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ELECTRODE CORPORATION
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SUMMARY

In October 1993, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request to conduct a health hazard evaluation (HHE) at Electrode Corporation, Chardon, Ohio. The requestors expressed concern about employee exposures in the plating, degreasing, etching, and coating processes, and potential exposures to asbestos in the diaphragm pre-coat area.

On November 9, 1993, NIOSH investigators collected personal breathing zone (PBZ) and general area (GA) air samples for inorganic acids, organic solvents and metals, and conducted confidential employee interviews. Bulk material samples were also collected for mercury and asbestos analyses. On December 16, 1993, a return site visit was conducted, PBZ and GA air samples were collected to assess employee exposures to inorganic acids and organic solvents during the coating processes, and bulk material samples were collected for asbestos analyses.

Three bulk samples showed that material removed from a crate of diaphragm anodes contained 80 to 90% chrysotile asbestos. However, asbestos was not detected on surface and air samples.

Results of PBZ air sampling for n-butanol showed that employees working on the inside conveyor coating line were overexposed: full-shift PBZ air samples ranged from 16 to 182 milligrams per cubic meter (mg/m^3), 15-minute short-term PBZ air samples ranged from 13 to 183 mg/m^3 . The higher n-butanol concentrations exceed the NIOSH and the American Conference of Governmental Industrial Hygienist (ACGIH) ceiling limits of 50 mg/m^3 , but did not exceed the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) of 300 mg/m^3 . Sampling results for ethanol, hydrogen chloride (HCl), and 1,1,1-trichloroethane showed no exposures above the pertinent criteria.

Perchloroethylene samples showed that the etch technician was exposed to a concentration of 11 mg/m^3 , and a GA concentration in the etch department was 2 mg/m^3 . The concentrations detected are below the OSHA 8-hour PEL of 689 mg/m^3 , however, NIOSH considers perchloroethylene to be a potential occupational carcinogen and recommends that exposures be controlled to the lowest feasible level (LFL).

Two of three full-shift PBZ air samples for metals showed nickel concentrations that exceeded the NIOSH Recommended Exposure Limit (REL) of 15 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$), but did not exceed the OSHA PEL of 1,000 $\mu\text{g}/\text{m}^3$. Titanium was detected on all three samples (range 2 to 10 $\mu\text{g}/\text{m}^3$), but concentrations did not exceed the OSHA PEL of 15,000 $\mu\text{g}/\text{m}^3$, however, NIOSH considers nickel and titanium to be occupational carcinogens and recommends that exposure be controlled to the LFL.

Mercury vapor concentrations in the mercury cell pre-coat area and the outside storage area ranged from 8 to 105 $\mu\text{g}/\text{m}^3$ during the first visit. The highest concentrations were found inside unopened crates of mercury anodes. While no one is actually exposed to the concentrations detected the measured concentrations indicate the potential for brief exposures (when opening the crates) to concentrations at or above the NIOSH and ACGIH criteria of 50 $\mu\text{g}/\text{m}^3$ and the

OSHA criteria of 100 $\mu\text{g}/\text{m}^3$. A bulk material sample collected in the mercury anode repair room did not contain mercury.

Confidential employee interviews were conducted to address worker concerns about fatigue, sleeplessness, memory loss, the potential for asbestosis from asbestos contaminated anodes, and the threat of sarcoidosis and/or ulcerative colitis as a result of work-related exposures. The symptoms reported by employees were consistent with but not specific to the organic solvents used at this plant. Workers exposed to asbestos-contaminated anodes are not at risk for asbestosis, however, exposure to even low levels of asbestos increases a workers' risk for lung cancer and malignant mesothelioma. Furthermore, workers were informed that sarcoidosis and ulcerative colitis are not occupationally related diseases.

The industrial hygiene sampling data indicate that workers were overexposed to n-butanol in the coating area, perchloroethylene in the degreasing area, and nickel in the plating area. Diaphragm anodes contaminated with asbestos constitute a potential health hazard to employees working in the pre-coat diaphragm area. Titanium exposure is also a potential health hazard to employees in the plating area and coatings laboratory. Recommendations for engineering controls, an improved respiratory protection program, and improved work practices are included in the Recommendations Section of this report.

Keywords: SIC 3471 (Electroplating, Plating, Polishing, Anodizing and Coloring), asbestos, n-butanol, nickel, perchloroethylene, titanium, hydrogen chloride.

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INTRODUCTION

On November 8, 1993 and December 16, 1993, the National Institute of Occupational Safety and Health (**NIOSH**) representatives conducted site visits at Electrode Corporation, a subsidiary of Eltech Systems. Electrode Corporation is located in Chardon, Ohio, and is a fabrication and servicing facility for anodes and cathodes used in various chemical industries (chlor-alkali, steel, and paper) to drive electrolytic cells. The NIOSH visits were conducted in response to a confidential employee request received in October 1993, to evaluate worker exposures in the shipping, receiving, anode washing, pre-coating, etching, plating, coating, and post-coating departments, and the coating laboratory.

BACKGROUND

The plant was constructed in 1969 of metal and masonry. Since the original construction the building has been expanded several times. The latest addition, completed in early 1993, contains a new lunchroom and training room. The plant operates three 8-hour shifts starting at 7:00 a.m., with 30 minute overlaps between shifts. Production employees assigned to the first and second shifts rotate shifts every 2 weeks, but can request permanent assignment to the second or third shift.

General ventilation is supplied to the production areas through five air make-up units located throughout the facility. Each unit is equipped with a natural gas heater. Additional heat is provided during the winter months by overhead gas-fired convection and radiant heaters. Large pedestal fans are used throughout the plant for cooling, and workers can also open outside doors and windows. A new roof was installed over the conveyor coating area in 1992, and two severely corroded roof exhaust fans were removed and discarded.

PROCESS DESCRIPTION

Diaphragm, mercury cell, electrogalvanizing (**EGL**), and membrane gap cell (**MGC**) anodes and cathodes are manufactured in the fabrication area. The application of proprietary precious metal coatings (to improve conductivity and prevent corrosion) and the repair of anodes and cathodes, takes place in the servicing and finishing areas. Anodes constitute the largest number of structures handled by Electrode Corporation. Each type of anode has a different process line but follows a similar process flow.

A. DIAPHRAGM ANODES

Diaphragm anodes are used primarily in the chlor-alkali industry and consist of titanium or titanium-clad copper conductor bars and titanium mesh. Incoming crates of anodes are opened and counted in the shipping and receiving department. These crates are unpacked and evaluated in the diaphragm pre-coat area. Glanor anodes (a subset of diaphragm anodes) may become contaminated with asbestos during use, by the customer, in chemical cells where an asbestos diaphragm is used to separate the anode and cathode.

The anodes are cleaned prior to evaluation because of the possibility of asbestos contamination. The anode washer is located in the pre-coat diaphragm area, a large open area, and is housed in a wooden shell. The washer is separated from the shipping and receiving department by a 12-foot sheet of plastic, but the plastic sheeting does not reach the ceiling. Workers open and unpack crates of anodes, and then place the anodes in the anode washer. After washing, anodes requiring minor repairs are reworked prior to surface preparation.

The surface of the anode must be specially prepared prior to the application of coating. Part of the preparation includes a degreasing step in which perchloroethylene is used, followed by chemical etching. Application of the coating can be done manually or mechanically. Employees apply the coatings using rollers, brushes or spray coating. After application of the coating, the anodes are heat treated. The anodes are then inspected, straightened, cleaned, packed, and shipped to the customer.

B. MERCURY CELL ANODES

Mercury cell anodes undergo a similar process. However, because of possible mercury contamination the crates are not opened for visual inspection in the receiving area. Instead, the crates are sent to the mercury cell pre-coat area where the interiors of the unopened crates are evaluated for mercury contamination using an Arizona Instruments Corporation, Gold Film Mercury Vapor Analyzer, Model 411 (the instrument is returned to the factory for yearly calibration). A hole is carved into the side of the wooden crate and the mercury vapor analyzer probe inserted. If the mercury vapor analyzer reading is greater than 0.050 milligrams/cubic meter (**mg/m³**), the unopened crate is taken outdoors and rechecked 1-day later. Crates of anodes with readings below 0.050 mg/m³ mercury are unpacked and inspected. The remaining processes: surface preparation, coating, heat treatment and finishing are similar to those of the diaphragm anodes.

C. MEMBRANE GAP CELLS ANODES

This type of anode consists of a titanium mesh (front) attached to a nickel plated metal sheet (back). The perimeter of the back side contains a plastic frame-filler and caulking. An initial inspection is conducted to determine the extent of needed repairs. Repairs and welding are done after the plastic filler, caulking, and nickel plating, have been removed. Additional process steps are followed to prepare the surface of the anode for application of the coating. After coating and heat treatment, the anode is blasted with steel shot and nickel plated. Prior to shipment, the caulking and plastic frame-filler are reinserted in the anodes.

D. ELECTROGALVANIZING CELL ANODES

These anodes are delivered from the receiving department to the EGL area to be inspected and evaluated. EGL anodes have two sides: a coating side and a platinum plated contact area. To prepare the anode for the new coating, the old coating and plating is removed and the anode is chemically etched or undergoes abrasive blasting with an aluminum oxide grit. Employees then apply the coating followed by heat treatment. After the finishing activities are completed, the anodes are packed and shipped to the customers.

E. COATING LABORATORY

The coating laboratory is located in the coating area in an enclosed room. Chemical coatings are prepared in the laboratory inside laboratory exhaust hoods. Supply air is not provided to the coating laboratory. As a result, the laboratory is under extreme negative pressure and draws replacement air from the surrounding production areas through the two laboratory doors. Chemicals used in the production of coating are stored in a small 4 by 4 foot room along the back wall of the coating laboratory. The storage room is cooled by a small window air-conditioning unit.

F. PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment (**PPE**) is made available to the employees. Safety glasses are required throughout the factory. Natural rubber, latex, and vinyl gloves are available to workers in the coating and plating areas, and the coating laboratory. Rawhide and cloth gloves are supplied throughout the factory. Disposable half-mask respirators were used throughout the factory. Half-face air-purifying respirators were available but employee use was not mandatory. Workers wore cloth coveralls over their street clothes.

METHODS

Personal breathing zone (**PBZ**) and general area (**GA**) air samples were collected to assess employee exposures to hydrochloric acid, mercury, metals, and organic solvents. Additionally, surface sampling for asbestos was conducted and bulk material samples for asbestos and mercury analysis were collected. Samples were collected using battery-powered pumps attached via Tygon® tubing to the appropriate sampling media. A summary of pump flow rates, sampling media, analytical procedures and limits of detection follows.

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In addition, Material Safety Data Sheets (MSDSs), the written hearing protection policy, and the written respiratory protection policy were reviewed, and a confidential employee interviews with 12 workers who volunteered to be interviewed from the first and third shifts were conducted.

A. ASBESTOS

Five bulk material and three settled-dust samples were collected in the diaphragm pre-coat area. Bulk material samples were collected using tweezers and samples were stored in glass vials. Settled-dust samples were collected on 25-millimeter (mm) cellulose ester membrane filters attached via Tygon® tubing to an air sampling pump calibrated to a flow rate of 4.0 liters per minute (lpm). The air sampling pump was used to collect settled-dust by sweeping an area until the filter noticeably changed in color. Bulk material samples were analyzed for asbestos fibers with polarized light microscopy (PLM) according to NIOSH Method 9002.⁽¹⁾ Settled-dust sample filters were prepared according to NIOSH Method 7400 and analyzed by PLM.⁽²⁾

B. HYDROGEN CHLORIDE

Hydrogen chloride (HCl) is a hydrolysis product of the coatings applied to the anodes. A total of 10 samples for airborne HCl were collected on solid sorbent silica gel tubes connected via Tygon® tubing to low flow pumps calibrated at a flow rate of 0.20 lpm. Two samples were collected during the first site visit: one PBZ air sample collected on an etch technician and one GA air sample collected on the etch area platform. During the return site visit eight PBZ air samples were collected on five employees working in the conveyor coating area: four 15-minute samples to assess short-term exposures and four full-shift samples. Samples were analyzed for hydrochloric acid via ion chromatography according to NIOSH Method 7903.⁽³⁾ The laboratory analytical limit of detection (LOD) and limit of quantitation (LOQ), along with their corresponding minimum detectable concentration (MDC) and minimum quantifiable concentration (MQC), assuming a volume of 80 liters for full-shift samples and 3 liters for 15-minute samples are as follows:

Analyte (Acid)	LOD µg/sample	LOQ µg/sample	MDC µg/m ³	MQC µg/m ³	Minimum Volume (liters)
hydrochloric (full-shift)	2	6	25	75	80
hydrochloric (short-term)	2	6	667	2000	3

C. MERCURY

During the first site visit, several opened and unopened boxes of mercury cell anodes were screened for mercury vapor using an Arizona Instruments Corporation, Gold Film Mercury Vapor Analyzer, Model 411. This instrument utilizes a thin gold film which selectively adsorbs inorganic mercury from a measured air volume. The adsorbed mercury results in an increase in electrical resistance across the film proportional to the mass of inorganic mercury in the sample. The analyzer was used in the "sample mode" which collects a 125 milliliter air sample and has a MDC of 1 microgram of mercury per cubic meter of air (µg Hg/m³).⁽⁴⁾ The instrument was calibrated with mercury vapor prior to and after the survey according to manufacturer specifications.

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One bulk material sample of abrasive shot was collected in the mercury cell anode abrasive blasting area. The bulk material sample was analyzed for mercury by cold vapor atomic absorption spectroscopy according to the Environmental Protection Agency (EPA) Method 7471.⁽⁵⁾ The laboratory-assigned LOD and LOQ, and calculated MDC and MQC are as follows:

Analyte	LOD µg/g	LOQ µg/g	MDC µg	MQC µg	Sample Weight (grams)
Mercury	0.06	0.22	0.012	0.044	0.2

D. TRACE METALS

Three PBZ air samples were collected on employees working in the plating and coating areas. Samples were collected on mixed-cellulose ester membrane filters connected via Tygon® tubing to battery-powered pumps calibrated at a flowrate of 2.0 lpm. Samples were analyzed for metals according to NIOSH Method 7300 using inductively coupled plasma atomic emission spectrometry (ICP-AES).⁽⁶⁾ The laboratory-assigned LODs and LOQs and calculated MDCs and MQCs using a sample volume of 404 liters, for these selected metals are as follows:

Analyte (Metal)	LOD µg/sample	LOQ µg/sample	MDC µg/m ³	MQC µg/m ³	Minimum Volume (liters)
Cadmium	0.08	0.24	0.20	0.59	404
Nickel	1.0	3.3	2.5	8.2	404
Titanium	0.08	0.18	0.20	0.44	404

E. ORGANIC SOLVENTS

Air samples for organic solvents were collected on solid sorbent charcoal tubes connected via Tygon® tubing to low flow battery-powered pumps calibrated at a flowrate of 0.2 lpm. During the first site visit six PBZ air samples were collected in the degreaser and etch areas. Four samples were qualitatively analyzed to identify major constituents by gas chromatography/mass spectroscopy (GC/MS). Two samples were analyzed for perchloroethylene by GC according to NIOSH Method 1003.⁽⁷⁾ During the return site visit, eight PBZ air samples were collected on five employees working in the conveyor coating area: four 15-minute samples to assess short-term exposures and four full-shift samples. The four 15-minute short-term samples were analyzed for n-butanol, and the four full-shift samples were analyzed for n-butanol, ethanol and 1,1,1-trichloroethane. The laboratory assigned LODs and LOQs; and calculated MDCs and MQCs are as follows:

Analyte	LOD mg/sample	LOQ mg/sample	MDC mg/m ³	MQC mg/m ³	Minimum Volume (liters)
perchloroethylene	0.01	0.033	0.14	0.45	73
n-butanol	0.02	0.037	0.24	0.44	85
1,1,1-trichloroethane	0.01	0.033	0.12	0.39	85
ethanol	0.01	0.033	0.12	0.39	85
n-butanol	0.02	0.037	6.67	12.33	3

EVALUATION CRITERIA

To assess the hazards posed by workplace exposures, NIOSH investigators use a variety of environmental and occupational health evaluation criteria. These criteria suggest exposure levels which most workers may be exposed for a working lifetime without experiencing adverse health effects. However, because of wide variation in individual susceptibility, some workers may experience occupational illness even if exposures are maintained below these limits. The evaluation criteria do not take into account individual hypersensitivity, pre-existing medical conditions, or possible interactions with other workplace agents, medications being taken by the worker, or environmental conditions.

Evaluation criteria for chemical substances are usually based on the average PBZ exposure to the airborne substance over an entire 8- to 10-hour workday, expressed as a time-weighted average (TWA). Personal exposures are usually expressed in parts per million (ppm), milligrams per cubic meter (mg/m³), or micrograms per cubic meter (µg/m³). To supplement the 8-hour TWA where there are recognized adverse effects from short-term exposures, some substances have a short-term exposure limit (STEL) for 15-minute peak periods; or a ceiling limit (CL), which is not to be exceeded at any time. Additionally, some chemicals have a "skin" notation to indicate that the substance may be absorbed through direct contact of the material with the skin and mucous membranes.

The three primary sources of evaluation criteria for the workplace are: NIOSH Recommended Exposure Limits (RELs), the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).^(8,9,10) In July 1992, the 11th Circuit Court of Appeals vacated the 1989 Air Contaminants Standard. OSHA is currently enforcing the 1971 standards, which are listed as transitional values in the current Code of Federal Regulations, however, some states operating their own OSHA-approved job safety and health programs will continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 limits, or the REL, whichever are lower. The OSHA PEL reflect the economic feasibility of controlling exposures in the various industries where the agents are used. The NIOSH REL are based primarily on concerns related to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard, and the OSHA PELs included in this report are the 1971 values.

A. ASBESTOS

NIOSH recommends as a goal the elimination of asbestos exposure in the workplace; where it cannot be eliminated, the occupational exposure should be limited to the lowest possible concentration.⁽¹¹⁾ This recommendation is based on the proven carcinogenicity of asbestos in humans and on the absence of a known safe threshold concentration. Virtually all studies of workers exposed to asbestos have demonstrated an excess of asbestos-related disease. Therefore, NIOSH investigators believe that any detectable concentration of asbestos in the workplace warrants further evaluation and, if necessary, the implementation of measures to reduce exposures.

According to Proctor and Hughes' Chemical Hazards of the Workplace 3rd ed. (1991), "...prolonged or repeated exposure to asbestos may result in chronic lung disease

(asbestosis), inflammation of the pleura and specific cancers of the lung and digestive tract. Cancers causally associated with asbestos exposure include bronchogenic carcinoma, mesothelioma of the pleura and peritoneum; excesses of cancer of the stomach, colon, and rectum have been observed as well.... Cigarette smoking is strongly implicated as a co-carcinogen among workers exposed to asbestos."⁽¹²⁾

B. HYDROGEN CHLORIDE

Hydrogen chloride (**HCl**) and hydrochloric acid are strong irritants to the eyes, mucous membranes, and skin. The major effects of acute exposure are usually limited to the upper respiratory tract and are sufficiently severe to encourage prompt withdrawal from a contaminated atmosphere. Exposures can also cause coughing, burning of the throat, and a choking sensation. Effects are usually limited to inflammation, and occasionally ulceration of the nose, throat, and larynx. Acute exposures causing significant trauma are usually limited to people who are prevented from escaping; in such cases, laryngeal spasm or pulmonary edema may occur. High concentrations of the gas causes eye irritation and may cause prolonged or permanent visual impairment. Exposure of the skin to high concentrations of the gas or to concentrated solutions of the acid will cause burns; repeated or prolonged exposure to dilute solutions may cause dermatitis. Erosion of the exposed teeth may occur from repeated or prolonged exposure.^(12,13)

C. MERCURY

Acute exposure to high concentrations of inorganic mercury vapor can cause headaches, cough, chest pains, chest tightness, and difficulty in breathing. Additionally, mercury can produce soreness of the mouth and gums, nausea, fever, and diarrhea.^(13,14)

In the occupational setting, however, chronic exposure to mercury is more common, with the central nervous system (**CNS**) as the primary target organ. Clinical manifestations include increased irritability, depression, paranoia, insomnia, loss of memory, and tremors of the limbs (usually the hands). Mercury may be unsuspected as the cause of these symptoms since their onset is gradual. Other symptoms of chronic mercury intoxication include inflammation of the mouth and gums, damage to the kidneys, allergic skin rash, loss of appetite and weight, fatigue, and anemia.⁽¹⁵⁾

D. METALS

Cadmium - Cadmium is a component of the welding solder used in the diaphragm pre-coat area. The dust and fumes of cadmium are irritants to the respiratory tract.⁽¹⁶⁾ NIOSH considers cadmium to be a potential occupational carcinogen, as cadmium production has been associated with an increased risk of lung cancer.⁽¹⁷⁾

Nickel - Metallic nickel compounds cause sensitization dermatitis.⁽¹²⁾ NIOSH considers nickel to be a potential occupational carcinogen, as nickel refining has been associated with an increased risk of nasal and lung cancer.⁽¹⁸⁾

Titanium - NIOSH considers titanium to be a potential occupational carcinogen, as it has been associated with lung tumors in animals.⁽⁸⁾ Titanium-tetrachloride is used in the coating process and is highly corrosive. According to Lawson (1961), "...liquid titanium tetrachloride produces deep thermal burns. Both the liquid and the fumes can result in permanent eye damage. Exposure of the lungs to titanium tetrachloride fumes can result in moist lungs or frank hemorrhagic pulmonary edema, accompanied by severe respiratory distress and characterized by increased platelet and leukocyte counts."⁽¹⁹⁾

E. ORGANIC SOLVENTS

Perchloroethylene - Perchloroethylene or perc (also known as tetrachloroethylene) is a colorless liquid used as a degreasing agent. NIOSH considers perchloroethylene to be a human carcinogen and recommends that exposures be reduced to the lowest possible concentration. Exposure to perchloroethylene may cause CNS depression with symptoms such as headaches, fatigue, dizziness, nausea, and drowsiness. It can cause skin irritation (dermatitis), as well as eye, nose, and throat irritation. Long term exposure to perchloroethylene may cause skin irritation, liver and kidney damage, or peripheral neuropathy.⁽²⁰⁾

n-Butanol - n-Butanol is a colorless liquid used in the coating process. Exposure to high concentrations of n-butanol may cause CNS depression. It is also an eye and mucous membrane irritant. Toxic amounts can be absorbed through the skin, and contact dermatitis can occur due to defatting of the skin tissue.⁽¹²⁾ n-Butanol exposure at TLV levels of 80 ppm (240 mg/m³) has also been linked to hearing loss.⁽²¹⁾

1,1,1-Trichloroethane - Exposure to 1,1,1-trichloroethane (also known as methyl chloroform) may cause CNS depression. The liquid can be absorbed through the skin and can cause skin irritation.⁽¹²⁾

Ethanol - Exposure to ethanol can result in CNS depression. It is also an irritant to the eyes and mucous membranes. Chronic exposure to the vapor may result in irritation of mucous membranes, headache, and symptoms of CNS depression such as lack of concentration and fatigue. Although ethanol is an eye and mucous membrane irritant, it is not significantly irritating to the skin.⁽¹²⁾

F. SMOKING IN THE WORKPLACE

Environmental tobacco smoke (**ETS**) contributes to particulate and gaseous contaminants and increases the risk of developing lung cancer and respiratory illnesses.^(22,23) These

contaminants are also irritants and may cause short-term problems such as headaches, rhinitis, and sinus problems. For these reasons, exposures to cigarette smoke should be reduced to the lowest feasible concentration. The best method for achieving this is by eliminating smoking in the building. Until this can be accomplished, smoking should be restricted to a designated smoking area away from the factory floor and other common-use areas. The separate smoking area should be under negative pressure with respect to the adjacent areas, have a dedicated exhaust system (room air directly exhausting to the outside), and provide 60 cubic feet per minute per person of outside air.⁽²⁴⁾ Special care should be taken to ensure that the room does not draw contaminants from the production area.

RESULTS AND DISCUSSION

A. EPIDEMIOLOGIC SURVEY

Confidential interviews were conducted with 12 workers, representing 63% of both the first shift coating department and third shift etching workers. Interviews were conducted among workers who volunteered or requested to meet with NIOSH representatives. These interviews were informal and consisted of each employee describing perceived work-related health complaints. Commonly reported health concerns included fatigue, inability to sleep, nose bleeds, memory loss, acid burns, and skin rashes. Two employees were reportedly being medically evaluated for sarcoidosis, and many of the workers interviewed were concerned that conditions at the worksite may increase their own risk for this disease.

The concern among employees about sarcoidosis was widespread. Sarcoidosis is a relatively uncommon granulomatous disorder that affects many of the body's organ systems and is most often found in young adults. To date, the exact cause of sarcoidosis remains unknown. It remains to be determined whether there is a single cause for this disease, or whether it is a multicausal syndrome.⁽²⁵⁾ Research efforts have been directed at finding an infective agent for this disease, such as, mycobacteria, fungi, or viruses. Furthermore, there is evidence to suggest that sarcoid disease has a genetic component among some persons.⁽²⁵⁾ Thus, there is no historical evidence or current research to suggest that sarcoidosis is an occupationally related disease.

Workers are potentially exposed to asbestos from anodes that have been improperly cleaned prior to return to the plant for reprocessing. Because of potential exposures to asbestos, workers were concerned that they were at risk for developing asbestosis. Asbestosis can be thought of as a scarring/thickening of the lungs and progressively debilitating respiratory condition as a result of prolonged exposure to asbestos fibers. One's risk for asbestosis is a function of the amount of asbestos in the air and the length of time one is exposed. Asbestosis, therefore, is observed among workers who have been exposed to high levels of asbestos for many years; levels which were not observed or documented at this plant. Asbestos, however, is a carcinogen, and respiratory exposure to asbestos increases the risk for lung cancer and malignant mesothelioma.

B. INDUSTRIAL HYGIENE RESULTS

1) ASBESTOS

Three bulk material samples collected from unwashed diaphragm anodes contained between 80 and 90% chrysotile asbestos. However, the three surface samples

collected from the interior of a crate of anodes, and beneath it, and the bulk material sample of dust from the floor, did not contain asbestos. The two employees who opened this crate of asbestos-contaminated anodes wore 3M No. 8500 Non-Toxic Particle Masks. 3M 8500 masks do not provide adequate protection from asbestos fibers and are intended for use only with nuisance particulates. During our first visit workers unpacking crates and loading the anode washer did not wear respiratory protection.

2) *HYDROGEN CHLORIDE*

Concentrations of HCl detected on PBZ and GA air samples were below the NIOSH REL (Table 1). However, a review of previous sampling conducted by a consulting firm retained by Electrode Corporation showed airborne concentrations of 2.7 and 6.7 mg/m³ in the coating area. The second sample (6.7 mg/m³) is close to the OSHA PEL and the NIOSH REL of 7 mg/m³ which is a ceiling limit and should not be exceeded at any time. The composition of the coating varies according to the type of anode.

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Table 1
Hydrochloric Acid (HCl)
Air Sampling Results

Location/subject	Date 1993	Type	Time (min)	Volume (Liter)	HCl (mg/m ³)
Etch Technician	11/09	PBZ	399	80	0.11
Etch tanks	11/09	Area	402	80	0.21
Conveyor Coater Line 1	12/16	PBZ	457	91	0.062
Conveyor Coater Line 2	12/16	PBZ	465	93	0.27
		STEL	15	3	trace
Conveyor Coater Line 2	12/16	PBZ	430	86	0.049
		STEL	15	3	ND
		STEL	20	4	ND
Conveyor coater Line 1	12/16	PBZ	425	85	trace
Conveyor coater Line 1	12/16	STEL	15	3	ND
NIOSH REL	—	—	—	—	7 CL
ACGIH TLV	—	—	—	—	7.5 CL
OSHA PEL	—	—	—	—	7 CL

- PBZ - personal breathing zone
- STEL - short-term exposure limit
- ND - none detected
- mg/m³ - milligrams per cubic meter
- min - minute
- CL - ceiling limit
- trace - Values are between the laboratory limit of detection (LOD) and limit of quantitation (LOQ).

Therefore, the difference between the NIOSH HCl sampling results and those of the consultant are most likely due to different coating compounds being used at the time of sampling.

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3) MERCURY VAPOR

The results of direct reading measurements in the mercury cell anode pre-coat area and storage area using the mercury vapor analyzer are presented in Table 2. The results show that mercury vapor concentrations inside two unopened boxes were at or above the NIOSH REL of 0.05 mg/m³. Although

Table 2

Direct Reading Results with Mercury Vapor Analyzer
November 9, 1993

Location		Concentration (mg/m ³)
Mercury cell pre-coat area		
Back Wall	Reading #1	0.015
	Reading #2	0.028
Corner	Reading #1	0.006
	Reading #2	0.008
Unopened Box 1	Reading #1	0.055
	Reading #2	0.050
Unopened Box 2	Reading #1	0.058
	Reading #2	0.059
	Reading #3	0.105
Outside, mercury anode storage area	Reading #1	0.006
	Reading #2	0.008
	Reading #3	0.015
Limit of Detection		0.001
NIOSH REL		0.05 (skin)
ACGIH TLV		0.05* (skin)
OSHA PEL		0.1 (skin)

mg/m³ = milligram mercury per cubic meter of air

* = ACGIH has a proposed TLV of 0.025 mg/m³

sample results show high airborne concentrations of mercury vapor inside crates of anodes it must be understood that the samples collected were source samples and not PBZ air samples. While no one is actually exposed to the concentrations of mercury vapor inside the crates, the measured concentrations indicate the potential for brief exposures (when opening the crates) to concentrations at or above the NIOSH REL. The bulk material sample of steel shot collected in the mercury anode abrasive blasting area

3) **MERCURY VAPOR**

The results of direct reading measurements in the mercury cell anode pre-coat area and storage area using the mercury vapor analyzer are presented in Table 2. The results show that mercury vapor concentrations **inside** two unopened boxes were at or above the NIOSH REL of 0.05 mg/m³. Although sample results show high airborne concentrations of mercury vapor inside crates of anodes it must be understood that the samples collected were source samples and not PBZ air samples. While no one is actually exposed to the concentrations of mercury vapor inside the crates, the measured concentrations indicate the potential for brief exposures (when opening the crates) to concentrations at or above the NIOSH REL. The bulk material sample of steel shot collected in the mercury anode abrasive blasting area showed no detectable mercury vapor concentrations, at the laboratory-assigned LOD of 0.06 micrograms per gram (µg/g).

4) **METALS**

The results of PBZ air sampling for metals are presented in Table 3. The two workers in the nickel plating area were exposed to nickel levels of 24 and 29 µg/m³; both levels are above the NIOSH REL of 15 µg/m³. Concentrations of titanium ranged from 2 to

Table 3
Personal Breathing Zone Air Sampling Results for Metals
November 9, 1993

Location/Job	Time (min)	Volume (Liter)	Cadmium (µg/m ³)	Nickel (µg/m ³)	Titanium (µg/m ³)
Ni plating	316	632	ND	24	2
Ni plating and Blasting	311	622	ND	29	11
Lab Technician	202	404	ND	ND	2
MQC (404 L)	---	---	0.59	8.2	0.44
NIOSH REL	---	---	Ca LFL	Ca 15	Ca LFL
ACGIH TLV	---	---	10 (fume)	1000*	10,000
OSHA PEL	---	---	200 (dust) 100 (fume)	1000	15,000

µg/m³ - micrograms per cubic meter
 Ni - Nickel
 Ca - Carcinogen
 ND - None detected
 LFL - lowest feasible level
 *ACGIH has proposed lowering the TLV to 50 µg/m³

g/m³. While cadmium was not detected on any of the samples collected by the NIOSH investigators, the results of sampling by an outside consultant firm retained by Electrode Corporation showed cadmium at a concentration of 1,790 µg/m³ on March 4, 1993. It is likely that the difference between the concentrations detected by the

NIOSH investigators and the consultants is due to different anodes be processed at the time of sampling.

Other metals detected on the ICP-AES scan for metals, but not listed in Table 3 included: barium, copper, and iron. These metals are not included because the concentrations detected were between the laboratory LOD and LOQ; beryllium was detected, but was also found on the blanks, the concentrations reported were above the LOQ and less than 20% of the REL; calcium and aluminum were detected at concentrations less than 1% of the REL.

5) **ORGANIC SOLVENTS**

Four full-shift PBZ air samples collected on a laboratory technician, a coating technician, and two coaters, during the first visit were submitted for qualitative analysis via GC/MS. Perchloroethylene, 1,1,1-trichloroethane, butanol, ethanol, isopropanol, and limonene were detected on the qualitative samples.

The results of air sampling for perchloroethylene are presented in Table 4. These results showed a general area concentration of 2 mg/m³ and a concentration of 11 mg/m³ in the PBZ of the etch technician. These concentrations are below the OSHA PEL and the ACGIH TLV. However, NIOSH considers perchloroethylene to

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Location/subject	Type	Time (min)	Volume (Liter)	Perchloroethylene (mg/m ³)
Etch Technician	PBZ	397	89	11
Etch Area	Area	367	73	2
NIOSH REL	---	---	---	LFL Ca
ACGIH TLV	---	---	---	170 685 STEL
OSHA PEL	---	---	---	689 1378 CL

mg/m³ - milligrams per cubic meter
 Ca - carcinogen
 CL - ceiling limit
 PBZ - personal breathing zone
 STEL - short-term exposure limit
 LFL - lowest feasible level

carcinogen, and recommends that exposures be maintained at the LFL.

The results of PBZ air sampling for n-butanol are presented in Table 5. Full-shift sample results for coaters working on the inside line (line 2) showed n-butanol concentrations ranging from 16 to 182 mg/m³. Two samples, one full-shift (182 mg/m³) and one short-term sample (183 mg/m³), exceeded the NIOSH REL (150 mg/m³), the ACGIH TLV (152 mg/m³), and the OSHA action level (150 mg/m³). The

Table 5
Personal Breathing Zone Air Sampling Results for n-butanol
December 16, 1993

Location/subject	Type	Time (min)	Volume (Liter)	n-butanol (mg/m ³)
Conveyor coater, Line 1	full-shift	457	91	28
Conveyor coater, Line 1	full-shift	425	85	16
Conveyor coater, Line 2	full shift	465	93	182
	short-term	15	3	130
Conveyor coater, Line 2	full-shift	430	86	116
	short-term	15	3	183
	short-term	20	4	142
Conveyor coater, Line 2	short-term	15	3	13
NIOSH REL	---	---	---	CL 150 (skin)
ACGIH TLV	---	---	---	CL 152 (skin)
OSHA PEL	---	---	---	300

mg/m³ - milligrams per cubic meter
 Ca - carcinogen
 CL - ceiling limit

OSHA action level is 50% of the PEL. None of the coaters sampled wore respiratory protection.

Half-face air-purifying respirators with acid gas/organic vapor cartridges were worn by one coater in the line coating area and by two coaters in the batch area and would provide appropriate protection from the concentration of n-butanol found in the coating area. A similar respirator was worn by the laboratory technician who worked in the coating laboratory. In addition to inhalation exposures, n-butanol is absorbed through the skin and contributes to the overall body burden. The protective clothing (natural rubber, rawhide, or cloth gloves, cloth coveralls, Tyvek™ suits) worn by the coaters is not solvent resistant and in some instances (e.g., saturated rawhide gloves) would result in increased skin contact and increase absorption through the skin. All measured concentrations of ethanol and 1,1,1-trichloroethane were less than 1% of the REL.

6) OBSERVATIONS AND DISCUSSION

Workers were required to wear a face shield when working in the etch area, however, this rule was not enforced. When parts were removed from the degreaser tank, the

odor of perchloroethylene (the degreaser solvent) was detectable 20 to 30 feet away. The nickel plating tanks did not have local exhaust ventilation. In the platinum plating area, pieces of cardboard had been placed beneath the working surface of the downdraft table, which impeded the effectiveness of the downdraft ventilation. One worker was observed pouring 20% hydrochloric acid without gloves or adequate exhaust ventilation. Brooms and shovels are used to clean up the material in the blasting area.

The coating laboratory was under extreme negative pressure because supply air was not provided to the laboratory. Laboratory exhaust hoods were used in the laboratory, which also added to the negative pressure. The two doors leading into the coating laboratory from the production floor were always open and workers had removed several ceiling tiles inside the laboratory to draw replacement air. As a result the laboratory acts as a "wind tunnel;" papers placed on a table immediately blow away. All metal cabinets and laboratory exhaust hoods were covered with rust spots. Many ceiling tiles in the storeroom were badly damaged. During our two visits, the door to the chemical storeroom remained open throughout the day.

CONCLUSIONS

The industrial hygiene air sampling data shows that workers were overexposed to n-butanol, perchloroethylene, and nickel. Significant health effects can result from these overexposures. It should be emphasized that the n-butanol concentrations shown in Table 5 do not reflect the added exposure from skin absorption and may underestimate the worker's true exposure to n-butanol. Samples collected by the NIOSH investigators did not document overexposures to HCl and cadmium. However, the results of sampling by an outside consultant, retained by Electrode Corporation, showed overexposures to these two compounds within the 1993 calendar year. Additionally, there is the potential for overexposure to asbestos, mercury, and titanium at this plant.

Employee reports of fatigue, sleeplessness, and memory loss are consistent with exposure to the organic solvents that are used commonly at this plant (n-butanol, perchloroethylene, 1,1,1-trichloroethane). Symptoms associated with exposure to these process chemicals should be reduced with appropriate engineering controls (improved ventilation) and the use of PPE .

RECOMMENDATIONS

To safeguard employee health and to limit health hazards, immediate steps should be taken to eliminate or reduce these exposures. NIOSH and OSHA recommend that engineering controls be used as the first priority to reduce employee exposures, followed by administrative controls and changes in work practices, and, when necessary, the use of PPE (i.e., respirators, gloves, etc.). The following recommendations are offered to reduce worker exposures and improve worker safety and health at Electrode Corporation.

1. If technically feasible perchloroethylene should not be used in the degreasing operation. A less toxic degreasing agent should be substituted. NIOSH considers perchloroethylene to be a carcinogen.

2. **ASBESTOS PROTECTION:** To reduce the potential for employee exposures to asbestos in the diaphragm pre-coat area, all aspects of OSHA regulation 29 CFR 1910.1001 should be followed (medical monitoring, showers and change rooms, respiratory protection, etc.).⁽²⁶⁾ An isolated negative pressure room should be constructed and equipped with a dedicated local exhaust ventilation system. This room should be used to open, inspect, count and uncrate diaphragm anodes, and this room should be directly connected to the anode washer. Local exhaust ventilation for this room should consist of a slot hood on a wall (not overhead), placed so that it will draw potentially contaminated air away from the workers' breathing zone.⁽²⁷⁾
- a) The following administrative controls are recommended to prevent worker exposures to asbestos:
 - ! Ensure that steps are taken at the originating company to insure that asbestos is completely removed prior to shipping to Electode Corporation.
 - ! Require that the customer label all incoming crates containing asbestos contaminated anodes as follows: Danger Asbestos Dust Hazard, Cancer and Lung Disease Hazards, Authorized Personnel Only.⁽²⁸⁾
 - ! Refuse to accept contaminated anodes.
 - b) Until these engineering controls can be installed, and all aspects of OSHA Regulation 29 CFR 1910.1001 implemented, all employees working in the diaphragm pre-coat area and adjacent areas should wear appropriate respiratory protection when diaphragm anodes are being processed. OSHA regulation 29 CFR 1910.1001 states that employee exposures to asbestos fiber concentrations up to 2 fibers per cubic centimeter (**f/cc**) require the use of a half-face air-purifying respirator, other than a disposable respirator, equipped with high efficiency particulate air (**HEPA**) filters, and concentrations up to 10 f/cc require the use of a full-face air-purifying respirator equipped with HEPA filters. Further testing for airborne asbestos concentration is needed to determine the appropriate respiratory protection.
 - c) Electrode Corporation should provide workers with clean work clothing, at the plant, on a daily basis. To insure that clothing potentially contaminated with asbestos is not taken home, laundry services should be provided by the company. The provider of laundry services should be informed that the clothes may be contaminated with asbestos.
 - d) The anode washer should be evaluated to determine its effectiveness at removing asbestos from the diaphragm anodes. Increasing the number of washings or increasing the water pressure may improve the washer's performance but the manufacturer should be contacted for specific details. If necessary, new methods to clean asbestos-contaminated anodes should be evaluated and implemented. Waste water from the anode washer should be filtered and the filters disposed of in accordance with EPA regulations.⁽²⁹⁾
 - e) All spills or leaks from the anode washer should be cleaned immediately. The anode washer should be inspected and maintained regularly according to manufacturer specifications to prevent further leaks.

3. **VENTILATION:** General ventilation throughout the factory should be improved. A systematic assessment of ventilation requirements and a comprehensive design project are needed. Special attention should be given to local exhaust in the coating, degreasing and plating areas to control overexposures to n-butanol, perchloroethylene, and nickel. Regular maintenance and inspection of all ventilation systems in the plant is necessary, and records should be kept to document problems and corrective actions taken. Air flow characteristics should be evaluated on a regular basis and should include both qualitative tests, such as smoke tube tests, and quantitative measurements, such as capture velocity, slot velocity and hood static pressure.⁽³⁰⁾
 - a) The portable exhaust units or mobile hoods that are used in the conveyor coating area should have capture velocities of 200 feet per minute to overcome room drafts.⁽²⁷⁾ The flexible ducting for these portable units had several feet of excess ducting. The excess ducting on these units decreases their efficiency and should be eliminated. Improved local exhaust ventilation and general ventilation should be installed to reduce exposure to n-butanol and HCl in the conveyor coating areas.
 - b) The ceiling exhaust fan and windows in the batch coating area should be repaired. Local exhaust ventilation should be installed to exhaust fumes and vapors released from the coating and cooling of hot anodes in the batch area. The batch area should be evaluated to determine if additional general ventilation is needed.
 - c) Until the improved ventilation can be implemented, all workers hand coating anodes should wear NIOSH/Mine Safety and Health Administration (**MSHA**) approved respiratory protection consisting of half-face air-purifying respirators equipped with acid gas/organic vapor cartridges. The respiratory protection should be worn until testing shows that the n-butanol and HCl levels are below the NIOSH REL and that the local exhaust ventilation is adequate.
 - d) Supply air should be heated so that the work area remains comfortable throughout the colder months (this may prevent workers from covering fresh air supplies with cardboard).
4. **Plating Area:** The plating tanks should be equipped with local exhaust ventilation. Until local exhaust ventilation can be installed at the plating tanks, NIOSH/MSHA approved respirators equipped with cartridges, effective against metal dusts and fumes, should be worn when working in the vicinity of the nickel plating tanks. A ventilated workbench was exhausted with flexible ducting to a ceiling exhaust across the room. To increase efficiency, the exhaust should be hard ducted to an exhaust directly above the workbench.
5. **Coating Laboratory:** An engineering firm with expertise in laboratory design should be retained to redesign the entire coating laboratory. The laboratory should be designed with a dedicated heating, ventilating, and air-conditioning (**HVAC**) system, with a clean fresh air supply. At the time of our site visit, supply air was not provided to the coating laboratory. Air drawn from the adjacent production areas through the laboratory's two open doors. This practice has resulted in a wind tunnel effect, and, most likely, has contributed to the rusting of most metal surfaces and cabinets by drawing in airborne contaminants from adjacent areas. These conditions can be corrected by providing clean, fresh supply air, and closing the two doors. Supply air should be introduced through diffusers in a direction that does not cause cross drafts at the laboratory exhaust hood openings. The laboratory exhaust hoods

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should be designed with face velocities of 60 to 80 feet per minute (**fpm**), with a max of 100 fpm, and the entire laboratory HVAC system should be properly balanced.⁽³¹⁾

6. **Protective Clothing:** All employees who come in contact with coating chemicals (preparing or applying) should wear outer gloves made of butyl rubber, neoprene or nitrile, and Silver Shield™ or 4H™ undergloves until it can be determined with appropriate detector pads that neither n-butanol nor HCl is breaking through the primary (outer) glove.^(32,33,34,35) Gloves must be worn and replaced according to manufacturer specifications and if necessary, Glovemates™ or similar material may be worn as undergloves to absorb perspiration.⁽³⁶⁾ All other gloves, including rawhide or yellow or orange natural rubber, should be prohibited from use in the coating area and coating laboratory.
7. Employees working in the coating areas should be supplied with aprons made of similar materials to protect their bodies and clothes from splashes. Gauntlets made of similar material may also be used, if necessary, to protect the upper arms from splashes of coatings. Employees should wash promptly when skin is exposed to the coating. Wet or contaminated clothing should be removed promptly. Cloth coveralls and Tyvek™ suits are not adequate protection from the coating or chemicals and should not be worn in these areas. The protective clothing should be replaced, or maintained, cleaned and inspected according to manufacturer specifications to insure its effectiveness.
8. Pouring or mixing acids should be done under a laboratory exhaust hood wearing the following PPE: face shields, gloves and aprons.
9. **Respiratory Protection Program:** The company's written program should be improved. The present program repeats OSHA Regulation 29 CFR 1910.134, but does not explain how Electrode Corporation will carry out the regulation. The written program must explain exactly how Electrode Corporation will carry out fit testing, medical testing, etc. Workers wearing respirators had not been examined by a physician for a medical determination of fitness. The Respiratory Protection Program must provide workers with improved training and education in the proper selection of respiratory protection to insure that workers wear appropriate respiratory protection when working with asbestos contaminated anodes. Further training for the workers and the respiratory protection program administrator is recommended. Training can be obtained through respirator manufacturers, consultants or at NIOSH training courses.
10. **Hazard Communication:** Employee education regarding health hazards associated with the chemicals in the workplace should be improved. Material safety data sheets (**MSDS**) for all chemicals used in the plant should be readily accessible to all employees. Workers indicated that they have had to contact the chemical manufacturer directly to obtain MSDSs. The individual responsible for hazard communications training should be familiar with the chemicals used in the plant and their associated health hazards. Employee training should be performed at regular intervals, and should include discussions of any health and safety changes being implemented, and should allow for employee input. The hazard communications training program should be administered according to OSHA Regulation 29 CFR 1900.1200.⁽³⁷⁾
11. **Hearing Protection Program:** The written outline titled 'Hearing Protection' should specify how Electrode Corporation monitors noise, measures noise exposures, provides hearing protection, and conducts hearing tests. A 1989 OSHA inspection report shows that noise

levels in the mercury cell area exceeded the noise threshold limit for establishing a hearing conservation program. Although administrative controls were taken to reduce exposure, a follow-up noise survey or exposure assessment should be conducted to determine the effectiveness of the controls. Noise monitoring should be conducted when 85 dBA TWA is equalled or exceeded. A hearing protection program should be established to comply with OSHA 29 CFR 1910.95,⁽³⁸⁾ but also to monitor the effect of n-butanol on hearing loss.

12. Mercury Cell Area

- a) The current practice of checking crates for mercury contamination should be continued. Regular inspection with the mercury vapor analyzer of the entire mercury cell pre-coat area is recommended to detect mercury contamination.
- b) The mercury vapor analyzer should be calibrated regularly according to manufacturer specifications, with mercury vapor, and the results recorded in a logbook.
- c) The manual loading of the 25 to 45 pound mercury anodes from ground level up 4 feet into the abrasive blaster may cause ergonomic problems and should be supplemented with an overhead pulley, or crane, or an adjustable lifting cart.

13. Periodic air sampling for cadmium in the diaphragm pre-coat area is recommended to insure that the engineering controls are working as designed.

14. General Housekeeping and Safety Factors

- a) A no smoking policy should be established and enforced, and **NO SMOKING** signs should be posted throughout the entire facility. The break table and smoking area that occupy a corner of the batch coat area should be moved to an area away from the production floor. These activities should be restricted to designated areas away from contaminants. Eating and drinking should be prohibited in the work areas. Workers should wash their hands before eating, drinking, or smoking to eliminate the potential for hand-to-mouth ingestion of contaminants.
- b) All welding stations, regardless of size, should be enclosed with a welding curtain to reduce bystander exposures to ultraviolet radiation.
- c) Dry sweeping in the blasting areas should be replaced with a method that will produce less dust such as HEPA vacuuming.
- d) An exposed pipe coming up from the floor near Line 2 is a trip hazard and should be removed.
- e) All mechanical robots should be fully enclosed for safety. Lock out/tag out procedures should be followed in all work practices associated with them, such as routine evaluation and set-up, as well as in their computer program operating systems.
- f) When the robots are operating, the door to the enclosure should remain closed and interlocked to ensure that operation will cease when the door is opened. If visual access is necessary, a window should be installed or the door should be fitted with see-through mesh.

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