U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
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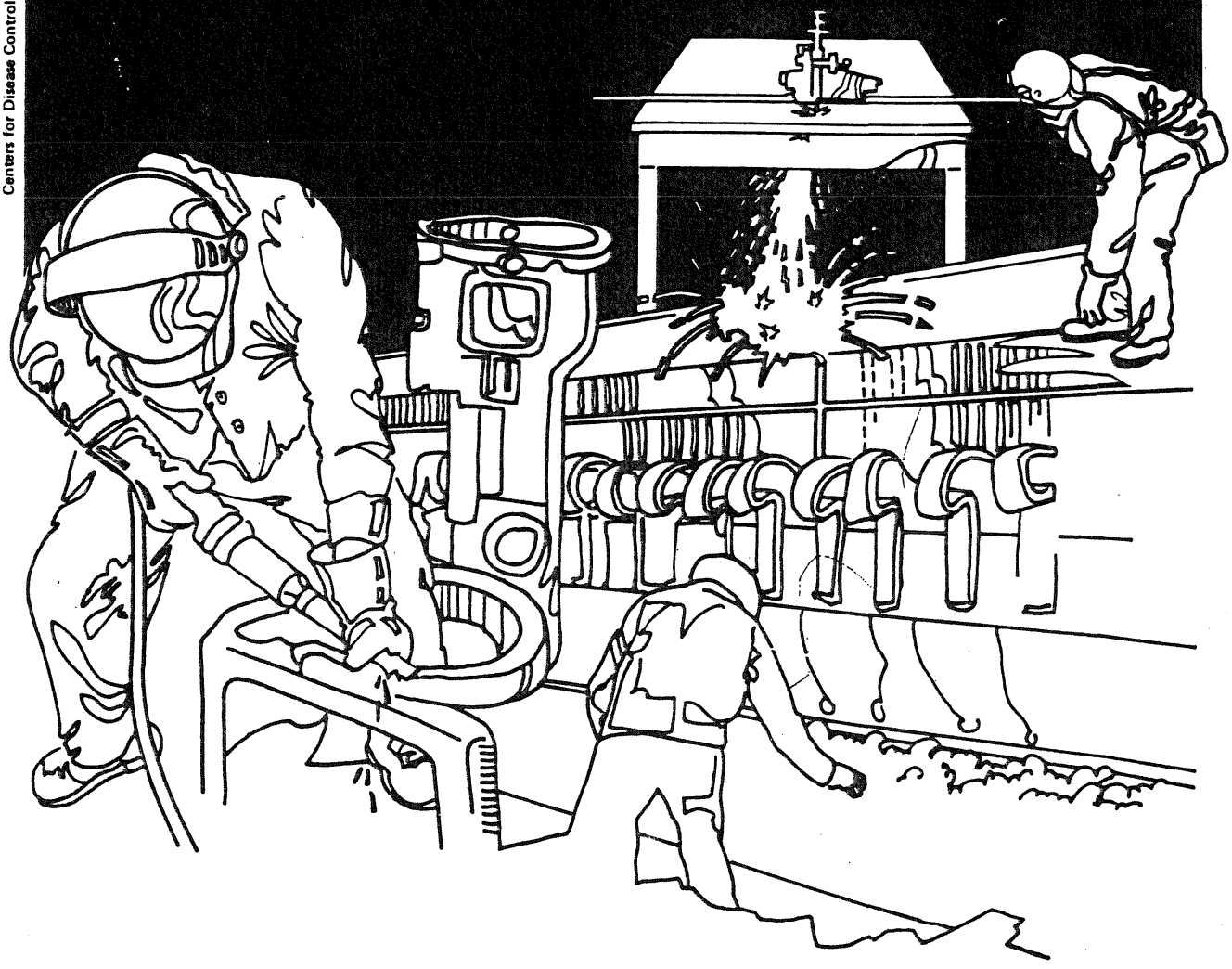
NIOSH



Health Hazard Evaluation Report

HETA 80-124,230-1168
(REVISED APRIL 1984)
ALUMINUM COMPANY OF AMERICA
ALCOA, TENNESSEE

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

HETA 80-124, 230-1168
AUGUST 1982
(REVISED APRIL 1984)
ALUMINUM COMPANY OF AMERICA
ALCOA, TENNESSEE

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I. SUMMARY

On May 2, 1980, the National Institute for Occupational Safety and Health (NIOSH) received a request from the United Steelworkers of America, Local 309, for a Health Hazard Evaluation at the Aluminum Company of America, Alcoa, Tennessee. The request sought evaluation of possible exposures to asbestos at the ingot preheating furnaces, to chlorine gas at the ingot remelt and casting areas, and to rolling oil at the hot mill area. A second request, received on August 25, 1980, sought evaluation of possible exposures to rolling oil at the cold mill area, to solvent vapors at the coil finish and paint lines, to caustic mist at the caustic etch line, and to lead in the battery repair area.

On May 20-21 and September 8-9, 1980 NIOSH investigators conducted initial walk-through investigations. Environmental measurements were performed October 6-10, and medical questionnaires and pulmonary function tests were administered to workers on November 2-6, 1980.

On the days of sampling, the following levels of worker exposure were measured: chlorine gas (up to 0.1 ppm); rolling oil mist (up to 1.1 mg/M^3); ethylene glycol (0.3-0.5 mg/M^3); kerosene (4.3-6.5 mg/M^3); sodium hydroxide (up to 0.64 mg/M^3); xylene (2.5-4.6 mg/M^3). None of these values exceeded the appropriate OSHA and ACGIH standards. Measurements for asbestos fibers, triorthocresyl phosphate, diethylamine, butylated hydroxytoluene, methyl ethyl ketone, and toluene did not exceed the limits of detection. Nitrosamines, which are potent animal carcinogens, were detected in the hot mill area. Polynuclear aromatic hydrocarbons (PNAs) were detected in 2 hot mill area samples. At the coil finish line, levels of perchloroethylene, considered by NIOSH to be a suspect carcinogen, ranged from 5-10 ppm.

The medical evaluation showed cigarette smoking to be associated with increased reporting of shortness of breath with exertion, cough, phlegm production, wheezing, and obstructive pulmonary function changes (decreased FEV_1, FEV_1/FEC, and MMEF).

Cold mill workers showed evidence of restrictive lung changes relative to hot ingot workers. This would be consistent with evidence that exposure to mineral oil mist can cause fibrotic lung changes, but further investigation would be required to verify this finding. Hot ingot workers intermittently exposed to chlorine did not show evidence of chronic obstructive lung changes. However, because less than half of this group participated in the study, possible hypotheses relating to long-term effects of chlorine exposure could not be thoroughly evaluated. No evidence of neurological problems due to rolling oil exposure was found.

Based on the results of this investigation, NIOSH concludes that a health hazard did not exist on the days of the study, but some workers were exposed to nitrosamines and perchloroethylene, both suspect carcinogens. Measures to reduce possible exposure to chemical and physical hazards and for medical monitoring of workers potentially exposed to chlorine are summarized.

KEYWORDS: SIC 3353 (Aluminum Shut, Plate, and Foil), rolling oil, chlorine, soduim hydroxide, asbestos, nitrosamines, PNAs, perchloroethylene.

II. INTRODUCTION

On May 2, 1980, the National Institute for Occupational Safety and Health (NIOSH) received a request (HE 80-124) from the United Steelworkers of America, Local 309, for a health hazard evaluation at the Aluminum Company of America in Alcoa, Tennessee. The requestor was concerned about possible exposures to toxic substances in three areas: the ingot preheating furnaces, where asbestos is in use; the remelt building and casting stations, where chlorine gas is used as a fluxing agent; and the hot mill area, where employees are exposed to oil. Employee health complaints included pulmonary irritation, skin rashes, eye irritation and possible neurological disorders.

On May 20-21, 1980 NIOSH investigators met with ALCOA management personnel and a union representative to explain the nature and scope of the health hazard program. A walk-through survey of the hot mill, remelt area and ingot preheat furnaces was conducted. Employees were interviewed with regard to work exposures and reported health problems. Medical records and environmental records were reviewed. A bulk sample of the rolling oil (XL-2178) used in the hot mill was requested for laboratory analysis of potential thermal decomposition products of the oil. This request was refused by ALCOA's management representatives, who cited the proprietary nature of the rolling oil. ALCOA later provided a generic listing of the components of the rolling oil to NIOSH, along with a selected toxicological review of those generic components.

On August 25, 1980, a second request for a health hazard evaluation (HE 80-230) at ALCOA was received from Local 309 of the USWA. Employees requested an evaluation of five additional exposures: potential rolling oil exposures in the cold mill area, solvent vapors at the coil finish line and paint line, caustic mist at the caustic etch line, and lead in the battery repair area.

On September 8-9 NIOSH personnel conducted a walk-through of the areas requested in HE 80-230. Environmental sampling had been proposed for the hot mill during this visit, but ALCOA informed NIOSH that the hot mill had burned out a bearing and might not be operating until September 10. In light of this problem, plans for environmental sampling were postponed and combined with later sampling in the areas for HE 80-230.

A number of the processes cited in HE 80-230 could not be observed during the days of the visit. Two of the four cold mills were not operating, including the single stand mill (C mill), to which many health complaints had been attributed. The coil finishing line was inoperative because of problems with the leveler. The vinylate process in the paint line area was not in operation and was being phased out with only one more run scheduled.

The caustic etch line, paint line, battery repair, 44 inch cold mill, and a tandem mill were observed on the walk-through. Work practices, engineering controls and protective clothing were evaluated where processes were operating. The NIOSH industrial hygienists reviewed ALCOA's environmental sampling data concerning the areas of the request.

On October 6-10, NIOSH conducted environmental sampling in the areas cited in the requests (as mentioned above).

Informal interview data from the 2 initial walk-through visits indicated the need for further medical evaluation of 1) possible long-term respiratory impairment from episodic exposure to high levels of chlorine gas and 2) possible respiratory, neurological, or irritant effects from exposure to rolling oil. A medical survey was performed November 2-6 in which questionnaires and pulmonary function tests were administered to workers in the hot ingot, hot mill, and cold mill areas.

Interim Report No. 1 was distributed in November 1980.

III. BACKGROUND

The ALCOA North Plant is primarily engaged in the remelting of scrap aluminum, ingot formation, ingot preheating (prior to milling), hot milling of the ingots to produce an aluminum coil of approximately 0.125 inches, cold milling of the coils to a thinner gauge, and finishing operations which include a paint line, caustic etch line, coil finishing and maintenance activities. Scrap aluminum is loaded into the remelt furnaces and fluxed with chlorine gas. The chlorine is injected into the molten aluminum through graphite pipes which are lowered into the molten aluminum. The chlorine reacts with impurities in the mix and forms a dross which floats to the top and is periodically skimmed off. The molten aluminum is then poured into ingots. Employees in the area were concerned about periodic exposures to chlorine when graphite pipes broke or became clogged and released chlorine gas.

In the preheat area, aluminum ingots are heated to temperatures suitable for milling. Thermocouples are inserted into the ingots to monitor temperature. Employees in this area were concerned about asbestos used to coat the thermocouple wires and the plugs which hold the thermocouples into the ingot.

The hot and cold mill areas press the ingots into progressively thinner gauge coil aluminum. Employees here were concerned about exposure to oil mist and noise.

The paint line coats coil aluminum with vinyl and various types of paint. Workers in this area had questions regarding exposure to solvents used in the paint, cleanup of rollers and paint spills with solvents and thermal decomposition products of the vinylate.

On the coil finishing line, aluminum coil is run through an enclosed system which levels the aluminum and cleans it with perchloroethylene which is recovered and reused. Employees here reported nausea, dizziness and headaches associated with leaks in the system and maintenance activities which involved working above an open storage tank of perchloroethylene.

The caustic etch line cleans aluminum sheets (approximately 2 feet by 4 feet) with a sodium hydroxide spray followed by a spray of nitric acid. The sheets move on an overhead conveyor belt which is about 8 feet above the ground. The system is partially enclosed, but workers here reported skin and respiratory irritation when working near either the entrance or exit to the system. Periodic leaks in the system and pumps were also reported to be a source of an irritating mist. No guarding was observed to prevent the overhead aluminum sheets from disengaging and injuring workers who pass below the conveyor belt.

In the maintenance shop, lead is occasionally melted to replace worn battery terminals. No local exhaust ventilation is used during this process. However, administrative controls limit this activity to no more than 45 minutes per shift.

IV. EVALUATION DESIGN AND METHODS SECTION

A. Environmental

1. Remelt furnaces and casting stations

Personal air samples (breathing zone) were collected for chlorine in these areas with long term detector tubes and portable battery operated pumps operating at 20cc/min. Air concentrations were estimated by reading the length of color change in the packed media within the tubes.

2. Ingot preheat area

Personal air samples for asbestos were obtained in this area through the use of portable battery operated pumps which pulled air across an open faced plastic cassette containing a mixed cellulose ester membrane filter (AA filter) at 2 liters/minute (l/min). They were analyzed by phase contrast microscopy and electonmicroscopy. Bulk samples of insulating wire and thermocouple plug material used in the ingot area were obtained and analyzed for asbestos using the same techniques.

3. Hot mill

Personal and area samples were collected for oil mist, decomposition products of oil mist, nitrosamines, polynuclear aromatic hydrocarbons (PNA's), diethylamine, triorthocresyl phosphate, ethylene glycol and butylated hydroxytoluene (BHT).

Oil mist was collected on AA filters with portable battery operated pumps at a flow rate of 2 l/min. Most of the samples were analyzed by infrared spectroscopy. The limit of detection was 100 micrograms/filter (ug/filter). In addition, several side by side air samples were analyzed by a gravimetric method which had been proposed by ALCOA's Research Department.

Potential organic decomposition products of oil mist were collected at a flow rate of 1 l/min on charcoal tubes which had a AA prefilter to prevent the collection of the oil mist on the charcoal tubes. The charcoal tubes were desorbed with 1 ml carbon disulfide and analyzed by gas chromatography.

Nitrosamines were collected on Thermasorb/N sampling cartridges at a flow rate of 2 l/min. The cartridges were eluted with a 25% methanol and 75% methylene chloride solution, and analyzed by gas chromatography/thermal electron analysis for N-Nitrosodimethylamine (NDMA) (minimum detectable limit (MDL) 6 ng/cartridge], N-Nitrosodiethylamine (NDEA) (MDL 15 ng/cartridge) and N-Nitrosomorpholine (NMOR) (MDL 15 ng/cartridge).

PNA's were collected on glass fiber/silver membrane filters with a porous polymer backup tube at 1.75 l/min. They were desorbed with benzene, evaporated to dryness then reconstituted with acetonitrile for high performance liquid chromatography analysis. The specific PNA analyses and their limits of detection (LOD) are as follows: fluoranthene - filter, LOD 0.05 ug/sample - porous polymer LOD 0.1 ug/sample; pyrene - filter LOD 0.07 ug/sample - porous polymer LOD 0.15 ug/filter; benzo(a)anthracene - filter and porous polymer LOD 0.03 ug/filter; chrysene - filter and porous polymer LOD 0.08 ug/sample and benzo(a)pyrene - filter and porous polymer LOD 0.03 ug/filter.

Diethylamine was collected on silica gel tubes at 200 cc/min and analyzed by gas chromatography according to NIOSH Method P&CAM #221. The LOD was 0.03 mg/sample.

Triorthocresyl phosphate was collected on AA filters at 1.5 l/min and analyzed by gas chromatography according to NIOSH Method 127. The LOD was 0.01 mg/filter.

Ethylene glycol air samples were collected on two types of sampling trains. One type contained a 13 mm glass fiber filter then a silica gel tube. Air was passed through this sampling train at 200 cc/min. The silica gel sections were treated with 2:98 2-propanol-water. The filters and silica gel were analyzed by gas chromatography using a flame ionization

detector. Detection limits for ethylene glycol per filter and section of silica gel were 3 and 4 ug respectively. Samples were also collected in a bubbler containing distilled water. The solutions from the bubblers were analyzed by a colorimetric method. Ethylene glycol in aliquots of the solutions were oxidized to formaldehyde with periodic acid, excess periodic acid was destroyed with sodium bisulfite, a solution of the disodium salt of chromotropic acid and concentrated sulfuric acid were added. The mixtures were allowed to cool to room temperature, and absorbances were measured at 570 nm.

Butylated hydroxytoluene was collected on silica gel tubes at 200 cc/min. They were analyzed by gas chromatography according to NIOSH Method P&CAM 226. The LOD was 0.01 mg/tube.

4. Paint line

Air samples for xylene, toluene, perchloroethylene and methyl ethyl ketone were collected on charcoal tubes at 50 cc/min and analyzed by gas chromatography according to NIOSH Method P&CAM 127. The LOD was 0.01 mg/sample for each of the above compounds.

5. Caustic etch

Sodium hydroxide was collected on AA filters at 1.5 l/min, and analyzed by atomic emission spectroscopy for sodium. The calculated values for sodium were converted to sodium hydroxide by use of a gravimetric conversion factor (1.7399). The LOD was 20 ug/filter.

6. Coil finishing line

Perchloroethylene was collected on charcoal tubes at 50 cc/min and analyzed by gas chromatography according to NIOSH Method S-335. The LOD was 0.01 mg/sample.

B. Medical

1. Study Population

There were approximately 550 workers in the hot ingot, hot mill, and cold mill areas at the time of the November 1980 medical survey.

Five job categories were studied: hot ingot, hot mill, cold mill (which included workers in the caustic etch process), overhead crane, and mechanical crafts specialist. Overhead cranemen and mechanical crafts specialists not working in the hot ingot area, hot line, or cold mills were not studied.

Lists of current employees were provided by the company. All individuals whose company seniority was five years or more were included in the pool of potential participants in the medical study. Workers in the caustic etch process were included regardless of company seniority.

Two hundred and thirty-two workers were selected for study population, including all eligible workers in the ingot department and approximately half of the eligible workers, selected at random, from the other 4 job categories. Both the company and the union encouraged participation.

2. Questionnaire

Questions were asked regarding:

a. Medical signs and symptoms, with particular focus on chronic respiatory symptoms (shortness of breath, morning cough, morning phlegm production, wheezing), neurological symptoms (numbness or tingling of extremities, abnormality of gait), and skin or mucous membrane irritation;

b. current and past work history; and

c. possible workplace exposure to chlorine gas, airborne asbestos, rolling oil mist, and skin exposure to rolling oil.

3. PFT data

Forced vital capacity (FVC), one-second forced expiratory volume (FEV_1), and maximal mid expirating flow (MMEF) were measured with an Ohio Medical Model 822 dry rolling seal spirometer with a Spirotech Model 200 computer. Temperature adjustment, direct air volume calibration, and paper chart function were checked each time the equipment was restarted.

Pulmonary function trials were administered by trained NIOSH personnel. Measurement techniques were consistent with the criteria set forth in the federal cotton dust standard.[1] Individuals were asked whether they had had a respiratory illness in the past 3 weeks, whether they had eaten a heavy meal within the past 2 hours, and whether they had smoked a cigarette within the past hour.

A test was considered adequate only if there were three acceptable trials and the two best curves differed by no more than 5% with respect to FVC and FEV_1.[2] Predicted normal values by age, sex, and height were calculated according to the Knudson's equations;[3] the predicted normal for black individuals was calculated by multiplying the Knudson value by 0.85.[4-6]

FEV_1 and FVC were considered to be normal if the best value obtained in an acceptable trial was ≥ 80% of the predicted normal value. FEV_1/FVC was considered to be normal if the ratio of the best values for FEV_1, and FVC was > 0.70. MMEF was measured and reported for each individual, but its potential significance is limited to comparison of group mean values and to comparison of an individual's values over time.

Pulmonary function data were categorized according to the following diagnostic criteria:

FEV_1	FVC	FEV_1/FVC	diagnostic category
≥ 80%	≥ 80%	≥ 0.70	no abnormalities
≥ 80%	≥ 80%	< 0.70	obstructive
< 80%	≥ 80%	> 0.70	obstructive
< 80%	≥ 80%	< 0.70	obstructive
< 80%	< 80%	< 0.70	obstructive with possible restrictive
< 80%	< 80%	≥ 0.70	restrictive with possible obstructive
≥ 80%	< 80%	≥ 0.70	restrictive

V. EVALUATION CRITERIA

The environmental evaluation criteria used in this report as related to airborne exposures to toxic substances are (1) NIOSH recommended standards, (2) Threshold Limit Values (TLVs) and their supporting documentation as set forth by the American Conference of Governmental Industrial Hygienists (ACGIH), and (3) Occupational Health Standards as promulgated and enforced by the Occupational Safety and Health Administration (OSHA), U.S. Department of Labor (29 CFR 1910.1000).

Appendix A summarizes the evaluation criteria for the sampled substances along with brief descriptions of their primary health effects. The following discussion pertains to those substances of predominant interest in the evaluation.

A. Chlorine gas

Chlorine gas is a primary irritant to the mucous membranes of the eyes, nose, throat, and entire respiratory tract. Its effects are due to the formation of hydrochloric acid and release of nascent oxygen from moisture on the membranes. Symptoms of acute elevated exposure may include cough, chest tightness, substernal pain, suffocating sensation, headache, and epigastric pain. Pulmonary function test data after accurate exposure may show obstructive changes and impaired oxygen diffusion into the blood. Severe exposure may result in onset within hours of pulmonary edema and chemical pneumonitis, which can be fatal.[7,8,9] Pulmonary edema

more often develops 6-36 hours after initial irritant symptoms have subsided and often is triggered by resumption of functional activity.[10,11]

Chronic chlorine gas exposure has been associated with symptoms of chronic bronchitis[8] and loss of ability to perceive smell.[9]

However, these studies are difficult to interpret due to methodological deficiencies and difficulties separating the effects of chlorine exposure from the effects of other exposures (eg. cigarette smoking) on pulmonary function.

B. Rolling oil

Most industrial metalworking fluids, including the rolling oils used in this plant, are based on mineral oil, a refined petroleum product. These fluids lubricate and dissipate heat from high heat and friction processes. Exposure to oil historically has not been a major cause of illness[15], but additives such as antioxidants, stabilizers, antimicrobials, and flame retardants and possible thermal decomposition products pose potential hazards that vary depending on the composition of the oil. Metalworking fluids are a major cause of industrial dermatitis.[16,17] Inhalation of oil mist may expose workers to infection or bacterial toxins from organisms in the oil.[18] Metalworking fluids may yield precursors to carcinogens, such as nitrosamines.[19] In a case-control study of deaths in Connecticut in 1935-1975, Rough et al[20] found an association between sinonasal cancer and exposure to cutting oils.

Pure mineral oil can be used for internal medicinal purposes and is not considered to be toxic when ingested orally, but it can be harmful when inhaled and can cause lipoid pneumonitis[21] (lipid pneumonia[22]; lipoid pneumonia[23]), which involves low-grade inflammation, granuloma formation, and local fibrotic response. This condition may involve mild fever, chest pain, and coughing[23] and may be development of associated with bronchitis, bronchiolitis, bronchiectasis, or bacterial pneumonia.[24] Chest x-ray appearances may resemble lung tumor or other forms of pneumonitis.[16] Fibrotic changes may follow, which have been reported to be associated with reduced forced vital capacity.[25,26] Ely et al[27] evaluated the mortality of 343 oil mist-exposed and 3122 non-exposed workers and found no excess for pneumonia, bronchitis, or respiratory malignancy. There also was no association between oil mist exposure and respiratory symptoms or pulmonary function findings on chemical evaluation of 242 oil-exposed and 1613 non-exposed workers. Experimental exposure of monkeys to mineral oil mist can cause fibrotic lung nodules and severe hypoplastic gastritis.[26]

Tricresyl phosphate (TCP) was included as a functional agent in rolling oil. The TCP used in the plant was reported by Alcoa to contain a small fraction of the ortho isomer, triorthocresyl phosphate (TOCP), as a minor contaminant. (It should be noted that no TOCP was detected in environmental samples.) High exposure to TOCP can cause peripheral neuropathy characterized by progressive weakness and muscle wasting. Other isomers of TCP are metabolized differently and are not considered to be neurotoxic.[28,29]

The identities of the biocides used in the rolling oils were provided to NIOSH on a confidential basis. The constituents were known to cause eye or skin irritation and allergic sensitization of the skin. In addition, they release free formaldehyde when used. Formaldehyde is a primary irritant of the nose, eyes, and upper respiratory tract and can cause pneumonitis (lung inflamation) and pulmonary edema. It has been found to be a mutagen and carcinogen in animals and in cell culture systems and should be handled as a potential occupational carcinogen.[30,31]

VI. RESULTS

A. Environmental

1. Remelt furnace area

In the remelt furnace area, 2 personal samples for chlorine had air concentrations of 0.1 ppm, and 9 samples were below the limit of detection (Table 1). The OSHA PEL for chlorine is a 1 ppm ceiling. NIOSH recommends a 0.5 ppm ceiling concentration. Asbestos was not found above the limits of detection on the 4 samples collected.

2. Hot and cold mills

In the hot mill area 8 personal samples for oil mist ranged from below the limit of detection to 0.4 mg/M^3 (Table 2). Twelve area samples ranged from below limit of detection to 1.1 mg/M^3. The OSHA PEL is 5 mg/M^3. All oil mist samples in the cold mill area were below the limit of detection. (It should be noted that the side by side air samples analyzed by infrared spectroscopy and a gravimetric method were in good agreement.)

Four personal samples for nitrosamines (Table 3) at the hot mill determined NMOR to be present at levels ranging form 0.08 to 0.30 ug/M^3, NDMA was present on one personal sample at 0.02 ug/M^3. One area sample at the continuous mill operators station detected the presence of NDMA (0.05 ug/M^3), NDEA (0.13 ug/M^3), and NMOR (0.41 ug/M^3). There is no OSHA standard for nitrosamines that is applicable in this setting.

Since nitrosamines are recognized to be potent animal carcinogens, NIOSH recommends that air concentrations of nitrosamines be kept to the lowest feasible levels.

No personal air samples (12) indicated the presence of PNA's (Table 4); however, two area samples detected pyrene at 0.44 and 0.99 ug/M^3. (It should be noted that pyrene is not considered to be carcinogenic.)

Four personal air samples for ethylene glycol (Table 5) ranged from 0.3 to 0.5 mg/M^3. The ACGIH TLV for ethylene glycol is 125 mg/M^3.

Triorthocresyl phosphate, diethylamine and butylated hydroxytoluene were not present in concentrations above the limits of detection on the days of sampling. Analysis of the charcoal tubes for decomposition products of oil mist indicated that the primary decomposition product was kerosene at levels well within the the standards for that compound.

3. Coil finishing

Five personal samples for perchloroethylene (Table 6) in this area ranged from 5-10 ppm. The OSHA PEL for perchloroethylene is 100 ppm. NIOSH recognizes perchloroethylene to be a suspect carcinogen and recommends air concentrations be kept to the lowest feasible level.

4. Caustic etch

Three personal samples for sodium hydroxide (Table 7) ranged from below the limit of detection to 0.03 mg/M^3. Area samples ranged from 0.14-0.64 mg/M^3. The OSHA PEL for sodium hydroxide is 2 mg/M^3.

5. Paint line

Two personal samples for xylene ranged from 2.5-4.6 mg/M^3 (Table 8). The OSHA PEL for xylene is 435 mg/M^3. No perchloroethylene, methyl ethyl ketone or toluene was found above the limits of detection.

B. Medical

1. Demographic Information

Of the 232 workers selected for the study, 165 (71%) participated. Thirty-six of 73 workers (49%) in the ingot remelt department participated, while participation in the other 4 job titles ranged from 73%-92%.

Mechanical crafts specialists and overhead cranemen were grouped according to usual work area, giving the following participation pattern:

	selected	participated	
hot ingot (intermittently exposed to chlorine)	92	48	(52%)
hot mill (exposed to rolling oil)	57	51	(89%)
cold mill (exposed to rolling oil)	83	66	(80%)

Three workers from the cold mill area who were selected initially despite having less than 5 years of company seniority were deleted from the study population prior to data analysis.

Ninety-eight percent of the study group was male. Ninety-one percent was white. Sixty-five workers (40%) were current cigarette smokers; 52 (32%) were past smokers; and 45 (28%) reported never having smoked cigarettes. Reported smoking habits were similar among participants relative to the five job categories and the 3 work area categories.

The average age and average plant seniority each were significantly lower for participants (45.0; 21.9) than for nonparticipants (52.2; 28.9). This pattern of lower age and lesser seniority of participants for hot ingot and cold mill workers was not noted among hot mill workers. Within the study group the average age and average plant seniority of participants differed among the 3 work areas.

	hot ingot		hot mill		cold mill	
	participant (n=48)	non-participant (n=44)	participant (n=51)	non-participant (n=6)	participant (n=63)	non-participant (n=17)
age	42.0	52.1	44.4	42.5	48.0	55.9
seniority	18.1	28.9	21.3	19.3	25.3	32.3

2. Respiratory Symptoms

As expected, current smokers were more likely to experience chronic respiratory symptoms than were workers who had never smoked. Reporting of respiratory symptoms by ex-smokers fell between the rates of reporting for current smokers and workers who never smoked.

Respiratory symptoms, by smoking status

symptom	current smoker (n=65) %	ex-smoker (n=52) %	never smoked (n=45) %	statistical significance (by Chi-square test)
shortness of breath with exertion	40	37	13	p=0.01
cough in the morning	26	4	4	p<0.01
phlegm in the morning	32	10	18	p=0.01
wheezy or whistling in the chest	52	29	18	p<0.01

Hot ingot workers were presumed to have been more likely than the rest of the workers to have incurred exposure to elevated levels of chlorine gas, while workers in the rolling mill areas were considered to be more likely to have inhaled rolling oil mist. No consistent patterns of reported chronic respiratory symptoms were observed among the 3 work areas overall or when workers in the 3 areas were stratified by smoking status (Table IX). Cold mill workers who were current smokers were more likely to report phlegm production in the morning than were workers in the other 2 areas.

3. Skin or Irritant Symptoms

No consistent pattern of skin or irritant symptoms was observed among workers in the 3 areas. Fewer hot mill workers reported nose irritation in the plant in the past year than did workers in the other 2 areas. Other possible symptoms of mucous membrane irritation (eye discomfort, throat dryness, and hoarseness) also were reported by fewer hot mill workers, although these differences were not statistically significant.

Skin and irritant symptoms, by work area

symptom	hot ingot (n=48) %	hot mill (n=51) %	cold mill (n=63) %	statistical significance (p value) (by Chi-square test) ("NS" if p>0.10)
skin rash in past 3 yrs	10%	22%	11%	NS
nosebleed in past 3 yrs	2%	8%	11%	NS
eye discomfort in plant in past yr	42%	35%	48%	NS
nose irritation in plant in past yr	42%	14%	43%	p<0.01
throat dryness in plant in past yr	38%	29%	33%	NS
hoarseness in plant in past yr	31%	12%	22%	NS

Mechanics in the rolling mill areas were presumed to be more likely to incur extensive direct exposure to rolling oil than were other workers. In order to assess skin or irritant effects of such direct contact, these mechanics were compared to other rolling mill workers (who were exposed to rolling oil) and to all workers in the hot ingot area (who routinely would not be exposed to rolling oil). No trends or dose-response pattern was observed. Nosebleeds were reported significantly more often by non-mechanic rolling mill workers.

Skin and irritant symptoms, by rolling oil exposure

symptom	rolling mill mechanic (n=20) %	other rolling mill (n=94) %	hot ingot (n=48) %	statistical significance (by Chi-square test) ("NS" if p > 0.10)
skin rash in past 3 yrs	5%	18%	10%	NS
nosebleed in past 3 yrs	0%	12%	2%	p=0.05
eye discomfort in plant in past yr	55%	40%	42%	NS
nose irritation in plant in past yr	20%	32%	42%	NS
throat dryness in plant in past yr	15%	35%	38%	NS
hoarseness in plant in past yr	10%	19%	31%	NS

4. Neurological Symptoms

Workers' concerns about "millwrights' shuffle" and other neurological symptoms were assessed for possible association with heavy exposure to rolling oil by comparing mechanics (millwrights) in the rolling mill areas to other workers in these areas and to hot ingot workers. Exposure to rolling oil was associated with reported numbness or tingling of the hands or feet in the past 3 years but not with other symptoms. In particular, none of 20 rolling mill mechanics reported difficulty with walking, foot drag, or tripping.

Neurological symptoms, by rolling oil exposure

symptom	rolling mill mechanic (n=20) %	other rolling mill (n=94) %	hot ingot (n=48) %	statistical significance (by Chi-square test) ("NS" if p > 0.10)
numbness or tingling of hands or feet in past 3 yrs	35%	26%	8%	p=0.02
numbness or tingling of arms or legs in plant in past yr	5%	13%	9%	NS
shaking or trembling of arms or legs in past 3 yrs	5%	13%	4%	NS
difficulty with walking not caused by injury in past 3 yr	0%	4%	2%	NS
foot drag or tripping when walking in the past 3 yr	0%	2%	0%	NS
lightheadedness or dizzy in plant in past yr	5%	13%	15%	NS
nausea or vomiting in plant in past yr	0%	7%	10%	NS

5. Pulmonary function measurement

Pulmonary function data were analyzed for 137 of the 162 workers in the study population. Testing was not performed on 4 workers because of medical contraindications or refusal to participate in this part of the study. PFT results were not analyzed for an additional 21 workers because of invalid PFT test data, recent use of breathing medication, or recent chlorine gas exposure.

Other factors that might affect PFT data were assessed. Six of 137 workers reported having had a heavy meal within the past two hours. Thirty-six reported having had a respiratory illness within the past 3 weeks. Forty-six of 54 current smokers had smoked within the past hour. PFT data did not reveal significant differences in FEV_1, FVC, or FEV_1/FVC relative to any of these factors, except that the workers who had had a recent heavy meal had significantly lower FEV_1 and FEV_1/FVC. Since the anticipated effect of a recent meal is decreased FVC, these data are included in the following presentation of data and analysis. Parallel analysis after deletion of data for these 6 workers did not change the pattern of findings or the strength of observed association.

Twenty-nine of 137 workers (21%) were diagnosed to have abnormal pulnomary function. Twenty-five (18%) had obstructive changes, of whom 3 (2%) may have had accompanying restrictive changes. Four (3%) had restrictive changes with possible obstructive changes.

Pulmonary function findings (n=137)

diagnostic category	#	%
obstructive changes	22	16
obstructive changes with possible restrictive changes	3	2
restrictive changes with possible obstructive changes	4	3
restrictive changes	0	0
no abnormality	108	79

Most workers with abnormal pulmonary diagnoses were smokers or ex-smokers. Overall, more than one quarter of all smokers and ex-smokers were abnormal, while only 5% of those who had never smoked had abnormal values.

Pulmonary function diagnoses, by smoking status

	current smoker (n=54)		ex-smoker (n=46)		never smoked (n=37)	
	#	%	#	%	#	%
obstructive changes	11	20	10	22	1	3
obstructive with possible restrictive changes	2	4	1	2	0	0
restrictive with possible obstructive changes	1	2	2	4	1	3
restrictive changes	0	0	0	0	0	0
no abnormality	40	74	33	72	35	95

FEV_1, FEV_1/FVC, and MMEF were reduced for current smokers and ex-smokers. FVC did not differ remarkably among workers relative to smoking status.

Pulmonary function test values, by smoking status

	current smoker (n=54)		ex-smoker (n=45)		never smoked (n=37)	
	mean	s.d	mean	s.d.	mean	s.d.
FEV_1 (% of predicted)	94.48	17.26	96.07	17.06	102.00	11.62
FVC (% of predicted)	100.00	17.08	100.24	14.14	102.00	10.13
FEV_1/FVC	.76	.08	.76	.09	.80	.06
MMEF (% of predicted)	64.22	25.80	70.39	26.32	83.03	27.19

The cold mill area had the highest rate of abnormal pulmonary function diagnosis, while the hot line had the lowest, but no consistent pattern was apparent by to work area when stratified by smoking category (Table X). Smokers and ex-smokers appeared to be more likely to be abnormal in each work area. All diagnoses of restrictive changes were among workers in the cold mill area.

When adjusted for smoking effects, average FVC was not similar for workers in the 3 work areas (Table XI). FEV_1/FVC and MMEF did not differ among workers in the 3 job areas. When "hot line" workers and "cold mill" workers (exposed to rolling oil) were compared to "ingot" workers (exposed to chlorine), the cold mill workers were found to have a significantly lower FVC (96.67 vs 104.99, adjusted for smoking, $p < .01$ which is significant when adjusted for multiple comparisons). The FVC for "hot line" workers, although lower than that for ingot workers was not statistically different ($p < .25$).

VII. DISCUSSION

A. Environmental

1. Remelt furnaces and casting stations

Two personal air samples for chlorine indicated exposures to chlorine at 0.1 ppm and 9 were below the limit of detection. These results are similar to the previous environmental sampling conducted by ALCOA's industrial hygiene staff. This indicates that normal exposures in the area are generally within OSHA and NIOSH guidelines. However, discussions with employees indicated that there are occasions (breakage and plugging of graphite pipes which deliver the chlorine) when large amounts of chlorine gas have been released and necessitated medical treatment for workers in the area. In our questionnaire study, over half of the "hot ingot" workers reported recent episodes of chlorine exposure for which they sought medical attention or which required them to leave the area. During these emergency situations, there is no adequate warning system for the employees. In the confusion of these emergency situations workers have, apparently, sometimes fled into the direction of the leaks rather than away from them. The level of chlorine which is considered to be immediately dangerous to life and health (IDLH) is 25 ppm. Breakage of pipes containing chlorine gas could, conceivably, lead to this exposure level in nearby areas.

2. Ingot preheat area

Analysis of the bulk sample of the insulating wire used in the past by ALCOA indicated that it was composed of an inner wrapping of chrysotile asbestos and an outer wrapping of fibrous glass. ALCOA has made a material substitution in this area. The use of asbestos for thermocouple wires and plugs has been discontinued. ALCOA has replaced the insulating wire with one composed of a double wrapping of fiberglass. Analysis of the synthetic fibrous plug material currently used to protect the thermocouple indicates it is composed almost entirely of delustered nylon. This substitution of materials is an excellent control measure. Cleanup of remaining asbestos materials in the furnaces and floor areas should be accomplished as soon as possible to prevent any reentrainment of the fiber into the air and consequent unnecessary exposure to asbestos.

3. Hot and cold mills

Although oil mist levels measured at the hot and cold mills were below the OSHA standard, production difficulties were encountered at both mills on the days of the sampling. During periods of full production, oil mist levels may be higher.

The highest personal sample for nitrosamines detected a level of 0.30 ug/M^3 (NMOR). Nitrosamines are potent animal carcinogens. The levels found at the hot mill, while relatively low, should not be dismissed. ALCOA should make efforts to determine and control the source of the nitrosamines detected in the hot mill area.

Noise exposure at the continuous mill was not evaluated. The noise levels in this area, however, were high enough to interfere with normal speech. ALCOA indicated that they realized there was a noise problem in this area, and had requested that their noise engineers undertake a project to correct the problem.

ALCOA uses a bactericide in their rolling oil that releases formaldehyde to kill bacteria. The manufacturer recommends a gradual addition of the bactericide to prevent the release of large amounts of formaldehyde. ALCOA makes the addition of the bactericide on a weekly basis. Bulk addition of the bactericide to oil containing a large amount of bacteria may release undesirable amounts of formaldehyde. This situation could not be observed on the days of sampling. It is possible that the addition of the bastericide to the rolling oil may be associated with the dermatitis and respiratory irritation reported in that area. ALCOA should conduct environmental monitoring during the addition of the bactericide to determine what, if any, levels of formaldehyde are released.

4. Coil finishing area

Personal samples for perchloroethylene ranged from 5-10 ppm. Perchloroethylene is a suspect carcinogen, and exposures should be controlled to the lowest feasible level. The source of leaks in the solvent system for the coil finishing line should be determined and controlled. The material substitution of a caustic at the coil finishing area should be considered. In the meantime, workers should be informed of the potential hazard in this area; and maintenance people or operators who must open the system and perform maintenance activities should be provided with adequate personal protective equipment, including impervious gloves and respirators.

5. Caustic etch line

Personal samples for sodium hydroxide in this area were below the OSHA standard; nevertheless, leaks in the system represent sources of possible skin and respiratory irritation. This irritation was not only reported by workers in the area, but was also experienced by the NIOSH investigators during the walk-through of the area and on the days of sampling. Control measures should be instituted to prevent leakage near pumps and at the entrance to the caustic etch line.

At the caustic etch line, the aluminum sheets are connected to an overhead conveyor belt by two clips. There is no guarding in the area. On one of the days of sampling, one of the sheets slipped loose from one of its clips and swung down in a guillotine-like fashion. Since the sheets are about 8 feet above the ground, this represents a significant safety hazard. Guarding of the conveyor belt should be instituted in this area.

6. Paint line

Personal samples for solvents in this area were well within recognized standards/criteria on the days of sampling for the solvents evaluated. Workers informed the NIOSH investigators that when paint spills occurred in this area, normal cleanup operations included mopping the floor with hydrocarbon solvents. However, floor cleaning and roller cleaning with solvents was not observed on the days of sampling. These situations should be observed by ALCOA's environmental staff and appropriate recommendations to control potential exposures during these activities should be made by them.

B. Medical

1. Generalizability of findings

The objective of this medical survey was to assess the possible health effects of episodic exposure to high concentrations of chlorine gas and of respiratory and/or skin exposure to rolling oil. The study population was selected by a random process so that the workers studied would be representative of workers in each job category. However, factors relating to study participation suggest that these findings should be generalized only with caution:

a. The significant difference in rates of participation between hot ingot area workers (52%) and workers in the other 2 work areas (80-89%) indicated that non-participation might not be a random event among the workers.

b. Participants had significantly less company seniority than did non-participants. This difference was similar within each of the job titles. Because medical findings may be associated with duration of exposure and/or time interval since first exposure to a workplace agent, chronic effects may have been underestimated.

c. Similarly, participants were significantly younger than were non-participants, which could decrease the likelihood of discerning premature development of a typically age-related medical finding that might be accelerated by workplace exposure to an agent.

2. Estimation of workers' exposures

Workers in the hot ingot area were presumed to have been more likely to have incurred one or more episodes of exposure to elevated levels of chlorine gas than were rolling mill workers. Significantly more hot ingot workers reported episodes of such chlorine exposure than did other workers. For analysis, exposure to chlorine gas was estimated using work area as surrogate for chlorine exposure instead of self-reporting because of potential differences among workers in their interpretation of the severity of a given exposure to chlorine gas.

Work area was used as the surrogate indicator of exposure to rolling oil mist. Rolling mill mechanics, who were reported to incur heavy direct exposure to rolling oil during maintainence and repair procedures, were presumed to experience heavier skin exposure to rolling oil that were production workers in the same areas.

3. Findings

Smoking, as expected, was found to be strongly associated with reporting of chronic respiratory symptoms. When smoking was taken into account, there was no clear association of medical symptoms with work area, although cold mill workers who were current smokers were more likely to report phlegm production in the morning. Insofar as several tests for statistical significance were performed, this isolated finding should be interpreted with caution. All workers in the study were potentially exposed either to chlorine gas or to rolling oil mist, so the finding that workers from different work areas are similar in their reporting of respiratory symptoms does not exclude the possibility that workers incur symptomatically similar impairment from different exposures.

Reporting of skin problems and mucous membrane irritation was similar among potentially chlorine- and rolling oil-exposed workers. Rolling mill mechanics were not found to differ from other employees in their reporting of the symptoms.

No consistent pattern of neurological symptoms was elicited that would suggest neurological impairment associated with rolling oil exposure. The finding of a statistically significant dose-response relationship of numbness or tingling of hands or feet with direct exposure to rolling oil is noteworthy but is difficult to interpret without other supporting evidence of neurological problems.

4. Pulmonary Function Data

As expected, current and past cigarette smokers were more likely to show obstructive changes than were nonsmokers.

All workers with the diagnosis of restrictive changes (with possible accompanying obstructive changes) worked in the cold mill area. Cold mill workers were found to have significantly lower FVC than did hot ingot workers, which indicated a restrictive pattern of lung changes. They also had lower FEV_1, which suggested the possibility of accompanying obstructive lung changes. However, the absence of difference of FEV_1/FVC between the 2 groups suggested that the measured decrement in FEV_1 could be explained readily by the decreased FVC values. Furthermore, MMEF values were found to be similar between the 2 groups, whereas a primary obstructive process should manifest a decrement in MMEF.

Hot mill workers showed PFT values that were intermediate between the hot ingot and cold mill workers and did not differ significantly from either of the other 2 areas.

These pulmonary function findings suggest that exposure to rolling oil mist may be associated with development of restrictive pulmonary function changes. This would be plausible in the context of documented lipoid pneumonia with secondary fibrotic changes that have been documented in humans and in animal studies. However, this finding is not consistent with environmental levels which demonstrated non-detectable levels of rolling oil in the cold mill area. Previous epidemiological studies of workers exposed to oil mist have not demonstrated significant pulmonary problems. Further investigation would be required to verify this finding and to identify any causitive agent with greater certainty.

VIII. RECOMMENDATIONS SECTION

1. Investigate material substitution for the graphite pipes in the remelt furnaces which are prone to clogging and breakage.

2. Install a continuous chlorine monitoring system with visual and audio warning systems at the remelt furnaces to ensure safe evacuation of the area during situations when chlorine gas is being accidentally released into the work areas.

3. Control nitrosamine exposures at the hot line.

4. Examine the effects of bulk addition of formaldehyde-releasing bacteriacide to the hot mill rolling oil to see if it is a significant source of formaldehyde.

5. Evaluate noise exposures at the continuous mill.

6. Investigate, determine and control perchloroethylene leaks at the coil finishing line. Endeavor to find a less toxic material substitution for perchloroethylene in this area.

7. Control leaks of sodium hydroxide at the caustic etch line. Install guarding for the aluminum sheets on the overhead conveyor belt.

8. Conduct environmental sampling during cleanup of rollers and spills with solvents on the paint line. Institute appropriate controls during these activities.

9. The U.S. Department of Labor recommends that a complete history, physical, and FVC and FEV_1 measurements be made available on a yearly basis to each employee who is exposed to chlorine at potentially hazardous levels. In addition, a 14" x 17" chest x-ray should be obtained initially and if indicated by respiratory symptoms or changes in measured pulmonary function.[32] (ALCOA has indicated that this is already part of their current monitoring program.)

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH

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1. Aluminum Company of America, Alcoa, Tennessee
2. United Steelworkers of America, Local 309
3. NIOSH, Region IV
4. OSHA, Region IV

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

TABLE I

AIR SAMPLING FOR CHLORINE; REMELT FURNACE

ALUMINUM COMPANY OF AMERICA
ALCOA, TENNESSEE
HETA 80-124 and 80-230

October 7-8, 1980

Job/Location	Date of Sample	Time of Sample	Type of Sample	Sample Volume (liters)	Chlorine (PPM)
Crane Operator/Little League	10/7/80	1618-2021	Personal	4.4	ND
Pour Helper/9 Station Little League	10/7/80	1620-1816	Personal	3.7	ND
Pour Helper (Floater)/8 Station Little League	10/7/80	1623-2023	Personal	5.2	ND
Crane Operator/Ponderosa	10/7/80	1637-2034	Personal	5.0	0.1
Pour Helper/Four Complex	10/7/80	1648-2032	Personal	3.5	ND
Pour Helper/Four Complex	10/7/80	1648-2032	Personal	4.6	ND
Pour Helper/Ponderosa Station 5	10/7/80	1633-2029	Personal	4.6	ND
Crane Operator/South End	10/8/80	1654-2104	Personal	3.9	ND
Pour Helper/8 Station	10/8/80	1656-2102	Personal	4.6	0.1
Pour Helper/5 Station	10/8/80	1702-2104	Personal	4.8	ND
Pour Helper/4 Station	10/8/80	1707-2108	Personal	Pump removed, sample invalidated	
OSHA PEL				1 ppm ceiling	
NIOSH Recommended Criteria				0.5 ppm - 15 min. ceiling	

ND = Not Detected on long term detector tubes

TABLE II

AIR SAMPLING FOR OIL MIST; HOT AND COLD MILLS

ALUMINUM COMPANY OF AMERICA
ALCOA, TENNESSEE
HETA 80-124 and 80-230

October 7, 8 and 10, 1980

Job/Location	Date of Sample	Type of Sample	Time of Sample	Sample Volume (liters)	Oil Mist Infrared Method (mg/M^3)	Oil Mist Gravimetric Method (mg/M^3)
HOT MILL						
Mill Clerk	10/10/80	Personal	0633-1340	854	BLD	-
80" Scrap Box Operator	10/10/80	Personal	0635-1335	840	0.3	-
Industrial Trucker; 80" Scrap Box	10/10/80	Personal	0639-1336	834	0.2	-
CM Relief	10/10/80	Personal	0652-1337	810	0.3	-
5' Above Ground, At Continuous Mill, Next to 4th and 5th Stands	10/10/80	Area	0702-1342	800	0.4	0.5
" "	10/10/80	Area	0702-1342	800	0.3	0.4
5' Above Ground, At Continuous Mill, Next to 1st Stand	10/10/80	Area	0704-1340	792	0.2	0.3
" "	10/10/80	Area	0704-1340	792	0.2	0.3
On I Beam Above 80" Scrapbucket	10/10/80	Area	0709-1344	790	0.7	0.8
On I Beam Above 80" Scrapbucket	10/10/80	Area	0709-1344	790	0.7	0.8
5' Above Ground, At Continuous Mill, Next to 1st Stand	10/8/80	Area	1507-2040	666	0.4	0.4
" "	10/8/80	Area	1507-2040	666	0.3	0.3
5' Above Ground, At Continuous Mill, Next to 5th Stand	10/8/80	Area	1454-2045	702	1.1	1.1
" "	10/8/80	Area	1454-2045	702	1.1	1.0
" "	10/8/80	Area	1502-2045	686	0.9	1.0
" "	10/8/80	Area	1502-2045	686	1.0	0.9
Continuous Mill Clerk	10/8/80	Personal	1431-2048	754	BLD	-
Assistant Continuous Mill Operator	10/8/80	Personal	1442-2037	710	0.4	-
Hot Line Laborer	10/8/80	Personal	1436-2038	724	0.2	-
Relief Man, Continuous Mill	10/8/80	Personal	1456-2048	704	0.2	-
COLD MILLS						
44" Mill, Assistant Operator	10/7/80	Personal	1402-2142	920	BLD	-
44" Mill, Head Operator	10/7/80	Personal	1406-2142	912	BLD	-
44" Mill, Reel Operator, #1 Assistant	10/7/80	Personal	1408-2143	910	BLD	-
44" Mill, At Reel Operator Station	10/7/80	Area	1422-2045	766	BLD	-
4 High Mill, Operator	10/7/80	Personal	1519-2130	742	BLD	-
4 High Mill, Mill Clerk	10/7/80	Personal	1521-2130	738	BLD	-
4 High Mill, Bridle Operator	10/7/80	Personal	1523-2135	744	BLD	-
4 High Mill, At Operators Station	10/7/80	Area	1524-2133	738	BLD	-
"C" Mill, Tickets	10/9/80	Personal	1702-2148	572	BLD	-
"C" Mill, Relief Operator	10/9/80	Personal	1705-2146	558	BLD	-
"C" Mill, Operator	10/9/80	Personal	1659-2148	578	BLD	-
Bridle Operator	10/9/80	Personal	1700-2148	576	BLD	-
OSHA PEL					5 mg/M^3	

BLD = Below Limit of Detection (limit of detection is 100 ug/filter)

TABLE III

AIR SAMPLING FOR NITROSAMINES; HOT MILL

ALUMINUM COMPANY OF AMERICA
ALCOA, TENNESSEE
HETA 80-124 and 80-230

October 8, 1980

Job/Location	Date Of Sample	Time Of Sample	Type Of Sample	Sample Volume (liters)	NDMA* ug/M^3	NDEA** ug/M^3	NMOR*** ug/M^3
CM Relief Operator 80" Mill	10/8/80	0652-1055	Personal	486	0.02	ND	0.30
Trucker, 80" Mill	10/8/80	0701-1055	Personal	468	ND	ND	0.05
Laborer, 80" Mill Scrap Box	10/8/80	0714-1055	Personal	442	ND	ND	0.11
Assistant CM Operator 80" Mill	10/8/80	0720-1055	Personal	430	ND	ND	0.08
Area Sample, Cont. Mill Oper. Station	10/8/80	0804-1055	Area	342	ND	ND	0.23
Area Sample, 2nd Stand 80" Mill	10/8/80	0823-1055	Area	304	ND	ND	0.18
Area Sample, Above 80" Mill Scrap Box	10/8/80	0834-1055	Area	282	ND	ND	0.38
Area Sample, Cont. Mill Oper. Station	10/8/80	1114-1352	Area	316	0.05	0.13	0.41
Limit of Detection					6 ng	15 ng	15 ng

* NDMA = N-Nitrosodimethylamine
** NDEA = N-Nitrosodiethylamine
*** NMOR = N-Nitrosomorpholine

ND = Not Detected

TABLE IV

AIR SAMPLING* FOR POLYNUCLEAR AROMATIC HYDROCARBONS; HOT MILL

ALUMINUM COMPANY OF AMERICA
ALCOA, TENNESSEE
HETA 80-124 and 80-230

October 8 and 10, 1980

Job/Location	Date Of Sample	Time Of Sample	Type Of Sample	Sample Volume (liters)	Pyrene (ug/M^3)
Trucker, 80" Mill	10/8/80	1509-2058	Personal	611	BLD
Continuous Mill Clerk	10/8/80	1431-2048	Personal	660	BLD
Laborer, 80" Scrap Box	10/8/80	1522-2051	Personal	576	BLD
Assistant Continuous Mill Operator	10/8/80	1442-2037	Personal	622	BLD
Continuous Mill Relief	10/8/80	1456-2048	Personal	616	BLD
Laborer, 96" Mill	10/8/80	1436-2038	Personal	634	BLD
Area Sample, 1st Stand At Continuous Mill	10/8/80	1514-2042	Area	574	0.44
Laborer, 80" Scrap Box	10/10/80	0635-1335	Personal	735	BLD
Continuous Mill Clerk	10/10/80	0633-1340	Personal	747	BLD
Assistant Continuous Mill Operator	10/10/80	0627-1334	Personal	747	BLD
Trucker, 80" Mill	10/10/80	0639-1336	Personal	730	BLD
Laborer, Scrap Shear Cutoff	10/10/80	0646-1334	Personal	714	BLD
Continuous Mill Relief	10/10/80	0652-1337	Personal	709	BLD
Area Sample 80" Mill Between 4th & 5th Stand	10/10/80	0702-1342	Area	700	0.99

BLD = Below Limit of Detection

Limit of Detection — 0.07 ug (filter); 0.15 ug (porous polymer tube)

* All of the samples were analyzed for benzo(a)pyrene, chrysene, benzo(a)anthracene and fluoroanthrene and found to be below the limit of detection for these substances.

TABLE V

AIR SAMPLING FOR ETHYLENE GYCOL; HOT MILL

ALUMINUM COMPANY OF AMERICA
ALCOA, TENNESSEE
HETA 80-124 and 80-230

October 9, 1980

Job/Location	Date Of Sample	Time Of Sample	Type Of Sample	Sample Volume (liters)	Concentration (mg/M^3)
Laborer, 80" Mill Scrap Box	10/9/80	0734-1336	Personal	72	0.5
Mill Clerk, 80" Mill	10/9/80	0742-1338	Personal	71	0.4
Trucker, 80" Mill	10/9/80	0744-1334	Personal	72	0.3
Continuous Mill Relief Operator, 80" Mill	10/9/80	0752-1341	Personal	70	0.3
Area Sample, 1st Stand At 80" Mill	10/9/80	0945-1346	Area	48	0.6
Area Sample, Continuous Mill Operators Station	10/9/80	0945-1344	Area	48	0.6
Area Sample, 5th Stand At 80" Mill	10/9/80	0945-1342	Area	47	0.2

ACGIH TLV $125\ mg/M^3$

TABLE VI

AIR SAMPLING FOR PERCHLOROETHYLENE; COIL FINISHING

ALUMINUM COMPANY OF AMERICA
ALCOA, TENNESSEE
HETA 80-124 and 80-230

October 8, 1980

Job/Location	Date Of Sample	Time Of Sample	Type Of Sample	Sample Volume (liters)	Perchloroethylene Concentration (PPM)
Entry End Shear	10/8/80	0630-1325	Personal	22	5
Shear Operator	10/8/80	0631-1325	Personal	24	10
Flat Sheet Stacker	10/8/80	0632-1325	Personal	25	10
Crane Relief	10/8/80	0632-1330	Personal	18	10
Supervisor	10/8/80	0635-1334	Personal	17	10
Entry End Shear	10/8/80	0644-1327	Area	9	9
Leveler Operator	10/8/80	0630-1030	Personal Sample Invalidated, Pump Failed		
Beam 93, Perchloro-ethylene Still	10/8/80	0646-1036	Area Sample Invalidated, Pump Failed		

OSHA PEL 100 ppm
NIOSH Recommended Criteria - lowest level attainable; a suspect carcinogen

TABLE VII

AIR SAMPLING FOR SODIUM HYDROXIDE; CAUSTIC ETCH AREA

ALUMINUM COMPANY OF AMERICA
ALCOA, TENNESSEE
HETA 80-124 and 80-230

October 9, 1980

Job/Location	Date Of Sample	Time Of Sample	Type Of Sample	Sample Volume (liters)	Sodium Hydroxide Concentration (mg/M^3)
Operator	10/9/80	1417-2127	Personal	645	0.03
Assistant Operator	10/9/80	1419-2127	Personal	642	BLD
Laborer	10/9/80	1420-2127	Personal	640	BLD
Next To Caustic Pump	10/9/80	1424-2127	Area	635	0.14
Above Sodium Hydroxide Tank	10/9/80	1430-2127	Area	626	0.64

OSHA PEL $2\ mg/M^3$
BLD = Below Limit of Detection (20 ug/filter)

TABLE VIII

AIR SAMPLING FOR XYLENE ON THE PAINT LINE

ALUMINUM COMPANY OF AMERICA
ALCOA, TENNESSEE
HETA 80-124 and 80-230

October 9, 1980

Job/Location	Date Of Sample	Time Of Sample	Type Of Sample	Sample Volume (liters)	Xylene mg/M^3)
Assistant Operator	10/9/80	0628-1415	Personal	26	4.6
Operator	10/9/80	0642-1416	Personal	Pump Stopped, Sample Invalidated	
Laborer	10/9/80	0636-1414	Personal	Pump Stopped, Sample Invalidated	
Utility Man	10/9/80	0858-1420	Personal	16	2.5
OSHA PEL					435 mg/M^3

TABLE IX

ALUMINUM COMPANY OF AMERICA
ALCOA, TENNESSEE
HETA 80-124 and 80-230

Percentages of workers with respiratory symptoms, by work area

	overall (n=162)	only current smoker	only ex-smoker	only never smoked
shortness of breath with exertion:				
hot ingot(n=48)	31%	42%	41%	0%
hot mill(n=51)	33%	32%	55%	20%
cold mill(n=63)	30%	48%	25%	17%
cough in the morning:				
hot ingot (n=48)	10%	21%	0%	8%
hot mill (n=51)	10%	20%	0%	0%
cold mill (n=63)	18%	38%	9%	6%
phlegm in the morning:				
hot ingot (n=48)	15%	21%	0%	25%
hot mill (n=51)	14%	17%	9%	13%
cold mill (n=63)	30%*	57%**	17%	17%
wheezing/whistling: in chest				
hot ingot (n=48)	42%	74%	24%	17%
hot mill (n=51)	33%	40%	36%	20%
cold mill (n=63)	32%	48%	29%	17%

* p=0.06
** p<0.01

TABLE X

ALUMINUM COMPANY OF AMERICA
ALCOA, TENNESSEE
HETA 80-124 and 80-230

Pulmonary function diagnoses, by work area

	hot ingot		hot mill		cold mill	
	n	%	n	%	n	%
All participants						
obstructive changes	7	(18%)	5	(11%)	10	(19%)
obstructive with possible restrictive	1	(3%)	1	(2%)	1	(2%)
restrictive with possible obstructive	0	(0%)	0	(0%)	4	(7%)
no abnormality	30	(79%)	39	(87%)	39	(72%)
Only current smokers						
obstructive changes	3	(19%)	3	(14%)	5	(31%)
obstructive with possible restrictive	1	(6%)	0	(0%)	1	(6%)
restrictive with possible obstructive	0	(0%)	0	(0%)	1	(6%)
no abnormality	12	(75%)	19	(86%)	9	(56%)
Only ex-smokers						
obstructive changes	3	(23%)	2	(20%)	5	(22%)
obstructive with possible restrictive	0	(6%)	1	(10%)	0	(6%)
restrictive with possible obstructive	0	(0%)	0	(0%)	2	(9%)
no abnormality	10	(77%)	7	(70%)	16	(70%)
Only never smoked						
obstructive changes	1	(11%)	0	(0%)	0	(0%)
obstructive with possible restrictive	0	(0%)	0	(0%)	0	(0%)
restrictive with possible obstructive	0	(0%)	0	(0%)	1	(7%)
no abnormality	8	(89%)	13	(100%)	14	(93%)

TABLE XI

ALUMINUM COMPANY OF AMERICA
ALCOA, TENNESSEE
HETA 80-124 and 80-230

Pulmonary function test values, by work area

	ingot (n=34)			hot line (n=49)			cold mill (n=57)		
	crude mean	s.d.	adj.for smoking*	crude mean	s.d.	adj.for smoking*	crude mean	s.d.	adj.for smoking*
FEV_1 (% of predicted)	100.97	16.17	101.25	96.98	16.20	97.36	94.33	15.19	93.82
FVC (% of predicted)	104.87	12.26	104.99	101.16	14.84	101.32	97.19	14.83	96.97
FEV_1/FVC	.77	.08	.77	.76	.09	.77	.78	.08	.77
MMEF (% of predicted)	73.97	27.13	74.58	70.00	27.50	70.83	70.69	27.47	69.57

* For each of these three factors, the co-factors of analysis were 4 levels of smoking (0 for never smoked, 1 for ex-smoker, 2 for <1 pack/day, 3 for 1 pack/day or more).

APPENDIX A

Evaluation Criteria
Aluminum Company of America
Alcoa, Tennessee

SUBSTANCE	EVALUATION CRITERIA	SOURCE	OSHA STANDARD	PRIMARY HEALTH EFFECTS
Chlorine	0.5ppm (ceiling)*	NIOSH	1ppm (ceiling)	(see text)
Ashestos	0.1 fibers 1cc	NIOSH	2 fibers 1cc	
Oil Mist	5 mg/M^3	OSHA	5 mg/M^3	(see text)
Nitrosamines	**	NIOSH	--	suspect carcinogens
Polynuclear Aromatic Hydrocarbons	**	NIOSH	--	suspect carcinogens
Ethylene Glycol	125 mg/M^3	ACGIH	--	Headache; nausea, vomiting; abdominal pain; hypotension; palpitation; flushing; chest pain, depressed central nervous system; skin irritation.
Diethylamine	10ppm	ACGIH	25ppm	Short-term: eye/skin/respiratory tract irritation or burns. Long-term: chronic skin irritation; corneal swelling.
Triorthocresylphosphate	0.1 mg/M^3	ACGIH	0.1 mg/M^3	Paralysis of lower arms or legs (appearing days-weeks after exposure); nausea, vomiting, diarrhea, abdominal pain shortly after exposure.
Sodium Hydroxide	2 mg/M^3 (ceiling)	NIOSH	2 mg/M^3	Burn/irritation of eyes/skin/mucous membranes/respiratory tract
Perchloroethylene	**	NIOSH	100ppm	Short-term: headache, nausea, drowsiness, dizziness, incoordination, unconsciousness; eye/nose/throat irritation; flushing; liver damage. Long-term: skin irritation; liver damage, kidney damage.
Xylene	435 mg/M^3	NIOSH	435 mg/M^3	Short-term: eye/nose/throat/respiratory irritation; dizziness, staggering, drowsiness; unconsciousness; loss of appetite, nausea, vomiting, abdominal pain; liver and kidney damage; delayed-onset breathing difficulty.
Methyl Ethyl Ketone	200ppm	NIOSH	500ppm	Eye/nose irritation; headache; dizziness; vomiting.
Toluene	100ppm	NIOSH	200ppm	Short-term: eye/respiratory tract/skin irritation; fatigue, weakness, confusion, headache, dizziness, drowsiness; skin tingling or numbness unconsciousness. Long-term: drying or cracking of skin.

* Ceiling - Exposure shall not exceed this concentration.
** Suspect carcinogen - Exposure levels shall be kept as low as feasible.