NIOSH

TECHNICAL REPORT

Occupational Health Control Technology for the Primary Aluminum Industry

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health

OCCUPATIONAL HEALTH CONTROL TECHNOLOGY FOR THE PRIMARY ALUMINUM INDUSTRY

John W. Sheehy, P.E.

U. S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
Cincinnati, Ohio 45226

June 1983

For sale by the Superintendent of Documents, U.S. Government
Printing Office, Washington, D.C. 20402

DISCLAIMER

Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

DHHS (NIOSH) Publication No. 83-115

PREFACE

This report was completed from information available from the NIOSH control technology study "Control Technology Assessment of the Primary Aluminum Smelting Industry" Contract No. 210-78-0014. The contract was terminated prior to preparation of the final report.

ABSTRACT

Aluminum producers have developed and installed engineering controls for the protection of worker health. Nonetheless, in some situations exposures to hazardous agents continues. This report documents effective control technology for minimizing worker exposure in selected areas of the primary aluminum reduction process. Specific chemical agents investigated include fluorides in the potrooms, hydrocarbon vapors in the green carbon plant, sulfur dioxide and hydrocarbons in the carbon bake plant, airborne particulates in ore handling operations, and metal dust and fumes in the rodding room.

The report summarizes the results of surveying 12 U. S. plants and 2 Japanese (Sumitomo) facilities. Plants surveyed included prebake and horizontal and vertical Soderberg types. Results of the study indicate that total fluoride levels can be controlled below 2.5 mg/m^3, and that concentrations of coal tar pitch volatiles exceed 0.20 mg/m^3 even in the better controlled green carbon plants. The worker exposure data which was collected at U. S. plants is presented in this report.

CONTENTS

ACKNOWLEDGEMENTS

We especially thank the following primary aluminum companies for their participation in the study: Anaconda Aluminum Company, National Southwire Aluminum Company, Consolidated Aluminum Corporation, Aluminum Company of America, Noranda Aluminum Company, Kaiser Aluminum and Chemical Corporation, Reynolds Metals Company, Eastalco Aluminum Corporation, Martin-Marietta Aluminum Company, and Sumitomo Aluminum Smelting Company, Ltd.

We also thank the following who provided technical comment and greatly assisted in the preparation of this report: Mr. Seymour Epstein, Aluminum Association; Mr. Bonney, Alcoa; Mr. Michael Wright, United Steelworkers of America; and Messrs. Thomas Bloom, James Jones, James Gideon, Walter Haag and Dr. George Carson of NIOSH. We thank Messrs. Clyde Witham and Konrad Semrau of SRI, and Mas Koketsu, Gary Stough and Joel Cohen (formerly SRI) who performed field work for the study. Special thanks to Ruby Watson for typing and editorial comments on this report.

I. INTRODUCTION

BACKGROUND

In 1886, Hall in America and Heroult in France independently discovered an electrolytic reduction process for making aluminum.[1] Today, the same Hall-Heroult process is used by the approximately 31 primary aluminum reduction plants operating in the United States. These plants employ an estimated 30,000 workers. The Hall-Heroult process (whether prebake or Soderberg) is a heavy industrial process and involves the release of various chemicals, some hazardous, into the workplace atmosphere, presenting a potential worker health problem. As a result the aluminum industry is subject to occupational health regulations promulgated by the Occupational Safety and Health Administration (OSHA) as well as by state and local regulatory agencies. Aluminum producers have invested in engineering controls and have attempted to provide needed information for the protection of workers. Nonetheless, in some situations exposures to hazardous chemical agents continue.

Most occupational exposures in aluminum reduction plants occur via inhalation. The major chemical hazards identified include carbon dust, benzene soluble hydrocarbons, sulfur dioxide, fluorides, alumina, and metal dust and fumes. Emissions such as fluorides (gaseous and particulate) and hydrocarbons can be released from reduction cells into the potroom working ares. In the mixing of paste for Soderberg anodes and in the forming of green anodes for prebake pots, hydrocarbon vapors are produced during the heating of coal tar pitch and may escape into the green carbon room air. In the carbon bake plant hydrocarbons and sulfur dioxide can escape from the furnaces during the baking of the anodes. Metal fumes can escape when pouring cast iron in the anode rodding area.

OBJECTIVES

The purpose of this report is to document the effective control technologies for minimizing worker exposure to these potentially toxic chemicals. Control technology is defined as: (1) technical innovations substituting less hazardous process and equipment for more hazardous ones; (2) isolation of workers from hazards by means such as process automation, process and equipment enclosure and ventilation and enclosed filtered air cabs and control rooms; (3) general room ventilation; and (4) work practices.

"Effective" or "good" controls were those observed and judged by the survey team to substantially reduce worker exposure to potentially hazardous substances. In some cases, the control "effectiveness" was determined by comparing workplace environmental concentration with the OSHA permissible exposure limits (PELs).

In addition to engineering controls, the use of personal protective equipment to reduce worker exposure was observed and documented.

The study was performed through surveys of 14 primary aluminum reduction plants: 1- to 5-day surveys at 12 U. S. plants (seven centerwork and two sidework prebake plants, and two horizontal and one vertical Soderberg plant); and walkthrough visits at two Sumitomo primary aluminum reduction plants in Japan (one vertical-stud Soderberg plant and one centerwork-prebake plant). The surveys, all made in 1979, were conducted by 2- or 3-men teams.

This report describes control technology currently used for prebake and Soderberg primary aluminum smelting plants. Discussions cover the effective control technologies found in the following operations: ore handling and storage, green carbon plant, carbon bake plant, anode rodding, and potlines.

This report is not a design manual but describes the best features of the engineering controls. It emphasizes controls of chemical hazards, but does deal briefly with physical conditions as heat and noise. The best controls were not found in any one existing plant but in a number of the plants surveyed.

II. PROCESS DESCRIPTION

The Hall-Heroult process is used today by aluminum companies throughout the world to produce nearly all the primary aluminum. In the process, alumina (Al_2O_3) is dissolved in an electrolyte of molten cryolite with additions of alumina fluoride and calcium fluoride. Electricity is passed through the cell which breaks down the alumina to metallic aluminum and oxygen. The aluminum collects at the bottom of the cell while the oxygen combines with the carbon anode to form CO_2 or a mixture of CO_2 and CO. The anodes consist of either a number of prebaked carbon blocks (e.g., 20) or a single large anode called a Soderberg. The prebake anodes are formed and baked in a separate operation while the Soderberg anode is baked in-situ in the electrolytic cell. The cell bath temperature is approximately 900°C. Molten aluminum in the cell is collected or tapped using suction methods.

The reduction process takes place in an electrolytic cell or pot composed of a rectangular steel tank with an inner lining of carbon blocks or monolithic lining. The linings form the cathode of the cell. A bank of pots is referred to as a potline. Annual production of a newly constructed potline may vary from 60,000 to 100,000 tons of aluminum metal while older plants have rated capacities of 20,000 to 40,000 tons per potline per year.[2,3]

The normal aluminum reduction pot life is 3 to 5 years. During the first few months of use, large quantities of cryolite and in some cases sodium fluoride are absorbed into the carbon lining of the pot. After about 500 days, the linings become nearly saturated and probably have taken in 90 percent of all the cryolite they will absorb. The linings continue to deteriorate, causing the eventual need for replacement. The pots may be relined by installing new refractories and carbon blocks, either in place, or by removing the steel shell and relining the pot outside the potroom.

Besides the potlines most primary reduction plants include anode preparation, alloying, ingot casting, cathode reprocessing including fluoride reclaimation, power rectification, maintenance, and shipping and material handling facilities.

Along with potroom activities, anode preparation is a major production area. An anode is composed of coal tar pitch and calcined petroleum coke. The pitch is either solid crushed coal tar or hot liquid pitch. In prebake operations, coal and pitch are mixed and then hot pressed at about 120°C to form a green pressed bloc (green anode). The size of the prebaked anodes varies from plant to plant. A typical anode is about 3-feet by 2-feet by 2-feet and weighs 500 to 600 pounds; however, newer facilities may have anodes twice this size. The green pressed blocks are sintered at 1,100 to 1,200°C for up to 5 to 7 days in an anode bake plant. Total time for heating, baking, and cooling may be several weeks. Most bake furnaces are sunken pits with interconnecting flues known as ring furnaces. With one exception, all baking furnaces used in U.S. aluminum plants are ring types with open-top pits. Following baking but before installation in the prebake pot, a steel rod is connected to the top of the anode and sealed with molten metal, typically cast iron; this is referred to as the anode rodding operation.

In the potroom, the prebake anode is suspended by its steel rod from a bus bar over the pot; the bus is adjusted downward as the anode is consumed. Anode life varies, but is on the order of three weeks. The anode is consumed until about 10 percent of the carbon remains (the remaining carbon is called the carbon butt) at which time the anode is withdrawn from the pot and replaced. The remaining carbon is removed from the anode steel support and recycled back into the paste plant. (The procedure for removing spent anodes and setting fresh anodes in the pot is carbon changing).

Soderberg plants, because the anode is self-baking while suspended over the electrolytic pot, eliminate the need for forming and pressing the anode mixture; there is no prebaking or rodding of anodes. Instead, the anode mixture or paste is periodically charged to the top of the anode. The baked portion is suspended over the cell at a height that can be regulated by screw jacks. The lower portion of the anode is heated to over 900°C when dipped into the electrolyte. In a large modern Soderberg cell, the anode can be up to 20-feet by 6-feet by 3-feet and weigh up to 30,000 pounds. Replacement of the studs, either vertical or horizontal, is one of the major labor activities in the pot operation.

III. APPLIED CONTROL TECHNOLOGIES

The study assessed control technology currently used for prebake and Soderberg primary aluminum smelting plants. This section describes the effective control technologies found in the following operations: ore handling and storage, green carbon plant, carbon bake plant, anode rodding, and potlines. In Soderberg plants self baking anodes are used which eliminates the need for forming and baking green anode blocks; thus, anode pressing in the green carbon plant and the carbon bake plant in aluminum production are unnecessary.

ORE HANDLING AND STORAGE

Ore handling operations consist of unloading raw materials from ships and barges, dumping railroad cars, and conveying raw materials to storage hoppers. Several of the primary aluminum plants surveyed were applying effective control technology in their ore unloading operations.

The design of the Hartmann unloader (Figure 1) used to unload alumina and coke from barges is highly effective in reducing worker exposures to particulates. It has two vacuum pickup nozzles that can be moved back and forth along the length of a barge or from side to side across its width. The barge itself can also be moved forward along the mooring by means of a winch and a cable connected to it. Near the end of the emptying operation, a crane lowers a Bobcat power shovel into the barge to work the remaining alumina or coke into position for removal by the vacuum pickup nozzle. The Bobcat has an open cab and the operator wears a battery pack airflow mask that continuously supplies air over the wearer's face. An outside contractor performs the final cleaning of the barges. Only about 200 pounds of material is left in the barge after removal by the Hartmann system. It takes approximately two shifts to empty each barge.

At one plant a vacuum-type 200 ton/hour Hartmann unloader is used to remove the alumina and coke from barges. The vacuum unloader is operated from an enclosed building situated on the walkway above the level of the barge. During the survey, however, the operator was working on the walkway outside the building because the height of the river did not allow proper viewing of the operation from inside the enclosure.

At a second aluminum plant, the Hartmann vacuum unloader is operated from an enclosed air-conditioned cab situated overhead. At this plant the Bobcat power shovel used to push the alumina or coke material to the suction pipe is equipped with an enclosed air-conditioned cab.

Several conveyor systems for transferring raw materials from the harbor facility to storage silos are designed to be highly effective in preventing the escape of dust and loss of material. One belt conveyor recently constructed to carry ore from the barge unloading system at the river to the main storage silos is of superior design. Alumina ore is unloaded from the barge into a holding bin from which it is moved by belt conveyor to the main storage silos that supply the reduction plant. The point at which the ore is transferred from the holding bin to the conveyor belt is hooded and ventilated by an exhaust system fitted with a Mikropul pulse-jet fabric filter. The main storage

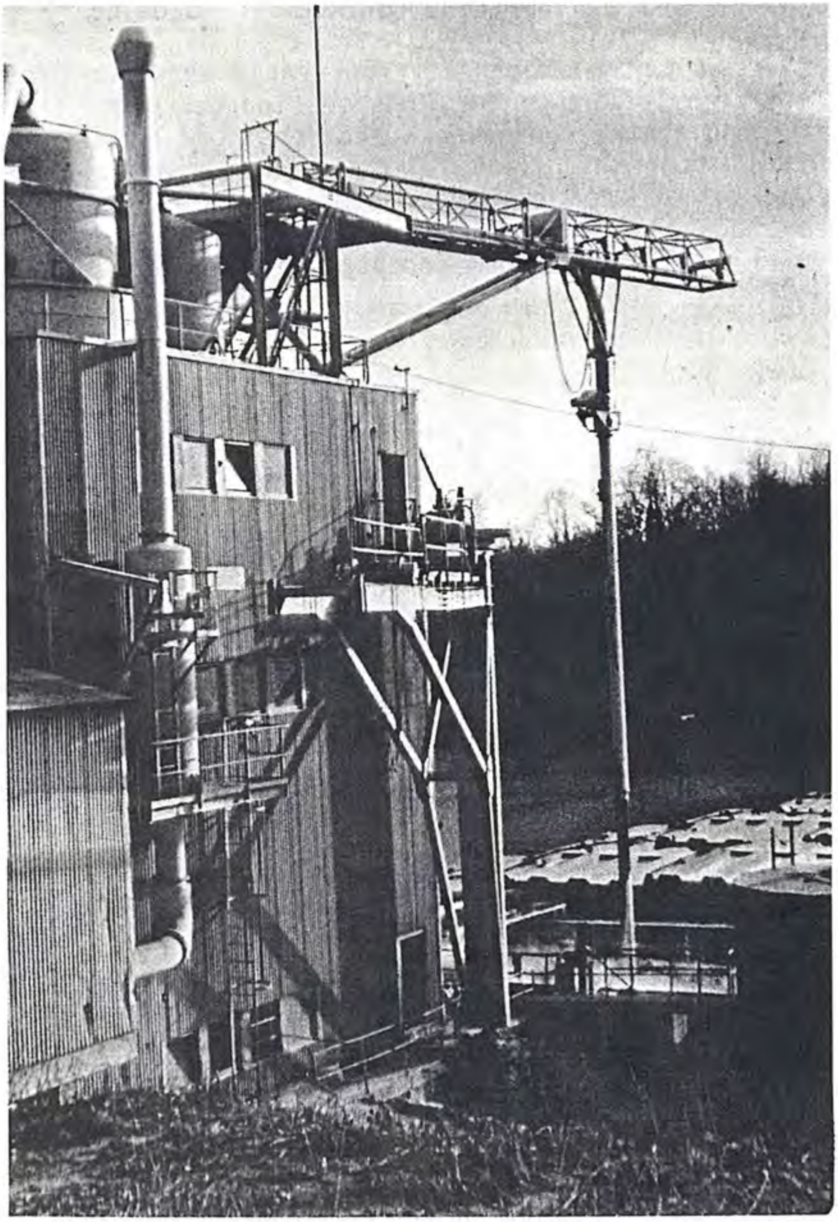


Figure 1. The Hartmann Pneumatic Unloader removes alumina from barges at the harbor facility and transports it to storage hoppers a short distance away.

silos are much higher than the river bank, and the conveyor is supported by a trestle. The conveyor belt, shown in Figure 2, is fully enclosed by an essentially monolithic cylindrical housing that provides mechanical support, but prevents ore loss by spills or blowing wind, and protects the ore from the weather. The housing has a vacuum system to collect spilled ore.

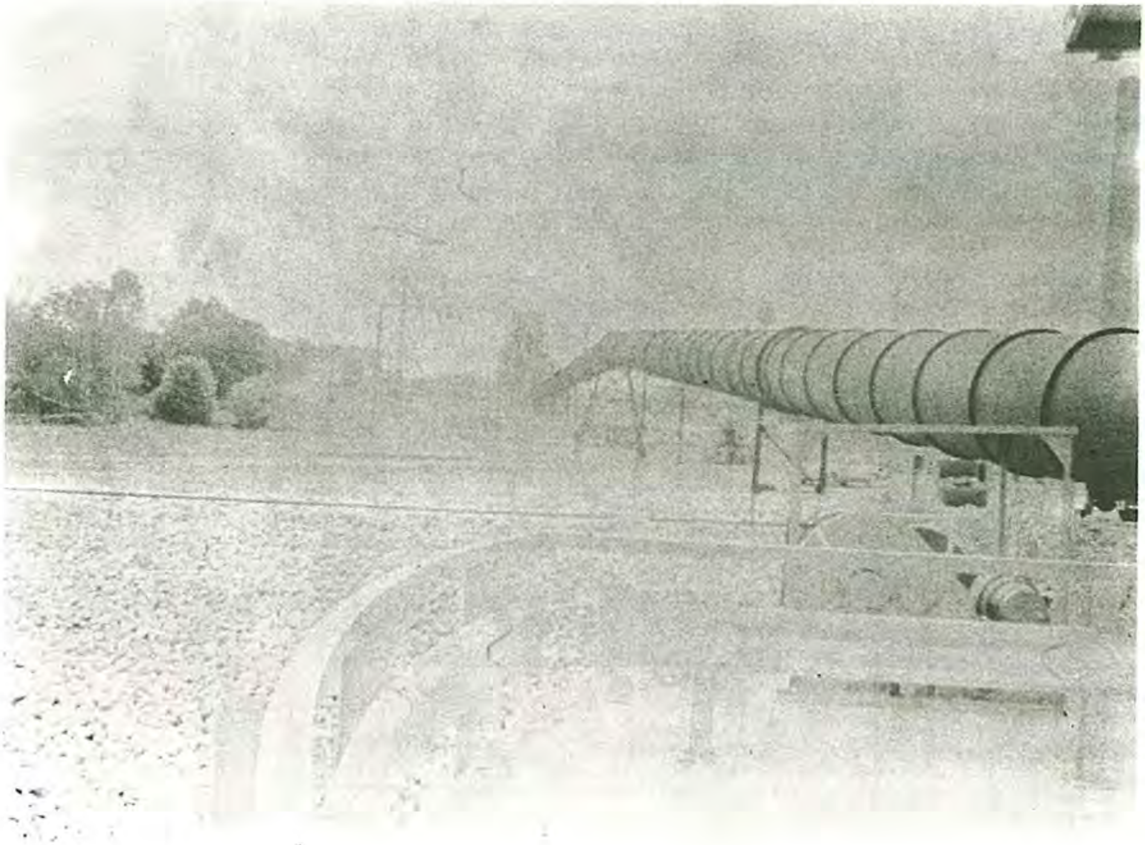
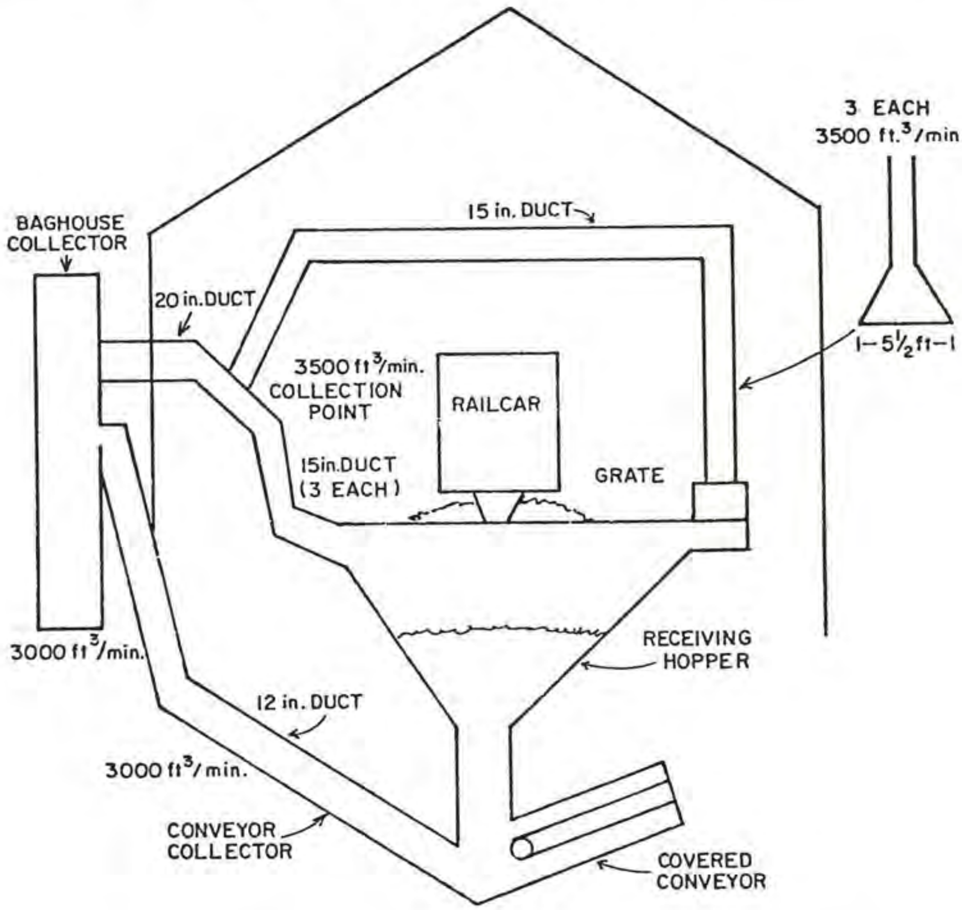


Figure 2. Enclosed conveyor system for transporting alumina.

At another plant a covered conveyor system transfers material from the ore unloading station to the alumina and coke storage tanks. The system appears to be effective and well maintained. After the coke and alumina are unloaded, they are stored in reservoir tanks, from which they are gravity-fed (at a metered rate) to a conveyor belt. Continual process weighing scales meter the flow. Air is exhausted to small shaker-type baghouses at all conveyor transfer points, including the station where ore is loaded onto the conveyor, to reduce atmospheric emissions.

An effective control technique for reducing dusting and exposure problems during coke unloading operations was observed at the Sumitomo plant in Toyama, Japan. The coke is unloaded by a crane with a clamshell bucket; however, the coke is treated with a fine spray of light oil before it is loaded onto the ship, which decreases subsequent dusting.

At some plants, coke is delivered by rail. A railcar dumping building is provided at one plant. Although such a setup was not observed in operation, it appears to be an excellent method of eliminating emissions during the unloading of coke received by rail. Figure 3 illustrates this system which was apparently designed and built by Kaiser engineers. Unloading is essentially automatic; operations are monitored from a control panel inside the building. Coke is emptied from the hopper car through a grate into a separate hopper that feeds a covered, exhausted conveyor that transports the coke to storage silos. The angle of repose of the coke on the receiving grate reportedly provides an effective seal against dust generation within the building.



Note: Building ventilation by full-width doors.

Figure 3. This is a diagram of a railcar dumping station, which helps to eliminate emissions during the unloading of coke received by rail.

The building housing, shown in Figure 4, the system is 20-feet by 40-feet by 20-feet-high and a portion of the ductwork inside is shown in Figure 5. Dust-laden air is exhausted from the collection hopper and from the covered conveyor into a Mikropul baghouse collector at a rate of 24,000 ft^3/min. There are a total of seven collection points. Although the station was not seen in operation, it appears to provide adequate suppression of emissions.

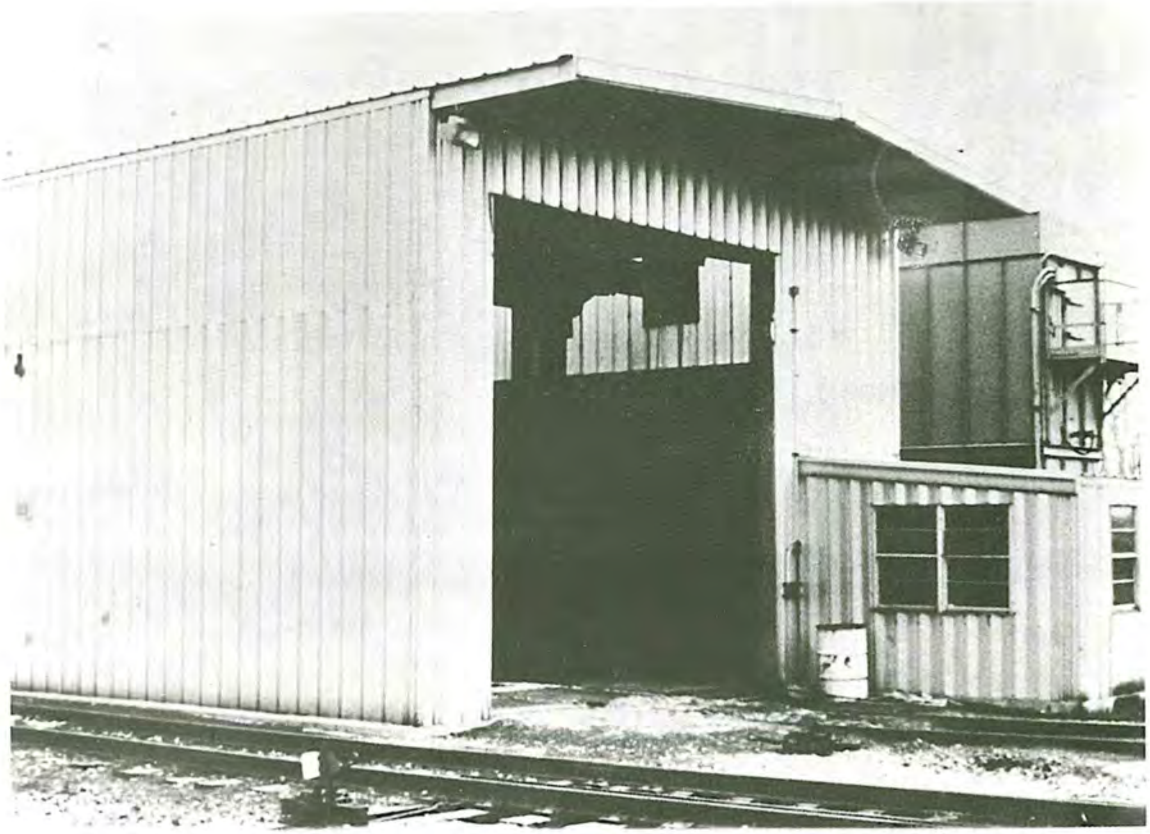


Figure 4. Railcar dumping building.

At one plant the study team observed control technology for reducing working exposure during green pitch unloading operations. Liquid pitch in a heated tank car is pumped through a closed piping system to storage tanks. The unloading operation is performed outside and the worker exposure is limited to the time needed to secure the unloading lines.

The survey team did see personnel using respirators in ore unloading operations. At one plant, the Bobcat operator wore a powered air purifying helmet. This respirator provides a curtain of filtered air in the wearer's breathing zone and appears to reduce the dust exposure experienced by the operator.

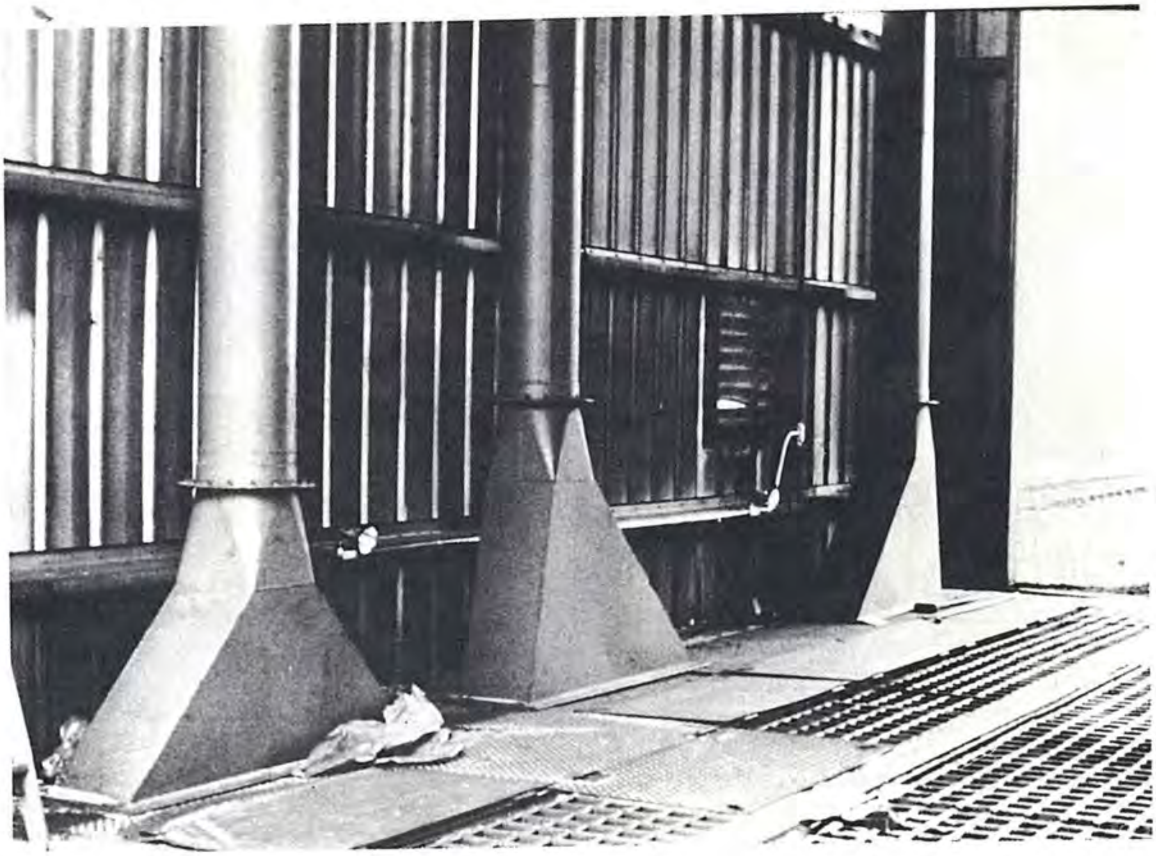


Figure 5. Ductwork railcar dumping building.

GREEN CARBON PLANT

Green carbon plant operations consist of mixing coal and pitch and hotpressing the mixture together to form green anode blocks.

Control technology observed in green carbon plants (green mills) includes process automation, enclosure and ventilation, and enclosed filtered air control rooms. In several plants the green mills are almost completely automated, and there is little need for workers to be in the production area.

At one plant the operator is able to control the process equipment in the green mill from inside an enclosed and ventilated control room. The processes are monitored by observing the operations on a control board. Only the batch mixers are not fully automated. One operator must spend approximately half his time in the mixer area, where he wears a dust and mist respirator. Automated process equipment in the plant includes an air-swept ball mill, where fresh coke and crushed butt material are ground further and classified; a pneumatic conveyor with exhaust ventilation, which routes coke through the grinding system; and vibratory feeders, which discharge materials from silos. The paste formed by mixing coke and pitch is conveyed on enclosed belts and in screw conveyors to bins in the anode press building. In this building the paste is automatically dropped onto a hydraulic press, where the anode is formed. One operator runs the anode press, and normally works in a control booth that is ventilated with filtered air. Flashing on the freshly formed anode is removed by chain dragging.

At a second plant, the study team observed a totally automated mixer system that requires no operating personnel other than maintenance workers. Pre-weighed hardened pitch and sized coke are charged to one of nine batch mixers. Paste materials are charged cold, and then heated and mixed for approximately 45 minutes. At the end of the mix cycle, the anode mix is dumped through a pneumatically operated door to a covered conveyor belt. The steel cover over the pneumatic equipment very effectively contains emissions during mixer discharging. Two area samples taken on the mixer deck showed benzene soluble hydrocarbon levels averaging 0.02 mg/m^3. Figure 6 is a schematic of the enclosure of the pneumatic equipment at the mixer discharge point. One drawback to the enclosure is that the automatic mixer door is bolted on, and it is relatively difficult to replace following maintenance of the mixer. As a result, the door is not always replaced during normal operations. The door should be redesigned to make replacement easier. As a safeguard, an interlock could be installed so that the door would have to be in place for the mixer to operate. After it is discharged from the mixer, the anode mix is transported on a covered conveyor belt to the anode vibratory press room. Dust-laden air is exhausted from the conveyor at a rate of 15,000 ft^3/min.

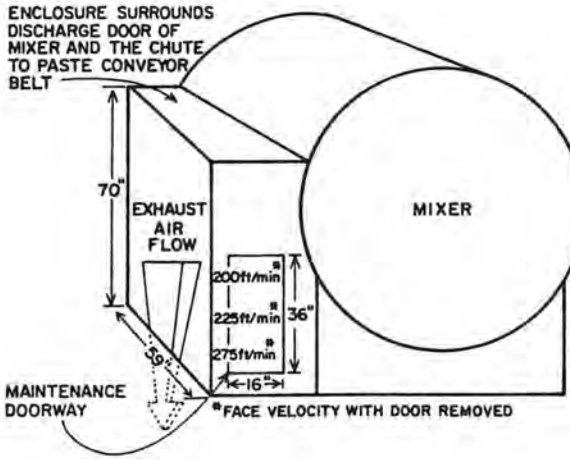


Figure 6. This steel cover (depicted schematically) effectively reduces emissions in the area of the mixer during discharging operations.

At another plant, the green carbon plant is almost completely automated and is monitored from a central control room. The control room is enclosed, heated, and air-conditioned, but is not under positive pressure. Coke is reduced in size in a primary crusher and ground in a ball mill. The ground coke is sized by screening and air classification and stored in hoppers for future use. Pitch, ground coke, and crushed butts are fed to electrical scales and then to one of three mixers. The mixer system is totally automated and is monitored from the control room only. The mixer operator exposure (one sample) to benzene soluble hydrocarbons was 0.16 mg/m^3. The aggregate batch is preheated for 9 minutes. During both coke and pitch charging, dust-laden air is exhausted from the mixer. The mixers have bottom dump doors that are self-cleaning, and no operator need be present when the mix is discharged to a covered conveyor. A portion of the mix is routed to a vibrator press that produces large anodes at a rate of 60 per hour. The overhead covered conveyor feeds the anode mix into a filling hopper that moves laterally to feed measured amounts of mix into one of three stationary hoppers situated above the vibrator table, then on to the next stationary hopper and the next. The press molds are sprayed with water-soluble lubricant and then filled with mix from the stationary hoppers. After the mold is filled, a tamper drops down to cover its surface and the mold is vibrated to form an anode. An area sample taken at the vibrator press deck showed benzene soluble hydrocarbon levels of 0.42 mg/m^3.

Ventilation systems at several green carbon plants appeared to reduce emissions significantly. At one plant, covers and exhaust ports over all the conveyors are used to reduce emissions of coke dust. Coke and pitch are transported by screw conveyors, drag chains, bucket elevators, and belt conveyors, all of which are covered. Transfer points are exhausted to a single electrostatic precipitator. (Figure 7 shows an example of an exhaust duct from a screw conveyor.)

Each 40-foot-long screw conveyor usually has 4- or 6-inch-diameter exhaust ducts at 20-foot intervals. The screw conveyors are exhausted at a rate of approximately 200 ft^3/min per takeoff. Screens are exhausted at a rate of 400 ft^3/min per unit. All of the covers, ventilation ducts, and exhaust systems appeared to be well maintained, and the general area was relatively clean.

Extensive enclosures and local exhaust ventilation were observed at another green carbon mill, which was quite clean although the general housekeeping could be improved. This mill has seven separate exhaust systems for coke crushing, butt conveying, storage filling, storage discharge, blending and heating the mix, ball mill classifying, and intermediate classifying. Each classifying system is served by a small unit dust collector. Design exhaust velocities for all the various screens, screw conveyors, and impactors are 3600 ft/min, which should be adequate to prevent dust from settling in the ducts. Most of the screens and screw conveyors are exhausted at a rate of 300 ft^3/min, and impactors and grinders are exhausted at 2500 to 3200 ft^3/min. The paste mixers have a forced-air exhaust of 1000 ft^3/min at 2 inches static pressure. A covered conveyor, that conveys paste mix to the anode press has four takeoffs, although only two are in operation at any given time (one at the mixer and one at the end of the conveyor).

In another green carbon plant, the study team found a ventilated mixer hood designed to remove emissions during the discharge of anode paste from the mixer. Air is exhausted from the hood only when the mixer is being dumped.

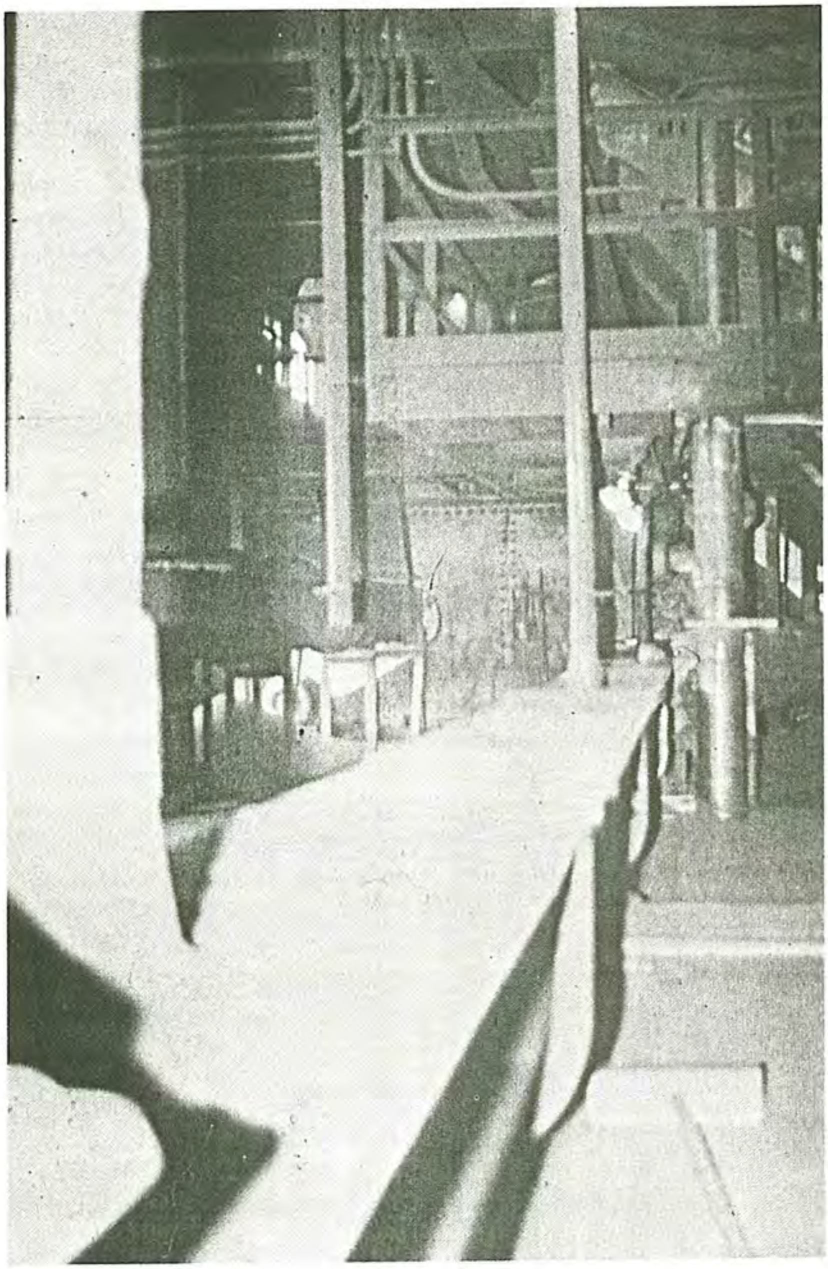


Figure 7. Exhaust duct from a screw conveyor.

During mixing (when not dumping), the 4-1/2-square-inch blast gate is closed by a solenoid to increase draft in other areas of the building. Each of the eight mixers is hooded, and draft is supplied by two fans that provide air for the dust collection system for the entire building. Figure 8 is a schematic drawing of the paste collection bin and mixer hood. The hoods are exhausted to a dropout chamber and then to the atmosphere. Face velocities at the hood opening, as measured by the survey team, ranged from 50 to 400 ft/min. The mixer door opens downward, allowing a direct exhaust air path from the point of emission to the hood. The mixer operator in this green mill had total particulate exposure of 3.5 mg/m^3 and a benzene soluble hydrocarbon exposure of 0.38 mg/m^3.

At one plant the vibrator forming machine (anode press) is equipped with a fume collection system that ventilates the anode press at approximately 650 m^3/min. The anode press operator monitors the press operation from a partially enclosed plexiglass booth.

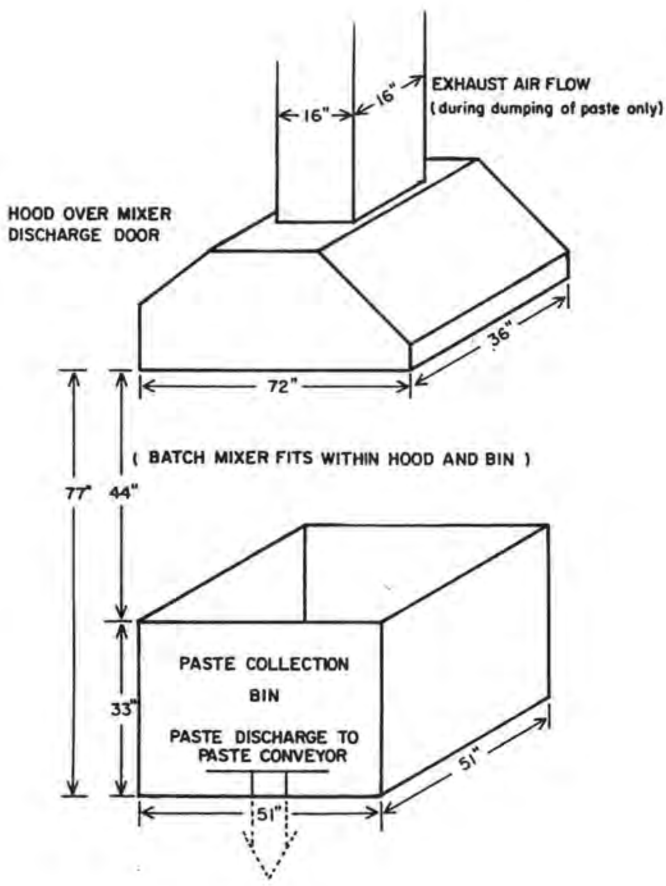


Figure 8. A schematic drawing of a paste collection bin and a ventilated mixer hood, which removes emissions during the discharge of anode paste from the mixer.

CARBON BAKE PLANT

In the carbon bake plant, the green anode blocks formed in the green carbon plant are sintered for up to 5 to 7 days at 1000^o to 1200^{o}C. The principal hazardous chemicals to which workers in carbon bake plants may potentially be exposed are sulfur dioxide, hydrocarbon vapors, carbon dust, and sometimes fluorides (in operations where anode butt scraps are reclaimed for use in new anodes). The carbon bake plants surveyed in the United States use the open-type ring furnace; the prebake plant visited in Japan uses the closed-type ring furnace.

The NKM (Ned.Kraanbouw Mij) multipurpose crane, which is used at a plant with the open-type ring furnace, is one of the most effective controls for reducing dust levels in the working area. Working in an enclosed cab the crane operator is protected from significant exposures while the crane is placing anode blocks in the furnace pits, covering the anodes with coke, removing the packing material and taking out the baked anodes. The enclosed cab is supplied with filtered and conditioned air. Area samples taken inside the NKM crane cab showed total particulate levels of 0.9 mg/m^3 compared to 6.3 mg/m^3 outside the cab. Total fluoride levels were 0.2 mg/m^3 inside the cab and 0.5 mg/m^3 outside. The NKM crane performs the entire operation; however, a furnace operator and several utility men work in the bake plant building and occasionally may be exposed. The crane (shown in Figures 9 and 10) can vacuum the coke, separate the fines from the coarse material, and keep dust formation at a minimum. The fine granular coke (petroleum coke) used to fill the pits and cover the anodes is supplied from a charging bin carried on the crane itself. The coke is discharged into the pit from a spout directed by the crane operator. The crane is also equipped with a vacuum system, which is used to aspirate the coke from the pits when the bake anodes are removed. Air and coke, drawn from the pit through a two-sectional telescopic pipe, enter a cyclone separator mounted on the crane, where the coarse coke is removed and returned to the crane charging bin for reuse. (The suction pipe is designed to operate between 70 and 250 mm Hg suction.) The fine dust is collected by a fabric filter (also mounted on the crane) and is recycled to the green carbon plant for use in forming anodes. Removal of the fines minimizes the amount of airborne dust that would result if the material were reused to fill the pits. The crane also contains an anode tong capable of carrying as many as eight anodes per pass. The NKM crane, which weighs 80 tons, requires durable steel structures and building founda- tions. (Most plants use smaller cranes, weighing 10 to 15 tons.)

Three area samples taken on the floor of the carbon plant showed an average total particulate level of 0.4 mg/m^3. The ventilation system in a well-controlled carbon bake plant (with open-type ring furnaces) keeps the flues of the furnaces under sufficient draft to prevent most of the fumes formed during anode baking from escaping into the room atmosphere. Hydrocarbon vapors evolving from the baking of the anodes are drawn through the porous mass of coke and through unsealed interstices in the refractory pit walls into the furnace gas flues, where most of the vapors are burned. The flue gases are discharged either directly to the atmosphere through stacks or first to scrubbers and then to the stacks. The ventilation system also includes a roof

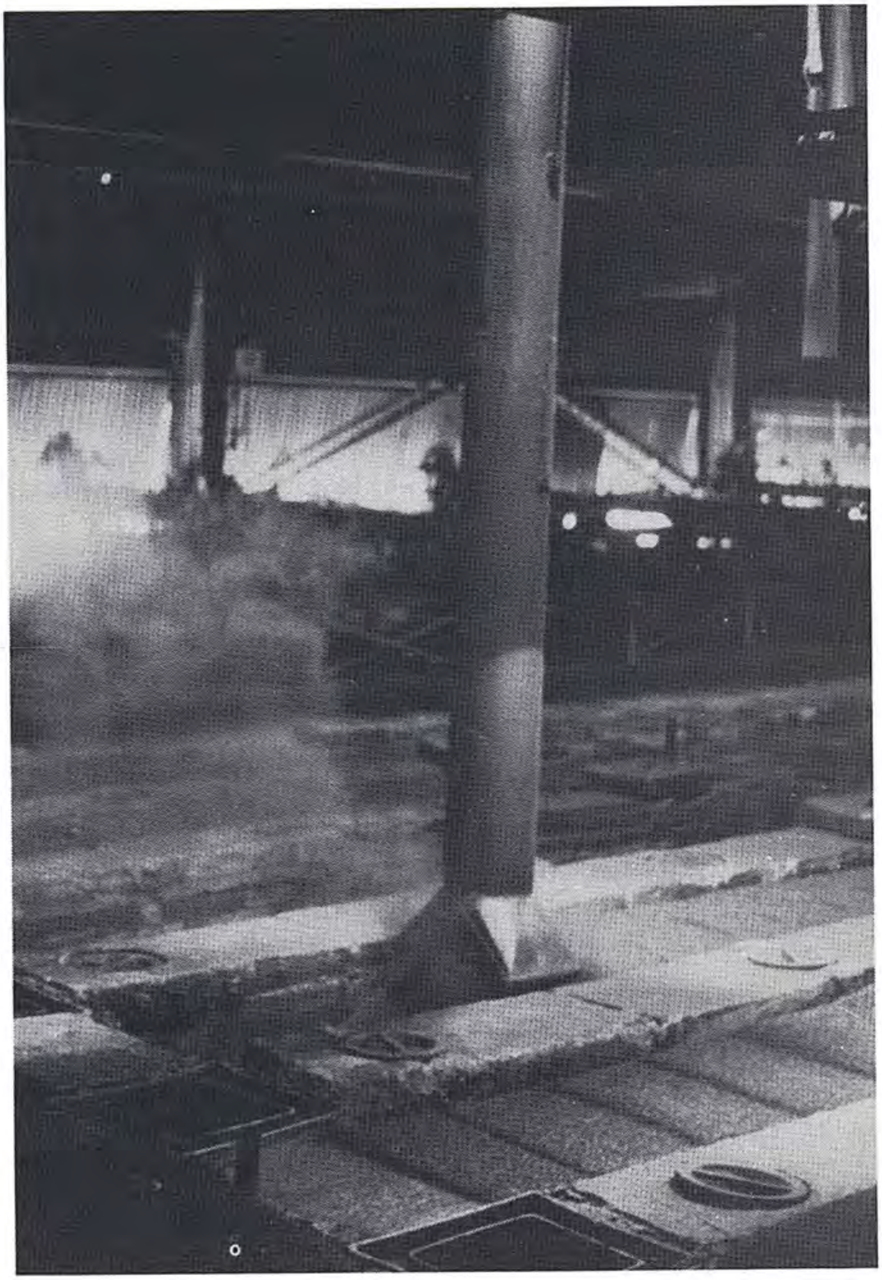


Figure 9. The NKM multipurpose crane can vacuum the coke, separate the fines, and keep dust formation at a minimum.

monitor operating under natural draft. The side doors on the building could be raised to allow direct entry of fresh air for ventilation and cooling.

The carbon bake plant operations at the prebake plant visited in Japan are highly automated. Two large NKM-design multipurpose cranes with a carrying capacity of 30 metric tons (megagrams) are used to perform most functions within the building. The green anode blocks are placed into the baking chamber of the closed-type ring furnace. The crane operator adds coke between each block

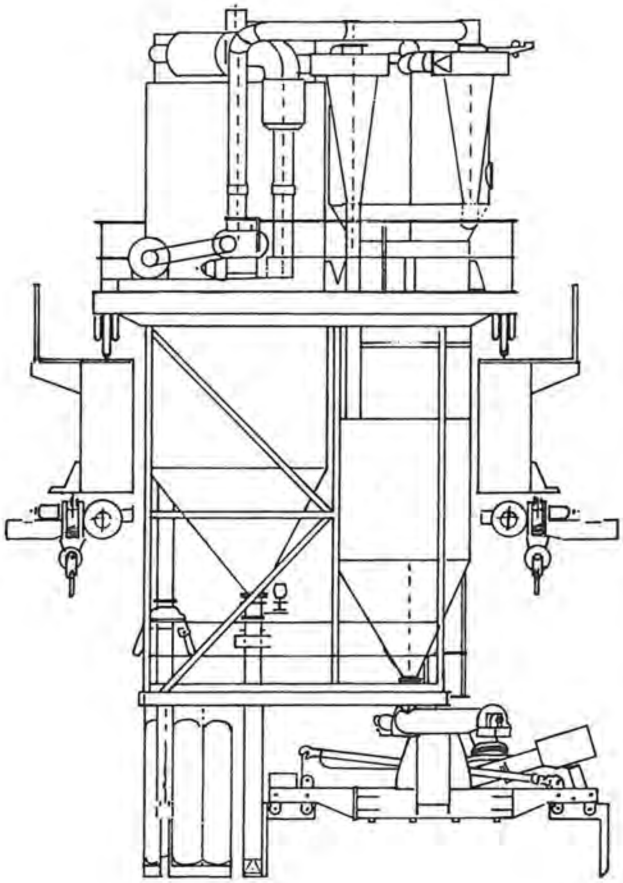


Figure 10. The NKM multipurpose crane is equipped with a spoutvacuum system, cyclone separator, fabric filter, and an anode tong.

and between each layer to prevent the blocks from baking together or from baking to the walls of the furnace and to provide passages for gas to escape. The coke is added through a delivery chute on the crane. The crane is also used to move the firing manifolds and the waste gas exhaust manifolds, and to move and position the 25-metric ton (megagram) cover for the firing sections. After the cooling cycle, the coke packing material is vacuumed and then the anodes are unloaded from the chambers by lifting out the anode blocks.

The crane operator performs these tasks from within an enclosed cab provided with filtered and conditioned air. Located above the work area, the operator in the cab is protected from heat, dust, and hydrocarbon vapors that may be present in the bake plant atmosphere.

During the baking of the anodes, a large cover lined with insulating bricks on a steel frame is lowered over the firing section. This cover reduces the emission of hydrocarbon vapors into the bake plant and also aids in the uniform baking of the anodes. Following the firing cycle, the covers are removed and the anodes are slowly cooled for approximately one week. The baked anode blocks are then removed.

ANODE RODDING

Anode rodding in prebake plants consists of reconditioning spent rods used in the prebake pot. Rods are brought into the department and manually hung on an overhead conveyor belt. They then pass through the rod straightener, spent butt remover, butt crusher, cast iron thimble remover, and shot cleaner. A graphite release agent is applied, the rods are mated with an anode, and cast iron is poured into the anode stub hole to form a thimble. (Figure 11 shows the operator pouring the cast iron thimble.) The anodes are then moved to the potroom for use as needed. The butt crusher, chipper, and combination press operators may be exposed to dusts and fluorides from the spent butts. Operators who pour the cast iron into the anode may be exposed to iron oxide fumes.

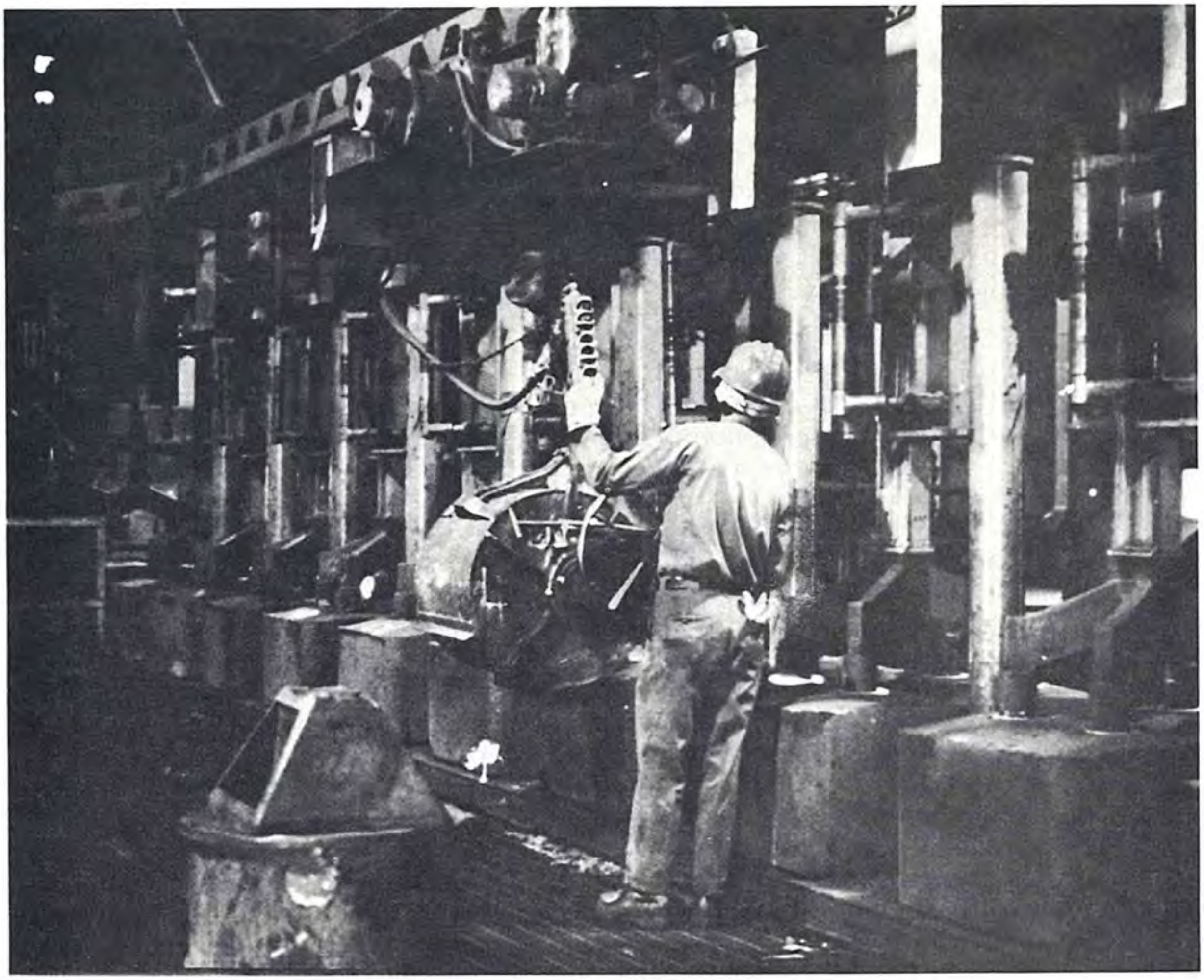


Figure 11. Thimble casting operation - rodding room.

Operations in the anode rodding room of one surveyed plant were highly automated and relatively noisy. Spent anode butts brought from the potroom are placed on an overhead free-sliding conveyor designed to carry the rods with the butts still attached. Rods are straightened in two dimensions by a hydraulic press and conveyed to a Pangborn Rotoblast Cleaner. Steel shot is used in the cleaner for final cleaning of the butts. Butts and cast iron thimbles are removed in a Nash butt breaker that requires only one operator. The butt is pressed off by a hydraulic piston from the bottom and two opposing stationary jaws from the top.

Butts and thimbles are crushed to fist size in an impactor that is fed by an underground covered conveyor from the butt remover. Thimbles are removed magnetically. The covered conveyor and the impactor are exhausted to a bag filter dust collector located outside of the building. Stubs are cleaned in a rotoblast cleaner using shot, and inspected. Stubs that require repair are sawed off with a tungsten blade and new stubs are welded onto the rod in a semi-automatic MIG welding station. At the time of the survey, the welding station was hooded but the hood was not being used.

After final cleaning and before attachment to the anodes by cast iron, rods are dipped into a bin of graphite. In attaching the rod to the anode one operator pours the molten iron into the anode stub hole. A sample taken on the pour operator showed a total particulate concentration of 2.2 mg/m^3 and an iron (as Fe) concentration of 0.12 mg/m^3. Iron for the anode rod assemblies is melted (normally there are 11 melts per day) in one of three Lectromelt induction furnaces. The survey team found that the Lectromelt electrical induction furnace (manufactured by the Lectromelt Furnace Corporation, Pittsburgh, PA), and the associated hooding provided an effective method of reducing metal fume and associated gaseous emissions from the working area. Two area samples taken next to the Lectromelt furnaces showed average total particulate levels of 1.5 mg/m^3 and average iron (as Fe) levels of 0.07 mg/m^3. The furnace is similar in design to much larger units used in the steel industry. Electrodes are essentially allowed to float on top of the molten metal and supply current for melting the iron charge. The entire furnace decouples from the stationary exhaust hood and tilts 45^o for pouring molten metal. Alloying, slagging, and any other operations are conducted through the pour spout of the furnace.

There are two hoods on each Lectromelt furnace, one surrounding the immersed electrodes, and one over the slagging/pouring spout. The design airflow for each furnace is 9,000 acfm (66^oC). Measurements made during the survey indicate a 400 fpm face velocity at the pour spout hood and approximately 1,000 fpm at the electrode hood. Visually, it was apparent that the electrode hood did very well, but that the pour spout hood was not too effective. The probable reason for this poor performance was that the break point in the exhaust duct (where the duct comes apart during pouring of molten metal) had no effective seal; there was a significant in-leakage that reduced airflow upstream. The furnace hoods for all three furnaces are exhausted to a bag filter. The bag filter exhausts to a 31-inch-diameter, 60-foot stack.

A schematic drawing of the furnace hood is given in Figure 12A and 12B.

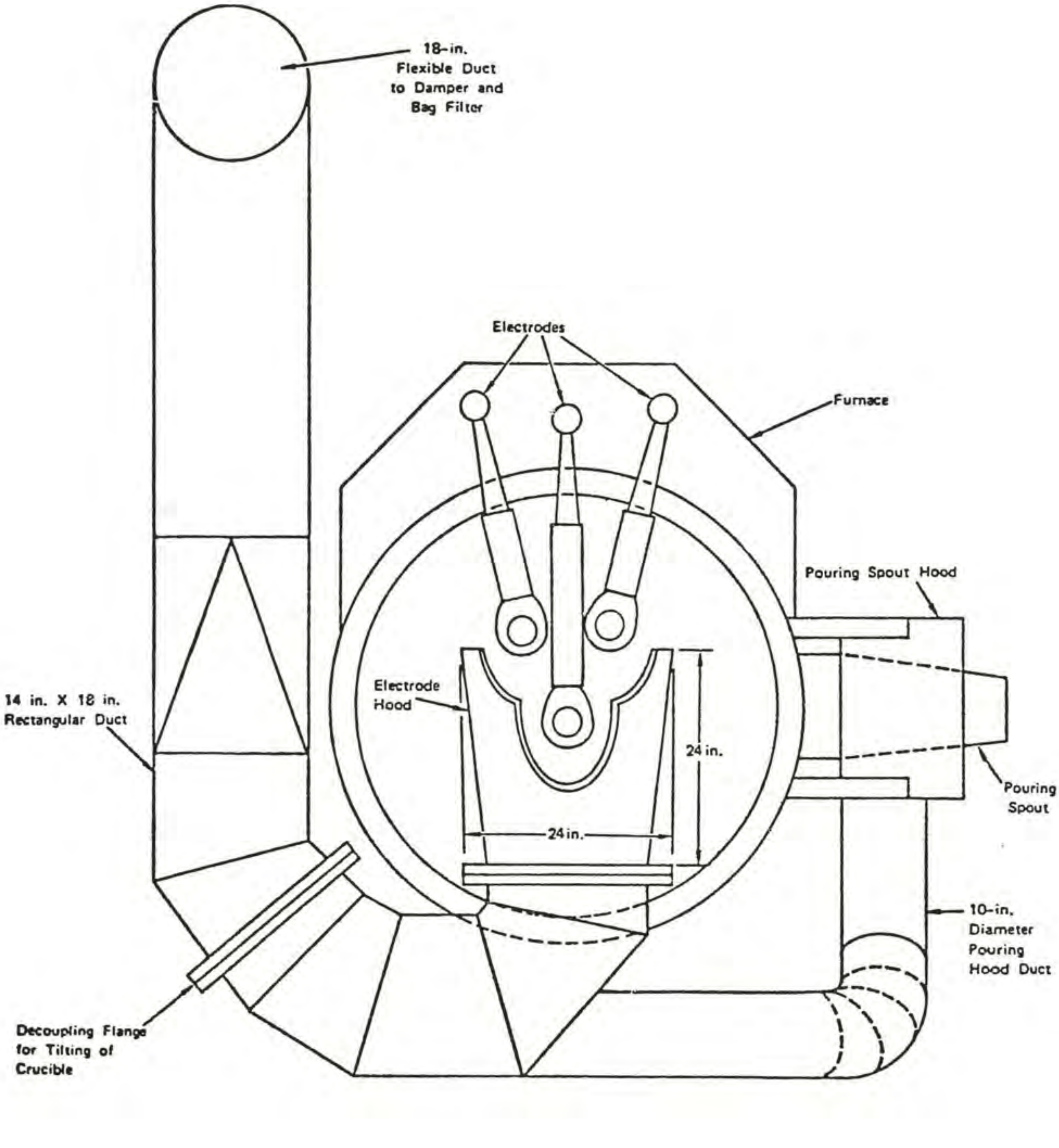


Figure 12A. Lectromelt hooding: side view.

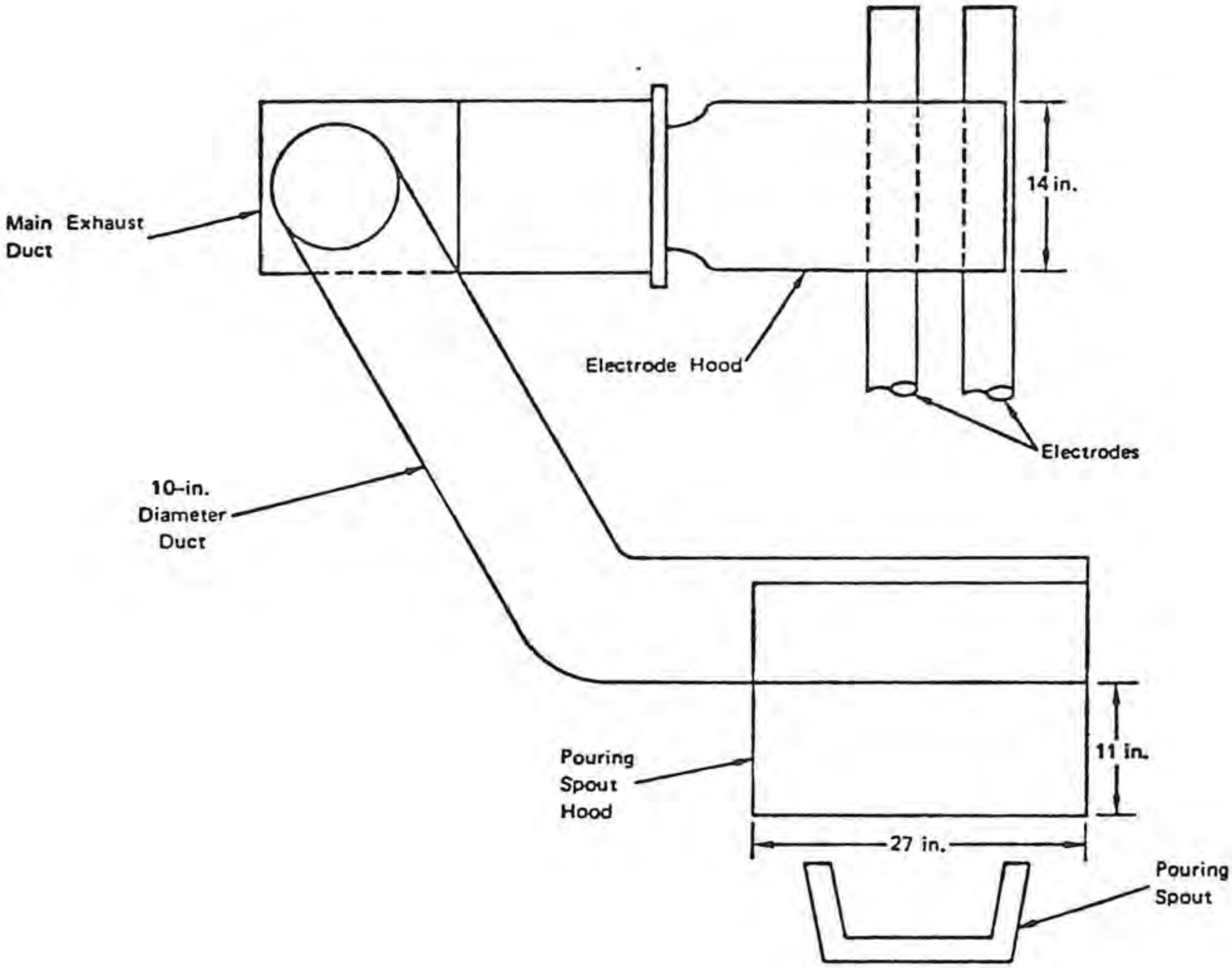


Figure 12B. Lectromelt hooding: top view.

As can be seen from the figure, the electrode hood is approximately 14-inches by 24-inches. The pour spout hood is approximately 15-inches by 27-inches. The pour spout hood duct is 10-inches in diameter and the electrode hood duct is a 14-inch by 18-inch rectangle. The main rectangular duct is connected to a flexible 18-inch-diameter hose with a butterfly valve for damper control. A flexible duct, able to withstand the high temperatures of the furnace, would allow the hood to remain in place and fully operational during pouring of hot metal.

The approximate cost of the hooding system was $100,000 (1976 dollars) each for three furnaces.

In a second primary aluminum plant anode rods enter the rodding room on an overhead conveyor where they are prepared for the attachment of fresh anodes by going through a rod straightener, a thimble removal press, 10-foot-long graphite stub immersion station, and a radiative electric heater for stub drying. Concurrently, the anodes enter the rodding room on a conveyor and move to a station where they are cleaned by compressed air. Following this point, the anode rod and the anode blocks come together, and molten cast iron is poured, anchoring the blocks to the rod assembly.

Iron for the anode-rod assemblies is melted in three Lectromelt induction furnaces. The furnaces are exhausted through movable hoods that vent to a baghouse outside the building. The hood arrangement on the induction furnaces appeared to effectively reduce emissions in the workplace. A personal sample taken on the furnace operator showed iron (as Fe) concentrations of 0.18 mg/m^3. An area sample at the Lectromelt furnace showed iron (as Fe) concentration of 0.13 mg/m^3. Thimbles melted in the furnaces are not precleaned, and the hopper where the metal pieces are collected for melting is hooded. This hopper is subsequently used to charge the induction furnaces.

The crucible holding the molten iron received from the furnace is suspended from a small radio-operated crane. The cast iron pouring crucible is suspended from a track so that the crucible can be moved to follow the anode, which is on a moving assembly line. After a cast iron thimble has been poured the crucible is pushed forward to begin pouring a new thimble. The pour station is operated by two workers, one pours cast iron and the other standing behind a heat shield guides the rods into anodes. The pour station is equipped with a slotted exhaust hood shown in Figure 13 that extends the length of travel of the pouring crucible. The slot exhaust hood appeared to provide excellent control of the metal fume from the work station. A sample on the thimble pour operator showed an iron (Fe) concentration of 0.16 mg/m^3. The slot hood is 4-foot 1-1/2-inches long, within a rectangular slot 4-foot 3-inches long. Two splitter vanes in the triangularly-shaped duct adaptor direct air into a 14-inch duct. A screen tack welded to the slot opening prevents large objects from entering the hood. The hood is situated just above and behind the moving anodes.

Control technologies found in the rodding room of a third aluminum plant included an automatic welding system for anode stem repairs, and mechanical ramming for setting anode stems. Repairs to the stems generally entail welding of new steel stubs onto the cleaned stem. The stems are two-pronged aluminum and steel assemblies. the stub-welding station has an exhaust system for removal of the welding fume. The hood itself sits immediately behind the welding machine, drawing air away from the working zone (at about 1,500 fpm face velocity). The rectangular exhaust port is supplied by its own fan and is about 9-inches by 30-inches. The welding is performed with one of two automatic welders at the same station. This arrangement allows the worker to be setting up one stem for welding, while the other is being automatically welded behind a curtained-off area.

The (anode rod) stem is inserted into preformed recesses in the fresh carbon anode and a strong connection is formed by ramming a granular mixture of 11 percent pitch and carbon into the narrow space between the stem and the inside wall of the recess in the carbon anode. The machine for anode ramming is shown in Figure 14. To prevent contact between molten cryolite and the steel portion of the stem, an aluminum collar is fastened around the stem just above

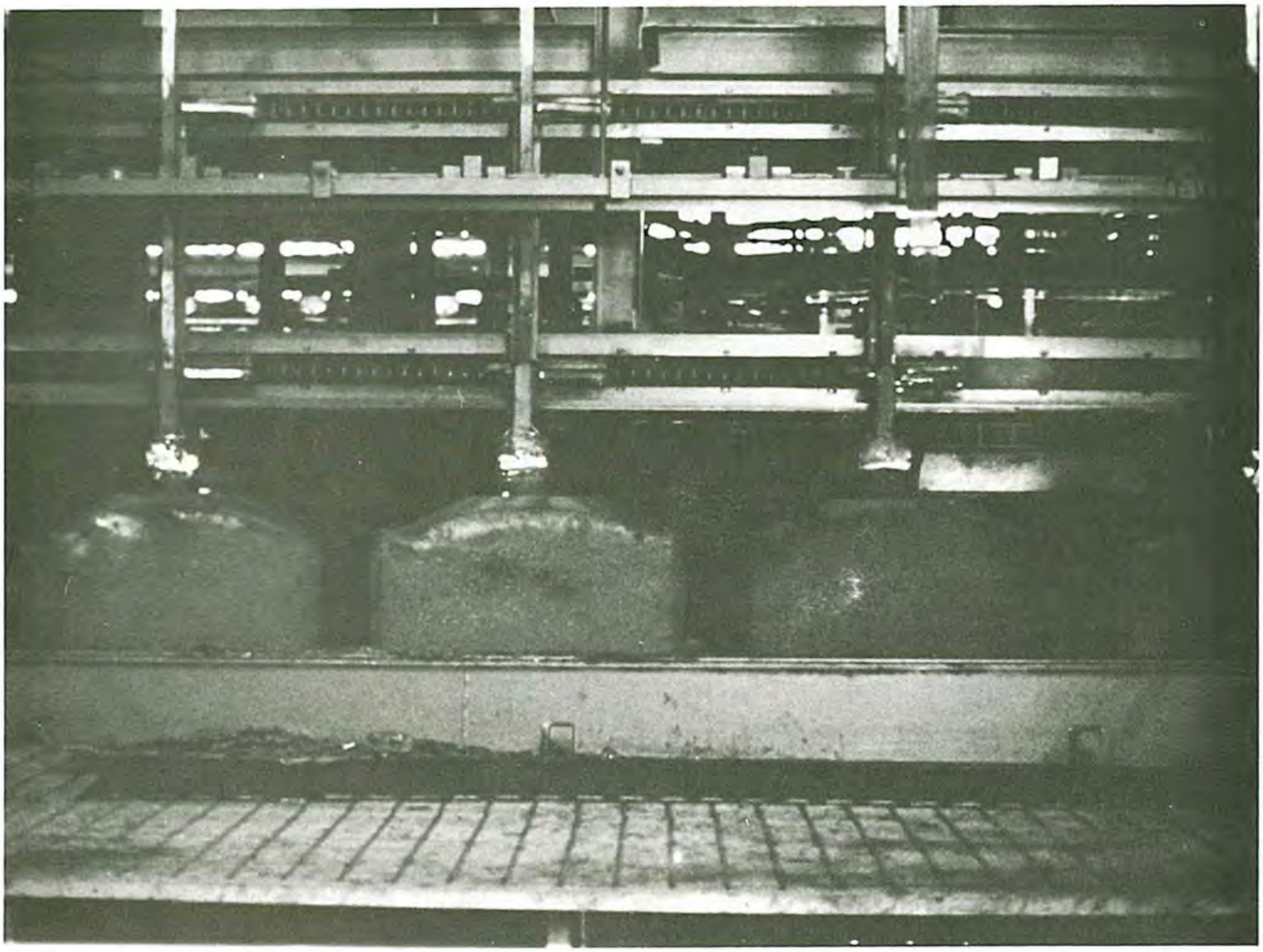


Figure 13. Anode thimble pouring station showing a slot exhaust hood.

the anode and filled with a granular mixture of 30 to 35 percent pitch and carbon. The anode with its attached stem and collar then passes under the gas burners that heat the mixture in the collar sufficiently for the pitch to soften or melt (about 1 minute) and form a crust over the surface of the pitch/carbon mixture. During this heating process, some pitch fumes are emitted, but no exhaust system is provided to collect these fumes and keep them from spreading through the working area.

An effective control technology in the rodding room of a fourth plant was an aluminum spraying machine which uses air pressure to coat anode blocks with molten aluminum.

At this plant anode blocks are received from the bake plant and are fitted with an anode assembly and sprayed with an aluminum coating, preparing them for use in the reduction cells. When the anode assemblies are returned from the potrooms, they are cleaned, straightened, and attached by a bolt and nut

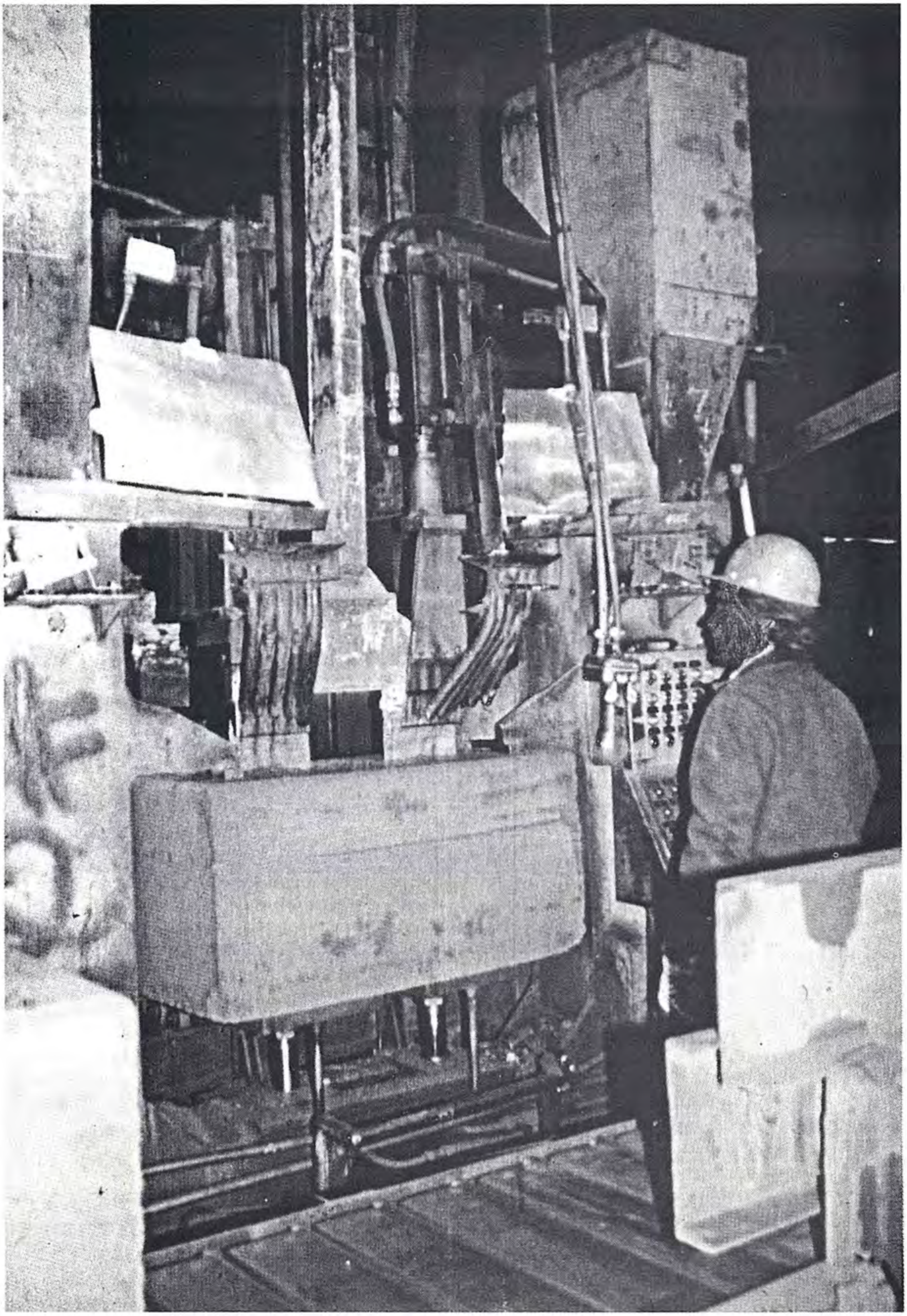


Figure 14. Anode ramming.

to a stub anchored in the anode block. The workers in this area are required to handle the anode blocks, contact bars and stubs, pour the anchoring thimbles, and perform some highly physical work.

Rodding room personnel include the following: carbon cleaner, removes the cast iron thimble from the anode stub; reconditioner, disassembles the anode assembly; rodder, positions fresh anode bar and bolts to anode stub; metal pourer, pours anchor holding stub into anode block; mobile equipment operator, operates tractor and two motors; spray station attendant, operates the aluminizing spray machines; electric furnace operator, operates the induction furnaces; anode laborer, performs general duties in the rodding room.

An operation which provides an example of good engineering technology was the aluminum spraying of the anode blocks. This operation was performed by the spray station personnel from a position away from the spraying line and appeared to eliminate much of the aluminum dust and fume exposures as well as the possibility of burns from the molten aluminum.

Molten aluminum is brought in from the holding furnace located in the ingot plant to two warming furnaces in the rodding room. The warming furnaces are fired by two natural gas burners. Molten aluminum flows from the warming furnace through a runner feeding three channels. At the tips of these channels, three air jets, each separately oriented, direct the molten aluminum onto the anode block. The orientation of one jet is designed to cover two sides and half of the top of the anode block. As the anode block travels on the conveyor system and reaches the first aluminum spraying station, the first air jet directs the molten aluminum to the top section of the block. The other two jets direct their sprays to cover the middle and bottom section of the block. A second identical spraying station, located on the opposite side of the conveyor's travel path, performs a similar spraying job on the remaining two sides and top of the anode block.

Two operators man this spraying station. One operator is engaged in keeping the furnace runners in operating condition, while the other worker operates the control console. The control console is protected by an enclosure and the operators wear face shields and gloves.

The sprayed anode blocks travel on a roller conveyor system to the loading station, where they are loaded automatically in three rows of seven blocks, each onto a flatcar.

Samples were collected on two spray machine personnel to determine the extent of exposure to particulates and to the aluminum dust generated by the process. Total particulates were in the range of 6.8 to 7.4 mg/m^3 while aluminum concentrations were between 2.0 and 3.3 mg/m^3. The threshold limit value (TLV) for total particulate is 10 mg/m^3 and the OSHA standard is 15 mg/m^3; there is no TLV or standard for aluminum.

POTLINE OPERATIONS--PREBAKE PLANT

In a bath comprised primarily of cryolite and aluminum fluoride, aluminum oxide is converted to aluminum metal in an electrolytic reduction cell (pot). In these potline operations the oxygen from the aluminum oxide passes to the anode and reacts with carbon to form carbon dioxide. In prebake plants the carbon anode is baked before it is installed over the electrolytic cell, while in Soderberg operations the carbon anode is formed from a continuous, self-baking anode paste which fills a rectangular steel mold above the reduction cell.

Center-Work Prebake

Good examples of control technology observed in center-work prebake potline operations are hoods, dual-draft control on pot hoods, computer-controlled automatic systems for crustbreaking and oreing, Electrification Charpente Levage (ECL) cranes, and air ejector systems for tapping. (In center-work prebake plants the crustbreaking and ore charging is along the centerline of the cell.)

At one plant the hooding on the pots was observed to be very effective in containing pot emissions and permitting capture and removal by the pot exhaust system. An area sample taken above two pots showed a total particulate concentration of 1.2 mg/m^3 and a total fluoride level of 0.07 mg/m^3. Personal samples on two potroom operators showed total particulate levels of 6.5 and 10.9 mg/m^3 and total fluoride levels of 0.4 and 0.7 mg/m^3. Personal exposures tend to be higher than area samples because potroom operators most often work near the pots with the hood open; on the other hand, the area sample is over the pot with the hood normally closed and emissions well contained. Side shields were well maintained and were replaced soon after carbon changing operations were completed. The hood is supported by a superstructure that carries the anode buss bar, an alumina charging hopper, a hydraulically operated crustbreaker, and a cell-gas collection manifold. Figure 15 shows a view of the pot and pot hood, and Figure 16 a schematic drawing of a pot.

The pot hood consists of 10 removable shields along each side of the pot which are held in place by their weight. Each shield is sufficiently small and light (it can be removed by one man) to permit access to the interior of the cell housing. These shields are removed only as necessary for carbon changing or for other pot operations, and they are replaced as soon as the operation is completed. The shield, which is curved and ribbed to give strength, has two handles that are vertically mounted to allow for easy removal. Shields are inspected frequently for placement, warpage, and damage; they are replaced as needed.

The cell is also equipped with a newer type of pot end door (Figure 17), a hinged aluminum door that folds and swings to the side, out of the way. A steel strip along the top allows the door to be held back by the magnetic field. The door appears to do a good job of sealing. It is simple to replace, and warping appears to be less of a problem. The end door permits access to the end of the cell for observation or for tapping metal.

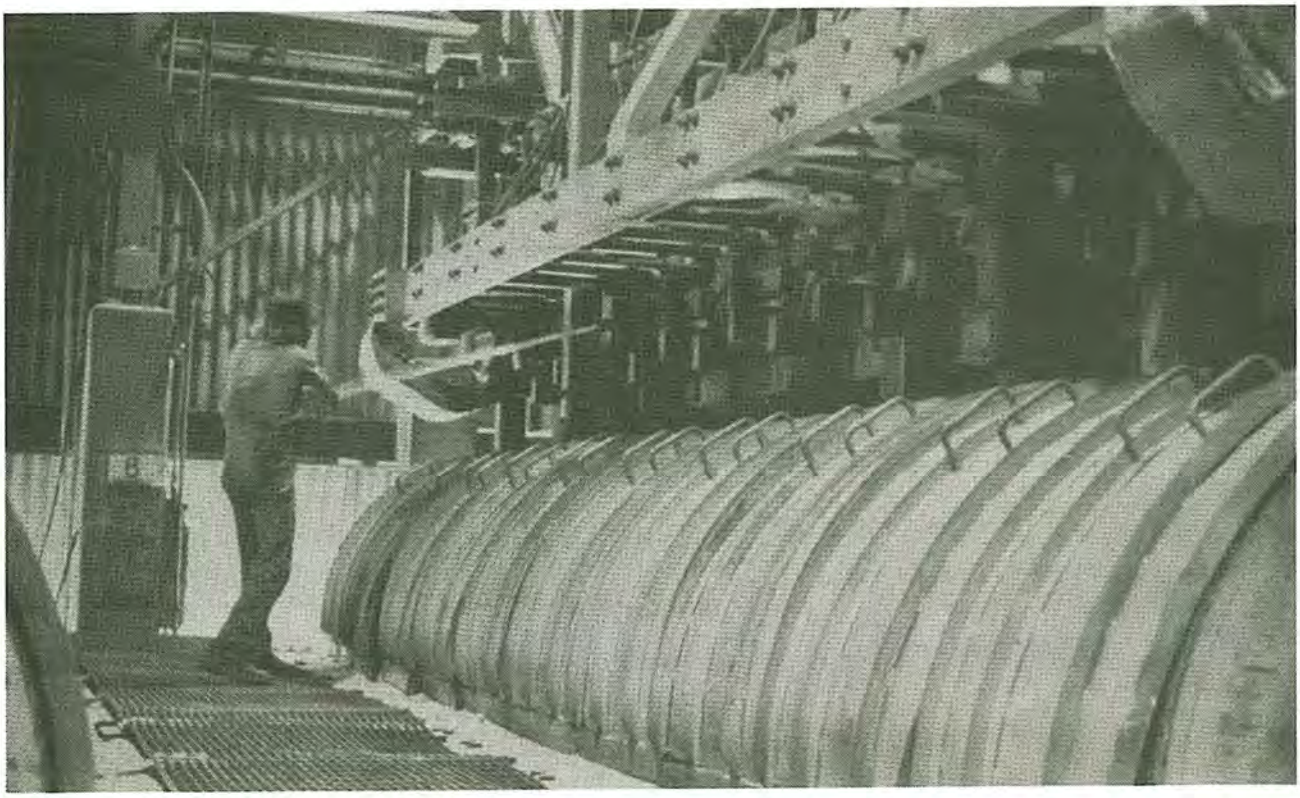


Figure 15. Hooding on the pots is very effective in containing pot emissions.

A dual (high and low) draft control on the pot hoods is found to improve hood efficiency when shields are off the pots. Each pot is supplied with a dual-draft system that is controlled manually by a damper operated by a lever located at one end of the pot. Anytime the pot shields are removed, the damper is moved to the higher exhaust rate to maintain hooding efficiency. Standard practice calls for no more than six pots at a time to be on high draft per section (33 pots). The nominal pot hood exhaust rate is 4550 acfm at low volume. If six pots are on high-draft, the exhaust rate is calculated to be 4060 acfm on low draft and 6720 acfm on high-draft. Gases are exhausted from the hood along both sides for the full length of the pot. (Each side has an exhaust slot, which is actually divided into six equally spaced slots along the length of the pot.) Gases from the pot are exhausted to 9-inch by 9-inch ducts (one on each side of the pot), which join and connect to the manifold that leads to the dry scrubber. Expanding-type ducting is used in the manifold at each pot to maintain a constant velocity in the duct.

A good example of a potline operation control technology is a computer control system that automatically performs the crustbreaking and the addition of alumina ore to the pots, thereby reducing the need for potroom personnel to open the side shields. This system also monitors the operating voltage of the

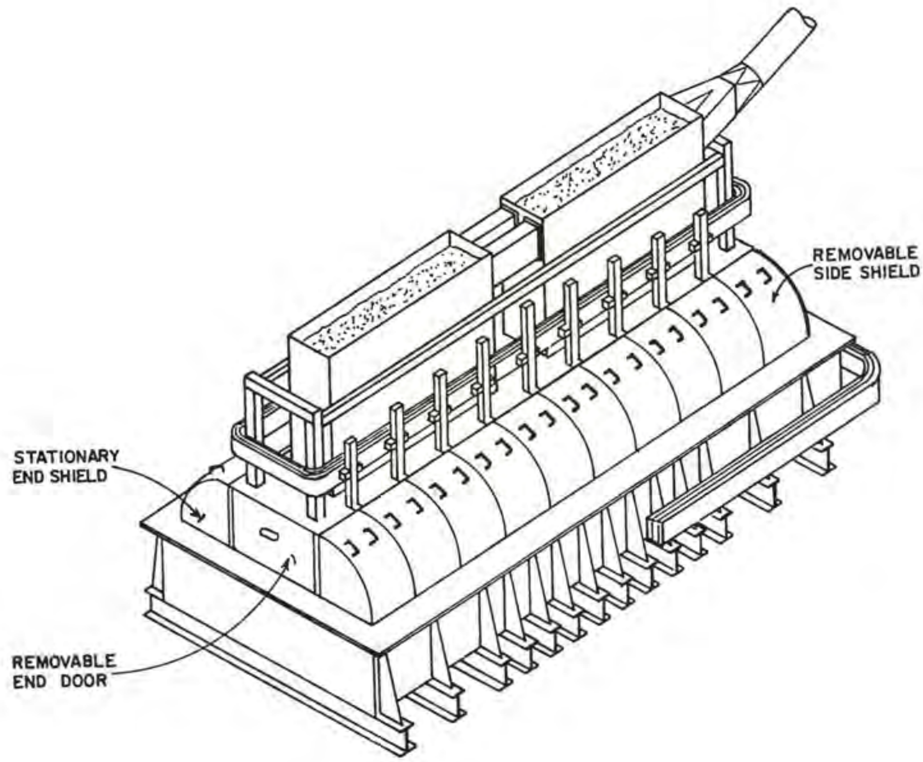


Figure 16. The drawing shows a hooded prebake aluminum reduction cell.

pots and adjusts the anodes as they are consumed. Many anode effects (an anode effect is the generation of vapor under the anode that increases electrical resistance) are terminated by the automatic system, which reduces the number of times the pot hooding needs to be removed. Ore addition and anode-to-cathode distance adjustment are controlled by a computer. In the automatic addition of ore, alumina from the pot-charging hopper is introduced into the pot, close to the centerline. The crust-breaker is suspended along the centerline of the pot and hydraulically operated by cylinders located at each end and at the center of the superstructure. Alumina from a bin carried by an overhead P&H crane is added to the pot-charging hoppers located on top of the superstructure of the cell. The bin is fitted with a skirt that rests on the rim of the open-topped pot-charging hopper, this skirt provides a seal to retain the alumina that flows from the bin into the hopper. The pot ore hoppers have a capacity of 10,000 pounds, which is enough for a 2-day supply.

The computer has two analog scanners in each potroom which are monitored from the control room. Anode effects are computer-announced by an audible alarm and by incandescent lights situated on each pot. (The lights are off when the pot is performing normally.) Anode effects occur at a frequency of about one per pot per day, and may cause pot emissions to increase several fold. Anode effects and most pot operations are handled through the pot end door, thus eliminating the need to remove pot shields.

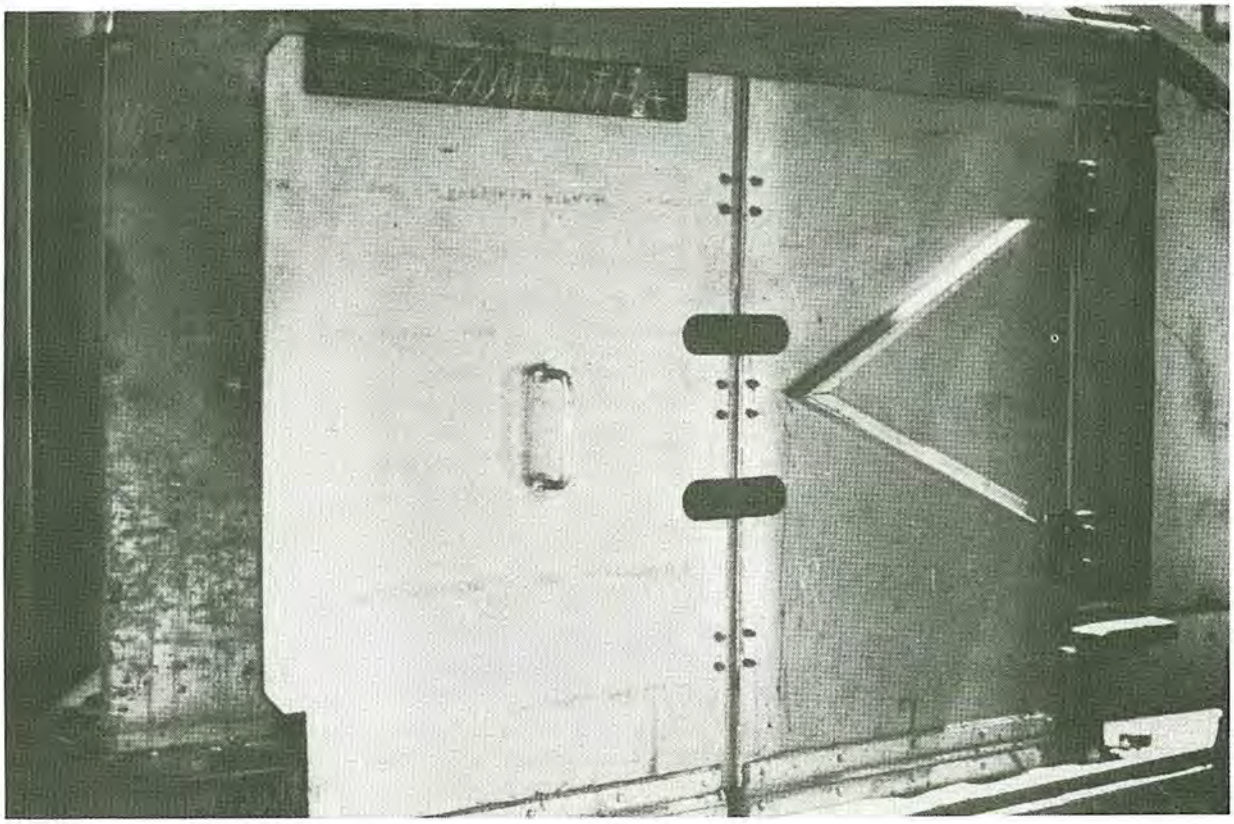


Figure 17. The newer type of pot-end door is a hinged aluminum door that folds and swings to the side out of the way.

The use of the specially designed ECL crane for removing spent anodes and setting fresh anodes has good potential for reducing worker exposure during potline operations. By using the crane, potroom personnel can replace anodes very quickly, without exposing the pot operator to the pot emissions. The crane operator is located in a closed, air-conditioned cab for protection from the gases, fumes, and heat rising from the pots. (The air conditioning unit is made by Lintern Aire.) The crane operator must keep the cab door closed to avoid unnecessary exposure, however, this may be difficult if windows fog up and block his view. A personal sample on the ECL craneman showed total particulates of 8.6 mg/m^3 and total fluoride levels of 0.5 mg/m^3. This crane equipped with a pneumatically driven punch for breaking the crust around the anode to be removed, a dual-wrench for anode-to-buss connections, an arm for anode removal and placement, and a bin and feed spout for the alumina used to cover a newly placed anode. The cab moves laterally between two pots, and can be positioned almost directly over an individual pot.

The procedure for changing carbon by use of an ECL crane is as follows: pot shields are removed, and the crane breaks the crust at the anode. (Three shields per pot are removed to permit access. No more than three pots at a time are actually open.) A worker occasionally has to rake away chunks of the frozen bath as the anode is removed. The crane suspends the anode in the air at the end of the pot while one or two workers scrape bath material from the top. The fresh anode is replaced by the crane after the buss bar has been cleaned with a wire brush. Alumina from a hopper on the crane is placed on top of the anode to inhibit oxidation and provide insulation. The anode is bolted in place by the crane and the shields are replaced. Bath that has been removed from the anodes is shoveled back into the pot through the end door. Cleaning of bath from the spent anode is continued throughout the shift until the anode is transferred back to the rodding room. Air blasts are used as a final anode cleaning step in potline operations.

Tapping of the pots by use of an air-ejector system to siphon the molten aluminum effectively reduces worker exposures to the pot emissions. Total particulate levels for two tappers sampled were 4.0 and 4.1 mg/m^3 while total fluoride levels for the same two tappers were 0.1 and 0.2 mg/m^3. The air ejector system was observed during the survey in the following tapping operation. The sliding end door of the pot hood is opened, a hole is punched in the crust with a pneumatic punch carried by the crane, and the siphon nozzle of the vacuum crucible is inserted. A compressed-air ejector produces the vacuum in the crucible. During the survey, some fume that appeared in the air discharge from the ejector was blown back into the pot hood, and an emission escaped out the other end of the pot; however, no visible fumes emerged from the open door of the pot hood itself. Once a sufficient amount of metal (determined by weight) has been tapped, the siphon is removed and the end door is closed.

Side-Work Prebake

A sideworked prebake plant of Pechiney design was surveyed. There are a total of 480 pots in operation on the two lines. The first potline began operation in 1970 and the second in 1976. The two potlines are identical. The architectural layout of each potline consists of four rows of 60 cells each with two rows per building. The pots are approximately 10-feet-wide by 26-feet-long by 5-feet-high, and are situated at floor level to allow clearance of the pot tending machines and automatic semi-gantry machines. Each pot contains 18 anode assemblies connected to the center anode Buss bar.

The potroom operations are highly automated and the potroom crew generally consists of one pot operator per section, an assistant pot operator per room, and one general factory worker per line. The potline equipment includes a semi-gantry crane which breaks crust and feeds ore without the presence of an operator, and the manned pot tending machine (PTM) used for anode changes and tapping.

The unattended operation of the ECL-designed semi-gantry machines has reduced significantly the number of workers who must be continually present in the potrooms and near the pots. The semi-gantry machines are computer controlled and perform automatically the pot working opeations such as ore addition, crustbreaking, and elimination of anode effects. The semi-gantry works both sides of a pot at the same time. The pot hood doors open automatically for the semi-gantry machine, and if not opened to the proper position, the semi-gantry will not permit further operation.

The machine travels along a track support on the inside aisle of the building. The opposite end of the machine is self-supporting on the floor of the building. Use of the machines essentially eliminates the need for workers to be present for pot working operations. However, due to sophisticated functions and very close clearances, maintenance is an extremely important function. There are three semi-gantry machines per potroom.

The specially designed ECL pot tending machines (PTMs) allow for quick anode changes, metal tapping, and liquid electrolyte transfer, while reducing the PTM's operator exposure to potroom emissions. The manned PTMs can also perform the semi-gantry functions. The operator of the PTM works in an enclosed cab.

Anode changing is performed by a two-man team with the PTM. Two hoods are opened during anode changing, one on the pot being changed, and the other on the pot being prepared. The pot hood is closed immediately after replacing an anode. Oreing over with alumina is performed later. During the time that the PTMs are working on the pots, doors are operated manually and computer control is blocked out in that pot. Whenever the PTM is working the pot, the hood door is raised all the way up and emissions can be observed escaping from the pots.

The primary and secondary potroom ventilation systems capture and clean pot emissions, and prevent the possible recirculation of large amounts of emissions back into the work areas. The primary ventilation consisting of the pot hooding, ducts, and scrubber effectively contains pot emissions when the hoods are closed. The features of the hood include a permanent top pan mounted to the superstructure beneath the anode buss. The pan is slotted to allow anode stem to buss contact. Stem seals are mounted on the anode stems to seal off the slotted areas of the pan and, at the same time, to allow stem movement during jacking operations. Movable side doors operated by electrical motors and associated gearboxes provide access to the pot when required by pot working and tending machines. Permanent end panels and wing panels on each end of the pot complete the hood closure. the top and bottom of the doors are sealed with a fiberglass skirt. A full-time maintenance crew replaces the skirt every 28 days, and inspects the pot hood condition.

Air is exhausted from the pot enclosure at the rate of 3,000 cfm through two ducts mounted to the top of the pan in the center of the pot. The exhaust air duct are 12-inches in diameter and connect to an expanding duct manifold. The manifold expands at each pot and is exhausted to a dry scrubber for fluoride and particulate removal.

Because the hood doors must be fully open to work the pot, hood collection efficiency drops to a low value whenever the pot is being worked. Pot emissions escape into the potroom and generally rise vertically to the roof monitors in the ceiling. The hood doors are open an estimated 1-1/2 hours out of 30 hours of operation. During the time that the hood doors are closed, it is estimated by company personnel and the study teams visual observations, that collection efficiency of the hood is greater than 98 percent.

The secondary ventilation system consists of air flowing from the louvers opened along the outside walls into the building between the electrolytic cells , then up through air ducts to the roof scrubbers. There are 104 roof scrubbers in the two potlines with exhaust fans on each scrubber. Each fan draws 108,000 cfm for a total air movement in the two potlines in excess of 10 million cfm. In addition to a fan, each scrubber has a waterpump, a recirculating tank, 80 sprayers and a mist eliminator. A total of 104,000 gallons of water per minute is circulated through the scrubbers. Roof monitor scrubber fluoride collection efficiency is about 65 percent.

Potroom personnel were sampled for total particulates and fluoride exposures. Total particulate concentrations ranged from 3.5 mg/m^3 for a swing helper to an average of 1.7 mg/m^3 for 2 assistant carbon changers. Total fluoride exposure among potroom workers ranged from a high of 0.73 mg/m^3 for swing helper to an average of 0.14 mg/m^3 for the carbon changers. In no instance was the threshold limit value established by the American Conference of Governmental Industrial Hygienists of 2.5 mg/m^3 total fluorides closely approached. Total particulate and fluoride data is shown in Table 1.

The effectiveness of the enclosed cab on the PTMs was shown by the samples collected both inside and outside the cab. Total dust levels inside the cab were approximately one-third those outside (1.9 mg/m^3 versus 5.3 mg/m^3) and total fluorides inside the cab were one-eighth those outside.

Table 1.

Location	Number of Samples	Total Particulate (mg/m^3)	Total Fluoride (mg/m^3)
Carbon changer	2	3.1	0.14
Asst. carbon changer	2	1.7	0.40
Swing helper	1	3.5	0.73
Tapper	2	2.9	0.33
Inside cab-pot tending machine (area sample)	1	1.9	0.08
Outside cab-pot tending machine (area sample)	1	5.3	0.61
OSHA PEL	-	15	2.5
TLV	-	10	2.5

POTLINE OPERATIONS--VERTICAL STUD-SODERBERG

In Soderberg plants, the carbon anode is formed from a continuous, self-baking anode paste that fills a rectangular steel mold above the electrolytic reduction cell. The anode mixture of coke and pitch is periodically renewed at the top of the anode. The Soderberg process eliminates the operations of pressing green anodes, carbon baking, and rodding performed in prebake plants. Soderberg cells contain either horizontal or vertical studs. Control technology in the vertical-stud Soderberg process is discussed below.

The vertical-stud Soderberg plant surveyed during this study contains three potlines; each has 220 reduction cells, 110 in each potroom. The vertical-stud Soderberg cells have been modified by Sumitomo and feature computer control for the total operation, special technology for cathode structure and for the anode paste, and automatic crustbreakers fitted to the cell. The computer activates the crustbreaking and ore-feeding operations, adjusts the height of the anode, puts out anode effects, and maintains continuous monitoring of the cell performance.

An automatic crustbreaker feeds ore to the cell. This machine breaks through the crust of cryolite and permits the alumina to enter the cell. Following the crustbreaking, an ore truck pours additional ore in the cell. The truck proceeds down an aisle and delivers floury alumina to each cell through a lowered spout.

A vehicle carrying briquettes in a hopper also replenishes the anode paste. This vehicle proceeds along the side of a cell and delivers briquettes to the anode casing through a feed spout. During both the alumina feeding and briquette feeding, the operators are inside the vehicle cab and are not exposed to emissions from the cells.

The tapping of metal from the cell is performed by a tapping crew consisting of two vehicle drivers and one assistant. The assistant punches a hole in the crust to permit the tapping crucible siphon to be lowered into the cell. The crucible is carried on a truck that is specially adapted with a crane to lift the crucible on and off the truck and also to position the crucible during the tapping. With the help of the assistant, the tapping vehicle driver places the siphon into the tapping hole, activates the vacuum for the siphon, and observes the weight of the tapped metal by checking a scale mounted in the cab. During the tapping operation, the vehicle driver is protected from pot emissions by the cab enclosure and the assistant wears a respirator. Following the tapping, the crucible is hoisted onto the truck and carried to a transfer point where the contents are transferred to another crucible by an overhead crane. The crane operator is located behind a protective shield during this transfer.

The pulling and replacement of the vertical studs is accomplished by an ECL-designed crane that attaches onto the stud, loosens the holding clamp and removes the stud. The crane is equipped with a Sumitomo-designed automatic paste dispenser that collects most of the fumes and vapors into an extendable snorkel while simultaneously feeding anode paste briquettes into the vacated stud hole. The pulled stud is placed in a holding rack carried by the crane, and a fresh stud is picked up and placed in the cell. The clamp is tightened and the crane repeats the operation on another stud. This task takes approximately 50 seconds. When the rack of studs has been exchanged, the crane returns for more fresh studs. The operator of the crane is located in an enclosed cab provided with clean, filtered air. The fumes and vapors collected by the snorkel are processed through a set of filters and discharged into the potroom.

Although the study team was not able to view a pot rebuilding operation at this plant, it did observe the baking of a new cell. For containing and capturing the vapors and gases released during this process and startup, a specially designed hood is placed on the cell, one that completely envelops the lower portion of the cell. Exhaust ducts are attached to the hood, and while the cell is being baked and started, the exhaust ventilation removes the emissions to the gas-cleaning system. Many prebake cells are already equipped with hooding to control the emissions during bake-in; however, the vertical stud Soderberg cell is not and therefore requires some type of containment to prevent the release of contaminants into the work area during bake-in and startup.

Each potline cell is equipped with a primary gas collection system consisting of two exhaust pipes to draw off the volatile gases. Approximately 500 m^3/hr are exhausted from each cell. As the gases enter the skirt that surrounds the anode block, they are drawn toward the ends of the cell and pass through a gas flame. The volatile gases are combusted, and the other contaminants are collected by means of a series of ducts and dust boxes that lead to an electrostatic precipitator. The secondary system of gas collection consists of natural draft ventilation, which introduces air from the basement under the potroom through metal grates along the side of the cells. The air rising from the floor to the roof monitors located in the ceiling of the potline building carries the particulate and gaseous emissions from the cells. The effectiveness of tnis system was demonstrated when dusting occurred during the addition of alumina to the cells; the rising air currents swept up the particles and carried them toward the ceiling.

POTLINE OPERATIONS-HORIZONTAL-STUD SODERBERG

Good potroom control technologies were identified at a horizontal-stud Soderberg plant built in the late sixties. The plant consists of three potlines, 168 pots each with two potrooms per line. The nominal capacity is 1,000 lbs. of aluminum per pot per day. The pots are all manually tended with no computer control. In each potroom there are a total of 23 potroom workers per shift along with 41 anode tenders on day shift performing all the functions necessary to kept the production of aluminum proceeding. There are three pot tenders per room, three crane operators, and three potroom helpers. The pot tenders responsibilities include adding ore, handling anode effects, adding bath materials, dressing up the pots to ensure optimum operation of the pots. The anode tender (day shift only - 7 days per week) pulls pins, installs pins, removes and replaces channels, raises and changes flex connections, changes anode buss and hangers, daubs holes, and performs other duties on the pot anode. An anode crew generally consists of four pinpullers, four pin setters, 16 flex raisers, nine channel/ hangers and 1 person plugging holes and racking. One quarter of the crew are off at all times. The crane operator runs the overhead crane to move a variety of equipment and materials in the potroom. In addition to the potroom personnel, there is a three-man tapping crew.

Alumina ore is supplied in the potroom from a central feed station. An air slide supplies ore to a surge bin which is then fed by gravity to the ore bucket. There is no dust collection system on the feed station.

Crust breaking is performed periodically with a pneumatic hammer operated from a truck that drives along the aisle way. The truck has a heat-splash shield for protection of the driver.

Tapping is performed using a vacuum crucible that is evacuated by an ejector. A muffler on the ejector reduces the noise level during this operation. The tapping crucible is supported by the overhead crane. Metal is tapped by weight with visual observation by a sight glass. The pot hood door is required to be fully open during tapping allowing the escape of heavy emissions about 7 feet above floor level. Approximately 50 cells per shift are tapped by the crew.

The horizontal-stud Soderberg pots are of the channel type, and as the anode paste is baked and gradually lowered, the anode paste becomes bounded by a box structure formed from horizontal steel channels placed one above the other. Before anode paste is added to the pot, a 3-foot-wide aluminum sheath is stapled around the upper edge of the anode paste enclosure. The top of the anode is also blown off with an air blast to assure good contact with the new paste.

Flex raising is performed by removing the bolts holding the electrical connectors to the studs and raising the connectors to the next horizontal row of studs. Flex raising requires that the workers stand inside the hood and on a heat shield placed over the crust. Pneumatic wrenches are used to remove the bolts. A truck is situated along side the pot with a fan directing air at the workers standing beside the pot. Before reattaching the flex connectors, the contacts are sanded with a 4-foot sanding tool that can be operated while standing outside the pot. The majority of the emission produced during flex raising is from accumulated dust falling while working around the buss bar.

Stud pulling is required before the channel can actually be removed and is performed with a pneumatic press. The press is suspended from a vehicle and operated by hand (Figure 18). The press hooks onto the pin and exerts pressure against the channel, thus removing the pin. Cryolite is forced into the pin holes to reduce air burning by means of a hand plunger. The whole process of stud pulling creates a heavy visible emission but workers are not directly in it except when actually pulling the pin off the crust. Stud setting is performed after the new channel has been placed on top of the other channels forming the anode enclosure. Two men on a travelling cart cleaned and straightened pins into a pin rammer (Figure 19) which then forces the pin into the relatively soft anode paste. The pins are supported by holes in the channel until the anode is baked. The pin punctures the aluminum sheath that is also moving down with the anode. Exposure during this task is relatively light.

As the anode advances into the bath, additional channels are placed on the unbaked paste to give support. The channels are lowered into the pot super-

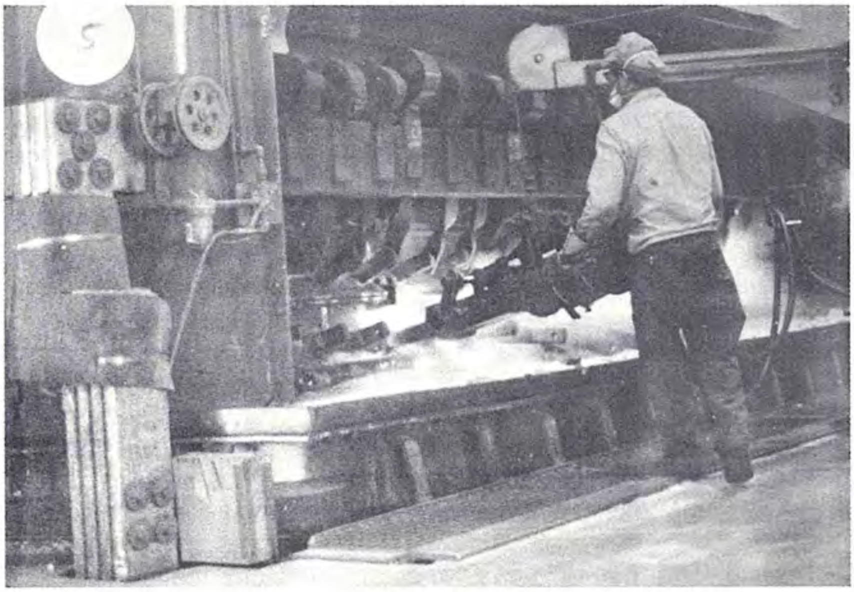


Figure 18. Stud pulling using pneumatic press.

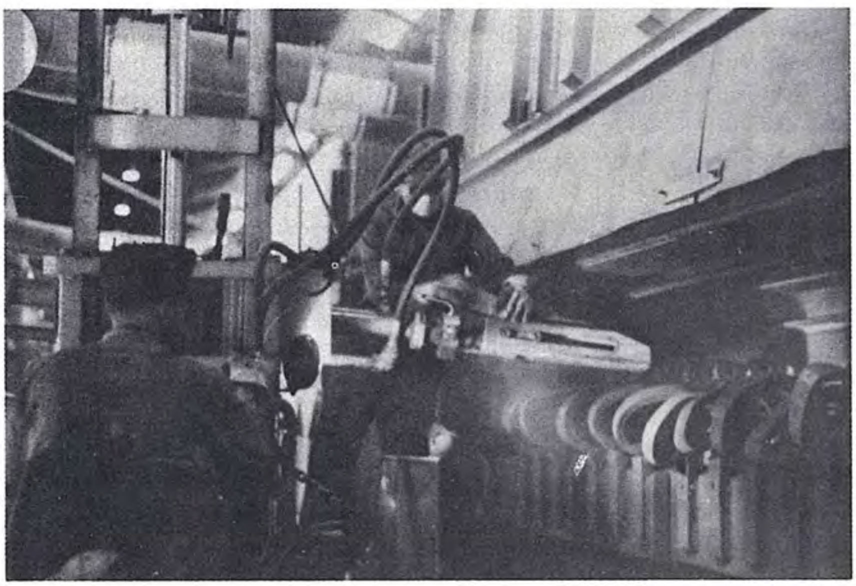


Figure 19. Two men on traveling cart set pins into pin rammer in stud setting operation.

structure by the crane and the channels are locked into place and bolts are tightened to complete the channel hanging operation.

The pot hood design is a workable system that effectively reduces pot emissions when the doors are closed (however, the pot draft is not sufficient to capture emissions efficiently when the doors are open). The pot with a side door open is shown in Figure 20. The doors on the pot hooding are rigid and air operated. The pots are designed such that ore, discharged from the ore hopper at the top of the pot, drops down along the inside of the pot door and is evenly distributed along the length of the pot through channels in the door . The doors have a steel skirt attached to the bottom which sits up about 2 to 3 inches from the pot shell and is designed to be sealed off with alumina. Because of their massive size, warpage did not appear to be too severe.

The pot end doors are flexible and roll up out of the way for operations such as channel hanging and pot end crust-breaking. Seals on both the side doors and the end doors appeared to be good. Buss bars are sealed in the hood with Kao wool.

Pot emissions are exhausted from the hood through four air offtakes (approximately 10 inches diameter) located at the four corners of the pot hood. The offtakes are connected to an expanding duct exhaust manifold which serves 14 pots. Each manifold is exhausted by a 50,000 cfm fan, thus providing approximately 3,600 cfm exhaust per pot. There are no dampers off the pot hoods for airflow adjustment.

Figure 20. Potroom view showing pot hoods and overhead cranes.

Thirty-five ton capacity cranes are used in the potrooms for tapping, refilling ore hoppers, and removing cells for rebuild. The cranes have enclosed air conditioned cabs. A photograph of the crane in operation is shown in Figure 20. The crane operator also carries anode paste to the pots. The paste is brought from the paste plant in boxes (by transport truck) that are picked up by the crane. The boxes have legs that extend to rest on the ore hoppers on top of the pot. The craneman dumps the paste from the box and returns the box to the truck. There is a heavy emission as the paste is dumped; however, only the craneman in an enclosed cab is at the emission level.

Channel pulling operation at this plant can be performed by one man once the required studs and supporting bolts are removed. A specially designed vehicle with a hooked arm is operated from the aisleway to remove the channel (Figure 21). After removal the channel is taken immediately outside and stored. The entire operation takes only about 45 seconds and the door is open only about 30 seconds.

The type of oreing buckets and pot hoppers used at this plant help to control alumina dust emissions. An ore bucket (shown in Figure 22) is gravity fed from a central feed station in the potroom. A crane carries the ore bucket to the pot where the bottom of the ore bucket is placed very close to the top of the hopper so that ore falls only a very short distance to fill the pot hopper. The craneman can see exactly how full the hopper is and can guard against overfilling. Each pot hopper has a lip that extends up both sides of the hopper which reduces ore spillage and dispersion of alumina dust.

Situated throughout the potrooms are "cool-out" shelters where a worker can remain without the required respiration protection. These shelters approximately 6-feet by 6-feet by 8-feet-high are equipped with a room air conditioner which maintains the temperature at 70°F. The air in this room is also filtered to remove particulates. Workers are able to enter the room to escape the heat around the pots. This is especially necessary during the hot summer weather when the air entering the potroom through the wall openings is very warm.

Personal and area air samples were collected in the potlines for total particulates, fluorides, and hydrocarbons (benzene soluble). The sample results are presented in Tables 2 and 3. Area samplers were positioned on top of a pot operating in a tracking mode (i.e., with no work being performed directly on the pot). The results indicate good containment of particulates, as well as hydrocarbons. Potroom personnel such as the pot operator, craneman, and the tapping crew show low levels of exposure to particulates, and fluorides; however, the anode crew members (dependent upon the operation) received total particulate exposures as high as 47.3 mg/m^3 during channel pulling. The personnel on the anode crew are required to wear respiratory protection during the performance of their jobs.

Benzene soluble exposures were generally from two to three times the standard of 0.2 mg/m^3 (except for the pin puller exposure of 8 times the standard).

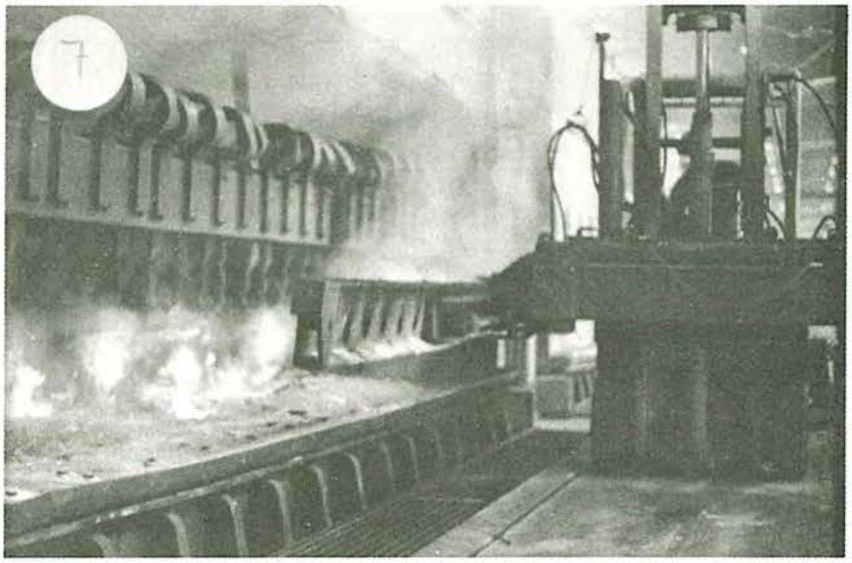


Figure 21. Channel pulling operation using specially designed vehicle with hooked arm.

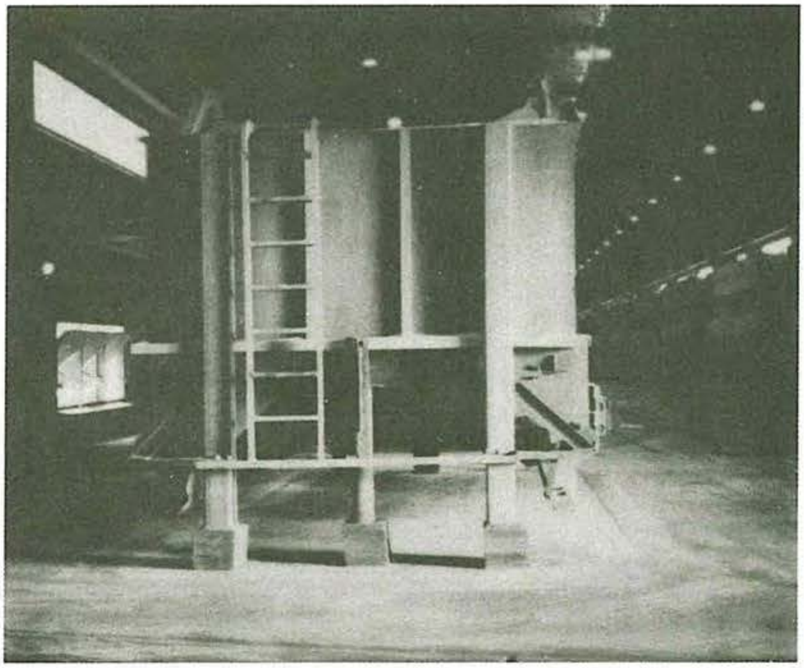


Figure 22. Double sided ore bucket carried by crane for oreing pot hoppers.

Table 2. Air sampling results - particulates and fluorides (mg/m^3)

Location[1]	Total[2] Particulates	Total Fluoride
Pot operator	2.6[3]	0.2
Tapping crew	1.6	--
Craneman	1.0	--
Anode crew:		
Pin puller	3.2	0.2
Pin driver	4.6	1.6
Flex raiser	19.4	1.5
Channel puller	26.0	0.8
Plugger racker	10.3	1.3
Above pot anode		
Area sample	1.1	--

1. All workers wore respirators.
2. Values for total particulates are the average of two samples.
3. Value for total particulate for pot operator is average of three samples.

Table 3. Air sampling results - hydrocarbons (mg/m^3).

Location[1]	No. of Samples	Benzene Soluble Fraction
Pot operator	2	0.46
Tapping crew	2	0.50
Craneman	2	0.40
Anode crew:		
Pin puller	1	1.64
Pin driver	1	0.50
Flex raiser	1	0.52
Channel puller	1	0.56
Plugger racker	1	0.70
Above pot anode		
Area sample	2	0.50

1. All workers wore respirators.

POT REBUILDING

At one plant, pot rebuilding is performed with the pot shell in place in the potroom. The molten metal and bath are tapped out, the pot is deactivated and electrically shunted, the fume collection system blanked off, the superstructure removed, and the lining wetted down with water. Although the wetting down process generates ammonia and acetylene vapors for the ensuing 36 or more hours, the process does tend to minimize cryolite and carbon dust once the pot digging begins. The potdigger superstructure is lowered onto the pot shell. The digging mechanism, a Keibler-Thompson Corporation Slageater, is remotely operated from the adjacent pot deck through electrical servo-mechanisms that activate hydraulic and pneumatic controls on the pot digger. The "digging head" is interchanged with a backhoe bucket, which removes the spent cathode lining into bins for transport out of the potroom. If the steel pot shell does not need extensive repair, the empty pot shell is relined in place. Otherwise, the old shell is pulled from the potroom and replaced by a refurbished shell. At this plant anode burnoffs are rare and cathode linings last an average of 2,000 days. An area sample taken at the "Slageater" operator station showed total particulate level of 2.8 mg/m^3 and total fluoride of 1.3 mg/m^3.

When a pot must be completely rebuilt at a second plant, the bath and the hot metal are siphoned from the pot, the superstructure is removed, and the entire pot shell is removed with a Lansdale crane to a site out-of-doors where the lining material is removed by turning the shell over with a crane. When only the cell sidewall lining needs repair, rebuilding is performed in the potroom. Pot walls are dug out using jack hammers and shovels. Workers are required to wear dust respirators and hearing protection.

Pots taken out of service at a third prebake plant are moved to a small enclosed room shown in Figure 23 where they are wetted and are allowed to soak. There is no ventilation in the room, and any gases that evolve from the wetted pots probably end up back in the pot relining area. After soaking, the pot is removed from the room and placed in a large open area. The pots are then dug out with a pot digger operated by one person in an enclosed cab. Large cables that run under the floor and that are connected to the pot shell allow the pot to be turned upside down for emptying. Pots are relined with carbon blocks and cathode paste in a separate area and then are brought back into the potroom to be returned to service.

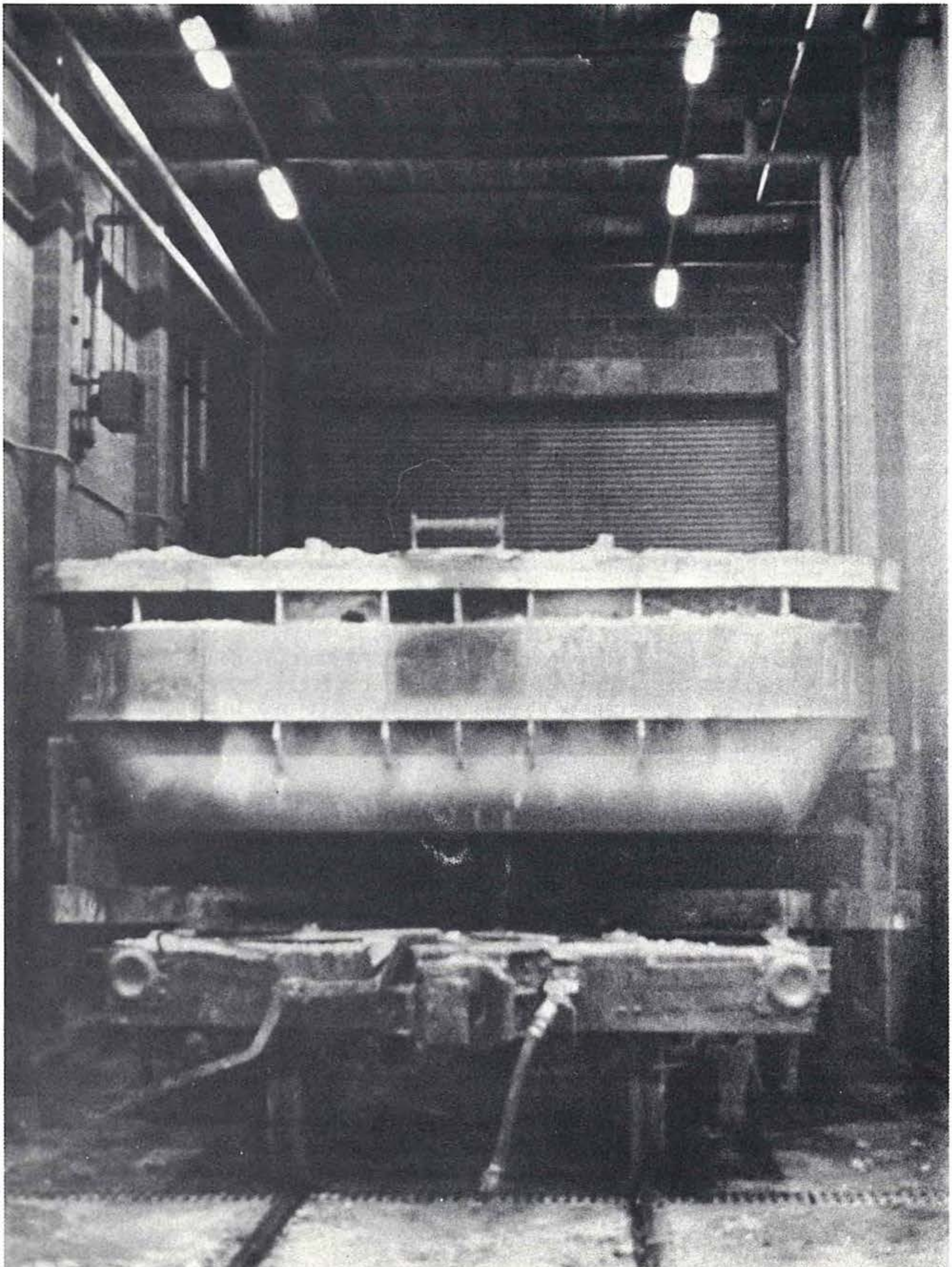


Figure 23. Pot shell cathode soaking in alcove.

IV. SAMPLING METHODOLOGY

In this study personal and area in-plant air samples were taken in the green carbon plant, carbon bake plant, anode rodding room, and potrooms. Samples were taken to determine the effectiveness of the control system regarding worker exposure and the ability of the system to reduce or eliminate the release of the contaminant at the source. Either a Bendix BDX-44 or a MSA Model G monitoring pump attached to the belt of the workers was used for personal sampling. Tygon tubing connected the pump to the sampling medium, which was located as close to the breathing zone as practical. Area samples were obtained with similar equipment and with a General Metal Works high volume sampler placed in a strategic location. An attempt was made to obtain area samples at the breathing zone height.

The sampling pumps were calibrated in the field with a rotameter that had been previously calibrated using a bubblemeter (buret set in an inverted position). The pump flow rate was checked before and after each pump use. The average of the starting and final flow rates for total sampling period was used in calculating concentrations.

The analysis for particulate fluoride, and gaseous fluoride was performed on a single sample, following the NIOSH-approved analytical method P&CAM 212. Total particulate samples were collected on tared polyvinyl chloride filters. The analysis for benzene-soluble organic material followed the NIOSH-approved method P&CAM 217.

On some samples, benzene-soluble organics were determined using gravimetric method developed by H.J. Seim et al.[6] With this method the filtrate is placed in an aluminum weighing dish rather than in a Teflon dish as in NIOSH method P&CAM 217.

Samples for metal fumes were collected on mixed cellulose ester filters (MCEF). Metal fume samples were ashed and were analyzed using atomic absorption spectroscopy following NIOSH method P&CAM 173. Iron was analyzed colorimetrically. A summary of sampling and analytical techniques is presented in Table 4. Instantaneous spot noise measurements were taken using a General Radio Model 1565 hand-held sound level meter (Type II). A general Radio Model 1562 sound level calibrator was used to check the calibration of the meter.

Table 4.

Chemical	Method of Collection	Sample Flow rate (L/min)	Sample Time (min)	Method of Analysis	NIOSH Ref. # (P&CAM)
Fluorides (part. & gas)	Tared MCEF 0.8 um backed by alkali-impregnated cellulose pad	2.5	360	GRAV, ISE	212
Hydrocarbons	Ag filter & glass-fiber backed by Chromasorb 102	1.5	360	GRAV	217
Particulate	Tared PVC	-	-	GRAV.	-
Metals	MCEF 0.8um	2.0	360	AA	173

MCEF - Mixed cellulose ester filter
ISE - Ion specific electrode
GRAV - Gravimetric
AA - Atomic absorption spectrophotometry

V. PROTECTIVE EQUIPMENT AND HYGIENE PROCEDURES

All the primary aluminum plants surveyed had formal health and safety programs. This included the use of personal protective equipment such as respirators, protective clothing, and safety equipment.

RESPIRATORS

In ore unloading operations, respirators were worn during loading and unloading operation, tractor operation, and barge sweeping. At one plant disposable dust masks were worn by Bobcat and forklift operators and workers loading and unloading the banana wagons which haul Al_2O_3. In another plant, a payloader is used in the barge to push material over to a snorkel system for unloading. The payloader cab is open and the operator wears a dust respirator. At a third plant, a John Deere tractor placed in the barge to push ore to the extendable suction ducts for unloading. The tractor operator is provided an airflow helmet supplied with filtered air (a powered air purifying respirator equipped with a filter). The respirator provides a positive pressure curtain of filtered air under the helmet and reduces the operator's exposure to dust. The tractor operator may also assist by manually directing the suction pipe to pick up the last small pieces of ore. The pump to the respirator helmet, however, is attached to the tractor, and the respirator is useless when the operator leaves the tractor to manually direct the suction nozzles.

In one plant, pitch is received by railroad tank car. The worker unloading the car who is potentially exposed to pitch vapors while opening the tank car vent and sampling heated pitch, wears an organic vapor cartridge respirator.

In the green carbon area workers were observed wearing dust respirators during maintenance operations. A batch mixer operator, who spends approximately 50 percent of his time in the mixing area, of the green carbon plant wore a single use half mask dust and mist respirator whenever in the mixing area.

In the carbon bake area of one plant, the packer/unpacker occasionally wore a dust respirator, specifically during the task of blow cleaning the preformed hole.

Dust respirators are required for prebake pot rebuilding operations such as digging out pot walls. In one plant, workers who perform the pot ramming operation, wear single use half mask respirators for hydrocarbon emissions. At another plant, workers in the pot-ramming area use pneumatic tampers to line the pot with a monolithic cathode-paste lining. These workers are exposed to volatiles from the paste during this operation, and are required to wear half mask respirators with the acid/gas organic vapor cartridges and particulate filter.

In a horizontal Soderberg paste plant the operator, who spends most of his time in a control booth or lunchroom supplied with conditioned fresh air, wears an half mask respirator equipped with acid/gas organic vapor cartridges preceeded by a particulate filter when collecting samples of the paste mix. The mobile equipment operator at this paste plant is required to wear the half mask respirator while he removes the paste from the mixer and fills the paste bucket that he transports to the potrooms or pot-ramming area.

In the potroom of the horizontal Soderberg plant the paste tender is required to wear respiratory protection during the time he is in the potroom. He uses either a half mask respirator or a full-face powered, air-supplied helmet. The paste tender cleans off the top of the paste box using compressed air, roughens the surface of the existing paste, lines the box with aluminum sheet, and adds fresh paste. During these tasks he is exposed to volatile hydrocarbons. The other potroom workers are required to wear half mask respirators, full-face powered air-supplied helmets, or full-face twin-cartridge respirators.

Because of reliance on respiratory protection in the paste plant and potrooms of this horizontal Soderberg facility, a respirator maintenance program under the direction of the plant industrial hygienist has been initiated. Each worker is responsible for cleaning and maintaining his assigned respirator. Replacement cartridges are available from foremen and maintenance stations equipped with cleansing compounds, disinfectant, and dryers are located in the break rooms. Area foremen periodically check the condition of the respirators. Complete replacement units are obtained through the store room.

PROTECTIVE CLOTHING AND SAFETY EQUIPMENT

Nearly all the aluminum plants surveyed require employees in the production areas to wear safety glasses usually with side shields, safety shoes, and hard hats. Potroom workers are required to wear long-sleeved shirts and safety shoes with nonconducting soles. One plant requires personnel to wear long-sleeved shirts, safety glasses with side shields and nonconducting hard-toes shoes in all areas of the plant. Another plant forbids workers to wear finger rings. This plant also requires workers to wear safety shoes with metatarsal guards and nonconducting soles. One plant offers potroom workers wood soles to attach to their safety shoes. At several plants goggles are worn during butt cleaning.

Hearing protection was used at several plants for these operations: unscheduled maintenance of ore handling equipment; using a hand-held pneumatic chisel to remove bath material; when removing cell superstructure for digging out pot cells; and working in the anode rodding room.

For specialized operations, almost all the surveyed plants provided additional safety equipment such as aluminized jackets, face shields, goggles, gloves, spats, air-supplied respirators, self-contained breathing respirators, and safety belts.

MEDICAL

The study team found that all the aluminum plants surveyed provided some type of medical assistance by physicians, registered nurses, or medical technicians. Generally, companies provided a physician on-site for from 4 to more than 20 hours per week and employed from 1 to 6 full-time registered nurses or medical technicians. Pre-employment physical examinations were required at all U. S.

plants surveyed. These examinations typically included a general examination, pulmonary function test, sight and audiometric tests, urinalysis, blood test, chest x-ray, and EKG (if employee is over 35). The examination may include sputum analysis, pelvic examination, and a psychological test. In some plants annual examinations are given to employees over 40; all others receive examinations every other year. One company offers an annual physical examination to potroom workers and some auxillary personnel, and another company offers an annual examination to all hourly personnel.

Most of the plants routinely measure pre-shift and post-shift urinary fluoride levels. Typically, the preshift specimen is taken following two days off the job. The post-shift test is conducted at the end of three to seven consecutive work days. If the pre-shift fluoride level is greater than a certain level such as 4.0 mg/L, or the post-shift level is greater than a predetermined level such as 7.0 mg/L, the worker's dietary intake, personal hygiene, basic work practices, and environmental controls are further evaluated. Employee participation in the urinary fluoride program at three aluminum plants was 40, 80, and 80 to 90 percent. One company provide personnel potentially exposed to particulate polycyclic organic matter/coal tar pitch volatiles at least 30 days per year the opportunity for an annual cytologic examination of sputum.

SAFETY TRAINING

A number of plants hold monthly safety meetings. First-line supervisor in one plant are trained in first aid. Another company gives all new employees a booklet on safety to read and a series of questions on safety to answer. The questionaire is submitted to their supervisor.

VI. CONCLUSIONS

ORE UNLOADING OPERATIONS

1. The vacuum-type Hartmann unloader for alumina and coke is highly effective in reducing exposure to particulates in ore-handling operations. The Hartmann unloader is operated from an enclosed air conditioned cab overhead.

2. The ship unloading crane for alumina designed by Alesa Alusuisse Services appears to be an excellent method for raw materials unloading with reduced dust emissions.

3. The application of a fine spray of light oil to coke by the supplier before it is loaded on a ship results in much less dusting during unloading operations.

4. Covered conveyor belts with necessary exhaust ventilation can be highly effective in preventing the escape of dust and loss of valuable materials. One excellent example is a covered belt conveyor which carries ore from the barge unloading system along the river to the main storage silos. The cylindrical housing through which the conveyor runs is essentially monolithic and supports and encloses the conveyor. The housing has a vacuum system to collect ore that spills.

5. The alumina ore delivery system at a vertical-stud Soderberg plant minimizes dusting and spillage. Alumina is delivered to the potlines by a 6-ton truck. The trucks are filled at a station equipped with a cloth skirt (that encloses the delivery lines at the tank opening) and exhaust system and dust collector.

6. A railcar dumping building (although not observed in operation) may be an excellent system for controlling emissions during coke unloading.

CARBON PLANT

1. One of the most effective control technologies for minimizing worker exposure in the green carbon plant is to have operators monitor equipment from an enclosed ventilated control room. Several green carbon plants have highly automated operations eliminating the need for workers to present during paste production. In one plant the anode press is also operated remotely protecting the operator from possible exposure.

2. Covers and exhaust ports over all conveyors, drag chains, bucket elevators and transfer points in the green carbon plant significantly reduce emissions of coke dust.

3. The automated anode paste mixer and specially designed mixer hoods at one plant are very effective in reducing worker exposure.

4. The use of continuous paste mixers in green carbon plants effectively reduces exposure to polynuclear aromatic hydrocarbons by eliminating the need for continual operator presence.

5. The fully automated batch mixers in a horizontal stud Soderberg carbon paste plant eliminate the necessity for workers to be normally present around those operations. All operations are performed by a single operator from an air conditioned control room. Occasionally the operator, dolly drivers, casers, and maintenance persons do work in the paste plant production area.

6. NKM cranes are highly effective in reducing dust levels in the bake plant working area. The crane operator is able to avoid significant exposures by remaining in the enclosed cab while placing the anode blocks into the furnace pits, and removing the baked anodes. The NKM crane cab enclosure provided a seven-fold reduction in total particulate levels.

7. ECL cranes in the bake plant are very effective in reducing dust levels in the working area. Crane operators sit in an air conditioned cab to operate the crane.

8. Pit-size clamshell buckets used in the carbon bake plant have significant potential for reduction of coke dust levels.

9. Sufficient draft is maintained on the ring furnaces at a number of carbon bake plants to capture and burn volatiles given off by baking anodes, thus preventing escape of dust and fumes into the working area. At one plant ring furnace draft is automatically controlled.

10. Brick covers over the firing section of bake plant ring furnace reduce hydrocarbon emissions to the working area. One company official stated the use of the covers reduces fuel requirements and provides more uniform baking of the anodes.

11. In the carbon bake plant machines for removing furnace walls for rebuild reduce work time and greatly reduce worker exposure to dust associated with tearing walls down by hand. Rebuilding the flues outside the furnace pit also reduces worker exposure to dust and the need to work in confined spaces.

ANODE RODDING

1. In the rodding room, the hooding over the induction furnace (used to melt iron for anode rod assemblies) effectively reduces emissions to the workplace.

2. The slot exhaust system at the cast iron thimble pour station in the rodding room does an excellent job of removing metal fume from the work station.

3. Mechanical ramming of the anode stems performed at one plant eliminates emissions that are produced during anode stem operations.

4. The automatic welding system for stem repair has potential for reduced exposure to welding fume for the worker who sets up the stem for welding.

5. An aluminum spraying machine which uses air pressure to coat the anode block with molten aluminum eliminates much of the aluminum dust and fume exposure as well as the possibility of burns from the molten aluminum.

POTLINES

1. A most effective control technology found in the prebake potline operations is the pot hooding and exhaust systems. The hoods consisted of shields that are light, easy to handle, and permit pot operations such as carbon changing with a minimum of hood area open.

2. In prebake plants a dual draft control (high and low draft) on the pothoods for periods when shields are off the pots is a good approach for improving hood efficiency.

3. Computer control systems that automatically perform crust breaking and alumina ore addition reduce the need for potroom personnel to open pot hoods (in prebake plants). The computer also minimizes the duration of unfavorable operating conditions (such as anode effects) and the associated release of contaminants from the cell bath.

4. The specially designed ECL cranes allow quick anode changes and metal tapping while significantly reducing operator exposure.

5. Computer controlled semi-gantry cranes that perform pot operations such as ore addition, crust breaking, and elimination of anode effects, reduce significantly the number of workers required to be continually present near the pots.

6. A crucible cleaner essentially eliminates worker exposure for this operation.

7. A pneumatic alumina ore delivery system used for prebake pots reduces ore dust emissions.

8. A remote controlled pot-digger eliminates the need for an operator to work directly above a pot and reduces labor required for digging out the pot.

9 .The pot hood system for a horizontal-stud Soderberg cell effectively captures emissions to the potroom during the time the hooding doors are closed. However, draft is not sufficient to capture emissions efficiently during the times that the doors are open.

10. In a horizontal-stud Soderberg potroom many of the operations use semi-automatic machinery, or specially-designed equipment (such as oreing and channel pulling) that reduce the time that workers will be exposed.

11. The use of air conditioned, enclosed cab overhead cranes in horizontal stud Soderberg potrooms at one plant reduced exposure to the crane operator.

12. The cold shelters installed in a horizontal-stud Soderberg potroom may reduce worker exposure, but the effectiveness of this control technology depend on how much time a worker can actually stay in the shelter.

13. In a vertical-stud Soderberg potline operation, stud pulling was easily accomplished by a single person in a crane equipped with a Sumitomo-developed automatic paste dispenser. The crane operator is well protected from the cell emissions. Stud-pulling is a task that can result in high exposure to the anode crew.

14. A specially designed ventilated hood appeared to effectively contain and capture emissions released during the bake-in of a new vertical-stud Soderberg cell. The hood completely covers the lower portion of the cell during bake-in.

MISCELLANEOUS

1. The individual worker at the two primary aluminum smelting plants in Japan appeared to be extremely knowledgable about his job functions and to take pride in the performance of work. According to the management personnel at one plant this trait results in a clean, orderly work area, and also makes for a productive individual.

2. The full face powered air-supplied helmet worn by the operator of bob-cat power shovel during ore unloading, provides filtered air in the wearer's breathing zone and reduces his exposure to dust.

3. Along with the control techniques just described, good work practices, housekeeping, and maintenance of ventilation systems are essential for the protection of workers from excessive exposure.

VII. RECOMMENDATIONS

1. Receiving pitch in solid form may reduce exposure to pitch volatiles, however, this could not be confirmed from this study and further research is needed.

2. Conveyor belts for hot pitch and hot anode mix should be routinely scraped and cleaned. Otherwise these materials can drop onto the floor or equipment below releasing hydrocarbon fumes into the workplace atmosphere.

3. The ECL crane operator must keep the door of the cab closed to avoid unnecessary exposure. (Fogged windows or other visibility problems may require the crane operator to open the cab door; and in such cases efforts should be made to overcome the problems of visibility.)

4. In order for filtered air enclosed cabs and rooms to effectively protect the worker, filters must be checked frequently and replaced as needed.

5. The potential for exhaust fumes discharged from roof level stacks to reenter the working area should be recognized and evaluated for each process building.

6. High noise levels continue to be a significant problem in the anode rodding area. Extensive engineering will be required to reduce ambient noise levels to legal limits. Meanwhile, hearing protection should be worn by employees who are in the noisy areas for extended periods of time.

7. Where practical or efficient, a better respirator program would have one person assigned to clean, sanitize, and fit-test respirators.

REFERENCES

1. Taylor, W. Manufacturing Processes-Aluminum Manufacture, J. Soc. Occup. Med. 28:25-6, January 1978.

2. Varley, P.C. The Technology of Aluminum and Its Alloys. Newnes-Butterworths, London 1970.

3. The ABC's of Aluminum, Reynolds Metal Company, Louisville, KY, 1950.

4. General Industry Standards, U.S. Department of Labor, OSHA Safety and Health Standards (29 CFR 1910), OSHA 2206, November 1978.

5. Threshold Limit Values for Chemical Substances and Physcial Agents in the Workroom Environment, ACGIH, Cincinnati, OH, 1977.

6. Seim, H. J. Personal Communication. July 16, 1981.

☆U.S. GOVERNMENT PRINTING OFFICE: 1983--659-096/634

DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
CENTERS FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
ROBERT A. TAFT LABORATORIES
4676 COLUMBIA PARKWAY, CINCINNATI, OHIO 45226

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE. $300

Special Fourth Class-Book

U.S.MAIL

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF HHS
HHS 396

Redistribution using indicia is illegal.

DHHS (NIOSH) Publication No. 83-115