INVESTIGATION OF POTENTIAL HAZARDS IN THE RHODE ISLAND JEWELRY INDUSTRY

SURVEYS CONDUCTED BY:
James H. Jones
Donald L. Slovin
Leo M. Blade

REPORT WRITTEN BY:
James H. Jones
Donald L. Slovin

DATE OF REPORT:
April 29, 1983

REPORT #: 128.4

Industrial Hygiene Section
Industrywide Studies Branch
Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Surveillance, Hazard Evaluations and Field Studies
Cincinnati, Ohio

ABSTRACT

In 1980, The National Institute for Occupational Safety and Health conducted a survey of the health problems associated with the costume jewelry industry in Rhode Island. The survey was intended to provide a preliminary evaluation of the prevalence and severity of occupationally related diseases in this large industry. The Rhode Island jewelry industry is characterized by more than a thousand small shops; transient workers move frequently from one shop to another. The study concentrated on the processes of casting, soldering and electroplating, and it investigated 15 facilities. Surveys varied in intensity from brief walk-through inspections and interviews to detailed studies incorporating environmental and biological monitoring. Employee interviews failed to reveal patterns of acute or chronic illnesses among any group of employees except for dermatitis in electroplaters probably caused by nickel dust exposure. Other exposures that were found in some instances to be excessive were to silica and to lead in casting and to cadmium in silver solder operations. Two workers were found to have elevated urine cadmium concentrations. Results, overall, indicate that exposures in this industry are to well recognized hazards which could be reduced by education programs, engineering controls, and the occasional use of personal protective equipment. The results of this study should be viewed with the knowledge that only a very small portion of this industry was sampled, and that therefore the data may not accurately reflect the conditions throughout the entire industry.

INTRODUCTION

In October 1979, hearings were held in Providence, Rhode Island, by the Subcommittee on Labor Standards of the Committee on Education and Labor of the U.S. House of Representatives.[1] These hearings concentrated on health hazards to workers in the jewelry industry. Testimony was heard from physicians, jewelry workers, representatives of the jewelry industry, labor groups, and government agencies. A considerable diversity of opinion was presented as to the degree of hazard present in the jewelry industry. Most witnesses outside of the industry felt that the jewelry industry had a high incidence of occupational illness, and that the hazards were generally not appreciated. However, few systematically derived data were available on the extent or severity of illness related to jewelry manufacture.

Concern with the potential hazards of the jewelry industry also has been indicated in articles on the subject in newspapers, magazines, and in publications distributed to workers.[2,3,4,5] These articles provide descriptions of the toxicities and biological effects of materials commonly used in the jewelry industry and thus advise workers of potential health effects that should be guarded against.

The purpose of this inquiry was to acquire preliminary information to gauge the significance of the jewelry industry as a cause of health problems, especially previously unrecognized problems. The jewelry industry is an especially difficult industry for which to obtain such information for several reasons. First, a large percentage of workers in the industry are employed in very small shops. Over 90% of the more than 1,000 jewelry businesses in Rhode Island employer fewer than 100 people, and many of these firms employ fewer than 20 workers. Therefore, a small sample of firms could easily miss workplaces where hazards were not well controlled, even if such workplaces actually represented a significant fraction of the industry. Second, many of the workers are very transient, moving from firm to firm. Therefore, very few workers accumulate long experience with a single company. Third, many workers move in and out in the industry. Workers who have suffered occupational illness would be likely to stop working in the industry and would therefore be unavailable for interview.

Despite these problems, a limited survey, consisting of walk-through surveys and limited environmental and medical sampling, was judged to provide an overview of the health problems involved in the Rhode Island costume jewelry manufacturing industry.

BACKGROUND

In 1938, Wuraftic and Hickey, of the Rhode Island Department of Public Health, published the results of an extensive survey of jewelry businesses in Rhode Island.[6] The surveyors visited 289 firms employing 10,315 of the 13,000 people then employed in the industry and recorded, for each company, such information as number of employees, exposures, and control measures provided. Then, as now, most of the workers (85%) worked for companies with fewer than 100 employees. Also, then, as now, most of the plants were located in the greater Providence area. The categories into which the work was divided are quite applicable, with few exceptions, to the industry today. These included the following:

1) tool and machine work,
2) press work,
3) soldering,
4) electroplating,
5) polishing,
6) lacquering,
7) bench work, and
8) miscellaneous (including abrasive blasting and gluing).

Only two (0.7%) of the plants surveyed in 1938 required a pre-employment physical examination. Only 0.4% of plants with fewer than 100 workers had a first-aid room although over 90% of the plants had some first-aid supplies available. General housekeeping was considered good in 61.2% of the plants, fair in 29.8%, and poor in 9.0%. The largest source of accidents was stamping and pressing machines. The chemical exposures were highest in degreasing, pickling, bright dipping, electroplating, and lacquering processes. Chemical exposures were documented to acids, alkalis, ammonia, carbon tetrachloride, cyanide, chromic acid, plating solution, trichloroethylene, and other solvents.

The 1938 report made recommendations such as the following: increased lighting, better inventilation, safety glasses for grinders, use of guards on machinery, local exhaust for plating tanks, safety education of workers, and improved housekeeping. As will be seen, most of these recommendations are still quite appropriate for many firms in the jewelry industry.

Since 1938, few studies have specifically evaluated the health hazards of the jewelry industry, and most have not included industrial hygiene data. Sparks and Wegman[7] reported on a proportional mortality study performed for all men who had died in Attleboro, Massachusetts, (adjacent to the Rhode Island border) between 1956 and 1975 and who had the occupation of jewelry worker listed on the death certificate. They found significantly more deaths from pancreatic cancer than would have been expected based on U.S. mortality data. Among a subpopulation of polishers, stomach cancer mortality was found in excess.

Two papers have reported chronic toxicity from mercury in a jewelry manufacturing process that uses a mercury-cadmium amalgam. Jones and Longley[8] performed urine mercury levels, air mercury levels, and physical examinations for jewelry workers at seven plants in Australia. Three of 36 workers had some symptoms of mercurialism. Levels of mercury vapor in air ranged from 0.17 to 35.0 mg/m^3; the NIOSH recommended standard is 0.05 mg/m^3 for an 8-hour time-weighted average (TWA) exposure.[2,3] Urine mercury concentrations were as high as 3700 µg/mL, far above the presumed toxic level of 100 µg/mL. Copplestone and McArthur[9] noted high urine mercury levels in jewelry workers from a factory in New Zealand that used a similar process. Although no workers had overt signs or symptoms of mercurialism, urine mercury levels ranged to 2090 µg/mL and air levels to 0.9 mg/m^3.

Baker et al.[10] investigated an outbreak of cadmium intoxication among silver solderers in a jewelry factory in New Mexico. The solder contained 15.6% cadmium. Seventy-five per cent of the workers reported symptoms compatible with acute cadmium toxicity, such as shortness of breath, chest pain, and dizziness. The mean blood cadmium level of exposed workers was 2 1/2 times that of unexposed workers. Urine B_2-microglobulin levels, which reflect the renal tubular injury occurring in early cadmium nephrotoxicity, were within normal limits.

NIOSH has performed two health hazard evaluations in jewelry plants. In one, a company involved in the manufacture of gold and silver jewelry was evaluated by Burton.[11] This company had plating, painting and gluing, and silver soldering operations. The plating operation was judged to be well ventilated, and no employees reported any symptoms. Area and breathing zone air samples for ammonia and hydrogen cyanide in the plating area were well within the existing OSHA standards for 8-hour TWAs of 50 ppm and 10 ppm, respectively. In the painting and gluing operations, however, employees noted dizziness, headache, and nausea. Air levels for solvent vapors were low, but there was less shop activity on the day of the survey than usual. No air samples were collected at the soldering operation.

The second NIOSH evaluation, by Kronoveter[12], was at an art studio, part of which was involved in handcrafting jewelry. The process consisted mostly of hand soldering with gold and silver foils and the baking of enamels. No mechanical exhaust ventilation system was in use. The silver solder was analyzed for cadmium, but none was found. The report does not mention any signs or symptoms among workers. No air sampling was conducted.

STUDY DESIGN

In this evaluation, three processes frequently used in the industry were studied:

1) casting,
2) electroplating, and
3) soldering.

Processes that are seldom used or not likely to involve health problems were not included. Thus, some areas studied in the extensive industrial hygiene survey of 1938 were not included such as press and bench work, which have few chemical exposures, and lacquering, which is much less common now than it was in the 1930's. In addition, because NIOSH has been evaluating paint spraying operations in other industries, spray painting was not evaluated here.

The study protocol provided for two one-week visits to the Rhode Island area. The first visit consisted of unannounced walk-through surveys, during which observations were made of processes and work practices and some workers were interviewed. No sampling was planned for this first trip. On the second trip, several visits were made to firms not visited on the first trip. In addition to observational surveys, environmental sampling and medical testing were performed on this second visit when appropriate. A third trip was made specifically to evaluate cadmium exposure to silver solderers.

The first surveys took place January 21-25, 1980. Using the Dun & Bradstreet Market Identifier File, a list of firms with Standard Industrial Classification (SIC) numbers 3911 (jewelry, precious metal), 3915 (jewelry findings), and 3961 (costume jewelry)[13] was generated and stratified by number of employees. Several firms of varying sizes were randomly chosen from this list. It was judged that the six or seven plants that were selected would include examples of all processes of interest. These visits were all unannounced to ensure that typical working conditions were observed. At each plant an opening conference was held with management to acquaint them with the purpose of the visit. A walk-through survey was then performed, during which processes and work practices were observed. Management was interviewed concerning the size of the firm, the nature of the firm's work, safety programs, and medical care available to employees. Employees were interviewed with attention to the occurrence of acute and chronic health problems. They were asked about the occurrence of such symptoms and signs as fever, cough, nausea, abdominal pain, tremor, fatigue, nasal stuffiness, constipation, poor appetite, shortness of breath, painful urination, eye irritation, skin problems, chest pain, and wheezing, both within the past two days and past several months. A short job history, smoking history, and allergic history were also obtained.

The firms visited on the first survey had the following operations and numbers of employees:

A - soldering and assembly - 16 employees,
B - manufacture of imitation pearls - 18 employees,
C - casting - 5 employees,
D - soldering and assembly - 10 employees,
E - stamping and pressing, soldering, polishing, electroplating - 150 employees,

F - stamping and pressing - 15 employees,
G - polishing - 2 employees, and
H - stamping and pressing, soldering, polishing, and electroplating - 80 employees.

The second set of surveys was performed in June 1980. The firms visited at that time were selected systematically. Using the Buyer's Guide of the Manufacturing Jewelers and Silversmiths of America, Inc.[24] and the Rhode Island Directory of Manufacturers[25], an attempt was made to select several firms, each of which would be primarily involved with one or two of the processes of greatest concern - casting, electroplating, or soldering. Some of the firms were contacted in advance to insure that they were indeed performing the processes of interest. This prior contact was intended to insure that our limited survey time would be spent as efficiently as possible. Our experience from the first visit indicated that the smaller companies often move, and that their activities are not always accurately reflected by descriptions in the Jeweler's Association Guide. To insure that the more hazardous workplaces were surveyed, the smaller companies were visited; experience has indicated that these firms tend to have poorer working conditions than do larger companies.

Plant visits on the second trip once again began with an opening conference, followed by a walk-through survey. Environmental sampling was then performed. As before, employees working in the processes of interest were interviewed. Where appropriate, blood samples were collected for lead analysis, and urine samples were collected for cadmium analysis.

On the second trip, the following firms with the noted operations and number of employees were visited:

I - soldering - 10 employees,
J - casting and assembly - 25 employees,
K - soldering, electroplating, and assembly - 25 employees,
L - casting and assembly - 150 employees,
M - casting and soldering - 100 employees, and
N - spraying operation - 50 employees.

A third trip was made in December 1980 for the purpose of testing for cadmium exposures in silver solders at two firms. Air samples were collected and analyzed for cadmium and lead. Solderers and soldering set-up workers were interviewed, and urine samples were collected for determination of B_2-microglobulin concentration. B_2-microglobulin is a low-molecular-weight protein whose presence in urine has been associated with early renal damage in workers chronically exposed to cadmium.

The two firms surveyed had the following operations and number of employees:

E - stamping and pressing, soldering, polishing, electroplating - 150 employees, and
O - stamping and pressing, soldering, polishing, and electroplating - 235 employees.

AIR SAMPLING METHODS

Metals

Personal breathing-zone air samples for measurement of exposures to metals were collected on 37-mm mixed-cellulose ester membrane filters with a 0.8-um pore size at a flow rate of 2 or 3 liters per minute (Lpm) using MSA Model G or DuPont P-4000 sampling pumps. Sample times ranged from 4 to 6 hours. Samples for multiple metals were analyzed by atomic absorption spectrophotometry using NIOSH Method P&CAM 173.[20] Samples for lead alone were analyzed using NIOSH Method S-341 [21] also by atomic absorption spectrophotometry. Samples for antimony alone were analyzed by hydride generation using the method of Pierce, et al.[22]

Respirable Dust and Free Silica

Personal breathing-zone air samples for measurement of exposures to respirable dust and free silica were collected using 37-mm polyvinyl chloride membrane filters with a 5-um pore size. The air, which first passed through nylon cyclones, was sampled at a flow rate of 1.7 Lpm with MSA Model G sampling pumps. The filter was weighed before and after sampling to determine the mass of respirable dust collected. The sample was then analyzed for free silica content by x-ray diffraction according to NIOSH Method P&CAM 259[20] with the following modifications: (1) filters were dissolved in tetrahydrofuran rather than being ashed in a furnace, and (2) standards and samples were run concurrently, and an external calibration curve was prepared from the integrated intensities rather than using the suggested normalization procedure. A bulk sample of the casting mold material was also analyzed in this manner.

PROCESS DESCRIPTIONS

Castings

Metals commonly used in casting include:

1) white metal, which consists typically of zinc, tin, and lead with small amounts of antimony, copper, arsenic, or nickel;
2) precious metals, such as gold, silver, and platinum; and
3) base metals such as brass, which consists of copper, zinc, and lead.

Two types of castings are predominately used in the jewelry industry: rubber mold casting and lost wax (or investment) casting.

Rubber mold casting is used for low melting point metals such as white metal. The metal is first melted in a melting pot. The molten metal is then poured into a rubber mold that has been dusted with talc to prevent the casting from sticking to the mold. After the casting has cooled, it is removed from the mold. Potential exposures are to fumes from the molten metal and to talc.

Lost wax (or investment) casting is used for higher melting point metals, such as precious metals or brass. In this process the first step is the production of a wax model casting using a rubber mold. Then a plaster like substance, called investment, is molded around the wax model. After the investment hardens, the mold is placed in a furnace where the wax is vaporized leaving a cavity in the mold the shape of the wax casting. Molten metal is then drawn into the mold in one of two ways: by centrifugal force using spin-casting or by a vacuum in vacuum-casting. Once the casting has cooled, the mold is removed, generally using high-pressure water. Potential worker exposures in lost wax casting are to fumes from molten metal and to investment dust, which usually contains a high percentage of silica.

Press Operations

The intial operation at many jewelry manufacturers is the cutting of metal stock to the proper size and shape using a press. Most presswork is done on power presses although a considerable number of foot presses are still used in the industry. The only exposure noted in this operation was to cutting fluids, usually water-based. Only a small number of presses required the use of cutting fluids. The major hazard was the potential for hands to be caught in a press. All of the presses seen in the surveys were guarded or required two handed activation of the press. These safety devices had not been defeated and were in actual use on every press observed. The widespead use of these guards was reportedly due to local OSHA emphasis on this problem in the early 1970's.

Soldering

Jewelry pieces are often joined by soldering. Soldering may be done by hand, by machine, or in ovens. The principal solder in use is a lead/tin alloy, but many users have been converting to an all-tin solder. Hard, or silver, solder is also used. Hard solder contains metals such as silver, copper, zinc, cadmium, or tin. It may also contain fluxes containing such materials as fluorides. In the soldering operation, the jewelry pieces are first placed on a heat resistant board. Most of these boards are now made of carbon or ceramic material; however, asbestos was widely used in the past. Not all shops have completely phased out asbestos boards. Solder and flux are added to the jewelry pieces, and the solder is then heated with a torch. Alternatively, the board is placed on a conveyor belt that carries it through an oven, melting the solder. Exposures in this operation are metal fumes from the solder, flux vapors, and airborne asbestos fibers if asbestos heating boards are used.

Electroplating

Electroplating is used to apply a thin layer of metal, such as copper, nickel, or a precious metal, to a base metal jewelry piece. The pieces are first put on racks; the racks are then moved through a series of baths. The first baths are used to clean the surface of the pieces. These baths may contain soap solutions, caustic, sulfuric acid, nitric acid, or water rinses. The racks are then moved to a plating bath containing salts of the metal to be plated. An electric current is applied to the bath and the rack causing the metal salts in the bath to dissociate and the metal ions to migrate to the surface of the jewelry pieces. Several layers of different metals may be plated. At the conclusion of the plating, the pieces are rinsed and dryed. In some cases the surface cleaning steps may utilize a solvent degreaser although solvents were not observed during the surveys. Exposures in this process are to acid mists, to the plating solutions, which contain various metal or cyanide salts, and sometimes to solvents used for degreasing and drying.

Polishing

The polishing operation involves surface finishing of the jewelry pieces using polishing wheels and polishing compounds. These compounds contain abrasive materials such as silica or aluminum oxide. The polishing wheel areas observed during the surveys were ventilated with local exhaust systems. Potential exposures are to dust from the metal being polished and to abrasives.

TOXICITY REVIEW

Arsenic

Arsenic may be found in the jewelry industry as a hardening agent in some alloys. Occupational exposure to inorganic arsenic occurs primarily through inhalation of arsenic-containing airborne particulates. Inhalation of arsenic trioxide vapor can also occur. Non-occupational arsenic absorption results almost entirely from eating food which contains traces of arsenic, seafood in particular, or from drinking contaminated water.

Among workers, dermatitis (skin rash) is the most common sign of arsenic toxicity and may be associated with development of areas of increased skin pigmentation or skin thickening ("arsenical warts"). Chronic occupational exposure to arsenic has been shown to cause skin cancer.[10]

Chronic occupational exposure to arsenic in high doses can cause damage to the nerves of the arms and legs (peripheral neuropathy). This neuropathy primarily affects the sensory nerves and has been associated with slowed sensory nerve conduction velocity.[11,12] Symptoms of tingling (paresthesias) and numbness have been reported. Chronic absorption of arsenic in high doses can also cause toxicity to the liver and occasionally cirrhosis. Arsenic has been shown to cause a rare form of liver cancer, angiosarcoma of the liver.[13] Inorganic arsenic, and especially arsenic trioxide, is a potent irritant of the respiratory tract. Chronic exposure results in inflammation of the eyes and nose, nosebleeds, and occasionally perforation of the nasal septum. Chronic exposure to arsenic in the smelting and pesticide formulating industries has been shown to cause excessive deaths from cancer of the lungs and bronchi.[14,15] The lung cancer mortality rate in workers chronically exposed to arsenic has been shown to increase with the duration and intensity of exposure.[16]

The NIOSH recommended standard for occupational exposure to inorganic arsenic in air is 2 ug/m^3 based on a 15-minute ceiling measurement.[17] The OSHA standard is 10 ug/m^3 measured as an 8-hour TWA.[18] No specific exposure standard exists for arsenic trioxide, but in view of its ability to cause cancer, exposure to arsenic trioxide (in both vapor and particulate forms) should be reduced to the lowest level feasible.

Asbestos

Asbestos is a generic term applied to a number of hydrated mineral silicates, including chryostile, amosite, crocidolite, tremolite, and anthophyllite. Asbestos consists of fibers of varying size, color, and texture. The uses of asbestos are numerous and include thermal and electrical insulation, fire blankets, safety garments, filler for plastics, and roofing materials. Some jewelry shops use asbestos boards to hold soldering work in progress. The most toxic route of entry is inhalation.

The most widely recognized disease caused by asbestos is asbestosis, followed by cancer of the lungs and digestive tract, and mesothelioma.

Asbestosis is a lung disorder caused by inhalation of asbestos and characterized by a diffuse interstitial fibrosis, including pleural fibrosis and calcification. Asbestos bodies may be found in the sputum, and the patient exhibits restrictive pulmonary function. Along with the clinical changes, a worker may have fine rales, finger clubbing, dyspnea, dry cough, and cyanosis.

The OSHA standard for occupational exposure to asbestos is 2 fibers greater than 5 microns in length per cubic centimeter for an 8-hour TWA exposure.

The NIOSH recommendation of 0.10 fibers greater than 5 microns in length per cubic centimeter for an 8-hour TWA was established to protect against asbestosis and to reduce to an acceptably low level the risk for the development of neoplasms.

Beryllium

Beryllium may be found as a hardening agent in some jewelry alloys. Beryllium compounds can be irritating to the respiratory tract. Exposure to the fumes of beryllium is associated with a chronic respiratory illness characterized by the development of granulomas in the lung with onset of dyspnea and cough years after exposure has ended. In high exposures an acute pneumonia, which may be fatal, also occurs. Beryllium is known to cause cancer in laboratory animals and is a human carcinogen.[16,28] The current OSHA standard for beryllium is 0.002 mg/m^3 for an 8-hour TWA exposure. NIOSH has recommended that the permissible exposure limit for beryllium be reduced to 0.5 ug/m^3 based on a 130-minute sample.[15,16]

Cadmium

Cadmium is a toxic heavy metal which may enter the body either by ingestion or by inhalation of cadmium metal or oxide. Once absorbed into the body, cadmium accumulates in organs throughout the body, but major depositions occur in the liver and kidneys. Acute inhalation exposure to high levels of cadmium can cause pneumonia or pulmonary edema, as well as liver and kidney damage.[29] Chronic exposure may lead to emphysema of the lungs and kidney disease, or cancer of the prostate.[30] There is also limited evidence that occupational cadmium exposure may be associated with lung cancer.[28,30]

NIOSH recommends that worker exposures to cadmium dust or fume be limited to a ceiling of no more than 200 ug/m^3 during a 15-minute sampling period or to a permissible exposure limit (PEL) of not more than 40 ug/m^3, as a TWA over a 10-hour shift. The OSHA standards for 8-hour TWA exposures to cadmium dust and cadmium fume are 200 $ug/m^3$100 and 100 ug/m^3, respectively. Normal values are not well established for urine cadmium, but a level below 10 ug/L or below 15 ug/g creatinine is considered acceptable.[15,16,29,30]

Chlorinated Solvents

Chemicals commonly used for degreasing in the jewelry industry are solvents such as 1,1,1-trichloroethane, trichloroethylene, and perchlorethylene. These solvents are all central nervous system depressants and can cause headaches, dizziness, and drowsiness. Trichloroethylene is also a respiratory and skin irritant and has been known to produce visual disturbances, tremors, loss of coordination, and liver and kidney damage. Perchloroethylene has been known to produce peripheral neuropathy. These or closely related compounds have produced cancer in laboratory animals. The current OSHA standards for 8-hour TWA exposure to these solvents are 350 parts of solvents per million parts of air (ppm) for 1,1,1-trichloroethane and 100 ppm for trichloroethylene and perchloroethylene. NIOSH has recommended that the permissible exposures be lowered to 350 ppm (15-minute ceiling) for 1, 1, 1-trichloroethane, and to 25 ppm and 50 ppm for 8-hour TWA exposures to trichloroethylene and perchloroethylene, respectively.[15,16,27]

Copper

Copper is a constituent of brass. Exposure may occur to copper fumes in brass casting operations and to copper dust during grinding or polishing of brass. Copper fumes may cause irritation of the eyes, nose, and throat, and an acute flu-like illness called metal fume fever. Exposure to copper dust may cause a feeling of illness similar to the common cold. The current OSHA standard for copper fume is 0.1 mg/m^3 as an 8-hour TWA, and for copper dust and mist it is 1 mg/m^3 as an 8-hour TWA.[15,27]

Cyanide salts

Cyanide salts are used in many plating baths. They are irritants of the eyes, mucous membranes, and skin. Reaction with acids may produce hydrogen cyanide gas, a potent toxin that can produce weakness, headache, unconsciousness, and death. The formation of this gas is not only a problem near the tanks but also in areas where cyanide salts and acids are stored near each other. The OSHA standard for exposure to cyanide is 5 mg/m^3 as an 8-hour TWA.[15,27] The NIOSH recommended permissible exposure limit is 5 mg/m^3 for a 10-minute ceiling.

Fluorides

The fluxes most commonly used in jewelry manufacturing contain fluoride compounds. Flourides are highly irritating to the eyes and mucous membranes. The more severe acute effects of fluoride (for example, skin burns) would not be expected from soldering. The OSHA standard for exposure to airborne fluoride is 2.5 mg/m^3 as an 8-hour TWA. The NIOSH recommended permissible exposure limit is also 2.5 mg/m^3 as an 8-hour TWA.(15,27)

Lead

Inhalation of lead dust and fumes is the major route of lead exposure in industry. A secondary source of exposure may be from ingestion of lead dust contamination on food, cigarettes, or other objects. Once absorbed, lead is excreted from the body very slowly. The absorbed lead can damage the kidneys, peripheral and central nervous systems, and the blood forming organs (bone marrow). These effects may be manifested as weakness, tiredness, irritability, or slowed reaction times. Chronic lead exposure is associated with infertility and with fetal damage in pregnant women.

Blood lead levels below 40 micrograms per 100 grams of whole blood (ug/100 g) are considered to be acceptable levels that may result from daily environmental exposure. However, fetal damage in pregnant women may occur at blood lead levels as low as 30 ug/100 g of whole blood. Lead levels between 40 and 60 ug/100 g in lead-exposed workers indicate excessive absorption of lead and may result in some adverse health effects including nerve damage and chronic kidney impairment. Levels of 60 to 100 ug/100 g represent unacceptable elevations that may cause serious adverse health effects. Levels over 100 ug/100 g are considered acutely dangerous and often require hospitalization and medical treatment. The current OSHA standard for exposure to airborne lead is 50 $\mu g/m^3$ for an 8-hour TWA.[14,15]

Nickel

Nickel salts are used in some plating baths. Skin contact with plating solution may cause an allergic skin rash. This rash is caused by sensitization to nickel. Once a person has been sensitized, exposure to very low levels of nickel may cause a reaction. This reaction may include asthma from inhalation of nickel salt solution mists. Nickel and its compounds have been reported to cause cancer of the lungs and sinuses. The current OSHA standard for exposure to nickel metal and soluble nickel compounds is 1 mg/m^3 for an 8-hour TWA. NIOSH has recommended that the permissible exposure limit for nickel be reduced to 0.015 mg/m^3 for an 8-hour TWA.[15,27]

Nitric Acid

Nitric acid is used as a surface cleaner for jewelry prior to either plating or soldering. Acute exposure to nitric acid mist may cause irritation of the eyes, nose, throat, and skin. Liquid nitric acid or high concentrations of nitric acid vapor may produce skin burns and ulcers. High concentrations of nitric acid vapor may also cause severe breathing difficulty which may have a delayed onset and result in pneumonia. Repeated or prolonged exposure may cause erosion of the teeth. The current OSHA standard for exposure to airborne nitric acid vapor is 2 ppm for an 8-hour TWA. NIOSH recommends a 2 ppm 8-hour TWA for a permissible exposure limit.[15,27]

Silica

Silica is a major constituent of the investment plaster used to make molds in investment casting. Chronic exposure to free silica dust during removal of the castings can result in a disease state known as silicosis. A worker affected by silicosis first notes the onset of shortness of breath on exertion. This becomes gradually worse and is accompanied by coughing. The silica causes nodules and fibrosis to form in the lung. The onset of symptoms and signs may occur a few months after exposure but, more typically, is delayed for several years depending on the extent of exposure. The current OSHA standard for exposure to respirable silica is (10 mg/m^3)/(% SiO_2+2) as an 8-hour TWA. The standards for exposure to cristobalite and tridymite are half that value. NIOSH has recommended a permissible exposure limit of 0.05 mg/m^3 8-hour TWA for quartz and a 0.025 mg/m^3 8-hour TWA for cristobalite and tridymite.[15,27]

Silver

Silver metal is used for precious jewelry and in silver solder. In addition, silver salts are used in some plating baths. Exposure to silver can cause a grayish pigmentation of the eyes, nose, throat, and skin known as argyria. In severe cases the lens may be clouded and vision disturbed; otherwise, argyria is believed to be a benign condition. The current OSHA standard for exposure to airborne silver is 0.01 mg/m^3 for an 8-hour TWA.[15,17]

Sulfuric Acid

Sulfuric acid is used in the electroplating process as a surface cleaner. Acute exposure to sulfuric acid liquid or mist may cause irritation of the eyes, nose, and throat, teeth erosion, skin burns, and breathing difficulties. Repeated or prolonged exposure to dilute solutions may cause skin and eye irritation, teeth erosion, and nose, throat and bronchial tube inflammation. The current OSHA standard for exposure to sulfuric acid mist is 1 mg/m^3 for an 8-hour TWA. The NIOSH recommendation for a permissible exposure limit is also 1 mg/m^3 for an 8-hour TWA.[15,27]

Talc

Talc, which is often used as an anti-sticking agent for rubber molds, is a hydrated magnesium silicate. It is known to cause pulmonary fibrosis or granulomotosis (talc pneumoconiosis). In addition talc is often contaminated with asbestos and silica, but the degree of contamination varies widely.[31] Talc contaminated with asbestos can lead both to pneumoconiosis and to an increased incidence of lung cancer and mesothelioma. The current OSHA standard for exposure to the non-asbestos form of talc is 2 mg/m^3 for an 8-hour TWA.[15,27]

Tin

Tin is a constituent of white metal and of some solders. Its fumes are believed to cause a benign pneumoconiosis, stannosis. Tin may also cause irritation of the eyes, nose, throat, and skin. No other systemic effects from industrial exposure are known. The current OSHA standard for airborne exposure to tin is 2 mg/m^3 for an 8-hour TWA.[15,16]

Zinc

Zinc is a constituent of white metal and brass. Exposure to zinc oxide fumes can produce the syndrome known as metal fume fever. In this syndrome, a worker will typically note a metallic taste in his mouth 4-12 hours after exposure. This is shortly followed by coughing, shortness of breath, and muscle weakness. A fever of about 102°F, chills, and profuse sweating then develop. A tolerance is produced, with the result that signs and symptoms are worse after a weekend off and improve later in the work week. The current OSHA standard for exposure to zinc oxide fume is 5 mg/m^3 for an 8-hour TWA. The NIOSH recommendation for a permissible exposure limit is also 5 mg/m^3 for an 8-hour TWA.[14,15]

RESULTS

Soldering

Environmental

Soldering operations were observed at eight shops. These shops predominantly used hand soldering techniques although two shops also used soldering ovens. Only one shop used local exhaust ventilation for control of soldering fumes although most soldering was done in large rooms with high ceilings, a design feature which tended to minimize the buildup of fumes.

Sixteen air samples were collected at the soldering operations of five shops for measurement of exposure to lead cadmium, copper, zinc, or silver (Table A-1). All but three samples were either personal samples or breathing zone samples collected at the work station. All air levels for the 12 samples analyzed for lead were below detection limits; those limits ranged from 0.004 mg/m^3 to 0.007 mg/m^3. All air levels for the four samples analyzed for copper and silver were below the detection limits of 0.003 mg/m^3. The 13 samples analyzed for cadmium ranged from less than 0.002 mg/m^3 to 0.009 mg/m^3; of the 13, seven were below the detection limit. The four samples analyzed for zinc ranged from 0.007 mg/m^3 to 0.011 mg/m^3. All of these levels are well below NIOSH recommended standards.

Medical

A total of six solderers were interviewed during the first and second surveys. No symptoms or signs were reported by any of them. Blood lead and urine cadmium analyses were performed on one solderer in Shop K who was using both silver and soft solder. His blood lead level was 10 ug/dL, well within the acceptable range. His urine cadmium concentration was 26 ug/L and his creatinine was 13 ug/g. Normal values are not well established for cadmium urine concentrations, but a level below 10 ug/L or below 15 ug/g creatinine is considered acceptable. Given those criteria, the worker in Shop K experienced excessive absorption of cadmium.

Because of the relatively high urine cadmium level found for the solderer in shop K, a third survey was conducted to test more silver solderers for urine cadmium. Urine cadmium and urine B_2-microglobulins were determined at two firms for a total of 16 persons who regularly perform silver soldering. These tests were also performed on nine employees who had been working "set-up"; these employees prepare the jewelry for soldering but do not themselves solder. None of the set-up employees had done any soldering within recent years, and all of the solderers had been soldering for many years. In both plants solderers and set-up employees worked in the same general area. A questionnaire was administered to each participant; this elicited information on work history, smoking history, allergic history, and the occurrence of various symptoms and signs, including coughing, stuffy nose, shortness of breath, chest pain, headache, chills, nausea, and diarrhea.

Table 1 lists the results of urine testing and a comparison of the two groups. Most of the participants (88%) were female. There was no significant difference between solderers and non-solderers for mean age (43 years versus 46 years) or number of smokers (35% versus 11%) (Student's t-test and Fisher's Exact Test, respectively). Non-solderers had, on average, worked at the plant twice as long as had solderers although, again, the difference was not significant statistically. Only one individual had a urine cadmium level that could be considered abnormal. This person had a urine cadmium of 14.3 ug/L (or 15.7 ug/g creatinine), and a B_2-microglobulin of 393 ug/g creatinine. This person had no symptoms or signs of cadmium toxicity; he had been a solderer for many years and was a smoker. NIOSH advised this person to consult a physician for follow-up. There were two other B_2-microglobulin concentrations that exceeded the acceptable level of 15 ug/g creatinine. These were 214 and 225, the former in a solderer and the latter in a non-solderer.

For the questionnaire, participants were asked to list those symptoms and signs that they had been having during the preceding 2 days and those that they had been having, occasionally or frequently, over the previous month. The results of the questionnaire are listed in Table 2. None of the differences between the groups are statistically significant (Fisher's Exact Test).

Table 1

Comparisons of Solderers and Non-Solderers
December 1980
Rhode Island

	Solderers	Non-Solderers
Number	16 (13 females)	9 (9 females)
Mean Age (yr)	43	46
Number of Smokers	5 (35%)*	1 (11%)*
Mean Seniority (yr)	4	8
Mean Years Soldering (yr)	17	-
Urine Cadmium (ug/L) less than 5	13 workers	6 workers
between 5 and 10	2 workers	2** workers
between 10 and 15	1 worker	-
Group B_2-microglobulin means (mg/g)***	97	95

* Percent of total respondents
** One non-solderer was not tested
*** One solderer and one non-solderer were not tested

Table 2

Symptoms and Signs Reported by Solderers and Non-Solderers
December 1980
Rhode Island

	Solderers	Non-Solderers
Symptom or sign present during preceding 48 hours	N = 17	N = 9
cough	4 (24%)*	2 (22%)
stuffy nose	5 (29%)	6 (67%)
shortness of breath	1 (6%)	2 (22%)
chest pain	3 (18%)	2 (22%)
headache	6 (35%)	6 (67%)
chills	1 (6%)	1 (11%)
nausea	1 (6%)	1 (11%)
diarrhea	1 (6%)	0 (0%)
common cold	3 (18%)	2 (22%)
Symptom or sign present during preceding month		
cough	4 (24%)	1 (11%)
stuffy nose	8 (47%)	3 (33%)
shortness of breath	5 (29%)	0 (0%)
chest pain	5 (29%)	1 (11%)
headache	9 (53%)	4 (44%)
chills	4 (24%)	2 (22%)
nausea	3 (18%)	0 (0%)
diarrhea	4 (24%)	0 (0%)

* Percent of total respondents

Castings

Environmental

Casting operations were observed at four shops. Three of these shops were casting brass using the investment press, and the remaining shop was casting white metal using rubber molds.

All three of the brass casting operations utilized spin casting. The spin casting machines were all enclosed and had local exhaust ventilation that appeared to be well designed. Two of the brass casting operations also used vacuum casting. Only one of them had exhaust ventilation for the metal melting pot. A canopy hood located several feet above the melting pot was used. This arrangement did not appear to be effective in capturing the metal fumes given off from the melting pot. Five air samples in brass casting area were collected at two plants. The samples were analyzed for lead, copper, and zinc. Results ranged from less than 10 $\mu g/m^3$ to 41$\mu g/m^3$ for lead; less than 6 $\mu g/m^3$ to 43 $\mu g/m^3$ for copper; and 26 $\mu g/m^3$ to 2.0 mg/m^3 for zinc. All levels were below OSHA standards and NIOSH recommended standards although the lead levels at one shop were above the action level. This was probably due to the inadequate ventilation for the metal melting pot.

Mixing of investment plaster was done in ventilated hoods in all three shops; however, this operation was being performed in only one shop during the time of the surveys. The investment mixing appeared to be quite dusty, and the hood did not contain all the dust. One breathing-zone air sample was collected for the worker performing this job. The respirable dust concentration was 0.54 mg/m^3, the quartz concentration was less than 0.06 mg/m^3, and the cristobolite concentration was 0.08 mg/m^3. This last level is above the NIOSH recommended standard of 0.025 mg/m^3 for cristobolite and above the OSHA standard of 0.29 mg/m^3 for respirable dust with this percentage of cristobolite. The details of these samples are found in Table A-2.

The white metal casting operation observed appeared to have an excellent local exhaust ventilation system. The melting pot was partially enclosed, and slot exhaust was located next to the pouring area of the work bench. This exhaust also served to remove airborne talc from dusting the rubber molds prior to pouring the metal into them. Three air samples were collected for lead, antimony, and copper. All resulted were below detection limits of 0.006 mg/m^3 for lead, 0.02 mg/m^3 for antimony, and 0.004 mg/m^3 for copper. Results of all air sapling for metals in casting operations appear in Table A-3.

Medical

Ten workers in casting operations were interviewed. One worker in white metal casting reported an occasional cough, and another reported occasional eye irritation and skin rash. Four of the eight workers in brass casting also noted eye and skin irritation from the dust. One also noted some skin irritation when washing castings to remove the investment mold. One blood lead level was obtained on a white metal caster. The result was 33 ug/dL.

Electroplating

Environmental

Electroplating operations were observed at three shops. Nickel, copper, rhodium, and gold plating were being performed. Although no local exhaust ventilation was being used, this is not unusual for plating of these metals. Also, very few plating workers were using protective equipment, such as rubber gloves or face shields. Two personal air samples were collected at plating operations and were analyzed for copper and nickel. The results ranged from 0.003 mg/m^3 to 0.011 mg/m^3 for copper and were both less than 0.004 mg/m^3 for nickel. (See Table A-4).

Medical

Five electroplaters were interviewed during this study. The platers had been plating for many years and had few complaints, except for one report of what appeared to be nickel dermititis.

Spraying

Environmental

Two spraying operations were visited; one was making imitation pearls, and the other was a spray painting job-shop. Both used small spray booths, but solvent odors were quite noticeble. The job-shop used a variety of coatings, among them epoxies. While the workers were spraying, they were observed to steady with their hands the objects being sprayed. They did not wear rubber gloves, and consequently their hands and arms were covered with paint. Housekeeping was also poor. There appeared to be potential for overexposure to solvents both through inhalation and skin absorption. No air samples were collected in these operations because paint spraying is being evaluated in other NIOSH studies.

Medical

Two sprayers were interviewed during this study. They both reported occasional cough, but no other signs. It was noted that the sprayers were all relatively young. It was reported that average turnover in this job is high with workers only staying a year or less.

DISCUSSION AND CONCLUSIONS

The purpose of these surveys was to assess the importance of the costume jewelry industry in Rhode Island as a source of health problems. The major processes in the industry were surveyed and studied. In addition, NIOSH investigators conducted walk-through surveys, interviewed current employees, and performed limited environmental and medical sampling. The deficiencies in using these methods have been noted. The firms sampled were not chosen randomly, and thus there is no way of knowing if the sample was representative of this entire industry. Medical sampling was not conducted at two of the five firms selected, thus resulting in a very small number of biological samples. Many of the firms were obviously not as busy as usual due to the economic climate, which reduced the number of interviews that could be done and tended to make conditions appear better than might be expected. Because of the task size some processes were necessarily neglected, such as polishing and epoxy use, which are known to have associated hazards.

Since the interviews were not done among a randomly chosen group of workers, and results were not compared to those of a control group; no statistical analysis was applied to them. Furthermore, current employees are a self-selected group--workers who had health problems on a particular job would tend to leave that job. Another problem with the interviews was that some employees did not speak English very well.

In summary, the interviews did not reveal a pattern of acute or chronic illness among any group of jewelry employees, with the exception of dermatitis in electroplaters which, most likely, was the result of exposure to nickel. No respiratory complaints were reported. Some employees in a fairly dusty casting operation complained of eye and nasal irritation from the dust. The importance of improved ventilation in this situation must again be emphasized, especially given a high free silica air level found at this firm, Shop L.

Based on observations and air sampling, most of the workers did not appear to be heavily exposed to lead. The two blood samples collected had lead levels below the currently accepted "safe" level of 40 ug/dL.

The cadmium testing suggests that while silver solderers face a definite potential for absorption, excess absorption is probably uncommon. However, the fact that one of the two individuals with elevated levels worked in a non-ventilated area indicates the importance of ventilation in reducing exposure.

Other deficiencies in the safety and health practices noted were as follows:

1) Insufficient use of personal protective equipment. For example, electroplaters often did not wear gloves or protective aprons; polishers sometimes did not wear safety glasses.

2) Lack of emergency shower and eye wash facilities.

3) Smoking in work areas where smoking can potentiate the hazards of the materials in use. Substances such as cadmium and lead often enter the body from deposits on cigarettes.

4) Although most of the firms had some informal arrangement for sending injured employees to local physicians or emergency rooms for treatment, none of the firms required pre-employment examinations or offered post-employment examinations.

The lack of acute or chronic symptoms or signs among workers does not necessarily imply that no problems exist. That a particular worker does not mention a specific symptom or sign does not mean that they are not suffering any toxic effects. And in many occupational diseases, such as silicosis, asbestosis, heavy metal toxicity, and solvent exposure, symptoms or signs may not appear until the disease has progressed considerably. Thus, exposures to known hazards should be monitored and kept below recommended standards and, in general, exposure to all chemicals should be kept as low as feasible.

Workers usually did not fully understand the potential toxicities of the materials to which they were exposed. Often they did not even know what compound they were working with; this is a significant problem for the industry. In many other industries, informed and involved workers have done much to improve conditions. Since adequate enforcement of regulations is difficult in a large group of businesses, worker education and concern is a valuable means of producing an overall improvement in environmental conditions. Some of this education can come from management, some from worker organizations, and some from third parties with an interest in occupational health. Management, too, needs to be better informed. In several plants visited, employers were generally unaware of the hazards that existed from materials in use. Industry associations and government agencies can provide considerable information in many aspects of occupational health and safety, especially to an industry with a predominance of firms too small to provide their own industrial hygiene programs.

A comprehensive study of this industry would be difficult to do with any assurance of accuracy, given the predominance of extremely small firms in the industry and the transience of the worker population. The conclusion based on this study, even with its deficiencies, is that most of the exposures in the costume jewelry industry are from well-known hazards and could be reduced with the use of engineering controls and personal protective equipment (e.g., respirators) and by worker and management education.

REFERENCES

1. Occupational Diseases and Their Compensation. Part 4: Jewelry Industry. Hearing Before the Subcommittee on Labor Standards of the Committee on Education and Labor. House of Representatives, October 2, 1979.

2. Martin, G.M. Hidden Jeopardy for Jewelry Workers. Job Safety and Health. Pages 22-31, January 1978.

3. Rhode Island Lung Association. Rhode Island Jewelry Operations and Associated Toxic Air Contaminants. Providence, 1980.

4. Quinn, M., Stock, L., Smith, S., and Young, J. What You Should Know About Health and Safety in the Jewelry Industry. Jewelry Workers Health and Safety Research Group, Providence, 1980.

5. Butterfield, B. Working in Jewelry. Providence Journal, June 1981.

6. Wuraftic, J. and Hickey, C. A Survey of Industrial Hygiene Conditions in the Jewelry Industry of Rhode Island. Rhode Island Department of Public Health, Providence, 1938.

7. Sparks, P.J. and Wegman, D.H. Cause of Death Among Jewelry Workers. J of Occup Med. 22 (11): 733-736, 1980.

8. Jones, A.T. and Longley, E.O. Mercury Exposure in a Jewelry Molding Process. Arch of Environ Health. 13: 769-775, 1966.

9. Copplestone J.F. and McArhtur D.A. An Inorganic Mercury Hazard in the Manufacture of Artificial Jewelery. Brit J Ind Med. 24: 77-80, 1967.

10. Baker, E.L., Coleman, C., Peterson, W.A., Landrigan, P.J., and Holtz, J.L. Subacute Cadmium Intoxication in Jewelry Workers: An Evaluation of Diagnostic Procedures. Arch of Environ Health. 34: 173-177, 1979.

11. Burton, D.J. Health Hazard Evaluation Determination Report No. 73-147-134. H. F. Barrows Company, North Attleboro, Massachusetts, DHEW, PHS, CDC, NIOSH, 1974.

12. Kronoveter, K.J. Health Hazard Evaluation and Technical Assistance Report No. TA 77-68. McDaniel Art Studio. Cincinnati, Ohio, DHEW, PHS, CDC, NIOSH, 1978.

13. Dun & Bradstreet Market Identifier File, 1982.

14. Proctor, N.H. and Hughes, J. Chemical Hazards in the Workplace. Lipincott, Philadelphia, 1978.

15. Occupational Safety and Health Administration. Occupational Safety and Health Standards for General Industry. 29 CFR Part 1910. USDOL, OSHA, Washington, D.C., 1979.

16. Key, M.M., Henschel, A.F., Butler, J., Ligo, R.N., Tabershaw, I.R., and Ede, L. (eds.). Occupational Diseases: A guide to Their Recognition. DHEW (NIOSH) Publication No. 77-181. DHEW, PHS, CDC, NIOSH, Cincinnati, 1977.

17. Doull, J., Klaasen, C.D., and Amdur, M.O., (eds.) Casarett and Doull's Toxicology. 2nd ed. Macmillan, New York, 1980.

18. Parkes, W.R. Occupational Lung Disorders. Butterworths, London, 1974.

19. Fabens, T. The Occupational Health Hazards of Jewelry Finishing., Unpublished Manuscript, 1975.

20. NIOSH Manual of Analytical Methods. 2nd ed. Vol. 1. DHEW (NIOSH) Publication No. 77-157-A, DHEW, PHS, CDC, NIOSH, Cincinnati, 1977.

21. NIOSH Manual of Analytical Methods. 2nd ed. Vol. 3. DHEW (NIOSH) Publication No. 77-157-C, DHEW, PHS, CDC, NIOSH, Cincinnati, 1977.

22. Pierce, F.D., Lamoreaus, T.C. Brown, H.R. and Fraser, R.S. An Automated Technique for the Sub-microgram Determination of Selenium and Arsenic in Surface Waters by Atomic Absorption Spectroscopy. Applied Spectroscopy 30 (1): 38-42, 1976.

23. NIOSH. Criteria for a Recommended Standard...Occupational Exposure to Inorganic Mercury. DHEW Publication No. HSM 73-11024. DHEW, PHS, NIOSH, Rockville, 1973.

24. The Buyer's Guide, 1979-1980. Manufacturing Jewelers and Silversmiths of America, Inc., Providence, 1979.

25. Rhode Island Directory of Manufacturers, 1979-80. Rhode Island Department of Economic Development, Providence, 1979.

26. Lowry, L., Meyer, and Teteet. B_2 microglobulin in urine as an index of chronic cadmium exposure. Clin Chem. 24: 1012, 1978.

27. Stricoff, R.S., Mackison, F.W., and Partridge, L.J., Jr. (eds.) Occupational Health Guidelines for Chemical Hazards. DHHS (NIOSH) Publication No. 81-123. DHHS, PHS, CDC, NIOSH, Rockville, 1981.

28. American Conference of Governmental Industrial Hygienists. Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1981. ACGIH, Cincinnati, 1981.

29. Scott, R., Patterson, P.J., Mills, E.A., et al. Clinical and Biochemical Abnormalities in Coppersmiths Exposed to Cadmium. Lancet. 2:396-98, 1976.

30. Webb, M.: Cadmium. Br Med Bull. 31:2465-50, 1975.

31. NIOSH Technical Report. Occupational Exposure to Talc Containing Asbestos. DHEW, PHS, CDC, NIOSH, Cincinnati, February, 1980.

APPENDIX

Table A-1

Results of Air Sampling at Soldering Operations

Plant/Job	Sample Time (min)	Sample Volume (L)	Concentration Lead (mg/m^3)	Cadmium (mg/m^3)	Copper (mg/m^3)	Zinc (mg/m^3)	Silver (mg/m^3)
Plant E							
Solderer	477	1400	<0.004	0.006			
Solderer	465	1400	<0.004	0.004			
Solderer	469	1400	<0.004	0.003			
Solderer	464	1400	<0.004	0.003			
Soldering Station	456	1400	<0.004	0.005			
Plant I							
Solderer	225	450	<0.007				
Solderer	226	450	<0.007				
Plant K							
Solderer	351	700	<0.004				
Plant M							
Solderer	350	700		<0.003	<0.003	0.008	<0.003
Solderer	347	690		<0.003	<0.003	0.007	<0.003
Solderer	344	690		0.009	<0.003	0.01	<0.003
Soldering Oven	318	640		<0.003	<0.003	0.008	<0.003
Plant O							
Solderer	444	1300	<0.004	<0.002			
Solderer	444	1300	<0.004	<0.002			
Solderer	431	1300	<0.004	<0.002			
Solderer Station	431	1300	<0.004	<0.002			
OSHA Standard			0.05	0.1	0.1	5*	0.01
NIOSH Recommendation			-	0.04	-	5*	-
ACGIH TLV			0.15	0.05	0.2	5*	0.1

* Zinc Oxide Fume

Table A-2

Results of Air Sampling at a Molding Operations

Plant/Job	Sample Time (min)	Sample Volume (L)	Respirable Dust (mg/m^3)	Respirable Free Silica Quartz (mg/m^3)	Respirable Free Silica Cristobalite (mg/m^3)
Plant L					
Mold Maker	304	520	0.54	<0.06	0.08
OSHA Standard			0.29	-	-
NIOSH Recommendation			-	0.05	0.025
ACGIH TLV			0.29	-	-

Table A-3

Results of Air Sampling at Casting Operations

Plant/Job	Sample Time (min)	Sample Volume (L)	Concentration Lead (mg/m^3)	Antimony (mg/m^3)	Copper (mg/m^3)	Zinc (mg/m^3)
Plant J						
White Metal Caster	253	510	<0.006	<0.02	<0.004	
White Metal Caster	247	490	<0.006	<0.02	<0.004	
White Metal Caster	246	490	<0.006	<0.02	<0.004	
Plant L						
Brass Caster	269	540	0.022		0.033	0.28
Brass Caster	272	540	0.030		0.039	0.31
Brass Caster	317	630	0.41		0.43	0.40
Plant M						
Brass Caster	156	310	<0.01		<0.006	0.026
Brass Caster	155	310	0.016		0.016	2.0
OSHA Standard			0.05	0.5	0.1	5*
NIOSH Recommendation			-	-	-	5*
ACGIH TLV			0.15	0.5	0.2	5*

* Zinc Oxide Fume

Table A-4

Results of Air Sampling at Electroplating Operations

Plant/Job	Sample Time (min)	Sample Volume (L)	Concentration Copper (mg/m^3)	Concentration Nickel (mg/m^3)
Plant K				
Plater	356	530	0.011	<0.004
Plater	315	630	0.03	<0.004
OSHA Standard			0.01	1
NIOSH Recommendation			–	0.015
ACGIH TLV			0.2	1