide (SO_2) control devices will contribute to the facility's overall emissions of GHGs via three mechanisms: (1) as a byproduct of the reaction chemistry in the scrubbers, (2) as indirect emissions from the generation of electricity required to power the scrubbing systems, and (3) as direct emissions from vehicle travel for the additional personnel that will be required at the facility to maintain and operate the scrubbing systems.

The estimate of carbon dioxide emissions resulting from the reaction of limestone with the sulfur dioxide in the exhaust streams is based on the theoretical reaction chemistry, assuming no other byproducts resulting from incomplete reaction. Consistent with the BART analysis, we assumed that 95% of the incoming sulfur dioxide reacts with the limestone, and hence is removed from the exhaust stream. There are three reactions taking place in the scrubber:

1) Dissolution of the limestone in the scrubbing water:

$$CaCO_3 + H_2O \rightarrow Ca^{+2} + HCO_3^- + OH^-$$

2) Dissolution of the sulfur dioxide in the scrubbing water:

$$SO_2 + H_2O \rightarrow 2H^+ + SO_3^{-2}$$

3) Oxidation of the sulfite ions to sulfate ions (and hence, formation of gypsum or calcium sulfate):

$$Ca^{+2} + HCO_3^- + OH^- + 2H^+ + SO_3^{-2} + \tfrac{1}{2} O_2 \rightarrow CaSO_4 + CO_2 + 2\ H_2O$$

Consistent with the chemical balance shown above, for every mole of SO_2 reacted, a mole of carbon dioxide is formed.

The inlet sulfur dioxide molar flowrate was estimated based on design parameters provided by Hatch Associates[1]. Assuming a minimum 95% sulfur dioxide control efficiency (that is, assuming that 95% of the sulfur dioxide reacts with the limestone), the mass of carbon dioxide evolved was calculated based on the reaction chemistry presented above.

[1] Hatch Associates. 2007. *Pre-Feasibility Report – SO_2 Scrubbing for the INTALCO Primary Aluminum Smelter*. November 5. Tables 3 and 6 (potline exhaust and anode baking furnace exhaust, respectively).

The implementation of the proposed scrubbing systems would also generate GHGs indirectly, as a result of consuming electricity. The generation of electricity at some off-site location would produce GHGs. The methodology described in the *California Climate Action Registry General Reporting Protocol (CCARGRP)*[2], for estimating indirect emissions of GHGs from electricity use was followed. Based on design specifications provided by Hatch Associates[3], the daily electricity usage of each scrubber (potline fumes scrubber and the anode bake furnace scrubber) were multiplied by a state-specific carbon dioxide emission factor. The state-specific emission factor was found in the USEPA *Emissions and Generation Resource Integrated Database for 2006* (eGrid2006)[4] for Washington state. To estimate the emissions of nitrous oxide and methane (two minor GHG components from combustion sources), the default emission factors provided in the CCARGRP[5] were used. To convert the estimated nitrous oxide and methane emissions to carbon dioxide equivalents, the CCARGRP provides an estimate of each compound's global warming potential (GWP)[6]. For example, methane has a GWP of 21 times that of carbon dioxide; therefore, to convert the methane emission rate to carbon dioxide equivalents, we multiply the methane emission rate by its GWP.

The last potential source of GHGs resulting from the implementation of the proposed scrubbing systems is from vehicle travel to and from the facility by additional personnel necessary for the operation and maintenance of the scrubbing systems. Based on facility estimates, the potline fumes scrubbing system would require nine additional employees per day on weekdays and six additional personnel per day on weekends. Similarly, the anode baking furnace scrubbing system would require six additional employees per day on weekdays and 4.5 additional personnel equivalents per day on weekends. It was assumed that each person would drive a roundtrip distance of 20 miles per day. This is approximately the roundtrip distance between the facility and downtown Bellingham, Washington. The emission estimates of carbon monoxide, nitrous oxide, and methane in the vehicle exhaust were based on assuming an average fuel economy. The fleet average (1988 to 2007) fuel economy from the USEPA[7] was used. The emission factor for carbon dioxide was provided in the CCARGRP for non-California gasoline[8]. The emission factors for nitrous oxide and methane from vehicles were based on the average of the 1988 to present emission factors provided in the CCARGRP[9]. To convert the nitrous oxide and methane emission rates to carbon dioxide equivalents, the GWP for each compound was applied as discussed above.

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[2] California Climate Action Registry. 2007. *California Climate Action Registry General Reporting Protocol (CCARGRP): Reporting Entity-Wide Greenhouse Gas Emissions*. Version 2.2. March. Chapter 6.
[3] Hatch Associates. 2007. *Pre-Feasibility Report – SO_2 Scrubbing for the INTALCO Primary Aluminum Smelter*. November 5. Tables 5 and 8 (potline fumes scrubbing and anode baking furnace scrubbing, respectively).
[4] United States Environmental Protection Agency (USEPA). 2007. Emissions and Generation Resource Integrated Database for 2006 (eGrid2006). Version 2.1. April. Year 2004 summary tables.
[5] California Climate Action Registry. 2007. *California Climate Action Registry General Reporting Protocol (CCARGRP): Reporting Entity-Wide Greenhouse Gas Emissions*. Version 2.2. March. Table C-2
[6] Ibid. Table III.6-1.
[7] United States Environmental Protection Agency (USEPA). 2007. Light-Duty Automotive Technology and Fuel Economy Trends: 1975 to 2007 (Table 1 – Cars and Trucks).
[8] California Climate Action Registry. 2007. *California Climate Action Registry General Reporting Protocol (CCARGRP): Reporting Entity-Wide Greenhouse Gas Emissions*. Version 2.2. March. Table C-3.
[9] Ibid. Table C-4 (used weighted average of the factors provided for various spans of model years).

The GHG emission calculations described above are presented in the attached tables. The total GHGs (in carbon dioxide equivalents) generated by the implementation of the proposed scrubbing system for the potline fumes was estimated to be 96,441 pounds per day, or 17,598 tons per year. The total GHGs (in carbon dioxide equivalents) generated by the implementation of the proposed scrubbing system for the anode baking furnace was estimated to be 7,298 pounds per day, or 1,330 tons per year.

Greenhouse Gases Emissions
Intalco (Ferndale, WA)

Scope **:**

Calculation of greenhouse gases from the implementation of a flue gas desulfurization system. There will be one scrubbing system for the potrooms and one for the anode baking furnace. The scrubbing system consists of a limestone-gypsum forced oxidation (LSFO) process.

Assumptions **:**

CO_2 is the primary greenhouse gas evolved. Other components, such as methane or nitrous oxide are in de minimus quantities. These will be included where there is sufficient information for their estimate.

Sources of Greenhouse Gases **:**

- Reaction chemistry of the limestone and sulfur dioxide (LSFO)
- Energy consumption of the scrubbing systems
- The addition of personnel as a result of the operation of the scrubbing systems (vehicle travel)

Summary of Potline Wet Scrubber GHG Emission Estimates **:**

Mass of CO_2 evolved from scrubbing potroom emissions	31,969 lb/day
Mass of GHGs (in CO_2 equivalents) evolved from electricity production for scrubbing system	64,294 lb/day
Mass of GHGs (in CO_2 equivalents) evolved from vehicle travel for additional personnel	177.9 lb/day
TOTAL GHGs (CO_2 equivalents)	**96,441 lb/day**
	17,597 tons/yr

Summary of Anode Bake Furnace Wet Scrubber GHG Emission Estimates **:**

Mass of CO_2 evolved from scrubbing anode bake furnace emissions	663 lb/day
Mass of GHGs (in CO_2 equivalents) evolved from electricity production for scrubbing system	6,516 lb/day
Mass of GHGs (in CO_2 equivalents) evolved from vehicle travel for additional personnel	118.6 lb/day
TOTAL GHGs (CO_2 equivalents)	**7,298 lb/day**
	1,330 tons/yr

GHG Emissions from Scrubbing Potline Emissions

Scrubbing Reaction Chemistry:

1) $CaCO_3 + H_2O$ ------> $Ca^{+2} + HCO_3^- + OH^-$

2) $SO_2 + H_2O$ ----------> $2H^+ + SO_3^{-2}$

3) $Ca^{+2} + HCO_3^- + OH^- + SO_3^{-2} + 2H^+ + 1/2\ O_2$ ----------> $CaSO_4 + CO_2 + 2H_2O$

So, for every one mole of SO_2 (64 grams) removed, one mole of CO_2 (44 grams) is evolved.

Based on the final Hatch pre-feasibility report (dated November 5, 2007):

Parameter	Value	Reference
SO_2 concentration	300 mg/Nm^3	Hatch, Table 3
Flowrate	1,814,880 scfm	Hatch, Table 3
	51,394 m^3/min	
SO_2 at inlet of FGD system	257.0 grams/second	Calculated, based on FGD inlet flow characteristics presented in Hatch, Table 3
	4.02 moles SO_2/second	Based on molar mass of SO_2 of 64 grams/mole
Removal efficiency	95% minimum	Hatch, Table 4
Moles of SO_2 reacted	3.81 moles SO_2/second	
Moles of CO_2 evolved	3.81 moles CO_2/second	
Mass of CO_2 evolved	167.8 grams CO_2/second	Based on molar mass of CO_2 of 44 grams/mole
	14,500,691 grams CO_2/day	
	31,969 lb CO_2/day	

GHG Emissions from Scrubbing Anode Baking Furnace Emissions

Scrubbing Reaction Chemistry:

1) $CaCO_3 + H_2O$ ------> $Ca^{+2} + HCO_3^- + OH^-$

2) $SO_2 + H_2O$ ----------> $2H^+ + SO_3^{-2}$

3) $Ca^{+2} + HCO_3^- + OH^- + SO_3^{-2} + 2H^+ + 1/2\ O_2$ ----------> $CaSO_4 + CO_2 + 2H_2O$

So, for every one mole of SO_2 (64 grams) removed, one mole of CO_2 (48 grams) is evolved.

Based on the final Hatch pre-feasibility report (dated November 5, 2007):

Parameter	Value	Reference
SO_2 at inlet of FGD system	5.33 grams/second	Hatch, Table 6
	0.083 moles SO_2/second	Based on molar mass of SO_2 of 64 grams/mole
Removal efficiency	95% minimum	Hatch, Table 7
Moles of SO_2 reacted	0.079 moles SO_2/second	
Moles of CO_2 evolved	0.079 moles CO_2/second	
Mass of CO_2 evolved	3.5 grams CO_2/second	Based on molar mass of CO_2 of 44 grams/mole
	300,772 grams CO_2/day	
	663 lb CO_2/day	

GHGs resulting from electricity generation associated with potline scrubber system[1]

Parameters			**Reference**
Electricity usage for potline wet scrubber	7,400	kWh/h	Hatch, Table 5
Electricity usage for potline wet scrubber	177,600	kWh/day	Assumes continuous operation of wet scrubber
N_2O global warming potential (GWP)	310		Table III.6.1 - CCARGRP
Methane GWP	21		Table III.6.1 - CCARGRP

Emission Factors			**Reference**
CO_2	360	lb/MWh	Emission factors for Washington state (eGrid 2006 Version 2.1, April 2007)
CO_2	0.36	lb/kWh	
N_2O	0.004	lb/MWh	Default emission factors for N_2O and methane for Washington state (Table C.2, CCARGRP)
Methane	0.037	lb/MWh	Default emission factors for N_2O and methane for Washington state (Table C.2, CCARGRP)

Emission Estimates		
CO_2	63,936	lb/day
N_2O	0.71	lb/day
Methane	6.57	lb/day

Conversion of non-CO_2 GHGs to CO_2 equivalents		
CO_2	63,936	lb/day
N_2O - CO_2 equivalents	220	lb/day
Methane - CO_2 equivalents	138	lb/day
Total CO_2 equivalents	**64,294**	**lb/day**

Notes:

[1]Based on methodology described in the *California Climate Action Registry General Reporting Protocol (CCARGRP)* (March 2007) and the data in the USEPA *Emissions & Generation Resource Integrated Database* (eGrid2006).

GHGs resulting from electricity generation associated with anode bake furnace scrubber system[1]

Parameters			**Reference**
Electricity usage for anode bake furnace wet scrubber	750	kWh/h	Hatch, Table 8
Electricity usage for anode bake furnace wet scrubber	18,000	kWh/day	Assumes continuous operation of wet scrubber
N_2O global warming potential (GWP)	310		Table III.6.1 - CCARGRP
Methane GWP	21		Table III.6.1 - CCARGRP

Emission Factors			**Reference**
CO_2	360	lb/MWh	Emission factors for Washington state (eGrid 2006 Version 2.1, April 2007)
CO_2	0.36	lb/kWh	
N_2O	0.004	lb/MWh	Default emission factors for N_2O and methane for Washington state (Table C.2, CCARGRP)
Methane	0.037	lb/MWh	Default emission factors for N_2O and methane for Washington state (Table C.2, CCARGRP)

Emission Estimates		
CO_2	6,480	lb/day
N_2O	0.07	lb/day
Methane	0.67	lb/day

Conversion of non-CO_2 GHGs to CO_2 equivalents		
CO_2	6,480	lb/day
N_2O - CO_2 equivalents	22	lb/day
Methane - CO_2 equivalents	14	lb/day
Total CO_2 equivalents	**6,516**	**lb/day**

Notes:

[1]Based on methodology described in the *California Climate Action Registry General Reporting Protocol (CCARGRP)* (March 2007) and the data in the USEPA *Emissions & Generation Resource Integrated Database* (eGrid2006).

GHGs resulting from vehicle travel for additional personnel associated with potline scrubber system[1]

Parameters			**Reference**
Additional operating personnel	3		One additional full-time operator per shift, three shifts per day (assumption)
Additional maintenance personnel (weekdays)	6		Four additional full-time maintenance personnel, one shift per day, plus one additional full-time maintenance personnel for off-shifts (assumption)
Additional maintenance personnel (weekends)	3		One additional full-time maintenance personnel for off-shifts (assumption)
Total additional personnel (weekdays)	9		
Total additional personnel (weekends)	6		
Daily round trip distance	20	miles/trip	Assumption (distance from plant to downtown Bellingham, WA is approximately 10 miles)
Total daily mileage (weekdays)	180	miles/day	
Total daily mileage (weekends)	120	miles/day	
Average fuel economy	20.3	miles/gallon	Fleet average (1988 to 2007 model years); USEPA, Light-Duty Automotive Technology and Fuel Economy Trends: 1975 to 2007, Table 1 (Cars and Trucks)
N_2O global warming potential (GWP)	310		Table III.6.1 - CCARGRP
Methane GWP	21		Table III.6.1 - CCARGRP
Emission Factors			**Reference**
CO_2 emission factor	8.78	kg/gallon	Non-CA gasoline; Table C.3, CCARGRP
N_2O emission factor	0.050	grams/mile	Weighted average of 1988 to present automobile model years; Table C.4, CCARGRP
Methane emission factor	0.049	grams/mile	Weighted average of 1988 to present automobile model years; Table C.4, CCARGRP
Emission Estimates			
CO_2 (weekdays)	171.4	lb/day	
N_2O (weekdays)	0.020	lb/day	
Methane (weekdays)	0.019	lb/day	
CO_2 (weekends)	114.3	lb/day	
N_2O (weekends)	0.013	lb/day	
Methane (weekends)	0.013	lb/day	
Conversion of non-CO_2 GHGs to CO_2 equivalents			
CO_2 (weekdays)	171.4	lb/day	
N_2O - CO_2 equivalents (weekdays)	6.2	lb/day	
Methane - CO_2 equivalents (weekdays)	0.4	lb/day	
Total CO_2 equivalents (weekdays)	**177.9**	**lb/day**	
CO_2 (weekends)	114.3	lb/day	
N_2O - CO_2 equivalents (weekends)	4.1	lb/day	
Methane - CO_2 equivalents (weekends)	0.3	lb/day	
Total CO_2 equivalents (weekends)	**118.6**	**lb/day**	
CO_2 (annual)	28.2	tons/yr	
N_2O - CO_2 equivalents (annual)	1.0	tons/yr	
Methane - CO_2 equivalents (annual)	0.1	tons/yr	
Total CO_2 equivalents (annual)	**29.3**	**tons/yr**	

Notes:

[1]Based on methodology described in the *California Climate Action Registry General Reporting Protocol (CCARGRP)* (March 2007).

GHGs resulting from vehicle travel for additional personnel associated with anode bake furnace scrubber system[1]

Parameters			**Reference**
Additional operating personnel	3		One additional full-time operator per shift, three shifts per day (assumption)
Additional maintenance personnel (weekdays)	3		Two additional full-time maintenance personnel, one shift per day, plus one additional half-time equivalent maintenance personnel for off-shifts (assumption)
Additional maintenance personnel (weekends)	1.5		One additional half-time equivalent maintenance personnel for off-shifts (assumption)
Total additional personnel (weekdays)	6		
Total additional personnel (weekends)	4.5		
Daily round trip distance	20	miles/trip	Assumption (distance from plant to downtown Bellingham, WA is approximately 10 miles)
Total daily mileage (weekdays)	120	miles/day	
Total daily mileage (weekends)	90	miles/day	
Average fuel economy	20.3	miles/gallon	Fleet average (1988 to 2007 model years); USEPA, Light-Duty Automotive Technology and Fuel Economy Trends: 1975 to 2007, Table 1 (Cars and Trucks)
N_2O global warming potential (GWP)	310		Table III.6.1 - CCARGRP
Methane GWP	21		Table III.6.1 - CCARGRP

Emission Factors			**Reference**
CO_2 emission factor	8.78	kg/gallon	Non-CA gasoline; Table C.3, CCARGRP
N_2O emission factor	0.050	grams/mile	Weighted average of 1988 to present automobile model years; Table C.4, CCARGRP
Methane emission factor	0.049	grams/mile	Weighted average of 1988 to present automobile model years; Table C.4, CCARGRP

Emission Estimates		
CO_2 (weekdays)	114.3	lb/day
N_2O (weekdays)	0.013	lb/day
Methane (weekdays)	0.013	lb/day
CO_2 (weekends)	85.7	lb/day
N_2O (weekends)	0.0099	lb/day
Methane (weekends)	0.0096	lb/day

Conversion of non-CO_2 GHGs to CO_2 equivalents		
CO_2 (weekdays)	114.3	lb/day
N_2O - CO_2 equivalents (weekdays)	4.1	lb/day
Methane - CO_2 equivalents (weekdays)	0.3	lb/day
Total CO_2 equivalents (weekdays)	**118.6**	**lb/day**
CO_2 (weekends)	85.7	lb/day
N_2O - CO_2 equivalents (weekends)	3.1	lb/day
Methane - CO_2 equivalents (weekends)	0.2	lb/day
Total CO_2 equivalents (weekends)	**89.0**	**lb/day**
CO_2 (annual)	19.3	tons/yr
N_2O - CO_2 equivalents (annual)	0.7	tons/yr
Methane - CO_2 equivalents (annual)	0.05	tons/yr
Total CO_2 equivalents (annual)	**20.0**	**tons/yr**

Notes:

[1]Based on methodology described in the *California Climate Action Registry General Reporting Protocol (CCARGRP)* (March 2007).