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ALUMAX OF SOUTH CAROLINA, INC.
GOOSE CREEK, SOUTH CAROLINA

NIOSH INVESTIGATORS:
C. Eugene Moss
Stanley A. Salisbury, CIH
Don Booher

I. SUMMARY

On April 20, 1990, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a health hazard evaluation (HHE) from employees at the Alumax of South Carolina Mt. Holly aluminum reduction plant, located in Goose Creek, South Carolina. Workers were concerned with dust, welding fumes, and possible health hazards associated with pot change-out, cruse cleaning, and pure bath. Because of the scope of this request, the evaluation was divided into two separate phases. The first centered on workers' exposure to gaseous and particulate fluorides, airborne metal fumes, and dust; the second phase addressed the levels of electromagnetic fields produced during potroom activities.

The first phase of the environmental evaluation was conducted on January 21-23, 1991, with the objectives being to monitor worker exposures to gaseous and particulate fluorides, airborne metal fumes, and crystalline silica. On May 18-20, 1992, NIOSH investigators conducted the second phase of this survey to evaluate potroom workers' exposure to electric and magnetic fields.

Environmental Survey

Personal breathing-zone (PBZ) and general area (GA) air samples were collected for gaseous and particulate fluorides, metal fumes, and dusts in the cathode change-out, carbon setting, bath pour-off, and several locations in Buildings 136 and 138. Air samples were collected for respirable free silica during the removal (also called "knock-out") of spent refractory liner.

The highest exposures to gaseous and particulate fluorides were limited mostly to workers involved in pot change-out and sweeping operations. Some PBZ concentrations exceeded the NIOSH Recommended Exposure Limit (REL), the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV), and the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit of 2.5 milligrams per cubic meter (mg/m^3) for an 8-hour time weighted average exposure to fluorides. The results of GA and PBZ samples collected for respirable crystalline silica suggest that potential over-exposures could exist during the knock-out of cruse and cruse lid refractory. Except for cathode repair welding operations, the concentrations of airborne metals were not significant. In non-welding environments, the metals present in the highest concentrations were aluminum and iron. Arsenic was not detected in any of the samples. There were trace amounts of chromium and nickel detected and concentrations were slightly above the NIOSH REL for these compounds. The NIOSH RELs for chromium and nickel are extremely low because these metals are carcinogens and NIOSH recommends that all work place carcinogens be controlled to their lowest feasible concentration.

Electric and Magnetic Field Survey

Static magnetic and sub-radiofrequency electric and magnetic field measurements were made on all potlines and other selected Alumax locations under normal work conditions over two shifts. Static magnetic field levels were as high as 673 gauss (G) at worker's locations but the time-weighted average (TWA) ranged from 150-160 G. The static

magnetic field levels did not exceed the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value of 600 G. Sub-radiofrequency electric and magnetic field levels ranged from 0.001 to 6 kilovolts per meter and 0.1 to 3 G, respectively. These levels were below the ACGIH TLV for sub-radiofrequency fields.

Hazard Determination

Based on the data collected in this survey, NIOSH investigators concluded the following: (1) over-exposures to fluorides can occur during activities such as pot change-out, replacing anodes, and sweeping; (2) potential over-exposures may occur to respirable crystalline silica during removal of the spent refractory liner; (3) extremely low frequency (ELF) electric and magnetic field levels were not in excess of present occupational standards; (4) the static magnetic field (SMF) TWA levels did not exceed present occupational standards, although there is opportunity to reduce such levels; (5) electricians are the one occupational group that are exposed to high SMF and ELF fields; and (6) ELF fields were detected in the potline area. Some of the recommendations made in this report include conducting additional air monitoring for gaseous and particulate fluorides and total welding fumes and to initiate monitoring of electric and magnetic fields produced at various locations within the plant.

KEYWORDS: SIC 3334 (Primary Production of Aluminum), aluminum, static magnetic fields, potroom, ELF, fluoride, hydrogen fluoride, metal fume, crystalline silica, free silica.

II. INTRODUCTION

On April 20, 1990, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a health hazard evaluation (HHE) from employees at the Alumax of South Carolina (ASC) Mt. Holly aluminum reduction plant located in Goose Creek, South Carolina (see Figure 1). Employees were concerned with airborne dust, welding fumes, and other possible health hazards associated with pot change-out, cruse cleaning, and pure bath activities. Because of the scope of this request, the evaluation was divided into two separate phases. The first centered on workers' exposure to gaseous and particulate fluorides, airborne metal fumes, and dust; the second phase addressed the levels of electromagnetic fields produced during potroom activities. This final report includes the all measurement results obtained from both the first and second portions of this evaluation.

Environmental Survey

The first phase of the evaluation was conducted on January 21-23, 1991, and the results sent to Alumax in a NIOSH interim report dated May 14, 1991.[1] NIOSH investigators monitored worker exposures to gaseous and particulate fluorides, airborne metal fumes and dusts, and crystalline silica.

Electric and Magnetic Field Survey

On May 18-19, 1992, two NIOSH investigators visited the Mt. Holly facility and made static and sub-radiofrequency electric and magnetic field measurements in the potrooms and switching yards.

III. BACKGROUND

Alumax of South Carolina (ASC) is a subsidiary of Alumax Inc., the nation's third largest integrated aluminum company. ASC is a two potline primary aluminum company with an annual rated capacity of 200,000 tons. The 360 pots on the two potlines at ASC were brought into full operation in 1980. There were approximately 650 production and salary workers at the Mt. Holly facility during the time of this evaluation. Figure 1 shows the general layout of the facility.

In general terms, there are three basic resources required for the production of aluminum -- alumina, carbon, and electricity. Aluminum metal production requires the removal of oxygen from the alumina by an electrolytic process. This process is performed at ASC in rectangularly shaped steel shells or pots that have been lined with carbon blocks (the cathode). Alumina is conveyed to the pots by an overhead crane system and dissolved in a bath of molten cryolite (sodium aluminum fluoride). An electric current (approximately 186,000 amperes DC) is passed through carbon blocks (anodes) that are suspended in the cryolite. (It should be noted that the production of this current also forms high levels of static magnetic fields.) The electrical energy supplied causes the release of oxygen from the alumina which is attracted to the anodes. The liquid aluminum is attracted to the carbon cathode and is deposited at the bottom of the pot. Figure 2 illustrates the general procedures used by Alumax to make aluminum. The Mt. Holly facility produces T-shaped, rolling, and 30-pound foundry ingot shapes.

The facility has two potlines, divided into four potrooms. Each potroom is about 2100 feet long and houses 90 pots, for a total of 360 pots. Each pot contains 24 anodes, with 12 on each side of a pot. There are six metallic shields on each pot side that covers each pair of anodes. There are a total of 8640 anodes at the facility.

The production of every pound of aluminum requires a half-pound of carbon for anodes. The anodes at ASC are made from a paste of coal tar pitch and petroleum coke, blended and molded under heat and pressure into rectangular shapes weighing about 1700 pounds. The anodes have copper rods placed in their matrix in order to suspend them in the pots as well as carry electrical current. At 1800°F the anodes are slowly consumed and require replacement every 25 days.

IV. EVALUATION DESIGN AND METHODS

Environmental Survey

Personal breathing-zone (PBZ) and general area (GA) air samples were collected for gaseous and particulate fluorides, metal fumes, and dusts in the cathode change-out, carbon setting, bath pour-off, and several locations in Buildings 136 and 138. Air samples were collected for respirable free silica during the removal (also referred to as "knock-out") of spent refractory liner from a cruse and cruse lid.

Fluorides (NIOSH Method 7902)

The revised NIOSH Sampling and Analytical Method No. 7902 for fluorides uses an integrated sampler cassette.[2] The front section of the cassette, containing a 37 millimeter (mm) mixed cellulose ester membrane filter (0.8 micron pore size) and a porous plastic backup pad, collects particulate fluorides. A backup section, containing a treated cellulose pad, collects gaseous fluorides. Following collection, the samples were analyzed by ion chromatography instead of analysis by ion specific electrode. This modification in the analysis was intended to offset negative bias in fluoride results caused by cryolite and aluminum oxide interferences.

Hydrogen Fluoride (NIOSH Method 7903)

For comparison to the revised NIOSH Method No. 7902, gaseous fluoride (as hydrogen fluoride) was sampled using NIOSH Method 7903.[2] Air samples were collected on silica gel sorbent tubes and analyzed by ion chromatography.

Metals (NIOSH Method 7300)

A quantitative determination of trace elements was made by collecting air samples on 37 mm diameter mixed cellulose ester filters (0.8 micron pore size). A sampling flow rate of 2.0 liters per minute (lpm) was used. The samples were analyzed by inductively coupled plasma-atomic emission spectrometry according to NIOSH Sampling and Analytical Method No. 7300.[2]

Respirable Dust (NIOSH Method 0600) and Crystalline Silica (NIOSH Method 7500)

Respirable dust samples were collected according to NIOSH Sampling and Analytical Method No. 0600.[2] Air samples were collected on 37 mm, 5.0 micron pore size tared polyvinyl chloride (PVC) filters using a standard 10 mm nylon cyclone. A flow rate of 1.7 lpm was used to optimize collection efficiency for dust particles smaller than 10 microns in diameter.

Quartz and cristobalite forms of crystalline silica were determined utilizing X-ray diffraction analysis in accordance with NIOSH Sampling and Analytical Method 7500.[2]

Electric and Magnetic Field Survey

Measurements of occupational levels of static magnetic and sub-radiofrequency electric and magnetic fields found in the potroom and electric switch yard of the Mt. Holly facility were designed to survey actual worker exposures to both electric and magnetic fields while they performed their work tasks in the aluminum reduction facility. While there is interest in determining exposure to magnetic fields, few published studies have been performed on aluminum reduction plant workers occupationally exposed to SMF.

Little information is known about the types and intensity of electromagnetic fields produced in aluminum reduction plants. However, it is reasonable to assume that potroom workers can be exposed to static magnetic fields (SMF) created by direct current at typical 30-130 kiloamperes (kA) levels used in electrolytic cells. These SMF can be both homogeneous and non-homogeneous depending upon how and where they are produced. As a result, these non-homogeneous SMF can have intense or small gradients and may be difficult to evaluate. In addition, it is also possible to have time-varying fields in aluminum plants that use rectified currents due to "AC ripple" from the incoming alternating current.

Thirty-five different data sets were recorded that measured SMF under different conditions. The number of measurements per data set varied considerably since different parameters were investigated at different locations and at different times. The number of measurements per data set ranged from as low as two to as high as 40, with the average being approximately ten. All SMF measurements were collected in this evaluation using an orthogonal sensing probe. This method was used since it would collect magnetic flux in all directions and the resultant value would be of more occupational significance than just data obtained from one direction. Measurements were taken along all pot lines, at different distances from the pot lines, on top of the catwalk between pots, underneath the pots during clean-out sessions, above the pots, at the end and middle of each pot room, in the switch yard, and near the rectifiers. The following equipment was used to document levels of electromagnetic fields (extremely low frequency [ELF]) produced at ASC:

Sub-radiofrequency Electric and Magnetic Fields

A Holaday Industries, Inc. model HI-3602 ELF Sensor, connected to a HI-3600 survey meter, was used to document both the magnitude of 60 hertz (Hz) electric and magnetic fields and the electrical frequency (as well as the waveforms) produced by such fields. The electric field (E-field) strength can be measured either in volts per meter (V/m) or kilovolts per meter (kV/m). The magnetic field (H-field) strength can be expressed in units of milligauss (mG). The nominal frequency range for this measurement system is 30 to 1000 Hz.

Sub-radiofrequency magnetic field measurements were also made with the EMDEX II exposure system, developed by Enertech Consultants, under project sponsorship of the Electric Power Research Institute, Inc. The EMDEX II is a programmable data-acquisition meter which measures the orthogonal vector components of the magnetic field through its internal sensors. Measurements can be made in the instantaneous read or storage mode. The system was designed to measure, record, and analyze power frequency magnetic fields in units of mG in the frequency range from 30 to 800 Hz.

Static Magnetic Fields

A GMW model DTM-132-DS static magnetic field system was used to measure SMF during this survey. This system has three separate digital tesla meters, packaged in a small cabinet, which is separated from three single axis probes (GMW model LPT-130-30) mounted orthogonally in a specially designed probe by a 20 meter (m) nylon cable (see Figures 3 and 4). The specially designed probe was always held by the NIOSH investigators in the same orientation, as shown in Figure 4, for all measurements made in this evaluation. Each of the single axis probes is capable of reading up to a maximum of 3000 gauss (G) with a resolution of 0.5 G. The portable system is battery operated and can be recharged in four hours. Background levels of static magnetic fields were documented with the probe outside of the building and at distances greatly removed from the potrooms. A small, round magnet (2.5 cm diameter) was used as a check source for field calibration purposes.

In addition, a limited number of area measurements were made with the Holaday monitors at selected work locations inside the facility. All measurements were made during daylight hours at waist height. Where possible, at least two readings were taken at each measurement site with the Holaday monitors and the average reading recorded. At this point in time, the lack of instrumentation or dosimetry techniques prevents the ability to monitor an individual worker for exposure to magnetic field.

All equipment used to document exposure to electric and magnetic fields had been calibrated within six months use either by NIOSH or their respective manufacturer. Most measurements were taken at positions considered to be typical of occupational exposure (one meter away and one meter from the floor).

V. EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed without experiencing adverse health effects. It is, however, important to note that not all exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or a hypersensitivity situation.

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects, even if the occupational exposures are controlled at the level set by the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus, potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information about chemical and physical agents become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH criteria documents and recommendations, (2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV), and (3) the U.S. Department of Labor (OSHA) occupational health standards.[3,4,5] Often, the NIOSH recommendations and ACGIH TLVs are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLVs usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended standards, by contrast, are based primarily on concerns relating to the prevention of occupational diseases. In evaluating the exposure levels and the recommendations for reducing these levels found in these reports, it should be noted that industry is legally required to meet those levels specified by an OSHA standard.

At present there is limited information from OSHA on exposure criteria for workers exposed to physical agents. Criteria for physical agents not covered by OSHA come from either ACGIH, NIOSH, or in some cases from consensus standards promulgated by the American National Standards Institute (ANSI).

<u>Inorganic Fluorides</u>

Inorganic fluorides may be a component of brazing fluxes and certain types of welding rods.[6,7,8] When fluoride-containing materials are present, both particulate and gaseous forms of fluoride can be liberated during the brazing or welding process. Exposure to fluorides can cause irritation of the eyes and respiratory tract, and long-term absorption of excessive amounts has caused fluorosis.[8,9] Carcinogen studies, conducted primarily to evaluate the effect of water fluoridation, indicate that there is inadequate evidence for carcinogenicity in humans.[10] The NIOSH REL for inorganic fluorides is 2.5 milligrams per cubic meter (mg/m^3) as a 10-hour time-weighted average (TWA), and is intended to prevent skeletal fluorosis (osteosclerosis, increased bone density due to excessive absorption of fluoride).[3,7] The ACGIH TLV and OSHA PEL for inorganic fluorides have also been set at 2.5 mg/m^3 for an 8-hour TWA exposure.

Silica (Quartz, Cristobalite)

Crystalline silica (quartz) and cristobalite have been associated with silicosis, a fibrotic disease of the lung caused by the deposition of fine particles of crystalline silica in the lungs. Symptoms usually develop insidiously, with cough, shortness of breath, chest pain, weakness, wheezing, and non-specific chest illnesses. Silicosis usually occurs after years of exposure, but may appear in a shorter period of time if exposure concentrations are very high.[11] The NIOSH RELs for respirable quartz and cristobalite, published in 1974, are 50 micrograms per cubic meter ($\mu g/m^3$), as TWAs, for up to 10 hours per day during a 40-hour work week.[12] These RELs are intended to prevent silicosis. However, evidence indicates that crystalline silica is a potential occupational carcinogen and NIOSH is currently reviewing the data on carcinogenicity.[13,14,15] The OSHA PELs and the ACGIH TLV®s for respirable quartz and cristobalite are 100 and 50 $\mu g/m^3$, as 8-hour TWAs, respectively.[4,5]

Metals

Table 1 summarizes the health effects of the metals which were measured in detectable quantities during sampling conducted on January 21-23, 1991.

Static Magnetic Fields[16-19]

In general, there are two conditions for magnetic field exposures which need to be understood. Exposures can occur either from a steady or time-varying field exposure. In a steady magnetic field the flux does not change with time and will not cause current to flow in a fixed object. In a time-varying field the magnetic flux passing through a surface changes with time and can induce an electrical current flow in conductive objects. Both types of fields create different biological effects.

Exposure to SMFs has been linked to slight increases in blood pressures, alternation in operation of artificial cardiac pacemakers, movement of implanted metal objects, rotation of sickle cells, influencing length of circadian cycle, and attractiveness of metal objects. Many scientists believe that the effect of static magnetic fields are very subtle and may not represent a particularly hazardous exposure. There have been no official occupational health limits set for SMFs. The Stanford Linear Accelerator Center proposed, in 1971, values of 2000 to 20,000 G, depending on time and exposure area of body, for an upper limit based on lack of complaints. In 1979, the Department of Energy, based on potential biological effects, established a level of 20,000 G. The only other limit for this type of exposure has been proposed by ACGIH in 1987. The ACGIH TLV for static magnetic fields states "Routine occupational exposures should not exceed 600 G whole body or 6000 G to the extremities on a daily, time-weighted average basis. A flux density of 20,000 G is recommended as a ceiling value."

Sub-Radiofrequency Electric and Magnetic Fields

At the present time there are no OSHA or NIOSH exposure criteria for sub-radiofrequency fields. The ACGIH has published TLVs for sub-radiofrequency electric (E) and magnetic (H) fields.[4] The TLV for magnetic fields (B_{TLV}) states "routine occupational exposure should not exceed:

$$B_{TLV} \text{ (in mT)} = 60/f$$

where f is the frequency in hertz." One millitesla (mT) equals 10 G. Conversely, the electric field TLV states "occupational exposures should not exceed a field strength of 25 kV/m from 0 to 100 hertz (Hz). For frequencies in the range of 100 Hz to 4 kHz, the TLV is given by:

$$E_{TLV} \text{ (in V/m)} = 2.5 \times 10^6/f$$

where f is the frequency in hertz. A value of 625 V/m is the exposure limit for frequencies from 4 kHz to 30 kHz."

This means, for example, at 60 Hz, which is classified as ELF, the electric field intensity TLV is 25,000 volts per meter (V/m) and the magnetic flux density TLV is 1 mT or 10,000 milligauss.

The basis of the ELF E-field TLV is to minimize occupational hazards arising from spark discharge and contact current situations. The H-field TLV addresses induction of magnetophosphenes in the visual system and production of induced currents in the body.

VI. RESULTS

Environmental Survey

Tables 2 and 3 contain the results from GA and PBZ air samples for gaseous and particulate fluorides. The NIOSH, ACGIH, and OSHA exposure limits for airborne gaseous or particulate fluorides are 2.5 mg/m^3 for an 8-hour TWA exposure. The samples which exceeded this limit were mostly limited to workers involved in the pot change-out operation. Excess exposure was also found for the sweeper operator.

Table 4 shows the results of GA and PBZ samples collected for respirable crystalline silica. Although only three samples were collected (two GA samples and one PBZ sample), both quartz and cristobalite were detected during the knock-out of cruse and cruse lid refractory.

Table 5 contains the results of samples for airborne metals in Buildings 136 and 138, as well as the Rod Shop and under the pots. Except for cathode repair welding operations, the concentrations of airborne metals were not significant. In non-welding environments, the metals present in the highest concentrations were aluminum and iron. Arsenic was not detected in any of the samples. There were trace amounts of chromium and nickel detected in some samples and these concentrations were slightly above the NIOSH REL for these compounds. The NIOSH RELs for chromium and nickel are extremely low because these metals are carcinogens and NIOSH recommends that all work place carcinogens be controlled to their lowest feasible concentration.

Electric and Magnetic Field Survey

Results for this evaluation are presented in one of three major categories: SMF, sub-radiofrequency electric or magnetic fields, or other findings.

Static Magnetic Fields

A. **SMF levels as a function of distance from the potlines.** Three different data set measurements were made on randomly selected pots (243, 244, and 231) to determine the SMF levels at varying distances from the potline. The results of these measurements were fitted to a third order polynomial and are shown in Figure 5. Several confirming checks were made at other pots in different potrooms that verified Figure 5. These confirming check measurements all agreed to within ±10%. All measurements were taken with the GMW instrument probe positioned in a tripod 107 centimeters (cm) from the ground.

B. **SMF levels as a function of location along the potlines.** In a series of preliminary measurements made along the potline it was demonstrated that:

1. SMF levels documented at the center line of a pot were higher than that recorded at the first landing on steps between the two pots, leading up to the elevated pot line platform, as shown in Figure 6.

2. SMF levels at two different heights (42" [107 cm] and 60" [152 cm]) were measured at a probe to pot distance of 79 cm and at every 41 cm horizontally across the top end of pot 243. The result of these measurements is shown in Figure 7 and indicates that the levels measured at 42" gave higher SMF levels. The figure shows that two SMF maximum points exist midway between the edge and center line of the pot (i.e., location 3 and 8, respectively).

   Using the findings reported in (A) and (B) above it was decided to take SMF measurements at locations along the potline as indicated in Figure 8a. The results of these measurements are shown in Figure 8b. Notice the consistent and relatively repetitive nature of the results as they vary over the range from 100 to 175 G at a pot to probe distance of 79 cm and at a probe height of 107 cm. SMF measurements were also performed on both sides (top and duct) of a given potroom at the same pot to probe distance. The results shown in Figure 9 indicate that there is not any radical difference in SMF levels from one side or the other. However, it was observed that the duct side of pots always had the smallest walkway which could result in somewhat higher occupational SMF levels due to the closer distance to the potline.

C. **SMF as function of worker's height.** Occupational measurements were made in several places and at different locations to estimate the SMF levels as a function of distance above the pot room floor. In making these measurements it became apparent that SMF levels measured at a worker's ankle were approximately two times greater than the levels measured at a head location. This finding was documented at several spots.

D. **SMF levels on elevated pot line platforms and near risers.** Since workers can and do walk up onto the elevated potline platform to perform various job tasks, SMF measurements were made at many different locations. In addition, risers were situated at some of the elevated platforms. The presence of these risers can produced high localized SMF levels.

Some preliminary measurements performed at Mt. Holly by NIOSH indicated that measurements made closer to the anode shield locations along the pot were higher than those further away (Figure 10). Using this information, and the fact that SMF measurements reported in section VI/A/3 showed that levels were almost two times higher for ankle locations than head locations, NIOSH investigators decided to make ankle measurements at anode locations along the width of several pots as a indicator of potential occupational exposure. These measurements were made 6" off the elevated platform deck at a position 6" in front of each anode shield and at an angle of about 45 degrees. These ankle-like measurements were altered by the presence of the risers. Results are shown in Table 6 and were obtained in all four buildings at the beginning and end of each potline. The SMF values from these eight pots ranged from 46 to 277 G. The impact of the presence of the risers on these measurements is clearly shown in Figure 11 for these same pots.

While the risers did influence the anode measurements made at ankle-height, they were also capable of producing some very high SMF levels. Measurements made at 2 and 12" from one side of a typical riser yielded levels as shown in Figure 12. These levels were approximately the same magnitude on the other side of the riser. In addition, measurements of several risers along different potlines produced results ranging from 344 to 522 G. It should be noted that even more elevated SMF levels occurred in the space between lines with two risers.

E. **SMF measured underneath pots.** There are workers who must work and clean in the space underneath pots. This work is performed normally by three-man teams who rotate job functions over the two to three hours it takes to clean this space. A team might clean three pots in a day. Measurements of SMF were made by the NIOSH investigators in such spaces after it was cleaned. Levels ranging from 82 to 680 G were documented, with the highest levels being found near the underground risers. This work activity has a high exposure potential since workers involved with cleaning procedures can be found at various locations under the pots for various time periods, depending on cleaning requirements. The average exposure under the pots is probably on the order of 200 to 300 G.

F. **SMF at mid-pot line cross-over and end of pot line areas.** There is a break in the middle of all four potlines to allow movement of personnel and equipment. During the course of a day workers will pass through these areas in performing various work tasks and duties. At these mid-potline areas the pot buss, carrying the DC current, travels for 40 feet under the potroom floor, at a depth of three feet, to the next pot. Measurements were made at waist level at two cross-over locations (between pots 445-446 and 245-246). Workers standing directly over the current path were exposed to levels of 120 to 135 G and, if standing away from the current path, were exposed to about 70 G.

At the beginning and end of each pot line there is a small space that workers can sometimes be located. At the beginning of a potline the electrical current enters from the transformer yard, while at the end of the potlines connections are made with the returning potline path. As with the mid-potline areas, the current path is also under the floor. These latter areas do not have as much traffic as the mid-potline areas, but some workers responsible for moving ladles can be found there several times during the course of a workday. If workers stand directly over the current path the SMF levels, as measured on pot 490, were as high as 179 G. However, these levels can be much smaller depending on the location where the worker stands. Overall, these levels were approximately within 20% of those recorded for the mid-potline areas.

G. **SMF levels in break-out rooms.** During non-work time periods employees often use designated "break-out" rooms for rest and eating. SMF measurements in these areas were less than 1 G, which is approximately equivalent to natural background levels. The NIOSH investigators do not consider SMF levels in these rooms to be of any major occupational concern.

H. **SMF levels above the superstructure and possible crane personnel exposure.** In each potroom, cranes are used to move anodes and ladles from one location to another. Since these cranes can come close to the top of the pots, measurements were made to estimate the potential exposure to SMF. Measurements made 13.3 feet off the ground and above pot 490 gave levels ranging from 90 to 118 G. The bottom of the crane housing can be located as low as 14 feet off the ground which suggest that foot exposure to crane personnel might be as high as 100 G for those time periods when the cranes are positioned over pots (i.e., anode replacements). According to company personnel, cranes are rarely positioned over a given pot for an extended period of time, such as 30 minutes, and, often, are not located/positioned over the superstructure when performing job tasks.

Extremely Low Frequency Levels

Limited measurement of ELF electric and magnetic field levels was made in the switching yard area, in the presence of 13.5 kV transformers and other AC sources, that produced 5 to 6 kV per meter (E-field) and magnetic field levels as high as 400 to 500 mG. Attempts were made to make measurements where facility electricians would be located. As the AC field undergoes rectification, levels of AC magnetic fields increased at some places in the rectification room to over 3 G. At locations in the potroom where the DC field was introduced into the potlines there were a few areas where both SMF and AC fields existed simultaneously. It was very apparent to the NIOSH investigators that electricians are the one group that can be exposed to high SMF, high E-fields (ELF), and high H-fields (ELF). Finally, ELF electric and magnetic field levels were recorded around pots 301 to 303 ranged from 3 to 5 mG and 1 to 2 V/m, respectively.

Other Findings

Workers can reach the elevated pot locations in the potrooms by climbing up small ladders, consisting of four tiers, which are positioned close to every pot and located over the buss bar on both sides of the pots. In general, most of these ladders are rigidly affixed but, during the course of the evaluation, it was observed that several ladders were loose and tilted to one side when stepped on by workers. Since we believe this potential trip/fall hazard required immediate attention, the safety personnel were alerted at the time of the site visit.

VII. DISCUSSION AND CONCLUSIONS

Environmental Survey

Fluorides

Based on the samples collected for gaseous and particulate fluorides, some Alumax workers are exposed to total fluoride levels in excess of the NIOSH REL, ACGIH TLV, and OSHA PEL of 2.5 mg/m^3. For example, total fluoride exposures on pot change-out workers ranged from 0.61 to 39.49 mg/m^3. While two of these personal samples were unusually high (14.14 and 39.49 mg/m^3) and should be treated as suspect (or contaminated) samples, the concentrations from the remaining PBZ samples on pot change-out workers suggest that exposures can exceed the 2.5 mg/m^3 exposure criteria.

Metals

Except for cathode repair welding operations, the concentrations of airborne metals were not significant. As may be expected at an aluminum reduction plant, in non-welding environments the highest metal concentrations were aluminum and iron. Chromium and nickel were detected in small amounts in some of the air samples. NIOSH considers these substances to be carcinogens and recommends that they be controlled to their lowest feasible concentration.

Lithium compounds were unexpectedly detected in both of the welding fume samples (see Table 5). According to a Material Safety Data Sheet (MSDS) obtained for the welding rods used in the Cathode Repair area, lithium compounds, as well as aluminum, magnesium, calcium, barium, potassium, sodium, silicon, sodium, and various other metallic and non-metallic compounds, are part of a complex mixture of chemicals typically present in welding fume. The MSDS further states that these compounds are not present in pure form, but only as complex combinations with other ingredients. Finally, the MSDS states that concentrations of these individual elements are still well below their respective PELs when total welding fume concentrations reach the OSHA PEL of 5 mg/m^3. While the NIOSH monitoring results for airborne metals support this MSDS statement, total welding fume concentrations were not measured during this evaluation.

Free (Crystalline) Silica

The results from the limited sampling conducted as part of this evaluation (two GA samples and one PBZ sample) suggest that there is a potential risk from exposure to respirable crystalline silica. Both quartz and cristobalite (forms of crystalline silica) were detected during the knock-out of cruse and cruse lid refractory material.

Electric and Magnetic Field Survey

Static Magnetic Fields

The major results of the data taken during this evaluation clearly shows the following:

A. SMF levels to worker's extremities are about ten times higher than those for whole body exposure.

B. Work performed under the pots results in a higher SMF time-weighted average exposure than any other job task.

C. SMF levels can vary considerably from one pot to another.

D. Work performed near the risers, whether above or below pots, will always produce higher SMF levels than work away from the risers.

E. While there are some locations at Mt. Holly which can produce SMF levels as high as 600 G, there were no indications that workers exceeds a TWA value of 600 G anywhere in the facility. This means that occupational exposure to SMF at Alumax is below the ACGIH TLV. This same conclusion was also reached based on magnetic field measurements performed by Alumax staff in an in-house report dated November 14, 1990. The 1990 report was based on field SMF measurements made for the whole body and chest, and compared to a computer model.

F. SMF tend to drop off rapidly as function of distance from their source.

G. SMF levels produced in pipes and/or nearly circular objects gave consistently higher SMF levels than non-pipe like objects. Measurements made 6" away from a 4" circular buss support channel close to the floor found levels as high as 690 G. Workers would stand near these channels as they write messages on the pot walls. These buss support channels are found on both sides of the pot. Exposure to the magnetic fields produced within these sources could be reduced if the channels were capped or shielded.

H. Shielding of SMF will be difficult and costly to accomplish. A quick test was performed on pot 244 to verify the shielding effectiveness of the anode covers. Measurements were made at the same distance from a given anode with and without its cover. The results of that test indicated that the cover afforded minimal SMF attenuation.

I. Various metal components found in the potroom, such as ladles, scrap metals, rods used to stir the aluminum ore, and pots taken out of action can have residual magnetic field effects that can contribute to worker exposure.

J. Anode replacement operations create a need for some workers to be in close contact with the pot line and sometimes in close proximity to the risers (depending on which pot is replaced). It was observed that the anode replacement operation took less than five minutes to complete. Hence, exposure to the higher fields that can occur at riser positions will be of a short duration.

Sub-Radiofrequency Fields

As far as it is known, prior to this evaluation no report existed that demonstrated the presence of ELF electric and magnetic fields in the immediate vicinity of the pots. These levels are relatively small, i.e., 1-2 V/m and 3-5 mG, respectively.

The presence of ELF fields in the switching yard is not at all unexpected. The magnitude of ELF present in the potrooms is from the rectification process. However, few if any workers are located for long periods of time at these locations.

VIII. RECOMMENDATIONS

1. Alumax should consider purchasing appropriate static magnetic and sub-radiofrequency electric and magnetic field monitoring instruments for use at the various areas within the facility, especially during service and maintenance activities.

2. The Health and Safety Group should initiate monitoring for levels of static magnetic fields and sub-radiofrequency electric and magnetic field produced at various sites within the plant.

3. Based on the air sampling results from this NIOSH evaluation, Alumax employees should be required to wear NIOSH-approved respirators during operations such as pot change-out, anode replacement, and sweeping to protect against possible over-exposures to total fluorides. The use of these respirators should be considered an interim measure while engineering or administrative controls are evaluated which could reduce workers exposures and eliminate the need for respiratory protection.

4. Additional monitoring for gaseous fluorides should be made during bath pour-off operations.

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X. AUTHORSHIP AND ACKNOWLEDGMENTS

Report Prepared By:	C. Eugene Moss, HP, CSS Health Physicist Industrial Hygiene Section
	Stanley A. Salisbury, CIH Industrial Hygienist Atlanta Regional Office
	Gregory A. Burr, CIH Industrial Hygienist Industrial Hygiene Section
Field Assistance By:	Calvin K. Cook Industrial Hygienist Industrial Hygiene Section
	Don Booher Technician Industrial Hygiene Section Industrywide Studies Branch
	Charles D. Lorberau Chemist Methods Development Section Division of Physical Sciences and Engineering
Originating Office:	Hazard Evaluations and Technical Assistance Branch Division of Surveillance, Hazard Evaluations and Field Studies
Report Formatted By:	Ellen E. Blythe Office Automation Assistant

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