

ENVIRONMENTAL SURVEYS OF ALUMINUM REDUCTION PLANTSAbstract

The National Institute for Occupational Safety and Health, under PL 91-596, is responsible for criteria development and epidemiological research of occupational exposures to toxic materials or harmful physical agents. One such research investigation dealing with the primary aluminum reduction industry has been initiated. To date, only the environmental portion of the investigation has been completed. The purpose of this report is to summarize the environmental surveys of four aluminum reduction plants in the Eastern United States, including pre-baked, horizontal pin Soderberg and vertical pin Soderberg operations. The major emphasis of the environmental studies was to determine the extent of worker exposures to potential carcinogenic compounds found in coal tar and petroleum pitch volatiles; however, exposures to total airborne dust, airborne fluorides, carbon monoxide, sulfur dioxide, ammonia and noise also were documented. The report presents a description of aluminum reduction processing and associated worker activities for the three production types that were surveyed, the environmental sampling procedures utilized, a summary of sampling results and conclusions that can be drawn from the surveys.



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## INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH), under PL 91-596, is responsible for criteria development and epidemiological research of occupational exposures to toxic materials or harmful physical agents. One such research investigation dealing with the primary aluminum reduction industry is projected to include environmental, mortality and morbidity studies. However, to date, only the environmental portion of the studies has been completed, with the detailed morbidity investigation just being initiated (July 1973).

The environmental investigations were conducted by the Division of Field Studies and Clinical Investigations (DFSCI) and the Division of Technical Services (DTS), and as such, covered various aluminum reduction plants in the Eastern (four plants) and Northwestern (six plants) United States, respectively. The purpose of this report is to summarize the investigations of the DFSCI and in certain instances to compare the results with those reported by DTS.<sup>1</sup> The four facilities surveyed in the Eastern United States involved pre-baked, horizontal pin Soderberg and vertical pin Soderberg operations. One of these facilities used petroleum pitch for anode production instead of the more commonly used coal tar pitch. The major emphasis of the environmental investigations was to determine the extent of worker exposures to potential carcinogenic compounds found in coal tar and petroleum pitch volatiles; however, exposures to total airborne dust, airborne fluorides, carbon monoxide, sulfur dioxide, ammonia and noise also were documented.

The report presents a description of aluminum reduction processing and associated worker activities for the three production types that were surveyed, the environmental sampling procedures utilized, a summary of sampling results and conclusions that were drawn from the surveys.

### DESCRIPTION OF PROCESSES<sup>2,3</sup> AND WORKER ACTIVITIES

Aluminum metal is produced from purified alumina (aluminum oxide)\* by a reduction process requiring the application of a large amount of energy. The process cannot be accomplished by thermal reduction with coke, as is iron ore, since the melting point of the aluminum oxide is much higher than that of aluminum metal. To overcome this problem in reducing the oxide to the metal by a thermal method, electrolysis is employed.

The basic industrial process was developed by Hall and Heroult in 1886. In this process, the alumina is dissolved in a bath of molten fluorides in a large steel shell (pot). A reduction plant consists of a number of these pots electrically connected in series. The electrically connected pots constitute a "pot line" and are located in "potrooms." Carbon electrodes are used at both the anode and cathode, but the aluminum metal in the cell is the true cathode. The passage of direct current results in the heavier aluminum sinking to the bottom of the pot to the cathode and oxygen being liberated at the anode with the formation of carbon monoxide (CO) and carbon dioxide (CO<sub>2</sub>). The aluminum is tapped

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\* Figure 1 contains a list of raw materials for aluminum production.

Figure 1. LIST OF RAW MATERIALS FOR  
ALUMINUM REDUCTION PROCESS

Aluminum Production

1. Alumina
2. Cryolite
3. Aluminum Fluoride
4. Fluorspar

Carbon Products

1. Petroleum Coke
2. Petroleum or Coal Tar  
Pitch
3. Anthracite Coal
4. Coke

(siphoned off) at intervals and generally cast into pigs or taken to holding furnaces for further treatment.

The material (bath) above the molten aluminum contains the alumina and fluoride electrolytes at about 1800°F. The top of the bath is made up of an insulating frozen crust of the bath material, which is about two inches thick.

The primary fluoride compound of the bath material is cryolite, which is an excellent electrolyte because it dissolves up to 20 percent of its weight in alumina, reduces the melting point of the ore and does not readily decompose. Fluorspar is added to lower the melting point of the mixture, while aluminum fluoride is used to increase current efficiency.

The pots, themselves, are basically rectangular steel tanks having special linings to resist the heat and also the corrosive effect of the molten fluorides. Usually, either refractory bricks or alumina are used to line the bottom and wall of the pot and act as insulation. Either cathode pot lining paste (that forms a monolithic carbon cathode) or several large carbon blocks and carbon paste (used to fill in the cracks and edges) are put over the refractory lining and serve as the cathode. This cathode is gradually eaten away and the pots generally require relining after about three years service.

Two basic types of processes exist for the preparation of anodes for the pots. In the "Soderberg" process, a fresh carbon paste mixture of anode material is added to the top of the pot and gradually baked in

place as the anode is consumed. In the "pre-bake" process, the anodes are prepared, pre-baked and placed in the pot.

#### Pre-Baked Anode Pots

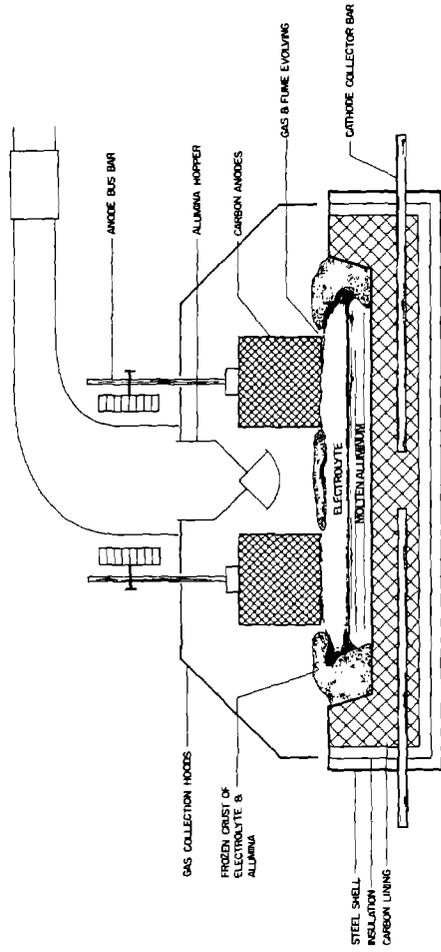
Pre-baked anodes consist of cured blocks of carbon, with a metal rod (usually aluminum or copper) inserted into them to provide support and conduct electricity. The pre-baked anodes are put into the molten aluminum and fluoride bath as shown in Figure 2. Pre-baked electrodes are made with soft pitch and coke and are baked before installation in order to make them harder, improve their electrical conductivity and to drive off the volatile compounds. Once in the pot, the anodes are lowered as they are gradually consumed. Each anode block will last several days before it must be replaced by a "carbon setting" crew.

In some facilities, the operators ("potmen") must manually lower the anodes, adjust the pot voltages and add the alumina and smaller amounts of fluoride compounds as required. In other plants, many of these routine tasks have been computerized and automated.

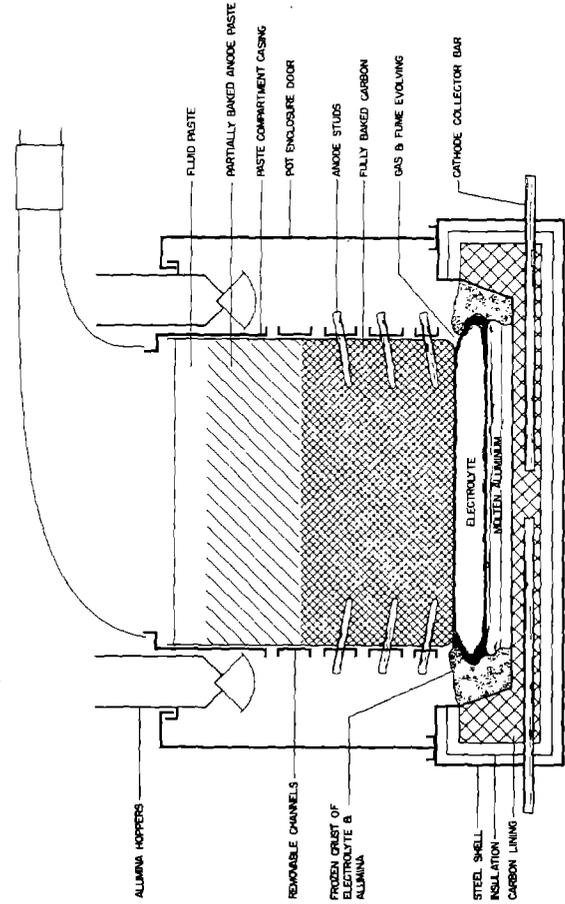
#### Soderberg Anode Pots

Use of Soderberg pots is an alternative to going to the cost and trouble of molding and baking of individual pre-baked electrodes. A metal shell is set up over the surface of the molten bath and packed with a coke and coal tar pitch paste. Further preparation is not required, since the anode is baked by conductive heat from the bath. The lowest section of the anode is always fully baked, while fresh carbon paste is added twice a week to replace what is consumed.

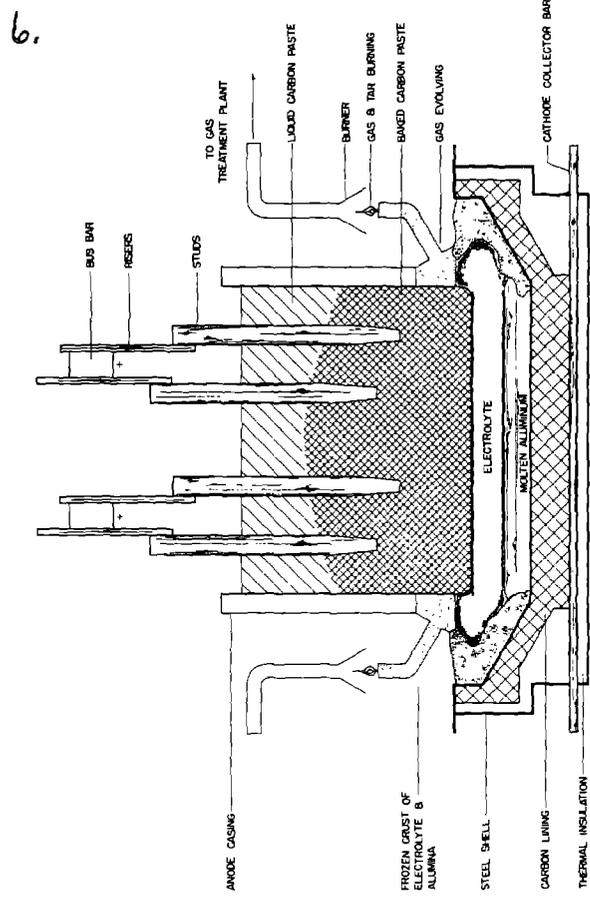
Figure 2. ALUMINUM REDUCTION POTS



PREBAKE



HORIZONTAL SODERBERG



VERTICAL SODERBERG

The "potmen" who operate these pots perform duties similar to their counterparts working on the pre-baked pots; however, the manner in which the crust of a pot is broken differs in these two processes. For the Soderberg pots, the "potman" rides a dolly equipped with an air hammer ("crustbreaker") to destroy the hard crust and allow the alumina to be charged into the molten bath. The "potmen", working with the pre-baked pots, has only to electrically activate a hydraulic ram that is built into the pot to break the crust. The general work pattern for the "tapping crew's" removal of the molten metal is the same for both the Soderberg and pre-baked pots, i.e., after punching a hole in the crust, the syphon of a large crucible is lowered to almost the bottom of the pot and the aluminum is drawn out by vacuum.

Most of the other personnel who work with Soderberg pots are concerned with the operation of the anode assembly, which includes the addition and removal of steel "pins" or "spikes" that are imbedded in the anode and conduct the electrical current. As the anode is consumed and lowered, these pins must be removed and relocated before they make contact with the molten bath. The pins may be orientated in the anode either vertically (vertical pin Soderberg design) or horizontally (horizontal pin Soderberg design) as shown in Figure 2.

The vertical pin design requires that a group of workers, the "spike setters", stand on a catwalk on top of the anode while loosening or tightening the bolts which attach the steel pins to the overhead bus bar.

For the horizontal pin design, a group of workers, the "pin pushers" and "pin pullers", are responsible for inserting and removing the pins. These pushers and pullers operate at floor level on small dollies that are equipped to insert and remove the pins. In both types of operations, the steel pins, which are pulled from the Soderberg anodes, are taken to a reconditioning area where they are cleaned and straightened before being reused.

In addition to the above mentioned job types, there are other workers in the potrooms of a horizontal pin Soderberg facility that comprise a group known as "anode men". This includes the "channel hangers" and "channel pullers", who install and remove the metal forms that fit around the steel pins and the "hijackers", who are responsible for adjusting the anode height.

#### Carbon Plant Operations

Pre-Baked Anode Block Production: A large operation at any pre-baked plant is the production of the anode block assemblies for use in the pots. These blocks are made with soft pitch and coke and, as received at the facility, are crushed in a ball mill, sized and sent to temporary storage bins. A weighed amount of the pulverized coke and pitch is removed from the bins and discharged into one of several mixers, where the mix is heated to about 150°C to form a carbon paste. The warm carbon paste is then conveyed to presses where the paste is formed into the shape of the anode block.

The freshly-made carbon anode blocks are baked in well enclosed gas fired pit furnaces with temperatures up to 1100°C over a several day baking and cooling cycle to harden the pitch or pitch binder and to improve the block's mechanical strength and electrical conductivity. It is assumed that all of the pitch volatiles are driven off into a collection system. This action thus shrinks and hardens the anodes. After inspection and cleaning, the blocks are anchored to aluminum or copper rods by pouring molten cast iron around the base of the rods. The assemblies are then ready to be utilized in the potrooms to replace consumed anodes.

Soderberg Anode Paste Production: The receiving, crushing, sizing, weighing and mixing of the carbonaceous raw materials is done very much as it is for pre-baked anode block production. The differences in procedures are in the proportion and softening point of the pitch used and the temperature at which the mixers are operated. The distinguishing characteristics from anode block production is that the warm paste discharged from the mixers is taken directly to the Soderberg potrooms rather than being pressed into blocks and then pre-baked.

Cathode Block and Paste Production: Manufacture of carbon blocks is performed by applying the general method of anode block production and the carbon cathode paste production follows nearly the same procedure as Soderberg anode paste production, except that in both instances anthracite coal is used instead of coke. The chief differences are in grades of raw materials and mixing temperatures employed.

### Cryolite Recovery Operation

At many aluminum reduction facilities, the fluorides that are present in the discarded pot lining are recovered and recycled as cryolite. Also, cryolite can be recovered from the caustic stream from wet scrubbers used to remove fluorides from the reduction pots.

After a rough reduction in size, the used pot lining is conveyed to a ball mill for production of small sized particles. This fine pot lining material is then placed in a slurry and the fluorides are digested in a caustic solution. (If wet scrubbers are used on the pots, this is the point in the recovery operation at which the caustic stream is utilized.) Cryolite is precipitated out of this slurry by dropping the pH and sending the slurry through a carbonator. The cryolite then is dried in an oven or kiln and is ready for use again in the potrooms.

### DESCRIPTION OF PLANTS SURVEYED

#### Plant A

This facility contained both vertical pin Soderberg (approximately 400) and pre-baked (approximately 150) pots. Anode and cathode carbon blocks and carbon pastes were produced in an on-site carbon plant for use in the potrooms. At the time of this survey, most of the carbon plant operations were being transferred to a new building and the measurements taken in this new building may not be representative of normal levels since the operations were in a "shakedown phase".

Ventilation was provided in the Soderberg potrooms for removal of gases such as carbon monoxide and hydrogen fluoride emitted from the pots. These gases were collected at a manifold, burned, sent to a wet scrubber and finally sent to a wet electrostatic precipitator before being discharged to the atmosphere. There was no local ventilation directly over the Soderberg anodes and the emissions were therefore expelled directly into the potrooms. Some ventilation was provided by natural updraft of the potroom air through monitor-type windows at the top of the potroom buildings. The pre-baked pots, which are newer than the Soderberg pots, were enclosed and provided with local exhaust ventilation on each pot. The gases from these pots were collected and the fluorides removed by dry scrubbing. The remaining particulates were collected by bag filters.

The furnaces that are used to cure the pre-baked anodes and cathode blocks were controlled so the volatiles that were emitted during the baking and cooling cycle were collected. In the new carbon plant building, material conveyors were closed and dust from the grinders and mixers was collected.

#### Plant B

This facility contained only pre-baked pots for the production of aluminum (approximately 1000). One of the potlines was computerized and somewhat automated in that the insulating crust at the top of the aluminum and fluoride electrolytes was broken in a predetermined sequence so that the potmen did not need to be in the vicinity of the pot to perform this operation.

Anode blocks and cathode paste for the rebuilding of pots were produced at the facility, while the needed cathode blocks were purchased from an external source.

Cryolite was recovered at this facility from the used pot lining of the pre-baked pots.

The pre-baked pots were each enclosed with shielding and provided with local exhaust ventilation, which removed the fumes and gases to multiclones followed by wet scrubbers. The cleaned gases were then vented to the outside ambient air. Hooded ventilation also was provided at some of the aluminum ore filling stations in the potrooms. In the carbon plant, local exhaust ventilation was used in several locations, including around the mixers.

#### Plant C

This facility produced aluminum using horizontal pin Soderberg pots (approximately 1000). At the time of this survey, only about 75 percent of the pots were operating. Carbon anode (used to replace carbon that burns off as CO and CO<sub>2</sub>) and cathode (used to rebuild pots) pastes were produced in the carbon plant of the facility. Cathode blocks were not produced at the facility but were purchased externally.

Cryolite was recovered at this facility from old pot lining as was done at Plant B. Cryolite also was recovered from the discharged caustic stream from the wet scrubbers, which were used to remove fluorides from the gases emitted from the pots.

Ventilation was provided in the potrooms in that air was drawn in through the sides of the buildings and then updrafted to the ceiling window-type monitors, such that the emitted gases were caught and cleaned by wet scrubbers in series with a dropout chamber (for large sized particulate). As was mentioned earlier, the discharge stream from the scrubbers was recycled to recover the fluorides as cryolite.

#### Plant D

This facility used pre-baked pots for the production of aluminum (approximately 700). Carbon anode blocks and the cathode paste for pot relining were produced at the facility; however, the carbon blocks for the cathode were purchased. This facility was the only one of the four plants surveyed in the Eastern United States that utilized petroleum pitch instead of coal tar pitch in the production of the carbon anode blocks. In the actual production of the anode blocks, there were two different techniques utilized during the sampling survey. One consisted of manual operations with hand operated cranes for placing and removing the blocks in the curing furnaces and hand operated "scoops" for removing the insulating and packing case from around the anode blocks. The second method utilized an overhead crane for block insertion and removal and dispersion and pickup of the insulation and packing coke. These latter operating procedures, of course, reduced the number of employees that worked directly above the curing furnaces.

There were no cryolite recovery operations at this facility.

There were no covers or local exhaust ventilation utilized on the pots. The plant relied solely on strong room air movement, through the use of roof ventilators, for ventilation in the potrooms. Local exhaust ventilation, roof ventilators and dust and fume collecting systems were utilized in the various areas of the carbon plant.

#### SAMPLING PROCEDURES\*

##### Pitch Volatiles and Total Airborne Dust

Both personal and hi-volume stationary samples were taken during the course of these surveys. Personal sampling included the use of small battery-powered pumps attached to the belts of the workers, with rubber tubing running to filter cassettes at the approximate breathing zone of the worker. Air was drawn through the combination of a 37mm Gelman Type A glass fiber filter preceded by an  $0.8\mu$  pore size silver membrane filter at 1.7 liters per minute (lpm) during the employee's work shift. The stationary sampling consisted of using the same filter arrangement as the personal samplers except that a Gast vacuum pump was used to pull approximately 7.0 lpm through the filters. These samplers were generally located in the working area, positioned about three feet above floor level.

The analysis of the samples for total airborne dust was accomplished by weighing previously tared filters, with the difference in the weight being the total dust collected.

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\* Mention of commercial products in this report does not constitute endorsement by the National Institute for Occupational Safety and Health.

After being weighed, these same filters were analyzed for benzene solubles in order to give a measure of worker exposure to pitch fumes. The basic procedure<sup>4</sup> is to weigh the filters, extract them with hot benzene in a Soxhlet extractor, air dry the filters, reweigh them and consider the loss in weight to be the benzene solubles.

#### Airborne Fluorides

Two different sampling methods were used to collect airborne fluorides in the potrooms and at the cryolite recovery operations. The first consisted of the use of a Millipore AA filter for particulate fluorides followed by a midget impinger filled with 10-15 milliliters (ml) of 0.1N sodium hydroxide to absorb gaseous fluorides. The second method used a Gelman GA 4, 0.8 $\mu$  pore size filter as the collection media. This filter was impregnated with sodium formate so that the gaseous as well as the particulate fluorides would be captured. Both methods used battery-powered personal pumps operating at a flow rate of 1.5 lpm.

To analyze these filters for fluorides, they were ashed, a buffer solution was added and the amount of fluorides determined by a specific ion electrode. The caustic impinger solutions also were analyzed by a fluoride specific ion electrode after the addition of a buffer solution<sup>5</sup>.

#### Carbon Monoxide, Sulfur Dioxide and Ammonia

A Drager hand pump was used to draw samples of air through detector tubes. The operation of these tubes is generally based on a reaction occurring between the packing in the tube and the particular gas to be sampled, which causes a change in color. The length of the color stain is directly proportional to the concentration of the gas being sampled.

Noise

In addition to air sampling, noise level measurements were made. The measurements were made on the "A"-slow scale of a General Radio Type 1565A sound level meter calibrated with a Type 1562A calibrator.

DISCUSSION OF SAMPLING RESULTS

General

As was discussed in the previous section, sample collection for pitch volatiles, total airborne dust and airborne fluorides was done by both personal and stationary (general area) sampling and carbon monoxide, sulfur dioxide and ammonia was done by stationary sampling. Since personal sampling was conducted on workers only during the working portion of their shift and the stationary samples do not represent a particular worker's actual exposure to an air contaminant, it was necessary to estimate eight hour time weighted average (TWA) exposures for the various job types found in aluminum reduction processing. This estimation also was deemed necessary for comparisons with the Occupational Safety and Health Administration (OSHA) standards, which also are on an eight hour TWA basis.

The TWAs were calculated from the personal samples by prorating the amount of time the worker of a given job type spent in performing his tasks during a shift. For example, if a worker completed his tasks within four hours and then left the working area, the personal sampling results were multiplied by a factor of 4/8. For job types, where the duties were

repetitive in nature and lasted the entire shift, the assumption was made that the contaminant concentration measured during the sampling period was representative of the exposure for the entire shift.

For calculation of TWAs from stationary samples (including detector tubes), time studies on the work habits of the workers were utilized. The method used to determine the TWA was that of multiplying the average time (in hours) spent by a worker in each sampling area by the average contaminant concentration in the given area and then summing these individual products and dividing by eight, the total time in hours of a work shift.

It should be noted that any respiratory protection worn by the workers was not taken into account in arriving at the TWA estimates.

In presenting the comparative sampling results for the four Eastern United States plants, as presented below, it should be pointed out that such a comparison is extremely difficult because, even though similar processing techniques between the plants are utilized, there are differences in work procedures for the same job types, equipment is different, etc.

#### Pitch Volatiles

Comparative pitch volatile TWA exposure estimates\* are presented in Table 1. Reliable data were not available for Plant B; therefore, estimates of worker exposure to pitch volatiles at this facility are not presented here. (Blank samples registered a large weight loss after benzene extraction, which essentially made the sampling results invalid.)

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\*Exposure estimates are based on measured pitch volatile concentrations. These concentrations are subject to question as is discussed throughout this section.

TABLE 1. PITCH VOLATILES

Time Weighted Average (TWA) Exposures<sup>a,b</sup>

Job-Type	Plant A		Plant B		Plant C		Plant D <sup>f</sup>	
	Number of Samples <sup>c</sup>	Concentration, mg/m <sup>3</sup> Ranged TWA <sup>e</sup>	Number of Samples <sup>c</sup>	Concentration, mg/m <sup>3</sup> Ranged TWA <sup>e</sup>	Number of Samples <sup>c</sup>	Concentration, mg/m <sup>3</sup> Ranged TWA <sup>e</sup>	Number of Samples <sup>c</sup>	Concentration, mg/m <sup>3</sup> Ranged TWA <sup>e</sup>
<u>Pre-Baked Potroom</u>								
Potman	3	0.0-0.2	0.2	Results are questionable and therefore are not presented here	Operation not used at plant	Not measured		
Tapper/anode setter	3	0.0-2.1	0.5					
Craneman-general	2	0.4-0.7	0.4					
<u>Vertical Pin</u>								
<u>Soderberg Potroom</u>								
Potman	10	0.0-6.8	2.2	Operation not used at plant	Operation not used at plant	Operation not used at plant		
Tapper	5	1.0-63.4	12.0					
Tapping craneman	3	0.0-7.1	3.0					
Pin setter	2	2.7-7.5	2.5					
Head pin setter	3	11.3-19.0	7.5					
Pin craneman	2	0.0-5.9	2.7					
Line foreman	1	0.6	0.5					
Paster	1	8.1	4.2					
Paste craneman	1	1.5	1.0					
Pot changer	1	6.4	6.0					
Utility worker	1	0.8	0.6					
<u>Horizontal Pin</u>								
<u>Soderberg Potroom</u>								
Potman		Operation not used at plant		Operation not used at plant	Operation not used at plant	Operation not used at plant		
Flex raiser							4.6-8.7	4.5
Pin puller							29.9	18.5
Channel puller							2.2-3.3	1.5
Channel hanger							6.5	2.5
Hijacker							7.4	3.5
Hoie dauber							11.6-32.5	17.0
Pin driver							3.3	1.6
Toolman							8.3-26.9	12.0
Anode craneman							2.2	1.2
Tapping craneman							35.3-60.0	17.5
Tapper							4.8-5.5	3.8
Tapper helper							3.0-3.6	2.0
							6.4-7.6	4.4

TABLE 1. PITCH VOLATILES (continued)

Job-Type	Plant A		Plant B		Plant C		Plant D <sup>f</sup>	
	Number of Samples <sup>c</sup>	Concentration, mg/m <sup>3</sup> TWA <sup>e</sup> Range <sup>d</sup>	Number of Samples <sup>c</sup>	Concentration, mg/m <sup>3</sup> TWA <sup>e</sup> Range <sup>d</sup>	Number of Samples <sup>c</sup>	Concentration, mg/m <sup>3</sup> TWA <sup>e</sup> Range <sup>d</sup>	Number of Samples <sup>c</sup>	Concentration, mg/m <sup>3</sup> TWA <sup>e</sup> Range <sup>d</sup>
Miscellaneous Potroom								
Pot reliner	Results are questionable and are therefore not presented here		1	15.9	8.3	1	1.3	0.3
Carbon Plant-- Pre-baked anode block production			Results are questionable and therefore are not presented here	Operation not used at plant				
Operator-Tech	2	0.0-0.4				1	2.4	2.4
Ball mill opr.								
Weigher	1	0.1				1	0.6	0.6
Batch car opr.	1	9.0				1	0.8	0.8
Mixer operator						1	2.9	2.9
Hydraulic press opr.						1	1.8	1.8
Butt line laborer						1	1.7	1.7
Butt line crane-man						2	0.7-1.0	0.8
Laborer-green mill						1	1.0	1.0
Craneman-curing furnace						2	0.4-2.3	1.4
Material handler-curing furnace						1	7.6	6.0
Curing furnace opr.						1	16.7	10.4
Coke packer						1	6.2	4.7
Anode block puller						1	6.1	5.3
Blanket cutter						2	0.8-1.5	1.2
Anode block cleaner								
Laborer-curing furnace								

19.

TABLE 1. PITCH VOLATILES (continued)

Time Weighted Average (TWA) Exposures<sup>a,b</sup>

Job-Type	Plant A		Plant B		Plant C		Plant Cf	
	Number of Samples	Concentration, mg/m <sup>3</sup> TWAe	Number of Samples	Concentration, mg/m <sup>3</sup> TWAe	Number of Samples	Concentration, mg/m <sup>3</sup> TWAe	Number of Samples	Concentration, mg/m <sup>3</sup> TWAe
Carbon Plant-- Soderberg Anode Paste Production								
Ball mill operator					1	2.5	1	1.9
Pitch pump operator					1	12.6	1	9.5
Batch car operator	1	0.0			1	8.3	1	6.2
Mix dumper	1	2.0			1	1.1	1	1.0
Mixer operator	1	5.2			2	2.4-4.1	2	2.0
Blowing off lining					1	11.8	1	8.9
Paster and caser					1	2.8	1	1.3
Dolly driver								
Carbon Plant-- Cathode mixing and forming								
Mixer operator	1	1.0						
Craneman joint press	1	5.8					1	4.1

Operation not used at plant

Operation not used at plant

Operation conducted at anode  
paste production area

20.

- a. Occupational Health and Safety Administration Standard--0.2mg/m<sup>3</sup>
- b. In determining TWA exposures, credit was not given for time that workers wore respirators since a specific time study was not conducted
- c. Number of personal samples used to estimate TWA
- d. Range of personal sample results used to calculate TWA
- e. TWA for given job type at each plant
- f. Petroleum pitch used at Plant D; coal tar pitch used at other plants

For the remaining three facilities, the general trend appears to be that the highest measured pitch volatile concentrations occurred in the potrooms where horizontal pin Soderberg type anodes were used, followed closely by measured concentrations in potrooms where vertical pin Soderberg pots were used. Usually, there were lower measured pitch volatile concentrations in the carbon plant areas than in the Soderberg potrooms. The lowest concentrations occurred in the pre-baked anode potrooms.

The high pitch volatile concentrations, as measured by the benzene soluble technique, in the Soderberg potrooms are not surprising, since the pitch was heated and the volatiles were driven off directly into the potroom atmosphere. There was no provision for local exhaust ventilation over the Soderberg anodes at either Plant A or Plant C. Only general room ventilation was available for removal of pitch volatiles from the potrooms.

In the carbon plant facilities, the lower pitch volatile concentrations reflect the fact that the pitch was usually handled here at relatively low temperatures where little volatilization of the pitch occurs. The baking of the carbon pre-baked anode blocks requires similar temperatures to those used in the potrooms, but the curing furnaces in the carbon plants were well enclosed to collect the volatiles being released.

As expected, the lowest concentrations were measured in the pre-baked potrooms since theoretically all of the volatiles present in the carbon anode should have been removed at the curing furnaces in the carbon plant prior to anode use in the potrooms. Whether or not the concentrations

measured in the pre-baked potrooms at Plant A are actually from pitch volatiles is debatable.

Because of the limited number of measurements at Plant A in the pre-baked anode production area, conclusions cannot be drawn about the comparison of the measured pitch volatile concentrations at Plant A (coal tar pitch used) versus Plant D (petroleum pitch used).

It must be noted that the OSHA standard of  $0.2 \text{ mg/m}^3$  benzene solubles for worker exposure to pitch volatiles was adopted based on information from animal experiments and the coke oven industry. The chief disadvantage of the benzene solubles standard is that it is not specific for the polynuclear aromatic compounds that are potentially carcinogenic. The benzene soluble fraction, as measured by the analytical technique, only gives the concentration of organic material present that is soluble in benzene. The carcinogenic compounds may or may not be present in the environs of aluminum reduction operations.

There also have been various difficulties with the analytical procedure, which makes the results of the benzene soluble determination insensitive and somewhat unreliable. The low air volumes obtained by personal sampling require that very small weight differences be detected in order to obtain accurate results, particularly when the concentration of benzene solubles is at or below the  $0.2 \text{ mg/m}^3$  standard. If the analyst is not careful during the extraction of the filters with benzene, some of the insoluble particulates or fragments of the filters can be removed from the filters and not be recovered. This would increase the weight loss of the filters and produce a falsely high benzene soluble result (pitch volatile concentration).

To further look into this problem, 15 samples collected at Plant A were specifically analyzed for 14 polynuclear aromatic compounds that have been commonly found in coke oven effluent. As is shown in Table 2, the results indicate that few of these compounds were detected in any quantity, except for those concentrations representative of exposures to the "tapping craneman", "pin setter" and "pin craneman", all who work directly above the Soderberg pots.

NIOSH is presently conducting research to obtain a better qualitative and quantitative analytical method for the polynuclear aromatic compounds commonly emitted in the aluminum reduction process. It is hoped that a routine method can be developed that will allow determination of the concentration of any potential carcinogenic agent that might be present. In the meantime, the value of studies, as reported here, and the associated concentrations as measured by the benzene solubles technique only can serve as an index for classifying the relative exposures for various job types within the industry.

To bring into perspective the sampling that was conducted by NIOSH<sup>1</sup> on the aluminum reduction facilities in the Northwestern United States, an attempt has been made (Table 3) to present those results for comparison with those from the Eastern United States plants. Only the data where job types could be identified as similar in name were compared. As was mentioned previously, this type of comparison is difficult because of the differences from plant to plant in operating procedures, equipment used, etc. Also, for the two studies, slightly

TABLE 2. COAL TAR PITCH VOLATILES  
Benzene Soluble Fraction and Polynuclear Aromatic Analysis (Plant A)

Job Type	B.S. <sup>a</sup> mg/m <sup>3</sup>	BaP <sub>1</sub> µg/m <sup>3</sup>	Flu µg/m <sup>3</sup>	Pyr µg/m <sup>3</sup>	BcA µg/m <sup>3</sup>	Chr µg/m <sup>3</sup>	BaA µg/m <sup>3</sup>	BaAn µg/m <sup>3</sup>	BbF µg/m <sup>3</sup>	BjF µg/m <sup>3</sup>	BkF µg/m <sup>3</sup>	BeP µg/m <sup>3</sup>	BaP µg/m <sup>3</sup>	DBahA µg/m <sup>3</sup>	BghiP µg/m <sup>3</sup>	Ant µg/m <sup>3</sup>
Tapper/Anode Setter, Pre- baked potroom	2.1	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Craneman, Pre- baked potroom	0.7	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Potman, Pre- baked potroom	<0.2	0.03	ND	ND	ND	1.1	1.8	ND	ND	ND	ND	ND	ND	ND	ND	ND
Potman, Soder- berg potroom	3.0	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Potman, Soder- berg potroom <sup>b</sup>	14.5	0.07	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tapper, Soder- berg potroom	9.2	0.2	ND	ND	ND	0.6	1.3	ND	3.0	3.3	ND	ND	ND	ND	ND	ND
Tapper, Soder- berg potroom	14.4	0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tapping Crane- man, Soderberg potroom	5.0	3.1	ND	ND	ND	46.6	33.0	ND	54.4	ND	27.2	14.4	17.7	ND	60.2	8.5
Pin Setter, Soderberg pot- room	7.5	53.0	24.4	28.2	12.2	82.7	42.1	ND	58.2	11.6	31.9	31.9	60.1	ND	26.3	3.8
Pin Craneman, <sup>c</sup> Soderberg pot- room	6.0	28.6	ND	ND	ND	40.8	38.4	ND	36.0	8.2	16.8	22.3	43.2	ND	ND	ND
Paster, Soder- <sup>b</sup> berg potroom	11.1	0.7	ND	ND	ND	5.5	5.3	ND	5.8	ND	ND	ND	ND	ND	ND	ND
Pot reliner, <sup>c</sup> Soderberg potroom	1.4	0.02	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Batch Car Oper- ator, Anode Block Production	9.0	0.5	1.7	ND	ND	1.6	0.7	ND	4.0	ND	2.8	ND	ND	ND	ND	ND
Mixer Operator, Anode Paste Production	5.2	1.0	ND	ND	ND	4.1	3.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Blank	<0.1	<0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

a. See attachment for list of abbreviations  
b. Glass fiber filter edge broken, edge disintegrated during extraction  
c. Glass fiber filter edge broken  
ND - None detected

## LIST OF ABBREVIATIONS USED IN TABLE 2

<u>ABBREVIATION</u>	<u>DEFINITION</u>	<u>UNITS</u>	<u>METHOD OF ANALYSIS</u>
B.S.	benzene soluble fraction	mg/m <sup>3</sup>	Parma 1013
BaP <sub>1</sub>	benzo(a)pyrene	µg/m <sup>3</sup>	(thin layer chromatographic method)
Flu	fluoranthene	µg/m <sup>3</sup>	Gas chromatography and Ultra-violet method
Pyr	pyrene	µg/m <sup>3</sup>	Gas chromatography and Ultra-violet method
BcA	benz(c)acridine	µg/m <sup>3</sup>	Gas chromatography and Ultra-violet method
Chr	chrysene	µg/m <sup>3</sup>	Gas chromatography and Ultra-violet method
BaA	benz(a)anthracene	µg/m <sup>3</sup>	Gas chromatography and Ultra-violet method
BaAn	benz(a)anthrone	µg/m <sup>3</sup>	Gas chromatography and Ultra-violet method
BbF	benzo(b)fluoranthene	µg/m <sup>3</sup>	Gas chromatography and Ultra-violet method
BjF	benzo(j)fluoranthene	µg/m <sup>3</sup>	Gas chromatography and Ultra-violet method
BkF	benzo(k)fluoranthene	µg/m <sup>3</sup>	Gas chromatography and Ultra-violet method
BeP	benzo(e)pyrene	µg/m <sup>3</sup>	Gas chromatography and Ultra-violet method
BaP	benzo(a)pyrene	µg/m <sup>3</sup>	Gas chromatography and Ultra-violet method
DBahA	dibenz(a,h)anthracene	µg/m <sup>3</sup>	Gas chromatography and Ultra-violet method
BghiP	benzo(g,h,i)perylene	µg/m <sup>3</sup>	Gas chromatography and Ultra-violet method
Ant	anthanthrene	µg/m <sup>3</sup>	Gas chromatography and Ultra-violet method

TABLE 3. Comparison of Time Weighted Average (TWA)  
Pitch Volatile Results in Aluminum Reduction  
Facilities in the Eastern United States<sup>a</sup> Versus  
Those in the Northwestern United States<sup>b</sup>

<u>Type of Plant &amp; Job Type</u>	<u>Eastern Facilities</u>		<u>Northwestern Facilities</u>	
	<u>Number of Samples</u>	<u>Concentration,mg/m<sup>3</sup>c</u>	<u>Number of Samples</u>	<u>Concentration,mg/m<sup>3</sup>c</u>
<u>Pre-Baked</u>				
Potrooms				
Potman	3	0.2	13	0.2
Tappers/anode setters	3	0.5	34	0.1-0.5
Pot reliner	1	0.3	29	0.4
<u>Carbon Plant</u>				
Ball mill opr.	1	2.4	3	0.2
Press opr.	1	2.9	6	0.1
Mixer opr.	1	0.6	3	0.3
<u>Vertical Pin Soderberg</u>				
Potrooms				
Potman	10	2.2	5	0.3
Tapper	5	12.0	10	0.3
Pin setter	5	2.5-7.5	40	1.1
<u>Carbon Plant</u>				
Mixer Operator	1	2.6	2	< 0.1
<u>Horizontal Pin Soderberg</u>				
Potrooms				
Potman	4	4.5	42	0.5
Flex raisers	1	18.5	10	0.3
Pin pullers	2	1.5	4	0.4
Channel hangers	1	3.5	4	0.5
Tappers	4	2.0-3.4	5	0.3
Pot reliners	1	8.3	5	0.1

- a. Four plants surveyed
- b. Six plants surveyed
- c. Composite value

different sampling techniques were used and two different laboratories were used for the analytical work. For the former, the differences were as follows:

<u>Eastern Plants</u>	<u>Northwestern Plants</u>
Glass fiber/silver membrane filter	Silver membrane filter*
Closed face filtering (4mm diameter opening)	Open face filtering
Combining of filters for same job types at Plant D	Combining of filters for same job types at all plants

The quantitative comparisons as presented in Table 3, show that the Northwestern plant results were considerably lower. However, both sets of data do indicate relatively higher measured concentrations of pitch volatiles in the horizontal and vertical pin Soderberg potrooms than in the other processing areas of the plants.

Total Airborne Dust

Total airborne dust TWA exposure estimates for the Eastern United States plants are presented in Table 4. As was found with the pitch volatile results, the highest concentrations were measured in the horizontal pin Soderberg potrooms. Particularly high exposures were noted for the "anode men", who work near the sides of these pots. The second highest exposures were found in the vertical pin Soderberg potrooms, with "tappers" and "pin setters" having the potential for greatest exposures.

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\* Glass fiber/silver membrane filters were used at two plants.

TABLE 4. TOTAL AIRBORNE DUST  
Time Weighted Average (TWA) Exposures<sup>a</sup>

Job-Type	Plant A		Plant B		Plant C		Plant D	
	Number of Samples <sup>c</sup>	Concentration, mg/m <sup>3</sup> Ranged	Number of Samples <sup>c</sup>	Concentration, mg/m <sup>3</sup> Ranged	Number of Samples <sup>c</sup>	Concentration, mg/m <sup>3</sup> Ranged	Number of Samples <sup>c</sup>	Concentration, mg/m <sup>3</sup> Ranged
<u>Pre-baked Potroom</u>								
Potman	4	0.7-6.2	8	1.1-24.5	3	3.6-7.8	3	3.6-7.8
Tapper/anode setter	3	6.6-14.7			2	4.3-8.4	2	4.3-8.4
Craneman-general	2	1.0-2.2			2	9.1-17.7	2	9.1-17.7
Anode setter					2	11.3-15.4	2	11.3-15.4
Tapper								
Craneman-anode setter								
Craneman-tapping								
Craneman-oreing								
Laborer								
Operation not used at plant								
<u>Vertical Pin</u>								
<u>Soderberg Potroom</u>								
Potman	12	0.6-22.2						
Tapper	6	6.5-81.3						
Tapping craneman	3	10.5-15.8						
Pin setter	2	7.3-8.1						
Head pin setter	3	16.8-48.1						
Pin craneman	3	0.9-6.6						
Line foreman	1	2.7						
Paster	2	9.7-17.7						
Paste craneman	1	5.2						
Pot changer	1	9.1						
Utility worker	1	1.4						
Operation not used at plant								
<u>Horizontal Pin</u>								
<u>Soderberg Potroom</u>								
Potman	16	5.4-35.5			16	5.4-35.5		
Flex raiser	2	57.1-65.1			2	57.1-65.1		
Pin puller	4	6.6-13.8			4	6.6-13.8		
Channel puller	2	15.6-27.8			2	15.6-27.8		
Channel hanger	2	7.0-10.8			2	7.0-10.8		
Hijacker	4	17.1-47.7			4	17.1-47.7		
Operation not used at plant								

TABLE 4. TOTAL AIRBORNE DUST (continued)

Job-Type	Plant A		Plant B		Plant C		Plant D <sup>f</sup>		
	Number of Samples <sup>c</sup>	Concentration, mg/m <sup>3</sup> Ranged TWA <sup>e</sup>	Number of Samples <sup>c</sup>	Concentration, mg/m <sup>3</sup> Ranged TWA <sup>e</sup>	Number of Samples <sup>c</sup>	Concentration, mg/m <sup>3</sup> Ranged TWA <sup>e</sup>	Number of Samples <sup>c</sup>	Concentration, mg/m <sup>3</sup> Ranged TWA <sup>e</sup>	
Horizontal Pin									
<u>Soderberg Potroom (continued)</u>									
Hole dauber	2	8.6-11.2	4.4						
Pin driver	8	8.2-91.4	11.5						
Toolman	2	5.9-7.4	3.5						
Anode craneman	3	38.2-77.6	35.0						
Tapping craneman	4	4.8-6.5	4.0						
Tapper	4	8.6-14.1	6.5						
Tapper helper	4	6.1-12.2	5.4						
Miscellaneous									
<u>Potroom</u>									
Pot reliner	4	0.1-2.1	1.0	3	0.2-1.1	0.7	3	2.1-35.6	9.0
Sweeper opr.							1	0.6-58.9	5.0
								19.7	15.0
Carbon Plant--									
Pre-baked anode									
<u>Block production</u>									
Operator-tech.	2	4.2-9.1	6.2				2	4.4-4.9	4.6
Ball mill opr.									
Weigher	1	3.4	1.7						
Batch car opr.	1	13.6	6.8	2	13.8-46.4	12.9	2	4.0-4.9	4.4
Mixer opr.	1	5.1	3.0	2	9.6-10.4	7.6	2	2.0-2.8	2.4
Hydraulic press opr.				2	0.4-6.3	0.5	2	4.1	4.1
Butt line laborer							2	4.4-5.0	4.7
Butt line craneman							2	6.8-10.7	8.8
Laborer-greenmill							2	1.4-9.9	4.1
Craneman-curing furnace							8	2.6-6.9	5.0
Material handler-curing furnace							4	2.1-4.2	3.2
Curing furnace opr.							4	1.2-29.0	9.0
Coke packer							4	12.9-61.7	27.2
Anode block puller							2	17.2-19.2	13.7
Blanket cutter							6	5.8-44.8	14.7
Anode block cleaner							4	3.2-6.0	4.7
Laborer-curing furnace									

Operation not used at plant



A clear pattern is not evident for the other operational areas of the facilities. As might be expected, the worker exposure to total airborne dust appears to be a function of degree of automation or effectiveness of controls instituted at the work site. For example, at the two curing furnaces sampled at Plant D, the room which had been remodeled and had its operation automated was found to have lower personal exposures than the room with the older (non-automated) furnaces. Also, the benefit of good ventilation was shown by the levels\* measured in the three different pre-baked potrooms. While not excessive, total dust exposures were slightly higher at Plant D, which at the time of the survey had no local exhaust ventilation over the pre-baked pots. At Plants A and B, the pre-baked pots were well enclosed and ventilated, but the volume of air exhausted to the collection system at each pot at Plant B was much less than at Plant A. This probably resulted in the fact that the total airborne dust concentrations measured at Plant B were generally greater than those for the pre-baked potroom at Plant A.

There was a wide range of exposures at the various carbon facilities. Again, worker exposure was largely dependent upon the conditions at the particular plant. However, one dusty operation which was obvious was that of the batch car operation. Usually, the housekeeping in this area was considered poor due to accumulated carbon dust. This particular problem was overcome at Plant D by mechanizing this operation and allowing the worker on the floor below where the batch car was located to operate it remotely. Generally, after the carbonaceous raw

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\*Individual personal and stationary area samples are not presented in this report.

materials have been discharged, the dust levels and worker exposures decrease as was evidenced in the mixing and anode and cathode block forming areas.

In comparison with the OSHA standard (15 mg/m<sup>3</sup>--total nuisance dust standard) that would apply to these measured concentrations, most of the areas of the facilities could be considered within acceptable limits, with the exception of certain job types such as the "anode workers" in the Soderberg potrooms and the workers in the mixing areas of the carbon plants. The nuisance dust standard may not be a good health standard to apply since it assumes the dust to be biologically inert, which may not be the case for the carbonaceous materials used in these facilities. Also, depending on the outcome of the analytical developmental work on the carcinogenic compounds and the results of a mortality study that the Aluminum Association is considering and the morbidity study sponsored by NIOSH, the significance of these levels of exposure probably will have to be re-evaluated at a later date.

As was done with the pitch volatile results, an attempt was made to compare the results of the Eastern reduction plants with those found at the Northwestern plants. This information is presented in Table 5 and, as such, indicates that the total airborne dust levels found in the Northwestern plants are somewhat lower than those of the Eastern plants. (The possible reasons for this were discussed previously.) The data for the Northwestern plants and the job types presented do not present a clear difference between the total airborne dust levels throughout the

TABLE 5. Comparison of Time Weighted Average (TWA) Total Airborne Dust Results in Aluminum Reduction Facilities in the Eastern United States<sup>a</sup> Versus Those in the Northwestern United States<sup>b</sup>

Type of Plant & Job Type	Eastern Facilities		Northwestern Facilities	
	Number of Samples	Concentration, mg/m <sup>3c</sup>	Number of Samples	Concentration, mg/m <sup>3c</sup>
<u>Pre-Baked</u>				
Potrooms				
Potman	15	3.9	13	3.9
Tappers/anode setters	11	11.6	40	7.2
Pot reliner	15	3.1	28	2.7
<u>Carbon Plant</u>				
Ball mill opr.	2	4.6	2	1.9
Press opr.	4	1.5	6	5.7
Mixer opr.	5	5.4	3	1.1
<u>Vertical Pin Soderberg</u>				
Potrooms				
Potman	12	6.5	5	2.0
Tapper	6	20.0	10	4.6
Pin setter	5	18.9	40	7.4
<u>Carbon Plant</u>				
Mixer operator	1	4.4	2	1.7
<u>Horizontal Pin Soderberg</u>				
Potrooms				
Potman	16	16.0	41	4.5
Flex raisers	2	38.2	10	2.8
Pin pullers	4	7.5	4	1.8
Channel hangers	2	3.9	4	4.0
Tappers	8	6.0	5	2.4
Pot reliners	4	1.0	5	2.0

- a. Four plants surveyed
- b. Six plants surveyed
- c. Composite value

operational areas of the facilities as do the Eastern plant data, which show somewhat higher exposure levels in the Soderberg potrooms.

#### Airborne Fluorides

TWA exposures to airborne fluorides for each of the Eastern United States plants surveyed are presented in Table 6.

All of these estimates are well below the present OSHA standard of 2.5 mg F/m<sup>3</sup>. As expected, the greatest exposures came from the pre-baked potrooms at Plant D, since pot enclosure or local exhaust ventilation was not used. The levels measured in the Soderberg potrooms are conceivable because the pots are about 20 years old and the gas and fume collection systems may not have been functioning at peak efficiency. One trend which is difficult to explain is that the exposures to airborne fluorides were an order of magnitude greater in the newer and better ventilated pre-baked potrooms at Plant A than in the older and poorly ventilated Plant B potrooms. Sampling error may explain this anomaly.

The TWA exposures to airborne fluorides appear to have been quite similar at the cryolite recovery operations at both Plants B and C. These low exposure estimates reflect the short periods of time the workers spend near the processing operations, and the fact that much of the equipment was outdoors or in a partially enclosed structure.

TABLE 6. AIRBORNE FLUORIDES

Job-Type or Location	Time Weighted Average (TWA) Exposures <sup>a</sup>			
	Plant A	Plant B	Plant C	Plant D
	Number of Samples <sup>b</sup> Concentration, mg/m <sup>3</sup> Range <sup>c</sup> TWA <sup>d</sup>	Number of Samples <sup>b</sup> Concentration, mg/m <sup>3</sup> Range <sup>c</sup> TWA <sup>d</sup>	Number of Samples <sup>b</sup> Concentration, mg/m <sup>3</sup> Range <sup>c</sup> TWA <sup>d</sup>	Number of Samples <sup>b</sup> Concentration, mg/m <sup>3</sup> Range <sup>c</sup> TWA <sup>d</sup>
Pre-Baked Potroom				
General Potman	3 <sup>e</sup> 0.12-0.93 0.5-1.0	4 <sup>e</sup> 0.06-0.09 0.05-0.10	Operation not used at plant	12 <sup>f</sup> 0.12-3.6 1.0-1.5 12 <sup>f</sup> 0.12-3.6 0.2-0.8
Tapper/anode setter				
Vertical Pin Soderberg Potroom				
General	7 <sup>e</sup> 0.04-1.23 0.5-1.0	Operation not used at plant	Operation not used at plant	Operation not used at plant
Horizontal Pin Soderberg Potroom				
General	Operation not used at plant	Operation not used at plant	19 <sup>f</sup> 0.04-1.9 0.5-1.25	Operation not used at plant
Cryolite Recovery Operation				
Crusher operator		6 <sup>e</sup> 0.06-0.34 0.20-0.25	8 <sup>f</sup> < 0.02 0.10	
Ball mill operator		6 <sup>e</sup> 0.06-0.34 0.05-0.10	8 <sup>f</sup> < 0.02-0.03 0.25	
Filter press operator		6 <sup>e</sup> 0.06-0.34 0.05-0.10	8 <sup>f</sup> < 0.02-0.03 0.25	
Storage man			8 <sup>f</sup> < 0.02-0.02 0.20	
Dryer operator				

a. Occupational Health and Safety Administration Standard--2.5mgF/m<sup>3</sup>

b. Number of samples used to estimate TWA

c. Range of sample results used to calculate TWA

d. TWA for given job type or location at each plant

e. Only general area sampling conducted using Millipore AA filter--midjet impinger technique

f. General area sampling (using Millipore AA filter--midjet impinger technique, and Gelman sodium formate impregnation technique) and personal sampling (using Gelman sodium formate impregnation technique) were conducted

Ammonia

Ammonia was measured only at the cryolite recovery operation of Plant C. It was detected in the storage area and rod mill building; however, the estimated TWA worker exposure to this gas (1-6 ppm) was far below the current OSHA standard of 50 ppm. Ammonia was above the olfactory threshold at a potlining storage area at the Plant B cryolite recovery operation, but the necessary equipment to take measurements for this gas was not available at the time.

Carbon Monoxide

TWA exposures to carbon monoxide are presented in Table 7.

No worker was estimated to have a TWA exposure above the OSHA standard of 50 ppm. The highest exposure levels to carbon monoxide occurred in the horizontal pin Soderberg potrooms at Plant C, followed by the levels in the pre-baked potrooms at Plants B and D, the potrooms (vertical pin Soderberg and pre-baked) at Plant A and, lastly, the carbon facilities at all the plant sites.

It is surprising that enclosed and ventilated pots at Plant B would give slightly higher carbon monoxide exposures than unventilated pots at Plant D, but some of this can be explained by the general climatic conditions at the time of these surveys. At Plant B (surveyed during the winter), cold weather resulted in the potrooms being generally closed to outside air which reduced air for dilution ventilation. Also, the workers spent much of their non-work time in small, unventilated, break rooms where significant concentrations of carbon monoxide existed.

TABLE 7. CARBON MONOXIDE (continued)

Time Weighted Average (TWA) Exposures<sup>a</sup>

Job-Type or Location	Plant A		Plant B		Plant C		Plant D	
	Number of Samples <sup>b</sup>	Concentration, mg/m <sup>3</sup> TWA <sup>d</sup> Range <sup>c</sup>	Number of Samples <sup>b</sup>	Concentration, mg/m <sup>3</sup> TWA <sup>d</sup> Range <sup>c</sup>	Number of Samples <sup>b</sup>	Concentration, mg/m <sup>3</sup> TWA <sup>d</sup> Range <sup>c</sup>	Number of Samples <sup>b</sup>	Concentration, mg/m <sup>3</sup> TWA <sup>d</sup> Range <sup>c</sup>
Miscellaneous Potroom	Not measured		Not measured		Not measured		Not measured	
Pot reliner Sweeper operator			9	10-70	<5	6	<5-60	<5
Carbon Plant--Pre-baked Anode Block production	Not measured		Operation not used at plant		6	<5-60	<5	<5
General		3	<5-5	<5	7	<5-10	<5	<5
Carbon Plant--Soderberg Anode Paste Production	Not measured		Operation not used at plant		Operation not used at plant		Operation not used at plant	
Ball mill operator			2	5	<5	5	<5	
Pitch pump operator			2	5	<5	5	<5	
Batch car operator			2	5	<5	5	<5	
Mix dumper			2	5	<5	5	<5	
Blowing off lining			11	5-70	25-35	11	5-70	25-35
Paster and caster			11	5-70	25-35	11	5-70	25-35
Dolly driver			2	5	<5	2	<5	
Carbon Plant--Cathode Mising and Forming	Not measured		Not measured		Operation conducted at anode paste production area	7	<5-10	<5
General								

a. Occupational Health and Safety Administration Standard--50ppm

b. Number of samples used to estimate TWA

c. Range of sample results used to calculate TWA

d. TWA for given job type or location at each plant

TABLE 7. CARBON MONOXIDE

Time Weighted Average (TWA) Exposures<sup>a</sup>

Job-Type or Location	Plant A		Plant B		Plant C		Plant D	
	Number of Samples <sup>b</sup>	Concentration, mg/m <sup>3</sup> TWA <sup>d</sup>	Number of Samples <sup>b</sup>	Concentration, mg/m <sup>3</sup> TWA <sup>d</sup>	Number of Samples <sup>b</sup>	Concentration, mg/m <sup>3</sup> TWA <sup>d</sup>	Number of Samples <sup>b</sup>	Concentration, mg/m <sup>3</sup> TWA <sup>d</sup>
<u>Pre-Baked Potroom</u>								
General	3	<5-10						
Potman		5-10	13	<5-40			4	10-6-
Anode setter			13	<5-40				10-15
Tapper			13	<5-40				
Tapper/anode setter							4	10-60
Craneman-anode setter			13	<5-40				15-20
Craneman-tapping			13	<5-40				
Craneman-oreing			13	<5-40				
Craneman-General Laborer							4	10-60
							4	10-60
<u>Vertical Pin Soderberg Potroom</u>								
General	4	<5-90						
<u>Horizontal Pin Soderberg Potroom</u>								
Potman								
Flex raiser			9	10-70			9	10-70
Pin puller			9	10-70			9	10-70
Channel puller			9	10-70			9	10-70
Channel hanger			9	10-70			9	10-70
Hijacker			9	10-70			9	10-70
Hole dauber			9	10-70			9	10-70
Pin driver			9	10-70			9	10-70
Toolman			9	10-70			9	10-70
Anode craneman			9	10-70			9	10-70
Tapping craneman			9	10-70			9	10-70
Tapper			9	10-70			9	10-70
Tapper helper			9	10-70			9	10-70

Operation not used at plant

The warmer weather at Plant D (surveyed during the Spring) resulted in the buildings being more open to outside air. These workers also were more likely to spend their break time outdoors rather than in crowded lunchrooms. This explanation also can be used in regard to the higher values found in the potrooms at Plant C (cold weather) and the lower values in both types of potrooms at Plant A (warm weather).

The potroom concentrations of carbon monoxide also appear to be a function of ventilation. For example, even though it was warm at both Plants A and D, the levels detected were higher in the potrooms at Plant D, where only dilution ventilation was used.

The individual detector tube measurements of carbon monoxide were never found to exceed 5 ppm at any of the carbon facilities tested. At the Plant C carbon plant, the worker who blew off linings and the "paster and caser" were estimated to have received significant exposures to carbon monoxide; however, this was because they spent substantial parts of their time in the potrooms.

#### Sulfur Dioxide

Sulfur dioxide measurements were taken at all facilities except Plant A. The highest detector tube measurements were found in the potrooms at Plant D, but even here the levels were quite low. In all cases, TWA exposure estimates (Table 8) to sulfur dioxide were less than 1 ppm, far below the current OSHA standard of 5 ppm. This is not particularly surprising since the sulfur content of the cokes and pitches used is

TABLE 8. SULFUR DIOXIDE  
Time Weighted Average (TWA) Exposures<sup>a</sup>

Location	Plant A		Plant B		Plant C		Plant D	
	Number of Samples <sup>b</sup>	Concentration, ppm TWA <sup>d</sup> Range <sup>c</sup>	Number of Samples <sup>b</sup>	Concentration, ppm TWA <sup>d</sup> Range <sup>c</sup>	Number of Samples <sup>b</sup>	Concentration, ppm TWA <sup>d</sup> Range <sup>c</sup>	Number of Samples <sup>b</sup>	Concentration, ppm TWA <sup>d</sup> Range <sup>c</sup>
Pre-Baked Potroom	Not measured		2	<1	Operation not used at plant		3	<1-2
Horizontal Pin								
Soderberg Potroom	Operation not used at plant		Operation not used at plant		5	<1-2	Operation not used at plant	
Carbon Plant-- Pre-baked anode Block Production	Not measured		1	<1	Operation not used at plant		1	<1
Carbon Plant-- Cathode Mixing and Forming	Not measured		Not measured		Not measured		1	<1

- a. Occupational Health and Safety Administration Standard--5ppm
- b. Number of samples used to estimate TWA
- c. Range of sample results used to calculate TWA
- d. TWA for given location at each plant

typically low. This is probably also the case for the various fluoride bath constituents that go in to the pots.

### Noise

Noise measurements were taken for a variety of operations at Plant C (Table 9) and Plant D (Table 10).

While individual locations or operations measured at both facilities gave readings of over the OSHA eight-hour TWA of 90 dBA, none of the measurements exceeded the ceiling value of 115 dBA at either plant.

At Plant C, the noisiest areas were associated with the cryolite recovery operation, but employees were not generally exposed to this noise for a long period of time. The duration of worker exposure to high noise levels in the carbon plant is longer, but the noise is usually lower in sound intensity than at the cryolite recovery operations. The potrooms are generally quiet when no work is being done, but some of the routine tasks produce intense noise for short lengths of time.

At Plant D, the most intense noise was found to be for certain operations in the carbon plant. Lower readings were obtained for the rodding room and the lowest values were measured in the potrooms.

Before any conclusions can be drawn as to the potential health hazard from noise exposure at either facility, a more thorough time study is needed to establish the durations of the worker exposure.

TABLE 9. NOISE MEASUREMENTS (Plant C)

<u>LOCATION</u>	<u>DECIBELS (dBA)</u>
<u>Carbon Plant</u>	
Mixer floor	85
Ball mill	98
Control board	87
<u>Potrooms</u>	
Flex grinding	89
Crust breaking	100
Pin pulling	90
Pin pulling	96
General room - no activity	65-70
Crust break machine moving to new pot	95
Raise anode	93
<u>Cryolite Recovery</u>	
Near rod mill	98
Near rod mill	93
By discharge end of the kiln (outside)	108
Inside kiln operator's office	76

OSHA STANDARD

8-hour time weighted average--90 dBA; ceiling value--115 dBA.

The relationship between noise levels and permitted duration of exposure is given by:

$$T = 16 + 2(L-85)/5$$

T = permitted duration, in hours

L = effective noise level, in dBA-slow

TABLE 10. NOISE MEASUREMENTS (Plant D)

<u>LOCATION</u>	<u>DECIBELS (dBA)</u>
<u>Carbon Plant</u>	
Green mill area	85-96 (7 measurements)
Curing furnace area	78-95 (4 measurements)
Anode cleaning area	92-99 (3 measurements)
<u>Rodding Room</u>	84-94 (3 measurements)
<u>Potrooms</u>	
Carbon setting crew	70-78
No activity in area	65
Crustbreaker digging out old potlining	98

OSHA STANDARD

8-hour time weighted average--90 dBA; ceiling value--115 dBA.

The relation between noise levels and permitted duration of exposure is given by:

$$T = 16 + 2 (L-85)15$$

T = permitted duration, in hours  
L = effective noise level in dBA-slow



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CONCLUSIONS

From the data collected during the course of this study on four aluminum reduction facilities in the Eastern United States, the following conclusions are made:

1. Measured pitch volatile levels were highest in Soderberg potrooms since the pitch was heated and baked in this part of the processing. The volatiles were driven off directly into the potroom atmosphere and there was no local exhaust ventilation over the pots. Lower levels of pitch volatiles in the carbon plant facilities were probably due to the lower processing temperatures in the mixing area and the good enclosure and collection systems present at the curing furnaces. The lowest measured concentrations were in the pre-baked potrooms, as would be expected, since theoretically all of the volatiles in the carbon anode should have been removed previously at the curing furnaces.

Since the present OSHA standard for pitch volatiles, as measured by the benzene soluble technique, is insensitive, somewhat unreliable and not specific for the polynuclear aromatic compounds that are potentially carcinogenic, this study has not proved if such carcinogenic compounds are present in the environs of aluminum reduction operations. Work is currently underway to develop a better qualitative and quantitative analytical method. Also, the mortality study being considered by the Aluminum Association and NIOSH morbidity study will help to better evaluate the applicability of the pitch volatile and total nuisance dust standards as applied to the aluminum reduction industry.

2. Total airborne dust exposures were greatest in the horizontal pin Soderberg potrooms with the vertical pin Soderberg potrooms having generally the second highest concentrations. Many of the operations in the Soderberg potrooms were inherently dusty; in addition, these pots were not well enclosed or locally ventilated. Generally, total dust exposures in the pre-baked potrooms and carbon facilities were lower, largely dependent on how much a specific operation had been automated or how well it had been enclosed or ventilated.

The OSHA total nuisance dust standard of  $15 \text{ mg/m}^3$  may be the best health index for total airborne dust exposure in the potrooms where the bulk of the airborne material is alumina (although carbonaceous material is present). A more stringent standard may be necessary in the carbon plant facilities where most of the dust is some sort of carbon material.

3. All of the TWA exposure estimates for airborne fluorides indicate that every facility was well below the OSHA standard of  $2.5 \text{ mg F/m}^3$ . The levels of fluoride particulates and gases were generally higher in the potrooms than the cryolite recovery operations. This is best explained by the facts that workers were not directly involved with the cryolite recovery process for long periods of time and most of the equipment was outdoors.

4. Ammonia was measured at only one location, a cryolite recovery operation. The TWA worker exposure was found to be well below the present OSHA standard of 50 ppm.

5. No worker was estimated to have a TWA exposure to carbon monoxide that exceeded the OSHA standard of 50 ppm for an eight-hour workday. The highest exposures occurred in the horizontal pin Soderberg potrooms, followed by two of the plants with pre-baked potrooms. Concentrations of carbon monoxide were lower at the facility which had both Soderberg and pre-baked potrooms. This pattern was explained in terms of seasonal variations coupled with the degree of enclosure and ventilation provided at the pots.

Patterns of exposure levels to carbon monoxide in the potrooms generally can be explained by seasonal variations (building open to outside air during warm weather) and the degree of enclosure and ventilation provided at the pots.

Little or no carbon monoxide was detected at any of the carbon plant facilities measured.

6. All TWA exposure estimates for sulfur dioxide were less than 1 ppm, well below the present OSHA standard of 5 ppm. The low sulfur content of the coke and pitches probably was the main reason for the low concentrations. Apparently, the sulfur content of the various fluoride bath constituents also was low.

7. Noise measurements were taken at two of the four facilities surveyed. These data indicated that the noise levels were frequently over the eight-hour TWA exposure standard of 90 dBA for relatively short periods of time but never exceeded the ceiling standard of 115 dBA. Due

to the amount of activity and the nature of the operations, the noise levels are generally higher in the Soderberg potrooms than the pre-baked potrooms. The carbon plant facility producing only anode paste was quieter than the one producing the pre-baked anode blocks.

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16. Abstracts

The purpose of this report is to summarize the environmental surveys of four aluminum reduction plants in the Eastern United States, including pre-baked, horizontal pin Soderberg and vertical pin Soderberg operations. The major emphasis of the environmental studies was to determine the extent of worker exposures to potential carcinogenic compounds found in coal tar and petroleum pitch volatiles; however, exposures to total airborne dust, airborne fluorides, carbon monoxide, sulfur dioxide, ammonia and noise also were documented. The report presents a description of aluminum reduction processing and associated worker activities for the three production types that were surveyed, the environmental sampling procedures utilized, a summary of sampling results and conclusions that can be drawn from the surveys.

17. Key Words and Document Analysis. 17a. Descriptors

Environmental surveys, Carcinogens, Fluoride, Carbon monoxide, Sulfur dioxide, Dust, Ammonia

**PRICES SUBJECT TO CHANGE**

17b. Identifiers/Open-Ended Terms

Aluminum reduction plants, Coal tar pitch, Petroleum pitch volatiles

17c. COSATI Field/Group

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