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Alcoa Primary Metals
USA

# Pre-Feasibility Report

# SO2 Scrubbing for the INTALCO Primary Aluminum Smelter

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Project Report

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# SO2 Scrubbing for the INTALCO Primary Aluminum Smelter

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## Pre-Feasibility Report

## Table of Contents

**1. Summary ..... 2**

**2. Introduction ..... 4**

2.1 Process Selection ..... 4
2.2 FGD System Configuration ..... 4

**3. FGD System for the Potrooms ..... 6**

3.1 Design Basis ..... 6
3.2 Process description ..... 7
3.3 Mass balance of an FGD system treating the fumes from the potrooms ..... 8
3.4 Consumables ..... 10
3.5 Scope of work ..... 10

**4. FGD System for the Baking Furnace ..... 12**

4.1 Design basis ..... 12
4.2 Process description ..... 13
4.3 Mass balance for an FGD system to treat the fumes from the baking furnace ..... 14
4.4 Consumables ..... 15
4.5 Scope of work ..... 15

**5. Capital cost estimates ..... 18**

5.1 Methodology ..... 18
5.2 Cost estimate for the potline FGD system ..... 20
5.3 Cost estimate for the baking furnace FGD system ..... 20


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# 1. Summary

This report is a pre-feasibility study for the implementation of flue gas desulphurisation (FGD) systems at the primary aluminum smelter of Intalco Works in Ferndale, Washington. The study focus is on controlling the $SO_2$ emissions from the potrooms and from the baking furnace. The target removal is set for 95% of the released $SO_2$ at the emissions sources.

For both solutions the well known Limestone/Gypsum Forced Oxidation (LSFO) process is applied. This widely used process uses limestone as a reagent and produces gypsum as a by-product. This product can either be reused or safely stored in a landfill.

**Potlines**

For the potlines the selected configuration is a gas collection system that connects to each dry scrubbing system and redirects all fumes to a central FGD system. The FGD system comprises of two large open spray tower type absorbers in which the fumes are washed and cleaned. One such unit is operating while the second is on standby. The limestone handling as well as the gypsum recovery is done in a single plant serving both absorbers. Appropriate redundancy is built-in to ensure the 100% availability that is required in a smelter that operates 24 hrs a day, every day of the year.

The FGD system is designed to handle 1,814,880 SCFM of fumes from the potrooms. This equates to an annual SO2 emission reduction of 7,875 tpa. The associated limestone consumption is 14,244 tpa while the water intake is 500,000 US Gallons per day. The annual gypsum production is 27,130 ton.

The cost estimate is a factored cost estimate using information derived from previous studies and cost databases. The following table presents the results for the potline FGD system.

**Table 1: Capital cost estimate for the potline FGD system**

| All values in million USD | POTLINE FGD | | |
|---|---|---|---|
| | Equipment | Installation | Subtotal |
| Reagent feed system | $6.98 | $6.98 | $13.96 |
| SO2 removal system | $25.24 | $25.24 | $50.49 |
| Flue gas system | $21.64 | $21.64 | $43.27 |
| Byproduct handling | $7.17 | $7.17 | $14.33 |
| General support equipment | $10.11 | $10.11 | $20.23 |
| **TOTAL PROCESS CAPITAL** | $71.14 | $71.14 | $142.28 |

**Anode Baking Furnace**

A smaller source of $SO_2$ emissions are the fumes from the anode baking furnace. In this case a single collector duct is tied into the existing dry scrubbing system to connect to the FGD system. This FGD system is much smaller but has the same configuration as the potline FGD system. It provides for 100% available scrubbing.


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The FGD system is designed to handle 172,510 SCFM of fumes from the potrooms. This equates to an annual $SO_2$ emission reduction of 175 tpa. The associated limestone consumption is 342 tpa while the water intake is 35,000 US Gallons per day. The annual gypsum production is 640 ton.

The cost estimate is a factored cost estimate using information derived from previous studies and cost databases. The following table presents the results for the potline FGD system.

**Table 2: Capital cost estimate for the baking furnace FGD system**

| All values in million USD | BAKING FURNACE FGD | | |
|---|---|---|---|
| | Equipment | Installation | Subtotal |
| Reagent feed system | $0.36 | $0.36 | $0.72 |
| SO2 removal system | $4.13 | $4.13 | $8.25 |
| Flue gas system | $3.54 | $3.54 | $7.07 |
| Byproduct handling | $0.36 | $0.36 | $0.71 |
| General support equipment | $0.50 | $0.50 | $1.01 |
| **TOTAL PROCESS CAPITAL** | $8.88 | $8.88 | $17.76 |


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# 2. Introduction

This report presents a pre-feasibility study on the implementation of FGD systems at the Intalco primary aluminum smelter in Ferndale, Washington.

The aluminum smelter has two primary sources of sulphur emissions, one is the pot rooms and the second is the anode baking furnace. This report includes the design and cost information on a dedicated FGD system for each of these main sources.

## 2.1 Process Selection

In previous studies Best Available Technologies were identified. For studies at the Alcoa Tennessee smelter the limestone-gypsum forced oxidation (LSFO) process was selected for further evaluation .

## 2.2 FGD System Configuration

### *2.2.1 Pot room system*

The FGD system is designed to capture fumes from the potrooms under fully operational conditions.

A comprehensive evaluation was done to see what configuration would be more effective: a set of scrubbing towers per potline (equal to two potrooms) or one central system with long collector ducts feeding into the central system.

Two main criteria were used to decide what configuration to apply: 1) The sum of all fumes must be treated in one scrubbing tower and 2) maintenance must be minimized.

The first criteria was met after calculations showed that the sum of all flows would result in a scrubbing tower with a diameter of 60 feet. A large diameter tower is not uncommon and several FGD wet scrubbing towers with diameters of this size have been constructed world-wide. Having many smaller scrubbing towers versus one large tower design combined with collector ducts made of regular gauge steel is considered to be less cost effective than the latter case.

The second criteria concerns maintenance. The LSFO process basically is the circulation of a slurry of water, limestone and gypsum. It is abrasive and to a certain extent corrosive. Therefore, a lot of maintenance activity is associated with the circulation pumps and the scrubbing tower. Based on the design criteria of minimized maintenance, the selected system configuration was based on a single large scrubbing tower that would treat all of the pot room ventilation flows. Potroom flow would be combined into a single stream by a network of ducts, collecting fume from the current dry gas cleaning systems. .

An additional consideration was the continuous operation of a smelter. A single scrubbing tower must be taken down for service five to ten days per year (conservatively). This means that during periods of maintenance, there would be no scrubbing of $SO_2$ if a single scrubbing tower were installed. To provide 100 percent scrubbing availability during maintenance periods, a second scrubbing tower of the same size would be added to the design to ensure continuous $SO_2$ treatment during periods when the first scrubbing tower is taken out of service.


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### *2.2.2 Baking furnace system*

The FGD system for the baking furnace is of a simpler concept. The baking furnace is currently operated with an evaporative cooling tower followed by a dry gas cleaning system. The new FGD system will be connected downstream to the dry gas cleaning unit.

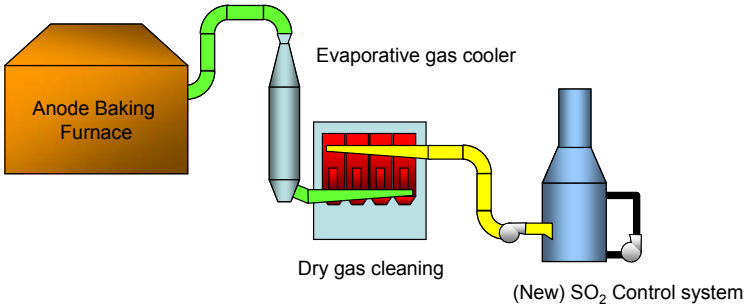


**Figure 1: Overall gas cleaning concept for the anode baking furnace.**


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# 3. FGD System for the Potrooms

## 3.1 Design Basis

The design basis for both scrubbing systems has been based on technical process information provided by Alcoa. The information is based on actual operating conditions and operating information for Intalco Works.

The following table presents the design basis for the FGD system serving the potlines.

**Table 3: Design basis for the potline FGD system at Intalco Works**

| Design parameter | Unit | Value |
|---|---|---|
| Number of potrooms in service | - | 6 |
| Number of GTCs per potroom | - | 1 |
| Total number of GTCs connected | - | 6 |
| No. of reduction cells per potroom | - | 120 |
| Ventilation flow for one reduction cell | ACFM | 3,000 (@212 °F) |
| | SCFM (70 °F) | 2,354 |
| Air addition in each dry gas cleaning unit | SCFM | 20,000 (Estimate) |
| Total flow of fumes to the FGD system | SCFM | 1,814,880 |
| Nominal fume temperature | °F | 180 |
| **Composition of the fumes at the inlet of the FGD system** | | |
| Sulphur dioxide ($SO_2$) | ppmv | 105 (300 mg/Nm$^3$) |
| Hydrogen fluoride ($HF_g$) | mg/Nm$^3$ | 5 |
| Water vapour ($H_2O$) | vol% | 3 |
| Particulates | mg/Nm$^3$ | 10 |

In addition, the following system requirements are applied in the design of the system.

**Table 4: Design requirements**

| Aspect | Unit | Requirement |
|---|---|---|
| Desulphurization efficiency | % | Min. 95 |
| Removal efficiency of particulates and fluorides | - | No increment |
| Residual droplets | mg/Nm$^3$ | Max. 100 |


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| | | |
|---|---|---|
| Spare scrubbing capacity | % | 100<br>(1 full scrubbing tower stand-by/no spare spray layers inside one scrubbing tower) |
| Limestone properties:<br>- CaCO3 content<br>- Reactivity<br>- Particle size distribution | <br>%<br><br>Microns | <br>Min. 85<br>Must comply with vendor specification.<br>96% < 75 microns<br>(To be verified with vendor) |
| Gypsum by-product:<br>- Application<br>- Sulfate / Sulfite ratio<br>- Residual moisture | <br>-<br>-<br>% | <br>Disposal<br>99 / 1 (Full oxidation)<br>15 |
| Chloride concentration in the slurry | ppm | 5,500 |
| Waste water requirements | - | None. |

## 3.2 Process description

The fumes from the potrooms are extracted from the stack of the existing dry gas cleaning systems (GTCs). Each stack will be provided with an adaptor and a valve that connects to the collector duct for the FGD system. This design allows for the GTCs to continue operation as it is today. The goal is that the GTCs do not "see" the additional FGD system. To achieve this, pressure control is applied in the collector duct whereby the pressure at the GTCs is maintained constant by a dedicated fan in the collector duct.

The collector ducts go over the potrooms and come together at the central FGD system. In each collector duct a damper is added in order to isolate an individual duct.

The combined fumes are blown into the scrubbing tower. The tower is an open spray design and has two spray layers installed. Each layer has a dedicated recycle pump. Because there is a second scrubbing tower in standby there is no need to have additional spray layers installed.

Above the spray layers are two chevron type horizontal mist eliminators. Below the lower mist eliminator is the main wash system and between the two mist eliminators is a second wash system. There is no need for a third wash system at the top of the stack as this can be washed manually once a year.

The two scrubbing towers vent to a combined stack that emits cleaned gases at a level approximately 150 feet above the ground.


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Two slurry pumps recycle the slurry through the spray levels with the appropriate nozzles. These can be either hollow cone or full cone nozzles. The slurry is semi-atomized into a spray of droplets that mix with the incoming fumes.

The bottom of the scrubbing tower fulfills several functions. It has to provide enough liquid head for the pumps, it provides for enough retention time for the gypsum to grow into a desirable particle size distribution so that is can be dewatered properly, it is used for pH control, and it provides for the means to oxidize all the sulphite into sulphate.

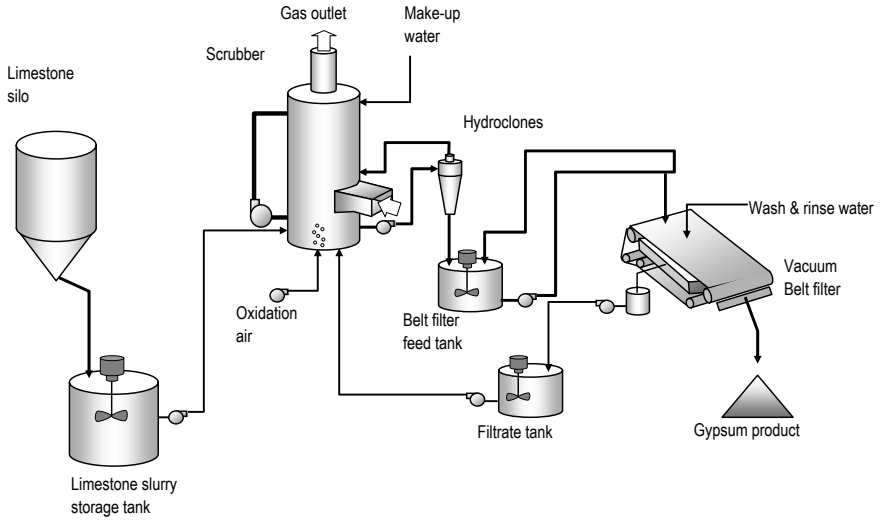
The fumes from the potroom contain close to 20 volume percent of oxygen. Experience with similar scrubbing systems of this type shows that 20 volume percent of oxygen is enough to provide full oxidation of sulphite into sulphate. However, for safety reasons (one wants to have the slurry fully oxidized at all times), a small amount of compressed air is introduced by a small blower.

A bleed system withdraws slurry from the scrubbing tower. A loop is used to measure the pH while the rest is fed to a hydroclone battery. This is the first stage of solids dewatering. The overflow of the hydroclones is returned to the scrubbing tower while the underflow is collected and fed to a vacuum filter. The system is engineered such that the underflow can be fed directly onto the filter.

The thickened slurry is dewatered on the vacuum filter to about 85 percent dry solids. The filtrate and wash/rinse water is collected and returned to the scrubbing tower. The gypsum is left with 15 percent moisture which prevents the need for a liquid purge stream otherwise needed to purge impurities from the process. The gypsum is moist enough to be stored in semi open warehouse and can be loaded into dump trucks and taken to a third party.

Limestone is delivered in powder form and added to the process water and fed from the slurry tank to the scrubbing tower via a pH control system.

## 3.3 Mass balance of an FGD system treating the fumes from the potrooms





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| GAS (lb/hr) | Fumes from one potroom | Fumes from 6 potrooms | Oxidation air | Clean gases | |
|---|---|---|---|---|---|
| N2 | 1,025,647 | 6,153,884 | 4,514 | 6,158,398 | |
| O2 | 285,454 | 1,712,725 | 1,368 | 1,713,645 | |
| CO2 | 413 | 2,479 | 3 | 3,751 | |
| H2O | 25,375 | 152,251 | 82 | 324,134 | |
| H20 (l) | - | - | - | 653 | |
| SO2 | 316 | 1,893 | - | 95 | |
| SO3 | - | - | - | - | |
| HCl | - | - | - | - | |
| HF | 5 | 32 | - | 1 | |
| Particulate | 5 | 32 | - | 11 | |
| Mass flow (lb/hr) | 1,337,216 | 8,023,295 | 5,967 | 8,200,687 | |
| Volume flow (ACFM) | 369,114 | 2,214,685 | 1,365 | 1,984,246 | |
| Volume flow (SCFM) | 302,481 | 1,814,887 | 1,343 | 1,877,773 | |
| Temperature (°F) | 189 | 189 | 77 | 98 | |
| Pressure (Inch WG) | 407.7 | 407.7 | 405.3 | 405.3 | |

| LIQUID / SOLIDS (lb/hr) | Absorber recycle | Absorber bleed | pH loop | Hydroclone overflow | Hydroclone underflow |
|---|---|---|---|---|---|
| Liquid | 30,849,560 | 78,847 | 25,708 | 46,671 | 6,467 |
| Solids | 5,444,040 | 13,914 | 4,537 | 4,086 | 5,291 |
| Total | 36,293,600 | 92,761 | 30,245 | 50,757 | 11,759 |
| Solids concentration | 15 | 15 | 15 | 8 | 45 |
| Density (SG) | 1.10 | 1.10 | 1.10 | 1.05 | 1.34 |
| Flow (GPM) | 66,050 | 169 | 55 | 96 | 18 |

| LIQUID / SOLIDS (lb/hr) | Vacuum filter feed | Filter wash water | Rinse water | Filtrate | Gypsum |
|---|---|---|---|---|---|
| Liquid | 6,467 | - | 10,530 | 16,068 | 929 |
| Solids | 5,291 | - | - | 26 | 5,265 |
| Total | 11,759 | - | 10,530 | 16,095 | 6,194 |
| Solids concentration | 45 | - | - | 0.2 | 85 |
| Density (SG) | 1.34 | 1.00 | 1.00 | 1.01 | 1.50 |
| Flow (GPM) | 18 | - | 21 | 32 | - |

| LIQUID / SOLIDS (lb/hr) | Limestone | Process water | Limestone slurry to absorber | | |
|---|---|---|---|---|---|
| Liquid | - | 9,757 | 9,757 | | |
| Solids | 3,252 | - | 3,252 | | |
| Total | 3,252 | 9,757 | 13,009 | | |
| Solids concentration | 100 | - | 25 | | |
| Density (SG) | 2.80 | 1.00 | 1.19 | | |
| Flow (GPM) | - | - | - | | |

| LIQUID / SOLIDS (lb/hr) | Process water intake | Water to absorber | Water to limestone preparation | Water to gypsum dewatering | Water for oxidation air cooling |
|---|---|---|---|---|---|
| Liquid | 174,362 | 152,973 | 9,757 | 10,530 | 1,102 |
| Solids | - | - | - | - | - |
| Total | 174,362 | 152,973 | 9,757 | 10,530 | 1,102 |
| Solids concentration | - | - | - | - | - |
| Density (SG) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Flow (GPM) | 348 | 306 | 19 | 21 | 2 |


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## 3.4 Consumables

The following list presents the main consumables for the FGD system treating the fumes from the potrooms.

**Table 5: Consumables**

| Consumable | Unit | Value |
|---|---|---|
| Process water | US Gallons per day | 500,000 |
| Limestone | Short tons per day | 39 |
| Compressed air | SCFM | 150 |
| Electric power | kWh/h | 7,400 |

## 3.5 Scope of work

The following is the scope of work used to develop the cost estimates. The overall basis is a lump sum contract with a single vendor/contractor.

GTC connections

All GTC stacks will be equipped with an adaptor that connect them to common scrubber ducts. The adaptors fit on the stacks and a valve is included.

Collector ducts

Each GTC will be connected to a collector duct and fan system. There are six collector ducts and fan systems, including isolation valves. The work includes structural steel work needed to position the collector ducts over the potrooms and to the central FGD system.

Scrubbing tower

Two scrubbing towers are included and they both are identical in size and have the same equipment and controls so that they can be operated independently from each other.

On the bottom, two 48-inch diameter pipes are connected to the tower and the suction of the recycle pumps. Each suction pipe has included a butterfly type valve to isolate a pump. Each recycle pump operates at 33,000 GPM. The discharge is also 48 inches in diameter and goes up the spray levels. Inside the scrubbing tower two spray levels are installed that form a network of smaller diameter pipes in order to provide equal distribution of the slurry over the cross section of the tower.

A common water supply system (tank and pumps) serves both scrubbing towers. It will connect to the three wash levels above the mist eliminators.

A common air compressor is included for the supply of oxidation air. To prevent clogging of the line where air is injected, water is injected to saturate the air before it hits the slurry in the scrubbing tower.


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Primary dewatering

A first dewatering step is needed to create the right slurry density for final dewatering. A set of hydroclones is included to thicken the slurry from 15 percent solids to about 45 percent. The hydroclone set has included a chute to intercept the thickened slurry in case of a line blockage. In that case all slurry is returned.

Secondary dewatering

A vacuum belt filter is included for the dewatering of the gypsum slurry. This has included a vacuum system, wash & rinse system and discharge chute. In order to provide limited redundancy, two 75 percent capacity filters are included.

A filtrate collection system is incorporated to return any liquids to the scrubbing tower.

The vacuum filters are elevated in a building and the lower section has a dump & storage area for the gypsum. A front loader picks up the gypsum and dumps it into a dump truck for disposal.

Limestone system

The scope of work also includes an integrated silo and slurry preparation tank. Trucks are equipped with unloading equipment to deliver the limestone powder into the tank. The tank is provided with an agitator and pump set. The pumps are connected to a loop that passes both scrubbing towers. Slurry is drawn from the loop based on pH control. Dosing valves are included.

General systems and facilities

To prevent any uncontrolled releases into the environment, a slurry collection system is included in and around the central system to collect spills and overflows. A sump with a submerged pump is included and all slurry is transferred to the operating scrubbing tower.

The vendor will provide all automation and control systems to minimize manual intervention required from operating personnel.

Chemical sampling and analysis is added to the current work load of the laboratory staff. Some new equipment like slurry analysers will be provided.


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# 4. FGD System for the Baking Furnace

## 4.1 Design basis

The following table presents the design basis for the FGD system serving the baking furnace.

**Table 6: Design basis for the baking furnace FGD system – Intalco Works**

| Design parameter | Unit | Value |
|---|---|---|
| Number of fires in service | - | All |
| Total flow of fumes in the existing stack | ACFM | 216,000 |
| Nominal fume temperature | °F | 205 |
| **Composition of the baking furnace fumes at the inlet of the FGD system** | | |
| Sulphur dioxide ($SO_2$) | ppmv | 25 (5.33 grams/sec) |
| Hydrogen fluoride ($HF_g$) | mg/Nm$^3$ | 5 |
| Water vapour ($H_2O$) | vol% | 20.7 |
| Particulates | mg/Nm$^3$ | <5 (0.35 grams/sec) |

In addition, the following system requirements are applied in the design of the system.

**Table 7: Design requirements for the baking furnace FGD system**

| Aspect | Unit | Requirement |
|---|---|---|
| Desulphurization efficiency | % | Min. 95 |
| Removal efficiency of particulates and fluorides | - | No increment |
| Residual droplets | mg/Nm$^3$ | Max. 100 |
| Spare scrubbing capacity | % | 100<br>(1 full scrubbing tower stand-by/no spare spray layers inside one scrubbing tower) |
| Limestone properties: | | |
| - CaCO3 content | % | Min. 85 |
| - Reactivity | | Must comply with vendor specification. |
| - Particle size distribution | Microns | 96% < 75 microns<br>(To be verified with vendor) |


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| | | |
|---|---|---|
| Gypsum by-product:<br>- Application<br>- Sulfate / Sulfite ratio<br>- Residual moisture | <br>-<br>-<br>% | <br>Disposal<br>99 / 1 (Full oxidation)<br>15 |
| Chloride concentration in the slurry | ppm | 7,500 |
| Waste water requirements | - | None. |

## 4.2 Process description

The fumes from the ring duct are passed on to the evaporative cooling tower to cool the fumes and to precipitate some of the tars. The fumes are led into the dry gas cleaning system in which alumina is injected for particulate, tar, and fluoride removal. The fumes pass the bag filters and enter the plenum outlet.

The combined fumes are blown into the scrubbing tower. The tower is an open spray design and has two spray layers. Each layer has a dedicated recycle pump. Because there is a second scrubbing tower in standby there is no need to have additional spray layers.

Above the spray layers are two chevron type horizontal mist eliminators. Below the lower mist eliminator is the main wash system and between the two mist eliminators is a second wash system. There is no need for a third wash system at the top of the stack as this can be washed manually once a year.

The scrubbing tower has an integrated stack that emits the clean gases at a level approximately 150 feet above the ground.

Two slurry pumps recycle the slurry through the spray levels with the appropriate nozzles. These can be either hollow cone or full cone nozzles. The slurry is semi-atomized into a spray of droplets and washes the incoming fumes.

The bottom of the scrubbing tower fulfills several functions. It has to provide enough liquid head for the pumps, it provides for enough retention time for the gypsum to grow into a desirable particle size distribution so that is can be dewatered properly, it is used for pH control, and it provides for the means to oxidize all the sulphite into sulphate. All this is incorporated within the design.

Air is injected under the liquid level of the scrubber tower bottom to provide for the required oxidation sulphites into sulphates. A small blower is used to inject the air.

A bleed system withdraws slurry from the scrubbing tower. A loop is used to measure the pH while the rest is fed to a hydroclone battery. This is the first stage of solids dewatering. The overflow of the hydroclones is returned to the scrubbing tower while the underflow is collected and fed to a vacuum filter. The system is engineered such that the underflow can be fed directly onto the filter.

The thickened slurry is dewatered on the vacuum filter to about 85 percent dry solids. The filtrate and wash/rinse water is collected and returned to the scrubbing tower. The gypsum is left with 15 percent moisture which will prevents the need for a liquid purge stream otherwise needed to purge


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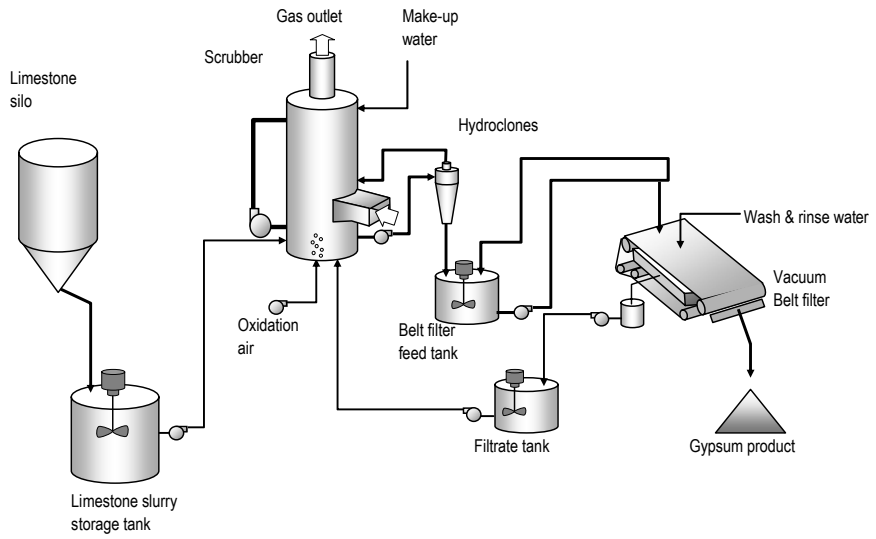
impurities from the process. The gypsum is moist enough to be stored in semi open warehouse and can be loaded into dump trucks and taken to a third party.

Limestone is delivered in powder form and added to the process water and fed from the slurry tank to the scrubbing tower via a pH control system.

## 4.3 Mass balance for an FGD system to treat the fumes from the baking furnace




| GAS (lb/hr) | Fumes from dry gas cleaning system | Oxidation air | Clean gases | | |
|---|---|---|---|---|---|
| N2 | 516,752 | 224 | 516,977 | | |
| O2 | 24,683 | 68 | 24,741 | | |
| CO2 | 88,656 | 0 | 88,687 | | |
| H2O | 99,881 | 4 | 111,652 | | |
| H20 (l) | - | - | 61 | | |
| SO2 | 42 | - | 2 | | |
| SO3 | - | - | - | | |
| HCl | - | - | - | | |
| HF | 3 | - | 0 | | |
| Particulate | 3 | - | 1 | | |
| Mass flow (lb/hr) | 730,020 | 297 | 742,121 | | |
| Volume flow (ACFM) | 218,111 | 68 | 202,525 | | |
| Volume flow (SCFM) | 172,510 | 67 | 176,787 | | |
| Temperature (°F) | 212 | 77 | 145 | | |
| Pressure (Inch WG) | 407.7 | 405.3 | 405.3 | | |

| LIQUID / SOLIDS (lb/hr) | Absorber recycle | Absorber bleed | pH loop | Hydroclone overflow | Hydroclone underflow |
|---|---|---|---|---|---|
| Liquid | 1,616,844 | 26,676 | 25,427 | 1,097 | 152 |
| Solids | 285,325 | 4,707 | 4,487 | 96 | 124 |
| Total | 1,902,170 | 31,383 | 29,914 | 1,193 | 276 |
| Solids concentration | 15 | 15 | 15 | 8.05 | 45 |
| Density (SG) | 1.09 | 1.09 | 1.09 | 1.02 | 1.31 |
| Flow (GPM) | 3,500 | 58 | 55 | 2.3 | 0.4 |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| LIQUID / SOLIDS (lb/hr) | Vacuum filter feed | Filter wash water | Rinse water | Filtrate | Gypsum |
|---|---|---|---|---|---|
| Liquid | 152 | - | 247 | 378 | 22 |
| Solids | 124 | - | - | 1 | 124 |
| Total | 276 | - | 247 | 378 | 146 |
| Solids concentration | 45 | - | - | 0 | 85 |
| Density (SG) | 1.33 | 1.00 | 1.00 | 1.00 | 1.50 |
| Flow (GPM) | 0.4 | - | 0.5 | 0.8 | - |

| LIQUID / SOLIDS (lb/hr) | Limestone | Process water | Limestone slurry to absorber | | |
|---|---|---|---|---|---|
| Liquid | - | 235 | 235 | | |
| Solids | 78 | - | 78 | | |
| Total | 78 | 235 | 314 | | |
| Solids concentration | 100 | - | 25 | | |
| Density (SG) | 2.80 | 1.19 | 1.00 | | |
| Flow (GPM) | - | 0.5 | 0.5 | | |

| LIQUID / SOLIDS (lb/hr) | Process water intake | Water to absorber | Water to limestone preparation | Water to gypsum dewatering | Water for oxidation air cooling |
|---|---|---|---|---|---|
| Liquid | 11,865 | 10,279 | 235 | 247 | 1,102 |
| Solids | - | - | - | - | - |
| Total | 11,865 | 10,279 | 235 | 247 | 1,102 |
| Solids concentration | - | - | - | - | - |
| Density (SG) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Flow (GPM) | 24 | 21 | 0.5 | 0.5 | 2.2 |

## 4.4 Consumables

The following list presents the main consumables for the control system.

**Table 8: Baking furnace FGD consumables**

| Consumable | Unit | Value |
|---|---|---|
| Process water | US Gallons per day | 35,000 |
| Limestone | Short tons per day | 1.0 |
| Compressed air | SCFM | 50 |
| Electric power | kWh/h | 750 |

## 4.5 Scope of work

The following is the scope of work used to develop the cost estimates. The overall basis is a lump sum contract with a single vendor/contractor.


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GTC connection

New fans will be installed to replace the existing fans downstream of the dry gas cleaning system. The fans are provided with an inlet manifold that connects to the scrubbing towers. Isolation dampers are included to separate one scrubbing tower from operation.

Scrubbing tower

Two scrubbing towers are included and they both are identical in size and have the same equipment and controls so that they can operate independently from each other.

The bottom two 4 inch diameter pipes are connected to the tower and the suction of the recycle pumps. Each suction pipe has included a butterfly type valve to isolate the pump. Each recycle pump operates at 1,750 GPM. The discharge is also 4 inches in diameter and goes to the spray levels. Inside the scrubbing tower two spray levels are installed and form a network of smaller diameter pipes in order to provide equal distribution of the slurry over the cross section of the tower.

A common water supply system (tank and pumps) serves both scrubbing towers. It will connect to the three wash levels around the mist eliminators.

A common air compressor is included for the supply of oxidation air. To prevent clogging of the line where air is injected, water is injected to saturate the air before it hits the slurry in the scrubbing tower.

Primary dewatering

A first dewatering step is needed to create the right slurry density for final dewatering. A set of hydroclones is included to thicken the slurry from 15 percent solids to about 45 percent. The hydroclone set has included a chute to intercept the thickened slurry in case nothing can go to the filter. In that case all slurry is returned.

Secondary dewatering

A vacuum belt filter is included for the dewatering of the gypsum slurry. This has included a vacuum system, wash & rinse system and discharge chute. In order to provide limited redundancy two 75 percent capacity filters are included.

A filtrate collection system is incorporated to return any liquids to the scrubbing tower.

The vacuum filters are elevated in a building and the lower section has a dump & storage area for the gypsum. A front loader picks up the gypsum and dumps it into a dump truck for disposal.

Limestone system

The scope of work also includes an integrated silo and slurry preparation tank. Trucks are equipped with unloading equipment to deliver the limestone powder into the tank. The tank is provided with an agitator and pump set. The pumps are connected to a loop that passes both scrubbing towers. Slurry is drawn from the loop based on pH control. Dosing valves are included.


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General systems and facilities

To prevent any uncontrolled releases into the environment, a slurry collection system is included in and around the central system to collect spills and overflows. A sump with a submerged pump is included and all slurry is transferred to the operating scrubbing tower.

The vendor will provide all automation and control systems to minimize manual intervention required from operating personnel.

Chemical sampling and analysis is added to the current work load of the laboratory staff. Some new equipment like slurry analysers will be provided.


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# 5. Capital cost estimates

In this section are provided all capital cost estimates for both the potroom FGD system and the baking furnace FGD system.

All equipment cost estimates are based on cost proposals provided by Alstom Power and Babcock Power for Alcoa's smelter in Alcoa, TN and a pre-feasibility study prepared by Hatch for the Alcoa TN smelter, entitled "$SO_2$ Scrubber for Alcoa Tennessee" (June 7, 2007 (Hatch report number PRH322820.0001).

## 5.1 Methodology

For this high level study, costs have been scaled based on specific design and operational aspects of FGD systems. The key three scaling parameters are the volume of gases going through, the amount of limestone consumed and the amount of gypsum by-product produced. These three parameters help scale certain parts of the FGD system scale properly; however, to apply such method a break down is required for the cost provided in the study for Alcoa Tennessee works. This was not presented in the previous study and as such it has been included here.

Based on Hatch' experience with cost analysis of FGD systems the following break down is derived and applied in this study:

**Table 9: Break down of FGD sub system costs**

| Sub system | Fraction of cost of the total |
|---|---|
| Reagent feed system | 10% of TPC |
| $SO_2$ removal system | 35% of TPC |
| Flue gas system | 30% of TPC |
| By-product handling | 10% of TPC |
| General support equipment | 15% of TPC |
| TOTAL PROCESS CAPITAL (TPC) | 100% |


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**Table 10: Cost break down of the Alcoa Tennessee works FGD system.**

| All values in million USD | TENNESSEE POTLINE FGD | | |
|---|---|---|---|
| | Equipment | Installation | Subtotal |
| Reagent feed system | $6.50 | $6.50 | $13.00 |
| SO2 removal system | $22.75 | $22.75 | $45.50 |
| Flue gas system | $19.50 | $19.50 | $39.00 |
| Byproduct handling | $6.50 | $6.50 | $13.00 |
| General support equipment | $9.75 | $9.75 | $19.50 |
| **TOTAL PROCESS CAPITAL** | $65.00 | $65.00 | $130.00 |

This table is used as a basis for the tables that follow and represent the results for the Intalco smelter.

Next step in the methodology is to convert the sub system costs from one case to another. For this the general formula of cost scaling is applied:

$$P_2 = P_1 \times \left( \frac{Q_2}{Q_1} \right)^n$$

From the Hatch database of cost information related to large FGD systems is further derived:

**Table 11: Exponent n for scaled cost estimation.**

| **Sub system** | **Exponent n** |
|---|---|
| Reagent feed system | 0.33 |
| $SO_2$ removal system | 0.50 |
| Flue gas system | 0.50 |
| By-product handling | 0.40 |
| General support equipment | 0.15 |

These exponents apply to large scale FGD units. For the baking furnace, which is much smaller, in the report is applied an exponent of 0.8 for all sub systems. This is consistent with earlier work prepared by the Alcoa team.

In order to scale costs between the different cases the following scaling factors have been applied:


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**Table 12: Scaling parameters.**

| Parameter | Scaling value | | |
|---|---|---|---|
| | *Tennessee* ($Q_1$) | *Intalco Potline* ($Q_2$) | *Intalco Baking Furnace* ($Q_2$) |
| Clean flue gas flow (ACFM) | 1,582,432 | 1,948,246 | 202,525 |
| Limestone consumption (tpa) | 10,407 | 12,921 | 315 |
| Gypsum production (tpa) | 19,272 | 24,607 | 578 |

Example:

$$P_2 = 8.93x\left(\frac{12,921}{10,407}\right)^{0.33} = 9.59$$

This example shows that for Intalco the estimate costs for the reagent (limestone) feed system is 9.59 million USD.

## 5.2 Cost estimate for the potline FGD system

The following table presents the results from the cost estimation for the FGD system, servicing the potline ventilation fumes at Intalco.

**Table 13: Cost estimate for the Intalco Works potline FGD system**

| All values in million USD | POTLINE FGD | | |
|---|---|---|---|
| | Equipment | Installation | Subtotal |
| Reagent feed system | $6.98 | $6.98 | $13.96 |
| SO2 removal system | $25.24 | $25.24 | $50.49 |
| Flue gas system | $21.64 | $21.64 | $43.27 |
| Byproduct handling | $7.17 | $7.17 | $14.33 |
| General support equipment | $10.11 | $10.11 | $20.23 |
| **TOTAL PROCESS CAPITAL** | $71.14 | $71.14 | $142.28 |

## 5.3 Cost estimate for the baking furnace FGD system

The following table presents the results from the cost estimation for the FGD system, servicing the potline ventilation fumes at Intalco.


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**Table 14: Cost estimate for the Intalco Works baking furnace FGD system.**

| All values in million USD | BAKING FURNACE FGD | | |
|---|---|---|---|
| | Equipment | Installation | Subtotal |
| Reagent feed system | $0.36 | $0.36 | $0.72 |
| SO2 removal system | $4.13 | $4.13 | $8.25 |
| Flue gas system | $3.54 | $3.54 | $7.07 |
| Byproduct handling | $0.36 | $0.36 | $0.71 |
| General support equipment | $0.50 | $0.50 | $1.01 |
| **TOTAL PROCESS CAPITAL** | $8.88 | $8.88 | $17.76 |

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